FCN | Future Energy Consumer Needs and Behavior

E.ON Energy Research Center

RWTH AACHEN UNIVERSITY

FCN Working Paper No. 17/2019

Green and Regional? A Multi-Criteria Assessment Framework for the Provision of Green Electricity for Electric Vehicles in Germany

Paul Fabianek, Christian Will, Stefanie Wolff and Reinhard Madlener

October 2019

Institute for Future Energy Consumer Needs and Behavior (FCN)

School of Business and Economics / E.ON ERC

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

FCN Working Paper No. 17/2019

Green and Regional? A Multi-Criteria Assessment Framework for the Provision of Green Electricity for Electric Vehicles in Germany

October 2019

Authors' addresses:

Paul Fabianek
RWTH Aachen University
Templergraben 55
52056 Aachen, Germany
E-Mail: Paul.Fabianek@rwth-aachen.de

Christian Will
Daimler AG & Institute of Industrial Production
Karlsruhe Institute of Technology (KIT)
Hertzstr. 16
70187 Karlsruhe, Germany
E-Mail: Christian.Will@partner.kit.edu

Stefanie Wolff, Reinhard Madlener
Institute for Future Energy Consumer Needs and Behavior (FCN)
School of Business and Economics / E.ON Energy Research Center
RWTH Aachen University
Mathieustrasse 10
52074 Aachen, Germany
E-Mail: SWolff@eonerc.rwth-aachen.de, RMadlener@eonerc.rwth-aachen.de

Publisher: Prof. Dr. Reinhard Madlener
Chair of Energy Economics and Management
Director, Institute for Future Energy Consumer Needs and Behavior (FCN)
E.ON Energy Research Center (E.ON ERC)
RWTH Aachen University
Mathieustrasse 10, 52074 Aachen, Germany
Phone: +49 (0) 241-80 49820
Fax: +49 (0) 241-80 49829
Web: www.fcn.eonerc.rwth-aachen.de
E-mail: post_fcn@eonerc.rwth-aachen.de

Green and regional? A multi-criteria assessment framework for the provision of green electricity for electric vehicles in Germany

Paul Fabianek[a], Christian Will[b,*], Stefanie Wolff[c], Reinhard Madlener[c]

[a] RWTH Aachen University, Templergraben 55, 52056 Aachen, Germany, paul.fabianek@rwth-aachen.de;

[b] Daimler AG & Institute of Industrial Production, Karlsruhe Institute of Technology (KIT), Hertzstr. 16, 70187 Karlsruhe, Germany, +49 (0)721 608-44563, Christian.Will@partner.kit.edu; [*]Corresponding author

[c]Institute for Future Energy Consumer Needs and Behavior (FCN), School of Business and Economics / E.ON Energy Research Center, RWTH Aachen University, Mathieustrasse 10, 52074 Aachen, Germany, SWolff@eonerc.rwth-aachen.de; RMadlener@eonerc.rwth-aachen.de.

October 2019

Abstract

Based on economic and ecological criteria this paper proposes an evaluation framework for the provision of green electricity for charging plug-in electric vehicles in Germany, using the Analytic Hierarchy Process (AHP) approach for a Multi-Criteria Decision Analysis. The framework allows for a transparent evaluation of the supply of green electricity for electric vehicles from different stakeholder perspectives, without the direct involvement and reassessment by the experts. The relevant criteria for the evaluation are derived from literature, an analysis of eco-labels for electricity tariffs, and 33 expert interviews from four different stakeholder groups (municipal utilities, academia and science, non-governmental organizations, and automobile manufacturers). Eight criteria have been found to be particularly relevant for green electricity service evaluation: *regionality*, *transparency*, *balancing period*, *additionality*, *land use*, *greenhouse gas emissions*, smart charging (via a *flexibility discount*), and *quality premium*. The evaluation framework comprises *value scores* which represent the degree to which a specific green charging service satisfies a given quality criterion, and combining them with the AHP-weights. The results differ markedly between stakeholder groups and point to the particular importance of *additionality*, technology-specific *greenhouse gas emissions*, and *transparency*. The framework seems useful for service design by (municipal) utilities, charge point operators, non-governmental organizations, and aggregators offering smart charging solutions.

Keywords: Plug-in electric vehicles (PEVs); Green electricity tariffs; Analytic hierarchy process (AHP); Smart charging; Energy services.

1. Introduction

Sales of electric vehicles have seen a rapid growth in recent years and all major vehicle markets (IEA 2019). One of the main reasons for this worldwide trend are policy targets aimed at reducing greenhouse gases and local pollutant emissions in the transport sector, and strong monetary and non-monetary incentives provided by governments dedicated to promoting electric mobility.

In most European countries, all-electric and plug-in hybrid electric vehicles – collectively referred to as plug-in electric vehicles (PEVs) – use a power mix that is dominated by fossil fuels and thus CO_2-intensive energy sources (Eurostat 2016). One approach for a genuine reduction of greenhouse gas emissions is the targeted charging of PEVs with electricity exclusively from renewable energy sources. For example, both Austria and the Canton of Thurgau in Switzerland require applicants for PEV purchase subsidies to have signed up for a green electricity tariff (BMVIT 2016; Flammer 2019). However, such green electricity is not a homogeneous product (Leprich 2008), since it can have different characteristics with regard to energy source, country of origin, age of the power plant, etc.

In this context, this study examines which economic and ecological criteria can be used to assess the quality of electricity charging services from the point of view of various groups of stakeholders. Deviating from classic sustainability analyses, we mostly omit social-economic dimensions of sustainability in favor of a stronger focus on factors contributing to climate change; also in view of the increasing public awareness of the anthropogenic impact on climate change in recent years. By applying the Analytic Hierarchy Process (AHP) method (Saaty 1977; Saaty 1987), and on the basis economic and ecological criteria, we develop a multi-criteria decision aid framework for the provision of green electricity for charging PEVs in Germany. This framework is used to quantify the quality of green power charging services (GPCS) for PEVs. It can be useful for PEV service design pursued by (municipal) utilities, charge point operators, non-governmental organizations, and aggregators offering smart charging solutions.

The remainder of this paper is structured as follows. Section 2 presents the related literature, while Section 3 describes the methodology used for identifying and assessing the criteria for the evaluation framework. In section 4, quality criteria of green electricity are collected from the literature, and expanded by the analysis of German electricity eco-labels and the evaluation of expert interviews conducted. Section 5 describes the scale used by each criterion, allowing for the comprehensive characterization of a given green power charging service. In section 6, the criteria weights gained from the AHP, an illustrative case study for Germany, and the limitations of the study are discussed. Section 7 concludes.

2. Related work

Energy services are discussed under three fundamentally different paradigms: (1) the classic electric utility business itself can be understood as a service, (2) services regarding the financing, planning or installation of generators, and (3) services enabled by energy usage (Salah et al. 2017). In general, Fell (2017) summarizes 185 articles on energy services as "functions performed using energy which are means to obtain or facilitate desired end services or states". The literature on (3) often revolves around services enabling energy savings (e.g. Vine 2005). In contrast, we apply the definition of energy services “as services that are facilitated by energy, in particular for energy-intensive applications, offered on the mass market” (Salah et al. 2017, p. 615) for households (e.g. individual mobility, household temperature control). For the case of mobility, car sharing with billing by time or kilometer instead of kWh is an example of such a service. Fundamentally, private companies thereby offer the service directly to the customer which was previously provided by the customers themselves, i.e. buying at a car specifically for the services of mobility and transport[1]. Based on this definition, Salah et al. (2017) offer a range of design options for energy services in the categories of inherent product properties, pricing, infrastructure requirements and resulting risk. These design options could be combined to differentiated energy services, targeting various customer groups.

Specifically, demand-side flexibility and the type of energy source as one of the major product properties are of particular interest in today’s discussion on high shares of renewables in power generation. Kowalska-Pyzalska (2018) refers to them as *innovative energy services* and divides them into four categories: green energy tariffs and programs, demand-side management and demand response tools, smart metering information systems, and small-scale renewable generators. Based on this classification, we reviewed the relevant literature in order to define the most important drivers and barriers to the adoption of innovative energy services. As a mixture of the first two categories, we specifically focus on GPCS.

2.1 Green power

Independently of energy use, differentiating electricity tariffs for green power with different attributes is common practice among utilities, as supplying the highest quality or niche markets are key strategies of competition (Friege and Herbes 2016). Central Europe, with a high level of competition on the retail market, has seen a growing number of green electricity tariffs lately, and Germany in particular has been referred to as the “most mature market for green electricity”

[1] The Household Production Theory by Becker (1965) and Lancaster (1966) refers to goods being purchased to gain utility from a specific service in the household, e.g. nutrition and enjoyment from a cooked meal, rather than the good itself being the source of utility.

(Herbes and Ramme 2014). Beyond the price, the payment structure, and the share of renewables, many studies have looked at possible attributes for differentiating green electricity services. Common predictors for adopters of green electricity services are high income, altruistic or pro-environmental values (cf. review by Herbes et al. 2015), while Ozaki (2011) indicates that uncertainty about the quality of green electricity and inconvenience of switching might deter adoption despite strong pro-environmental values. Furthermore, Lee and Heo (2016) review literature on the willingness-to-pay (WTP) for green electricity in a number of countries. Further related work is discussed in more detail in Section 4 for the collection of significant quality criteria for the further analysis.

However, customers might not be able to assess the long-term benefits or risks of a particular GPCS due to a lack of thematic insight. This is due to two reasons: First, GPCS are more complex than traditional electricity tariffs and currently rarely available to an average consumer. Secondly, electricity is in general considered a low-involvement product, which leads to a lower awareness of differentiation opportunities (Walsh et al. 2005; Watson et al. 2002). Therefore, we make use of expert knowledge which tends to be more holistic.

2.2 Smart charging

While targeted marketing of green power may already lead to improved market conditions for renewable energy production (e.g. Jensen and Skytte 2002), Jochem et al. (2015) and Schuller et al. (2015) show that using the flexibility of PEVs (i.e. demand response measures) through smart charging (Kempton and Letendre 1997) could increase the use of green power (given significant PEV penetration). A considerable body of research has discussed optimization approaches and pricing mechanisms that influence charging events to generate revenues on wholesale electricity or ancillary service markets (e.g. Reddy et al. 2016; Schücking et al. 2017; Hu et al. 2016; García-Villalobos et al. 2014; Habib et al. 2015). Ensslen et al. (2018) discuss how specific smart charging or billing services, as well as charging infrastructure service equipment, could promote vehicle adoption, while Will and Schuller (2016) find the significance of consumers' notions of supporting the grid and expanding renewables as potential drivers for the adoption of controlled charging schemes. Hackbarth and Madlener (2013, 2016) and Wolff and Madlener (2019) found that consumers would be willing to pay a surcharge for fast-charging. On average, consumers would be willing to pay 0.16 €/month for a reduction of 1 min in charging time (Wolff and Madlener 2019). Noel et al. (2019) show that the ability to feed power back to the grid (i.e. vehicle-to-grid, V2G; Kempton and Tomić 2005) can contribute to PEV purchase decisions in some Scandinavian countries. Under consideration of users' preferences, Chen et al. (2019) discuss a multi-objective scheduling algorithm for PEV charging events. Similarly, Clairand et al. (2018) analyze effects of an aggregator's smart charging approach. Combining cost-minimization with technical constraints by the grid, PEV users can choose between different charging times and thereby achieve a discount of between 5% and 50% compared to the direct charging scenario. However, such technical studies mostly impose only basic restrictions, if any, on electricity origin or quality.

2.3 Quality-criteria for Green Power Charging Services

Axsen and Kurani (2013) conduct choice experiments and discover that some customers consider PEVs and green power as a natural pair and that pairing a PEV with a GPCS increased interest in PEVs.

Choice experiments by Nienhueser and Qiu (2016) and Wolff and Madlener (2019) confirm this finding: consumers would be willing to pay more for an increase of the share of green power in the electricity mix for PEV charging. Nienhueser and Qiu (2016) find for the US an increase in WTP for public charging of PEV if the electricity used is guaranteed to be from renewable energy sources. For Germany specifically, an increase in the share of green power by 1% was found to be worth 0.42 €/month. For charging green only, consumers would be willing to pay 42 €/month. A consumer group identified as environmentalists would be willing to pay more than twice as much (Wolff and Madlener 2019). Ensslen et al. (2016) show fleet managers' WTP for carbon reductions to rise with smart charging availability.

However, a detailed analysis of the specific quality criteria needed to contribute to a WTP for green charging services is missing to date. Will et al. (2017b) offer a theoretical selection of attributes and suggest an 'environmental quality score' for assessing customers' valuation of environmental quality.

3. Methodology

As preliminary steps in our research, we derived the relevant quality criteria for the multi-criteria evaluation from the literature, analyzed eco-labels of German electricity tariffs, and conducted 33 expert interviews in Germany and Switzerland in the summer of 2017. The experts belong to four different stakeholder groups related to the energy or electric mobility sector (see Table 1). As a next step, the experts compared each criterion in pairs using an AHP. We then calculated stakeholder-specific weightings of the criteria. Following the stakeholder-specific weightings, each criterion requires a scale, i.e. a value score for the degree to which a specific service, with its unique combination of attributes, satisfies the quality criteria and contributes to the overall quality of the service. The result, i.e. the weighted value scores per criterion, allows for the evaluation of varying GPCS from the perspectives of the different stakeholders, without having to contact the stakeholders again for each charging service individually.

3.1 Expert selection and interview method

We selected four stakeholder groups for which we contacted potential interview partners with a professional connection to the topics "green electricity" and/or "electric mobility" (Table 1). In the following, we refer to the interview partners as *experts*.

Table 1: Stakeholders, interview partners and affiliations

Stakeholder groups	Number of experts	Affiliation
Municipal utility	8	RheinEnergie, Smart Lab, STAWAG, Stadtwerke Flensburg Stadtwerke München , Südwestdeutsche Stromhandels GmbH, Thüga
Academia	10	ETH Zürich, Forschungszentrum Jülich, hfwu, KIT, Öko-Institut , Paul-Scherrer-Institute, University of St. Gallen, Wissenschaftszentrum Berlin
NGO	5	BUND, Deutsche Umwelthilfe, Grüne Liga, NABU, Robin Wood
Automobile manufacturers	10	BMW, Daimler, Elektromobilität NRW, Ford, RWTH Aachen (Chair of Production Engineering of E-Mobility Components , Streetscooter, VW

An additional six institutions across all stakeholder groups were unable to participate, either due to time constraints or a lack of know-how on the subject of the interviews.

In a first step, we conducted semi-structured interviews with an average duration of 30-45 minutes each, which have advantages over structured interviews in enhanced discovering and discussing previously unknown aspects and perspectives (Wilson 2013).

The experts should question the relevance of ordinary criteria (e.g. from eco-labels and literature) and also identify new criteria that they consider particularly important. A fifth of the interviews were conducted in person, the remaining experts were interviewed by telephone. The answers were recorded in the form of summarizing notes.

In addition to the literature review and the evaluation of the eco-labels, these exploratory interviews contribute to a theoretical saturation – sampling and analyzing data until no new data appear – in the search for quality criteria (Ando et al. 2014), i.e. contribute to the completion of the list of criteria (Glaser and Strauss 2009).

3.2 Analytic Hierarchy Process (AHP)

Criteria weights for GPCS are derived by conducting AHP (Saaty 1977; Saaty 1987) as a Multi-Criteria Decision Analysis (MCDA). In accordance with Saaty (1987) we asked interview partners *x* to compare every possible criteria pair in isolation on a scale from *1 = criteria A equally important to B* to *9 = A significantly more important than B* which is an intuitive and therefore popular AHP application (Wimmler et al. 2015). We received such pairwise comparisons from 28 out of the 33 interviewed experts.

The results of the comparisons between all *n* criteria are stored in the evaluation matrix $A = (a_{ij})\ \forall i,j = 1,2\ldots,n$:

$$A_x = \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix} \qquad \forall x \in \{1,2\ldots,28\} \tag{1}$$

Afterwards, the priority vector is calculated with the eigenvalue method (Saaty 1977). Furthermore, Saaty (1987) expanded AHP with a mathematical test for consistency based on the maximum eigenvalue.

We applied the AHP Excel template by Goepel (2013), which allows for the improvement of inconsistent evaluation matrices with the help of the maximum deviation approach (Saaty 2003; Gastes und Gaul 2012). In addition, the template contains the aggregation of individual valuations (A_x) via the geometric mean of the individual evaluation matrices. Each stakeholder group can therefore be interpreted as a synergistic individual, based on the criteria appraisal of individual experts (Aull-Hyde et al. 2006; Forman and Peniwati 1998). The eigenvalue method can then be applied to calculate criteria weights w_i from the perspective of the different stakeholders, based on their aggregated individual evaluation matrices.

3.3 Development of Value Scores

A *value score* represents the degree to which a specific GPCS satisfies a given quality criterion (Buede and Choisser 1992). A spectrum of value scores v_{ij} is described for each criterion *j* by values ranging from 0 (criterion not satisfied) to 10 (criterion perfectly satisfied) (Eisenführ and Weber 2003). Using these value scores and the criteria weights, a specific GPCS *b* can be evaluated with respect to its quality from the point of view of a specific stakeholder group (Kühnapfel 2014):

$$quality\ of\ service\ b = \sum_{i=1}^{n} w_i \cdot v_{ij} \tag{2}$$

4. Collecting and selecting quality criteria

This section describes the collection and selection of relevant quality criteria from the literature, the German eco-labels, and the expert interviews.

4.1 Literature review

Representative sustainability studies consider social, economic, and ecological target criteria (Hermanni 2016; Leßmann 2016). Some publications focus on the assessment of renewable energy technologies under the framework conditions of a specific country (China: Zhang et al. 2015; Algeria: Haddad et al. 2017; India: Mainali and Silveira 2015; Spain: San Cristóbal 2011; Scotland: Troldborg et al. 2014). Others assess concrete scenarios for the regional supply of renewable energies (Istanbul: Kaya and Kahraman 2010; Venezuelan rural areas: Rojas-Zerpa and Yusta 2015; Thassos, Greece: Mourmouris and Potolias 2013). Afgan and Carvalho (2002), Chou and Ongkowijoyo (2014) and La Rovere et al. (2010) investigate the general sustainability of various renewable energy technologies (wind, solar, hydro, etc.), while Sütterlin and Siegrist (2017) and Borchers et al. (2007) focus on their public perception and WTP. Madlener and Stagl (2005) compare alternative promotion policies for renewable energy, taking social, economic and environmental sustainability indicators explicitly into account.

Table 2 summarizes which ecological criteria from the aforementioned sources have been identified as applicable for the decision-making process:[2]

- *Land use* takes into account the area required for energy production per unit of output.
- *Greenhouse gas emissions* describe the mass of greenhouse gases or CO_2-equivalents per unit of energy. Emissions are considered over the entire lifecycle of a power plant.
- *Environmental impact* or *friendliness* includes qualitative criteria such as water consumption, noise, waste production, soil contamination, and negative influences on the characteristic landscape and the ecosystem. This includes local air pollution from combustion processes.

Higher investment as well as operating and maintenance costs for renewables power generation are plant-related costs and therefore barely accountable for the customer. Therefore, they are considered to be included in the criterion *quality premium* as part of the wholesale market price, the EEG surcharge, and other fees or charges.

4.2 Eco-labels for green power tariffs

According to Reichmuth (2014), there are five major eco-labels in Germany. Table 3 summarizes and describes the evaluation criteria used by these five German electricity eco-labels. Label certification authorities, such as Grüner Strom Label e.V., EnergieVision e.V., TÜV NORD, TÜV SÜD describe the criteria that must be fulfilled in order to obtain their label.

[2] The literature provides further criteria for social and technical dimensions. However, these seem to be out of scope for service selection from the customer's point of view. Table A.1 in Appendix A gives a complete overview.

Table 2: Collection of criteria from related literature with ecological dimension

Criteria	Afgan and Carvalho (2002)	Chou and Ongkowijoyo (2014)	Haddad et al. (2017)	Kaya and Kahraman (2010)	La Rovere et al. (2010)	Madlener and Stagl (2005)	Mainali and Silveira (2015)	Mourmouris and Potolias (2013)	Rojas-Zerpa and Yusta (2015)	San Cristóbal (2011)	Troldborg et al. (2014)	Zhang et al. (2015)
Land use	✓	✓	✓	✓	✓	✓	✓	✓	✓	○	✓	✓
Greenhouse gas emissions	✓	✓	✓	✓	✓	✓	✓	✓	✓	(✓)	✓	✓
Environmental impact	○	✓	✓	○	✓	✓	○	✓	○	○	✓	○

✓ - Criterion available (✓) - analogous criterion available ○ - criterion not used

4.3 Expert interviews

Approximately half of the 33 experts were concerned about the higher price of the green electricity or the *quality premium*, i.e. the difference in price between green electricity and electrical energy from unknown sources (so-called *grey* electricity). An offer of financial incentive models for shifting the charging load, e.g. in the form of variable or time-flexible tariffs, was suggested by two thirds of the experts as a possible criterion for the evaluation of the GPCS. Therefore, we discuss a *flexibility discount* below.

Avoiding *uncoupled guarantees of origin (GoO)*, i.e. the preference for tariffs where generation and GoO are provided by the same generator, was considered as decision-relevant for 24% of the respondents. Some 15% of the respondents regarded the self-generation of green electricity, e.g. by solar photovoltaic systems (PV), as a decision-relevant criterion. Every third respondent considered self-generation to be economically feasible for private customers.

4.4 Selection and definition of criteria

Land use and *greenhouse gas emissions* are used most frequently as criteria, in both the studies referred to in Section 4.1 (Table 2) and in other studies (Martín-Gamboa et al. 2017; Wimmler et al. 2015; Shmelev and van den Bergh 2016; Wang et al. 2009). Therefore, we make use of them in this study as well. *Environmental impact* is defined in various ways and often overlaps with other selected criteria. Therefore, though frequently used, it is not considered as a stand-alone criterion.

In the following, the criteria from the eco-labels (Table 3) are evaluated with regard to their relevance to our study.

Table 3: Criteria collection from German eco-labels for green power tariffs

Criteria	**Description**	**ok-power**	**Grüner-Strom-Label**	**TÜV SÜD EE01**	**TÜV SÜD EE02**	**TÜV NORD (A75-S026-1)**
Climate neutrality	Compensation of CO_2 emissions	○	○	(✓)	(✓)	○
Corporate group independence of the green electricity supplier	No direct holdings in lignite/coal-fired power plants	✓	✓/○	○	○	○
	No direct assets in nuclear power plants	✓	✓	○	○	○
Regionality	Renewable energy is produced and consumed in the same region	○	(✓)	(✓)	(✓)	○
Coupling	No separate trading of guarantees of origin (GoO) and amount of electricity	○	✓	○	○	○
Origin of electricity	100% from renewable sources	✓	✓	✓	✓	✓
Transparency	Additional information on e.g. power plant portfolio is available	✓	✓	○	○	✓
Ecological requirements	Ecological requirements for various renewable energy generators	✓	✓	○	○	○
Supply balancing model	Energy feed-in balanced annually	✓	✓	✓	✓	✓
	Simultaneous feed-in (quarter-hour basis)	○	○	○	✓	○
Additional environmental benefit, i.e. through replacing conventional generation (*additionality*)	Through quota for generators younger than age limit, i.e. new plant quota or new investment quota (NPQ)	✓	○	✓	○	✓
	Small surcharge goes into green project fund (SC)	✓	✓	✓	✓	✓
Consumer-friendly contract design	Fair tariff conditions, no hidden clauses	✓	✓	✓	✓	✓

✓ - criterion required (✓) - optional ○ – criterion not required

The criterion *climate neutrality*, which describes the compensation of GHG emissions by e.g. reforestation projects, is not considered in this paper since the lack of transparency and the resulting risk of misuse of this methodology has been criticized (e.g. Harthan et al. 2010; Umweltbundesamt 2016). We also exclude the criterion *corporate group independence of the green electricity supplier* as it is related to energy policy rather than to service quality.

The criterion *coupled GoO* which can enhance the credibility and transparency of green electricity products (Leprich 2008; Reichmuth 2014; Seebach and Mohrbach 2013; Leprich et al. 2015; Meffert et al. 2010) as well as the criterion *consumer-friendly contract* are integrated into the criterion *transparency* (and thus indirectly covered).

Consumers' WTP is higher for regional generation shares in the electricity mix (Kalkbrenner et al. 2017; Mengelkamp et al. 2019) as well as for electricity products of municipal utilities as regional providers compared to electricity products of non-local power providers (Kaenzig et al. 2013), which further hints at the significance of regional production. Furthermore, regional green power labeling can be used to systematically upgrade the options for the marketing of regionally generated electricity (Peters et al. 2018a, 2018b). Consequently, the criterion *regionality* is included in the selection of evaluation criteria. Additionally, the German Federal Council (Bundesrat 2015), the German Federal Ministry of Economics and Energy (BMWi 2016) and the German Federal Environment Agency (Umweltbundesamt 2017) agreed that regional marketing of green electricity can promote acceptance of the energy system transformation and introduced a registry for regional GoO (Umweltbundesamt 2017).

Gohla-Neudecker et al. (2011) and Will et al. (2017a) argue that charging vehicles with electricity based on renewable energies is more viable with a strict proof of supply and demand occurring within the shortest possible *balancing period*. In this manner, time-specific approaches for determining the average CO_2 emissions of the electricity mix at the time of charging could be realized (Jochem et al. 2015). This could also provide greater flexibility for intermediate storage and compensation for volatile electricity generation (Will et al. 2017a). For this reason, the *balancing period* will be part of the AHP analysis.

A contribution to the expansion of renewable energy capacity and a promotion of the German energy transition (*Energiewende*) through green electricity procurement is a central quality criterion for GPCS (Gillenwater 2008; Reichmuth 2014; Schulze 2015; Timpe et al. 2008). In the following, we use the commonly used term *additionality* (Gillenwater 2008). We differentiate between additionality through increased demand or an age limit for generators (*new plant quota*, *NPQ*) and tariff obligations to pay a small premium to support otherwise economically infeasible capacity expansion investments (*subsidy contribution*, *SC*).

The *green power* or *quality premium* is rated by many experts as relevant for customers' decision-making. This was confirmed in some studies dealing with customers' WTP for green electricity (Herbes et al. 2015; Roe et al. 2001; Sundt and Rehdanz 2015). In this paper, it is taken into account in the form of a surcharge to be paid on top of the lowest electricity tariff (for *grey* electricity).

Financial incentive models for influencing household loads (Wissner and Liebe 2015), e.g. in the form of time-dependent or variable tariffs, are summarized and used in the criterion *flexibility discount*. With the help of demand-side management, power demand can be reduced at peak-load times and shifted to base-load times (Liebe et al. 2015; Paetz et al. 2013), especially with the intensive, yet comparatively flexible load of PEVs.

5. Value scores for quality criteria

Table 5 provides an overview of all criteria; it shows the corresponding scales of the value scores, including brief explanations. With reference to data and values from the literature and from market research, we set up the scales of value scores. The following subsections describe each quality criterion in more detail.

5.1 Regionality

A system based on postcode distances (BMWi 2016) and NUTS[3] levels 1 and 2 (i.e. in Germany federal states and government districts) is used to determine the degree of a GPCS's *regionality*. This is comparable with the definition of the regional GoO (*Regionalnachweise*) introduced in Germany at the beginning of 2019, which allows for tracking and trading of electric power produced from renewable energy sources in postcode areas within 50 km of the generator (Umweltbundesamt 2018).

5.2 Transparency

On the basis of the criteria catalogues of some eco-labels (Grüner Strom Label e.V. 2015; EnergieVision e.V. 2016b; TÜV NORD 2014) the information which should be presented by the service supplier to create transparency for the customer was determined (see Table 5). The value score for *transparency* increases with the number of fulfilled sub-criteria.

Table 4: Sub-criteria of transparency in eco-labels for electricity

Sub-criteria	**Description**	**ok-power**	**Grüner-Strom-Label**	**TÜV NORD (A75-S026-1)**
Coupling	No separate trading of GoO and amount of electricity	✓	✓	○
Information on generator	Type of generator, location, time of commissioning, performance/ production data, etc.	✓	✓	(✓)
Customer protection	Fair and transparent contractual conditions, no hidden clauses, etc.	✓	✓	○
Size of subsidy	Obligation of reinvestment, use of funds	✓	✓	○
Accessibility to simple and clear information	Information is easily understandable and retrievable and presented clearly on the provider's website	○	○	○

✓ - criterion is met (✓) - optional ○ - criterion is not met

[3] "Nomenclature des unités territoriales statistiques" is a hierarchical standardization of administrative regions.

Table 5: Scales of value scores for each quality criterion

Criteria \ Value Scores	0	1	2	3	4	5	6	7	8	9	10
Regionality[1]	P is in the EU (incl. Switzerland and Norway)	P is in the next but one neighboring country	P is in a neighboring country	P is in the same country	P is a max. of two federal states away	P is in the same federal state	P is a max. of two administrative districts away	P is in a neighboring administrative district	P is in or around the next but one PC-area of C	P is in or around PC-area of C	C-location = P-location
Transparency[2]	0 aspects	-	1 aspect	-	2 aspects	-	3 aspects	-	4 aspects	-	5 aspects
Balancing period	> 3 a	≤ 3 a	≤ 1 a	≤ 6 M	≤ 3 M	≤ 1 M	≤ 1 W	≤ 24 h	≤ 1 h	≤ 15 min	Simultaneous[3]
Additionality NPQ[4]	0%	≤ 10%	≤ 20%	≤ 30%	≤ 40%	≤ 50%	≤ 60%	≤ 70%	≤ 80%	≤ 90%	> 90%
Additionality SC[5]	0	≤ 0.1	≤ 0.2	≤ 0.3	≤ 0.4	≤ 0.5	≤ 0.6	≤ 0.7	≤ 0.8	≤ 0.9	> 0.9
Land use[6]	> 4,000	≤ 4,000	≤ 3,000	≤ 2,000	≤ 1,000	≤ 800	≤ 600	≤ 400	≤ 200	≤ 100	≤ 50
Greenhouse gas[7]	> 100	> 90	> 80	> 70	> 60	> 50	> 40	> 30	> 20	> 10	≤ 10
Flexibility discount[8]	≤ 0%	≤ 2%	≤ 4%	≤ 6%	≤ 8%	≤ 10%	≤ 12%	≤ 14%	≤ 16%	≤ 18%	> 18%
Quality premium[9]	> 20%	> 18%	> 16%	> 14%	> 12%	> 10%	> 8%	> 6%	> 4%	> 2%	≤ 2%

[1] consumer perspective; [2] aspects are coupling, information on generator, customer protection, size of subsidy, accessibility to simple and clear information; [3] Simultaneous (produced energy is directly used); [4] NPQ = new plant quota; [5] SC = surcharge (Cent/kWh); [6] consumed area (m²/kW); [7] life-cycle greenhouse gas emissions (gCO_2eq/kWh); [8] price difference in standard tariff; [9] green electricity price compared to the cheapest electricity tariff. P = power plant, M = month(s), C = consumer, W = week(s), PC = postal code.

5.3 Balancing period

The *balancing period* is the time period during which the GoO are canceled. As examples of long *balancing periods*, European GoO are valid for 12 months (European Parliament; Council 4/23/2009), while Texas and California allow balancing within three years (U.S. Department of Energy 2017; CEC 2016). The shortest possible balancing period in the German energy sector is a time interval of one quarter-hour (see EPEX SPOT intraday auction; TÜV SÜD 2015b). Simultaneous quantity balancing, or simply power balancing, refers to the verification that the generation of electricity from renewable energy sources takes place in immediate temporal proximity to the demand e.g. by self-consumption of on-roof PV production (Bertoldi and Huld 2006; Salah et al. 2017).

5.4 Additionality NPQ and additionality SC

One way of promoting the expansion of renewable energy generation capacity is through a *new plant quota* (criterion: *additionality NPQ*). It specifies the percentage of electricity supplied that is required to come from renewable energy power plants being no older than, for example, six years. A further possibility is the explicit promotion of additional generation capacity with the help of a subsidy. Contribution values commonly seen in the market are the basis for the value scores of the criterion *additionality SC* (Table 5).

5.5 Land use

The scale of fulfilment is derived from the mean values of the consumed area specific to each production technology, following Troldborg et al. (2014).

5.6 Greenhouse gas emissions

The Intergovernmental Panel on Climate Change (IPCC) has compiled results from a large number of primary sources on the release of *greenhouse gas emissions* from various technologies (Schlömer et al. 2014). By reviewing life cycle assessment (LCA) publications, Turconi et al. (2013) and Weisser (2007) come to comparable technology-specific GHG values. Schlömer et al. (2014) calculate a different GHG value for biomass technology because they take the Albedo effect into account. Schlömer et al. (2014) is the only source we are aware of that publishes specific median values; therefore, their aggregated data form the basis for the calculation of the value scores.

5.7 Flexibility discount

Optimized charging allows PEV users to adjust their charging times and/or speeds according to the specifications of a GPCS (e.g. electricity supplier, grid operator) in exchange for lower-cost electricity. Classical time-of-use tariffs, e.g. for night storage heaters, with significantly reduced night rates are examples of price signalling already applied today. Despite their rare application in the context of mobility and due to the low penetration levels of smart meters in Germany, we use these tariffs as a proxy for the *flexibility discount* granted by a GPCS provider. An indicative survey in eleven German cities revealed price differences between the standard tariff of the default provider and the lower night rate of the same provider. The tariffs showed discounts between 0.4% and 19.2%, with an average of 12.3% for an exemplary electricity consumption of 3,650 kWh/a at night.

In other countries, optimized charging can also be achieved through flexible tariffs with fluctuating electricity prices at different times. In the Netherlands, for instance, there is an energy supply company offering a smart charging option at private charging stations using a smartphone app (Jedlix 2017). In a pilot test of that app, savings of between 10% and 15% in electricity charging costs were achieved (Spruit 2015).

5.8 Quality premium

For the customer, *green* power is not necessarily more expensive than conventional *grey* power. For example, in an indicative survey of tariffs in eight randomly selected German cities in July 2017, the cheapest overall tariff was that of a supplier of green electricity with GoO from Scandinavian hydro-power plants. Green electricity certified with a higher-quality label – we chose *ok-power* as an example – was on average 5.3% more expensive than the cheapest electricity in this survey. Green electricity with requirements going beyond higher-quality labels, which is offered, for example, by Greenpeace Energy in the form of the *Solar power plus* tariff, is on average 22.2% more expensive than the cheapest provider. Therefore, we define this price difference in terms of a *quality premium*.

6. Discussion

The fulfilment of each criterion can be judged for a given GPCS with the help of the value scores described previously. In the following, we show the result of the AHP to describe how much each criterion contributes to the quality of any GPCS and define a specific service as an example. Furthermore, the limitations of this approach are discussed in Section 6.3.

6.1 Criteria weights from AHP

The paired comparisons of the criteria selected by 28 experts were evaluated and aggregated within the four stakeholder groups (Table 6).

Table 6: Stakeholder-specific relative importance of criteria

Criteria	Weight/ relative importance [%]			
	Automobile manufacturers	Academia	Municipal utilities	NGO
Regionality	6.3	5.3	15.2++	5.4
Transparency	10.2+	9.5	16.5++	10.5+
Balancing period	8.8	6.2	8.3	5.8
Additionality (NPQ, SC)	11.4+	12.0+	7.2	29.6+++
Land use	4.8	6.5	6.4	15.0++
Greenhouse gas emissions	14.8+	30.3+++	6.0	23.2+++
Flexibility discount	22.3+++	14.3+	12.2+	6.0
Quality premium	21.3+++	15.5++	28.2+++	4.5

Notes: Relative importance > 20% (+++), 15-20% (++), 10-15% (+)

The economic criteria (*quality premium*, *flexibility discount*) are most important to automobile manufacturers and municipal utilities, who both have a direct economic interest in selling their products and maintaining a competitive market position.

Regionality only mattered significantly for the municipal utilities (> 15%), who in terms of competition act primarily as local suppliers. Therefore, the local roots of the municipal utilities[4] represent a unique selling point (Friege and Herbes 2016). Ecological criteria (*land use*, *greenhouse gas emissions*) and *additionality* as a means to support the German *Energiewende* were awarded little importance by the municipal utilities. For the majority of German electricity customers, ecological issues are also not the major focus of attention (Eisele 2016). This could be the reason why municipal utilities as rather customer-oriented stakeholder groups do not focus explicitly on ecological benefits of their tariffs.

In the case of green electricity for PEVs, the following specific aspect should be taken into account. According to Frenzel et al. (2015), nine out of ten German PEV buyers, i.e. early adopters, are male, on average 51 years old, particularly well-educated, have an above-average income, and strive to behave in an ecologically sustainable manner. A survey among 284 BMWi3 owners (PEV owners) also revealed their above-average ecological affinity (Prestl et al. 2017). According to Friege and Herbes (2016) the discussed criteria increase the WTP for green electricity. In combination, these findings indicate that PEV buyers are willing to pay more for green electricity. The providers of supply options could therefore raise the requirement for ecological criteria and, given sufficient transparency, attach less weight to the *quality premium*, i.e. demand higher prices for this higher quality.

[4] When discussing regionality, it is important to note that municipal utilities do not necessarily own regional production facilities. As a result, the above definition of this criterion may be diluted. This discrepancy should be subject to further research.

Academia considers *greenhouse gas emissions* to be of the highest importance. This result coincides with the fact that *greenhouse gas emissions* were also the most frequently cited criterion in the scientific literature on the sustainability of energy systems (Martín-Gamboa et al. 2017; Wimmler et al. 2015; Wang et al. 2009).

The criterion of *additionality*, which should lead to an investment-supported promotion of the energy transition, is far more important to the NGOs than to the other stakeholder groups. The second-most important criterion for NGOs is *greenhouse gas emissions*, followed by *land use*. This prioritization of ecological criteria coincides with the self-image of NGOs as actors for nature conservation and climate protection that is publicly propagated.

Experts from academia assigned some weight to economic criteria, while NGOs ranked these among the least significant.

6.2 Case Study: *Greenpeace Energy Solarstrom plus* in the City of Sindelfingen, Germany

In order to illustrate the applicability of the developed evaluation framework, we evaluate a green power tariff based on *Solarstrom plus* offered by Greenpeace Energy (Greenpeace Energy eG 2017c) specifically for charging PEV. This GPCS is characterized by a high price level and good transparency. In addition, a small subsidy contribution is explicitly added to the tariff in order to ensure further investments in renewable energy capacity. The tariff is certified with the *ok-power* seal (initiation model) from TÜV Nord and a very high rating by ÖkoTest (Greenpeace Energy eG 2017a; EnergieVision e.V. 2016a). Run-of-river power plants account for 85% of the installed capacity of the generation pool, whereas wind and solar provide the remaining 15% (Greenpeace Energy eG 2017b).

The real tariff does not incentivize controlled charging, as the energy price is fixed per kWh. To illustrate the applicability of the developed evaluation framework for GPCS, we expand the *Solarstrom plus* tariff with a variable price in order to make flexibility discounts available for the consumer. In this scenario, green electricity is provided for charging a PEV with an annual electricity demand of 3,650 kWh in the city of Sindelfingen, Baden-Wüttemberg, Germany. The value scores were determined with the help of the information published by Greenpeace Energy.

The scores in Table 7 result from the combination of the value scores for *Solarstrom plus* with the stakeholder-specific weighting. The maximum possible score is 900. The stakeholder groups score in the range of 453.8 to 764 and display a heterogeneous landscape of quality appraisal.

Table 7: Quality scores for criteria of the tariff *Greenpeace Energy Solar Power plus* across the stakeholders

Criteria	**Value scores**	**Stakeholder-specific weighting [%]**				**Stakeholder-specific score**			
		Automobile manufacturers	**Academia**	**Municipal utilities**	**NGO**	**Automobile manufacturers**	**Academia**	**Municipal utilities**	**NGO**
Regionality	3	6.3	5.3	15.2	5.4	18.9	15.9	45.6	16.2
Transparency	10	10.2	9.5	16.5	10.5	102.0	95.0	165.0	105.0
Balancing period	2	8.8	6.2	8.3	5.8	17.6	12.4	16.6	11.6
Additionality (NPQ, SC)	11	11.4	12.0	7.2	29.6	125.4	132.0	79.2	325.6
Land use	6	4.8	6.5	6.4	15.0	28.8	39.0	38.4	90.0
Greenhouse gas emissions	8	14.8	30.3	6.0	23.2	118.4	242.4	48.0	185.6
Flexibility discount	5	22.3	14.3	12.2	6.0	111.5	71.5	61	30
Quality premium	0	21.3	15.5	28.2	4.5	0.0	0.0	0.0	0.0
					Sum:	**522.6**	**608.2**	**453.8**	**764.0**

With a score of 764 the NGOs rate this GPCS the highest. This is mainly due to the focus on ecological criteria and additionality. The NGOs such as Robin Wood e.V. or BUND e.V. – both recommending this tariff in public (Greenpeace Energy eG 2017a) – could be seen as validation.

The experts from academia rank the tariff with a score of 608.2, followed by those from the automobile manufacturers (522.6) and the municipal utilities (453.8). The explanation lies in the tariff's very low value scores in the economic criterion *quality premium*, which carry more significance for these two stakeholder groups. The strong valuation of automobile manufacturers for the flexibility discounts significantly increased this tariff's score for this particular stakeholder.

In conclusion, this example demonstrates the application of the carefully defined value scores, and also the significant influence that the individual stakeholder group's perspective has on the quality appraisal of the given GPCS.

6.3 Limitations

Since the population size of the *experts* cannot be reasonably estimated and a sample with a verifiable confidence level was beyond the scope of this study, a qualitative interview technique was chosen for the expert interviews. The results of the interviews were checked for plausibility. Up to ten experts were interviewed for each stakeholder group (Table 1).

Personal interviews always entail the possibility of unintentional systematic distortion of the results by the interviewer (interviewer bias). Due to the complexity of the research topic and the deliberately chosen semi-structured interview technique, it was not reasonable to use written or computer-aided interviews only, which could considerably reduce or even avoid such distortions. To mitigate the extent of a possible systematic bias, a standardized interview guide was developed in advance and used in the interviews.

In order to check the pairwise evaluation of the criteria of the individual experts for consistency, a consistency check was carried out for the AHP procedure (Saaty 1987; Lane and Verdini 1989; Garbuzova-Schlifter and Madlener 2016). Consistency values (CR) of the pairwise comparisons above the critical threshold of $CR = 0.15$ were found in 57% of the responses. In these cases, the experts were confronted with inconsistencies in their first, more intuitive assessment and asked for a revision of their scoring. It is important to note that the adjustment of the weights by the experts only led to negligible changes in the prioritization of the criteria, while at the same time leading to satisfying consistency.

The final criteria weights of the specific stakeholder groups appear plausible, as they seem to reflect the role or task of the respective stakeholders' inherent interests. In particular, the NGO independent recommendation for the supply option described in the mentioned case study can be seen as a validation of the weighting system presented here.

This study discusses a more normative, and somewhat more neutral weighting of the criteria due to its methodological orientation towards expert interviews. Academia and NGOs, in particular, can assess the sustainability of supply options or even make purchase recommendations on the basis of their expertise in this exact field. Based on this, a survey of representative customer preferences could significantly deepen the understanding of criteria perception and possibly also make it usable for marketing and sales strategies.

With the help of discrete choice analyses, for example, the range of possible GPCS could be clarified better to the respondents. Such analytical methods, however, are usually based on statistically independent criteria, a requirement that is often difficult to meet in practice. The quality criteria used in this study also partly overlap. This had to be tolerated due to the aggregation of the diverse sources, the complexity of the topic, and due to the limited sample size. Subsequent researchers should therefore pay close attention to a clear definition of the criteria and are advised to comprise intensive pre-testing of the criteria system.

7. Conclusions

By charging PEVs with today's German electricity mix, which still contains a high proportion of fossil fuels of approx. 60% (Bruger 2018), the ecological value-added mostly lies in shifting pollutant emissions from residential areas to centralized power generation facilities. It therefore seems prudent to prioritize the use of renewable energy, which causes only relatively low CO_2 emissions in power generation.

It is apparent that the interests of the four stakeholder groups (NGOs, municipal utilities, automobile manufacturers, academia) have a significant influence on their weighting of quality criteria: For the experts from municipal utilities and automobile manufacturers, low costs (i.e. *quality premium*) and the possibility of economically optimized charging (i.e. *flexibility discount*) were particularly important. Especially in the case of intensive but flexible loads, such as PEVs, the adaptation of charging duration and power promises some economic potential. The transparency of the supply options and the regional production of green electricity were important to mostly locally operating municipal utilities, while purely ecological criteria did not play a similar role for this group of stakeholders. The lowest possible greenhouse gas emissions during the lifecycle were very important to experts from academia. Economic quality criteria also played a role but on a lower level. NGOs rated ecological criteria and in particular additionality most highly, while economic criteria received little or no attention. This clearly reflected their intrinsic ecological goals.

By combining value scores and weights, a multi-criteria evaluation framework was created. This framework allows for the evaluation of any possible approach for the supply of green electricity for PEVs from the perspectives of different stakeholders, without the need for repeated involvement of the experts. Using a specific GPCS as an example, the applicability of the newly developed multi-criteria evaluation framework was demonstrated. As a result, the application of the evaluation framework leads to a plausible prediction of stakeholder-specific evaluations.

This study contributes to a better understanding of how ecological and economic criteria of green power charging services (GPCS) are weighted by relevant stakeholder groups. In addition, it provides a model to evaluate specific services with regard to their perceived quality – without the need for repeated expert surveys.

Further research potential lies in refining the weighting of the evaluation criteria to better suit a user respectively customer perspective by confronting PEV owners with GPCS. The complexity of the quality criteria might have to be adjusted for such customer interviews and a more standardized surveying method should be applied to a larger sample. In particular, the assumption that PEV buyers have so far shown a higher demand for ecological quality and an increased WTP for green electricity is worth examining.

As a final point, most interview partners stressed that electrifying transport can only benefit the planet in combination with renewable energy sources used in power generation. With increasing penetration of PEVs, the question of GPCS quality will become increasingly important. In this regard, the present study can help to guide decision-makers in business and administration to achieve a more sustainable future of transportation.

Appendix

Table A.1: Criteria collected from literature (extensions of Table 2)

Dimensions	**Criteria**	Afgan and Carvalho (2002)	Chou and Ongkowijoyo (2014)	Haddad et al. (2017)	Kaya and Kahraman (2010)	La Rovere et al. (2010)	Madlener and Stagl (2005)	Mainali and Silveira (2015)	Mourmouris and Potolias (2013)	Rojas-Zerpa and Yusta (2015)	San Cristóbal (2011)	Troldborg et al. (2014)	Zhang et al. (2015)
Ecological	Land use	✓	✓	✓	✓	✓	✓	✓	✓	✓	○	✓	✓
	Greenhouse gas emissions	✓	✓	✓	✓	✓	✓	✓	✓	✓	(✓)	✓	✓
	Environmental impact	○	✓	✓	○	✓	✓	○	✓	○	○	✓	○
Social	Risk of accidents / incidents	○	○	✓	○	○	✓	○	✓	○	○	○	✓
Technical	Energy generation	○	○	○	○	✓	○	✓	○	○	✓	✓	○
	Efficiency of generation	✓	○	○	✓	✓	○	✓	✓	✓	○	○	○
	System reliability	○	○	✓	○	○	○	✓	✓	✓	○	✓	○
	Technological maturity	○	○	✓	○	○	○	○	○	○	○	✓	✓
	Generation capacity / availability	○	○	✓	○	✓	○	○	✓	✓	(✓)	○	○

✓ - criterion available (✓) - analogous criterion available O - criterion not used

References

Afgan, Naim H.; Carvalho, Maria G. (2002): Multi-criteria assessment of new and renewable energy power plants. In *Energy* 27 (8), pp. 739–755. DOI: 10.1016/S0360-5442(02)00019-1.

Ando, Hikari; Cousins, Rosanna; Young, Carolyn (2014): Achieving Saturation in Thematic Analysis. Development and Refinement of a Codebook. In *Comprehensive Psychology* 3, 03.CP.3.4. DOI: 10.2466/03.CP.3.4.

Aull-Hyde, Rhonda; Erdogan, Sevgi; Duke, Joshua M. (2006): An experiment on the consistency of aggregated comparison matrices in AHP. In *European Journal of Operational Research* 171 (1), pp. 290–295. DOI: 10.1016/j.ejor.2004.06.037.

Axsen, Jonn; Kurani, Kenneth S. (2013): Connecting plug-in vehicles with green electricity through consumer demand. In *Environ. Res. Lett.* 8 (1), p. 14045. DOI: 10.1088/1748-9326/8/1/014045.

Becker, Gary S. (1965): A Theory of the Allocation of Time. In *The Economic Journal* 75 (299), p. 493. DOI: 10.2307/2228949.

Bertoldi, Paolo; Huld, Thomas (2006): Tradable certificates for renewable electricity and energy savings. In *Energy Policy* 34 (2), pp. 212–222. DOI: 10.1016/j.enpol.2004.08.026.

BMVIT (2016): Leichtfried und Rupprechter präsentieren E-Mobilitätspaket - Verkehrsministerium, Umweltministerium und Automobilimporteure investieren gemeinsam 72 Millionen Euro. Pressegespräch mit J. Leichtfried (Verkehrsminister), A. Rupprechter (Umweltminister) und G. Kerle (Sprecher d. österr. Automobilimporteure). Bundesministerium für Verkehr, Innovation und Technologie. Wien, Austria. Available online at https://infothek.bmvit.gv.at/e-mobilitaetspaket/, checked on 2/18/2019.

BMWi (2016): Regionale Grünstromkennzeichnung. Eckpunktepapier, 11. März 2016. Bundesministerium für Wirtschaft und Energie (BMWi). Available online at https://www.bmwi.de/Redaktion/DE/Downloads/P-R/eckpunktepapier-regionale-gruenstromkennzeichnung.pdf?__blob=publicationFile&v=5, checked on 7/16/2017.

Borchers, Allison M.; Duke, Joshua M.; Parsons, George R. (2007): Does willingness to pay for green energy differ by source? In *Energy Policy* 35 (6), pp. 3327–3334. DOI: 10.1016/j.enpol.2006.12.009.

Bruger, Bruno (2018): Stromerzeugung in Deutschland | Energy Charts. Edited by Fraunhofer-Institut für Solare Energiesysteme ISE. Available online at https://www.energy-charts.de/energy_pie_de.htm, updated on 6/4/2018, checked on 6/4/2018.

Buede, Dennis M.; Choisser, Robert W. (1992): Providing an analytic structure for key system design choices. In *J. Multi-Crit. Decis. Anal.* 1 (1), pp. 17–27. DOI: 10.1002/mcda.4020010104.

Bundesrat (2015): Beschluss des Bundesrates. Entschließung des Bundesrates zum Erfordernis einer Grünstromvermarktungsverordnung. Available online at http://www.bundesrat.de/SharedDocs/drucksachen/2015/0401-0500/408-15(B).pdf?__blob=publicationFile&v=1, checked on 8/5/2017.

CEC (2016): Renewable Energy - Tracking Progress. California Energy Commission (CEC). Available online at http://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf, updated on 12/22/2016, checked on 7/20/2017.

Chen, Jie; Huang, Xiaoqing; Tian, Shiming; Cao, Yijia; Huang, Bicheng; Luo, Xiaoyue; Yu, Wenlong (2019): Electric vehicle charging schedule considering user's charging selection from economics. In *IET Generation, Transmission & Distribution* 13 (15), pp. 3388–3396. DOI: 10.1049/iet-gtd.2019.0154.

Chou, Jui-Sheng; Ongkowijoyo, Citra S. (2014): Risk-based group decision making regarding renewable energy schemes using a stochastic graphical matrix model. In *Automation in Construction* 37, pp. 98–109. DOI: 10.1016/j.autcon.2013.10.010.

Clairand, Jean-Michel; Rodriguez-Garcia, Javier; Alvarez-Bel, Carlos (2018): Smart Charging for Electric Vehicle Aggregators Considering Users' Preferences. In *IEEE Access* 6, pp. 54624–54635. DOI: 10.1109/ACCESS.2018.2872725.

Eisele, Jürgen (2016): Werthaltige Segmentierung. In Bernhard Keller, Hans-Werner Klein, Stefan Tuschl (Eds.): Marktforschung der Zukunft - Mensch oder Maschine? Wiesbaden: Springer Fachmedien Wiesbaden, pp. 245–261.

Eisenführ, Franz; Weber, Martin (2003): Rationales Entscheiden. 4th ed. Berlin, Heidelberg, s.l.: Springer Berlin Heidelberg (Springer-Lehrbuch). Available online at http://dx.doi.org/10.1007/978-3-662-09668-0.

EnergieVision e.V. (2016a): Greenpeace Energy eG. Greenpeace Energy Ökostrom. Available online at http://www.ok-power.de/strominformationen/greenpeace-energy-oekostrom.html, checked on 8/10/2017.

EnergieVision e.V. (2016b): Kriterien für das Gütesiegel „ok-power" für Ökostromprodukte. Edited by EnergieVision e.V. Available online at http://www.ok-power.de/files/ok_power_theme/PDF-Downloads/ok-power%20Kriterien%20V%208.2.pdf, checked on 8/5/2017.

Ensslen, Axel; Gnann, Till; Globisch, Joachim; Plötz, Patrick; Jochem, Patrick; Fichtner, Wolf (2016): Willingness to Pay for E-Mobility Services. A Case Study from Germany. In : Proceedings of the Second Karlsruhe Service Summit Workshop. 25.-26.02.2016. Karlsruhe, Germany.

Ensslen, Axel; Gnann, Till; Jochem, Patrick; Plötz, Patrick; Dütschke, Elisabeth; Fichtner, Wolf (2018): Can product service systems support electric vehicle adoption? In *Transportation Research Part A: Policy and Practice. DOI:* 10.1016/j.tra.2018.04.028.

European Parliament; Council (4/23/2009): DIRECTIVE 2009/28/EC on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC. In *Official Journal of the European Union* (52), pp. 16–63. Available online at https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0028&from=DE, checked on 2/18/2018.

Eurostat (2016): Stromerzeugung, Stromverbrauch und Marktüberblick. Available online at http://ec.europa.eu/eurostat/statistics-explained/index.php/Electricity_production,_consumption_and_market_overview/de#Stromerzeugung, checked on 4/26/2017.

Fell, Michael James (2017): Energy services. A conceptual review. In *Energy Research & Social Science* 27, pp. 129–140. DOI: 10.1016/j.erss.2017.02.010.

Flammer, Larissa (2019): Thurgauer erhalten beim Kauf eines Elektroautos 4000 Franken. Edited by Tagblatt. Available online at https://www.tagblatt.ch/ostschweiz/frauenfeld/thurgauer-erhalten-beim-kauf-eines-elektroautos-4000-franken-ld.1083190, updated on 1/8/2019, checked on 2/18/2019.

Forman, Ernest; Peniwati, Kirti (1998): Aggregating individual judgments and priorities with the analytic hierarchy process. In *European Journal of Operational Research* 108 (1), pp. 165–169. DOI: 10.1016/S0377-2217(97)00244-0.

Frenzel, Ina; Jarass, Julia; Trommer, Stefan; Lenz, Barbara (2015): Erstnutzer von Elektrofahrzeugen in Deutschland. Nutzerprofile, Anschaffung, Fahrzeugnutzung. Edited by DLR. Institut für Verkehrforschung. Available online at http://elib.dlr.de/96491/.

Friege, Christian; Herbes, Carsten (2016): Einführung in die Vermarktung Erneuerbarer Energien. Wiesbaden: Springer Fachmedien Wiesbaden.

Garbuzova-Schlifter, Maria; Madlener, Reinhard (2016): AHP-based risk analysis of energy performance contracting projects in Russia. In *Energy Policy* 97, pp. 559–581. DOI: 10.1016/j.enpol.2016.07.024.

García-Villalobos, J.; Zamora, I.; San Martín, J. I.; Asensio, F. J.; Aperribay, V. (2014): Plug-in electric vehicles in electric distribution networks. A review of smart charging approaches. In *Renewable and Sustainable Energy Reviews* 38, pp. 717–731. DOI: 10.1016/j.rser.2014.07.040.

Gillenwater, Michael (2008): Redefining RECs—Part 1. Untangling attributes and offsets. In *Energy Policy* 36 (6), pp. 2109–2119. DOI: 10.1016/j.enpol.2008.02.036.

Glaser, Barney G.; Strauss, Anselm L. (2009): The discovery of grounded theory. Strategies for qualitative research. 4. paperback printing. New Brunswick: Aldine.

Goepel, Klaus (2013): Implementing the analytic hierarchy process as a standard method for multi-criteria decision making in corporate enterprises. A new AHP excel template with multiple inputs. In Library of Congress Publication of Data (Ed.): The International Symposium on the Analytic Hierarchy Process (ISAHP). Hotel Istana, Kuala Lumpur, Malaysia.

Gohla-Neudecker, B.; Kuhn, P.; Hamacher, T.; Wagner, U. (2011): Sustainable mobility — Modelling a cost-efficient supply of renewables for EVs. In : 2011 International Conference on Clean Electrical Power (ICCEP). 2011 International Conference on Clean Electrical Power (ICCEP). Ischia, Italy, 14.06.2011 - 16.06.2011: IEEE, pp. 189–195.

Greenpeace Energy eG (2017a): Ihr unabhängiger Energieversorger. Greenpeace Energy. Available online at https://www.greenpeace-energy.de/privatkunden.html?AF=GOOG-LEGPE&gclid=COaQr8-jotUCFcQp0wodwsEAxA, checked on 7/24/2017.

Greenpeace Energy eG (2017b): Lieferantenkraftwerke. Solarstrom plus. Available online at https://www.greenpeace-energy.de/privatkunden/oekostrom/tarif-solarstrom-plus/lieferantenkraft-werke-solarstrom-plus.html, checked on 7/27/2017.

Greenpeace Energy eG (2017c): Solarstrom plus. Available online at https://www.greenpeace-energy.de/privatkunden/oekostrom/tarif-solarstrom-plus.html, checked on 7/24/2017.

Grüner Strom Label e.V. (2015): Grüner Strom-Label. Kriterienkatalog 2015 Version 1.2. Bonn. Available online at http://www.gruenerstromlabel.de/index.php?eID=tx_nawsecuredl&u=0&t=1501106767&file=fileadmin/dateien/PDF-Dokumente/GruenerStrom-Kriterienkatalog2015_V1.2.pdf&hash=2a25af3541f1978e002555a042d7dae8c9747492, checked on 6/12/2017.

Habib, Salman; Kamran, Muhammad; Rashid, Umar (2015): Impact analysis of vehicle-to-grid technology and charging strategies of electric vehicles on distribution networks – A review. In *Journal of Power Sources* 277, pp. 205–214. DOI: 10.1016/j.jpowsour.2014.12.020.

Hackbarth, André; Madlener, Reinhard (2013): Consumer preferences for alternative fuel vehicles. A discrete choice analysis. In *Transportation Research Part D: Transport and Environment* 25, pp. 5–17. DOI: 10.1016/j.trd.2013.07.002.

Hackbarth, André; Madlener, Reinhard (2016): Willingness-to-pay for alternative fuel vehicle characteristics. A stated choice study for Germany. In *Transportation Research Part A: Policy and Practice* 85, pp. 89–111. DOI: 10.1016/j.tra.2015.12.005.

Haddad, Brahim; Liazid, Abdelkrim; Ferreira, Paula (2017): A multi-criteria approach to rank renewables for the Algerian electricity system. In *Renewable Energy* 107, pp. 462–472. DOI: 10.1016/j.renene.2017.01.035.

Harthan, Ralph O.; Brohmann, Bettina; Fritsche, Uwe R.; Grießhammer, Rainer; Seebach, Dominik (2010): Positionspapier Klimakompensation. Öko-Institut e.V. Berlin, Freiburg, Darmstadt. Available online at https://www.oeko.de/oekodoc/1011/2010-071-de.pdf, checked on 8/5/2017.

Herbes, Carsten; Friege, Christian; Baldo, Davide; Mueller, Kai-Markus (2015): Willingness to pay lip service? Applying a neuroscience-based method to WTP for green electricity. In *Energy Policy* 87, pp. 562–572. DOI: 10.1016/j.enpol.2015.10.001.

Herbes, Carsten; Ramme, Iris (2014): Online marketing of green electricity in Germany—A content analysis of providers' websites. In *Energy Policy* 66, pp. 257–266. DOI: 10.1016/j.enpol.2013.10.083.

Hermanni, Alfred-Joachim (2016): Business Guide für strategisches Management. 50 Tools zum geschäftlichen Erfolg. Wiesbaden: Springer Gabler. Available online at http://www.springer.com/.

Hu, Junjie; Morais, Hugo; Sousa, Tiago; Lind, Morten (2016): Electric vehicle fleet management in smart grids. A review of services, optimization and control aspects. In *Renewable and Sustainable Energy Reviews* 56, pp. 1207–1226. DOI: 10.1016/j.rser.2015.12.014.

IEA (2019): Global EV Outlook 2019. International Energy Agency. Paris. Available online at www.iea.org/publications/reports/globalevoutlook2019/, checked on 7/1/2019.

Jedlix (2017): Jedlix Partners. Available online at https://jedlix.com/partners/, checked on 7/20/2017.

Jensen, S. G.; Skytte, K. (2002): Interactions between the power and green certificate markets. In *Energy Policy* 30 (5), pp. 425–435. DOI: 10.1016/S0301-4215(01)00111-2.

Jochem, Patrick; Babrowski, Sonja; Fichtner, Wolf (2015): Assessing CO2 emissions of electric vehicles in Germany in 2030. In *Transportation Research Part A: Policy and Practice* 78, pp. 68–83. DOI: 10.1016/j.tra.2015.05.007.

Kaenzig, Josef; Heinzle, Stefanie Lena; Wüstenhagen, Rolf (2013): Whatever the customer wants, the customer gets? Exploring the gap between consumer preferences and default electricity products in Germany. In *Energy Policy* 53, pp. 311–322. DOI: 10.1016/j.enpol.2012.10.061.

Kalkbrenner, Bernhard J.; Yonezawa, Koichi; Roosen, Jutta (2017): Consumer preferences for electricity tariffs. Does proximity matter? In *Energy Policy* 107, pp. 413–424. DOI: 10.1016/j.enpol.2017.04.009.

Kaya, Tolga; Kahraman, Cengiz (2010): Multicriteria renewable energy planning using an integrated fuzzy VIKOR & AHP methodology. The case of Istanbul. In *Energy* 35 (6), pp. 2517–2527. DOI: 10.1016/j.energy.2010.02.051.

Kempton, Willett; Letendre, Steven E. (1997): Electric vehicles as a new power source for electric utilities. In *Transportation Research Part D: Transport and Environment* 2 (3), pp. 157–175. DOI: 10.1016/S1361-9209(97)00001-1.

Kempton, Willett; Tomić, Jasna (2005): Vehicle-to-grid power fundamentals. Calculating capacity and net revenue. In *Journal of Power Sources* 144 (1), pp. 268–279. DOI: 10.1016/j.jpowsour.2004.12.025.

Kowalska-Pyzalska, Anna (2018): What makes consumers adopt to innovative energy services in the energy market? A review of incentives and barriers. In *Renewable and Sustainable Energy Reviews* 82, pp. 3570–3581. DOI: 10.1016/j.rser.2017.10.103.

Kühnapfel, Jörg B. (Ed.) (2014): Nutzwertanalysen in Marketing und Vertrieb. Wiesbaden: Springer Fachmedien Wiesbaden (essentials).

La Rovere, Emilio Lebre; Soares, Jeferson Borghetti; Oliveira, Luciano Basto; Lauria, Tatiana (2010): Sustainable expansion of electricity sector. Sustainability indicators as an instrument to support decision making. In *Renewable and Sustainable Energy Reviews* 14 (1), pp. 422–429. DOI: 10.1016/j.rser.2009.07.033.

Lancaster, Kelvin J. (1966): A New Approach to Consumer Theory. In *Journal of Political Economy* 74 (2), pp. 132–157. DOI: 10.1086/259131.

Lane, Eric F.; Verdini, William A. (1989): A Consistency Test for AHP Decision Makers. In *Decision Sciences* 20 (3), pp. 575–590. DOI: 10.1111/j.1540-5915.1989.tb01568.x.

Lee, Chul-Yong; Heo, Hyejin (2016): Estimating willingness to pay for renewable energy in South Korea using the contingent valuation method. In *Energy Policy* 94, pp. 150–156. DOI: 10.1016/j.enpol.2016.03.051.

Leprich, Uwe (2008): Fokus Ökostrom: Bestandsaufnahme und Perspektiven. Kurzstudie. Saarbrücken. Available online at https://www.htwsaar.de/wiwi/fakultaet/personen/profile/leprich.uwe/publikationen/Leprich%20Oekostrom%2019122008%20final.pdf, checked on 8/5/2017.

Leprich, Uwe; Hoffmann, Patrick; Luxenburger, Martin (2015): Zertifikate im Markt der Erneuerbaren Energien in Deutschland. In Carsten Herbes, Christian Friege (Eds.): Marketing Erneuerbarer Energien. Wiesbaden: Springer Fachmedien Wiesbaden, pp. 203–239.

Leßmann, Sophia (2016): Determinanten der Nachhaltigkeit. Wiesbaden: Springer Fachmedien Wiesbaden.

Liebe, Andrea; Schmitt, Stephan; Wissner, Matthias (2015): Quantitative Auswirkungen variabler Stromtarife auf die Stromkosten von Haushalten. Wissenschaftliches Insitut für Infrastruktur und Kommunikationsdienste GmbH (wik). Bad Honnef. Available online at http://www.vzbv.de/sites/default/files/downloads/Auswirkungen-variabler-Stromtarife-auf-Stromkosten-Haushalte-WIK-vzbv-November-2015.pdf, checked on 8/5/2017.

Madlener, Reinhard; Stagl, Sigrid (2005): Sustainability-guided promotion of renewable electricity generation. In *Ecological Economics* 53 (2), pp. 147–167. DOI: 10.1016/j.ecolecon.2004.12.016.

Mainali, Brijesh; Silveira, Semida (2015): Using a sustainability index to assess energy technologies for rural electrification. In *Renewable and Sustainable Energy Reviews* 41, pp. 1351–1365. DOI: 10.1016/j.rser.2014.09.018.

Martín-Gamboa, Mario; Iribarren, Diego; García-Gusano, Diego; Dufour, Javier (2017): A review of life-cycle approaches coupled with data envelopment analysis within multi-criteria decision analysis for sustainability assessment of energy systems. In *Journal of Cleaner Production* 150, pp. 164–174. DOI: 10.1016/j.jclepro.2017.03.017.

Meffert, Heribert; Rauch, Christian; Lepp, Hanna Lena (2010): Sustainable Branding — mehr als ein neues Schlagwort?! In *Marketing Review St. Gallen* 27 (5), pp. 28–35. DOI: 10.1007/s11621-010-0075-9.

Mengelkamp, Esther; Schönland, Thomas; Huber, Julian; Weinhardt, Christof (2019): The value of local electricity - A choice experiment among German residential customers. In *Energy Policy* 130, pp. 294–303. DOI: 10.1016/j.enpol.2019.04.008.

Mourmouris, J. C.; Potolias, C. (2013): A multi-criteria methodology for energy planning and developing renewable energy sources at a regional level. A case study Thassos, Greece. In *Energy Policy* 52, pp. 522–530. DOI: 10.1016/j.enpol.2012.09.074.

Nienhueser, Ian Andrew; Qiu, Yueming (2016): Economic and environmental impacts of providing renewable energy for electric vehicle charging – A choice experiment study. In *Applied Energy* 180, pp. 256–268. DOI: 10.1016/j.apenergy.2016.07.121.

Noel, Lance; Papu Carrone, Andrea; Jensen, Anders Fjendbo; Zarazua de Rubens, Gerardo; Kester, Johannes; Sovacool, Benjamin K. (2019): Willingness to pay for electric vehicles and vehicle-to-grid applications. A Nordic choice experiment. In *Energy Economics* 78, pp. 525–534. DOI: 10.1016/j.eneco.2018.12.014.

Ozaki, Ritsuko (2011): Adopting sustainable innovation. What makes consumers sign up to green electricity? In *Bus. Strat. Env.* 20 (1), pp. 1–17. DOI: 10.1002/bse.650.

Paetz, Alexandra-Gwyn; Kaschub, Thomas; Jochem, Patrick; Kopp, Martin; Fichtner, Wolf (2013): Monetäre Anreize zur Steuerung der Ladelast von Elektrofahrzeugen - eine modellgestützte Optimierung. In *Z Energiewirtsch* 37 (1), pp. 1–12. DOI: 10.1007/s12398-012-0095-z.

Peters, Paul Clemens; Madlener, Reinhard; Schemm, Ralf (2018a): Potenziale zur Erhöhung des regionalen Markenkerns im Stromvertrieb am Beispiel der regionalen Grünstromkennzeichnung gemäß EEG 2017. In *Z Energiewirtsch* 42 (1), pp. 35–55. DOI: 10.1007/s12398-017-0213-z.

Peters, Paul Clemens; Madlener, Reinhard; Schemm, Ralf (2018b): Potenziale zur Erhöhung des regionalen Markenkerns im Stromvertrieb am Beispiel der regionalen Grünstromkennzeichnung gemäß EEG 2017. Teil 2 (Multikriterien-Analyse). In *Z Energiewirtsch* 42 (1), pp. 57–87. DOI: 10.1007/s12398-017-0214-y.

Prestl, Willibald; Brendle, B.; Beer, M. (2017): Local energy systems for electric mobility. In Johannes Liebl (Ed.): Grid Integration of Electric Mobility. Wiesbaden: Springer Fachmedien Wiesbaden (Proceedings), pp. 125–141.

Reddy, K. Srikanth; Panwar, Lokesh Kumar; Kumar, Rajesh; Panigrahi, Bijaya Ketan (2016): Distributed resource scheduling in smart grid with electric vehicle deployment using fireworks algorithm. In *J. Mod. Power Syst. Clean Energy* 4 (2), pp. 188–199. DOI: 10.1007/s40565-016-0195-6.

Reichmuth, Matthias (2014): Marktanalyse Ökostrom. With assistance of Christian Lorenz, Christina Beestermöller, Christian Nabe, Christiane Markgraf, Johannes Schließer, Juliane Gerstenberg et al. Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (BMUB). Dessau-Roßlau, Deutschland. Available online at https://www.umweltbundesamt.de/sites/default/files/medien/376/publikationen/texte_04_2014_marktanalyse_oekostrom_0.pdf, checked on 7/19/2017.

Roe, Brian; Teisl, Mario F.; Levy, Alan; Russell, Matthew (2001): US consumers' willingness to pay for green electricity. In *Energy Policy* 29 (11), pp. 917–925. DOI: 10.1016/S0301-4215(01)00006-4.

Rojas-Zerpa, Juan C.; Yusta, Jose M. (2015): Application of multicriteria decision methods for electric supply planning in rural and remote areas. In *Renewable and Sustainable Energy Reviews* 52, pp. 557–571. DOI: 10.1016/j.rser.2015.07.139.

Saaty, R. W. (1987): The analytic hierarchy process—what it is and how it is used. In *Mathematical Modelling* 9 (3-5), pp. 161–176. DOI: 10.1016/0270-0255(87)90473-8.

Saaty, Thomas L. (1977): A scaling method for priorities in hierarchical structures. In *Journal of Mathematical Psychology* 15 (3), pp. 234–281. DOI: 10.1016/0022-2496(77)90033-5.

Salah, Florian; Flath, Christoph M.; Schuller, Alexander; Will, Christian; Weinhardt, Christof (2017): Morphological analysis of energy services. Paving the way to quality differentiation in the power sector. In *Energy Policy* 106, pp. 614–624. DOI: 10.1016/j.enpol.2017.03.024.

San Cristóbal, J. R. (2011): Multi-criteria decision-making in the selection of a renewable energy project in spain. The Vikor method. In *Renewable Energy* 36 (2), pp. 498–502. DOI: 10.1016/j.renene.2010.07.031.

Schlömer, Steffen; Bruckner, Thomas; Fulton, Lew; Hertwich, Edgar; McKinnon, Alan; Perczyk, Daniel et al. (2014): Annex III: Technology-specific cost and performance parameters. In IPCC (Ed.): Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report. Intergovernmental panel on climate change (IPCC). Cambridge, Großbitannien, New York, USA, pp. 1329–1356.

Schücking, Maximilian; Jochem, Patrick; Fichtner, Wolf; Wollersheim, Olaf; Stella, Kevin (2017): Charging strategies for economic operations of electric vehicles in commercial applications. In *Transportation Research Part D: Transport and Environment* 51, pp. 173–189. DOI: 10.1016/j.trd.2016.11.032.

Schuller, Alexander; Flath, Christoph M.; Gottwalt, Sebastian (2015): Quantifying load flexibility of electric vehicles for renewable energy integration. In *Applied Energy* 151, pp. 335–344. DOI: 10.1016/j.apenergy.2015.04.004.

Schulze, Olaf (2015): Energiebeschaffung für Unternehmen. In Marko Geilhausen, Juliane Bränzel, Dirk Engelmann, Olaf Schulze (Eds.): Energiemanagement. Wiesbaden: Springer Fachmedien Wiesbaden, pp. 77–233.

Seebach, Dominik; Mohrbach, Elke (2013): Wie können Herkunftsnachweise zur Differenzierung des Ökostrommarkts in Deutschland beitragen? In *Energiewirtschaftliche Tagesfragen* 63 (3), S. 62 - 65.

Shmelev, Stanislav E.; van den Bergh, Jeroen C.J.M. (2016): Optimal diversity of renewable energy alternatives under multiple criteria. An application to the UK. In *Renewable and Sustainable Energy Reviews* 60, pp. 679–691. DOI: 10.1016/j.rser.2016.01.100.

Spruit, Arie (2015): Eneco: SmartCharging app saved up to 15 percent on the monthly electricity costs of 40 Tesla drivers in a test conducted over the past 4 months. EUROPAWIRE. Rotterdamm. Available online at http://news.europawire.eu/eneco-smartcharging-app-saved-up-to-15-percent-on-the-monthly-electricity-costs-of-40-tesla-drivers-in-a-test-conducted-over-the-past-4-months-7654321234567890/eu-press-release/2015/07/28/#, updated on 7/28/2015, checked on 7/20/2017.

Sundt, Swantje; Rehdanz, Katrin (2015): Consumers' willingness to pay for green electricity. A meta-analysis of the literature. In *Energy Economics* 51, pp. 1–8. DOI: 10.1016/j.eneco.2015.06.005.

Sütterlin, Bernadette; Siegrist, Michael (2017): Public acceptance of renewable energy technologies from an abstract versus concrete perspective and the positive imagery of solar power. In *Energy Policy* 106, pp. 356–366. DOI: 10.1016/j.enpol.2017.03.061.

Timpe, Christof; Seebach, Dominik; Bürger, Veit (2008): Hintergrundpapier des Öko-Instituts zu Ökostrom. Edited by Öko-Institut e.V. Available online at http://www.oeko.de/oekodoc/982/2008-318-de.pdf.

Troldborg, Mads; Heslop, Simon; Hough, Rupert L. (2014): Assessing the sustainability of renewable energy technologies using multi-criteria analysis. Suitability of approach for national-scale assessments and associated uncertainties. In *Renewable and Sustainable Energy Reviews* 39, pp. 1173–1184. DOI: 10.1016/j.rser.2014.07.160.

Turconi, Roberto; Boldrin, Alessio; Astrup, Thomas (2013): Life cycle assessment (LCA) of electricity generation technologies. Overview, comparability and limitations. In *Renewable and Sustainable Energy Reviews* 28, pp. 555–565. DOI: 10.1016/j.rser.2013.08.013.

TÜV NORD (2014): Kriterienkatalog "Geprüfter Ökostrom" nach dem TÜV NORD CERT Standard A75-S026-1. Revision 03. TÜV NORD CERT GmbH. Available online at https://www.tuev-nord.de/fileadmin/Content/Global/TUEV_NORD_Archiv/pdf/kriterienkatalog-oekostrom.pdf, checked on 8/5/2017.

TÜV SÜD (2015a): Zertifizierung von Stromprodukten aus Erneuerbaren Energien mit Neuanlagenkomponente kurz: Produkt EE01. Version 01/2015, Revision 1. TÜV SÜD Industrie Service GmbH. München. Available online at https://www.tuev-sued.de/uploads/images/1337578665958523510243/ee01.pdf, checked on 8/5/2017.

TÜV SÜD (2015b): Zertifizierung von Stromprodukten aus Erneuerbaren Energien mit zeitgleicher Produktion kurz: Produkt EE02. Version 07/2015. TÜV SÜD Industrie Service GmbH. Available online at https://www.tuev-sued.de/uploads/images/1337578329085069670207/ee02.pdf, checked on 8/5/2017.

U.S. Department of Energy (2017): Renewable Generation Requirement. Available online at https://energy.gov/savings/renewable-generation-requirement, checked on 7/18/2017.

Umweltbundesamt (2016): Kompensation von Treibhausgasemissionen. Umweltbundesamt Deutschland. Available online at http://www.umweltbundesamt.de/umwelttipps-fuer-den-alltag/mobilitaet/kompensation-von-treibhausgasemissionen#textpart-1, updated on 1/7/2016, checked on 7/15/2017.

Umweltbundesamt (2017): Regionalnachweisregister. Umweltbundesamt Deutschland. Available online at https://www.umweltbundesamt.de/themen/klima-energie/erneuerbare-energien/regionalnachweisregister, checked on 5/31/2017.

Umweltbundesamt (2018): Herkunfts- und Regionalnachweis-Durchführungsverordnung. In : Bundesgesetzblatt (BGBl) (I), S. 1853.

Vine, Edward (2005): An international survey of the energy service company (ESCO) industry. In *Energy Policy* 33 (5), pp. 691–704. DOI: 10.1016/j.enpol.2003.09.014.

Walsh, Gianfranco; Groth, Markus; Wiedmann, Klaus-Peter (2005): An Examination of Consumers' Motives to Switch Energy Suppliers. In *Journal of Marketing Management* 21 (3-4), pp. 421–440. DOI: 10.1362/0267257053779091.

Wang, Jiang-Jiang; Jing, You-Yin; Zhang, Chun-Fa; Zhao, Jun-Hong (2009): Review on multi-criteria decision analysis aid in sustainable energy decision-making. In *Renewable and Sustainable Energy Reviews* 13 (9), pp. 2263–2278. DOI: 10.1016/j.rser.2009.06.021.

Watson, Anna; Viney, Howard; Schomaker, Patrick (2002): Consumer attitudes to utility products. A consumer behaviour perspective. In *Markting Intelligence & Plan (Marketing Intelligence & Planning)* 20 (7), pp. 394–404. DOI: 10.1108/02634500210450837.

Weisser, Daniel (2007): A guide to life-cycle greenhouse gas (GHG) emissions from electric supply technologies. In *Energy* 32 (9), pp. 1543–1559. DOI: 10.1016/j.energy.2007.01.008.

Will, Christian; Jochem, Patrick; Fichtner, Wolf (2017a): Defining a Spot Market for Unbundled Real-Time Renewable Energy Certificates. In IEEE (Ed.): Proceedings of the 14th International Conference on the European Energy Market. EEM17. Dresden, Germany, 06.-09.06.2017.

Will, Christian; Jochem, Patrick; Pfahl, S.; Fichtner, Wolf (2017b): Economic and Sustainability-Potential of Carbon-Neutral Charging Services for Electric Vehicle Customers. Proceedings of the 30th International Electric Vehicle Symposium & Exhibition. EVS30. Institut für Industriebetriebslehre und Industrielle Produktion (IIP). Available online at https://publikationen.bibliothek.kit.edu/1000075814, checked on 7/24/2018.

Will, Christian; Schuller, Alexander (2016): Understanding user acceptance factors of electric vehicle smart charging. In *Transportation Research Part C: Emerging Technologies* 71, pp. 198–214. DOI: 10.1016/j.trc.2016.07.006.

Wilson, Chauncey (2013): Semi-Structured Interviews. In : Interview Techniques for UX Practitioners. 1st ed.: Elsevier B.V., pp. 23–41.

Wimmler, C.; Hejazi, G.; Fernandes, E. de Oliveira; Moreira, C.; Connors, S. (2015): Multi-Criteria Decision Support Methods for Renewable Energy Systems on Islands. In *JOCET* 3 (3), pp. 185–195. DOI: 10.7763/JOCET.2015.V3.193.

Wissner, Matthias; Liebe, Andrea (2015): Der flexible Verbraucher – Potenziale zur Lastverlagerung im Haushaltsbereich. Wissenschaftliches Insitut für Infrastruktur und Kommunikationsdienste GmbH (wik). Bad Honnef. Available online at http://www.verbraucherportal-bw.de/site/pbs-bw-new/get/documents/MLR.Verbraucherportal/Dokumente/Dokumente%20pdfs/Verbraucherschutz/Studie%20Energie%20Der_flexible_Verbraucher_WIK_Endbericht.pdf, checked on 8/5/2017.

Wolff, Stefanie; Madlener, Reinhard (2019): Charged up? Preferences for Electric Vehicle Charging and Implications for Charging Infrastructure Planning. In *FCN Working Paper* 3/2019.

Zhang, Ling; Zhou, Peng; Newton, Sidney; Fang, Jian-xin; Zhou, De-qun; Zhang, Lu-ping (2015): Evaluating clean energy alternatives for Jiangsu, China. An improved multi-criteria decision making method. In *Energy* 90, pp. 953–964. DOI: 10.1016/j.energy.2015.07.124.

List of the latest FCN Working Papers

2019

Specht J.M., Madlener R. (2019). Mitigation and Valuation of the Investment Risk in Engineered Geothermal Systems: A Real Options Analysis, FCN Working Paper No. 1/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, January.

Hackstein F., Madlener R. (2019). Sustainable Operation of Geothermal Power Plants: Why Economics Matters, FCN Working Paper No. 2/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, February.

Wolff S., Madlener R. (2019). Charged up? Preferences for Electric Vehicle Charging and Implications for Charging Infrastructure Planning, FCN Working Paper No. 3/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, March.

Höfer T., von Nitzsch R., Madlener R. (2019). Using Value-Focused Thinking and Multi-Criteria Group Decision-Making to Evaluate Energy Transition Alternatives, FCN Working Paper No. 4/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, April.

Glensk B., Madlener (2019). *Energiewende @ Risk*: On the Continuation of Renewable Power Generation at the End of Public Policy Support, FCN Working Paper No. 5/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, May.

Höfer T., Madlener R. (2019). A Participatory Stakeholder Process for Evaluating Sustainable Energy Transition Scenarios, FCN Working Paper No. 6/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, May.

Gimpel-Henning J., Madlener R. (2019). Synthetic Low-Voltage Grid Replication Using Spatial Information and Private Customer Load Profiles, FCN Working Paper No. 7/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, June.

Gimpel-Henning J., Madlener R. (2019). Large-Scale Grid Clustering to Predict Future Electricity Grid Extension Costs, FCN Working Paper No. 8/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, June

Gimpel-Henning J., Madlener R. (2019). Analyzing Actual Low-Voltage Grid Overloads Due to the Diffusion of Electric Vehicles, FCN Working Paper No. 9/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, July.

Schreiner L., Madlener R. (2019). A Pathway to Green Growth? Macroeconomic Impacts of Power Grid Infrastructure Investments in Germany, FCN Working Paper No. 10/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, August.

Schreiner L., Madlener R. (2019). Investing in Power Grid Infrastructure as a Flexibility Option: A DSGE Assessment for Germany, FCN Working Paper No. 11/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, August.

Wintgens L., Madlener R. (2019). Multi-Criteria Decision Analysis of Technological Alternatives to Conventional Expansion of the German Electricity Grid, FCN Working Paper No. 12/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, August.

Schultes G., Madlener R. (2019). Investment Under Uncertainty in a Power-to-Gas Plant in Germany: A Real Options Analysis, FCN Working Paper No. 13/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, September.

Karami M., Madlener R. (2019). Smart Predictive Maintenance Strategy Based on Cyber-Physical Systems for Centrifugal Pumps: A Bearing Vibration Analysis, FCN Working Paper No. 14/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, September.

Liu X., Madlener R. (2019). Get Ready for Take-Off: A Two-Stage Model of Aircraft Market Diffusion, FCN Working Paper No. 15/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, October.

Liu X., Madlener R. (2019). The Sky is the Limit: Assessing Aircraft Market Diffusion with Agent-Based Modeling, FCN Working Paper No. 16/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, October.

Fabianek P., Will C., Wolff S., Madlener R. (2019). Green and Regional? A Multi-Criteria Assessment Framework for the Provision of Green Electricity for Electric Vehicles in Germany, FCN Working Paper No. 17/2019, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, October.

2018

Koenen J., Madlener R. (2018). Predictive Analysis of an Energy Trading Company's Outstanding Receivables Using Markov Chains, FCN Working Paper No. 1/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, January.

Vonsien S., Madlener R. (2018). Cost-Effectiveness of Li-Ion Battery Storage with a Special Focus on Photovoltaic Systems in Private Households, FCN Working Paper No. 2/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, February.

Pereira G.I., Specht J.M., Pereira da Silva P., Madlener R. (2018). Technology, Business Model, and Market Design Adaptation Toward Smart Electricity Distribution: Insights for Policy Making, FCN Working Paper No. 3/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, March.

Heesen F., Madlener R. (2018). Revisiting Heat Energy Consumption: Household Production Theory Applied to Field Experimental Data, FCN Working Paper No. 4/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, April.

Atasoy A.T., Harmsen – van Hout M.J.W., Madlener R. (2018). Strategic Demand Response to Dynamic Pricing: A Lab Experiment for the Electricity Market, FCN Working Paper No. 5/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, April.

Zeng Y., Schmitz H., Madlener R. (2018). An Econometric Analysis of the Determinants of Passenger Vehicle Sales in Germany FCN Working Paper No. 6/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, April.

Specht J.M., Madlener R. (2018). Business Models for Energy Suppliers Aggregating Flexible Distributed Assets and Policy Issues Raised, FCN Working Paper No. 7/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, April.

Ralovski I., Madlener R. (2018). On the Global Diffusion of Desktop 3D Printers and the Case of Total Adoption in the Customized Hearing Aid Industry, FCN Working Paper No. 8/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, May.

Washausen S., Madlener R. (2018). Economic Evaluation of Germany's Strategic Oil Reserves in Comparison With Major Other Industrialized Countries, FCN Working Paper No. 9/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, June.

Schach M., Madlener R., 2018. Economic and Geopolitical Impacts of the LNG Supply-Side Competition Between the USA and Russia, FCN Working Paper No. 10/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, July.

Wolff S., Madlener R: (2018). Driven by Change: Commercial Drivers' Acceptance and Perceived Efficiency of Using Light-Duty Electric Vehicles in Germany, FCN Working Paper No. 11/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, August.

König M., Madlener R. (2018). Conceptualization of a Distributed Energy Storage Community: An Economic Analysis for Germany, FCN Working Paper No. 12/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, September.

Höfer T., Madlener R. (2018). Locational (In-)Efficiency of Renewable Power Generation Feeding in the Electricity Grid: A Spatial Regression Analysis, FCN Working Paper No. 13/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, October.

Sobhani S.O., Sheykhha S., Madlener R. (2018). An Integrated Two-Level Demand-Side Management Game Applied to Smart Energy Hubs with Storage, FCN Working Paper No. 14/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, November.

Karami M., Madlener R. (2018). Business Model Innovation for the Energy Market: Joint Value Creation for Electricity Retailers and their Residential Customers, FCN Working Paper No. 15/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, November.

Colmenares G., Löschel A., Madlener R. (2018). The Rebound Effect and its Representation in Energy and Climate Models, FCN Working Paper No. 16/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, December.

Hackbarth A., Madlener R. (2018). Combined Vehicle Type and Fuel Type Choices of Private Households: An Empirical Analysis for Germany, FCN Working Paper No. 17/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, December.

Zimmermann G., Madlener R. (2018). Techno-Economic Evaluation of Combined Micro Power and Heat Generation Assets: Implications for the Multi-Tenant Building Market in Germany, FCN Working Paper No. 18/2018, Institute for Future Energy Consumer Needs and Behavior, RWTH Aachen University, December.

FCN Working Papers have been published since 2008 and are free of charge. They can mostly be downloaded in pdf format from the FCN / E.ON ERC Website (www.eonerc.rwth-aachen.de/fcn) and the SSRN Website (www.ssrn.com), respectively. Alternatively, they may also be ordered as hardcopies from Ms Sabine Schill (Phone: +49 (0) 241-80 49820, E-mail: post_fcn@eonerc.rwth-aachen.de), RWTH Aachen University, Institute for Future Energy Consumer Needs and Behavior (FCN), Chair of Energy Economics and Management (Prof. Dr. Reinhard Madlener), Mathieustrasse 10, 52074 Aachen, Germany.