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Working Paper

The hidden winners of renewable energy promotion: Insights into sector-specific wage differentials

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Institute for Employment Research
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IAB

IAB-Discussion Paper 12/2014

Articles on labour market issues

The hidden winners of renewable energy promotion

Insights into sector-specific wage differentials

Manfred Antoni
Markus Janser
Florian Lehmer

The hidden winners of renewable energy promotion

Insights into sector-specific wage differentials

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Mit der Reihe „IAB-Discussion Paper“ will das Forschungsinstitut der Bundesagentur für Arbeit den Dialog mit der externen Wissenschaft intensivieren. Durch die rasche Verbreitung von Forschungsergebnissen über das Internet soll noch vor Drucklegung Kritik angeregt und Qualität gesichert werden.

The “IAB-Discussion Paper” is published by the research institute of the German Federal Employment Agency in order to intensify the dialogue with the scientific community. The prompt publication of the latest research results via the internet intends to stimulate criticism and to ensure research quality at an early stage before printing.

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Abstract

In light of Germany´s transition approaches towards a sustainable energy system this paper examines differences of employment structure and wage differentials between renewable energy establishments and their sector peers. To do so, we have developed a novel data set by linking company-level information from the German Renewable Energy Federation with establishment-level data of the IAB Establishment History Panel. According to our descriptive evidence, there are significant differences in wages and in several other characteristics. Looking at the top-four renewable energy sectors, our estimates show that human capital and other establishment-level characteristics mostly explain the wage differential among manufacturers and energy providers. However, we find a persistent 'renewable energy wage premium' of more than ten percent in the construction installation activities and the architectural and engineering services. We interpret this premium as a positive indirect effect of the promotion of renewable energies for the benefit of employees in renewable energy establishments within these two sectors.

Zusammenfassung

Vor dem Hintergrund der Energiewende in Deutschland untersuchen wir die Beschäftigtenstruktur und Entlohnung in Betrieben, die im Bereich Erneuerbare Energien tätig sind. Wir vergleichen diese Betriebe mit solchen, die zwar im gleichen Wirtschaftszweig, aber nicht explizit im Kontext Erneuerbarer Energien aktiv sind. Hierfür haben wir einen neuen Datensatz aufgebaut, in dem wir Unternehmensdaten des Bundesverbandes der Erneuerbaren Energien e.V. mit den Betriebsdaten des IAB Betriebshistorik-Panels verknüpft haben. Unsere Ergebnisse zeigen signifikante Unterschiede auf Ebene der Löhne sowie auf Ebene mehrerer relevanter Betriebsmerkmale. Wenn wir uns die vier Hauptwirtschaftszweige im Feld der Erneuerbaren Energien näher betrachten, sehen wir, dass sich die Lohnunterschiede in den Branchen der Hersteller und der Energieerzeuger fast ganz durch die auf das Personal bezogenen Merkmale (z.B. Qualifikation) sowie andere strukturelle Betriebsmerkmale (z.B. Betriebsgröße) erklären lassen. Wir finden jedoch eine dauerhafte „Erneuerbare Energien Lohnprämie" von über zehn Prozent im Handwerk und im Bereich Technische Planung/Architektur. Wir interpretieren diese Lohndifferenz als einen positiven indirekten Effekt der Förderung Erneuerbarer Energien zugunsten der Beschäftigten von Handwerks- und Projektierungsbetrieben, die durch ihre Arbeiten an der Energiewende beteiligt sind.

JEL classification: J31, P48, Q42, Q52, C81

Keywords: Wages Differentials, Renewable Energy Establishments, Green Jobs, Human Capital, Record Linkage

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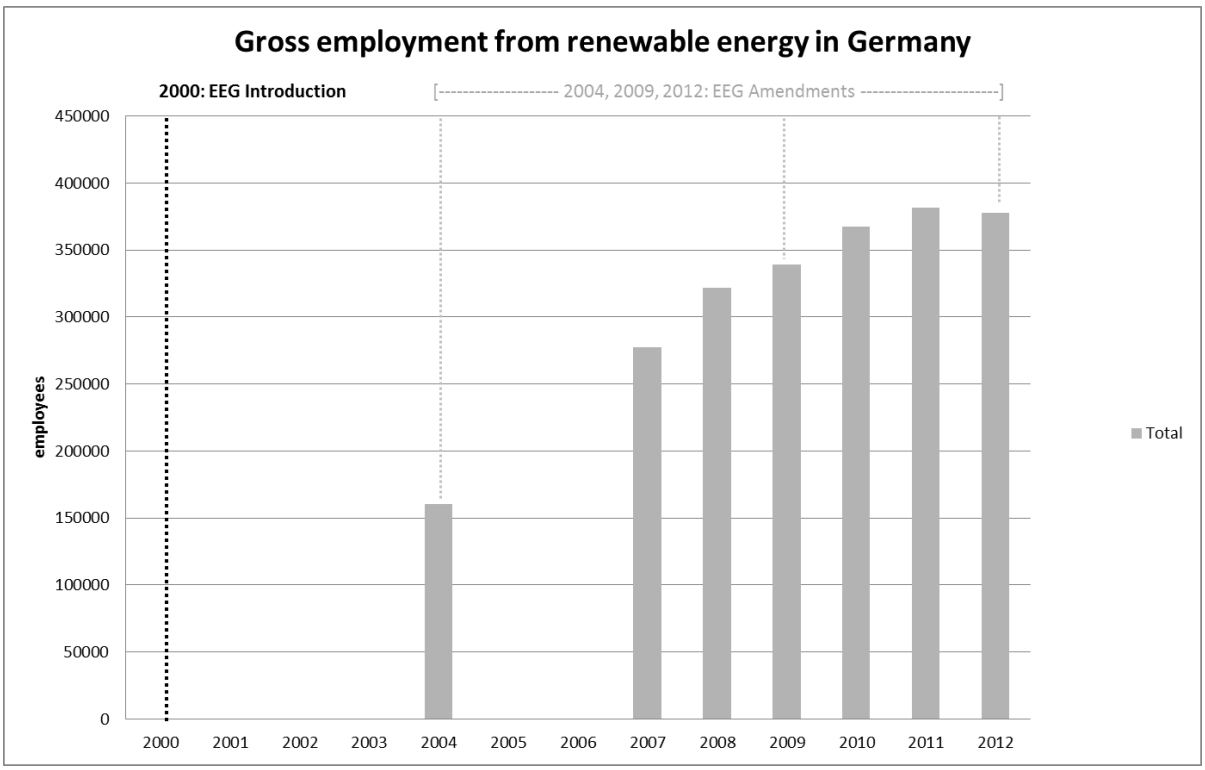
1 Introduction

The global strive for mitigation of climate change has led to a growing and dynamic renewable energy (RE) market in Europe, connected with a considerable increase in employment within this field of economic activity (Ragwitz et al. 2009, Blanco et al. 2009). Particularly Germany, one of the European RE pioneer countries, has seen a boom of renewables, supported by fixed feed-in tariffs and further instruments of public promotion. In conjunction with an increase in exports of RE products and services, there was a substantial growth in turnover and employment (Lehr/Lutz/Edler 2012; Blazejczak et al. 2011).

Figure 1 shows publicly available data on gross employment from renewable energy in Germany, based on input-output analyses (O'Sullivan et al. 2013). The dotted lines indicate the year of the introduction of the Renewable Energy Sources Act (EEG) and its amendments, respectively. The figure shows a growing employment effect. However, the total employment decreased slightly in 2012, which reflects the current dynamic market situation. On an international level, several studies observe positive employment development in the area of RE, for example in the USA (Sommers 2013), Canada (Böhringer et al. 2012), China and India (Poschen 2012; Arora 2010).

Figure 1
Gross employment from renewable energy in Germany



Source: Gross employment from renewable energy in Germany: O'Sullivan et al. 2013, Years of EEG introduction and its amendments: Bruns et al. 2011

Public promotion has played – and still plays – an important role for stimulating supply and demand of those emerging markets. Within the European Union, and again,

especially in Germany, the promotion of renewable energy sources has quite a long history. First research funding activities started in the 1970s, whereas joint efforts to foster renewable energies in a larger scale started in the 1990s (International Energy Agency (IEA) and International Renewable Energy Agency (IRENA) 2014; Bruns et al. 2011).

With regard to the large allocation of feed-in tariffs and subsidies for the development of RE sources, there is a broad public interest in the economic impacts of those promotion activities. The quantitative development of the renewable energy supply is monitored on a broad level (for example, see International Energy Agency (IEA) and International Renewable Energy Agency (IRENA) 2014). However, there is only little statistical data available about the actors within the RE product markets. Consequently, for the evaluation of quantitative employment effects of RE products and services, there is only macroeconomic data available, which can only provide rough estimates. There is even less evidence about the quality of those jobs, especially in terms of wages. An important question is whether workers within RE product markets also benefit in terms of wages from the promotion of renewable energy sources.

In order to fill this gap with reliable empirical data from Germany, we tackle the following research questions: Is there a difference in wages between RE establishments and others? If yes, what are the determinants for this wage differential and how do they differ between sectors? Do those wage differentials merely reflect differences in establishment characteristics or other external influences, such as the promotion of renewable energy sources?

In this paper, we focus on German RE establishments[1]. Because of Germany's role as a RE pioneer, the insights into RE establishment characteristics, RE wage differentials and potential indirect effects of RE promotion are also highly relevant on an international level. The German 'Renewable Energy Sources Act' (Erneuerbare Energien Gesetz (EEG)), the first feed-in tariff system worldwide, has strongly shaped the supply and demand of RE. In the meantime, many other countries have started to promote RE energy sources. To date, 97 states or regions have introduced feed-in tariff systems, often based on or very similar to the EEG. Therefore, some of the phenomena presented below might be observable in other regions of the world as well.

[1] In this paper, we mostly use the term 'establishment', because our data considers production sites and single plants (see Section 4 for more details). However, we use the notion 'company' if we talk about the entire legal entity, which can consist of many different production sites and single plants, i.e. establishments. Besides data availability, the focus on the establishment-level allows us to analyse effects closer to the production process. Finally, there is also the term 'firm' which is often used in literature but less specific. We only use it, if it is explicitly used in literature.

In our analyses, we focus on the following top-four-RE sectors: *Manufacture of electronic components and boards; Electric power generation, transmission and distribution; Electrical, plumbing and other construction installation activities* and *Architectural and engineering activities and related technical consultancy*. We find significant differences in human capital and other observed characteristics between RE and non-RE establishments. Furthermore, RE establishments pay considerably more than non-RE establishments within three of four sectors. In the sector *Electric power generation, transmission and distribution*, however, things are different: RE establishments pay about three log percent less. Differences in human capital and other establishment-level characteristics explain most of the wage differential among manufacturers. In two sectors (*Construction installation activities* and *Architectural and engineering services*), however, endowments differences between RE establishments and non-RE establishment explain a distinctly lower share of the raw wage gap. In both sectors, an unexplained gap of on average more than ten log percent remains, which we denote as 'renewable energy wage premium'. We take this as first indication of workers within specific parts of the RE product market benefiting indirectly from the promotion of renewable energy sources.

The remainder of the paper is organised as follows: the next section gives insights into the institutional background of Germany´s transition to a more sustainable energy system. Section 3 introduces our theoretical background. Section 4 describes the data linkage process and the resulting data set, whereas section 5 presents descriptive evidence on human capital structure and other structural characteristics of German renewable energy establishments. Section 6 introduces our empirical strategy and the economic estimates and contains the corresponding results. Section 7 concludes and provides an outlook on upcoming research.

2 Institutional Background

This section offers a brief overview of the past and present of RE promotion activities in Germany. Since the 1970s, Germany has played a pioneering role in the field of environmental and climate protection. In terms of the promotion of RE technologies, Germany has applied several strategies to foster the installation and supply of RE. Particularly in the 1990s and 2000s, there were several approaches to improve the conditions for RE products and services. Several policies and measures on the European level supported those national strategies. According to the database of the IEA/IRENA Global Renewable Energy Policies and Measures Database (International Energy Agency (IEA) and International Renewable Energy Agency (IRENA) 2014), there were seventeen European and six national RE promotion policies and measures running in the year 2009, e.g. the European Directive on the Taxation of Energy Products and Electricity and the German Market Incentive Programme (see also *Table A-1 and Table A-2* in the *Appendix*). Bruns et al. (2011, p 57 et seq.) point out that the different stages of feed-in tariff systems in Germany have been 'key policy measures' of the RE market development. Hence, in the remaining of this

section we focus on the development and changes of the German feed-in tariff system.

In the light of the Fukushima nuclear catastrophe in 2011, Germany's Federal Government decided to accelerate the transition towards a more sustainable, nuclear-free and low-carbon energy system. One of the key targets of the German energy transition efforts, and most relevant for the work in hand, is the expansion of the RE share in the total energy consumption. In this context, RE does not only cover electricity supply, but also heat and fuel supply. The increase of the RE share in Germany's gross final energy consumption is shown in *Figure A-1* in the *Appendix.*

The principles of the current feed-in tariff system in Germany are as follows: operators of RE power plants receive remuneration for their electricity delivered. This compensation is fixed over a number of years and includes a degression model. The degression rates depend on the RE technology (solar, wind, biomass etc.). The difference between the specific feed-in tariff and the electricity prize at the energy exchange is financed by a levy, which is paid by most of the electricity consumers as a share of the electricity price. Energy-intensive companies are exempt from this levy.

This system is the result of an evolutionary and still on-going societal negotiation process. It started with the introduction of the Electricity Feed-In Act (StrEG, 'Stromeinspeisungsgesetz'), which came into force on 1 January 1991. The StrEG allowed small and medium-sized RE producers for the first time to feed their electricity into the networks of the big utility companies. This privileged market access was achieved by the legal obligation of electricity network operators to purchase electricity from RE sources and to pay fixed minimum fees for them. The introduction of the StrEG was seen as a milestone of reducing the monopolies of the big utility companies and to stimulate competition.

After two revisions in 1994 and 1998, the StrEG was redesigned and replaced by the Renewable Energy Sources Act (EEG - 'Erneuerbare Energien Gesetz'), which came into effect on 1 April 2000. Compared to the StrEG, the EEG included a broader range of RE sources and increased the support of solar energy. Furthermore, the EEG offered improved planning reliability for RE investors and thus indirectly also increased the planning reliability for other actors involved in RE value chains. Concretely, the EEG defined a longer remuneration guarantee (20 years instead of the period of the act's validity) and fixed compensation rates per kilowatt-hours. In order to stimulate innovation and progress in efficiency, the legislators built in a degressive mechanism that gradually reduced the guaranteed tariffs for new RE plants. To offer a high level of investment security, the tariff level of the year of first operation is subsequently fixed for the following 20 years. Additionally, power supply companies could now also receive remunerations, which had not been possible before (Bruns et al. 2011; Oschmann/Sösemann 2007).

There were three major revisions of the EEG, which came into force on 1 August 2004, 1 January 2009, 1 January 2012 and 1 April 2012. The first revision of the EEG in 2004 lead to an increased differentiation between specific technologies of RE and to adjustments of the level of the feed-in tariffs (e.g. decreasing tariffs for wind energy). The adjustment of 2009 came along with more ambitious RE targets and a floating degression model for solar energy. Closely related, the Renewable Energies Heat Act (Erneuerbare-Energien-Wärmegesetz – EEWaermeG) was introduced at the same time. This law regulates the promotion of heating by RE sources.

The EEG revision in 2012 has led to further adjustments in the management of the RE market (e.g. promotion of direct marketing of electricity from renewable energies on the electricity market). Again, the levels of the feed-in tariffs were changed. An additional amendment came into force on 1 April 2012 with adjustments towards the limitation of the promotion of photovoltaics.

Due to the strong growth of RE energy supply supported by the EEG, the reimbursements financed by EEG levys (EEG differential costs) have risen sharply (see *Figure A-2* in the *Appendix)*. After the elections in 2013, the Federal German Government intends to revise the EEG again in order to 'limit extent and speed of the overall cost increase' (German Federal Ministry for Economic Affairs and Energy 2014, p. 2) and – among others – to maintain security of supply and to improve the electricity market design (Loc. cit.).

3 Theoretical Background and Hypotheses

In the following, we identify the commonly acknowledged determinants of wages on the establishment-level and connect each specific determinant with information about the specific situation of RE establishments, as far as available. Based on this linkage, we develop hypotheses on whether there should be a difference in wages between RE and Non-RE establishments and in which direction this difference should tend.

According to classical economic models, wages are mainly determined by productivity. In addition, there are several theories and studies suggesting alternative determinants of wages. Wage differentials in general describe differences in wage rates due to observable or unobservable determinants. Such determinants originate from both the supply side and the demand side of labour. There is a considerable body of literature offering overviews on wage determinants, e.g. Lane et al. (2007), Akerman et al. (2013), Ilmakunnas/Maliranta/Vainiomäki (2004), and Willis (1987). On the establishment-level, we distinguish between determinants of wages in terms of human capital / personnel structure and those of other structural characteristics and residual differentials. During the remainder of this section, we relate wage determinants with the literature on structural characteristics of renewable energy companies.

The usage of renewable energy technology on a large scale is a rather new development. Only during the last 20 years, more and more companies have established large value chains in several technologies of renewable energy products and services. These value chains cover very different industry branches all along the economy. Because of the relatively new and cross-sectorial phenomenon of providing renewable energy products and services on a large scale, the body of scientific knowledge is yet relatively small. However, there are already different findings – often published from public bodies or international organisations – dealing with the special characteristics of renewable energy establishments. These sources constitute the basis for the following review.

Establishment-Level Wage Determinants and Human Capital Characteristics of Renewable Energy Establishments

According to the neoclassical theory of human capital, the stock of competencies and knowledge of an employee is an important determinant of wages (Mincer 1974; Becker 1994 (3rd ed.)). For example, Kilbourne et al. (1994) observe net positive returns to education, experience, cognitive and physical skills. In renewable energy establishments, medium skilled workers cover the highest share of the labour force, whereas high skilled workers also represent a relatively high share (International Labour Office and European Commission 2011; Strietska-Ilina et al. 2011; German Federal Environmental Ministry 2012). Those studies also show that the skill levels of the staff depend strongly on the specific technology of renewable energy (e.g. solar energy: high skill level; biomass: low skill level) and the function within the value chain (e.g. research and development: high skill level; production in partially automated processes: medium skill level). Furthermore, these studies observe a high level of training in the renewable energy related companies. The shortage of skilled labour force is another driver for higher wages (see Horbach 2014 (mimeo); Bennett and McGuiness 2009; Shah and Burke 2005). Skills shortage exists (partly) in some renewable energy segments, whereas the degree of shortage depends on the specific RE technology and the business life cycle (International Renewable Energy Agency (2013) International Labour Office and European Commission 2011).

Based on the IAB establishment panel, about 12 percent of establishments in the technology field ‘Climate protection, renewable energies, energy saving’ reported in 2012 that they had currently a lack of personnel, compared to about 7 percent of all establishments in the whole sample (Horbach 2014, mimeo). According to this survey, about 52 percent of ‘Climate protection, renewable energies, energy saving’ establishments stated problems to find (skilled) employees during the next two years, compared to 36 percent of all establishments in the whole sample (Horbach 2014, mimeo).

Women on average still earn less than men, as amply documented in the gender-wage-gap literature (e.g. Hirsch et al. 2010; Barth/Dale-Olsen 2009; Bertrand/Goldin/Katz.2010; Ransom/Oaxaca 2010; Kilbourne et al. 1994). Because the

share of women is below average in RE companies (ILO/EU 2011: 24 percent; Staiß et al. 2006: 17 percent), there seems to be another indicator, that the wages in this field might be higher than in comparable non-RE companies. Often connected to the gender pay gap, but also observed for men is the lower wage per hour in part-time employment (Gornick/Jacobs 1996; Ehrenberg/Rosenberg/Li 1988). The ILO (2011) reports a higher share of full-time workers in RE companies, which should also contribute to an above average payment of RE employers.

The age of employees is another documented factor of wages (Seike 2010; Shapiro/Sandell 1985). According to those findings, younger employees earn on average less than comparable older workers. In German RE businesses, both the share of young workers (<25 years) and the share of older workers (>55years) is slightly below the German average (Staiß et al. 2006), which suggests that the average effect of age of employees on the RE wage differential is unclear. A further determinant related to human capital might be worker flows. For instance, Duhautois/Gilles/Petit (2012) show that low labour turnover is related to higher wages, whereas this relationship is strongest for low skill levels and in large establishments. So far, empirical evidence on worker flows in the field of renewable energy products and services does not exist. Hence, we cannot derive assumptions related to the influence of worker flows based on existing RE literature. We finally consider the determinant of compensating wage factors. According to Eberts and Stone (1985), Arnould/Nichols (1983) and Smith (1978) higher wages are paid to compensate for working conditions that are especially demanding or dangerous. As renewable energy companies tend to have less hazardous working conditions than in comparable other companies (International Labour Office/European Commission 2011), there might be a sign for lower wages from this perspective.

Considering the combination of human capital related wage determinants and the characteristics of RE companies, it seems that the wages of RE companies should tend to be higher than in non-RE companies.

Establishment-Level Wage Determinants and Structural Characteristics of Renewable Energy Establishments

Besides the characteristics of the workforce shown above, several other important and well-documented structural characteristics determine wages. Oi/Idson (1999) estimate a substantial wage premium due to firm size, however it differs between gender and industry. According to their findings, both the organisation of work and the employee selection processes are the main reasons for the positive effect on wages. Several papers identify a ‘firm size wage premium’ (e.g. Heyman 2007; Blien 2001; Brown/Hamilton/Medoff 1990; Brown/Medoff 1989). However, some studies (e.g. Bellmann/Kohaut 1995) relativize the strong connection between establishment size and wages. A report published by the German Federal Environmental Ministry (BMU) stated that companies engaged in renewable energy product markets are mostly small- or medium-sized enterprises (Staiß et al. 2006). Following the argu-

ment of an establishment size wage differential, RE establishments would be expected to pay less than comparable establishments did. However, the average establishment size could have changed within the last years due to the dynamic and fast growing field of renewable energy products and services.

Another important determinant of wages is firm age which is – to some extent – related to firm size (Heymann 2007), respectively to worker characteristics (Brown/Medoff 2003). Brixy/Kohaut/Schnabel (2007) show that wages are lower in newly founded establishments than in comparable establishments. As the usage of RE on a larger scale is relatively new, the companies engaged in RE related products and services are said to be relatively young. A report of the International Labour Organization and the European Union corroborates this (ILO/EU 2011, p. 27). In respect to the establishment age wage gap, those companies might pay less than non-RE companies do.

The location of the establishment also plays a role for the level of wages, but it is related to human capital and other structural characteristics, too (e.g. Topel 1994; Groshen 1991). Whereas establishments in rural areas pay less on average, establishments in urban areas pay an 'urban wage premium' (Lehmer/Moeller 2010; Yankow 2006). The regional and local distribution of RE related activities is widely spread and depends on the RE type and on the specific part of the value chain (Ulrich/Lehr 2013). It is therefore not possible to derive a specific hypothesis for RE companies overall based on the regional wage differential.

Industry affiliation is regarded as a further wage determinant. Abowd et al. (2012) and several other studies show that there are significant differences between industries that cannot fully be explained by worker and company/establishment characteristics (e.g. Genre/Kohn/ Momferatou 2011; Gibbons/Katz 1992; Krueger/Summers 1988). Because most RE companies are part of sectors where employers usually pay high/medium wages (Staiß et al. 2006), RE employers are supposed to pay more than the average.

The export share of RE companies is another wage determinant that varies between the RE type, but basically all RE fields have at least a substantial export share (ILO/EU 2011 p. 26; German Federal Environmental Ministry 2012; Staiß et al. 2006). In accordance with labour market literature (e.g. Hauptmann/Schmerer 2013; Wagner 2012; Schank/Schnabel/Wagner 2010; Van Long/ Riezman/Soubeyran 2007), this points to higher wages in RE companies. Like in some cases above, there are also studies stating that the export wage premium vanishes after controlling for worker characteristics (e.g. Breau/Rigby 2006).

The rent-sharing theory and related empirical studies show that increasing profits can lead to increasing wages (Budd/Slaughter 2004; Mahmood 2003; Hildreth/Oswald 1997; Blanchflower/Oswald/Sanfey 1996). The profitability of RE companies differs widely between RE types, the business life cycle and the position

within the value chain (Staiß et al. 2006). Some RE companies have become profitable within the last years, but on the other hand, the production of solar panels in Germany is currently in a stage of crisis and high losses. Facing this heterogeneous situation, no hypothesis valid for all RE companies can be derived in terms of rent-sharing wage differentials.

Establishments are also actors within product markets. Those product markets are driven by product supply and demand, which are directly or indirectly influenced by factors such as regulation, consumer behaviour etc. Many studies show that product market regulations affect wages significantly (Abowd et al. 2012; Feldman 2012; Felbermayr/Prat 2011; Jean and Nicoletti 2002). The RE product markets in Germany are regulated, especially because of the EEG. The EEG provides the framework for Germany's feed-in tariff system and strongly influences the demand for new RE installations. Within the last years, the development of renewable energies increased vastly and led to a boom in the product markets of RE products and services. Therefore, the wages might be higher on average. However, as the EEG was reformed several times during the last years by withdrawing some of the favourable conditions for some RE types (particularly solar energy and onshore wind energy), wages are supposed to stop increasing or to decrease particularly in those RE fields.

To conclude this section, we assume that different characteristics influence the wages of renewable energy establishments. Consequently, we suppose that wages of renewable energy companies might differ from wages of other establishments within the same sector, leading to a renewable energy wage differential. Considering and weighting all of those potential wage determinants, we state the following main hypotheses for our study:

(1) On average, wages paid in RE establishments are higher than wages paid in other establishments.

(2) Personal and other organisational characteristics explain the RE wage differential substantially.

4 Data

For our empirical analyses we use a subset of a novel data set of the Institute for Employment Research (IAB).[2] These data enable us to differentiate between establishments that are involved with producing or distributing renewable energy and establishments that are not but are active within the same sectors. As the renewable energy value chain entails a variety of products and services, we cannot simply identify this involvement by a single characteristic such as an industry code or by a

[2] Due to data protection requirements these data are not yet available to the scientific community.

high share of certain occupations in a given establishment.[3] We use the membership in the German Renewable Energy Federation BEE (Bundesverband Erneuerbare Energie e.V.) as a proxy for a company's involvement in this value chain. The BEE is the umbrella organization of currently 25 German associations in the area of wind energy, solar energy, biomass, water power and geothermal energy. The data on renewable energy companies stem from membership lists provided by the BEE in 2009.[4] These lists comprise the name, legal form, address of the companies and an indicator for the association the company is affiliated with (e.g. The German Wind Energy Association). Therefore, we can also examine the differences between companies involved in the production or provision of the different types of renewable energy represented by the BEE.

As the membership list only provides identifying variables and the association indicator, we needed to add data that offered information about the structure of the companies' workforce and wages for our empirical analyses. In Germany, there is no research data set on the company-level that allows to link above identifiers with actual micro-data.[5] Our solution was to use administrative establishment-level data instead of company-level data.

The Establishment History Panel (BHP)[6] contains longitudinal data on the establishment-level since 1975 for West-Germany and since 1992 for East Germany. These data offer yearly information about the establishments' workforce, earnings distribution, the sector and the location of the establishment. Both employees liable to social security contributions and marginally employed are reported in total numbers and differentiated by gender, age, occupational status, qualification and nationality. The BHP also contains quantiles of age groups and wages, both for all employees and for full-time employees only. For each year, establishments are included if they register at least one dependent employee at the reference date of June

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3 In terms of industry code, only two sub-sectors (in a 5-digit classification) allow to identify parts of the RE technology 'solar energy' directly: 'manufacture of solar cells and solar modules' (26111) and 'manufacture of solar heat collectors' (28211) (German Federal Statistical Office 2014). Obviously these two sectors do not cover the entire value chain of solar power generation. We see a similar situation at the occupational classification: there are only a few specific RE-occupations listed, e.g. 'Specialist in renewable energy technology (26242)' (German Federal Employment Agency 2014).

4 We gratefully acknowledge that the BEE has provided us with this membership list free of charge. Beyond that, there is no financial or contractual relationship between the authors and the BEE or any of the associations or companies that are covered by these data.

5 The Research Data Centres of the Federal Statistical Office and the statistical offices of the German Länder do provide access to a Company Register which contains some basic information about all companies that are active in Germany. However, a record linkage with the BEE membership list would have been impossible due to the data protection legislation that governs the work of the statistical offices.

6 See Gruhl/Schmucker/Seth (2012) for more details about the BHP. Access to the BHP is provided by the Research Data Centre (FDZ) of the German Federal Employment Agency at the IAB.

30th. As the BHP is derived from mandatory employer notifications to the German social security system, the data are highly accurate and reliable.

Bringing the company-level information in the BEE membership list and the establishment-level data of the BHP together was no trivial task. The membership list does not provide any unique company identifier, and even if it did, such an identifier would not have been compatible to the establishment-level data. The BHP, on the other hand, only offers an establishment identifier.

We solved this dilemma by exploiting the fact that companies have to apply for a unique establishment number when they register an establishment for the first time. These numbers are mandatory, as they are needed for all social security notifications of employers about their dependent employees. When companies apply for such a number at a central unit of the Federal Employment Agency, the company name gets registered as the first part of the name of the establishment, even though establishments as dependent sub-units usually do not have an own name. As the IAB is part of the Federal Employment Agency, we have limited and strictly regulated access to this information.

We use record linkage techniques to identify establishments that belong to the BEE member companies. With these techniques, we are able to match the names and legal forms of the BEE member companies with the corresponding establishment-level information. In preparation of the actual linkage, we submitted these non-unique and error-prone identifiers in both data sets to a comprehensive preprocessing. That includes, for instance, parsing the information at hand into relevant elements and standardising the spelling of the resulting variables. For the actual record linkage, we compared the corresponding variables from both data sources and classified record pairs as links or non-links. We then use data on establishments classified as links in the empirical analysis.[7]

We define establishments identified by this procedure as being actively involved in value chains of renewable energy production and therefore denote them as our treatment group. Conversely, our control group is denoted as establishments not actively involved in value chains of renewable energy production but being active in the sectors defined in Section 5.

[7] Names and legal forms of the establishments in the administrative data were provided by the IT Services and Information Management Department of the IAB. The record linkage was conducted by the German Record Linkage Center (GRLC). For more details on the linkage process either see Antoni (2014) or contact the GRLC directly. The GRLC is funded by the German Research Foundation (DFG). The record linkage also benefitted from methods developed and described by Schäffler (2014).

For the sake of clarity, we summarise the definition of our treatment and control groups as follows:

- establishments belonging to BEE member companies are termed as 'renewable energy (RE) establishments',
- establishments belonging to non-BEE members as 'non-renewable energy (non-RE) establishments'.

5 Descriptive Evidence

As these data are uniquely suited to examine the structure of RE establishments, we continue with results from our descriptive analyses. We first find that renewable energy establishments are spread around several different economic branches (using the Classification of Economic Activities, issue 2008 (WZ 2008) of the German Federal Statistical Office). According to both the number of establishments and the number of employees, we identify the most important sectors and focus our analysis on them. On a 3-digit-level, the sectors are

- Manufacture of electronic components and boards (sector 261),
- Electric power generation, transmission and distribution (sector 351),
- Electrical, plumbing and other construction installation activities (sector 432), and
- Architectural and engineering activities and related technical consultancy (sector 711).

Altogether, these four sectors comprise 583 RE establishments with more than 75,000 employees. It is evident that these top-4 sectors are rather diverse economic divisions. That is why we refrain from talking about the "renewable energy industry" or the "renewable energy sector". Our data in fact indicate the cross-industries-character of renewable energy value-chains. Following this insight, we assume other activity areas of the "greening economy" to be a kind of cross-industry phenomenon.

Table 1 shows some basic characteristics of RE establishments and non-RE establishments of the four sectors in the year 2009. We observe that RE establishments pay distinctly higher wages than non-RE establishments: the average of *Gross daily median wages for fulltime employees* within the establishment is about 102 Euros for RE establishments and about 74 Euros for non-RE establishments.[8] This large wage premium indicates that there might be substantial differences in the characteristics of both groups. With respect to *Establishment size*, one difference is obvious: the average number of employees is 129 in RE establishments and only 11 in non-

[8] The table shows that this result holds for other percentiles of the wage distribution within the establishment and also for specific employment groups like the highly-skilled employees.

RE establishments. We interpret this as a first hint that RE establishments and non-RE establishments are hardly comparable on an aggregated level and should therefore be analysed on the sector level instead.

One could assume that high median wages paid by RE establishments are related to establishment size wage premia, at least to some extent. Further differences, which partly explain the observed wage premium, are a higher *Share of fulltime* employees in RE establishments (79 percent vs. 74 percent), a lower *Share of marginally* employed workers (10 percent vs. 16 percent) and a lower *Share of female employees* (28 percent vs. 32 percent). Regarding the skill composition and qualification levels within establishments the picture is mixed: on the one hand, the Share of qualified workers (and also the *Share of skilled workers*)[9] is somewhat lower in RE establishments (45 percent vs. 52 percent), but on the other hand the *Share of highly skilled workers* is distinctly higher (19 percent vs. 10 percent). The latter is also true for the *Share of white-collar employees*. Turning to the occupational structure (based on the Blossfeld classification, but excluding agricultural occupations) one observes marked differences for the *Share of skilled manual occupations* (23 percent in RE establishments vs. 38 percent in non-RE establishments) and for the *Share of engineers*, the latter being distinctly higher in RE establishments (15 percent vs. 10 percent). Management professions also play a more important role for RE establishments (6 percent vs. 2 percent). Next, *Appendix*

Table 1 entails information about the age structure: there is almost no difference between employees of RE establishments and those of the control group. For instance, the median age is 40.3 years as compared with 40.6 years for non-RE employees. A further aspect concerns the distribution of establishments over regions and region types. Ulrich et al. (2012) point out that there are regional concentrations in specific fields of the renewable energy sector. Our results underline this evidence. We find that renewable energy establishments are strongly represented in core cities and in the northern and eastern part of Germany (the latter is not documented in the table due to space restrictions).

As pointed out above, we argue that RE establishments and non-RE establishments should be compared on a more disaggregated 3-digit sector level. Interestingly, although the four sectors differ in several respects and sometimes substantially, the described differences between RE establishments and non-RE establishments on the aggregate level remain overwhelmingly existent within the sectors. As most prominent exception we observe that the wage premium is reversed in *Electric pow-*

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9 *Qualified workers*: employees in an establishment with either an upper secondary school leaving certificate as their highest school qualification or a vocational qualification (Gruhl/Schmucker/Seth 2012); Skilled workers: employees with the value ‘Skilled worker’ (value 2) in the B1 code (B1 code contains values of occupational status; e.g. employee in vocational training (0), unskilled worker (1), skilled worker (2), master craftsman (3), white-collar employee(4)) (Gruhl/Schmucker/Seth 2012)

er generation, transmission and distribution (sector 351). Here, the median gross daily wages for fulltime employees is on average 111 Euros for RE establishments, but about 120 Euros for non-RE establishments. Regarding other characteristics, it is evident that the *Share of female employees* is higher in RE establishments than in non-RE establishments, which is different from other sectors and the aggregate. Further differences with respect to the aggregate are, for instance, a comparable *Share of qualified employees* in RE and Non-RE establishments within *Electrical, plumbing and other construction installation activities (sector 432)* and that the median age is even a bit higher in RE establishments of this sector.

To sum up: the descriptive evidence shows for the aggregate and differentiated for each sector that there are marked differences in observed characteristics between RE establishments and non-RE establishments. In the next section, we present how these differences add to explain the observed wage differential.

6 Empirical Strategy and Econometric Estimates

6.1 Outline of the Estimation Approach

Our dependent variable is w (for RE establishments) and W (for Non-RE establishments), i.e. the median wage of establishments (*e*), given at a specific time (*t)* and affiliated to sector *(s).* In our basic model, wages are determined by three different parameters:

ϕ / Φ: establishment-level determinants of wages in terms of human capital / personnel structure

ψ / Ψ: establishment-level determinants of wages in terms of other establishment characteristics

τ / T: residual variable for all unobservable determinants (on establishment-level and others)

We denote the dependent variable w_{et} as median wages of establishments (e) involved in value chains of the renewable energy production. These wages are given at a specific time t. On the other hand, the dependent variable W_{et} is defined as median wages of establishments (e) in the same sector who are not involved in value chains of the renewable energy production, also given at time t.

(1) $$w_{et} = \phi + \psi + \tau$$

Wages of RE establishments are the sum of human capital determinants of wages ϕ (establishment-level), other structural determinants of wages ψ (establishment-level) and unobserved determinants τ (both on establishment-level and other levels).

(2) $$W_{et} = \Phi + \Psi + \mathrm{T}$$

Wages of non-RE establishments are the sum of human capital determinants of wages Φ (establishment-level), other structural determinants of wages Ψ (establishment-level) and unobserved determinants T (both on establishment-level and other levels).

Hence, the wage differential is

(3) $$w_{et} - W_{et} = \Delta w_{et} .$$

We have already identified the key independent variables for our empirical analyses in the literature review. The main criteria of our selection are empirical evidence and theoretical approaches in the literature regarding the observable determinants of wages and relations to the renewable energy value chain.

6.2 Oaxaca-Blinder Decompositions

A straightforward way to explain raw wage differentials between two groups is to employ the Oaxaca (1973) / Blinder (1973) decomposition technique. The decomposition is based on the wage regressions

(4) $$\ln w_{et} = x'_{et}\beta + \varepsilon_{et} \text{ and } \ln W_{et} = X'_{et}\mathrm{B} + \mathrm{E}_{et}$$

for RE establishments and the reference group of non-RE establishments, respectively. Here $\ln w_{et}$ and $\ln W_{et}$ represent the logarithm of gross daily median wages for fulltime employees within establishment e in year t, the x_{et} (X_{et}) are vectors of establishment level control variables, and the vectors β (B) contain the corresponding coefficients. The residuals ε_{et} (E_{et}) are assumed to be uncorrelated with all other right-hand side variables. We include a rich set of control variables: linear and squared terms of log establishment size and age, the median age of employees within the establishment, a dummy for being located in the eastern part of Germany, 12 variables measuring the shares of specific characteristics of workers within an establishment as being contained as average measure in *Table 2* (for instance *Share of full-time employees*, *Share of marginal part-time workers*, *Share of female employees, etc.)* and 11 variables capturing the *Share of occupational categories*. Twenty additional dummy-regressors related to the 5-digit industry level are included on the aggregated level of analysis (not differentiating on the 3-digit sector level).

The contributions of the various right-hand side variables to the mean wage difference $\overline{w} - \overline{W}$ between the RE establishments and non-RE establishments is obtained by feeding the regression results into the Oaxaca-Blinder decomposition

(5) $$\overline{w} - \overline{W} = \overline{X}(\hat{\beta} - \hat{B}) + (\overline{x} - \overline{X})\hat{B} + (\overline{x} - \overline{X})(\hat{\beta} - \hat{B})$$

The three expressions on the right hand side represent the coefficients, characteristics and interactions effect, respectively. The coefficients effect measures the wage difference due to differential remuneration of the characteristics of RE establish-

ments and non-RE establishments, the characteristics effect measures the wage difference due to differences of observed endowments, and the interaction effect measures the wage difference resulting for RE establishments if endowment differences were remunerated with the coefficient differences. An extension of the decomposition to the contributions of individual regressors or regressor groups (as e.g. dummy variable sets) is possible by applying the above formula to individual regressors.

We start the estimation approach by employing this Oaxaca-Blinder decomposition for the year 2009 both on an aggregate level and sector-specific. This tells us to which extent the wage differential can be explained by differences in characteristics being observed in our data. The unexplained gap reflects all factors which cannot be observed in our data. In order to eliminate at least the time-constant unobserved heterogeneity between RE establishments and non-RE establishments in a second step we apply establishment-fixed effects regression models considering the development of remunerations from the year 2007 to 2011 rather than wage levels in 2009.

6.3 Establishment Fixed Effects Regressions

More precisely, we estimate establishment fixed effects regressions – on the aggregated level and within the four sectors – for RE establishments and non-RE establishments separately. The wage equation for RE establishments and the reference group of non-RE establishments is then given as

(6) $$\ln w_{et} = x'_{et}\beta + \sum_{t=1}^{T} d_t \gamma_t + \phi_e + \varepsilon_{et} \quad \text{and} \quad \ln W_{et} = X'_{et}\mathrm{B} + \sum_{t=1}^{T} D_t \Gamma_t + \Phi_e + \mathrm{E}_{et}$$

respectively.

Now, $\ln w_{et}$ and $\ln W_{et}$ still represent the logarithm of gross daily median wages within establishment e in year t, but are deflated to 1995 prices. d_t (D_t) are year dummies and γ (Γ) contain the corresponding coefficients. The error term now also comprises the fixed establishment effects ϕ_e (Φ_e). The x_{et} (X_{et}) are defined as above with two exceptions: First, the dummy for being located in the eastern part of Germany is dropped since the location of the establishment is time invariant in nearly all cases. Second, only the squared establishment age term enters the fixed effects regression because the linear term would cause collinearity with the year dummies (since it also increases by unity each year).

We use the estimated coefficients from these regressions to generate predictions and then average them by year. Thus, the average wage increase (or decrease, respectively) of RE establishments and non-RE establishments from 2007 to 2011 can be decomposed as follows:

(7) $$(\ln\overline{w}_{\bullet 2011} - \ln\overline{w}_{\bullet 2007}) = (\overline{x}_{\bullet 2011} - \overline{x}_{\bullet 2007})\hat{\beta} + (\overline{\phi}_{2011} - \overline{\phi}_{2007}) + (\overline{d}_{2011}\hat{\gamma}_{2011} - \overline{d}_{2007}\hat{\gamma}_{2007})$$

The first term on the right-hand side captures the adjustment due to all observed time-varying characteristics such as the changes of establishment size, workforce composition and so on. The second term reflects the adjustment due to sample composition effects (Composition). Since unobserved time-constant factors cannot contribute to explain the wage development by definition, the fixed effects capture changes in the composition of the RE establishment (non-RE, respectively) sample. The third term contains the adjustment due to all unobserved time-varying factors, being captured by the year dummies (Trend).

6.4 Estimation Results

6.4.1 Results from Oaxaca-Blinder Decompositions

The left panel of *Table 2* contains the predicted gross median daily wages for all full-time employees of RE establishments and non-RE establishments, the predicted positive wage advantage of 35 log percent for RE establishments, and the Oaxaca-Blinder decomposition results. It can be seen from the table that the endowments effect is in general positive (26 log percent) and statistically significant at a one percent level. Hence, the wage premium of RE establishments over non-RE establishments can actually be explained for a large part by favourable characteristics of RE establishments. Especially establishment size effects and the 5-digit industry effects add positively to higher wages for RE establishments. To a smaller extent, further wage enhancing effects are given by the under-representation of female workers (2 log percent), by the aggregated share-variables capturing working-time and qualification effects (1 log percent) and by the occupational composition (3 log percent). Negative effects can be observed for establishment age and region, but both are below 1 log percent.

Turning to the coefficients effect, which measures the wage difference due to divergent remuneration of endowments of RE establishments and non-RE establishments, it becomes clear that this also adds to higher wages for RE establishments (17 percent). It should be noted that pay differentials might be due to unobserved heterogeneity between member and non-RE establishment. Especially on this aggregated level of analysis it is therefore not surprising that the unexplained gap is so large. Regarding the single regressor effects, the negative establishment size effect (-14 log percent) is overcompensated by the positive effects of median age within the establishment and the industry controls. The latter is a further hint that the sector matters when analysing the wage premium.

Most single interaction effects are statistically not significant at the five percent level, exceptions are the aggregated share variable (+5 log percent) and the 5 digit industry shares (-11 log percent). Altogether, the interaction effects sum up to a total of -7 log percent and add therefore negatively to the observed wage gap.

Turning to the *Manufacture of electronic components and boards-sector* it is obvious that the raw wage premium is 26 log percent. Especially establishment size, the occupational composition and the *Share of female employees* explain a crucial part

of the premium in this sector. The latter stems from the clear over-representation of male employees in RE establishments within this sector (see *Appendix*

Table 1). Altogether, the endowments effects sum up to 22 log percent, while both, coefficients and interaction effects are smaller (+ 15 log percent and -11 log percent, respectively) and statistically significant on a 5 and 10 percent level only. Altogether, the results show for this sector that our regressors are able to explain the observed raw wage premium to a large extent, hence indicating that unobserved heterogeneity plays a minor role here. Other possible reasons might be that this industry is facing a strong international competition and continuously falling product prices. Furthermore, the high costs for research and development in this sector also reduce the scope for rent sharing by an additional increase of wages. Finally, yet importantly, structural changes seem to take place due to technological change and the maturity of product life cycles. For example, photovoltaic-panels with silicon-based solar cells have reached a life cycle stage of semi-automated mass production. The related tasks have thus become more subject to routinisation in the sense of Autor/Levy/Murnane (2003) and therefore more 'offshorable', which puts wages under pressure (Blinder/Krueger 2013; Autor 2013). On the contrary, the wind energy sector is to some extent in a different stage of product life cycle. Intensified by the specific production processes, the production of wind power stations shows still a high degree of complex manual tasks. Wind energy related manufacturing establishments partly report a shortage of workers possessing those skills. Therefore, the stage of business cycle of the specific RE technology (wind, solar, biomass, geothermal energy etc.) could influence the demand of labour and thus the wage level. Hence, the influence of the RE technology might be worth considering in analyses of further research, but was out of scope of the work in hand.

A further central sector of the RE value chain is *Electric power generation, transmission and distribution (351)*. In contrast to the other observed sectors we find no wage premium in favour of RE establishments. This result is somehow unexpected. In the market bonus scheme of the EEG, the RE plant operators, i.e. the energy suppliers receive a bonus financed by the EEG levy on a monthly basis. One might expect that those establishments may profit most from the EEG system and share possible financial surpluses with their employees. However, this is not the case. Due to the long-term financial burdens of investing in the RE plants and due to the steadily changing support framework, most RE suppliers seem not be able to share this benefit with their workers. A possible explanation is that the investors of those capital-intensive businesses profit financially, if there is a surplus to be shared at all.

Whereas the small negative RE wage differential of *Electric power generation, transmission and distribution* is statistically not significant, some single regressor effects have an influence, for instance the endowments effects for *Establishment size* and *Region type* (both +2 log percent), *Region* (-4 log percent), *Share of female employees* (-2 log percent) or *Occupational composition* (-3 log percent). The same is true for the totalled endowments, coefficients and interaction effect. The result of

not differing wages between RE establishments and non-RE establishments is worth mentioning in the face of distinct differences in characteristics as described above and should be further examined in future work. If one contrasts the results of both sectors having examined up to now, it becomes clear that sector-specific analysis gives a much clearer picture than the analysis on the aggregated level.

The wage premiums in both other sectors - Electrical, plumbing and other construction installation activities (432) and Architectural and engineering activities and related technical consultancy (711) are 28 and 33 log percent, respectively. For the latter, two third of the raw wage premium can be explained by observed characteristics (again, establishment size and gender effects are important). However, the unexplained wage premium is still high. The same is true for Electrical, plumbing and other construction installation activities where 50 percent of the gap remains unexplained. We interpret the wage premium as a possible indirect effect of the promotion of renewable energies in favour of employees within the sectors Electrical, plumbing and other construction installation activities and Architectural and engineering activities and related technical consultancy. There are several possible explanations why employees in these two sectors benefit more from the promotion of RE than employees in other sectors: First, because the German domestic demand for RE products has grown strongly within the last years , planning, project management, installation and operation activities in the field of RE have boomed. Second, they benefited from the falling global product prices, whereas the high-tech manufacturing sector suffered because of this development (also see above).

Third, in both RE wage premium sectors, non-routine manual tasks and abstract, non-routine cognitive tasks seem to be prevalent. According to the task-based literature, these tasks are less offshorable and wages are not that much under pressure than in jobs with a higher degree of routinization (Blinder/Krueger 2013; Autor 2013; Auto/Levy/Murnane 2003). Fourth, another wage relevant advantage of ‘construction installation activities’ and ‘architectural and engineering activities’ is their relatively low capital- and R&D-intensity. On the contrary, the two other sectors (energy suppliers and high-tech manufacturers) are facing costly investments in terms of new RE plants or research and development, respectively. Fifth, the shortage of skilled labour might be another relevant driver for the wage premium. The skill-shares in our control variables might cover a substantial degree of this phenomenon, but our data could not cover the influence of a shortage of skilled labour. Sixthly, one could hypothesise that RE establishments use temporary agency work more often than non-RE establishments do and therefore are able to pay higher wages to their core workforce. Because of limitations of our data, we cannot cover this issue. However, there are no clear indications that temporary agency work is used more often in the RE-wage premium sector ‘construction installation activities’ than in ‘high-tech manufacturers’.

Finally yet importantly, the effects of being a member of an industry association could be worth to be analysed, too. As we use the membership of the renewable

energy association in Germany as a proxy for being a RE establishment, we are aware that this might cause selectivity concerning our treatment group. However, as many companies (RE and non-RE) are associated to industry associations, it seems not to be RE-specific to be member in such an association. Furthermore, the German renewable energy association seems not to be more effective or successful than any other industry association. Again, there are no hints that the effects of the membership are different across sectors.

Altogether, the sector-specific Blinder-Oaxaca decomposition of wages has shown that RE establishments in one sector differ from RE establishments in other sectors. Moreover, in two of the four sectors (construction installation activities as well as the architectural and engineering services), the observed wage differences cannot fully be explained by the differences in characteristics between RE establishments and non-RE establishments. Interpreting these results, we assume a positive indirect effect of the promotion of renewable energies (e.g. by the German Renewable Energy Sources Act - EEG).

6.4.2 Results from Establishment Fixed Effects Regressions

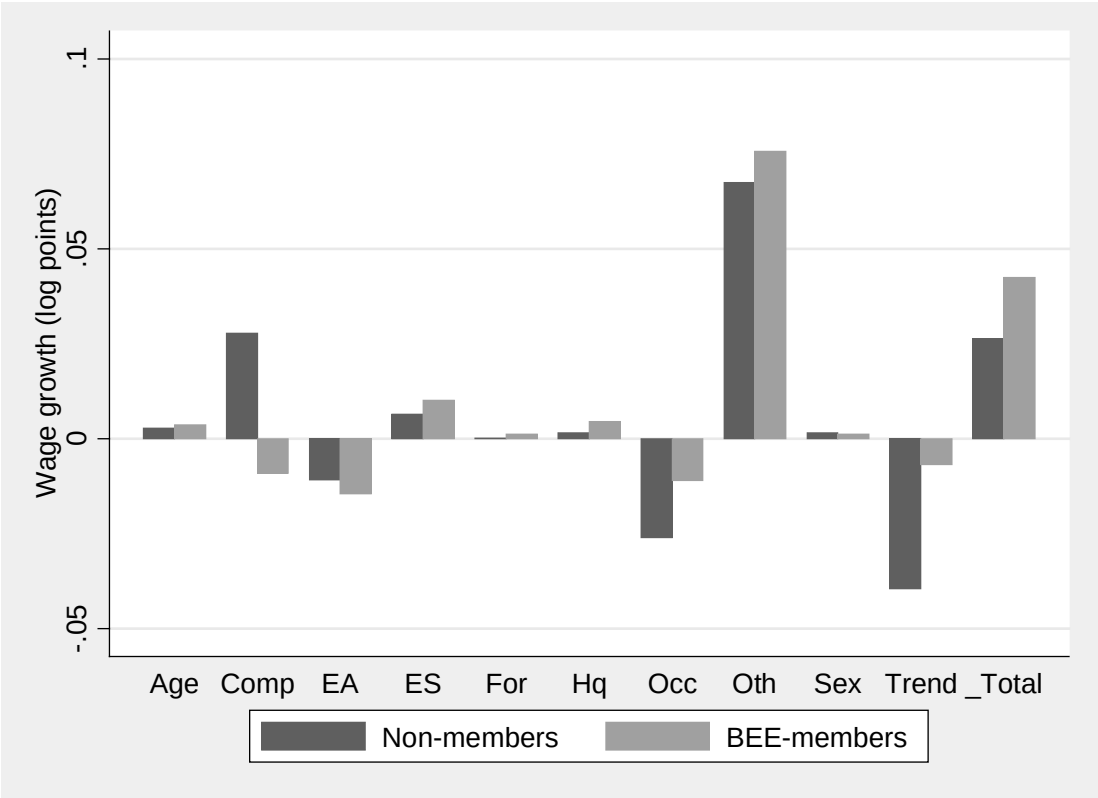
Both the inter- and intra-industry wage differentials shown in the Blinder-Oaxaca decomposition demand for further sector-specific analyses that consider unobserved heterogeneity issues. We do this by employing the fixed effects model, which considers the sources of wage increases or decreases among RE establishments and non-RE establishments. *Figure 2* shows an average real wage increase for full-time employees in RE establishment in the amount of 4 log percentage points (indicated by the light grey bar *_Total*). The corresponding increase within non-RE establishments, however, is almost the same, amounting to 3 log percentage points. That means that the raw wage premium remains nearly unchanged during the observation period.[10] Investigating the determinants of wage growth for both groups it is evident that changes in the workforce composition within the establishments as captured by the *Other Shares*-category[11] are mostly responsible for the average real wage growth. However, there are no differences between RE establishments and the reference of non-RE establishments. Such differences emerge with regard to the *Composition*- and *Trend*-effect. On an aggregated level it seems that the median wage in non-RE establishments benefits from non-random outmigration from the observation sample while the opposite is true for RE establishments. The negative

[10] This is corroborated by the result of Blinder-Oaxaca decompositions for each single year in the observation period 2007 to 2011. The raw wage premium ranges between 32 and 35 log percent. These results are not included in the paper for sake of brevity, but available from the authors on request.

[11] This category contains the effects of Share of full-time employees, Share of marginal part-time workers, Share of qualified employees, Share of skilled workers, Share of unskilled employees, Share of master craftsmen and foremen, Share of white-collar employees and Share of employees in midi part-time employment.

trend effect indicates time-variant unobserved heterogeneity that decreases wages predominantly in non-RE establishments.

Figure 2
Decomposition of wage growth of RE establishments and non-RE establishments from 2007 to 2011, Top-4-Sectors (Total)



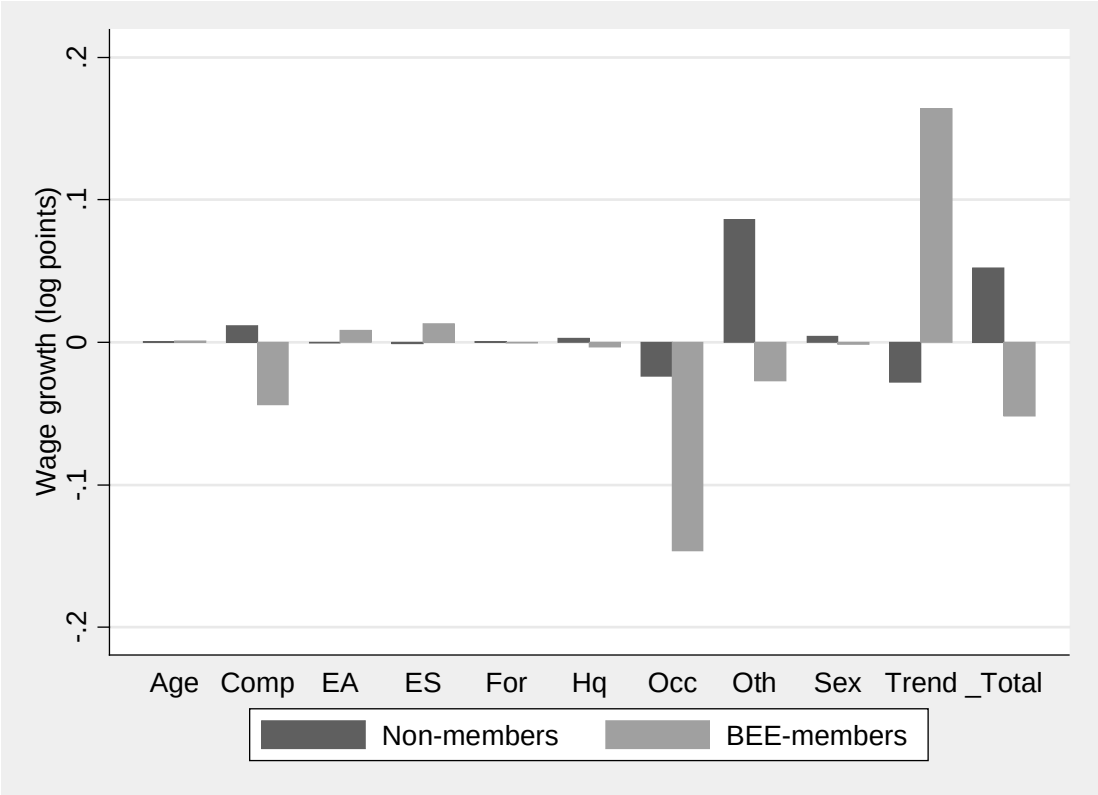
Notes: The dark grey bars represent changes in the non-RE establishments (log) wage growth due to the specific effect (age structure effect, composition effect, establishment size effect, …) and the light grey bars show the corresponding effects for RE establishments, respectively. _Total indicates total (real) wage growth from 2007 to 2011.

Source: Establishment History Panel of the Institute for Employment Research, own calculations.

As discussed above, sector-specific analyses should give a much clearer picture of what actually happens. Again, we start by considering the sector *Manufacture of electronic components and boards (261).* For the cross section 2009 we observed that the raw wage premium of 26 log percent could be almost entirely explained by difference in characteristics. *Figure 3* gives evidence that wage development is positive (+5 log percentage points) for non-RE establishments and negative (-5 log percentage points) for RE establishments, hence, the premium decreases significantly over the 5-year-period (from 34 log percent in 2007 to 23 log percent in 2011). Interestingly, wages within non-RE establishments are increased by components of the *Other Shares*-category (+9 log percentage points) while this is not the case for RE establishments (-3 log percentage points). Wages within RE establishments are significantly reduced by changes in the occupational composition (-15 log percent-

age points)[12] while again, this is not true for non-RE establishments where the decrease is much less pronounced (-2 log percentage points). Other observable time-varying characteristics like *Age structure, Establishment size, the Shares of female, foreign* or *highly-qualified workers* do not play any role in explaining wage growth differentials. The composition effect is small in magnitude for both groups. Ignoring the unobservable trend effects for a moment, *Median wages* within non-RE establishments should increase on average by 13 log percentage points; that of RE establishments should even decrease by 25 log percentage points. But this is not the case: We observe a marked positive trend effect for RE establishments amounting to 16 log percentage points and a small negative one for non-RE establishments (-3 log percentage points). Hence, it is actually an unobserved time-varying component, which favours RE establishment-wages within this sector.

Figure 3
Decomposition of wage growth of RE establishments and non-RE establishments from 2007 to 2011, Manufacture of electronic components and boards (261)



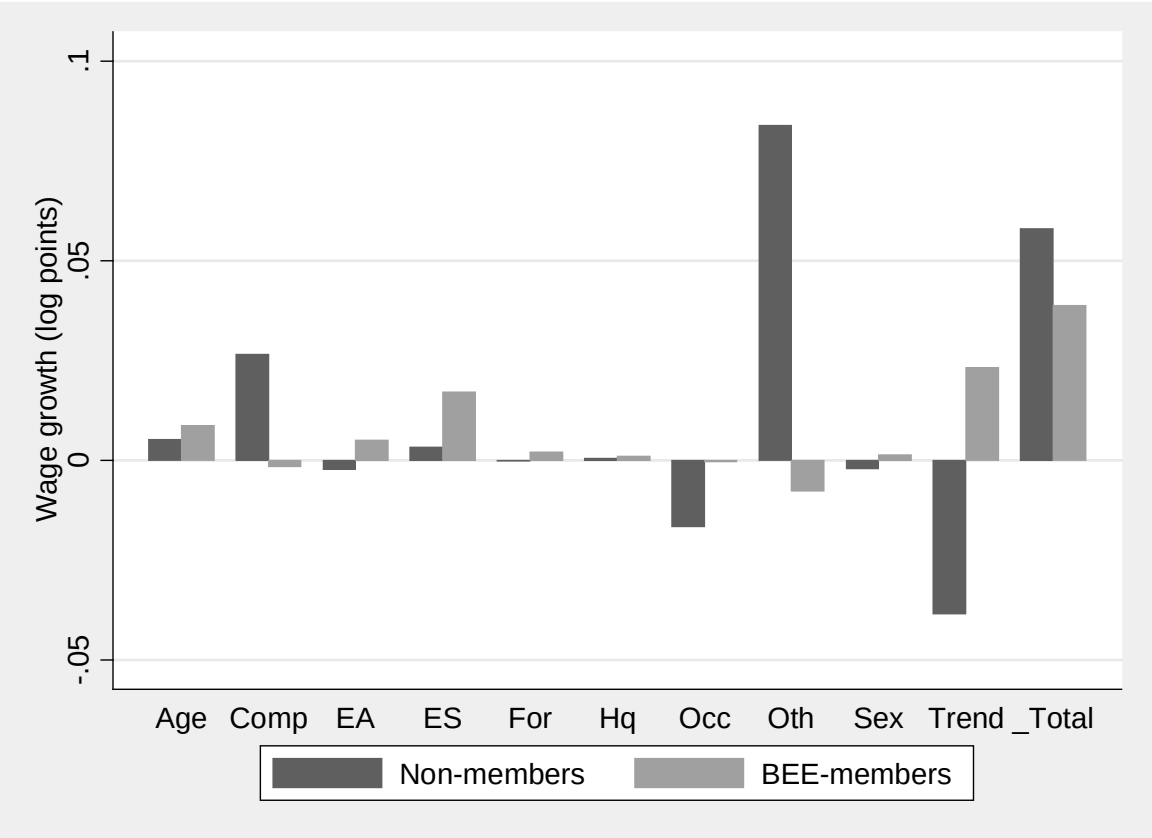
Notes: The dark grey bars represent changes in the non-RE establishments (log) wage growth due to the specific effect (age structure effect, composition effect, establishment size effect, …) and the light grey bars show the corresponding effects for RE establishments, respectively. _Total indicates total (real) wage growth from 2007 to 2011.

Source: Establishment History Panel of the Institute for Employment Research, own calculations.

[12] A closer look into the results shows that this is first of all caused by the predicted coefficient for the *Share of engineers*.

To a smaller extent, we observe the same in the sector *Electric power generation, transmission and distribution (351)*. The trend effect is + 2 log percentage points for RE establishments and -4 log percentage points for non-RE establishments only (see *Figure 4*). In contrast, composition effects (zero for RE establishments vs. +3 log percentage points for non-RE establishments) and effects of observable time-varying characteristics (+3 for RE establishments vs. +7 for non-RE establishments) rather increase wages within non-RE establishments. Altogether, the total wage increase is just slightly higher in non-RE establishments (+6 log percentage points) than among RE establishments (+4 log percentage points).

Figure 4
Decomposition of wage growth of RE establishments and non-RE establishments from 2007 to 2011, Electric power generation, transmission and distribution (351)



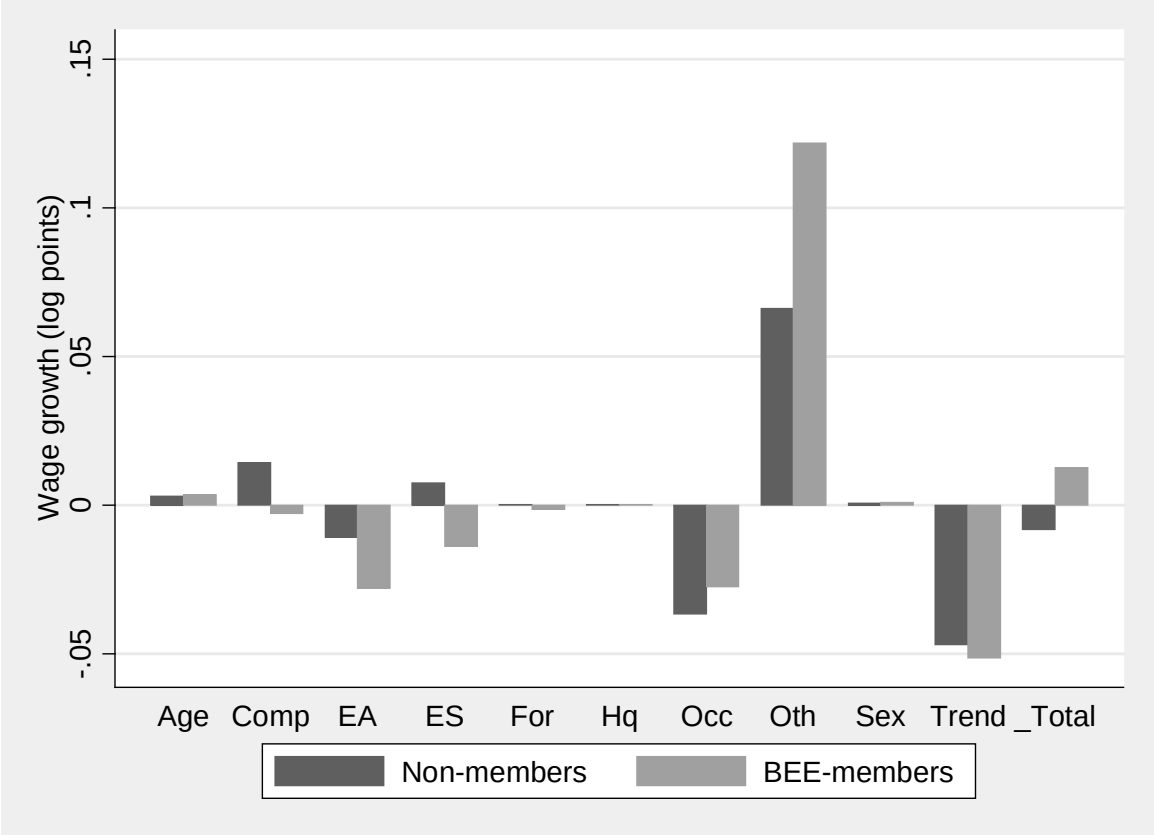
Notes: The dark grey bars represent changes in the non-RE establishments (log) wage growth due to the specific effect (age structure effect, composition effect, establishment size effect, …) and the light grey bars show the corresponding effects for RE establishments, respectively. _Total indicates total (real) wage growth from 2007 to 2011.

Source: Establishment History Panel of the Institute for Employment Research, own calculations.

Also in the two remaining sectors - *Electrical, plumbing and other construction installation activities* and *Architectural and engineering activities and related technical consultancy* – we observe that average wage growth of member and non-RE establishments tend to be comparably the same (see *Figure 5* and *Figure 6*). Consequently, the raw wage premiums remain constant over the observation period amounting to about 30 log percent. In both sectors, there are no differences at all

with regard to unobservable time varying factors. Altogether, we rather observe a pronounced heterogeneity between the sectors.

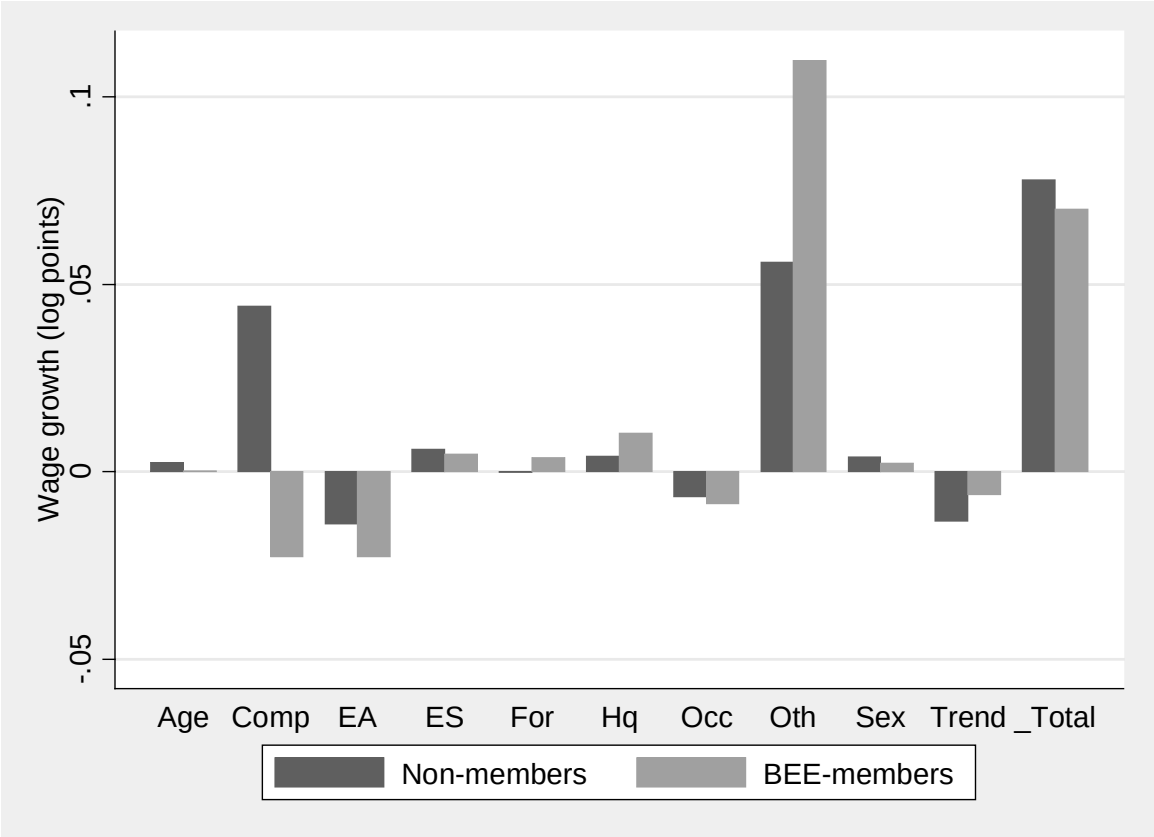
Figure 5
Decomposition of wage growth of RE establishments and non-RE establishments from 2007 to 2011, Electrical, plumbing and other construction installation activities (432)



Notes: The dark grey bars represent changes in the non-RE establishments (log) wage growth due to the specific effect (age structure effect, composition effect, establishment size effect, …) and the light grey bars show the corresponding effects for RE establishments, respectively. _Total indicates total (real) wage growth from 2007 to 2011.

Source: Establishment History Panel of the Institute for Employment Research, own calculations.

Figure 6
Decomposition of wage growth of RE establishments and non-RE establishments from 1999 to 2009, Architectural and engineering activities and related technical consultancy (711)



Notes: The dark grey bars represent changes in the non-RE establishments (log) wage growth due to the specific effect (age structure effect, composition effect, establishment size effect etc.) and the light grey bars show the corresponding effects for RE establishments, respectively. _Total indicates total (real) wage growth from 2007 to 2011.

Source: Establishment History Panel of the Institute for Employment Research, own calculations.

7 Sensitivity Analyses

Our main results are robust to variations in sample selection and specifications. This section gives a brief summary of these robustness analyses.[13]

7.1 Alternative Sample of RE Establishments

When looking on our relatively low observation numbers of RE establishments (*see Table 1*) one might be concerned whether our results are relevant in an economic sense or just valid for a handful of establishments being identified as "renewable" by membership in a federation. Considering the different sectors, it is obvious that the number of observations of RE establishments is particularly low (about 60) in the *Manufacture of electronic components and boards-sector.* This sector, however, contains the branch "manufacture of solar cells and solar modules" (26111) which is

[13] For sake of brevity, the results described in this section are not presented in the paper but are available on request.

one of the two major exceptions where the classification is not completely quiet about renewable energy activities. We use this information in a sensitivity check and classify all establishments within this branch as RE establishments. Doing this, we increase the number of establishments from 60 to an amount of 135.[14] Repeating the sector-specific Oaxaca-decomposition for the year 2009 with this sample obtains a raw wage premium of 15 log percent (instead of 26 log percent). Now, the endowments effects sum up to 16 log percent, coefficients and interaction effects are irrelevant (+ 1 log percent and -2 log percent, respectively). Though the raw premium decreases by 11 log percentage points, the results corroborate our view that unobserved heterogeneity plays a minor role in explaining wage level differentials in this sector.

Turning to wage growth differentials, the figure is similar to *Figure 3* presented above (and therefore not included for sake of brevity). The main difference concerns the negative composition effect, which is distinctly more pronounced for the alternative treatment sample. This is not surprising considering the difficult market environment for solar producers at the end of the observation period. The positive trend effect is halved, but still amounting to 8 log percentage points. Hence, it is still an unobserved time-varying component favouring RE establishment-wages within this sector.

7.2 Controlling for Differences in the Establishment-Size Distribution

When considering characteristics of the establishments, by far the most striking difference between RE establishments and non-RE establishments concerns their size, which is on average 122 in RE establishments and 8 in non-RE establishments (see *Appendix*

Table 1). We argued that this difference is a first hint that RE establishments and non-RE establishments are hardly comparable on an aggregated level and should therefore be analysed on the sector level instead. However, large differences remain on the sector level as well. Although we control for establishment size in our empirical sector-specific analyses, one might argue that the establishment size control does not capture all of the relevant heterogeneity. In order to verify this, one could repeat all analyses for different establishment size categories separately. One could also interact all regressors with establishment size (and establishment size squared). A third solution would be to repeat the decompositions with a counterfac-

[14] This branch contains 100 establishments in the year 2009, out of which 25 belong to the German Renewable Energy Federation and are classified as RE establishments in the main sample. Hence, we add 75 establishments to the treatment group.

tual sample where the size of RE establishments is reweighted in order to mimic the distribution of non-RE establishments.[15]

Taking the latter approach, the raw wage differentials in the year 2009 decrease relative to the unweighted sample by 2-8 log percentage points. The same is true for the endowments effects. The relation between explained and unexplained gap remains, however, almost unchanged: In two of the four sectors, the observed wage differences still cannot fully be explained by the differences in characteristics. Repeating the fixed effect estimates with reweighted samples corroborates the main results discussed above.

Besides taking establishment size differentials into account by creating a counterfactual sample one could go a step further by choosing a counterfactual approach considering all covariates. Doing so, we furthermore estimated several variants (one nearest neighbour and kernel) of propensity score matching within each sector. The average treatment effect on the treated turned out to be statistically significant in the *Construction installation activities (432)* and *Architectural and engineering services (711)* amounting to 10 log percent. This corroborates our finding of a RE wage premium in these sectors. For the two remaining sectors the ATET is not significantly different from zero.

8 Conclusions

Supported by energy policy targets and a broad range of promotion activities, the economic importance of RE products and services has grown considerably during the last years. Despite the large amount of public resources invested to increase the share of RE energy sources, the statistical data available about RE establishments and their employees was very limited. Before our project, there was no data available for research concerning the quality of RE jobs in Germany. Hence, there was no evidence on whether workers within RE value chains benefit in terms of wages from the promotion of renewable energy.

Our goal was to answer the following research questions: Is there a difference in human capital and other structural characteristics between RE establishments and others? Is there a difference in wages between RE establishments and others? If yes, what are the determinants for this wage differential and how do they differ between sectors? Do those wage differentials merely reflect differences in establishment characteristics or do they reflect other external influences, such as the promotion of renewable energy sources?

[15] We differentiate between four establishment-size categories: 1-19 employees, 20-99 employees, 100-499 employees, 500+ employees. Then we compute the shares of these cells in the treatment and control group and obtain the reweighting factors as the ratios of the shares among non-RE establishments to the respective shares among RE establishments.

In order to tackle these questions, we clarified the institutional and theoretical backgrounds in sections 2 and 3. Afterwards, we presented our novel data set REED (Renewable Energy Employment Data Set), a result of linking membership data of the German Renewable Energy Association to administrative data (IAB Establishment History Panel).

The descriptive statistics revealed the top-four RE sectors we focused on in the empirical analyses: *Manufacture of electronic components and boards; Electric power generation, transmission and distribution; Electrical, plumbing and other construction installation activities* and *Architectural and engineering activities and related technical consultancy*. Descriptive analyses of the establishments of these top-four RE sectors have shown significant differences of establishment characteristics and wage differentials between renewable energy establishments and their sector peers. Furthermore, we find that RE establishments pay considerably more than non-RE establishments within three of four sectors. In the sector electric power generation, transmission and distribution, however, things are different: RE establishments pay about 3 log percent less.

The estimation results have shown, that the observed differences in human capital and other establishment-level characteristics explain most of the wage differentials in the sectors of manufacturers and energy providers. In two sectors (construction / installation activities and architectural and engineering services), however, endowments differences between RE establishments and non-RE establishments explain a distinctly lower share of the raw wage premium. In both sectors, an unexplained wage differential of more than ten log percent remain which we denote as ‘renewable energy wage premium’.

In contrast, the R&D-intensive sector of manufacture of electronic components and the capital-intensive sector of electric power generation, transmission and distribution do not show this RE wage premium, maybe because of their capital costs and due to further structural changes.

To learn more about the dynamics of the wage differentials and their determinants over time (and to eliminate unobserved time constant heterogeneity) we have employed decompositions based on establishment-fixed effects regressions. For construction / installation activities and architectural and engineering services, the results show that these wage differences do not change significantly over time. That is, the wage premium is quite persistent within these sectors.

Whereas one might first think on high-tech manufacturers or renewable energy supply when thinking about workers who benefit from RE promotion, our results suggest that employees in the construction / installation activities and architectural and engineering services are the ‘hidden winners’ of the promotion of renewable energy. As the most likely interpretation for this development, we consider the explanation of

the wage premium as a positive indirect effect of the public promotion of renewable energies, e.g. by the German feed-in tariff system (EEG).

In this paper, we have covered the most relevant issues concerning the sector-specific analyses of establishment characteristics and wage differentials of RE establishments in Germany. However, our analyses have some shortcomings, which should be born in mind. As mentioned in the results section, the importance of shortage of skilled labour should be examined in more detail, but our data do not sufficiently cover this issue yet. Lack of information is also responsible in terms of temporary agency workers, as our data only allows us to determine where such workers are employed, but not by which establishments they are hired. Agency workers thus cannot be identified in the workforce of establishments in our data set. Therefore, there is an immanent risk of underestimating the extent and effects of temporary agency work on employment impacts of the RE expansion. The effects of being a member of an industry association would be a worthwhile topic for further research, too: whereas there is a huge body of literature dealing with associations of industrial relations (unions, employers' associations etc.), there is only little research available on the effects of industry associations on wages. After analysing the RE establishment-level, it seems reasonable to develop the RE employment dataset further by linking employee data of the establishments involved. This employer-employee approach appears to be a natural extension of our analyses of employment effects of the German energy system's transformation.

We identify the following policy implications in terms of promotion activities such as the case of the RE development in Germany: Firstly, there can be hidden stakeholders indirectly affected by the introduction, changing or ending of promotion activities, even if they are active in another sector or in a different part of the value chain, respectively. Secondly, one should keep in mind dimensions of quality of work, e.g. in terms of wages, when evaluating economic impacts of promotion activities.

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Tables

Table 1
Average characteristics of RE establishments and non-RE establishments in the year 2009

	WZ 2008, 3-digit code		261		351		432		711	
	Top-4-Sectors (Total)		Manufacture of electronic components and boards		Electric power generation, transmission and distribution		Electrical, plumbing and other construction installation activities		Architectural and engineering activities and related techn. consultancy	
Variables	**non-RE**	**RE**	**non-RE**	**RE**	**non-RE**	**RE**	**non-RE**	**RE**	**non-RE**	**RE**
Wage (gross average daily wage) quartile P25 for all full-time (ft) employees	64.55	85.48	71.75	84.21	108.32	96.72	59.21	75.49	70.03	87.48
Wage quartile Med for all ft employees	73.89	101.87	84.88	105.53	119.95	111.33	66.85	87.77	82.01	107.71
Wage quartile P75 for all ft employees	82.94	118.69	102.20	132.76	131.73	127.64	73.68	99.57	94.36	126.70
Wage quartile P25 for highly qualified ft employees	98.72	118.21	115.97	128.14	144.29	123.27	94.35	118.33	95.31	111.82
Wage quartile Med for highly qualified ft employees	107.61	132.84	129.59	144.41	154.21	137.34	100.29	130.64	104.61	127.41
Wage quartile P75 for highly qualified ft employees	115.94	144.46	141.14	157.21	159.44	148.32	105.80	140.49	113.73	139.92
Number of employees	10.5	129.3	55.8	624.6	54.7	173.4	8.3	34.8	8.7	41.6
Share of full-time employees	73.8	79.4	76.8	86.2	83.0	85.7	73.0	75.8	74.3	76.3
Share of marginal part-time workers	15.5	10.3	14.2	5.9	6.8	5.9	15.1	10.9	16.9	14.0
Share of female employees	32.2	27.8	39.5	27.5	22.3	27.6	21.9	20.3	50.9	35.2
Share of qualified employees	52.1	44.9	47.2	34.3	66.8	50.3	58.5	58.6	39.7	30.8
Share of highly qualified employees	9.7	19.0	12.7	19.1	12.7	20.8	1.5	6.1	23.9	30.4
Share of German employees	95.2	95.8	94.4	96.2	98.1	96.2	94.4	96.3	96.3	94.9
Share of trainees/apprentices	5.0	3.8	2.1	3.2	2.2	2.2	7.1	7.5	1.7	1.5
Share of skilled workers	28.6	19.4	16.9	15.2	27.1	18.6	42.4	37.2	5.0	3.8

Cont. Table1: Average characteristics of RE establishments and non-RE establishments in the year 2009	**WZ 2008, 3-digit code**		**261**		**351**		**432**		**711**	
	Top-4-Sectors (Total)		**Manufacture of electronic components and boards**		**Electric power generation, transmission and distribution**		**Electrical, plumbing and other construction installation activities**		**Architectural and engineering activities & related techn. consultancy**	
	non-RE	**RE**	**non-RE**	**RE**	**non-RE**	**RE**	**non-RE**	**RE**	**non-RE**	**RE**
Share of unskilled employees	12.0	8.1	19.9	14.8	8.5	6.0	16.6	12.3	3.8	3.5
Share of master craftsmen and foremen	2.2	1.9	1.2	0.6	5.1	3.0	2.8	3.0	0.8	0.4
Share of white-collar employees	33.1	51.4	40.7	56.6	43.1	59.6	13.4	24.9	66.8	69.9
Share of employees in midi part-time employment	4.4	5.3	5.6	3.3	7.0	5.3	3.6	4.8	5.4	6.4
Share of unskilled manual occupations	9.0	8.1	20.9	15.1	8.3	8.4	12.6	8.9	2.3	5.0
Share of unskilled services	4.2	4.4	6.7	4.6	6.0	4.3	3.2	4.4	5.7	4.5
Share of unskilled commercial and admin. occup.	5.3	5.1	3.4	3.1	3.5	6.2	4.6	3.8	6.6	6.0
Share of skilled manual occupations	37.5	23.0	21.1	13.4	31.2	18.1	57.6	49.2	3.3	3.7
Share of skilled services	0.7	0.7	0.4	0.2	1.4	0.9	0.2	0.2	1.4	1.2
Share of skilled commercial and admin. occup.	18.5	23.1	19.9	24.7	23.5	26.6	16.1	17.1	22.1	25.9
Share of technicians	11.0	11.4	11.1	12.6	9.4	10.1	2.4	9.4	26.4	13.8
Share of semiprofessions	0.1	1.0	0.2	0.1	0.5	0.6	0.0	0.1	0.2	2.5
Share of engineers	10.1	14.5	8.8	15.0	6.1	12.8	0.7	2.9	27.1	27.0
Share of professions	0.2	1.0	0.4	1.0	0.5	1.8	0.1	0.1	0.4	1.2
Share of managers	1.9	6.3	5.2	7.8	6.8	9.3	1.1	2.3	2.7	7.6
Age quartile P25 of the total of employees	33.6	32.9	35.4	31.2	37.8	35.2	32.0	32.0	36.1	32.8
Age quartile Med of the total of employees	40.6	40.3	42.4	39.0	44.1	41.8	39.6	40.2	41.9	39.8
Age quartile P75 of the total of employees	47.6	47.2	49.2	46.5	49.7	47.7	47.2	47.9	48.0	46.4
Core cities	28.7	36.7	24.2	36.2	18.6	33.3	24.4	28.4	37.3	47.4
Urbanized districts	38.2	34.5	46.7	31.0	35.5	26.2	39.0	40.0	36.4	36.1
Rural districts with features of concentration	17.4	16.6	16.1	20.7	23.4	22.7	19.0	16.8	14.2	10.8
Rural districts – sparsely populated	15.7	12.2	12.9	12.1	22.5	17.7	17.5	14.7	12.1	5.7
Total number of establishments	114,489	583	1,827	58	3,285	141	69,846	190	39,531	194

Source: Establishment History Panel of the Institute for Employment Research, own calculations.

Table 2
Decomposition of log gross average daily wages for all full-time employees at sample means (comparison group: non-RE establishments) for the year 2009

	WZ 2008, 3-digit code		261		351		432		711	
	Top-4-Sectors (Total)		Manufacture of electronic components and boards		Electric power generation, transmission and distribution		Electrical, plumbing and other construction installation activities		Architectural and engineering activities and related techn. consultancy	
	Coefficients	S.D.	Coefficients	S.D.	Coefficients	S.D.	Coefficients	S.D.	Coefficients	S.D.
Prediction RE establishments	4.556***	0.016	4.597***	0.047	4.656***	0.031	4.414***	0.027	4.609***	0.030
Prediction non-RE establishments	4.202***	0.001	4.340***	0.011	4.682***	0.009	4.131***	0.002	4.279***	0.003
Predicted difference	0.354***	0.016	0.257***	0.048	-0.026	0.032	0.282***	0.027	0.330***	0.030
ENDOWMENTS EFFECTS										
Establishment size	0.098***	0.006	0.087***	0.014	0.023**	0.011	0.099***	0.008	0.136***	0.011
Establishment age	-0.006***	0.001	0.005	0.006	-0.001	0.002	0.006*	0.003	-0.004***	0.001
Region	-0.008*	0.004	-0.033*	0.018	-0.040***	0.011	0.001	0.009	0.002	0.005
Region type	0.005***	0.001	0.007	0.005	0.017***	0.006	0.003	0.002	0.010***	0.003
Median age	-0.000	0.000	-0.010	0.006	-0.008**	0.004	0.001	0.001	-0.004***	0.001
Aggregated shares variables	0.009***	0.003	0.039**	0.017	0.025	0.022	-0.013**	0.006	0.010*	0.006
Share of female employees	0.020***	0.004	0.064***	0.013	-0.020**	0.009	0.006	0.005	0.070***	0.007
Occupational composition	0.027***	0.004	0.061***	0.016	-0.034**	0.014	0.035***	0.005	-0.002	0.007
5 digit industry shares	0.116***	0.007								
Total	**0.260*** **	**0.012**	**0.221*** **	**0.040**	**-0.040**	**0.029**	**0.139*** **	**0.018**	**0.219*** **	**0.020**

Cont. Table 2: Decomposition of log gross average daily wages for all full-time employees at sample means (comparison group: non-RE establishments) for the year 2009	**WZ 2008, 3-digit code**		**261**		**351**		**432**		**711**	
	Top-4-Sectors (Total)		**Manufacture of electronic components and boards**		**Electric power generation, transmission and distribution**		**Electrical, plumbing and other construction installation activities**		**Architectural and engineering activities and related techn. consultancy**	
			Coefficients	**S.D.**	**Coefficients**	**S.D.**	**Coefficients**	**S.D.**	**Coefficients**	**S.D.**
COEFFICIENTS EFFECTS										
Establishment size	-0.143***	0.039	-0.432***	0.120	-0.189**	0.082	-0.204***	0.074	-0.165**	0.072
Establishment age	-0.012	0.034	-0.048	0.056	0.078	0.065	-0.098	0.063	0.058	0.052
Region	0.004	0.008	0.032**	0.014	0.029*	0.016	-0.008	0.012	-0.008	0.015
Region type	-0.006	0.019	-0.094***	0.034	-0.082	0.066	0.062**	0.029	-0.027	0.030
Median age	0.190**	0.092	-0.054	0.311	-0.315	0.270	0.297***	0.104	0.335*	0.171
Aggregated shares variables	-0.086	0.271	-2.131*	1.258	-0.192	0.481	-0.795**	0.336	0.085	0.358
Share of female employees	0.018	0.037	0.028	0.078	0.005	0.038	0.067	0.053	-0.025	0.108
Occupational composition	0.122	0.163	-0.314	0.637	0.701	0.561	0.421**	0.195	0.568**	0.276
5 digit industry shares	0.219***	0.071								
Constant	-0.138	0.342	3.161**	1.344	-0.072	0.857	0.390	0.430	-0.665	0.415
Total	**0.166*** **	**0.027**	**0.148** **	**0.067**	**-0.036**	**0.033**	**0.132*** **	**0.039**	**0.157** **	**0.062**
INTERACTION EFFECTS										
Establishment size	-0.026	0.018	-0.180***	0.058	-0.018	0.012	-0.060**	0.028	-0.050	0.033
Establishment age	0.001	0.004	0.010	0.010	-0.002	0.008	-0.007	0.005	-0.009	0.010
Region	0.001	0.001	0.017	0.012	0.023*	0.014	0.000	0.001	0.000	0.001
Region type	-0.000	0.002	0.004	0.014	0.015	0.012	-0.005	0.004	0.006	0.009
Median age	-0.001	0.002	0.004	0.025	0.016	0.015	0.005	0.005	-0.017*	0.010
Aggregated shares variables	0.052**	0.021	-0.011	0.040	0.020	0.034	0.053*	0.029	0.014	0.017
Share of female employees	-0.002	0.005	-0.009	0.024	0.001	0.009	-0.005	0.005	0.008	0.033
Occupational composition	0.013	0.021	0.053*	0.032	-0.005	0.038	0.030	0.024	0.003	0.019
5 digit industry shares	-0.110***	0.016								
Total	**-0.072*** **	**0.022**	**-0.112***	**0.066**	**0.050**	**0.033**	**0.011**	**0.036**	**-0.046**	**0.050**

Notes: Standard errors in parentheses. Significance levels are reported at 1%(***),5%(**) and 10% (*) levels.

Source: Establishment History Panel of the Institute for Employment Research, own calculations.

Appendix

Table A-1
Instruments of Renewable Energy Policy of the EUROPEAN COMMISSION (Source: IEA/IRENA Global Renewable Energy Policies and Measures Database, International Energy Agency (IEA) and International Renewable Energy Agency (IRENA) 2014)

Title	Year	Policy Status	Policy Type	Policy Target
First Phase of European Climate Change Programme (EECP)	2001	Ended	Policy Support, Information and Education, Advice/Aid in Implementation, Voluntary Approaches, Negotiated Agreements (Public-private sector), Information and Education, Performance Label, Endorsement label, Information and Education, Information provision, Policy Support, Institutional creation, Economic Instruments, Direct investment, Infrastructure investments, Regulatory Instruments, Other mandatory requirements, Regulatory Instruments, Codes and standards, Economic Instruments, Market-based instruments, GHG emissions trading	Geothermal, Power, Geothermal, Heat
White paper: European transport policy for 2010: time to decide	2001	In Force	Policy Support, Strategic planning, Economic Instruments, Fiscal/financial incentives, Policy Support	Bioenergy, Biofuels for transport
Directive on Biofuels for Transport (2003/30/EC)	2003	In Force	Regulatory Instruments, Codes and standards, Regulatory Instruments, Other mandatory requirements	Bioenergy, Biofuels for transport
Directive on the Taxation of Energy Products and Electricity	2004	In Force	Economic Instruments, Fiscal/financial incentives, Taxes	Multiple RE Sources, Power, Multiple RE Sources, All, Multiple RE Sources, CHP, Multiple RE Sources, Heating
Biomass Action Plan	2005	In Force	Policy Support, Strategic planning	Multiple RE Sources, Power, Multiple RE Sources, All, Multiple RE Sources, CHP, Multiple RE Sources, Heating
European Photovoltaic Technology Platform	2005	In Force	Voluntary Approaches, Negotiated Agreements (Public-private sector), Policy Support, Insitutional creation, Policy Support, Strategic planning, Research, Development and Deployment (RD&D), Research programme , Technology deployment and diffusion	Solar, Solar photovoltaic
Solar Thermal Technology Platform	2006	In Force	Voluntary Approaches, Negotiated Agreements (Public-private sector), Policy Support, Insitutional creation, Policy Support, Strategic planning	Solar Thermal
EU Biofuels Strategy	2006	In Force	Policy Support, Strategic planning	Bioenergy

Biofuels Energy Technology Platform	2006	In Force	Voluntary Approaches, Negotiated Agreements (Public-private sector), Policy Support, Insitutional creation, Research, Development and Deployment (RD&D), Research, Development and Deployment (RD&D), Demonstration project, Research, Development and Deployment (RD&D), Research programme , Technology deployment and diffusion, Research, Development and Deployment (RD&D), Research programme , Technology development	Bioenergy, Biofuels for transport
Wind Energy Technology Platform	2006	In Force	Voluntary Approaches, Negotiated Agreements (Public-private sector), Policy Support, Insitutional creation, Research, Development and Deployment (RD&D), Research, Development and Deployment (RD&D), Research programme , Technology deployment and diffusion, Research, Development and Deployment (RD&D), Research programme , Technology development	Wind, Onshore, Wind, Offshore
Methane-to-Markets Partnership	2007	In Force	Voluntary Approaches, Information and Education, Information provision, Information and Education, Advice/Aid in Implementation	Bioenergy, Biomass for power, Bioenergy, Biomass for heat
Strategic Energy Technology Plan (SET-Plan): Towards a low carbon future	2007	In Force	Policy Support, Strategic planning, Policy Support, Insitutional creation	Multiple RE Sources, Power, Multiple RE Sources, All, Multiple RE Sources, CHP, Multiple RE Sources, Heating
Renewable Energy Road Map - Renewable energies in the 21st century: building a more sustainable future	2007	In Force	Policy Support, Strategic planning	Multiple RE Sources
An Energy Policy for Europe	2007	In Force	Policy Support, Strategic planning	Multiple RE Sources, Power, Multiple RE Sources, All, Multiple RE Sources, CHP, Multiple RE Sources, Heating
European Council Action Plan (2007-2009) Energy Policy for Europe	2007	In Force	Policy Support, Strategic planning	Multiple RE Sources, Power, Multiple RE Sources, All, Multiple RE Sources, CHP, Multiple RE Sources, Heating
Revised State Aid Guidelines for Environmental Protection	2008	In Force	Regulatory Instruments, Regulatory Instruments, Monitoring	Multiple RE Sources
3 x 20 20 by 2020: Europes Climate Change Opportunity	2008	In Force	Policy Support, Strategic planning	Multiple RE Sources, Power, Multiple RE Sources, All, Multiple RE Sources, Heating, Multiple RE Sources, CHP
EU Climate and Energy Package: Quality standards for fuels and biofuels	2009	In Force	Regulatory Instruments, Codes and standards	Bioenergy, Biofuels for transport

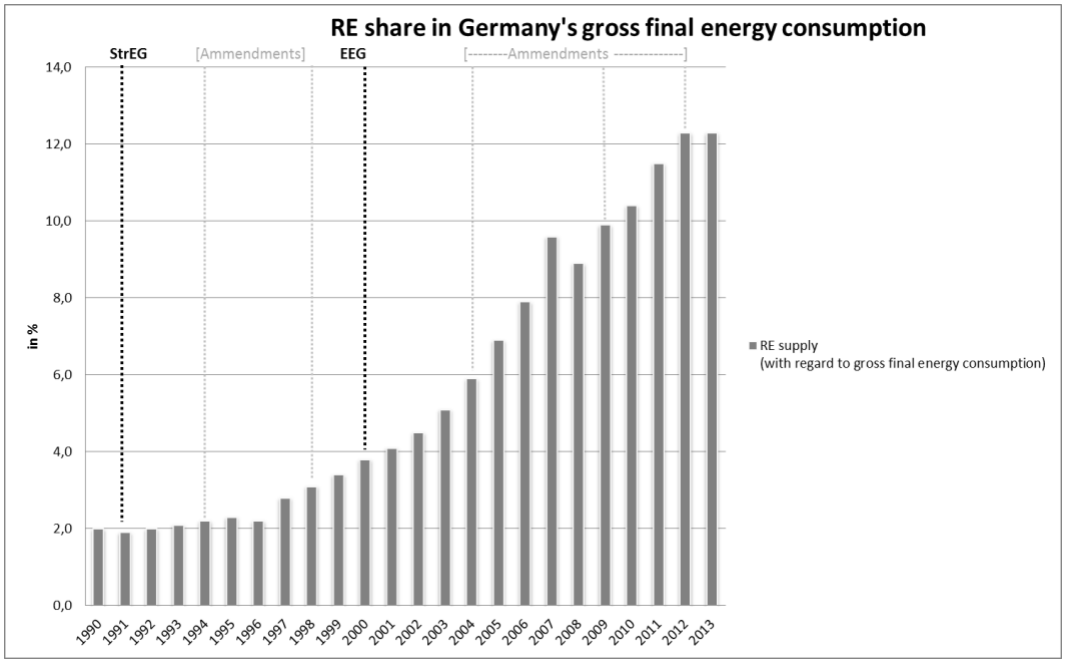
Table A-2
Instruments of Renewable Energy Policy of the GERMAN FEDERAL GOVERNMENT (Source: IEA/IRENA Global Renewable Energy Policies and Measures Database, International Energy Agency (IEA) and International Renewable Energy Agency (IRENA) 2014)

Title	Year	Policy Status	Policy Type	Policy Target	Source
250 MW Wind Programme	1989	Ended	Economic Instruments, Fiscal/financial incentives, Grants and subsidies	Wind	IEA/IRENA 2014
Full Cost Rates (Kostendeckende Vergütung)	1993	Ended	Economic Instruments, Fiscal/financial incentives, Taxes, Economic Instruments, Fiscal/financial incentives, Feed-in tariffs/premiums	Solar, Solar photovoltaic	IEA/IRENA 2014
Green Power	1996	In Force	Regulatory Instruments, Economic Instruments, Direct investment, Procurement rules, Regulatory Instruments, Monitoring, Regulatory Instruments, Other mandatory requirements	Wind, Onshore, Bioenergy, Biomass for power, Geothermal, Power, Hydropower, Multiple RE Sources, Power, Wind, Offshore	IEA/IRENA 2014
Federal Building Codes for Renewable Energy Production	1997	In Force	Regulatory Instruments, Codes and standards, Regulatory Instruments, Other mandatory requirements	Wind, Onshore, Bioenergy, Biomass for power, Multiple RE Sources, Power	IEA/IRENA 2014
Market Incentive Programme (Marktanreizprogramm)	1999	In Force	Research, Development and Deployment (RD&D), Research programme , Technology deployment and diffusion, Economic Instruments, Fiscal/financial incentives, Economic Instruments, Fiscal/financial incentives, Grants and subsidies, Economic Instruments, Fiscal/financial incentives, Loans	Solar Thermal, Bioenergy, Biomass for heat, Bioenergy, Biomass for power, Geothermal, Heat, Geothermal, Power	IEA/IRENA 2014
Solarthermie 2000Plus	2004 (amended 2008)	Ended	Research, Development and Deployment (RD&D), Economic Instruments, Fiscal/financial incentives, Grants and subsidies, Economic Instruments, Fiscal/financial incentives	Solar Thermal, Solar Thermal, Solar heat	IEA/IRENA 2014
Klimazwei Research Programme	2006	Ended	Research, Development and Deployment (RD&D), Research programme , Technology deployment and diffusion, Research, Development and Deployment (RD&D), Research programme , Research, Development and Deployment (RD&D), Demonstration project	Wind, Bioenergy, Biomass for heat, Geothermal, Heat	IEA/IRENA 2014

Integrated Climate Change and Energy Programme	2007	In Force	Policy Support, Strategic planning	Multiple RE Sources, Power, Multiple RE Sources, CHP, Multiple RE Sources, Heating, Multiple RE Sources, All	IEA/IRENA 2014
KfW Renewable Energies Programme (KfW-Programm Erneuerbare Energien)	2009	In Force	Economic Instruments, Fiscal/financial incentives, Loans, Economic Instruments, Fiscal/financial incentives, Grants and subsidies	Wind, Geothermal, Heat, Bioenergy, Biomass for heat, Bioenergy, Biomass for power, Multiple RE Sources, CHP, Multiple RE Sources, Power, Solar, Solar photovoltaic, Solar Thermal	IEA/IRENA 2014
Renewable Energies Heat Act (EEWärmeG)	2009	In Force	Regulatory Instruments, Other mandatory requirements	Solar Thermal, Bioenergy, Biomass for heat, Geothermal, Heat, Multiple RE Sources, CHP, Multiple RE Sources, Heating	IEA/IRENA 2014
Energy Concept	2010	In Force	Regulatory Instruments, Policy Support, Strategic planning	Multiple RE Sources	IEA/IRENA 2014
Biofuels Quota Act	2010	In Force	Regulatory Instruments, Codes and standards, Product standards, Regulatory Instruments, Codes and standards, Vehicle fuel-economy and emissions standards, Regulatory Instruments, Obligation schemes	Bioenergy, Biofuels for transport	IEA/IRENA 2014
National Energy Action Plan (NREAP)	2010	In Force	Policy Support, Strategic planning, Policy Support	Multiple RE Sources, Multiple RE Sources, All, Multiple RE Sources, CHP, Multiple RE Sources, Cooling, Multiple RE Sources, Heating, Multiple RE Sources, Power	IEA/IRENA 2014
KfW Programme Offshore Wind Energy	2011	In Force	Economic Instruments, Fiscal/financial incentives, Loans, Economic Instruments, Fiscal/financial incentives, Grants and subsidies	Wind, Onshore, Wind, Offshore	IEA/IRENA 2014
Law on Energy and Climate Fund	2011	In Force	Policy Support, Insitutional creation	Multiple RE Sources	IEA/IRENA 2014
Sixth Energy Research Programme (6.Energieforschungsprogramm - Forschung für eine umweltschonende, zuverlässige und bezahlbare Energieversorgung)	2011	In Force	Research, Development and Deployment (RD&D)	Multiple RE Sources, All	IEA/IRENA 2014

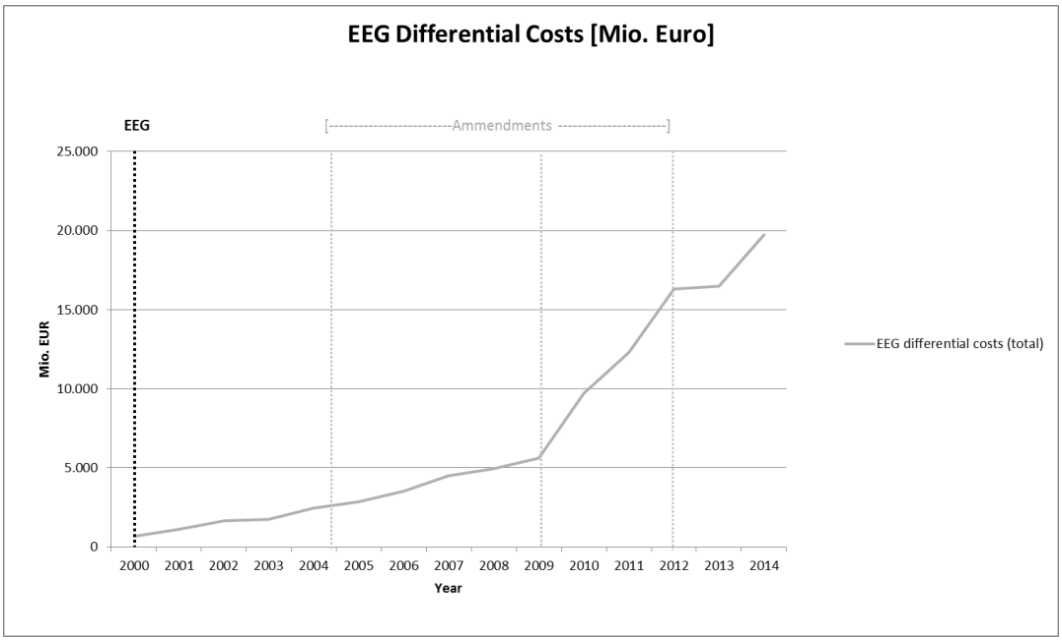
CHP Agreements with Industry (Vereinbarung zwischen der Regierung der Bundesrepublik Deutschland und der deutschen Wirtschaft zur Steigerung der Energieeffizienz)	2012	In Force	Voluntary Approaches, Negotiated Agreements (Public-private sector), Voluntary Approaches	Multiple RE Sources, CHP	IEA/IRENA 2014
2012 Amendment of the Renewable Energy Sources Act -EEG-	2012	In Force	Policy Support, Economic Instruments, Fiscal/financial incentives, **Feed-in tariffs/premiums**, Economic Instruments, Fiscal/financial incentives	Wind, Onshore, Bioenergy, Biomass for heat, Hydropower, Geothermal, Power, Solar, Solar photovoltaic, Wind	IEA/IRENA 2014, BGBl. I p. 1754

Figure A-1
RE share in Germany's gross final energy consumption



Source: German Federal Ministry for Economic Affairs and Energy (2014): Zeitreihen zur Entwicklung der erneuerbaren Energien in Deutschland unter Verwendung von Daten der Arbeitsgruppe Erneuerbare Energien-Statistik (AGEE-Stat). URL: http://www.erneuerbare-energien.de/fileadmin/Daten_EE/Dokumente__PDFs_/ee_energiedaten_agee_stat.pdf [Last Access: May 5, 2014].

Figure A-2
EEG Differential Costs (reimbursements financed by EEG levys)



Source: German Federal Ministry for Economic Affairs and Energy (2013): Zeitreihen zur Entwicklung der Kosten des EEG unter Verwendung von durch die Übertragungsnetzbetreiber (ÜNB) veröffentlichter Daten. URL: http://www.erneuerbare-energien.de/fileadmin/Daten_EE/Dokumente__PDFs_/ee_energiedaten_ue_n_b.pdf [Last Access: May 5, 2014].

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