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MEDEAS
MODELING THE RENEWABLE ENERGY TRANSITION IN EUROPE

Project Nr: 691287

Guiding European Policy toward a low-carbon economy. Modelling sustainable Energy system Development under Environmental And Socioeconomic constraints

D.7.2 (D23) Recommendations to increase public acceptance

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Document info sheet

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Abstract

This Deliverable focuses on labour demand effects of the low-carbon transformation and labour skills in relation to energy intensity across sectors. Energy intensity concerns the efficiency of energy utilisation in relation to economic output. Labour demand has been found to be a critical bottleneck in the low-carbon transformation. This requires education policies to anticipate upcoming demand. Labour skills are not only relevant to enable the adoption of renewable energies, but also important to increase energy efficiency and reduce energy intensity in the broader economy, including a number of energy-intensive industries. The policy conclusions are embedded in a broader transition framework. We highlight the relevance of structural adjustment assistance as a forward-looking, albeit narrow transition policy frame. This includes education assistance, as well as public goods provision for labour skill development.

The analysis is based on input-output models of the transition, with impact analyses on labour demand as well as gender effects and skill levels required for the transition. The conclusions also build on earlier (WP6) econometric analyses of skill level effects on sector-level energy intensities, i.e. the efficiency of energy utilisation.

We find that labour demand increases considerably in coal-based economies to facilitate the low-carbon transformation. We suggest upscaling the experiences from coordinated market economies which have vocational training structures with close collaboration between industries, education and research. Although uniform approaches to renewable energy policies exist, this coherence is currently lacking for vocational training and labour skills development more broadly.

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Executive summary

This Deliverable focuses on the labour dimensions of social acceptance. We review experiences from a number of case studies on transformations, ranging from trade policy, including agricultural trade liberalization, to institutional development and reform policies, as well as past climate change policies. Any policy change, whether concerning taxes, expenditures, or regulations, usually creates some losers, who have benefited from the status quo ante. Mitigation strategies of compensation, grandfathering, or phased implementation and incremental reforms with compromises between winners and losers have been frequent solutions under these conditions. The literature acknowledges the relations between potential winners and losers of transformations. These include carbon-intensive industries, with all their assets invested, workers involved in those industries, communities that largely depend on such industries, and also households with carbon-intensive assets. Forward-looking structural adjustment assistance is fundamental to overcome resistance and anticipate labour demand.

We focus on labour demand for renewable energy adoption and labour skills in relation to energy intensity, because labour demand has been found to be a critical bottleneck in the transformation. This requires education policies to anticipate upcoming demand. Labour skills are not only relevant to enable the adoption of renewable energies, but also important to increase energy efficiency and reduce energy intensity in the economy.

We find that continued transition to renewable energy implies a considerable potential to generate more jobs domestically through the renewable energy transition in the case of coal-based economies. In all analysed countries, the prevalence of male workers remains stable. Low skilled labour contributes only minor parts of the labour demand effects. Economies of scale, energy mix scenarios and the distinction between operational and capital expenditures require further model extensions to increase the robustness of the findings. We also find support for the high relevance of labour skills in improving energy efficiency and reducing energy intensity across a large number of energy-intensive sectors.

We conclude that education policies that take into account coordination between industries and education, such as in vocational education and training (VET), may be especially fruitful to enable renewable energy adoption while simultaneously improving energy intensity across industries. As numerous examples of social resistance indicate, however, this education policy needs to be accompanied by more general education concerning the social dimensions of the transformation. Building on the Council conclusions (European Commission, 2009) and the progress report (European Commission, 2015), emphasizing the multi-dimensional importance of collaboration on

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VET, we suggest, in addition to balancing the strong gaps in some countries, a focus on education for renewable energy adoption, to anticipate increased expected sector-specific labour demand.

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1. Introduction

This Deliverable focuses on the social policies and strategies to favour the necessary social adaptations for the energy system transformation, so as to derive recommendations for public acceptance. The focus is on labour demand.

In a special issue on social acceptance, Wüstenhagen et al. (2007) distinguished between three dimensions of social acceptance : socio-political, community and market acceptance. The authors suggest that especially market acceptance of renewable energies had been neglected back then. This situation has changed considerably, with increasingly competitive prices for renewables. In several countries, market acceptance has been largely fulfilled. This Deliverable therefore focuses on the socio-political dimensions, with a special emphasis on labour demand and labour skills in the transformation, as these are crucial to enable the transformation and have been analysed in the input-output framework that is at the core of the MEDEAS model family. We use a highly disaggregated input-output database that distinguishes between several electricity sectors. A comprehensive review of all social acceptance dimensions is then provided in Section 5, to embed our analyses into a broader context.

A comprehensive review of the socio-political dimensions of the energy transformation has been provided by Trebilcock (2014). This review summarizes the experiences from a number of case studies on transformations, ranging from trade liberalization to climate change. The review carefully analyses the relations between potential winners and losers of transformations, deriving conclusions for the importance of forward guidance in policy making. In a recent review on transition policies for climate change mitigation, Green (2018) describes the categories of losers that could prevent a transition. These include carbon-intensive industries, with all their assets invested, workers involved in those industries, communities that largely depend on such industries, and also households with carbon-intensive assets. The importance of institutional and governance dimensions has also been acknowledged by the IPCC in its fourth Assessment Report (AR4) (Somanathan et al., 2014).

Among the many potential social dimensions of the low-carbon transformation, we have selected those that are most closely related to the MEDEAS model framework. We chose to focus on labour demand and labour skills in relation to energy intensity, given the preceding analyses and the linkages to the MEDEAS model family that have been reported in WP6. Although there are numerous other social dimensions that need consideration for the low-carbon transformation, the

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modelling framework does not provide analytical results and conclusions for those. This would also require extensions in the modelling framework, such as agent-based model structures.

Our focus on labour dimensions is supported by several empirical findings. Labour demand is a critical bottleneck in the transformation, as a number of studies reported below have shown. Even when cost-efficient and highly competitive, renewable energy technologies require the labour skills necessary for their adoption and maintenance. This requires education policies to anticipate upcoming demand. Furthermore, labour skills are not only relevant to enable the adoption of renewable energies, but also important to increase energy efficiency and reduce energy intensity in the economy, as the analyses in WP6 have shown.

Three country-level case study examples are analysed, which can be classified as advanced in decarbonising their energy sector (Austria), or have adopted ambitious decarbonisation policies (Germany and the United Kingdom). In addition, three countries are analysed – Czechia, Poland and Bulgaria – which can be classified as coal-based economies. These cases are compared to the early adopters. We then discuss major social challenges connected to the decarbonisation policies, with a comparative analysis of social resistance in Czechia and Poland.

We find that in the case of early adopters, the continued transition to renewable energy would not increase domestic employment. Conversely, in the case of coal-based economies, there is a considerable potential to generate more jobs domestically through the renewable energy transition. In all analysed countries, the prevalence of male workers remained stable – gaining and losing sectors are usually characterised by 2/3 of male employment. The situation is usually balanced for medium and high skilled labour, with low skilled labour contributing only minor parts of the labour demand effects. The results have to be interpreted with caution however, since there may be significant economies of scale, when wider deployment of renewable energy sources takes place. The results are also conditional on the energy mix scenarios chosen (see the description of methods in Section 4 below). Finally, distinguishing between the employment effects caused by building renewable energy infrastructures and operating the sources would make the analysis more precise, but would require considerable extensions to the model, which is beyond the scope of this report.

We also find support for the high relevance of labour skills in improving energy efficiency and reducing energy intensity across a large number of energy-intensive sectors. We conclude that education policies that take into account coordination between industries and education, such as in vocational training, may be especially fruitful to enable renewable energy adoption and simultaneously improving energy intensity across industries.

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This Deliverable is structured as follows: Section 2 will introduce an overview on the social change dimensions related to policies of the low-carbon transformation. This section also provides the rationale for focusing on labour demand effects and labour skills as potential drivers of the transformation. Section 3 reviews the role of education policies in facilitating the renewable energy transition. Section 4 provides results concerning labour demand effects in the six countries chosen for the analysis. Section 4.1 provides the methodology for the input-output analysis. Section 4.2 starts with results at the EU28 level. Section 4.3 focuses specifically on the experiences of early adopters, whereas Section 4.4 focuses on coal-based economies. Section 4.5 provides a comparative analysis of social challenges and resistance in coal-based economies, with a focus on Czechia and Poland. Section 5 embeds the analyses into a broader social acceptance context. Section 6 derives conclusions and policy implications from the analyses.

2. A policy framework to address social changes expected from replacing fossil fuels

Every fundamental transformation will generate winners and losers. Not all societal actors will necessarily be part of win-win solutions, even if policies are highly balanced to generate maximum societal support. Therefore, any such transformation will likely come with resistance from those who will be on the losing side (Green, 2018; Trebilcock, 2014). This issue has only recently received the attention that it deserves, given its importance in the low-carbon transformation. Recently, an edited book on the political economic dimension has been published (Arent and Zinaman, 2017), covering analyses concerning the political constraints of carbon pricing, the political implications of renewable energy support policies, energy security in Europe, multi-level governance, including multilateral agreements, the removal of fossil fuel subsidies, as well as technology-specific political implications. Concerning energy security, the socio-economic implications of peak oil have to be considered (Friedrichs, 2010; Kerschner et al., 2013; Kerschner and Hubacek, 2009a). Concerning the example of fossil fuel subsidies, recent input-output analyses have shown that removing such energy subsidies is favourable to those low-income populations usually targeted with such policies (Feng et al., 2018). Political economic analyses have shown, however, that fossil fuel and related electricity subsidies can be very persistent and are very difficult to replace (Aklin and Urpelainen, 2013; Kimmich, 2016). Utilities governance and independent regulation is often crucial in this context to enable policy change and to facilitate transformation and technology adoption (Kimmich,

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2016, 2013a, 2013b). The costs of the low-carbon transformation can lead to considerable resistance and have significant social implications.

Given the fundamental properties of the low-carbon transformation, it is questionable whether we can find similar transformations and related challenges in the past. We could draw lessons concerning the social implications from past experiences, however, even if they have not been as fundamental as the low-carbon transformation. A very helpful, and probably the most comprehensive political economic perspective covering such past experiences has recently been written by Trebilcock (2014). This book covers case studies from trade policy, including agricultural trade liberalization, immigration policy, mortgage interest subsidies, public pension systems, institutional development and reform policies, as well as climate change policy. Given the long-term experience of the author and the multiple theoretical perspectives, this is a highly valuable resource to approach the social change dimensions of climate change policies. These issues have been largely neglected by economists, who have focused on proposing welfare-improving solutions, without considering how to reach those (Trebilcock, 2014). The author emphasizes that diagnosing the problems and even imagining, developing, and proposing policy alternatives are usually not the most challenging parts of the transformation. It is rather the existing policies, the related interests and actors and their expectations that make the transformations so difficult. Any policy change, whether concerning taxes, expenditures, or regulations, usually creates some losers, who have benefited from the existing policies. Mitigation strategies of compensation, grandfathering, or phased implementation and incremental reforms with compromises between winners and losers are frequent solutions under these conditions (Trebilcock, 2014).

Some of the case study insights are not easily transferrable, while others can provide guidance. In the context of trade liberalization and also in the case of immigration policies, gradualism has been important. Given the time pressure of realizing the low-carbon transformation, such gradualism becomes increasingly less feasible. Similarly, reciprocity among countries could profit from gradualism in those cases. Luckily, several countries have already generated experiences with a gradual introduction of low-carbon transformation policies. In these cases, some forms of reciprocity could be developed within the multi-level governance structure of multi-lateral agreements, but also among cities. The gradual phase-in of carbon taxes or cap-and-trade regimes has been practiced in several countries (Klenert et al., 2018), but many countries will have to leap-frog this policy process. The fast implementation of more fundamental transformation policies, however, will likely create stronger resistance, and therefore requires more fundamental solutions. Trebilcock discusses the limitations of gradualism and proposes alternative strategies. First, he suggests strengthening adaptation capacity, to be prepared for implementation once a stronger

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consensus develops. Second, he also suggests unilaterally induced reciprocity to speed up cooperation. Taxing the carbon emissions of imports appears fundamental to prevent carbon leakage, as well as labour and investment migration. The consumption-based perspective on carbon emissions building on input-output analyses clearly demonstrates the fundamental role of non-domestic emissions induced by consumption (Arto and Dietzenbacher, 2014). These findings also have considerable implications for labour demand and labour skills as part of the adaptation capacity of a country.

The most fundamental lesson learnt can probably be derived from the case study on institutional development reforms in developing countries. The institutional switching costs to democratic, transparent and economically effective governance are immense. These switching costs include learning costs, network effects of switching (Goyal, 2007; Kimmich and Sagebiel, 2016; Müller et al., 2018), institutional complementarities (Amable, 2016), but also the necessary human resources for enacting institutional change. Those switching costs have many similarities with the costs of low-carbon policy transformation. Finally, in the context of the low-carbon transformation, like in institutional development, also the cultural beliefs, expectations, norms and practices are fundamental. In fact, the general governance structure and political trust of an economy is closely related to the actual carbon price an economy has implemented. As the following Figure 1 illustrates, the higher the public trust in politicians, the higher the carbon price implemented. Sweden, Switzerland, Finland and Norway stand out in this regard. Conversely, the lower the corruption, as measured by the corruption perception index, the higher the carbon price. Again, Sweden, Switzerland, Finland and Norway stand out positively.

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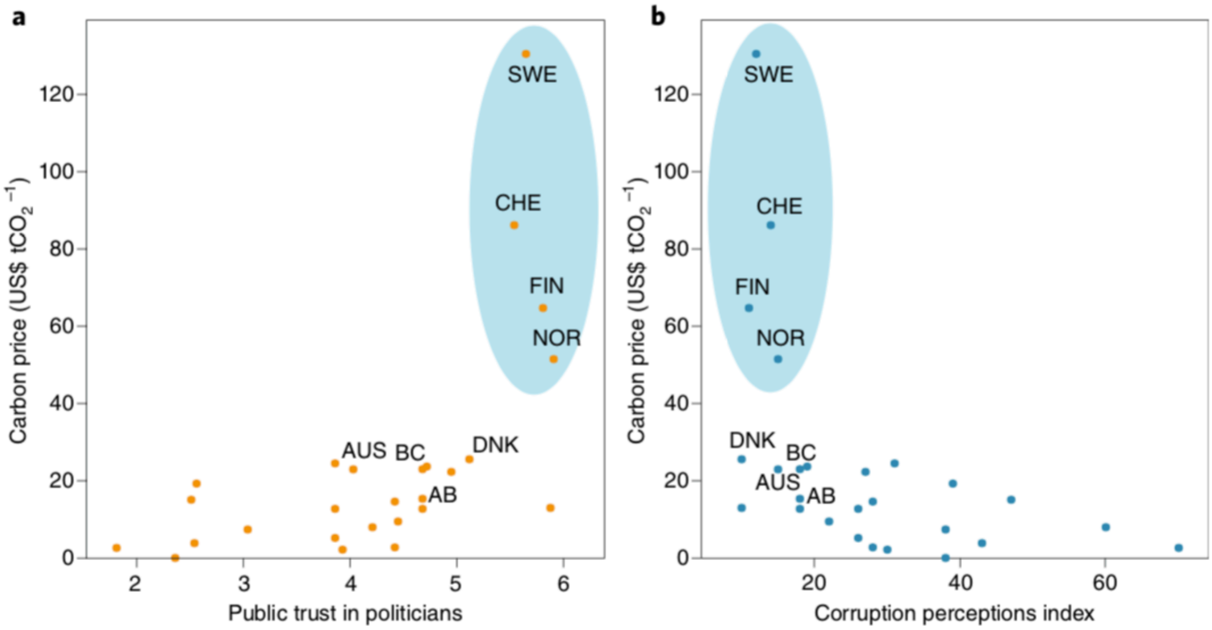

Figure 1 : Relations between carbon prices, public trust in politicians and the corruption perceptions index (Klenert et al., 2018).

The expected social changes of the low carbon transformation will be fundamental. These changes range from the very material involvement in the production process, providing labour, to the immaterial attitudes and expectations concerning renewable energies, including land uses for infrastructure, or landscape amenities, among others (Wüstenhagen et al., 2007). The expected social changes are therefore likely an important factor in social acceptance. But social acceptance concerning the landscape and technology changes is not the only issue, where the social dimension matters. Several social changes can also be drivers of the transformation. Education, for example, is a fundamental prerequisite for the transformation. Only when the labour skills are available in a country to roll out renewable energy technologies, will the adoption actually take place. Labour skills also matter more fundamentally in all energy-intensive sectors to facilitate the adoption of energy-efficient solutions, as the analyses in WP6 have shown (MEDEAS, 2018).

Given the MEDEAS modelling focus on the physical dimensions of the transformation and the related sector-based economic linkages of the input-output structure, we will focus on the labour aspects of those social change dimensions that also matter most in the model structure of MEDEAS. First, given the labour requirements to enable renewable energy technology adoption, we estimated the labour demand necessary across industries, resulting from the demand for renewable energies. We present updated results and derive conclusions and implications for policy in the Sections 4.1 and 4.2. We analyse the labour demand effects as a crucial topic for social and political acceptance (Silva et al., 2013) – apart from local economic effects as well as not-in-my-backyard

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problems and other influencing factors (Batel et al., 2013; Chassot et al., 2014a; Cohen et al., 2014; Kaldellis and Zafirakis, 2011; Stigka et al., 2014) – as well as in order to map the option space for the transition in terms of labour and education policies. The employment effects of adopting renewable energy have long been a popular topic to analyse (e.g. Llera et al., 2013; Moreno and López, 2008). However, the studies usually do not take into account the distributional effects of the transition (i.e. skill levels and gender), which are crucial for understanding the effects on different parts of the society, and which can also properly inform the policy decisions regarding labour (re-)allocation as well as education for the renewable energy « era ».

Second, given the central role of energy intensity variables in MEDEAS, we focused on the social determinants of energy intensities across industries in our preceding analyses in WP6 (MEDEAS, 2018). Specifically, we looked at the effects of labour skills on energy intensity across industries. We can now review implications for policy design, as described in Section 3, and derive conclusions in Section 5.

We embed the policy conclusions in a broader transition framework, which has been proposed to describe different types of policies in the context of the low-carbon transformation (Green, 2018). This framework describes four ideal types of policy approaches, separated along the lines of their scope (broad versus narrow), and along the lines of their orientation in time (forward versus backward looking), as in the following Table:

	Backward-looking	Forward-looking
Narrow scope	**Compensation (1)**	**Adjustment assistance (3)**
Broad scope	**Exemption (2)**	**Holistic adaptive support (4)**

Table 1: Policy orientation for the low-carbon transformation (Green, 2018)

The first policy approach of **compensation** focuses on monetary compensation to those agents who lose from the transition and provides monetary compensation for any monetary losses incurred. Typical examples are targeted unemployment compensation schemes or early retirement in the context of labour effects. Examples in other areas are household compensations or subsidies for

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increased living costs or compensation of industries for replacing lost assets incurred by low-carbon technologies. The orientation of this policy direction is narrow, and usually backward-looking.

The second approach has a broader scope and includes **exemption** policies. The typical examples are grandfathering, postponed and graduated implementation (Trebilcock, 2014). These have been used to implement tradable emission allowances. Exemption policies are also backward-looking, trying to maintain the status quo of actors, but is broader, usually transcending pure monetary loss compensation.

The third approach of structural **adjustment assistance** is forward-looking, but narrow, focusing on monetary or monetary-equivalent payments. This includes wage subsidies, subsidised education, assistance for relocation of workers, but also subsidies for households to support investments in energy-efficient and low-carbon technologies. The subsidies can also extend to infrastructures, innovation, and skills development in the sense of providing public goods.

The fourth approach of **holistic adaptive support extends** to non-financial losses, including intrinsic values or even mental effects. The support policies therefore include transition planning, counselling, support for re-employment and investments in social and cultural goods.

The focus on labour demand, education and skills investment, chosen in our analyses, belongs to the third approach. While acknowledging the relevance of the fourth approach of holistic support, the analyses conducted in WP6 do not allow to derive any conclusions concerning holistic support measures. We will therefore focus our main conclusions on education policies and the effects of investments into labour skills for the low-carbon transformation. This does not imply that holistic measures may not be important for the transformation. Section 5 provides a brief overview of other social acceptance dimensions and crucial factors influencing the transition to renewable energy, complementing the main focus of the report from the holistic point of view.

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3. Identification of appropriate labour and education policies to support the transformation

The fundamental economic governance of an economy has an effect on innovation and technology (Hall and Soskice, 2003), which also influences the adoption of renewable energies. Whereas liberal market economies like the UK have stronger competition, which tends to create path-breaking innovation, the innovation process in coordinated market economies like Germany is more incremental. This is also reflected in the adoption of renewable energies. Liberal market economies typically have limited coordination between industries, states, and finance. Coordinated market economies profit from a strong collaboration between industries, education, and research & development. Coordination is long-term oriented and long-term concerns also dominate over short-term profitability. Coordinated market economies generate highly skilled labour, which is fundamental for renewable energy adoption (Ćetković and Buzogány, 2016). A key pillar of the cooperation between industries and education is vocational training, which is lacking in most liberal market economies. A skilled workforce is lacking in the renewable energy sector in the UK, as has been shown in a report of the Imperial College London developed for Shell (Autio and Webb, 2015). Missing vocational training and manufacturing bases prevents the UK from realizing its potential in the low-carbon transformation (Ćetković and Buzogány, 2016): "Interestingly, the offshore wind market in the UK has so far largely benefited German (Siemens) and Danish (Vestas) companies as the dominant suppliers of offshore wind turbines." Ćetković and Buzogány also account for a third economic governance type to describe many economies of Central and Eastern Europe, namely, dependent market economies (Nölke and Vliegenthart, 2009). Some of these dependent market economies adopted renewable energy instruments similar to coordinated market economies. Yet, given their weaker coordination between industries, states and research, these policy instrument adoptions have only led to partial successes so far. As Ćetković and Buzogány (2016) conclude, a successful energy policy for renewable energy diffusion at the EU level requires developing capacities at the national level that are sensitive to the context of liberal and coordinated market economies. The different successes of liberal versus coordinated market economies in adopting renewable energies poses considerable challenges at the EU level. The EU develops a uniform and market-oriented approach to renewable energy policies, given the pressures from divergent national positions. Without policy learning, a successful adoption policy can be thwarted. In addition to the common market for energy and climate policy, this requires an adoption of approaches that are known from coordinated market economies, including policies for innovation and collaboration

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between industries and education (Ćetković and Buzogány, 2016): "Therefore, if balanced renewable energy development in the EU is to be achieved, it will require going beyond the common market model towards common industrial and innovation policies aimed at building local capacities, enhancing policy and technology diffusion, ensuring broader societal participation and exploring the comparative advantages of different national economies."

Concerning the collaboration between industries and education, this will require a consideration of policies to transfer the vocational training approach to the diverse economies of the EU. According to an EngineeringUK study from 2015, the UK requires a very strong increase in technicians at the level 3, i.e. technical skills at the sub-graduate level, and, to a lesser degree, also an increase in graduates with STEM (science, technology, engineering, and mathematics) skills (Autio and Webb, 2015). Among others, also accredited installers are lacking (Praetorius et al., 2010). Also knowledge flows within the innovation system between universities and industries is missing in the UK (Foxon et al., 2005).

Another key component to enable a successful low-carbon transformation is entrepreneurial skills, which should complement technical and engineering skills (Autio and Webb, 2015). Less often mentioned, and frequently neglected, is the capacity to innovate and adopt knowledge concerning institutions, i.e. incentive structures that facilitate technology adoption and scale-up. Finally, the support for renewable energy industries can generate the very same skills that are needed for the low-carbon transformation, but also lead to a diversification of the skill base of an economy (Lipp, 2007). Developing skilled labour can therefore also be an outcome and an additional policy target on its own.

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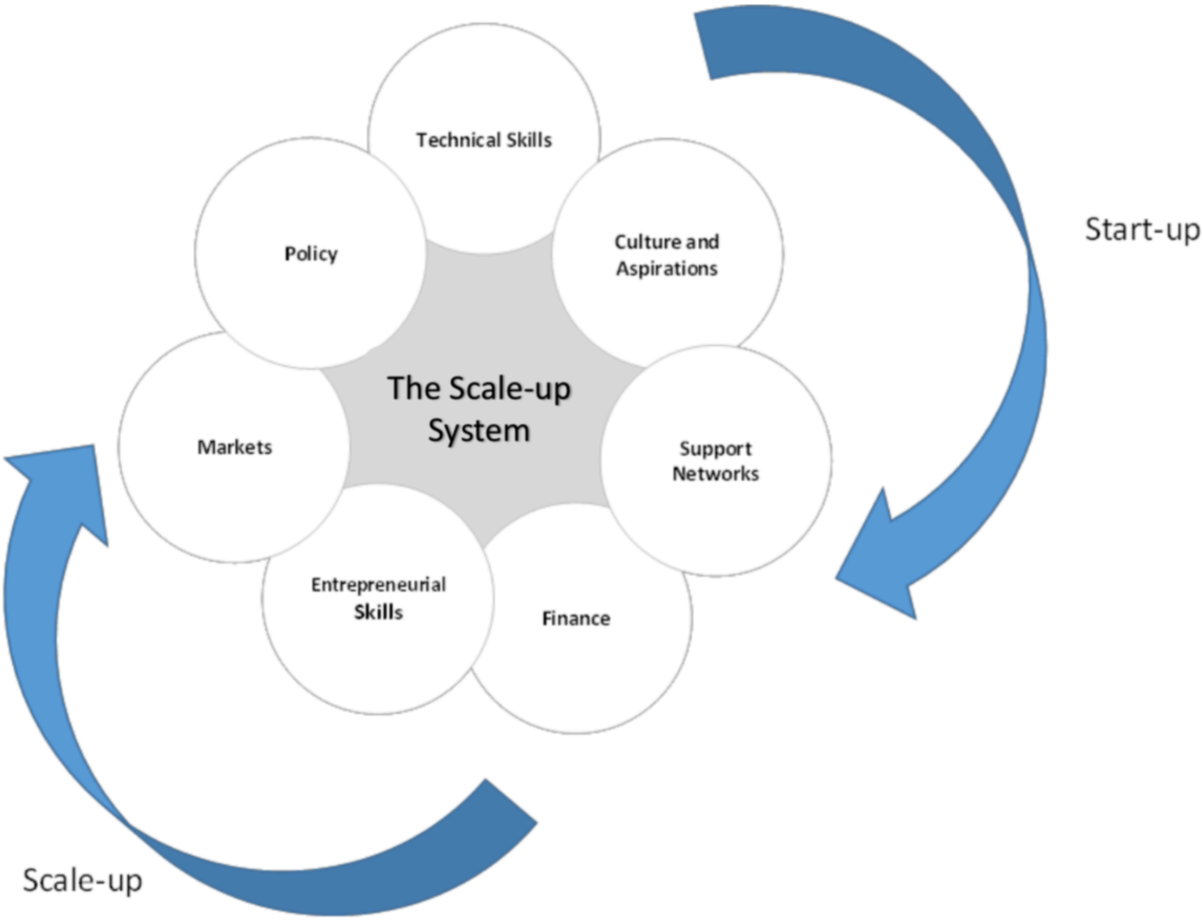

Figure 2: Preconditions for a successful low-carbon transformation (Autio and Webb, 2015)

How can the incremental innovation structure of a coordinated market economy be compatible with the need for a radical low-carbon transformation? As the literature on system innovation suggests, the low-carbon transformation and related technology adoption requires radical innovation (Negro et al., 2012). Incremental innovation and technological solutions that are already cost-efficient may also be preferred by policy makers, but then become an impediment to more radical innovations. But this problem is most strongly driven by the influence of incumbents on energy policies, and the networks between policy and incumbent industries that are too strong (Negro et al., 2012), whereas the networks between research and industries are lacking. The UK, for example, has adopted a co-firing policy for biomass in coal power plants, thereby creating a lock-in for coal and preventing more innovative solutions for the utilization of biomass (Negro et al., 2012).

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In fact, the focus on short-term profits in liberal market economies may even prevent radical innovation, because the process from research to market is interrupted.

4. Expected labour demand changes

Shifts in labour demand are among the most important aspects of the transition to the low-carbon economy. They can influence social as well as political acceptance. Our analysis provided in this section tracks and assesses the expected employment changes of a hypothetical 100% transition to renewable energy in electricity production as a significant step towards the low-carbon economy. It aims to inform future labour and to some extend also educational policies, related to renewable energy sources and their deployment. The work builds upon the analysis provided in Deliverable 6.2, part 2.6 Social policies, makes it more precise and extends it to more case studies.

We provide the assessment first for selected EU countries (three of them as "coal-based economies" and three as "early adopters" with already existing adaptation policies for the decarbonisation of their economies). Two of these countries are among the country level case studies of MEDEAS (Austria, Bulgaria). Even though the primary focus of MEDEAS is on the EU28, we do not provide results for the aggregated EU level, since the EU aggregation loses country-specific details due to large differences in energy mixes between the countries (i.e. coal-based countries versus countries with a high share of renewable or low-carbon sources of energy). Therefore, we consider the country level as much more important for any policy recommendations. As stated below, we can observe diverging trends taking place in the different countries that we analysed.

We analyse three country-level case study examples which can be either classified as advanced in decarbonising their energy sector (Austria), or have adopted ambitious decarbonisation policies (Germany and the United Kingdom (UK)) as the "early adopters". The analysis is focused on labour demand effects, which are assumed to take place in order to finalise the renewable energy transition in the power sector, as a significant step towards the decarbonisation of the economy. The cases are compared between each other.

Similarly, we analyse three countries in terms of labour demand effects induced by their hypothetical transition to renewable energy in the power sector (as a significant contribution towards the decarbonisation of their economies) – Czechia, Poland and Bulgaria – which can be

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classified as coal-based economies. These cases are compared to the early adopters. Major social challenges connected to the decarbonisation policies are then further discussed in section 2.2.

The six country-level studies are selected as somewhat typical representatives of different stages of the transition. Whereas Austria has been for a long time among the renewable energy leaders in electricity production together with the Scandinavian countries, Germany and the UK have recently adopted ambitious plans for decarbonising their economy (Energiewende and the 2008 Climate Change Act (Schumer and Ross, 2018), respectively). On the contrary, the Czech Republic and Poland are among the least ambitious countries, regarding their commitments to increase the share of renewable energy. Bulgaria currently generates approximately 19% of its electricity from renewable energy sources and 23% from hydropower, whereas the rest comes from fossil fuels (39%) and nuclear power (20%) ("Energy consumption in Bulgaria," n.d.).

We present the energy mix projections for each of the considered countries below (separately for 2015 and 2050), prior to the employment footprint results. We first analyse and briefly comment results for each country separately. In the Conclusions, we summarise and interpret the results and link them to the EU Social Policy.

4.1. Methodology

The modelling part is based on an input-output approach, and uses EXIOBASE v3 (Stadler et al., 2018) and its socioeconomic extension (employment in full-time equivalent employees) data for calculating the employment effects at the country levels. We contribute with calculations of the employment effects by economic sectors. EXIOBASE v3 (Stadler et al., 2018) provides input-output tables for the current economies. The EU Reference Scenario 2016 (Capros et al., 2016) provides the reference energy mix projections in electricity production for each of the EU 28 countries.

We link the current distribution of energy sources for electricity production from EXIOBASE v3 with country-specific projections regarding the energy mix in the future. Then we replace gradually the electricity production from non-renewable energy sources. The model counts with a 100% decline of the non-renewable electricity production, while keeping the demand constant.

We assess the labour market changes in various sectors in terms of impacts to high-skilled, medium-skilled and low-skilled labour and by gender, as in MEDEAS Deliverable 6.2 (MEDEAS, 2018). The skill classification is based on the International Standard Classification of Education (ISCED) 1997:

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- Low skill level: Primary education up to lower secondary education (first 9 years).
- Medium skill level: Upper secondary up to post-secondary, non-tertiary (e.g. from age 14-16, high schools, gymnasiums, etc.).
- High skill level: First and second stage of tertiary education (universities, colleges, but also vocational training).

We aim to analyse what types of labour (low-skilled, medium-skilled, and high-skilled) the renewable transition will need.

The energy mix projections used as scenarios for assessing the employment effects are adapted from the EU Energy Reference scenario 2016 (Capros et al., 2016), who provide reference (feasible) scenarios in terms of energy mix for various end uses for each EU28 countries, as well as for the EU28 as a whole. Starting from these scenarios and the proportions between the various energy carriers, we scale up renewable energy sources hypothetically to cover 100% of the electricity generation, without changing the overall output of the electricity production. The EU Energy Reference scenario shows projections given by each EU country until 2050. Matching the EXIOBASE v3 sectors to those from Capros et al. (2016) was done using the following concordance matrix.

Table 2: Concordance matrix matching EU Reference Scenario and EXIOBASE v3 sectors.

EU Energy Reference sector	**EXIOBASE v3 sector**
Solids	Production of electricity by coal
Gas (including derived gases)	Production of electricity by gas
Nuclear energy	Production of electricity by nuclear
Hydro (pumping excluded)	Production of electricity by hydro
Wind	Production of electricity by wind
Oil (including refinery gas)	Production of electricity by petroleum and other oil derivatives
Biomass-waste	Production of electricity by biomass and waste
Solar	Production of electricity by solar photovoltaic
-	Production of electricity by solar thermal
-	Production of electricity by tide, wave, ocean
Geothermal and other renewables	Production of electricity by Geothermal
Other fuels (hydrogen, methanol)	-
-	Production of electricity nec

Source: Capros et al. 2016, Stadler et al., 2018

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To simulate the situation in 2050, the non-renewable energy sources (in the EXIOBASE v3 structure – on the right side of the table: Production of electricity by coal, Production of electricity by gas, Production of electricity by nuclear, Production of electricity by petroleum and other oil derivatives) are replaced, scaling up the remaining share of renewable energy sources to cover the "current" (=2015) levels of electricity production. Note that since most of the modelled countries does not produce electricity from solar thermal, tide, wave and ocean, nor geothermal sources, these sources are usually not present in the 2050 energy mix projections (since zero levels cannot be scaled up).

We are aware of the limitations of the assumptions present in scaling up the electricity production from renewable sources based on these scenarios. However, there are no consistent datasets regarding future energy mix projections at the country levels that assess the feasibility of the fully decarbonised (and renewable energy sources based) electricity production across the EU countries.

4.1.1 Input-Output Analysis

The study is based on input-output analysis (IOA), which we apply in order to see the structural changes induced by the hypothetical 100% renewable energy transition throughout the economy. IOA allows capturing inter-industry linkages and measuring their direct and also indirect effects of externally imposed changes (Cella, 1984; Kerschner and Hubacek, 2009b). It therefore allows to track changes not only in the affected sectors, but also those transmitted throughout the supply chains in the economy – domestically as well as internationally, linked through trade relations. The following methodological section builds upon MEDEAS Deliverable 6.2, part 2.6.2 (MEDEAS, 2018), based on input-output analysis description provided in Miller and Blair (2009).

The basic input-output industry-to-industry transaction table (note: there exist also commodity-by-commodity tables, but since we use the industry-by-industry ones, we provide an explanation for this type of input-output tables) consists of rows showing "Who gives to whom?" and columns showing "Who receives from whom?" in an economy, as shown in a simplistic form in Table 3 below. There, each cell shows deliveries FROM the row industry TO the column industry, where the transaction is measured in monetary terms, for a given time period (usually one year).

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Industry to industry input-output table			
From↓ | To→	**Agriculture**	**Industry**	**Services**
Agriculture		*„What Industry pays for commodities delivered by Agriculture“*	
Industry			*„What Services pay for commodities delivered by Industrial sectors“*
Services		*„What Industry pays to Services“*	

Table 3: Simple input-output structure of an economy with three sectors (Agriculture, Industry, Services).

According to Miller and Blair (2009a), if the economy is divided into n sectors, and if we denote by X_i the total output of sector i and by Y_i the total final demand for sector i's product, we may write sector i's ***output***:

$$X_i = z_{i1} + z_{i2} + \ldots + z_{ii} + \ldots + z_{in} + Y_i$$

X_i … total output of sector i

z_{i1} … products going from sector i to sector 1

Y_i … total final demand for sector i's product

The z terms on the right-hand side represent the so-called interindustry sales by sector I (to sectors $1, 2, \ldots, i, \ldots, n$). The entire right-hand side is the sum of all sector i's interindustry sales and its sales to final demand (Y_i). The equation above represents the distribution of sector i's output – what the sector i delivers to other ($1, 2, \ldots, i, \ldots, n$) sectors. The following set of equations represents the outputs of each of the n sectors:

$$X_1 = z_{11} + z_{12} + \ldots + z_{1i} + \ldots + z_{1n} + Y_1$$

$$X_2 = z_{21} + z_{22} + \ldots + z_{2i} + \ldots + z_{2n} + Y_2$$

……………

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$X_i = z_{i1} + z_{i2} + \ldots + z_{ii} + \ldots + z_{in} + Y_i$

…………..

$X_n = z_{n1} + z_{n2} + \ldots + z_{ni} + \ldots + z_{nn} + Y_n$

Consider the information in the ***i***th column of ***z***'s on the right-hand side – these are ***sales to sector i*** (***i***'s purchases of the products of other sectors (***1, 2, …, i, …, n***) in the economy):

z_{1i}

z_{2i}

…

z_{ii}

…

z_{ni}

The column thus represents the sources and magnitudes of sector ***i***'s inputs. Clearly, during the sector's production, the industry also pays for other items such as **labour** and **capital** – and uses other inputs as well, for example inventoried items. All of these elements together are termed the **value added** in sector ***i***. In addition, **imported goods** (deliveries from sectors in a foreign economy) may be also purchased as inputs by sector ***i***. For graphical representation of the relations between these segments of the economy, see Figure 4 below. It shows a multi-regional input-output structure on an example of EXIOBASE (which we also use for our analysis), where labour, capital, inventoried items (value added) are termed as **Factor Inputs**.

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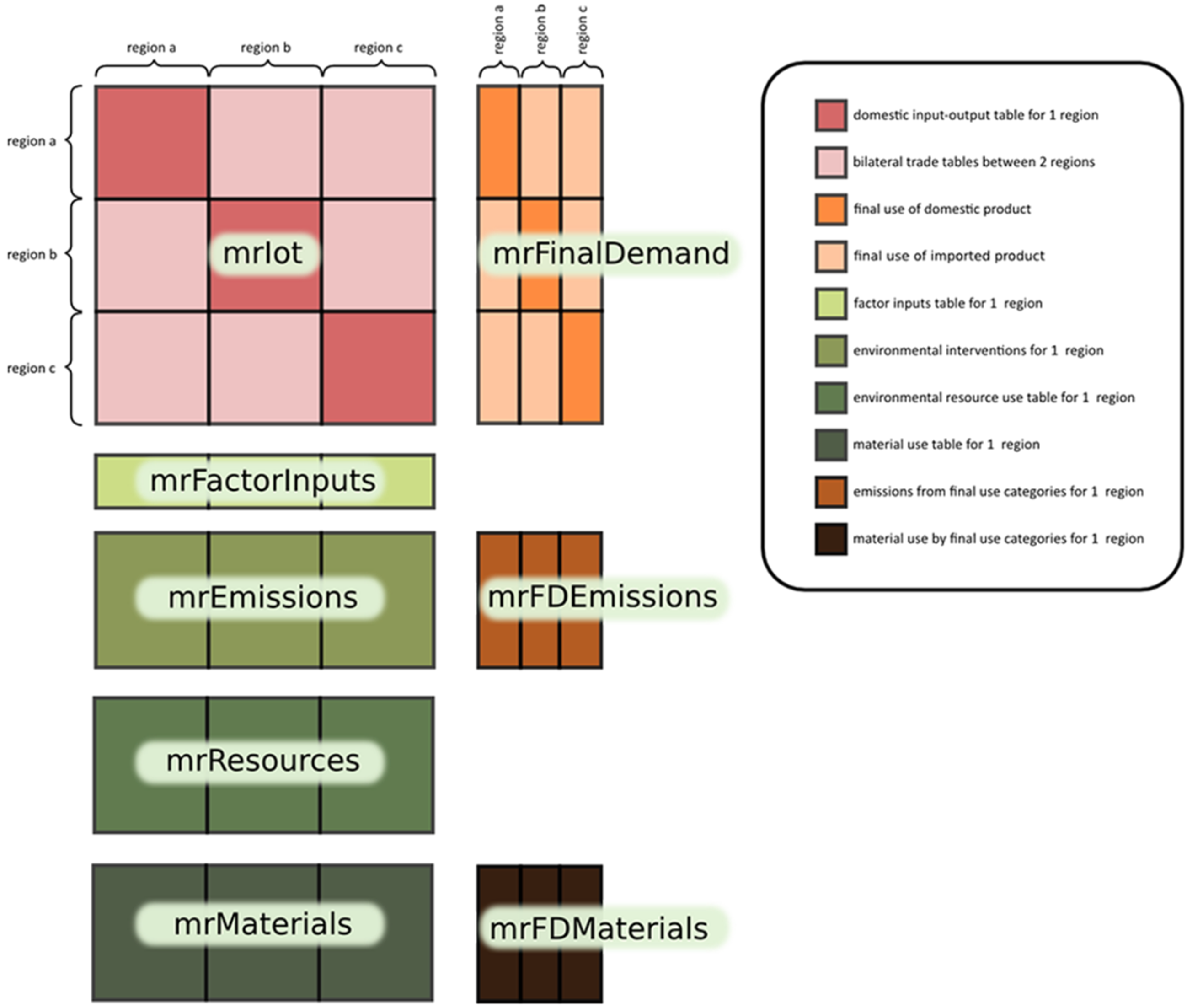

Figure 3. Multiregional Input-Output Table. Source: Wood et al. (2015)

All of the inputs (value added or the factor inputs as well as imports) are often lumped together as purchases from what is called the **payments sector**, whereas the ***z***'s on the right-hand side of the equation represent the purchases from the **processing sector**, the so-called **interindustry inputs**. Note that each sector can also use its output as its own input. Therefore, the interindustry inputs include also the so-called **intra-industry inputs** (what the sector delivers to itself).

The magnitudes of interindustry flows can be recorded in a table, with sectors of origin (i.e. sellers) listed on the left, and the same sectors, now "destinations" (i.e. purchasers), listed across the top – see Figure 3 above. If we focus on the "column reading" of the table, the cells show each sector's

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inputs (purchases from other sectors). From the row point of view, the figures represent each sector's **outputs** (sells to other sectors).

The interindustry flows from sector ***i*** to ***j*** (for a given period – most usually 1 year) depend entirely and exclusively on the total output required from sector ***j*** for the same period. For example, Miller and Blair (2009) give an example of cars. The more cars produced in a year, the more steel will the automobile producers need during that year. The so-called **technical coefficients** define the ratio of input from each other sector to the total output of a given sector (in other words, the Euros' or Dollars' worth of inputs from sector ***i*** per Euro's worth of output of sector ***j***) as shown below in Figure 5 (Miller and Blair, 2009).

Industry to industry input-output table					
From↓ | To→	Agriculture	Industry	Services	Final Demand (expenditures)	Total Demand (output) (Y)
Agriculture	0,3	0,2	0,1		
Industry	0,5	0,6	0,4		
Services	0,1	0,1	0,3		
Value added					
Total Supply (X)					

Figure 4. Technical coefficients in a simple input-output structure of an economy with three sectors.

It is important to note that IOA assumes **constant returns to scale**, i.e. fixed technical coefficients, regardless of the scale of production. In addition, input-output analysis requires that a sector uses **inputs in fixed proportions**. However, since the fixed proportion of technical coefficients may be also theoretically seen as the "technology of production" (what the sector needs from other sectors in which proportions to maintain its production), the proportions may be also modelled in the original transaction table (see Figure 3 above). This may be done by multiplying the matrix of interindustry and intraindustry monetary flows by coefficients reflecting the changes in inputs from selected (=modelled) sectors, if one would want to change the "production technology". Such approach could, for example, help the modelling process with assuming certain levels of technological progress (or other organizational changes in production).

In order to model an increased production from certain sectors (renewable energy sources), whereas downscaling production from other (non-renewable energy sources), the vectors (rows

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and columns of the respective sectors) were multiplied by coefficients, reflecting the increase or decrease in production in the given sector, compared to the reference base year (2015). Specifically, we focused on modelling EXIOBASE sectors dealing with electricity production (as also shown in Table 2 above), namely:

- Production of electricity by coal
- Production of electricity by gas
- Production of electricity by nuclear
- Production of electricity by hydro
- Production of electricity by wind
- Production of electricity by petroleum and other oil derivatives
- Production of electricity by biomass and waste
- Production of electricity by solar photovoltaic
- Production of electricity by solar thermal
- Production of electricity by tide, wave, ocean
- Production of electricity by Geothermal
- Production of electricity nec

Whereas the model assumes declining production in non-renewable energy sectors (Production of electricity by coal, Production of electricity by gas, Production of electricity by nuclear, and Production of electricity by petroleum and other oil derivatives, respectively), it works with gradual increase of electricity production from the rest of the sectors (excluding Production of electricity nec), according to the energy mix projections provided by Capros et al. (2016) and gradually scaled up to cover 100% of electricity production in each modelled case (EU28, Austria, Germany, the United Kindgdom, Czechia, Poland and Bulgaria). Figures 6, 7, 12, 13, 18, 19, 24, 25, 30, 31, 36, 37, 42 and 43 show always first the initial "current" state (year 2015), and then the final state (year 2050) of the energy mix for electricity production in each country, respectively for the EU28 in case of Figures 6 and 7.

The modelling process is done in two steps. First, the production levels of non-renewable energy sources are decreased by 50% by 2030, and the same 50% of electricity production is covered by increased share of renewable energy sources, maintaining the overall output of electricity production at the 2015 levels (2015 = the reference year). Second, by 2050, the production of electricity from the non-renewable energy sources is taken down to zero, whereas the production from renewables is scaled up to cover 100% of the electricity generation. Therefore, two modified input-output transaction tables are created, representing years 2030 and 2050 (note that in the

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following sections, we only provide the energy mixes for 2015 – the reference year – and then for 2050, since the 2030 situation is simply on the half way between these two).

In the input-output logic described above, the interindustry inputs (transactions) from the non-renewable sectors (Production of electricity by coal, Production of electricity by gas, Production of electricity by nuclear, and Production of electricity by petroleum and other oil derivatives) are multiplied by coefficients, representing the overall decline (2030 decline of 50%, 2050 decline of 100%) of production. The opposite is done for the renewable energy sources, which are multiplied by coefficients representing how much these sectors should grow in terms of production in order to cover the "gap" generated by decreasing production of electricity from the non-renewables.

As we already argued in Deliverable 6.2 (part 2.6), to identify key features of the post-carbon input-output economic structure, it is therefore necessary to focus on the technical coefficients and their expected evolution over the tracked period (i.e. until 2050). The determinants of the technical coefficients cover technological progress (Leontief, 1983), but also infrastructure policies, substitution due to relative price changes, as well as industrial structure (Peneder, 2003).

Last but not least, it is important to note that the analysis models the employment effects under "ceteris paribus"), i.e. assuming no other change in the economy (nor economic growth, nor any population dynamics). The static model should, however, show how strong are the supply chain linkages between the sectors of electricity production and other sectors in terms of labour demand. If other conditions (assumed developments of the economy's overall output, population developments etc.) are added, the analysis could provide even more detailed results.

4.2. Expected labour demand changes in the EU28 as a whole

First, we focus on analysing the employment effects on the EU28 as a whole. Nevertheless, since such analysis can only provide a limited detail for policy recommendations (taking into account that energy mixes vary widely across the European Union's countries), we also select six case studies to discuss their results in terms of employment effects of 100% renewable electricity transition in more detail in the next two sections.

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We first describe the changes in the energy mix in electricity production, showing the energy mix for 2015 and then for 2050, where renewable energy sources are assumed to scale up and cover 100% of electricity production. Concerning the "current" (=2015) energy mix for electricity production in the EU, the Union relies by almost two thirds on non-renewable energy sources: 22.9% is generated by coal; 17.3% by gas; and 23% by nuclear power; together with 0.7% of electricity from petroleum and other oil derivatives. Among the renewable energy sources, the highest share belongs to wind (offshore and onshore combined) – 13.8%, followed by hydropower – 11.2%, and biomass and biogas – 6.3%. Only 4.6% is currently produced from solar photovoltaics. Overall, 63.9% of electricity production needs to switch to different energy sources, which are currently provided by non-renewables.

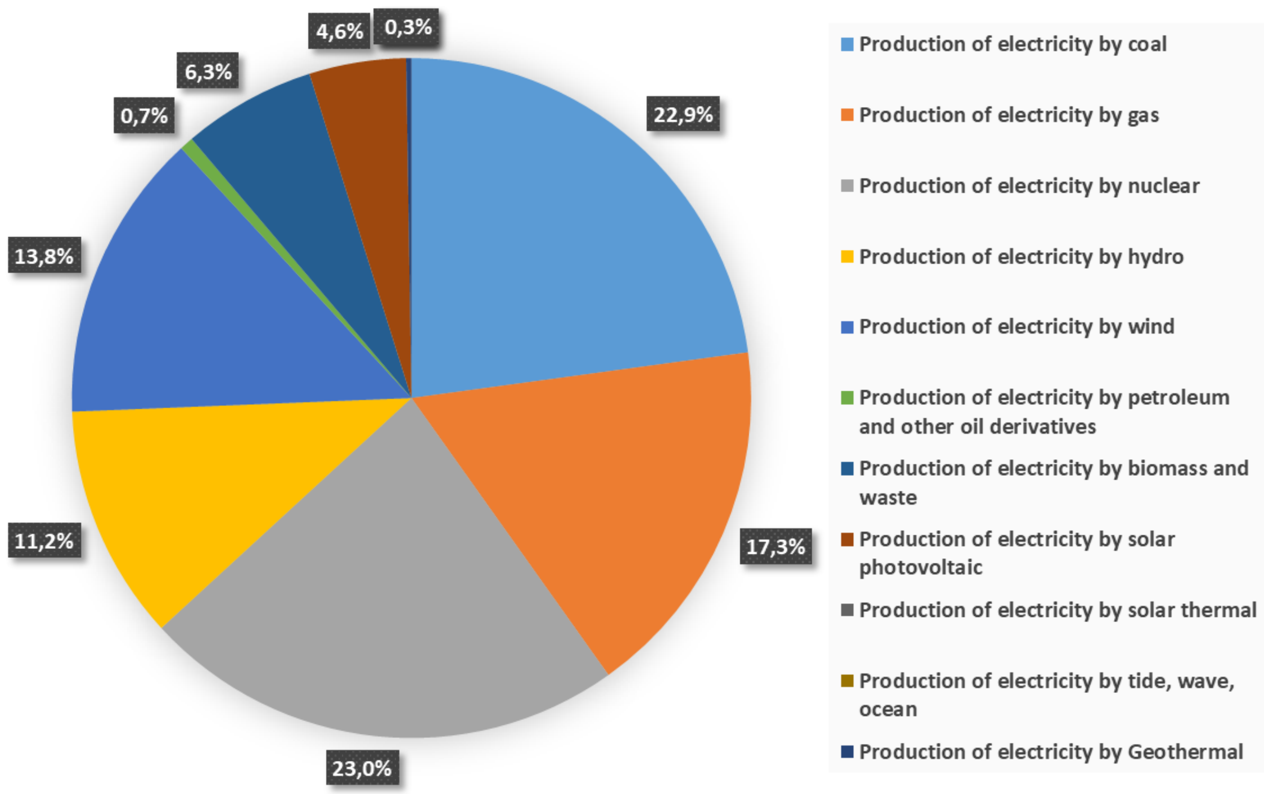

Figure 5 : Energy mix in production of electricity – EU28 (current 2015)

Source: Capros et al. 2016, adapted according to EXIOBASE v3 sectors

When the renewable energy sources are scaled up to provide 100% of all electricity production in the EU28, filling the 63.9% "gap" left by non-renewables, and respecting the proportions given by the EU Reference Scenario by Capros et al. (2016), as can be seen below at Figure 7, wind energy is by far the leader, providing 43.8% of electricity. Wind is followed by solar PV (19.2%), hydropower

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(18.8%) and biomass and waste (17.5%). The remaining 0.6% is filled by geothermal sources. To what extend this is a realistic scenario would have to be further checked by modelling conditions for additional installations of the renewable energy sources, as well as macroeconomic conditions allowing for such investments (i.e. "how much would the transition cost"). However, for a hypothetical case (bearing in mind that the "realistic" scenarios might give different proportions for each source), the following energy mixes are assumed, and associated employment effects are derived.

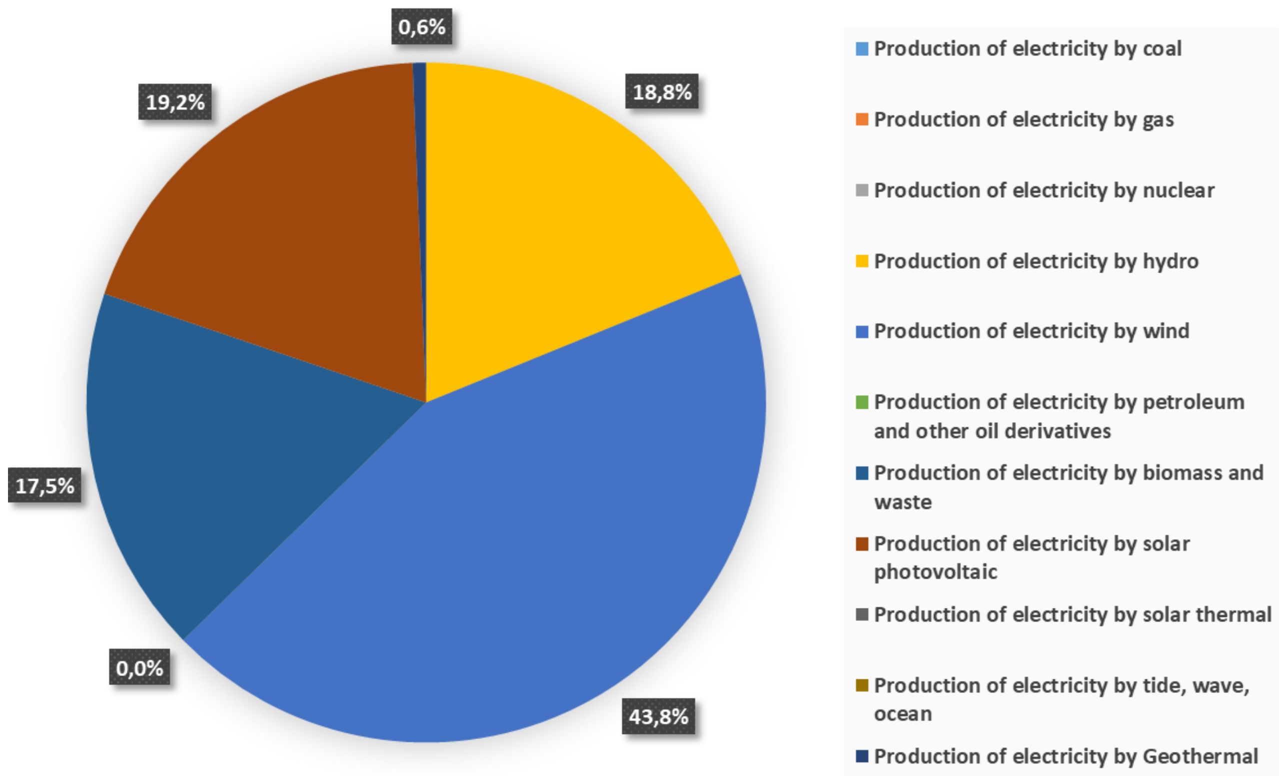

Figure 6 : Energy mix in production of electricity – EU28 (projection 2050)

Source: Capros et al. 2016, adapted according to EXIOBASE v3 sectors with renewable energy sources scaled up to cover 100% of the production

The results for the overall employment effects show a negative trend in domestic employment for the EU28, induced by the 100% renewable energy transition. Even though the 500 000 decline in full-time equivalent jobs does not mean a huge number compared to the overall EU28 population, this may be a serious reason for concern especially in those countries which would be the main "losers" (see the following sections). As will be seen below, the domestic decline in labour demand is "compensated" by increase in labour demand abroad (the "imported" labour demand). This may

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mean that renewable energy sources have supply chains which end (or start) in foreign countries, rather than in the EU28 area. If the EU28 would want to avoid such job losses due to renewable energy transition (in the power sector), it would be necessary to support policies to bring production of renewable energy devices to the domestic industries.

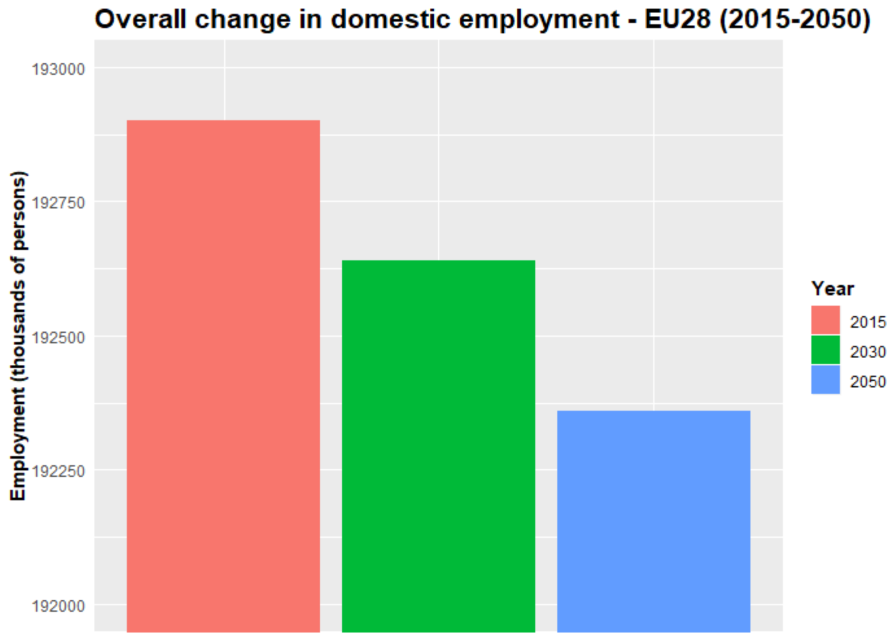

Figure 7 : Overall change in domestic employment – EU28 (2015-2050)

Source: EXIOBASE v3, own calculations

As mentioned above, the employment effects generated by the assumed EU28's 100% renewable energy transition in the power sector abroad are positive, opposite to the results for the domestic labour demand changes. The overall expected increase is by approximately 200 000 full-time job equivalents. Since this number does not even fully compensate the job losses inside the EU28, we can conclude that, in general, renewable energy sources might be less labour intensive than the non-renewable ones, taking into account not only their direct labour demand in terms of construction and operation and maintenance, but also in terms of indirect supply chain labour demand effects (supplies from other sectors).

It should be, however, noted that the analysis does not take into account any effects such as economic growth, technological progress, etc., as already explained in section 4.1.1. If such effects are taken into account, the analysis might give slightly different results (economic growth causing more jobs creation, while technological progress or changes in production patterns in terms of

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different input costs structure may cause differences in sector level results regarding labour demand changes).

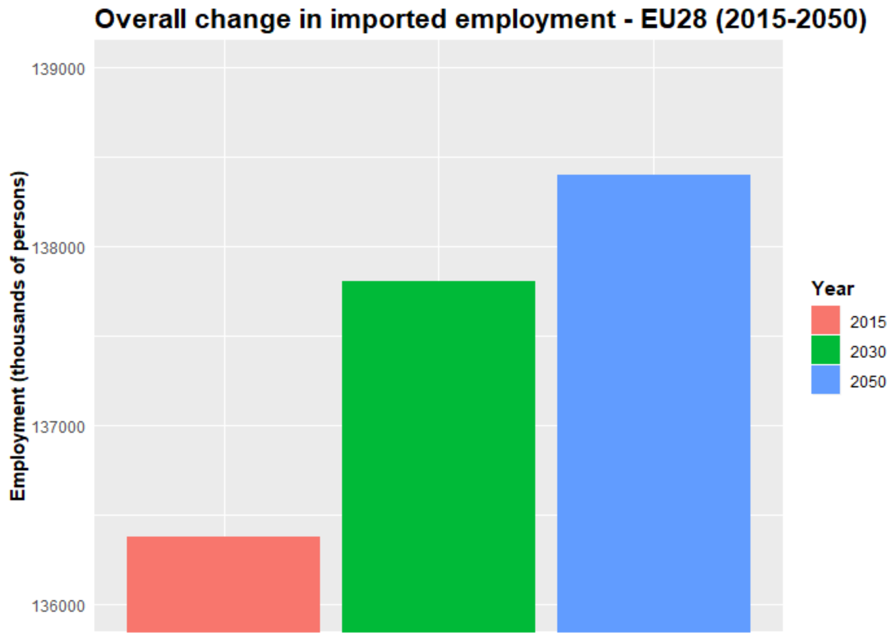

Figure 8 : Overall change in “imported” employment – EU28 (2015-2050)

Source: EXIOBASE v3, own calculations

Since our analysis focuses also on social aspects of the transition and not only the net employment effects, we provide below the results of the transition by different skill levels (as described in part 4.1) and by gender. Figures 10 and 11 show the main winners in terms of sectors gaining most from the expected transition, measured by changes in labour demand in these sectors, and, respectively, the main “losers” in terms of sectors losing most in their labour demand. More about the sector-level detail is presented and discussed in Deliverable 7.2d.

The analysis shows two main outcomes. First, by far the most labour intensive sector (together with its supply chains) is Biogasification of sewage sludge, incl. land application, which rises due to the increased demand for electricity from biomass and waste sources (this also applies to the country level examples, as will be seen below in sections 4.3 and 4.4). Second, if we compare the skill and gender structure of the winning versus losing sectors, they share very similar patterns, which is 1) dominance by men workers, and 2) dominance of high-skilled and medium-skilled workers. Whereas the latter may reflect the overall characteristics of the analysed EU28’s economy, the first is probably specific for the sectors related to energy and especially electricity production. The

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renewable transition therefore does not create a gender shift in employment patterns in the power sector. These trends can be, to some extent, observed in the other country-level cases as well.

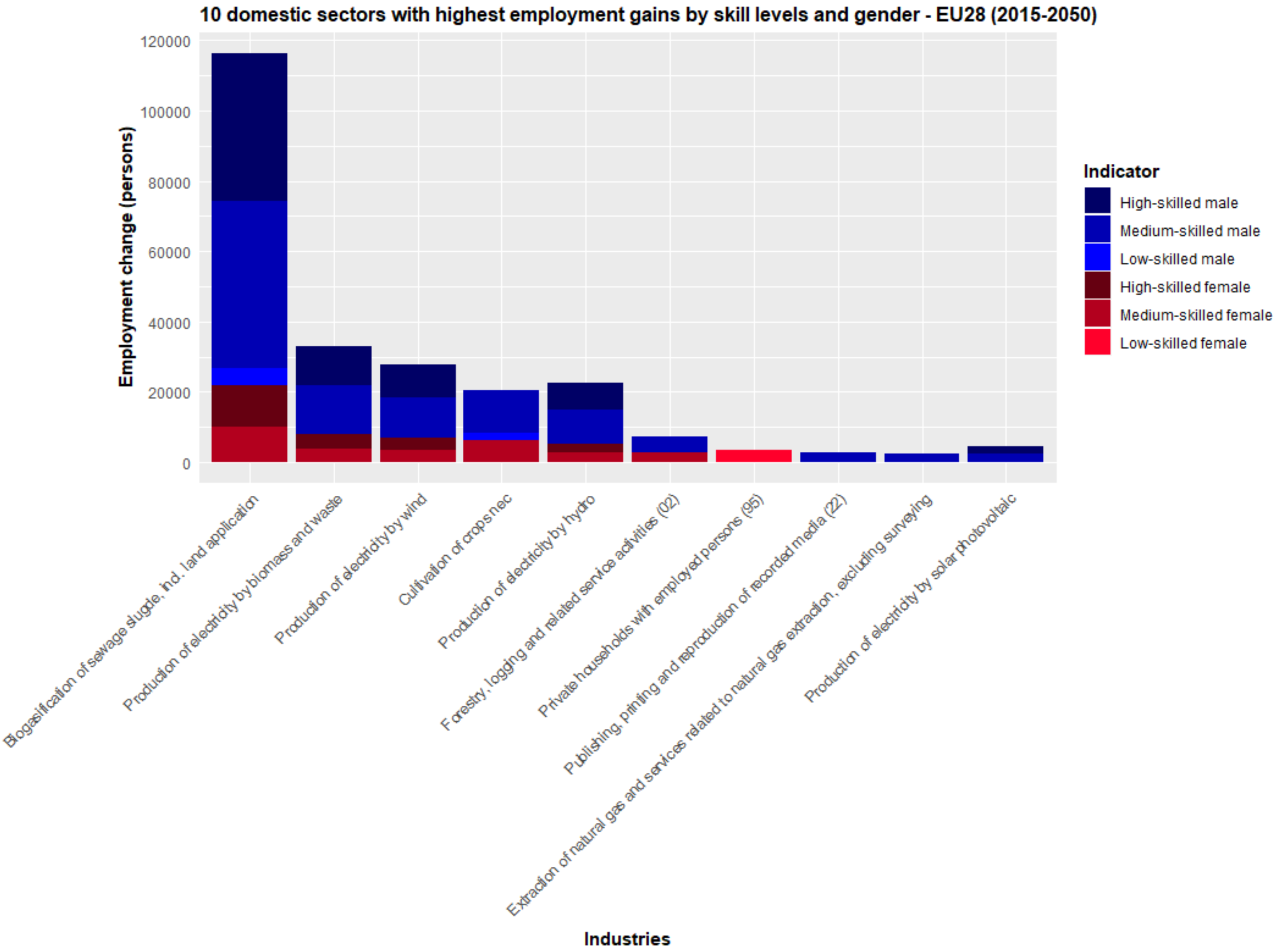

Figure 9: 10 domestic sectors with highest employment gains by skill levels and gender – EU28 (2015-2050)

Source: EXIOBASE v3, own calculations

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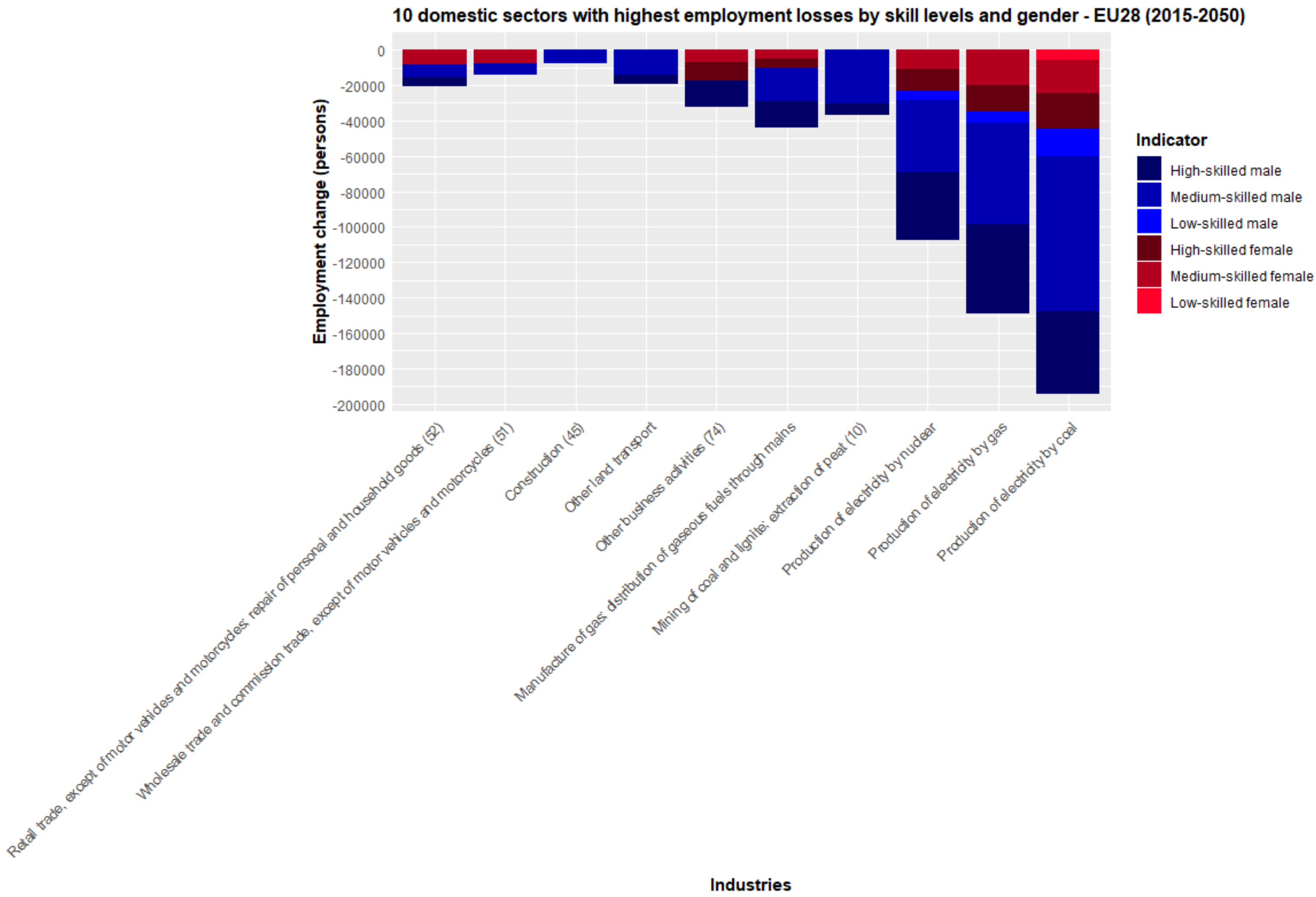

Figure 10: 10 domestic sectors with highest employment losses by skill levels and gender – EU28 (2015-2050)

Source: EXIOBASE v3, own calculations

4.3. Expected labour demand changes of early policy adopters

4.3.1 Austria

Currently (respectively in 2017), Austria's electricity is generated by 72.2% from renewable energy sources ("SHARES (Renewables) - Eurostat," 2019). The starting point for the model was set to 2015,

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where the most recent comprehensive data were available. In 2015, renewable energy sources generated 73.0% of electricity in Austria. Scaling up only renewable sources, the hydro part would generate 62.6%, wind 21.1%, biomass and waste 9.3%, and solar photovoltaic 6.9%.

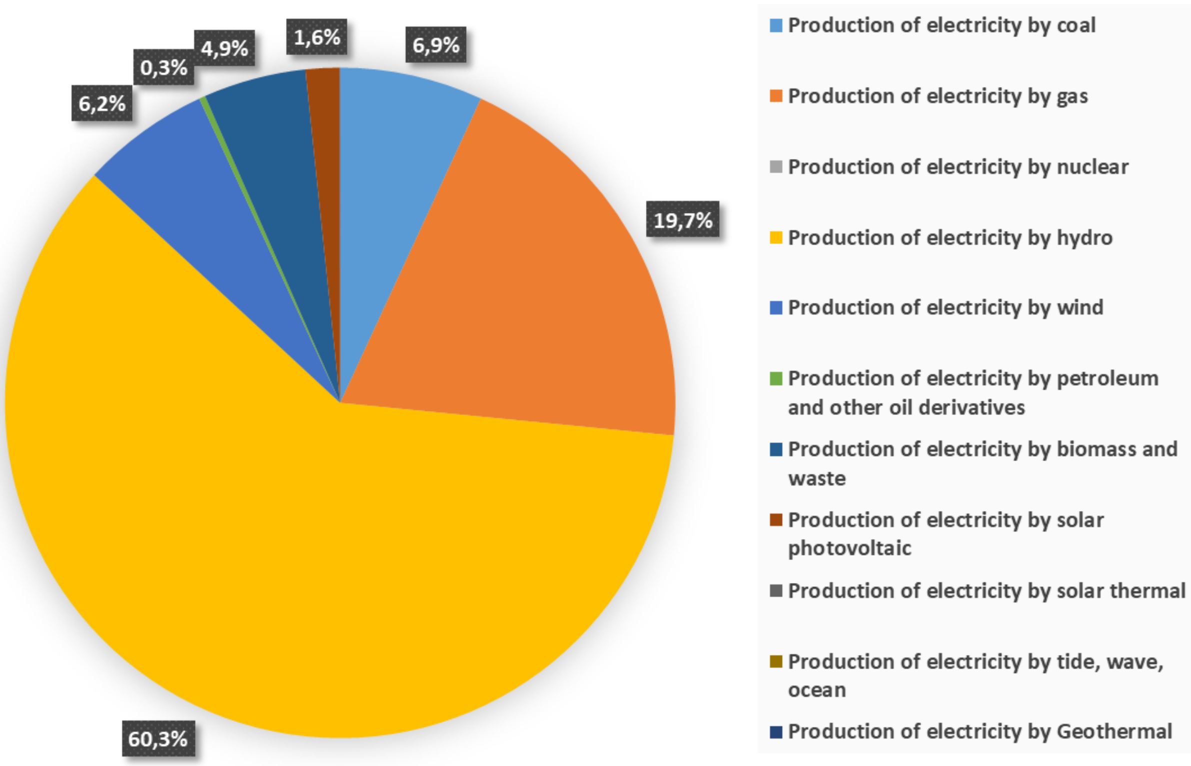

Figure 11 : Energy mix in production of electricity – Austria (current 2015)

Source: Capros et al. 2016, adapted according to EXIOBASE v3 sectors

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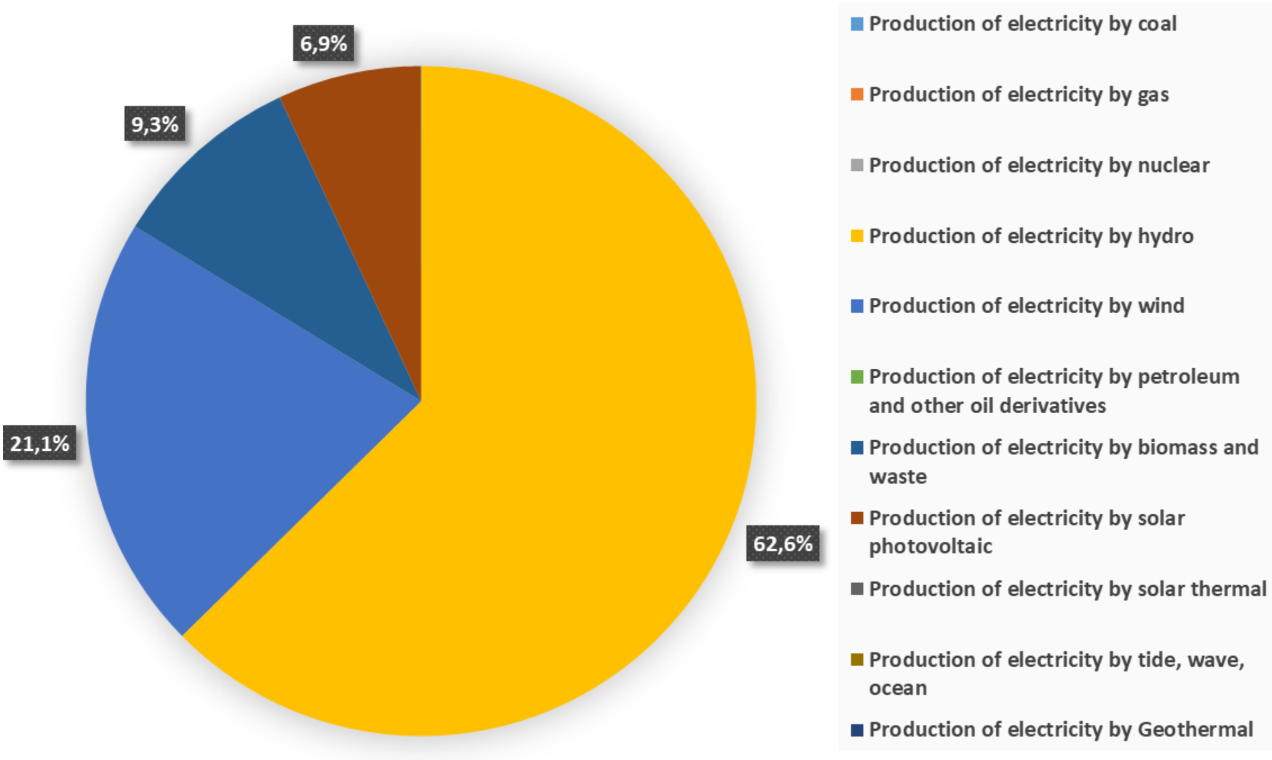

Figure 12 : Energy mix in production of electricity – Austria (projection 2050)

Source: Capros et al. 2016, adapted according to EXIOBASE v3 sectors with renewable energy sources scaled up to cover 100% of the production

In our analysis we find that the net domestic employment effects are slightly negative, decreasing the employment from approx. 3 060 000 full-time equivalent employees to some 3 057 000. The renewable energy sources in Austria are therefore less labour intensive in general then the non-renewable energy sources. Nevertheless, since the overall net job destruction is 3 000 full-time equivalent employees, the result also allows to consider measures such as minor working time reduction.

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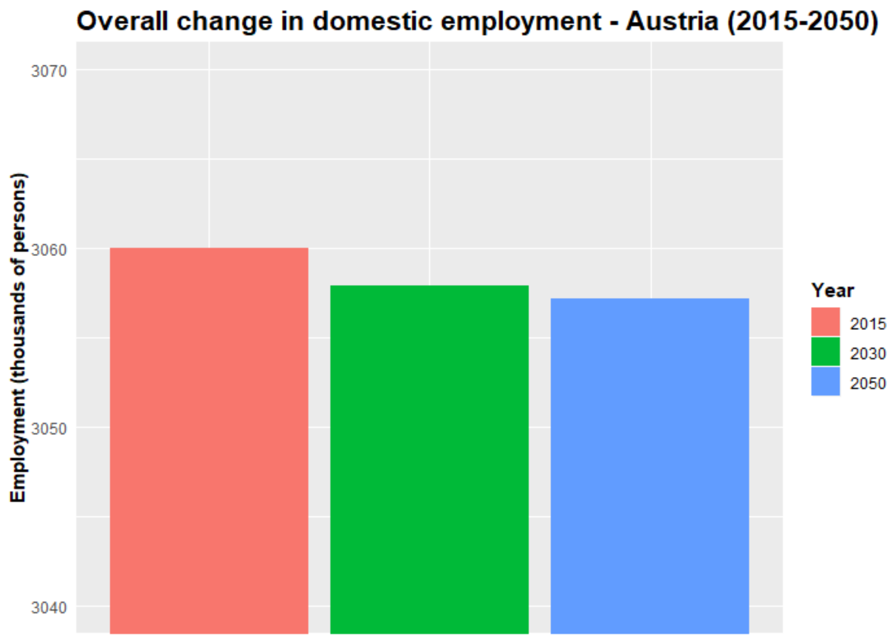

Figure 13 : Overall change in domestic employment – Austria (2015-2050)

Source: EXIOBASE v3, own calculations

Since the production of electricity does not only compile from domestic labour, we have analysed the "imported" employment to the Austrian economy as well. The overall effect is, however, very similar to the one observed in the Austrian economy itself, showing that the labour demand would decrease from approx. 5 120 000 employees by 5 000 to 5 117 000. The overall labour intensity of the remaining transition to renewable energies is therefore smaller than the one of remaining current electricity production from fossil fuels.

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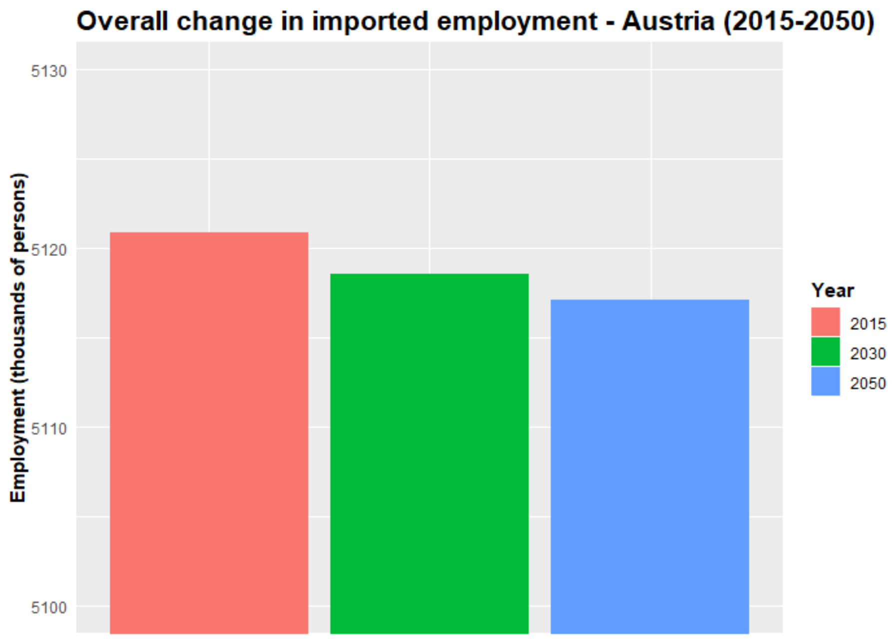

Figure 14 : Overall change in imported employment – Austria (2015-2050)

Source: EXIOBASE v3, own calculations

Regarding the skill levels and gender distribution, apart from forestry, all other gaining sectors are heavily dominated by men. Except from forestry again, there is a demand mostly for high-skilled and medium-skilled labour.

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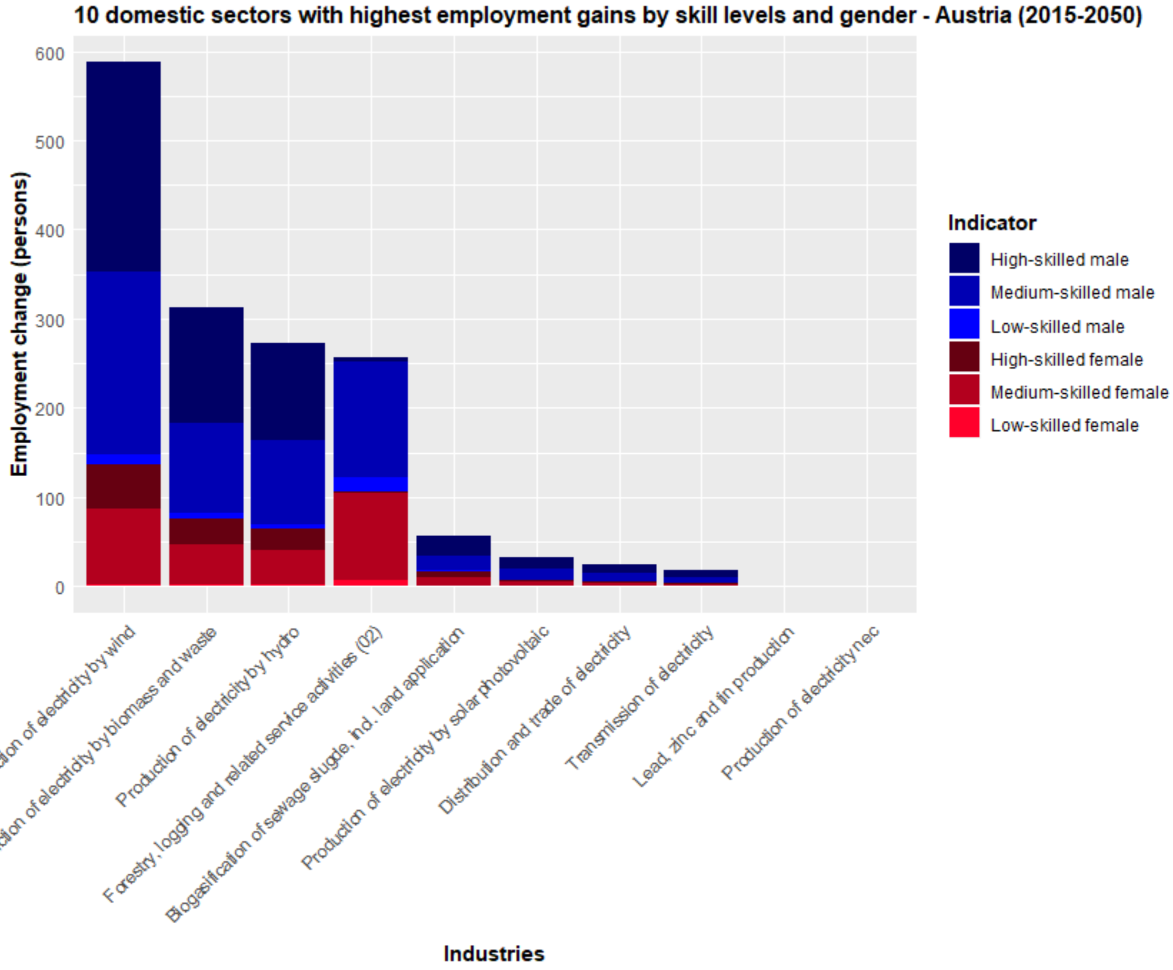

Figure 15: 10 domestic sectors with highest employment gains by skill levels and gender – Austria (2015-2050)

Source: EXIOBASE v3, own calculations

The male domination is true also for the losing sectors, apart from “Other business activities” and retail trade. We can then clearly see that – at least in the Austrian case – the male domination in the energy related sectors is present also in the renewable energy sectors.

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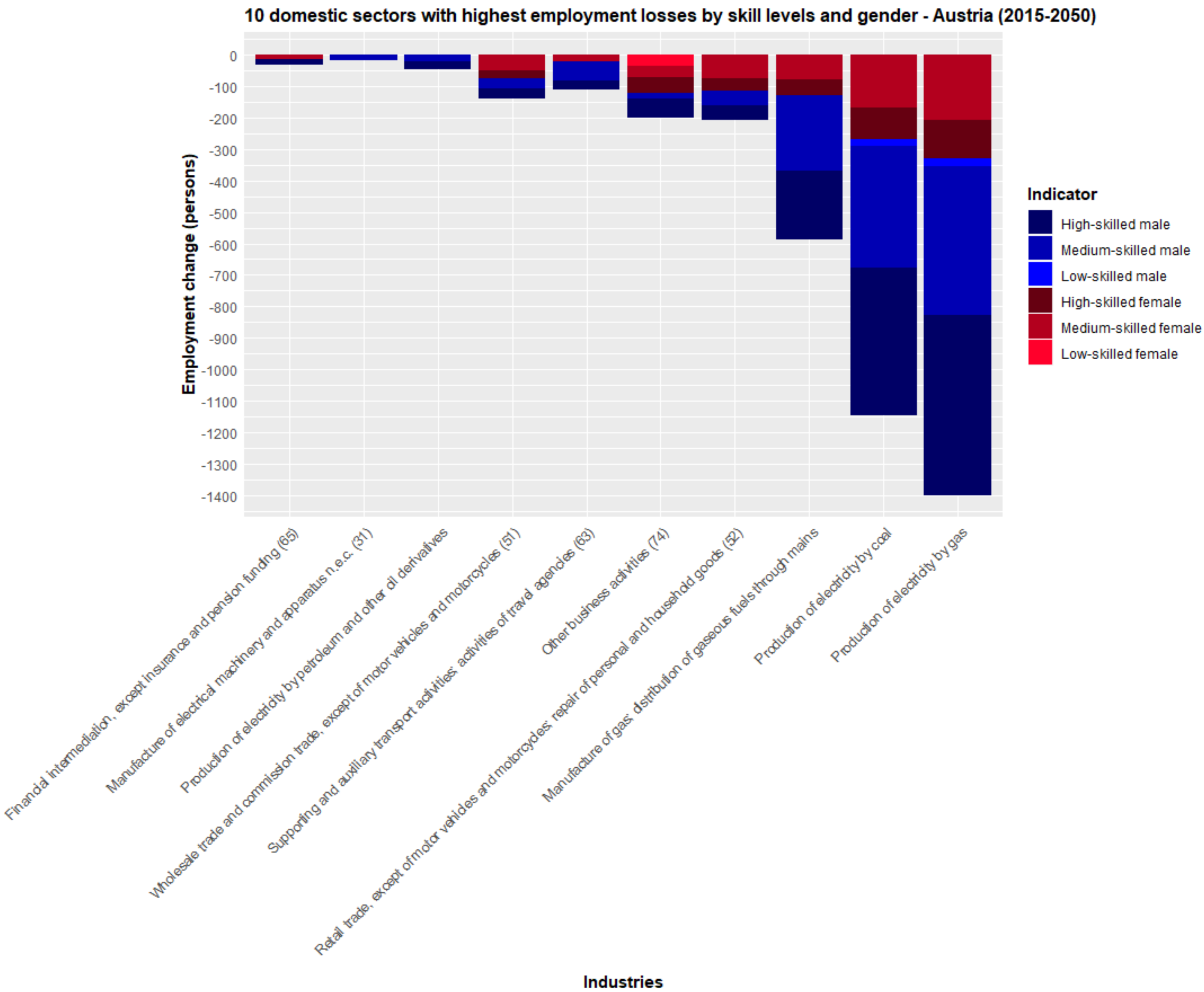

Figure 16: 10 domestic sectors with highest employment losses by skill levels and gender – Austria (2015-2050)

Source: EXIOBASE v3, own calculations

4.3.2 Germany

Germany generated 34% of electricity from renewable energy sources in 2017 ("Renewables in Electricity Production," 2018). The 2015 situation is similar, showing that Germany relies heavily on

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coal production (45.7%), respectively gas (12.5%). The starting point is therefore very different to the Austrian situation.

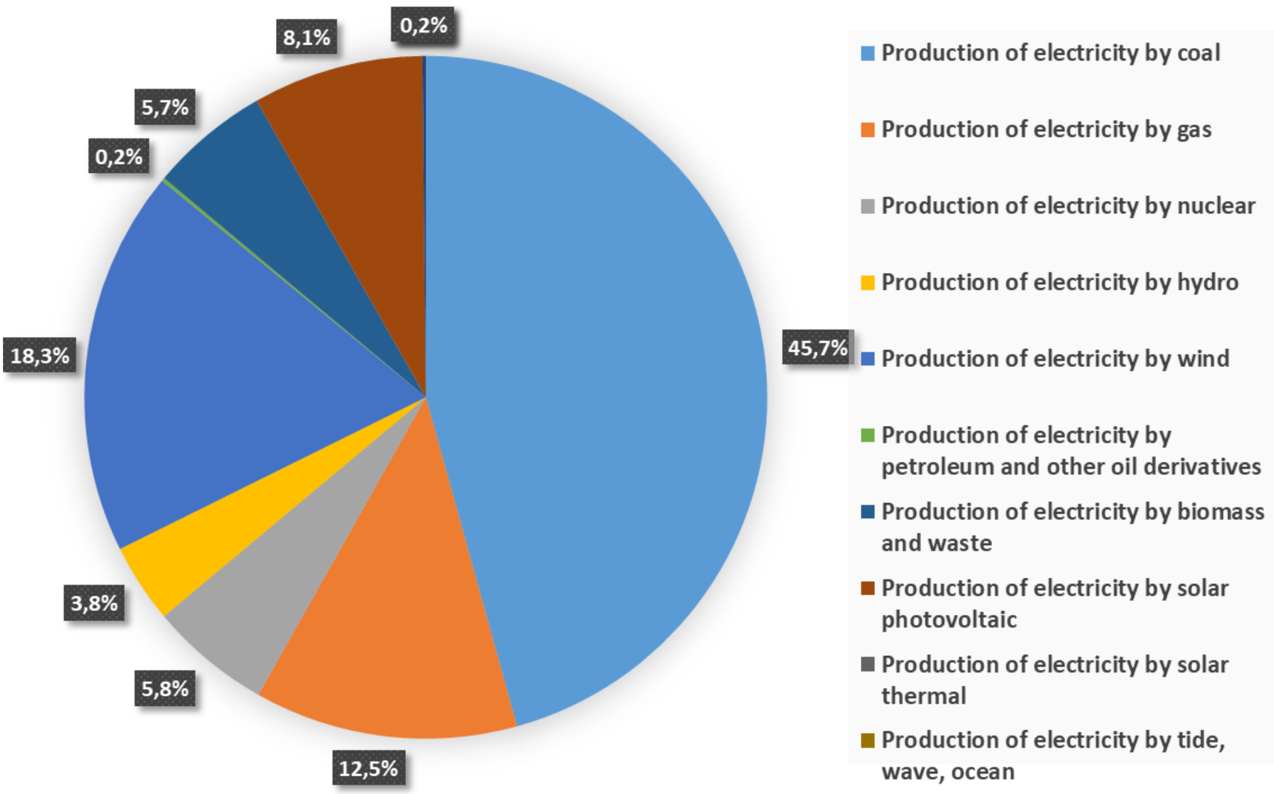

Figure 17 : Energy mix in production of electricity – Germany (current 2015)

Source: Capros et al. 2016, adapted according to EXIOBASE v3 sectors

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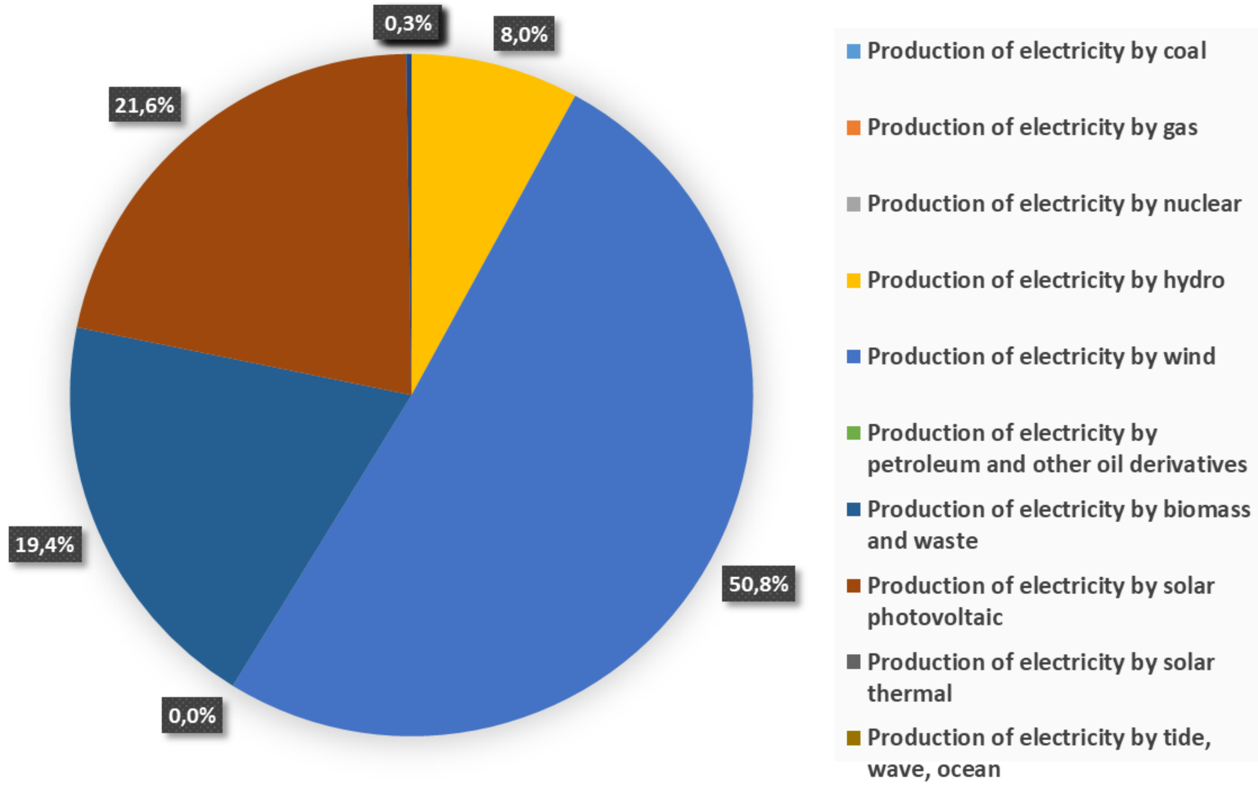

Figure 18 : Energy mix in production of electricity – Germany (projection 2050)

Source: Capros et al. 2016, adapted according to EXIOBASE v3 sectors with renewable energy sources scaled up to cover 100% of the production

The overall effects of decarbonising the rest of the power sector are, similarly to Austria, slightly negative, the labour demand falling from the current almost 30 830 000 full-time equivalent employees to above 30 810 000. The labour intensity of the renewables is therefore smaller also in Germany.

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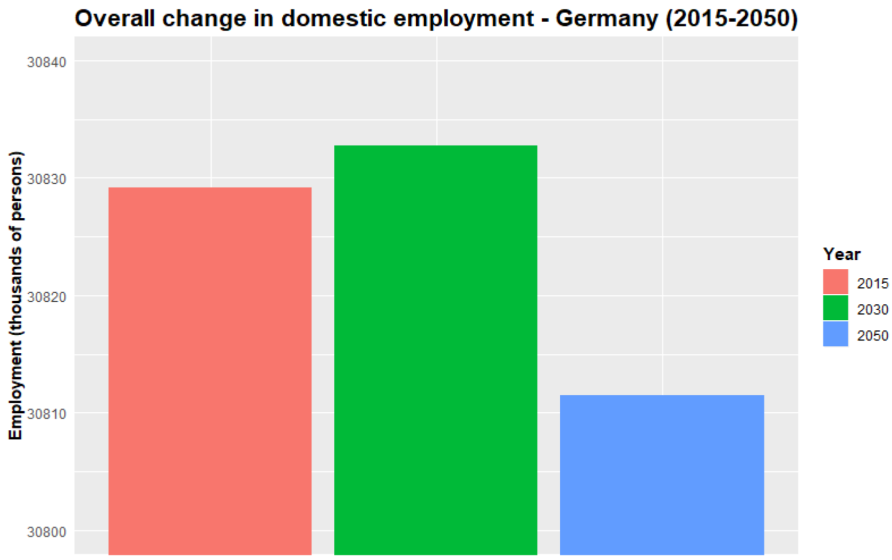

Figure 19: Overall change in domestic employment – Germany (2015-2050)

Source: EXIOBASE v3, own calculations

Quite the opposite is true for the labour demand from abroad in case of Germany. Whereas in Austria, it was falling as well, in the German case the 100% renewables-based electricity production increases the labour demand from 43 300 000 to 44 000 000 (approximately). This means that the renewable energy sources have a different supply chain structure, requiring more imports then domestically produced fossil fuels. This also makes sense since Germany still runs a significant number of coal power plants, which take coal from domestic sources. Taking this into account, the overall job losses can be also seen as not so significant. However, the analysis only focuses on decarbonisation in the power sector, which is not the exclusive consumer of the coal, peat and lignite mining products.

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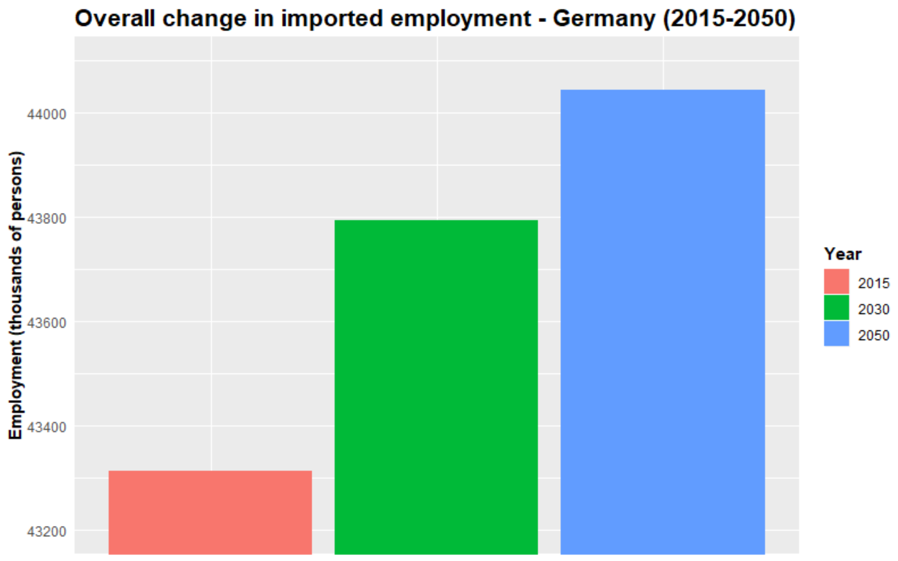

Figure 20: Overall change in imported employment – Germany (2015-2050)

Source: EXIOBASE v3, own calculations

The distributional employment effects are almost identical to the situation in Austria, in relative terms. Male domination is clearly visible in both winning and losing sectors, as well as the distribution between high, medium and low skilled labour demand, in all the sectors. This again means that the "renewable energy revolution" may not necessarily bring social changes in terms of gender equality or "social class". Note that some parts of the bars in case of the losing sectors by skill levels are missing in the analysis – they comprise the rest of the bars.

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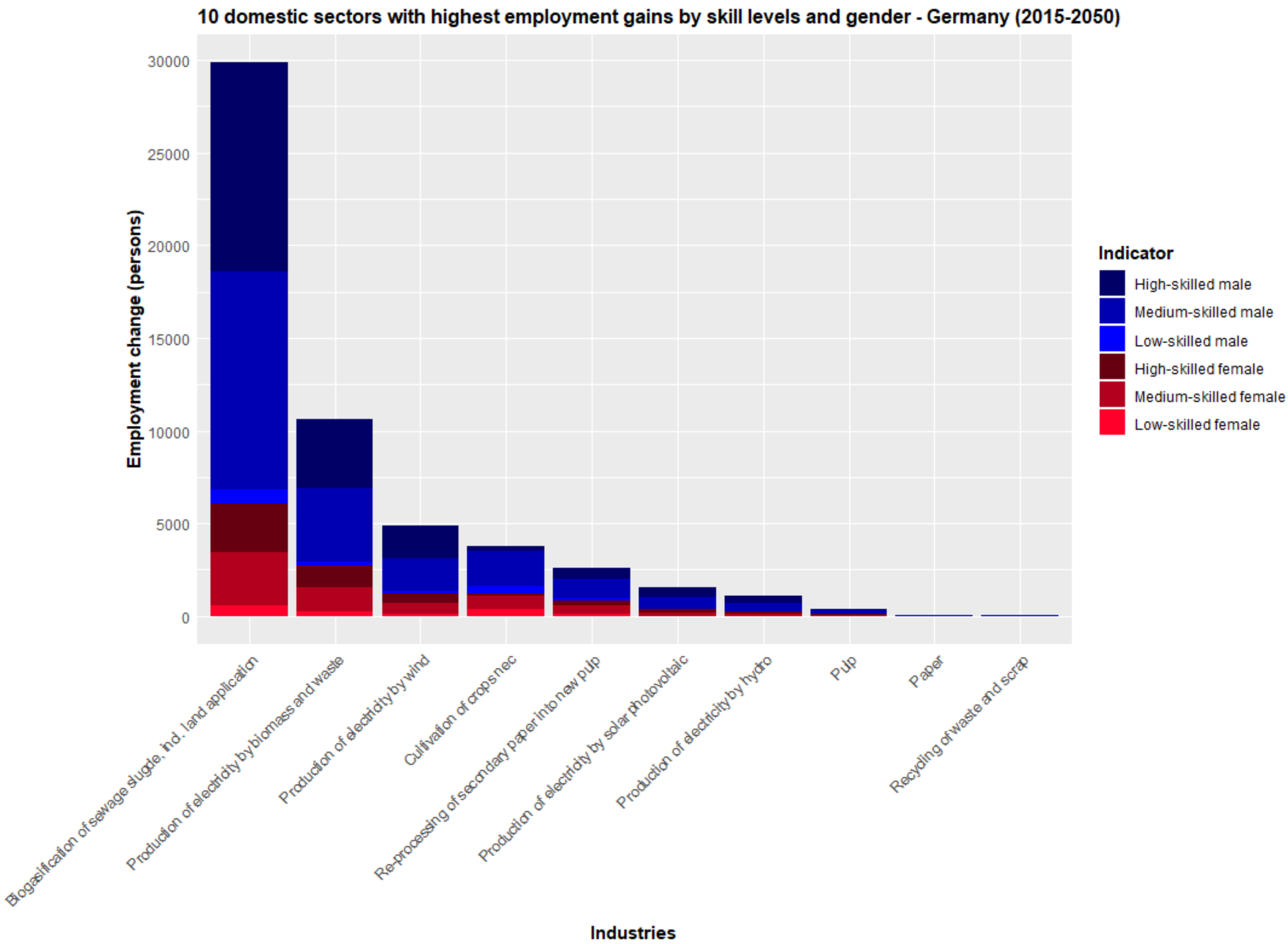

Figure 21: 10 domestic sectors with highest employment gains by skill levels and gender – Germany (2015-2050)

Source: EXIOBASE v3, own calculations

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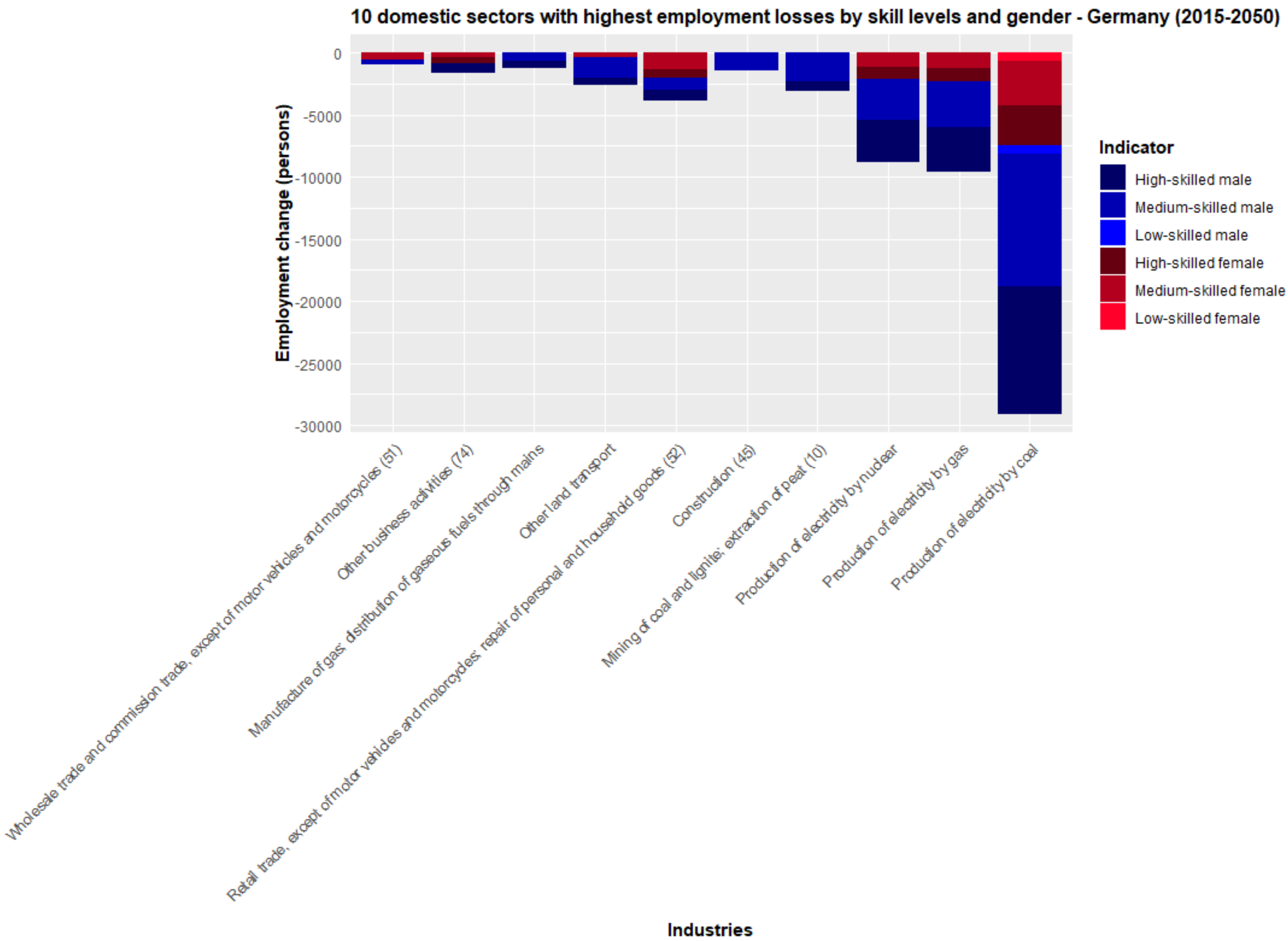

Figure 22: 10 domestic sectors with highest employment losses by skill levels and gender – Germany (2015-2050)

Source: EXIOBASE v3, own calculations

4.3.3 The United Kingdom

The UK was producing 30.2% of its electricity from renewable energy sources in 2017 ("Renewables in Electricity Production," 2018). The UK's case is somewhat different from both Germany and Austria, since the country relies on a mixture of gas and nuclear energy, but already has a significant share of electricity generated by wind (25.8%), as well as biomass and waste (13.8%).

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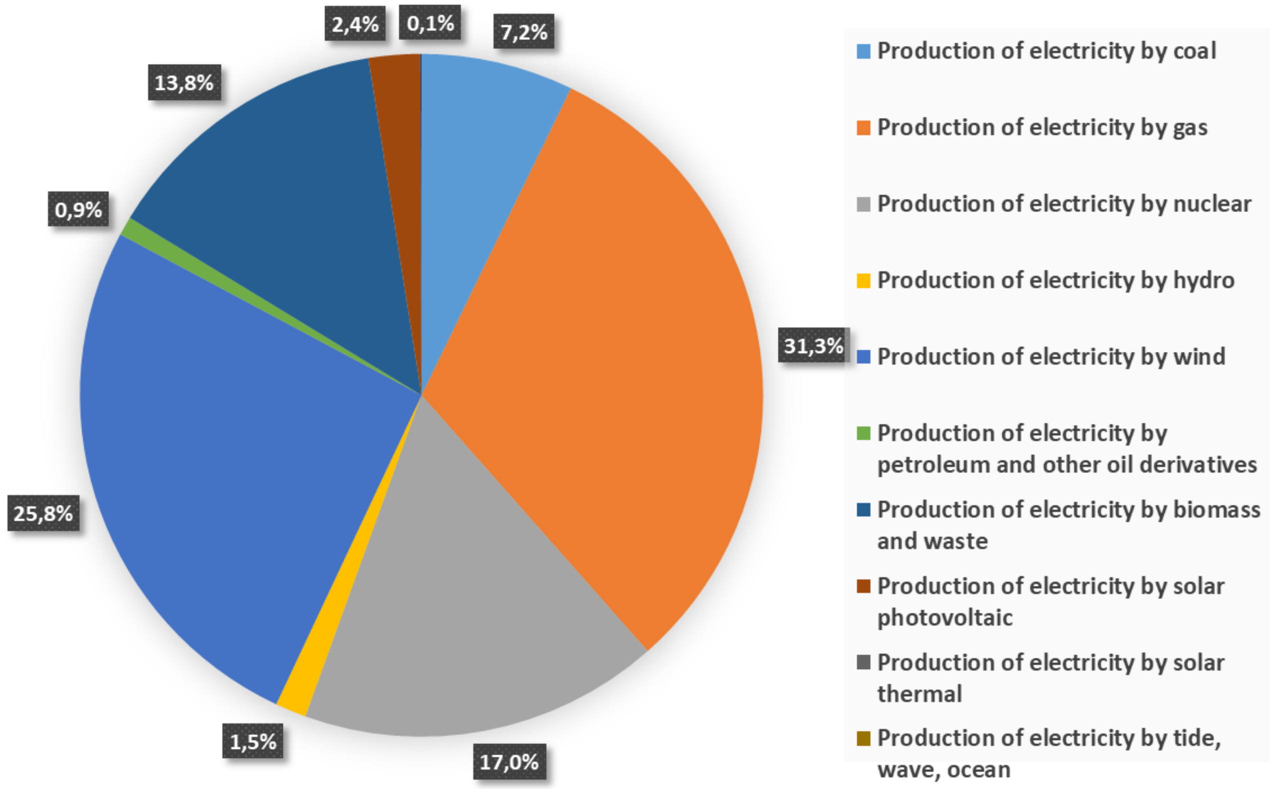

Figure 23 : Energy mix in production of electricity – United Kingdom (current 2015)

Source: Capros et al. 2016, adapted according to EXIOBASE v3 sectors

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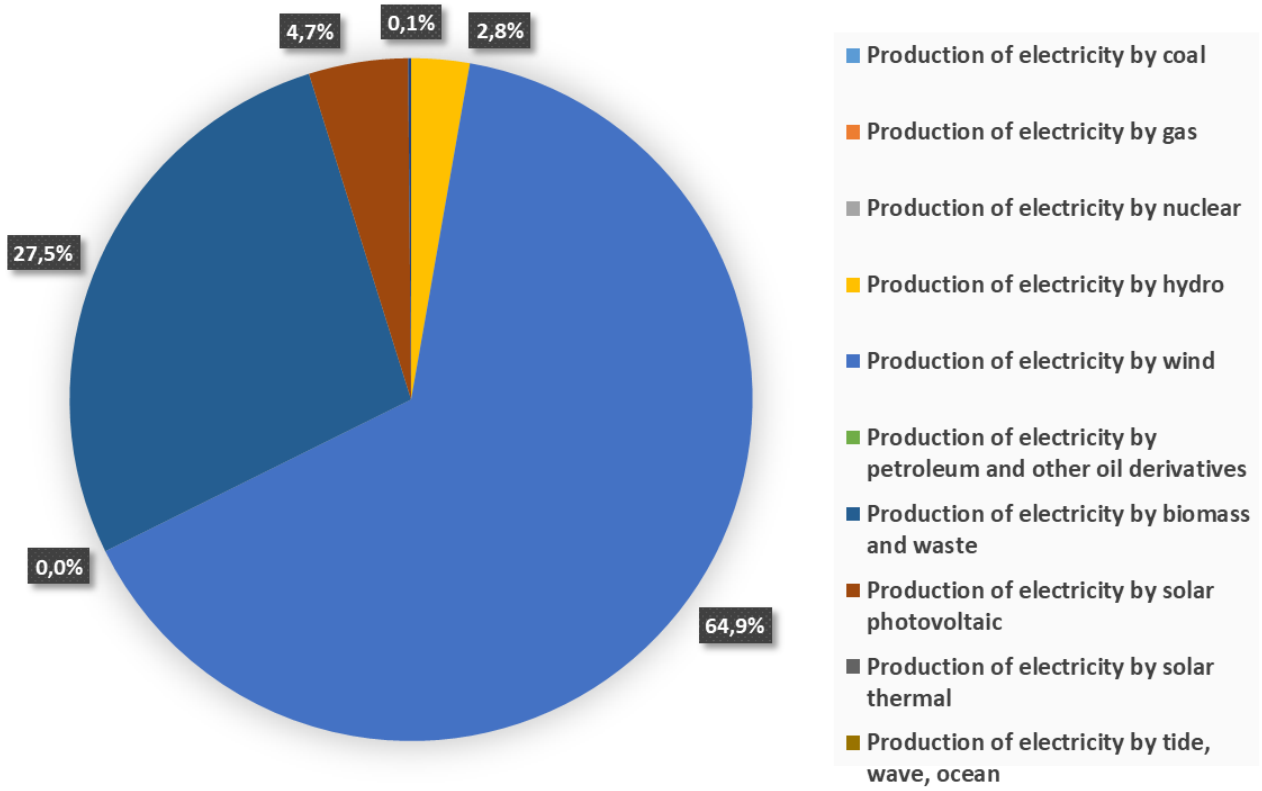

Figure 24 : Energy mix in production of electricity – United Kingdom (projection 2050)

Source: Capros et al. 2016, adapted according to EXIOBASE v3 sectors with renewable energy sources scaled up to cover 100% of the production

Concerning the total expected employment effects, the UK is again very likely to shrink in terms of labour demand generated by the transition to 100% renewable electricity production. It is supposed that given the current labour/output ratio, the labour demand in the UK would fall from 26 750 000 to 26 625 000 of full-time equivalents.

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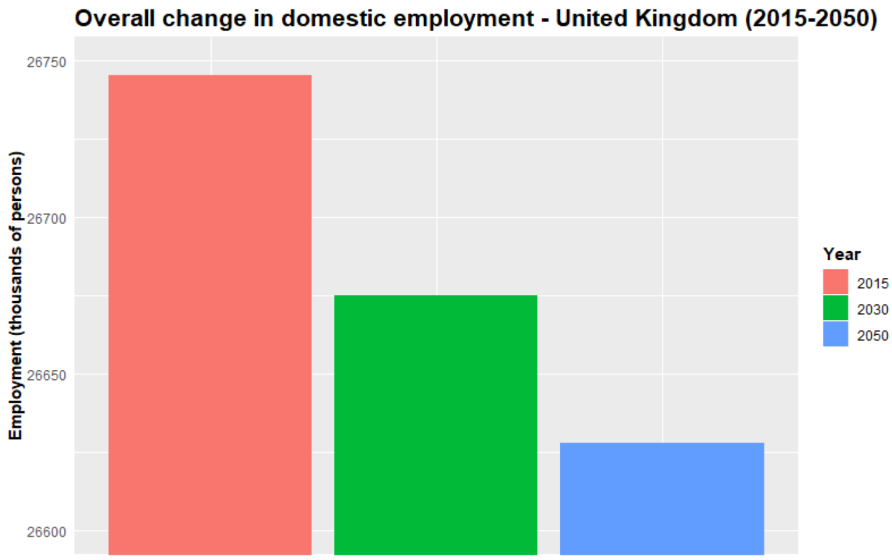

Figure 25: Overall change in domestic employment – United Kingdom (2015-2050)

Source: WIOD 2016 release, EXIOBASE v3, own calculations

Opposite to the German case, in the UK, the imported employment is assumed to rise, if the country scales up its renewable energy production of electricity to 100%, based on the modelled projection from the EU Reference Scenario from 2016. Specifically, it would rise from approx. 35 900 000 to 36 200 000 jobs. Since the analysis did not track where would the labour demand be generated, we can just assume that this increase would be linked to the main trade partners of the UK, importing the renewable energy related devices and equipment to the United Kingdom.

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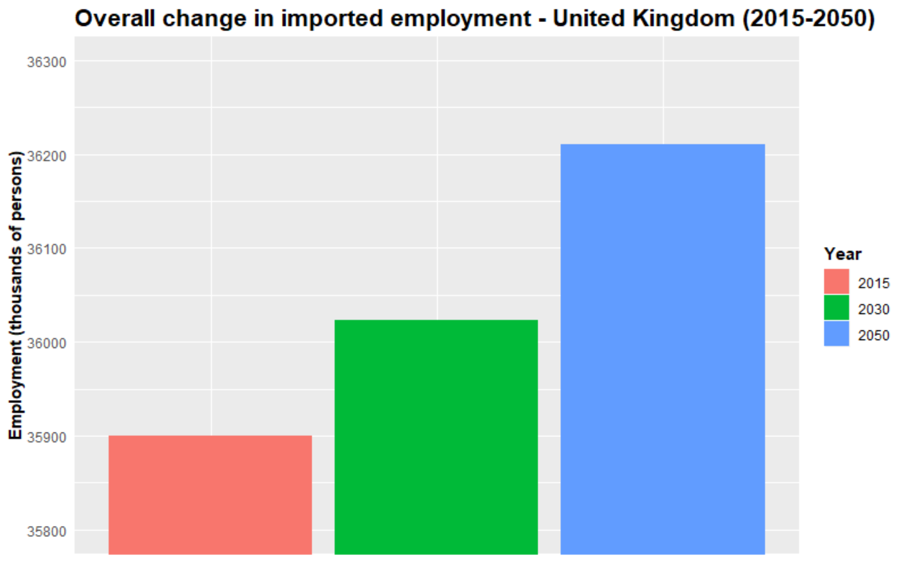

Figure 26: Overall change in imported employment – United Kingdom (2015-2050)

Source: EXIOBASE v3, own calculations

Male domination applies to the situation in the UK as well, except for the publishing sector. The medium-skilled labour force forms probably the biggest part of the expected job increases, whereas the situation remains most alarming for the high-skilled labour in the losing sectors in the UK's case. There does not seem to be any significant effects for medium and low skilled female employment, the calculations show.

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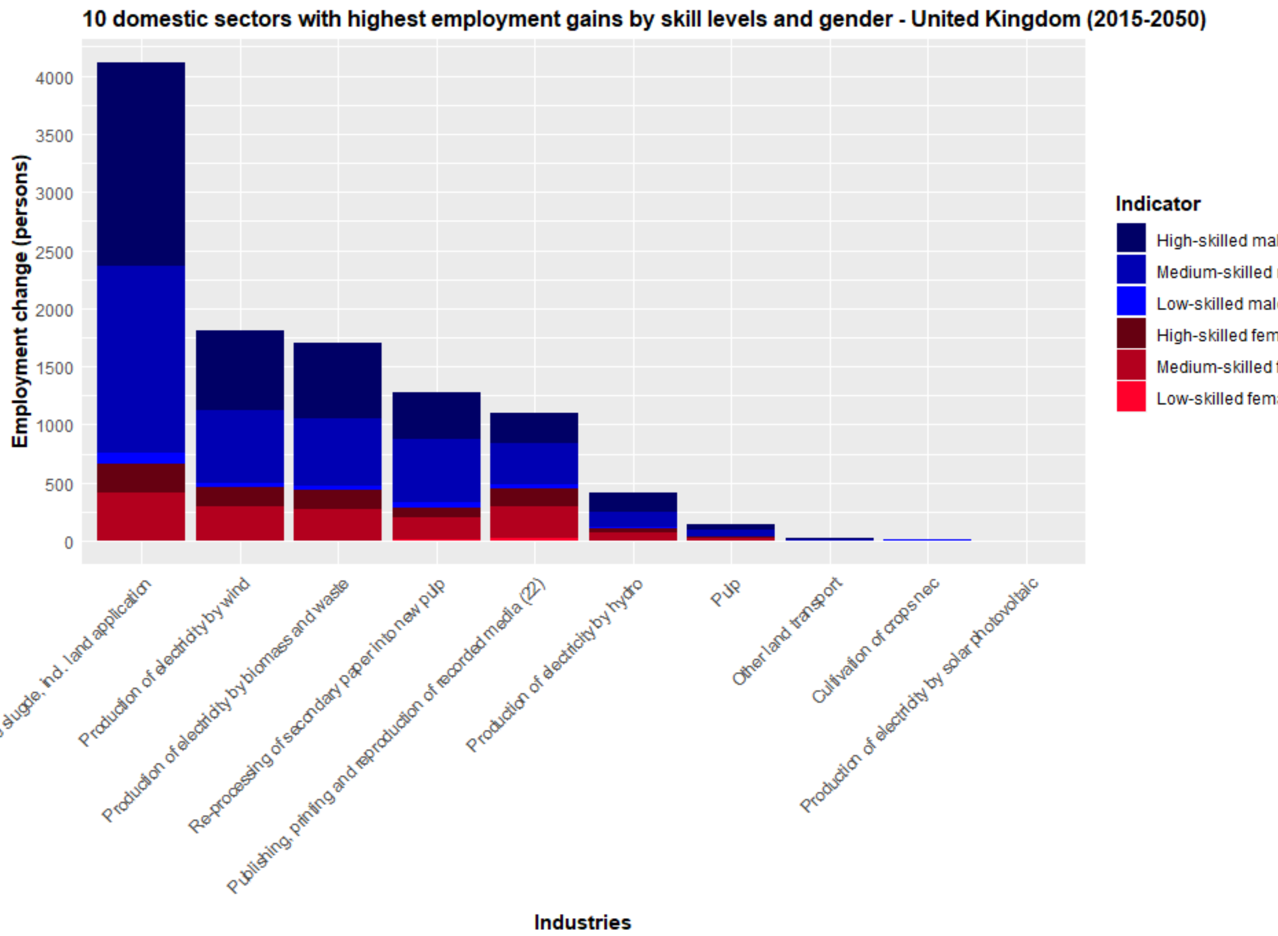

Figure 27: 10 domestic sectors with highest employment gains by skill levels and gender – United Kingdom (2015-2050)

Source: EXIOBASE v3, own calculations

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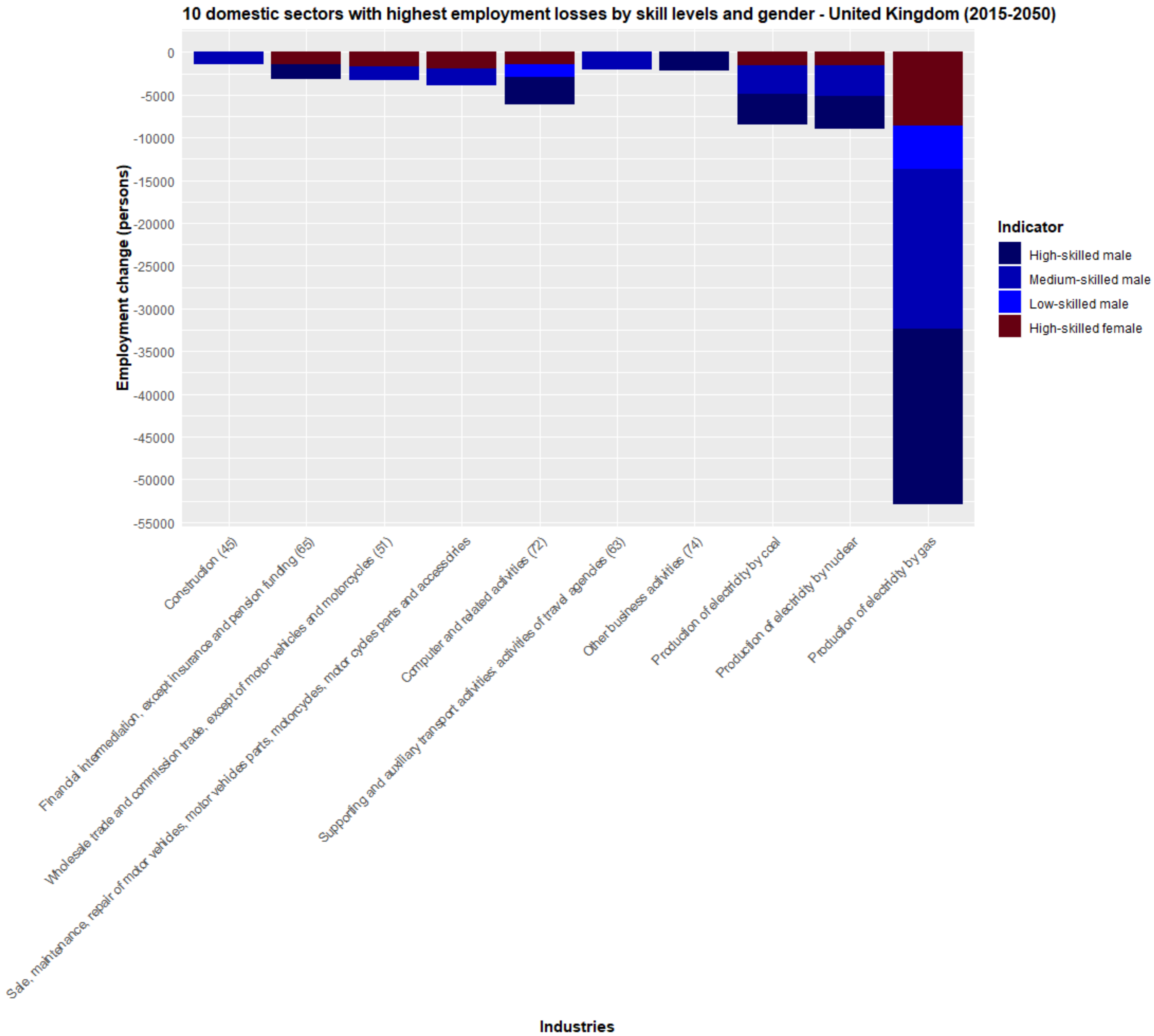

Figure 28: 10 domestic sectors with highest employment losses by skill levels and gender – United Kingdom (2015-2050)

Source: EXIOBASE v3, own calculations

4.4. Expected labour demand changes of coal-based economies

4.4.1 Czechia

The Czech Republic currently produces less than 14% of electricity from its renewable energy sources, that are dominated by hydropower ("SHARES (Renewables) - Eurostat," 2019). The rest of the electricity is produced from nuclear (34.6%) and coal (52.6%) sources, with a minor share of gas (4.5%).

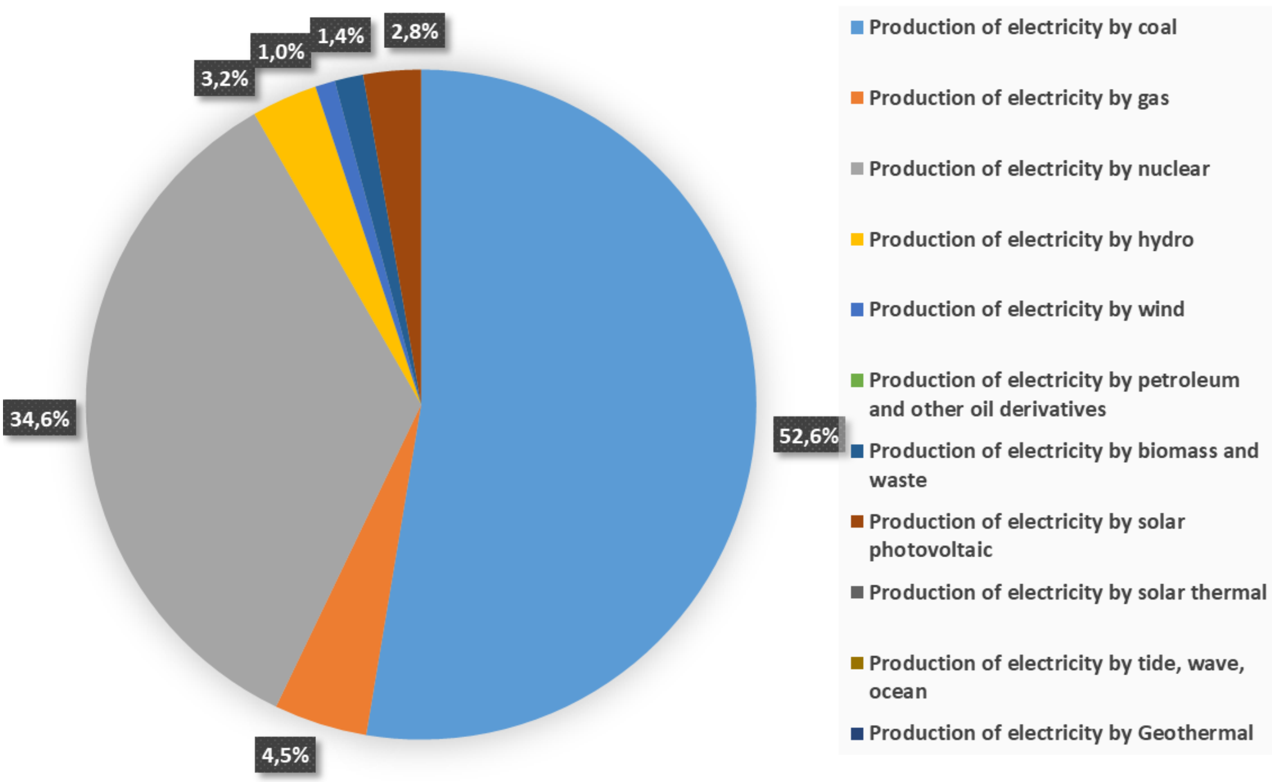

Figure 29 : Energy mix in production of electricity – Czechia (current 2015)

Source: Capros et al. 2016, adapted according to EXIOBASE v3 sectors

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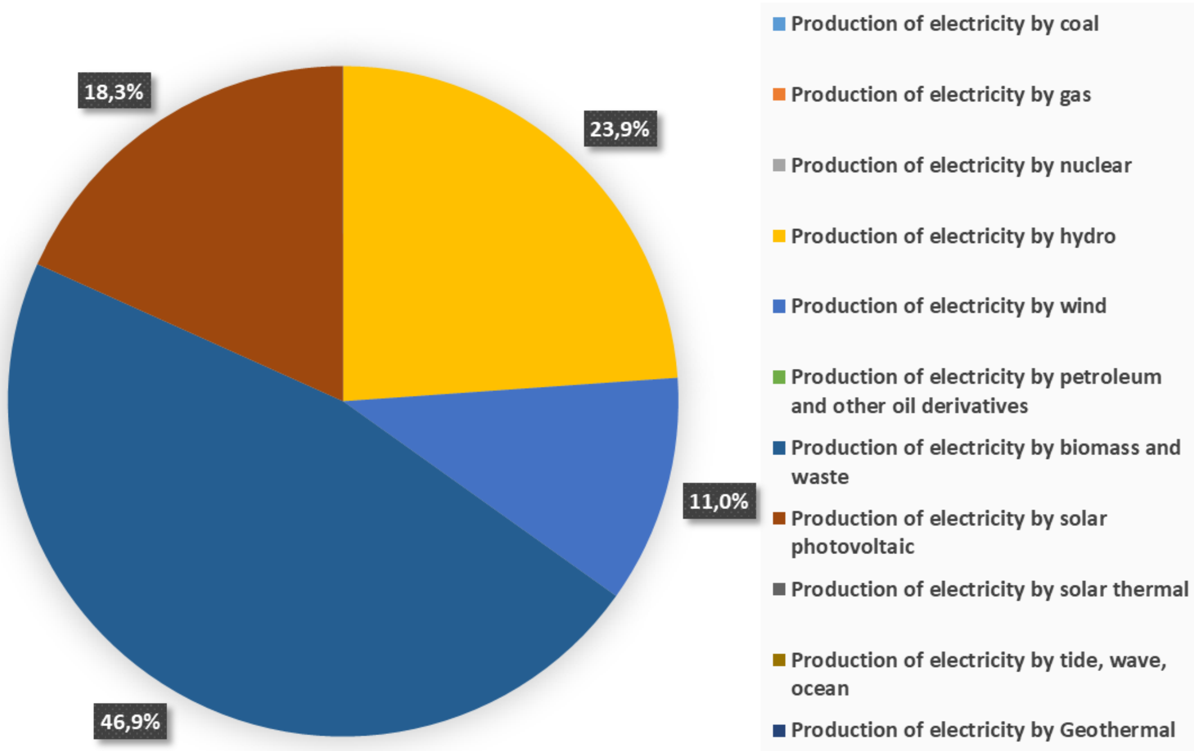

Figure 30 : Energy mix in production of electricity – Czechia (projection 2050)

Source: Capros et al. 2016, adapted according to EXIOBASE v3 sectors with renewable energy sources scaled up to cover 100% of the production

The total employment effects of scaling up the electricity production from renewable energy sources are positive for both domestic and imported labour. The employment demand grows from 3 190 000 to 3 210 000. The imported labour demand would grow from 3 350 000 to 3 750 000. This result shows to a big potential of the renewable energy in the Czech Republic in terms of labour demand, even domestically.

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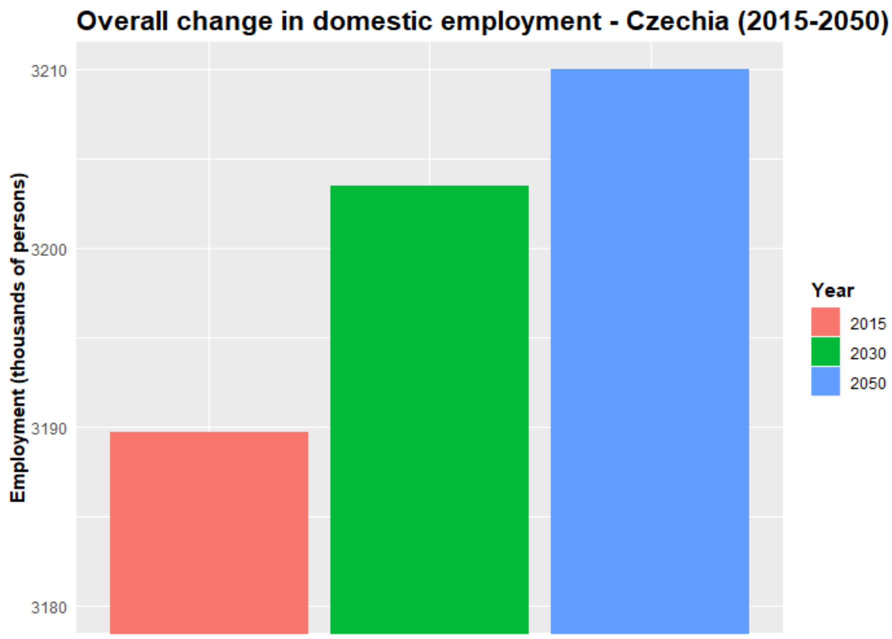

Figure 31: Overall change in domestic employment – Czechia (2015-2050)

Source: EXIOBASE v3, own calculations

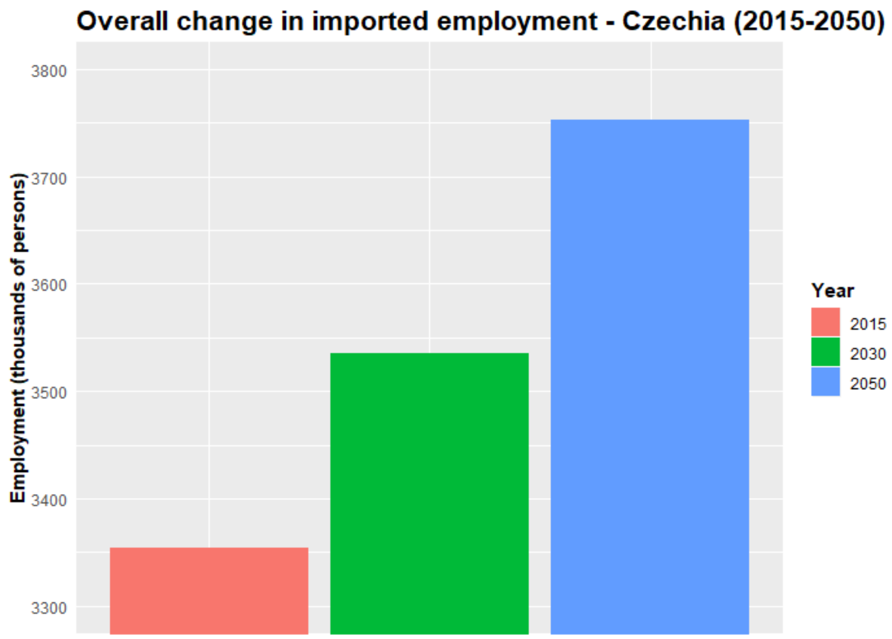

Figure 32: Overall change in imported employment – Czechia (2015-2050)

Source: EXIOBASE v3, own calculations

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Similar to the « early adopters », the male prevalence is significant also in Czechia, with an even higher share in the losing sectors, mostly coal and nuclear power and coal and lignite mining. The medium skilled male employment losses in mining are theoretically partly compensated by the gains in crops cultivation.

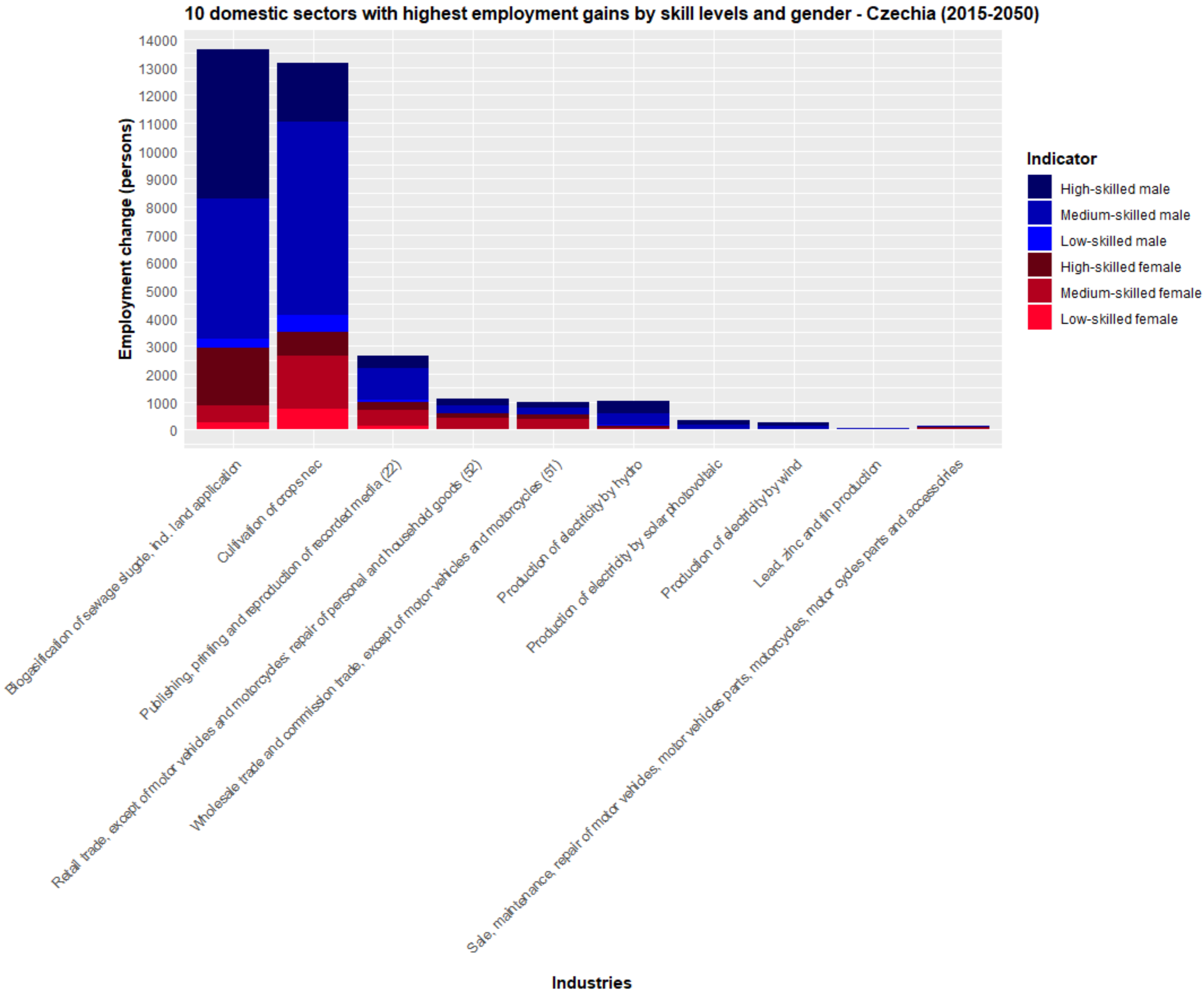

Figure 33: 10 domestic sectors with highest employment gains by skill levels and gender – Czechia (2015-2050)

Source: EXIOBASE v3, own calculations

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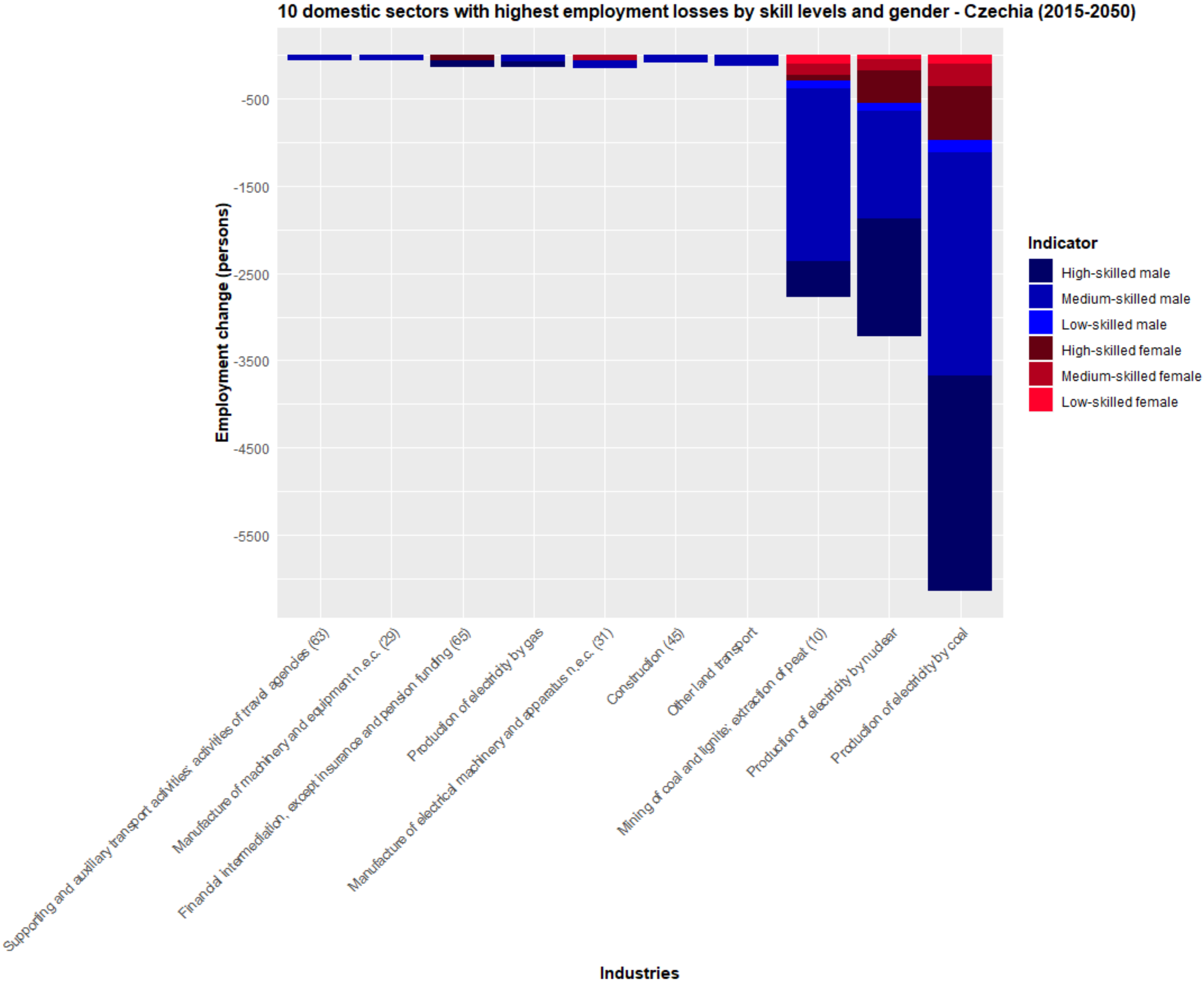

Figure 34: 10 domestic sectors with highest employment losses by skill levels and gender – Czechia (2015-2050)

Source: EXIOBASE v3, own calculations

4.4.2 Poland

Poland has even lower share of renewable energy in electricity production then the Czech Republic – slightly above 13% percent in 2017 (“SHARES (Renewables) - Eurostat,” 2019). Since there are no

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nuclear power plants in Poland, coal covers up to 80.1% of electricity production, wind and biomass being the second with 6.5%.

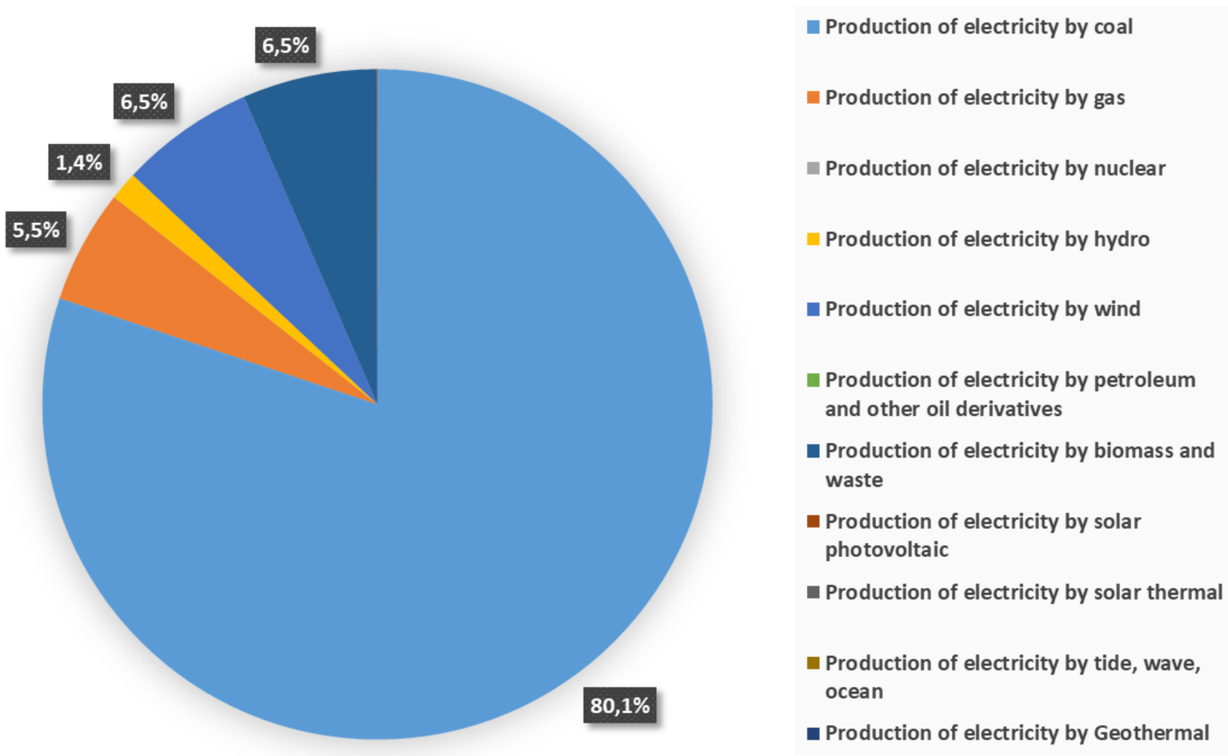

Figure 35 : Energy mix in production of electricity – Poland (current 2015)

Source: Capros et al. 2016, adapted according to EXIOBASE v3 sectors

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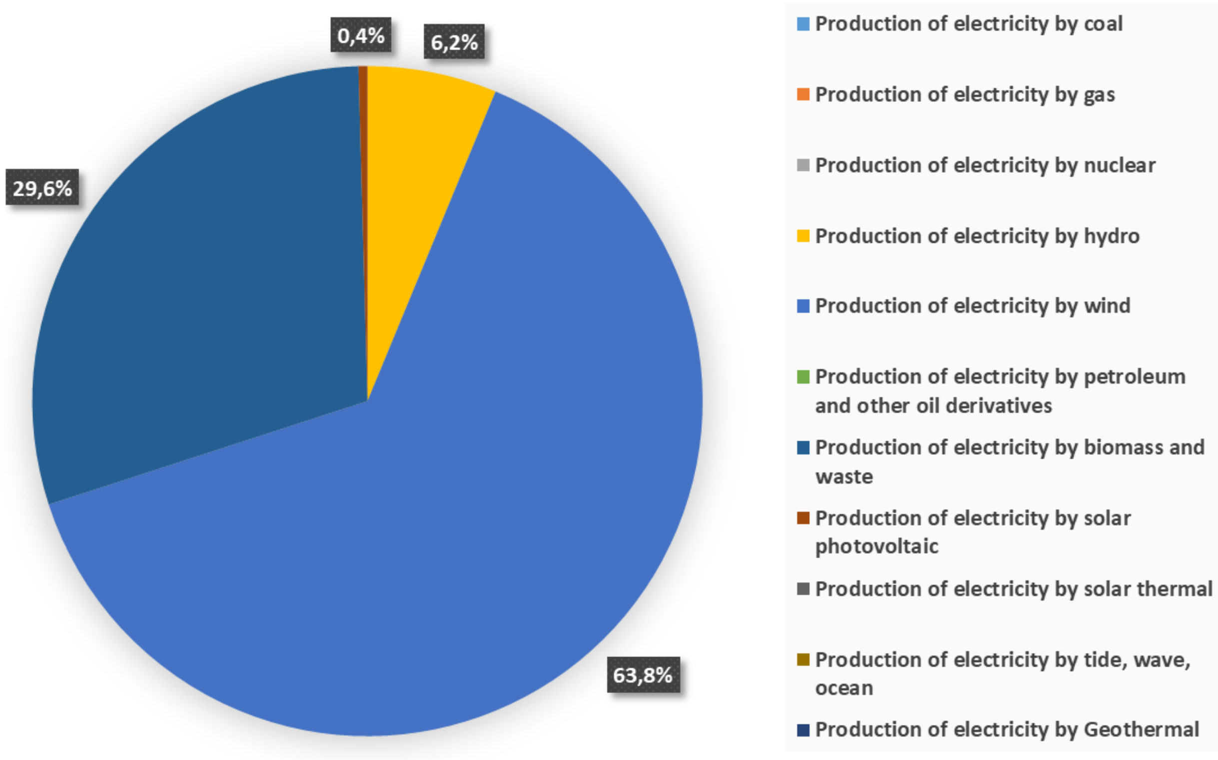

Figure 36 : Energy mix in production of electricity – Poland (projection 2050)

Source: Capros et al. 2016, adapted according to EXIOBASE v3 sectors with renewable energy sources scaled up to cover 100% of the production

In terms of overall employment effects, the renewable energy transition would mean gains both in the domestic as well as imported labour demand, in case of the former generating around 30 000 jobs, and same for the latter. Even though the domestic labour demand would decline first (until 2030), it would then grow up until 2050. This result confirms what was already clearly observable in the Czech case – that there is a big labour demand potential linked to the development of renewable energy in the coal-based economies, if the current labour-output ratio would be constant.

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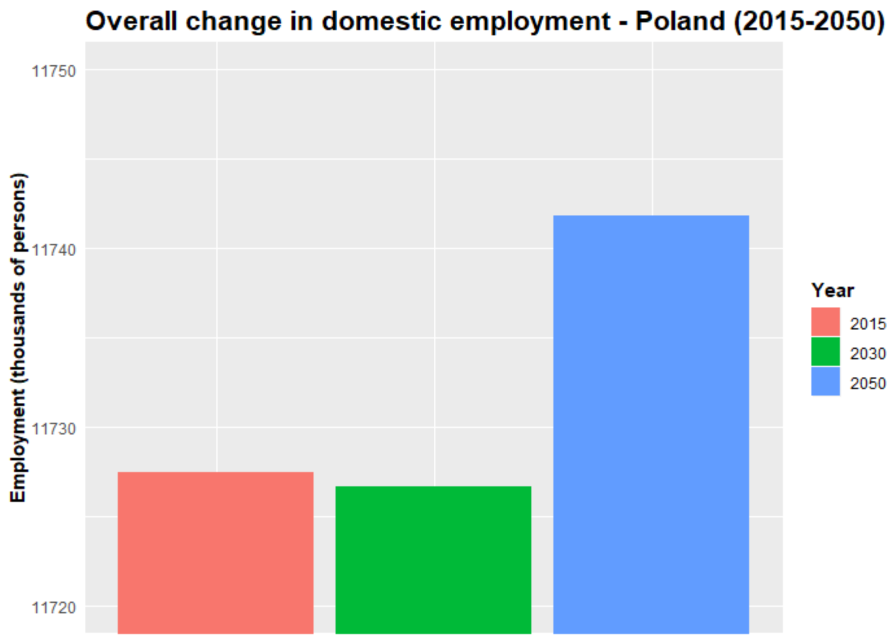

Figure 37: Overall change in domestic employment – Poland (2015-2050)

Source: EXIOBASE v3, own calculations

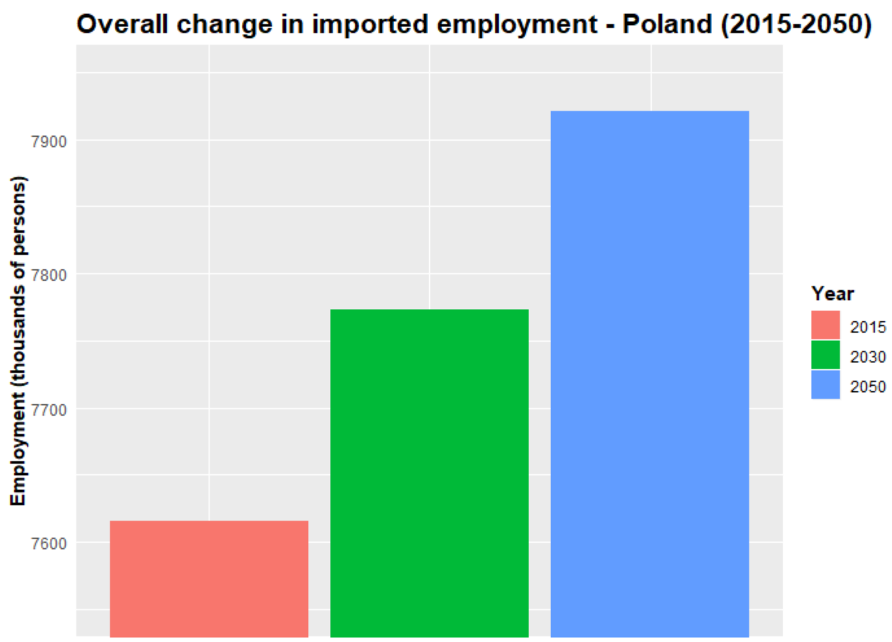

Figure 38: Overall change in imported employment – Poland (2015-2050)

Source: EXIOBASE v3, own calculations

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Again, gender and distributional skill levels follow the same pattern, both losses and gains being dominated by men-occupied sectors (except maybe partly of cultivation of crops). Interestingly, the female employment is almost missing among the losing sectors, showing a big gender imbalance in the Poland's current power sector.

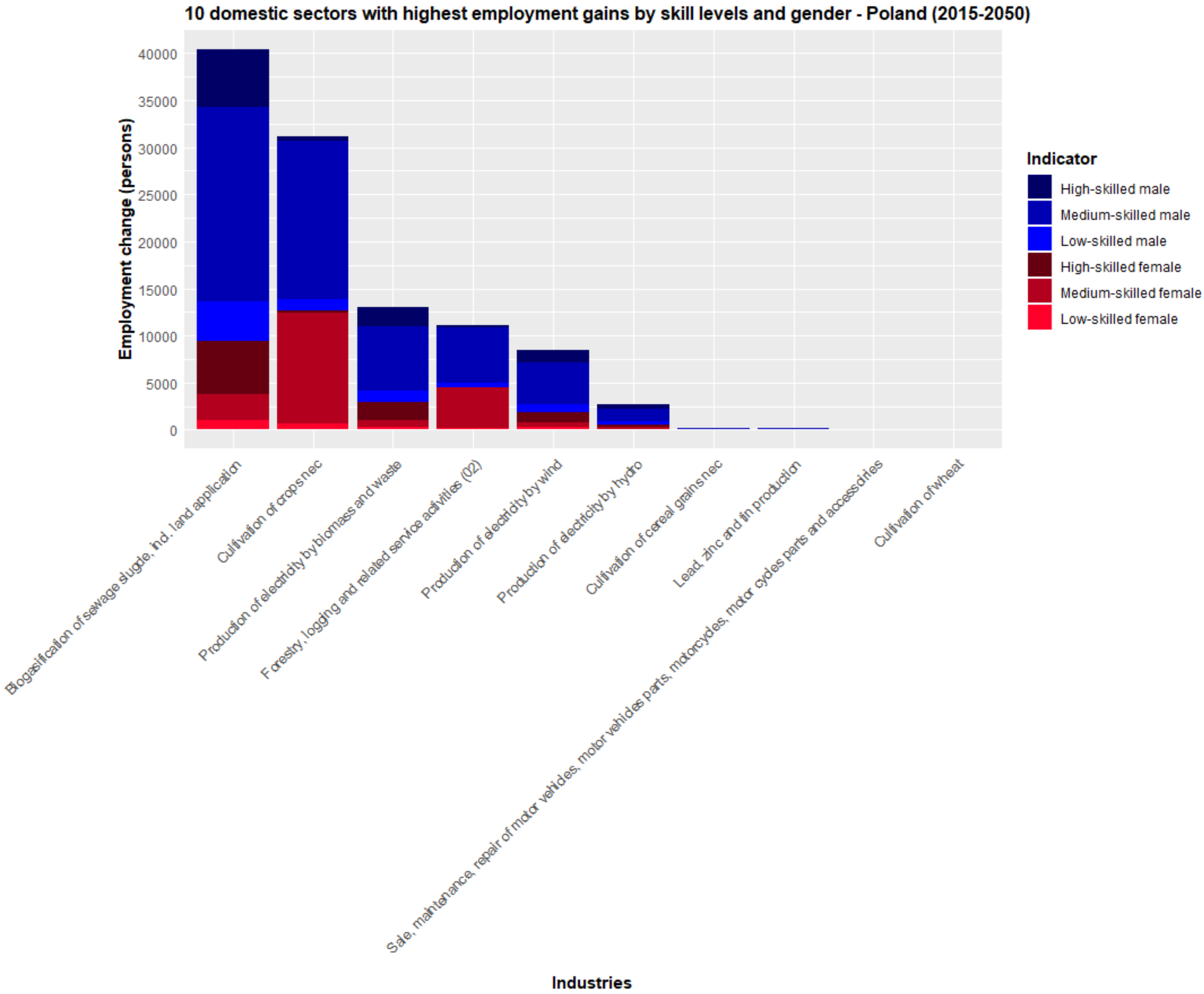

Figure 39: 10 domestic sectors with highest employment gains by skill levels and gender – Poland (2015-2050)

Source: EXIOBASE v3, own calculations

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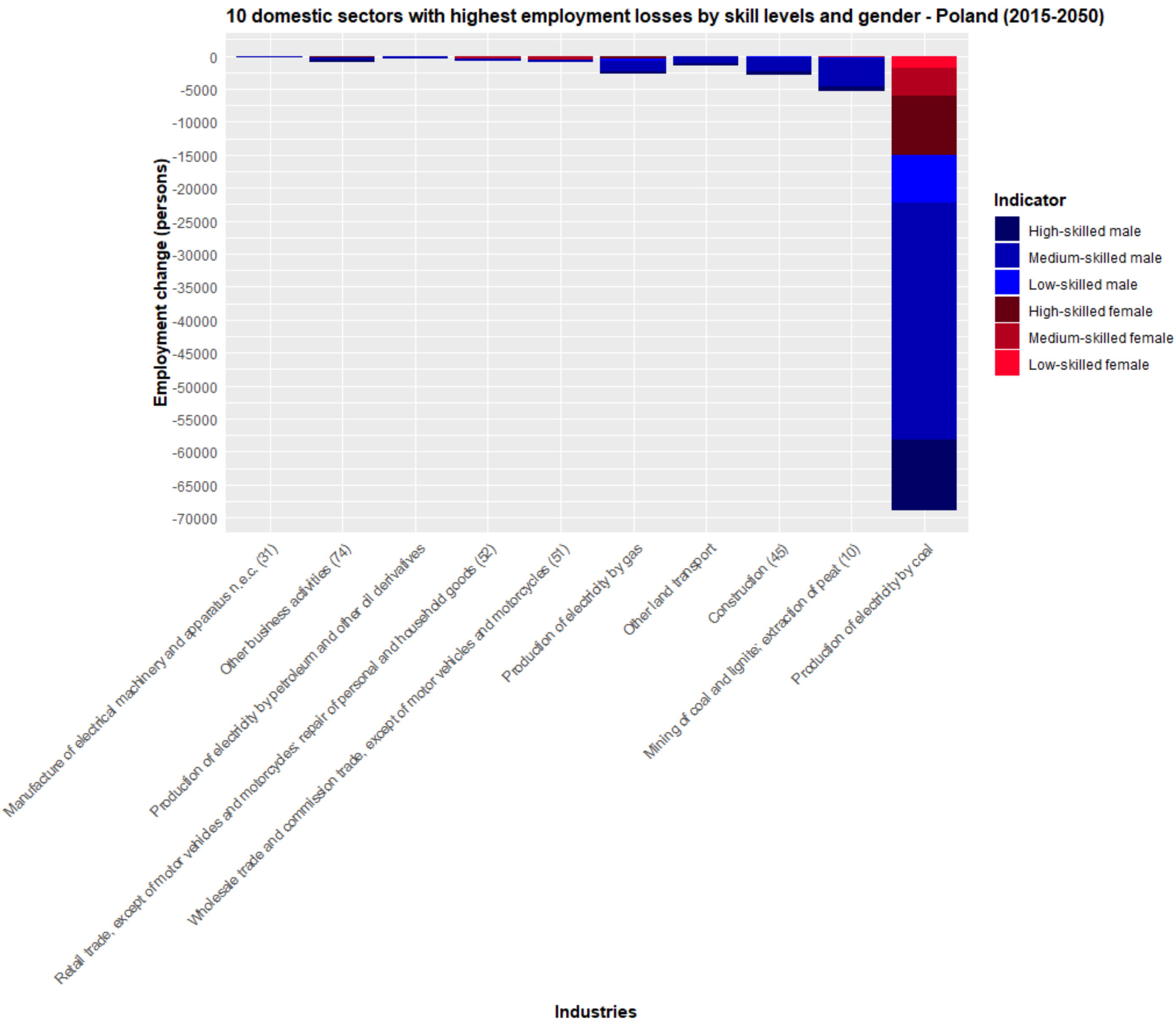

Figure 40: 10 domestic sectors with highest employment losses by skill levels and gender – Poland (2015-2050)

Source: EXIOBASE v3, own calculations

4.4.3 Bulgaria

Bulgaria has an energy mix structure very similar to the one of the Czech Republic. Bulgaria generates approx. 19% of its electricity from renewables with a majority of hydro power ("SHARES (Renewables) - Eurostat," 2019).

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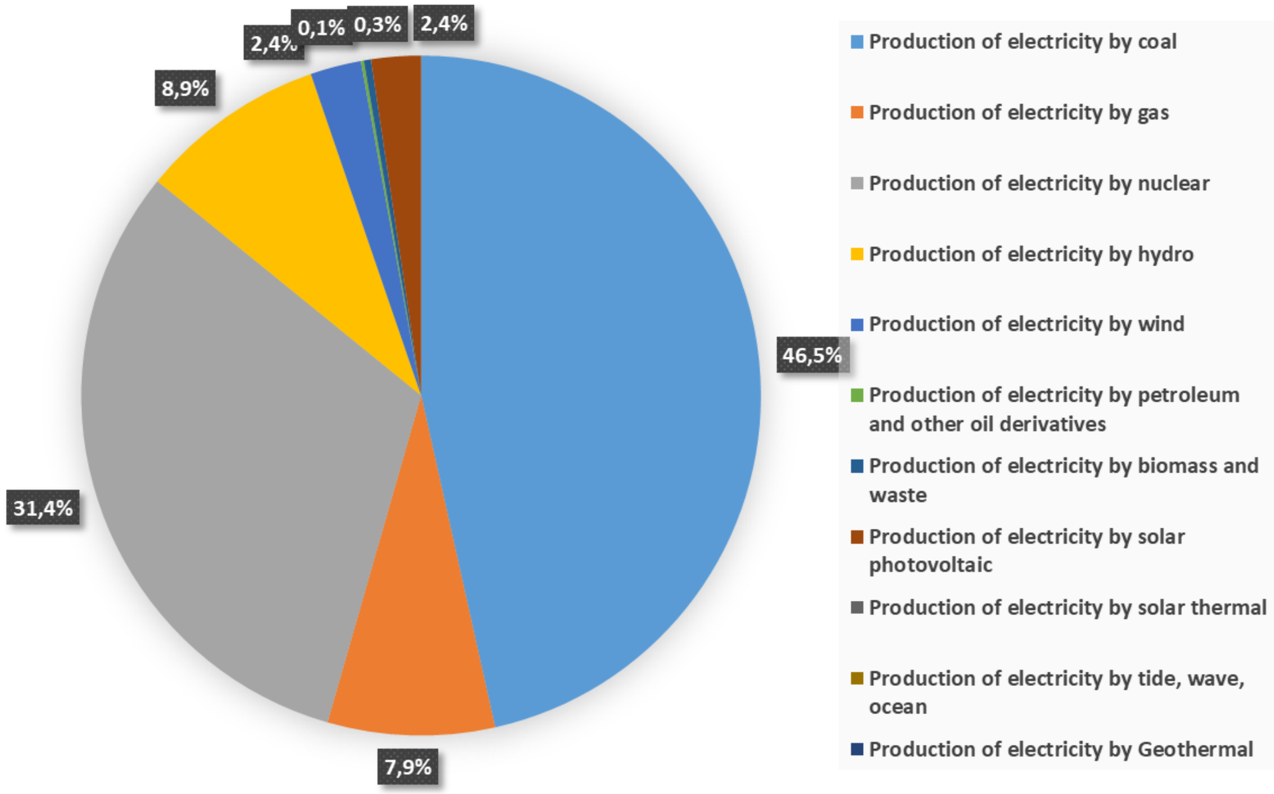

Figure 41 : Energy mix in production of electricity – Bulgaria (current 2015)

Source: Capros et al. 2016, adapted according to EXIOBASE v3 sectors with renewable energy sources scaled up to cover 100% of the production

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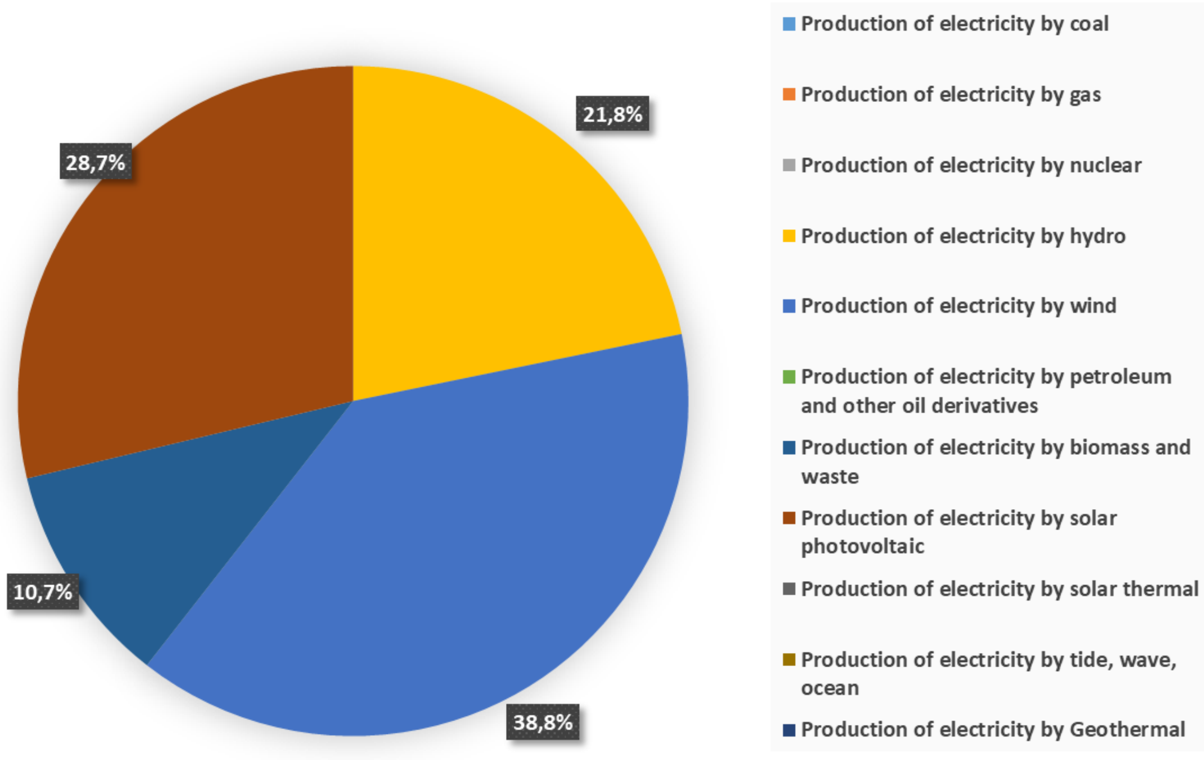

Figure 42 : Energy mix in production of electricity – Bulgaria (projection 2050)

Source: Capros et al. 2016, adapted according to EXIOBASE v3 sectors

The overall employment effects are somewhat ambiguous – domestically, a very moderate loss of jobs could be expected (falling from 1 866 000 to 1 863 000), while the imported employment would undergo an opposite pattern – growing slightly from 1 075 000 to 1 077 000, meaning probably that renewable energy sources require more imports from abroad than the current energy mix. This is in contrary with the results for the Czech Republic and Poland and may be due to the projected energy mix with a larger share of wind energy, which probably generates less job opportunities than biomass and waste, such as in the Czech case. Nevertheless, this does not correspond to the results for Poland, where wind is expected to cover majority (63.8%) of the electricity production and the calculation still expects job creation.

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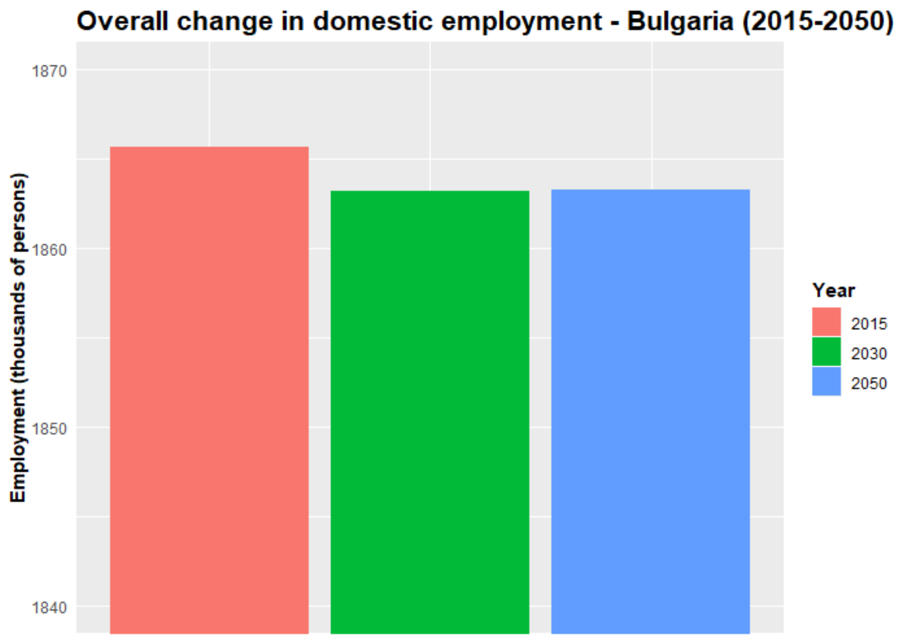

Figure 43: Overall change in domestic employment – Bulgaria (2015-2050)

Source: EXIOBASE v3, own calculations

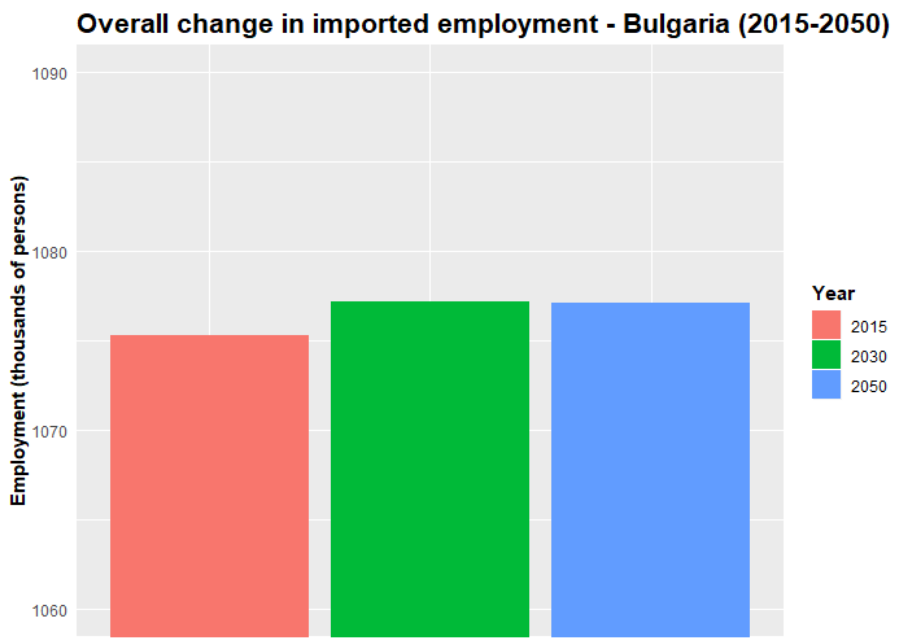

Figure 44: Overall change in imported employment – Bulgaria (2015-2050)

Source: EXIOBASE v3, own calculations

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The structure of distributional impacts, however, follows a similar pattern as the rest of the countries, with slightly less male domination in the sectors and more medium and low skilled labour required on both sides, winning and losing sectors.

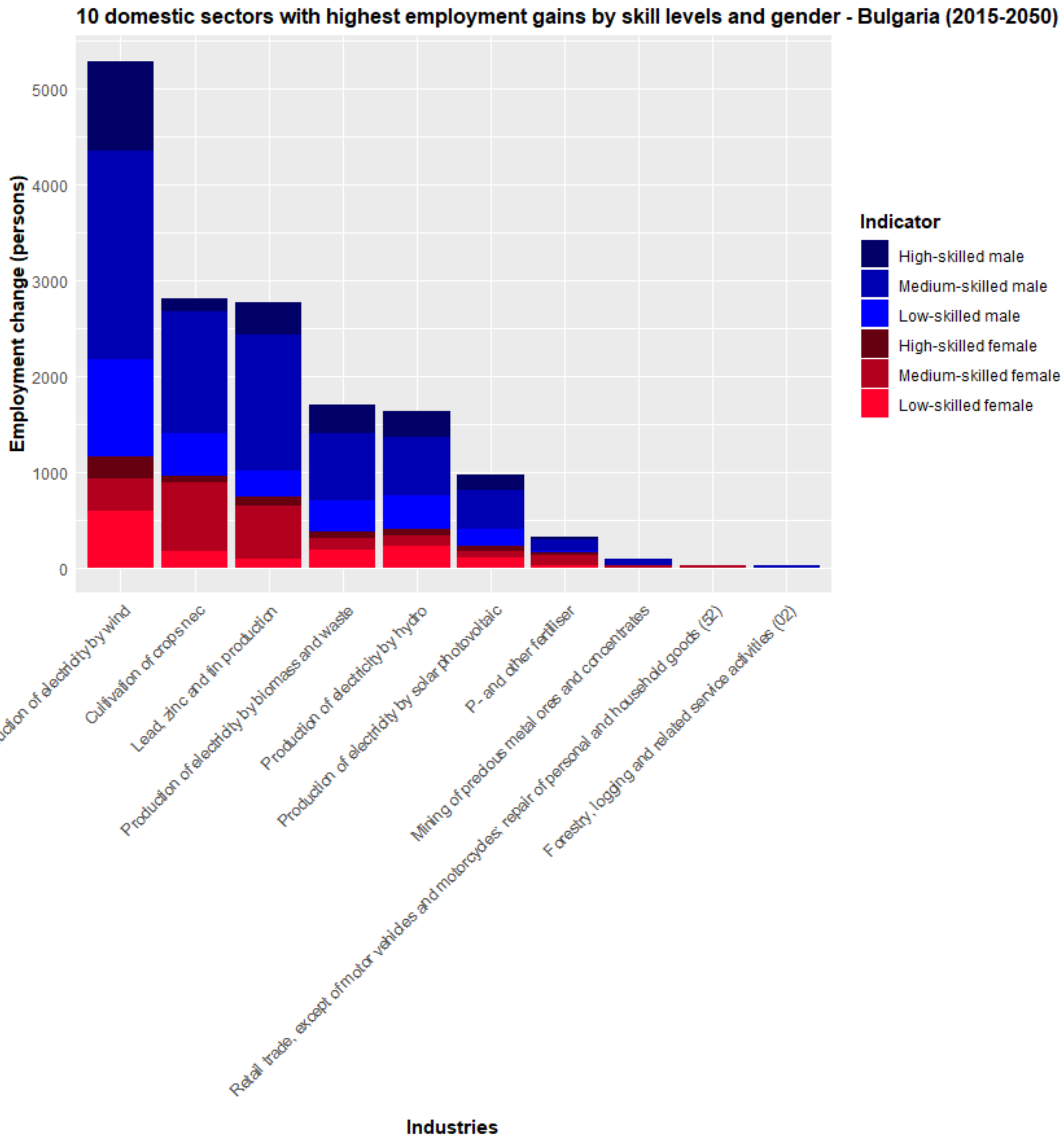

Figure 45: 10 domestic sectors with highest employment gains by skill levels and gender – Bulgaria (2015-2050)

Source: EXIOBASE v3, own calculations

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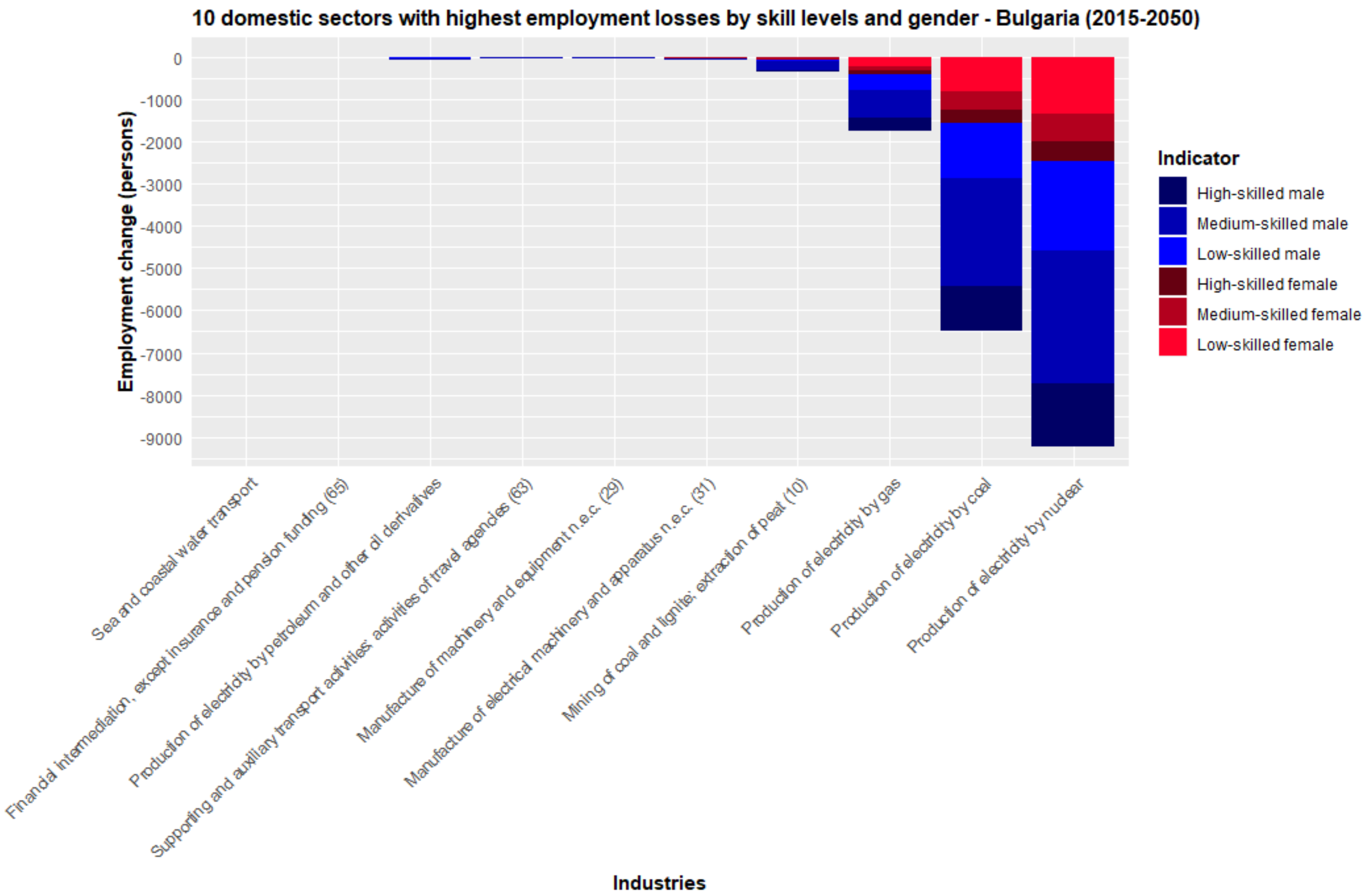

Figure 46: 10 domestic sectors with highest employment losses by skill levels and gender – Bulgaria (2015-2050)

Source: EXIOBASE v3, own calculations

4.5. Major social challenges of two coal-based economies

This analysis focuses on two major coal-based economies in the EU: Poland and Czechia. The analysis is comparative to show the differences and similarities of both countries.

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4.5.1 Coal in the energy mix of Czechia and Poland

There are two different categories of coal, hard coal and lignite. Lignite, or brown coal, is extracted in open-cast mines. Its quality – i.e. energy density, is lower than that of hard coal. Thus, it is usually used for heat and electricity generation in powerplants located close to mines, so called mine-to-mouth consumption. Hard coal, on the other hand, is extracted in underground mines, which makes it more labour-demanding and more expensive. Unlike lignite, hard coal is more energy dense and can be used for other purposes than just heat and electricity generation, for instance for metallurgy or for smelting. Hard coal is also internationally traded much more than lignite. The different labour demand intensities of hard coal and lignite may also explain some of the differential effects on labour demand in Poland and Czechia, respectively, as the following difference shows.

The energy mix in both countries is to a large extent dependent on coal, both hard coal and lignite. Although the share of coal is decreasing since the late 1980´s it still comprises 47% of installed capacity for 2017 for Czechia and 70% of installed capacity in 2018 for Poland, respectively. The share of lignite is more significant in Czechia than in Poland, where hard coal is the dominant resource (ERÚ, 2018; Macuk et al., 2019).

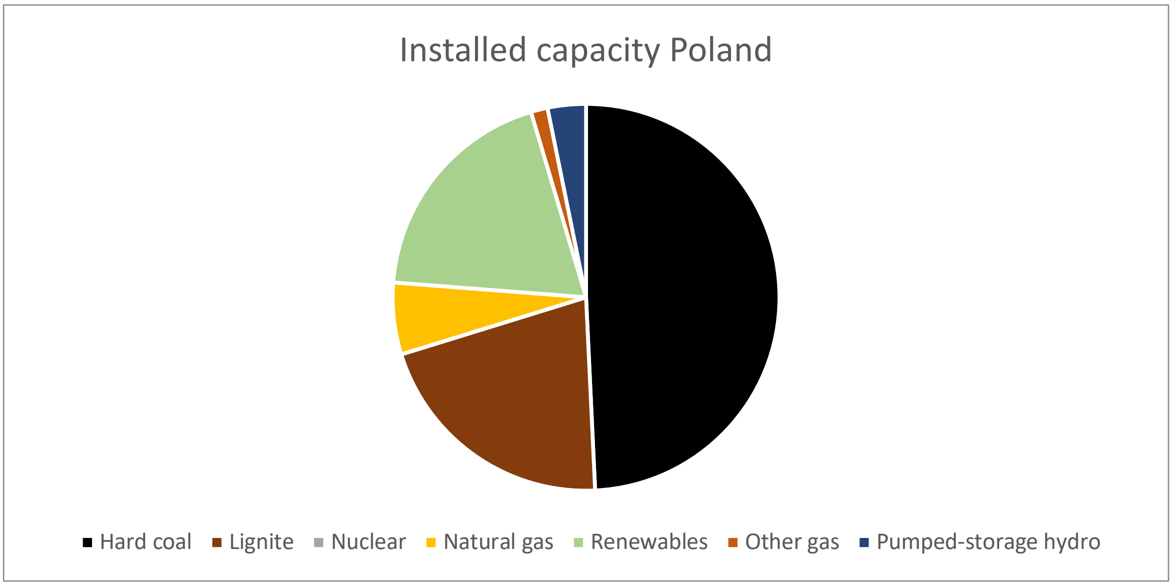

Figure 47: Installed capacity for Poland, adopted from Macuk et al., (2019)

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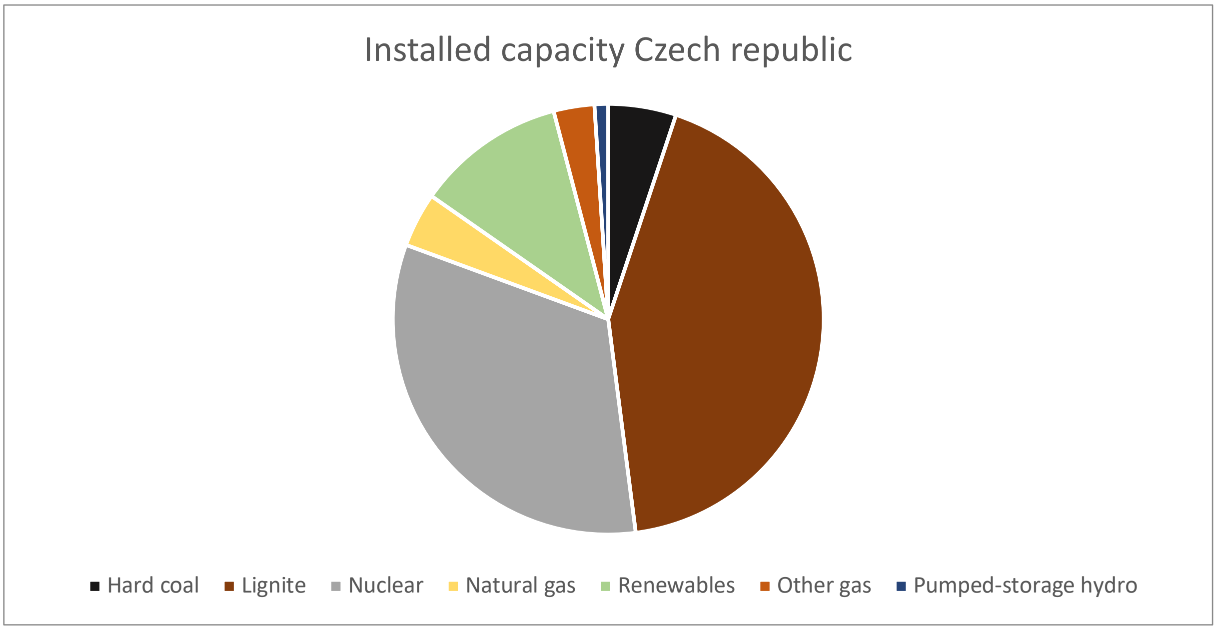

Figure 48: Installed capacity Czech Republic, adopted from ERÚ (2018)

Comparison of brown coal deposits in 2016	Poland	Czechia
Deposit total	91	51
Deposit exploited	8	10
Total mineral reserves (kt)	23385060	8729236
Economic prospected resources (kt)	12764100	2203911
Economic resources (kt)	9925800	2059859
Mine production (kt)	63060	38646

Table 4: Data adopted from (Czech Geological Survey, 2017) and (Szamalek and Tyminski, n.d.)

4.5.2 Economic indicators

Several economic indicators also show limitations for the further use of coal. Employment in lignite is decreasing in every company in both countries. In the Czech Republic it is an enormous (43%) decrease during the period from 2005 to 2016 (Danišová, 2017) and in Poland it meant a decrease from 388 000 down to 98 000 miners in the hard coal industry (Szpor and Ziolkowska, 2018). According to Patel et al. (2017) there is an annual coal subsidy of 115 Million EUR in the Czech

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Republic, whereas in Poland it is 920 Million EUR (van der Burgh, 2017). The European Union has launched a platform for coal regions in transition (European Commission, 2014). The aim of this platform is to enable a just transition, i.e. a socially just coal phase out, offering new economic opportunities. This platform is still relatively new but makes transition more likely to happen and to be socially accepted. In the Czech Republic there are three regions involved in a project called Re:start and in Poland the Silesia region is involved.

This is also expressed in the report by Greenpeace and Hnutí DUHA, where both organisations express the disbalances between royalties and dividends from the extracted resource. In the period from 2009 to 2016 four Czech lignite mining companies paid over 40 billion CZK in dividends to shareholders, which is more than they paid in personal costs (36 billion CZK), while royalties for that period only amounted to 1,7 billion CZK (Rovenský and Ceman, 2019).

The state energy policies of both countries are showing no clear plan for a coal phase-out, yet they recognise the decline of coal. In the Czech case the state energy policy counts with a decline of 11 to 21% share of coal in energy production (MPO, 2014), whereas in Poland the policy counts with 60% of electricity generation from coal (Ministry of Energy, 2018). A recent study conducted by Climate Action Network (CAN) Europe (Flisowska and Moore, 2019) shows this dissonance with both countries on the one hand involved in funding and supporting a just transition, while on the other hand they do not have any plan for a coal phase-out.

4.5.3 Social resistance to lignite mining

Environmental impacts of coal mining and coal combustion initiated civic resistance against current and even more against planned extensions or the opening of new mines. Given the fact that extractable deposits of lignite and coal are depleting, civic resistance effectively creates an additional burden to coal.

In every locality in both countries there was a certain act of resistance, be it participation in decision making processes (local elections and referenda), participation in legal procedures (environmental impact assessments), or protests. Most effective were the struggles when they were against opening new mines, or against expansion of current ones (because there are legal and effective ways to disagree with such plans, like local referenda, or Environmental Impact Assessment processes). In Czechia, the ČSA mine is going to be closed in 2024, also because of public pressure during negotiations of limits. Horní Jiřetín, a resisting town, is working on the transition to renewables. Regarding Poland the resistance is even more pronounced. An IEA report from 2016

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says: "Potential to increase production in existing mines is limited, and it is very difficult to open a new lignite mine and power plants in a new location because of the difficulties in obtaining public support/acceptance for such new open-cast excavation." This is interesting as both countries are among the few EU countries without a plan for a coal phase-out, yet there is significant domestic resistance against lignite projects (IEA, 2017; Vlček and Černoch, 2013).

The resistance to lignite mining in the North Bohemian Basin is described by Černoch et al. (2019). The authors identify three main narrative framings of the opposition: (1) local impact framing, (2) the low carbon transition framing and (3) an anti-system environmental frame. Especially the two latter narrative framings open up ways for acceptance of the low carbon transformation. Frantál and Nováková (2014) describe structural injustices connected with coal use in the affected regions. The authors refer to the uneven distribution of economic benefits and the "curse of coal". This includes higher unemployment rate versus higher than average income and pensions as well as environmental and health effects, including lower male life expectancy, higher infant mortality, and higher rates of abortion. Interestingly, the same authors also found that installed capacity of wind energy geographically correlates more with the installed capacity of coal energy than with realizable wind potential. They understand this as a confirmation of previous studies (Frantál and Kunc, 2011; Toke, 2005), indicating that attitudes of the local population in regions with industrial and environmental degradation are more positive towards renewable energy projects.

Badera and Pazderski (2017) provide a short list of local referenda concerning lignite mining in Poland, including the Gubin and Brody communes, the Legnica region, and the Babiak commune. All of them have 65-90% of disapproval in the population. The authors also register larger protests of farmers in the Miejska Gorka-Krobia commune against deployment of lignite mines. However, according to the authors, no large opposition in Zloczew indicates that the local population welcomes the idea of lignite exploitation. In 2017 a local civic association was established by local inhabitants endangered by opening of the mine, called "Nie dla odkrywki Zloczew" (No to open pit pine in Zloczew) (Sobczak, 2018). The mine would be a potential source for fuel to the powerplant Belchatów, the largest lignite-fired powerplant in Europe. Therefore, the activity of the local community could have a significant effect on the future of energy produced from lignite. The authors also provide a map of lignite reserves and conflicts connected to it. Their map is compared to the map from Euracoal, showing 5 regions where lignite is extracted. An updated Euracoal map is also showing that at least one civic response against lignite mining has been happening at every one of the five localities.

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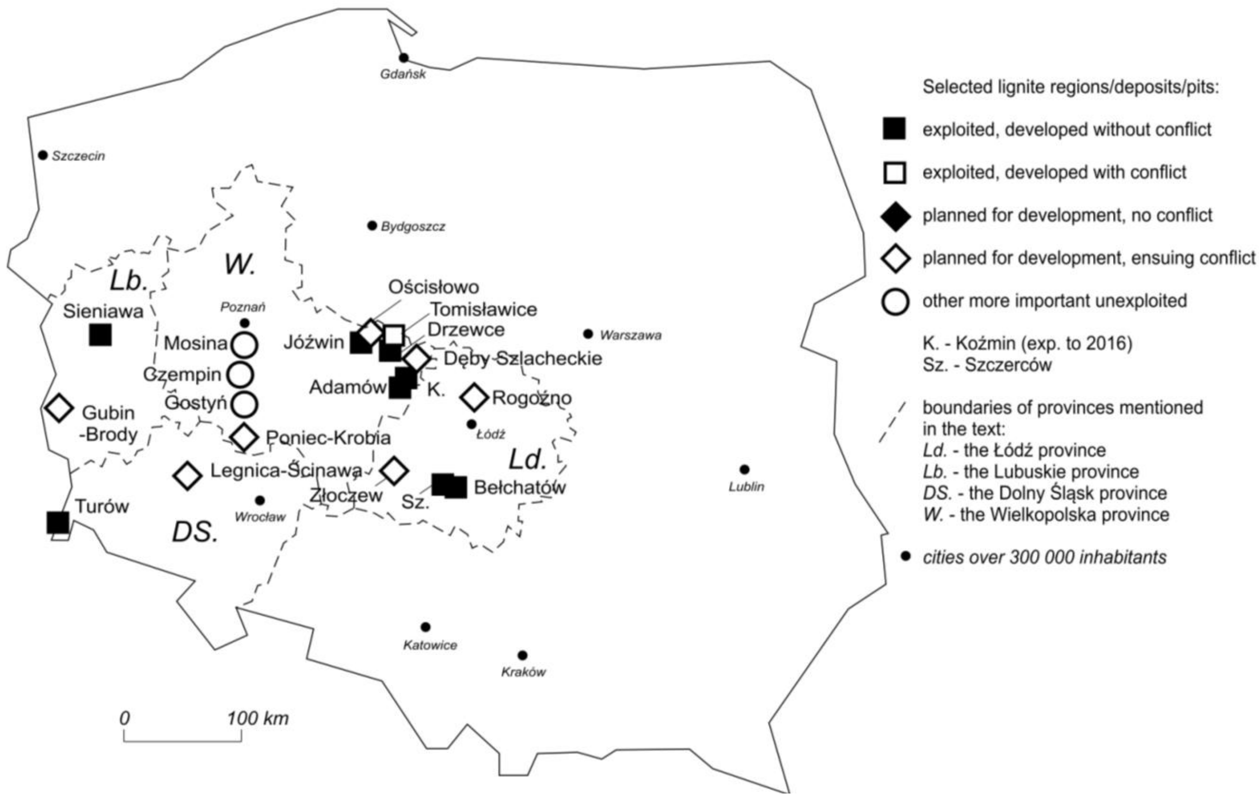

Figure 49: Map of lignite reserves and social conflict in Poland (Badera and Pazderski, 2017)

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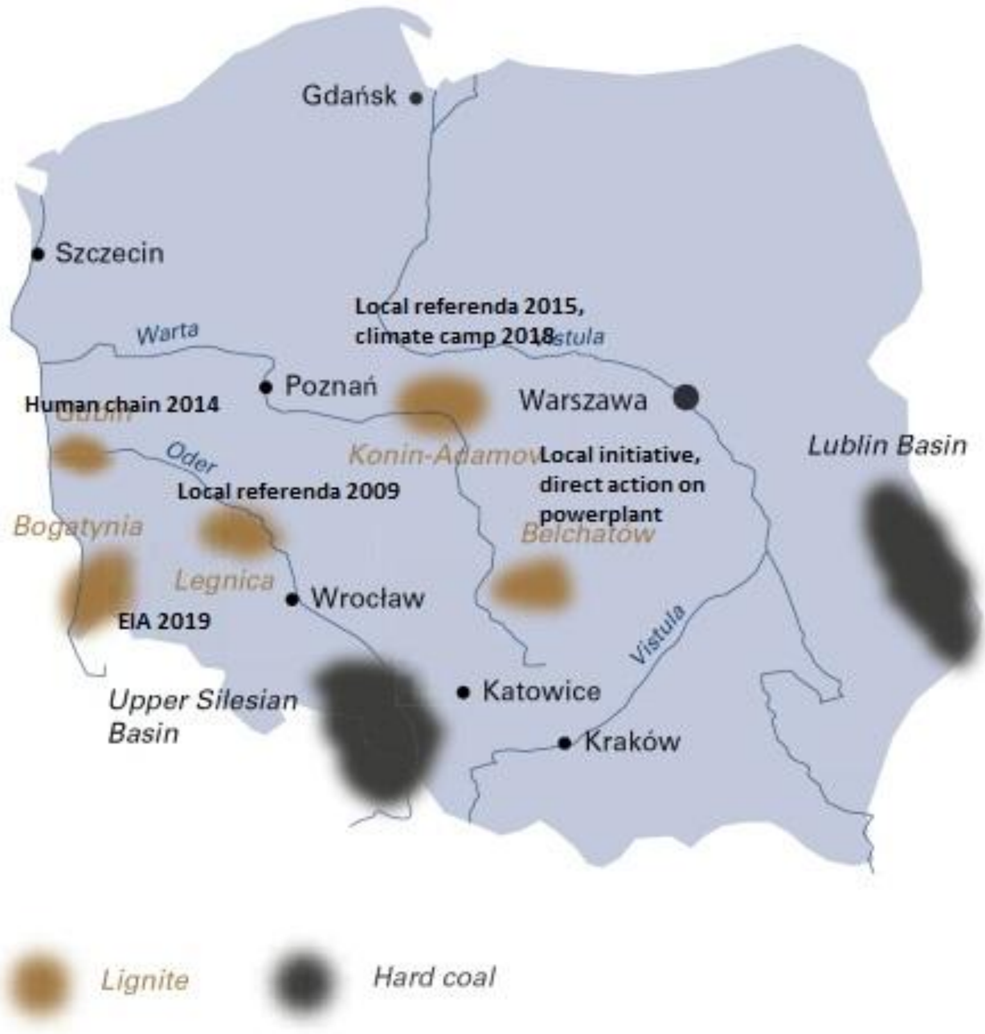

Figure 50: Map of coal reserves in Poland (Euracoal) updated with acts of resistance

A similar map showing reserves of lignite and hard coal in Czechia pictures three localities of lignite reserves. However, the location close to Brno is irrelevant. We also have to take into account that the North Bohemian Basin is by far the most important reserve. Therefore, there are also concentrated protest actions. However, also in the Sokolov Basin we can observe several civic acts against lignite production, such as those happening during the Miners day (“Sokolovská beseda - Příspěvky,” n.d.).

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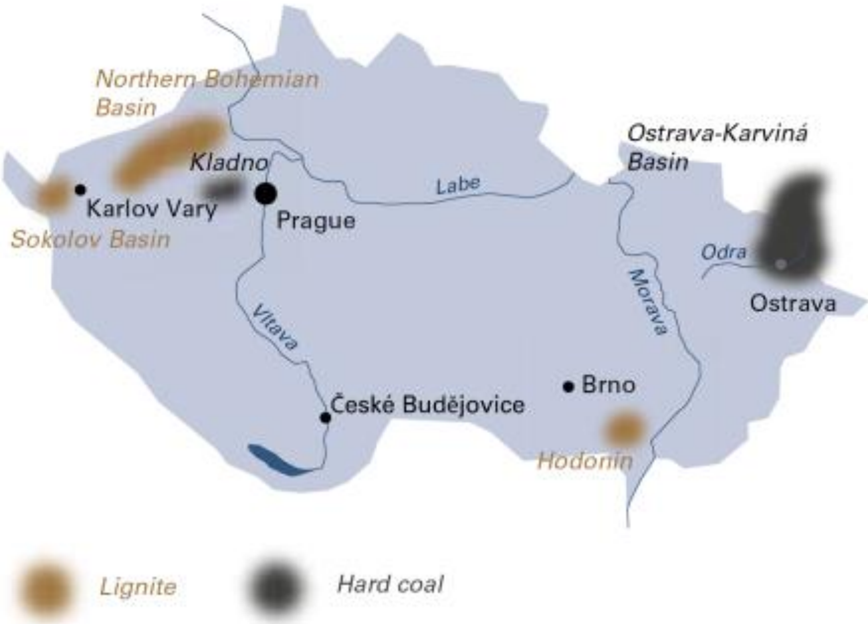

Figure 51: Map of coal reserves in Czech Republic (Euracoal)

Social resistance to coal mining can be seen for example in the involvement of civic society in various processes, for example for the Environmental Impact Assessment for Turów 4000 comments from the Czech side were signed (Greenpeace Česká republika, n.d.). Similar numbers have been documented concerning the expansion of the Bílina mine (Greenpeace Česká republika, 2018).

As this comparative analysis has shown in the context of this report, there is not only resistance against a transition towards a post-carbon society, but there is also significant public resistance against fossil fuel operations in particular against coal mining. This resistance may be underreported in some regions. Partly this may be due to strong vested interests and incumbencies in the fossil fuel industry which maintains good connections to high political ranks.

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5. Other social acceptance aspects related to renewable energy

A short description of the relevant social aspects for further consideration follows in this section. Whereas Chapter 4 focused exclusively on employment effects of the hypothetical 100% renewable energy transition (and associated requirements in labour and educational policy) as an example of adjustment assistance, Chapter 5 aims to provide a brief overview and a supporting guidance especially for the installation phase. Such approach takes into account that the transition to 100% renewable electricity system will require huge capital investments, resulting into series of installations and constructions of renewable energy power plants, as well as associated grid connections etc. Thus, in spite of growing demand for renewable energy, caused mostly by climate targets, the installation phase may become a barrier and a constraining factor for further installations of renewable energy power plants not only from the economic point of view (financial cost of the transition), but also from the social acceptance point of view.

In general, interest in social acceptance was triggered in recent decades with the triggered in renewable and low carbon energy technologies (Upham et al., 2015). Wüstenhagen et al. (2007b) provide a comprehensive introduction to the concept of social acceptance of renewable energy, to which we will stick most of the time in this chapter. In general, the authors, referring to the studies by McDaniel (1983) and Wolsink (1987), argue that there are four main issues related to the social acceptance of renewable energy. First, **support of key stakeholders** have to be taken into consideration. Second, **consistent and effective policies** need to be designed by the policy makers. Third, **roots of public attitudes** towards wind power (which, we believe, applies also to renewable energy in general) have to be mapped and understood. Fourth, the **ownership structure** (i.e. for example community owned or privately owned) of the new installations is a crucial issue for public acceptance of the renewable energy schemes.

In this chapter, we first focus on dimensions of social acceptance, to distinguish between various levels of support for versus opposition to renewable energy and installations of renewable energy infrastructures. Second, we provide an overview of specific aspects relevant for each source considered in the analysis above (in section 4): wind energy, solar photovoltaics, bioenergy, and hydropower. Note that in some case studies in Chapter 4, there is also geothermal energy listed, however, due to its limited potential for electricity production, we skip this source from our discussion here in this chapter.

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5.1. Dimensions of social acceptance

In general, the issue of public support for renewable energy has to take into account the specificities of renewable energy sources – smaller installations in more areas among the main factors, and therefore the need to address more communities (Wüstenhagen et al., 2007). The authors distinguish between three types of acceptance:

1. socio-political,
2. community, and
3. market acceptance (Wüstenhagen et al., 2007, p. 2683).

Figure 52 : Dimensions of renewable energy acceptance (Wüstenhagen et al., 2007)

5.1.1 Socio-political acceptance

Socio-political acceptance applies to the technologies and policies, and can be further divided into acceptance by 1) the public, 2) key stakeholders, 3) policy makers. It therefore includes factors such as societal acceptance of the renewable energy technologies by the broad public in general. The authors note that even though such "macro" acceptance might be high in societies, this may turn into low support when it comes to more "micro" level siting decisions, also known as the "not-in-my-backyard" (NIMBY) problems (e.g. Devine-Wright, 2011; van der Horst, 2007). At the level of key stakeholders and policy makers, this dimension considers factors such as comprehensive and

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transparent policy support, including economic incentives and support schemes that the investors can rely on.

5.1.2 Community acceptance

Community acceptance deals with the more detailed “micro” level of acceptance by local communities and stakeholders, and addresses issues such as procedural justice, distributional justice or trust between the key actors (Wüstenhagen et al., 2007). Community acceptance is also the level where NIMBY issues usually arise, in some cases even contrary to the otherwise positive attitudes towards renewable energy, as described above. According to the authors, factors playing a crucial role include fair distribution of costs and benefits (distributional justice), fair and participatory decision-making process (procedural justice), and mutual trust between the investors and other external actors and the community. Trust is also critical in value chain governance (Kimmich and Fischbacher, 2016). The NIMBY concept is further investigated by e.g. van der Horst (2007), who concludes that there are six additional factors influencing the acceptance of renewable energy projects (mostly referring to wind energy plants) with regards to their siting decisions.

First, it is the distance from the “source” which should be taken into account when measuring acceptance. Second, van der Horst (2007) suggests to consider the changes in attitudes during different stages of the planned project (before, during and after installation). Third, when researching the acceptance levels, the presence of passive versus active supporters/opponents and the strength of the voice they are given affects the results as well. Fourth, the focus on key opinion leaders might further influence the overall picture. Fifth, the general support for wind energy (in that case) regardless of the siting decision before the planning and installation process has to be considered too. Sixth, the presence of more seemingly “rational” rather than NIMBY arguments against the installation in the debate is the last issue that should be considered carefully in mapping community acceptance, according to van der Horst (2007).

Devine-Wright (2011) proposes more public engagement in creating energy transformation plans, in order to “break the cycle of NIMBYism”, arguing that the dichotomy of the views of seeing the large-scale renewable energy projects “either as ‘sites’ to be developed or ‘backyards’ to be avoided” (Devine-Wright, 2011, p. 23) should be overcome.

5.1.3 Market acceptance

Market acceptance refers to the acceptance by consumers, investors, or so-called “intra-firm” acceptance. In other words, it refers to the diffusion and adoption of market innovations. According

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to the authors, particularly when the consumers can easily switch the energy sources without being actively involved in the planning and installation processes, it is more a matter of green marketing and trading than of public and community acceptance. This dimension can be therefore seen as to some extent isolated from the two other dimensions explained above (Wüstenhagen et al., 2007, p. 2685). However, there are still links especially with socio-political acceptance. The more socio-political acceptance exists, the more likely market acceptance among consumers is, and vice versa: Green marketing may as well raise demand for renewable electricity and can indirectly also affect broad public acceptance of renewable energy.

Nevertheless, market acceptance can be also broadened to the investors' point of view. Such an approach can assess investor perceptions of regulatory risks and other uncertainties related to the investments in renewable energy technologies and infrastructures (Chassot et al., 2014b).

Another view embraces the concept of **prosumers**. Prosumers are, according to a definition by Parag and Sovacool (2016), "agents that both consume and produce energy", usually organised in community energy groups. Zafar et al. (2018, p. 1675) further clarify that prosumers are "consumers who also produce and share surplus energy with grid and other users. Prosumers are not only an important stakeholder of the future smart grids but also have a vital role in peak demand management." This concept is related to smart grid solutions and overlaps with one of the four key factors described by Wüstenhagen et al. (2007b), i.e. the ownership structure of energy sources. According to von Wirth et al. (2018), such micro-grid solutions, especially when locally co-owned and when the participants are aware of the local benefits of the system, have potential to help the transition efforts. The authors give examples of developing renewable energy technologies such as community owned wind energy or cooperatively managed hydropower systems (von Wirth et al., 2018, p. 2625). Van der Schoor and Scholtens (2015) also add that "renewable energy production offers opportunities for the local governance of energy production, in contrast to the much more centralized conventional energy production". Similarly, Seidl et al. (2019) argue that the so-called "distributed energy systems" approaches with localized scale of production and provision are a promising concept for promoting renewable energy deployment.

Finally, Wüstenhagen et al. (2007b) also highlight that there are companies with significant path dependency and ingrained procedures, when it comes to the management of the power system as well as new installations. These **"corporate cultures"** are important to address, according to the authors, since especially the big companies are also usually the key players and stakeholders in the energy policy of the states. Whether they oppose or support the transition is therefore a matter of

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careful intra-firm changes in the companies' strategies and policies, guided by the macroeconomic frameworks given by the state.

5.2. Some specific challenges to the social acceptance of different renewable energy sources

Since most of the factors influencing social acceptance are shared among the various renewable energy sources, such as many rather small installations (compared to coal or even nuclear power plants), we briefly stress some of the recommendations provided by different case studies, trying to distinguish between specific obstacles for each of the considered source. We focus on those sources which we assume to take over electricity production and replace the non-renewable energy sources: wind energy, solar photovoltaics, biomass and biogas for electricity production, and hydropower energy.

Bronfman et al. (2012, p. 246) find in their study using a trust-acceptability validation model that, in general, "social acceptance of an energy source is directly caused by perceived risk and benefit and also by social trust in regulatory agencies (both directly and indirectly, through perceived risk and benefit)". This also answers the usual NIMBY problems – if the risk perception is too high and the expected benefits too low, the community level of social acceptance is clearly very low.

Regarding wind energy, Wüstenhagen et al. (2007b) state that the rapid growth in installations of wind energy created some tensions in terms of social acceptance, respectively local resistance to new wind turbines installations. Especially the large-scale wind farm projects often lead to public opposition characterized as the NIMBY protests (Devine-Wright, 2011). However, the opposition is not constrained to wind power plants nor new to the energy sector in general, since there have been already long existing disputes over nuclear waste storage or, for example, hydropower dam constructions. A comprehensive study of barriers to wind energy installations as well as conditions for their acceptance is provided e.g. by Scherhaufer et al. (2018). Höltinger et al. (2016) in their case study of Austria also stress possible existence of significant disagreements between key stakeholders, regarding the scope of future deployment of wind energy – a factor which is, however, present for almost all renewable energy sources. The technological potential for installations should therefore not be confused with the socio-political potential.

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Hydropower dams are specific for their usually large(r) size, compared to other renewable energy sources. But it is not only the size what matters – the suitable locations are, according to Sternber (2008, p. 1609), often "drawn indirectly into the spatial reorganization of the social order" related to changes in land use, or breaking fish fauna mobility (Samadi-Boroujeni, 2012). Especially the need for resettlement usually results in some kind of public opposition and conflicts (Samadi-Boroujeni, 2012, p. 31).

Lobaccaro et al. (2019) in their study about the potential of solar photovoltaic energy conclude that "ad-hoc analyses (e.g. solar potential, daylight, energy) should be conducted throughout the different stages of the planning process taking into account multiple design and energy implications" in order to enhance the dialogue and the participatory manner of the installation phase of solar PV projects. According to McCormick (2010, p. 494), who discusses the social acceptance of bioenergy, there are several crucial issues influencing the legitimacy of an energy source (in this case bioenergy): "land use, greenhouse gas emissions, food security, international trade, and labour conditions". In addition, Wüste and Schmuck (2013) mention lack of information about the (bioenergy, but we believe that this factor also applies to all the other sources) projects as a key obstacle for public support.

6. Conclusions: Policy implications in terms of labour policies and employment structures

We have focused our analysis on labour demand effects and labour skills in relation to energy intensity. Labour demand has been found to be a critical bottleneck in the transformation. This requires education policies to anticipate upcoming demand. Even though the overall labour demand is expected to decrease, the transition still implies significant restructuring in the power sector as well as in the energy sector in total, resulting in different demands for training. Furthermore, labour skills are not only relevant to enable the adoption of renewable energies, but also important to increase energy efficiency and reduce energy intensity in the broader economy, including a number of energy-intensive industries.

The analysis has been based on input-output models of the transition, with impact analyses on labour demand as well as gender effects and skill levels required for the transition. The conclusions also build on econometric analyses of skill level effects on sector-level energy intensities. The policy

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conclusions have been embedded in a broader transition framework. We highlight the relevance of structural adjustment assistance as a forward-looking, albeit narrow transition policy frame. This includes education assistance, as well as public goods provision for skill development.

The MEDEAS model family uses an input-output structure to capture the interrelations between sectors, building on WIOD. This analysis builds on EXIOBASE v3, which provides a highly disaggregated electricity sector. This is fundamental to derive labour demand results when the composition of the electricity sector changes towards renewable energies. We show that, due to the underlying input-output structure, the MEDEAS model family can be used to evaluate labour demand impacts and skills effects. This provides a quantitative indicator to reflect social policy implications. The effects of labour skills on sector-level energy intensity could be endogenized in future stages of model development.

The EU 2020 strategy (e.g. Eurostat, 2018) speaks about the complementarity of the employment and energy transformation goals as well. According to it, “[the goals] are interrelated and mutually reinforcing” in terms that “educational improvements help employability and reduce poverty”, “R&D/innovation and more efficient energy use makes us more competitive and creates jobs”, and “investing in cleaner technologies combats climate change while creating new business or job opportunities” (European Commission, n.d.). “European social policies aim to promote employment,” states also the Eurofond on its website (European Foundation for the Improvement of Living and Working Conditions, 2019). The social policies of the EU are motivated by “technological progress, globalisation and an ageing population” (EUR-Lex, n.d.), and aim to promote employment, sustainable (economic) growth and greater social cohesion (EUR-Lex, n.d.). Specifically, the policies cover for example equal opportunities (Publications Office of the European Union, 2018), but also appropriate skills for the changing labour markets. Our analysis provides an information about the expected trends in labour demand at the sectoral level. We tried to distinguish the changes in employment patterns induced by the renewable energy transition itself from the other effects, in order to see in which direction these changes contribute to the modifying labour market. Therefore, our analysis in section 4 does not calculate with effects of economic growth (which could possibly boost the job gains), nor any other factors that could possibly influence the overall labour demand effects, such as working time reduction, work automation, changes in labour supply (changes in demographic structure of the population), or, for example, changes in production patterns in the renewable power sectors.

Our analysis in section 4 tried to shed light on compatibility of the EU climate and energy targets (if they would come as a 100% renewable power sector) with the Union’s goals regarding employment

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and labour policy. Whereas in the case of “early adopters”, the continued transition to renewable energy would usually mean some employment losses (at least domestically), in case of coal-based economies, there is a potential to generate more jobs through the renewable energy transition. The comparison of Poland and Czechia indicates that even though both countries are depending largely on coal and are not having a contingent governmental plan for coal phase-out, the coal industry is facing decline. The costs of coal use as well as environmental impacts are some of the reasons for growing social opposition. Especially lignite mining at certain locations is contested by social resistance in various forms and thus makes future prospects of lignite mining limited. Programs supporting the transition of coal regions at the European level have been introduced in both countries relatively recently, which could create opportunities for growing public acceptance of the transition.

Concerning the gender and labour skill effects, we find that in all analysed countries, there was a clear prevalence of men in the electricity-related sectors on both sides – gaining and losing sectors usually comprised by 2/3 of male employment. The situation is usually balanced for medium and high skilled labour, with low skilled labour making only minor part of the effects, which is probably mostly because of the low presence of this group throughout the analysed economies.

While this may sound as good news for generating new jobs, the results have to be interpreted with caution, since there may be significant economies of scale, if wider deployment of renewable energy sources would take place in the coal-powered countries such as Czechia, Poland or even in Bulgaria. This may result in much lower gains or even losses, such as in the case of the advanced countries as e.g. Austria. The results are also contingent on the energy mix that can be expected in such countries, since scaling up the reference scenario is only a hypothetical case. Taking the existing scenarios of each country implies strong assumptions in some cases, such as covering a significant part of renewable electricity production from biomass and biogas in the Czech Republic (47%). It is uncertain whether this share of bioenergy can actually be realized.

It would be further necessary to track employment changes at a more detailed, regional level (where the jobs would be created and where lost), which could only be achieved either through a different method, or through enhancing the scope of the input-output databases to capture the inter-regional flows, not only inter-country ones. Integrating assumptions about future developments of the labour-output ratio (e.g. due to economies of scale in case of increased production levels versus multiplication effects of the sectors’ development), which is now kept constant, would help to make the results more solid. Furthermore, the potential to requalify the labourers in the “threatened” sectors is a crucial topic to address by further analyses, so this can be fully taken into account by

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policy-makers. Last but not least, distinguishing between the employment effects caused by building renewable energy infrastructures and operating the sources would make the analysis more precise, but would require considerable extensions of the model.

Regarding the links to the European social policies, the analysis helps to track expected changes in employment related to the increased share of renewable energy sources, especially with regard to equal opportunities (European Commission, 2018). However, we find that – at least in the analysed countries – even renewable energy adoption does not bring significant changes in equal opportunities by gender. The overall effect is ambiguous. While in the coal-based countries, promotion of the renewable energy brings about more employment, in the case of "early adopters", there are job losses expected. It is not possible to conclude whether the adoption of more renewable energy also helps to pursue the employment goals of the EU social policy, especially the target of 75% people aged 20-64 to be at work (European Commission, 2010). This would have to be further compared to population projections. As such, the assumption that "clean technologies bring about more employment", present in the EU strategy, cannot be unequivocally related to the renewable energy transition.

However, the demands of the renewable energy transition for high- and medium- skilled labour are clearly in line with Europe's 2020 strategy goal to promote higher education. Moreover, the call for supporting skills development (European Commission, 2013) is also mutually coherent with the qualification requirements for the transition to 100% based renewable electricity production.

Education policies that take into account coordination between industries and education, such as in vocational education and training (VET), may be especially fruitful to enable renewable energy adoption while simultaneously improving energy intensity across industries. Building on the Council conclusions (European Commission, 2009) and the progress report (European Commission, 2015), emphasizing the multi-dimensional importance of collaboration on VET, we suggest, in addition to balancing the strong gaps in some countries, a focus on education for renewable energy adoption, to anticipate increased expected sector-specific labour demand.

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References

(1) Sokolovská beseda - Příspěvky [WWW Document], n.d. URL https://www.facebook.com/1833132733598838/photos/a.1833657416879703/2222082234703884/?type=3&theater (accessed 6.12.19).

Aklin, M., Urpelainen, J., 2013. Political Competition, Path Dependence, and the Strategy of Sustainable Energy Transitions. Am. J. Polit. Sci. 57, 643–658. https://doi.org/10.1111/ajps.12002

Amable, B., 2016. Institutional complementarities in the dynamic comparative analysis of capitalism. J. Institutional Econ. 12, 79–103.

Arent, D., Zinaman, O., 2017. The political economy of clean energy transitions. Oxford University Press.

Arto, I., Dietzenbacher, E., 2014. Drivers of the Growth in Global Greenhouse Gas Emissions. Environ. Sci. Technol. 48, 5388–5394. https://doi.org/10.1021/es5005347

Autio, E., Webb, R., 2015. Engineering growth: enabling world-class UK entrepreneurship in the low-carbon economy. Available SSRN 2609726.

Badera, J., Pazderski, L., 2017. Effects of lignite surface mining on local communities: controversies and areas of negotiation. Environ. Amp Socio-Econ. Stud. 5, 31–39. https://doi.org/10.1515/environ-2017-0014

Batel, S., Devine-Wright, P., Tangeland, T., 2013. Social acceptance of low carbon energy and associated infrastructures: A critical discussion. Energy Policy 58, 1–5. https://doi.org/10.1016/j.enpol.2013.03.018

Bronfman, N.C., Jiménez, R.B., Arévalo, P.C., Cifuentes, L.A., 2012. Understanding social acceptance of electricity generation sources. Energy Policy 46, 246–252. https://doi.org/10.1016/j.enpol.2012.03.057

Capros, P., De Vita, A., Tasios, N., Siskos, P., Kannavou, M., Petropoulos, A., Evangelopoulou, S., Zampara, M., Papadopoulos, D., Nakos, C., Paroussos, L., Fragiadakis, K., Tsani, S., Karkatsoulis, P., Fragkos, P., Kouvaritakis, N., Höglund Isaksson, L., Winiwarter, W., Purohit, P., Gomez Sanabria, A., Frank, S., Forsell, N., Gusti, M., Havlik, P., Obersteiner, M., Witzke, H.P., Kesting, M., 2016. EU Reference Scenario 2016 - Energy, transport and GHG emissions Trends to 2050. [WWW Document]. URL https://ec.europa.eu/energy/sites/ener/files/documents/REF2016_report_FINAL-web.pdf (accessed 12.7.18).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691287

Cella, G., 1984. The Input-Output Measurement of Interindustry Linkages. Oxf. Bull. Econ. Stat. 46, 73–84. https://doi.org/10.1111/j.1468-0084.1984.mp46001005.x

Černoch, F., Lehotský, L., Ocelík, P., Osička, J., Vencourová, Ž., 2019. Anti-fossil frames: Examining narratives of the opposition to brown coal mining in the Czech Republic. Energy Res. Soc. Sci. 54, 140–149. https://doi.org/10.1016/j.erss.2019.04.011

Ćetković, S., Buzogány, A., 2016. Varieties of capitalism and clean energy transitions in the European Union: When renewable energy hits different economic logics. Clim. Policy 16, 642–657. https://doi.org/10.1080/14693062.2015.1135778

Chassot, S., Hampl, N., Wüstenhagen, R., 2014a. When energy policy meets free-market capitalists: the moderating influence of worldviews on risk perception and renewable energy investment decisions. Energy Res. Soc. Sci. 3, 143–151.

Chassot, S., Hampl, N., Wüstenhagen, R., 2014b. When energy policy meets free-market capitalists: The moderating influence of worldviews on risk perception and renewable energy investment decisions. Energy Res. Soc. Sci. 3, 143–151. https://doi.org/10.1016/j.erss.2014.07.013

Cohen, J.J., Reichl, J., Schmidthaler, M., 2014. Re-focussing research efforts on the public acceptance of energy infrastructure: A critical review. Energy 76, 4–9. https://doi.org/10.1016/j.energy.2013.12.056

Czech Geological Survey, 2017. Mineral commodity summaries of the Czech republic 2017. Ministry of Environment of the Czech republic.

Danišová, I., 2017. Za 25 let poklesla těžba uhlí o více než polovinu. Stat. My 2017.

Devine-Wright, P., 2011. Public engagement with large-scale renewable energy technologies: breaking the cycle of NIMBYism. Wiley Interdiscip. Rev. Clim. Change 2, 19–26. https://doi.org/10.1002/wcc.89

Energy consumption in Bulgaria [WWW Document], n.d. . Worlddata.info. URL https://www.worlddata.info/europe/bulgaria/energy-consumption.php (accessed 6.21.19).

ERÚ, 2018. Roční zpráva o provozu ES ČR 2017. Energetický regulační úřad, Praha.

EUR-Lex, n.d. Employment and social policy [WWW Document]. Employ. Soc. Policy. URL https://eur-lex.europa.eu/summary/chapter/employment_and_social_policy.html?root_default=SUM_1_CODED=17 (accessed 6.26.19).

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691287

European Commission, 2015. Joint Report of the Council and the Commission on the Implementation of the Strategic Framework for European Cooperation in Education and Training (ET (2020). Off. J. Eur. Union 100, 25–35.

European Commission, 2014. Coal regions in transition [WWW Document]. Energy - Eur. Comm. URL https://ec.europa.eu/energy/en/topics/oil-gas-and-coal/coal-regions-in-transition (accessed 6.6.19).

European Commission, 2013. Towards Social Investment for Growth and Cohesion-Including Implementing the European Social Fund 2014-2020: Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Publications Office of the European Union.

European Commission, 2010. Europe 2020: A strategy for smart, sustainable and inclusive growth: Communication from the commission. Publications Office of the European Union.

European Commission, n.d. Europe 2020 strategy [WWW Document]. Eur. Comm. - Eur. Comm. URL https://ec.europa.eu/info/business-economy-euro/economic-and-fiscal-policy-coordination/eu-economic-governance-monitoring-prevention-correction/european-semester/framework/europe-2020-strategy_en (accessed 6.24.19).

European Commission, E., 2018. Council Decision (EU) 2018/1215 of 16 July 2018 on guidelines for the employment policies of the Member States. Off. J. Eur. Union.

European Commission, E., 2009. Council conclusions of 12 May 2009 on a strategic framework for Europe-an cooperation in education and training (‘ET 2020’). Off. J. Eur. Union.

European Foundation for the Improvement of Living and Working Conditions, 2019. Social policies [WWW Document]. Soc. Policies. URL https://www.eurofound.europa.eu/topic/social-policies (accessed 6.25.19).

Eurostat, 2018. Smarter, greener, more inclusive? — Indicators to support the Europe 2020 strategy — 2018 edition [WWW Document]. URL https://ec.europa.eu/eurostat/web/products-statistical-books/-/KS-02-18-728 (accessed 6.26.19).

Feng, K., Hubacek, K., Liu, Y., Marchán, E., Vogt-Schilb, A., 2018. Managing the distributional effects of energy taxes and subsidy removal in Latin America and the Caribbean. Appl. Energy 225, 424–436. https://doi.org/10.1016/j.apenergy.2018.04.116

Flisowska, J., Moore, C., 2019. Just Transition or Just Talk? Climate Action Network Europe.

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 691287

Foxon, T.J., Gross, R., Chase, A., Howes, J., Arnall, A., Anderson, D., 2005. UK innovation systems for new and renewable energy technologies: drivers, barriers and systems failures. Energy Policy 33, 2123–2137.

Frantál, B., Kunc, J., 2011. Wind turbines in tourism landscapes. Ann. Tour. Res. 38, 499–519. https://doi.org/10.1016/j.annals.2010.10.007

Frantál, B., Nováková, E., 2014. A curse of coal? Exploring unintended regional consequences of coal energy in the Czech Republic. Morav. Geogr. Rep. 22, 55–65.

Friedrichs, J., 2010. Global energy crunch: How different parts of the world would react to a peak oil scenario. Energy Policy 38, 4562–4569. https://doi.org/10.1016/j.enpol.2010.04.011

Goyal, S., 2007. Connections: an introduction to the economics of networks. Princeton University Press, Princeton.

Green, F., 2018. Transition policy for climate change mitigation: Who, what, why and how. Cent. Clim. Econ. Policy Work. Pap. Canberra Aust. Natl. Univ.

Greenpeace Česká republika, 2018. Lidé poslali proti rozšíření dolu Bílina tisíce připomínek, nyní se mohou k dolu vyjádřit na veřejném projednání (tisková zpráva).

Greenpeace Česká republika, n.d. Spolu za vodu! [WWW Document]. Greenpeace Čes. Repub. URL https://act.greenpeace.org/page/37872/action/1?locale=cs-CZ (accessed 6.6.19).

Hall, P.A., Soskice, D., 2003. Varieties of capitalism and institutional complementarities. Springer.

Höltinger, S., Salak, B., Schauppenlehner, T., Scherhaufer, P., Schmidt, J., 2016. Austria's wind energy potential – A participatory modeling approach to assess socio-political and market acceptance. Energy Policy 98, 49–61. https://doi.org/10.1016/j.enpol.2016.08.010

IEA, 2017. Energy Policies of IEA Countries: Poland 2016 Review. International Energy Agency.

Kaldellis, J.K., Zafirakis, D., 2011. The wind energy (r)evolution: A short review of a long history. Renew. Energy 36, 1887–1901. https://doi.org/10.1016/j.renene.2011.01.002

Kerschner, C., Hubacek, K., 2009a. Assessing the suitability of input–output analysis for enhancing our understanding of potential economic effects of Peak Oil. WESC 2006Advances Energy Stud. World Energy Syst. Conf. Workshop Adv. Innov. Vis. Energy Energy-Relat. Environ. Socio-Econ. Issues 34, 284–290. https://doi.org/10.1016/j.energy.2008.07.009

Kerschner, C., Hubacek, K., 2009b. Assessing the suitability of input–output analysis for enhancing

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691287

our understanding of potential economic effects of Peak Oil. Energy, WESC 2006Advances in Energy Studies 34, 284–290. https://doi.org/10.1016/j.energy.2008.07.009

Kerschner, C., Prell, C., Feng, K., Hubacek, K., 2013. Economic vulnerability to peak oil. Glob. Environ. Change 23, 1424–1433.

Kimmich, C., 2016. Can Analytic Narrative Inform Policy Change? The Political Economy of the Indian Electricity–Irrigation Nexus. J. Dev. Stud. 52, 269–285. https://doi.org/10.1080/00220388.2015.1093119

Kimmich, C., 2013a. Linking action situations: Coordination, conflicts, and evolution in electricity provision for irrigation in Andhra Pradesh, India. Ecol. Econ. 90, 150–158. https://doi.org/10.1016/j.ecolecon.2013.03.017

Kimmich, C., 2013b. Incentives for energy-efficient irrigation: Empirical evidence of technology adoption in Andhra Pradesh, India. Energy Sustain. Dev. 17, 261–269. http://dx.doi.org/10.1016/j.esd.2013.02.004

Kimmich, C., Fischbacher, U., 2016. Behavioral determinants of supply chain integration and coexistence. J. For. Econ. 25, 55–77. https://doi.org/10.1016/j.jfe.2016.08.001

Kimmich, C., Sagebiel, J., 2016. Empowering irrigation: A game-theoretic approach to electricity utilization in Indian agriculture. Util. Policy 43, B, 174–185. https://doi.org/10.1016/j.jup.2016.10.002

Klenert, D., Mattauch, L., Combet, E., Edenhofer, O., Hepburn, C., Rafaty, R., Stern, N., 2018. Making carbon pricing work for citizens. Nat. Clim. Change 8, 669–677. https://doi.org/10.1038/s41558-018-0201-2

Leontief, W.W., 1983. The Future of nonfuel minerals in the U.S. and world economy : input-output projections 1980-2030. Lexington Books, Lexington, Mass.

Lipp, J., 2007. Lessons for effective renewable electricity policy from Denmark, Germany and the United Kingdom. Energy Policy 35, 5481–5495. https://doi.org/10.1016/j.enpol.2007.05.015

Llera, E., Scarpellini, S., Aranda, A., Zabalza, I., 2013. Forecasting job creation from renewable energy deployment through a value-chain approach. Renew. Sustain. Energy Rev. 21, 262–271. https://doi.org/10.1016/j.rser.2012.12.053

Lobaccaro, G., Croce, S., Lindkvist, C., Munari Probst, M.C., Scognamiglio, A., Dahlberg, J., Lundgren, M., Wall, M., 2019. A cross-country perspective on solar energy in urban planning:

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691287

Lessons learned from international case studies. Renew. Sustain. Energy Rev. 108, 209–237. https://doi.org/10.1016/j.rser.2019.03.041

Macuk, R., Maćkowiak-Pandera, J., Gawlikowska-Fyk, A., Rubczyński, A., 2019. Energy transition in Poland. Forum Energii, Warszawa.

McCormick, K., 2010. Communicating bioenergy: a growing challenge. Biofuels Bioprod. Biorefining 4, 494–502. https://doi.org/10.1002/bbb.243

McDaniel, B.A., 1983. Economic and Social Foundations of Solar Energy [WWW Document]. Environ. Ethics. https://doi.org/10.5840/enviroethics1983521

MEDEAS, 2018. Deliverable 6.2. Costs of the transition.

Miller, R.E., Blair, P.D., 2009. Input-Output Analysis: Foundations and Extensions. Cambridge University Press.

Ministry of Energy, 2018. -Extract from draft- Energy policy of Poland until 2040 (EPP2040). Ministry of Energy, Warsaw.

Moreno, B., López, A.J., 2008. The effect of renewable energy on employment. The case of Asturias (Spain). Renew. Sustain. Energy Rev. 12, 732–751. https://doi.org/10.1016/j.rser.2006.10.011

MPO, 2014. State energy policy of the Czech republic. Ministry of Industry and Trade, Prague.

Müller, M., Rommel, J., Kimmich, C., 2018. Farmers' adoption of irrigation technologies: Experimental evidence from a coordination game with positive network externalities in India. Ger. Econ. Rev. 19, 119–139.

Negro, S.O., Alkemade, F., Hekkert, M.P., 2012. Why does renewable energy diffuse so slowly? A review of innovation system problems. Renew. Sustain. Energy Rev. 16, 3836–3846. https://doi.org/10.1016/j.rser.2012.03.043

Nölke, A., Vliegenthart, A., 2009. Enlarging the varieties of capitalism: The emergence of dependent market economies in East Central Europe. World Polit. 61, 670–702.

Parag, Y., Sovacool, B.K., 2016. Electricity market design for the prosumer era. Nat. Energy 1, 16032. https://doi.org/10.1038/nenergy.2016.32

Patel, S., van der Burgh, L., Worrall, L., 2017. Cutting Europe´s lifeline to coal: Czech republic. Overseas Development Institute.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691287

Peneder, M., 2003. Industrial structure and aggregate growth. Struct. Change Econ. Dyn., Technology and the Economy 14, 427–448. https://doi.org/10.1016/S0954-349X(02)00052-8

Praetorius, B., Martiskainen, M., Sauter, R., Watson, J., 2010. Technological innovation systems for microgeneration in the UK and Germany–a functional analysis. Technol. Anal. Strateg. Manag. 22, 745–764.

Publications Office of the European Union, 2018. Employment and social developments in Europe 2018. [WWW Document]. URL https://publications.europa.eu/en/publication-detail/-/publication/00248c95-b182-11e8-99ee-01aa75ed71a1/language-en (accessed 6.26.19).

Renewables in Electricity Production [WWW Document], 2018. . Enerdata. URL https://yearbook.enerdata.net/renewables/renewable-in-electricity-production-share.html (accessed 6.21.19).

Rovenský, J., Ceman, M., 2019. Shrnutí analýzy výročních zpráv českých hnědouhelných společností. Greenpeace ČR & Hnutí DUHA.

Samadi-Boroujeni, H., 2012. Hydropower: Practice and Application. BoD – Books on Demand.

Scherhaufer, P., Höltinger, S., Salak, B., Schauppenlehner, T., Schmidt, J., 2018. A participatory integrated assessment of the social acceptance of wind energy. Energy Res. Soc. Sci., Special Issue on the Problems of Methods in Climate and Energy Research 45, 164–172. https://doi.org/10.1016/j.erss.2018.06.022

Schumer, C., Ross, K., 2018. Looking Ahead to Plan for Today: How the UK's 2050 Target Drives Climate Action Today [WWW Document]. World Resour. Inst. URL https://www.wri.org/blog/2018/08/looking-ahead-plan-today-how-uks-2050-target-drives-climate-action-today (accessed 6.21.19).

Seidl, R., von Wirth, T., Krütli, P., 2019. Social acceptance of distributed energy systems in Swiss, German, and Austrian energy transitions. Energy Res. Soc. Sci. 54, 117–128. https://doi.org/10.1016/j.erss.2019.04.006

SHARES (Renewables) - Eurostat [WWW Document], 2019. URL https://ec.europa.eu/eurostat/web/energy/data/shares (accessed 6.21.19).

Silva, P., Oliveira, C., Coelho, D., 2013. Employment effects and renewable energy policies: applying input-output methodology to Portugal. Int. J. Public Policy 9, 147.

Sobczak, T., 2018. Odkrywka węgla brunatnego w Złoczewie. Kto popiera? [WWW Document]. Dz.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691287

Łódz. URL https://dzienniklodzki.pl/odkrywka-wegla-brunatnego-w-zloczewie-kto-popiera/ar/12978440 (accessed 6.6.19).

Somanathan, E., Sterner, T., Sugiyama, T., Chimanikire, D., Dubash, N.K., Essandoh-Yeddu, J.K., Fifita, S., Goulder, L., Jaffe, A., Labandeira, X., 2014. National and sub-national policies and institutions, in: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Stadler, K., Wood, R., Bulavskaya, T., Södersten, C.-J., Simas, M., Schmidt, S., Usubiaga, A., Acosta-Fernández, J., Kuenen, J., Bruckner, M., Giljum, S., Lutter, S., Merciai, S., Schmidt, J.H., Theurl, M.C., Plutzar, C., Kastner, T., Eisenmenger, N., Erb, K.-H., Koning, A. de, Tukker, A., 2018. EXIOBASE 3: Developing a Time Series of Detailed Environmentally Extended Multi-Regional Input-Output Tables. J. Ind. Ecol. 22, 502–515. https://doi.org/10.1111/jiec.12715

Sternberg, R., 2008. Hydropower: Dimensions of social and environmental coexistence. Renew. Sustain. Energy Rev. 12, 1588–1621. https://doi.org/10.1016/j.rser.2007.01.027

Stigka, E.K., Paravantis, J.A., Mihalakakou, G.K., 2014. Social acceptance of renewable energy sources: A review of contingent valuation applications. Renew. Sustain. Energy Rev. 32, 100–106. https://doi.org/10.1016/j.rser.2013.12.026

Szamalek, K., Tyminski, M., n.d. Brown coal 2017 [WWW Document]. Pol. Geol. Inst. URL http://geoportal.pgi.gov.pl/surowce/energetyczne/wegiel_brunatny (accessed 6.7.19).

Szpor, A., Ziolkowska, K., 2018. The Transition of the Polish Coal Sector. International Institute for Sustainable Development.

Toke, D., 2005. Explaining wind power planning outcomes:: some findings from a study in England and Wales. Energy Policy 33, 1527–1539. https://doi.org/10.1016/j.enpol.2004.01.009

Trebilcock, M.J., 2014. Dealing with losers: the political economy of policy transitions. Oxford University Press, USA.

Upham, P., Oltra, C., Boso, À., 2015. Towards a cross-paradigmatic framework of the social acceptance of energy systems. Energy Res. Soc. Sci. 8, 100–112. https://doi.org/10.1016/j.erss.2015.05.003

van der Burgh, L., 2017. Cutting Europe´s lifeline to coal: Poland. Overseas Development Institute.

van der Horst, D., 2007. NIMBY or not? Exploring the relevance of location and the politics of voiced

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 691287

opinions in renewable energy siting controversies. Energy Policy 35, 2705–2714. https://doi.org/10.1016/j.enpol.2006.12.012

van der Schoor, T., Scholtens, B., 2015. Power to the people: Local community initiatives and the transition to sustainable energy. Renew. Sustain. Energy Rev. 43, 666–675. https://doi.org/10.1016/j.rser.2014.10.089

Vlček, T., Černoch, F., 2013. The Energy Sector and Energy Policy of the Czech Republic. Masarykova univerzita.

von Wirth, T., Gislason, L., Seidl, R., 2018. Distributed energy systems on a neighborhood scale: Reviewing drivers of and barriers to social acceptance. Renew. Sustain. Energy Rev. 82, 2618–2628. https://doi.org/10.1016/j.rser.2017.09.086

Wolsink, M., 1987. Wind power for the electricity supply of houses. Neth. J. Hous. Environ. Res. 2, 195–214. https://doi.org/10.1007/BF02497872

Wood, R., Stadler, K., Bulavskaya, T., Lutter, S., Giljum, S., De Koning, A., Kuenen, J., Schütz, H., Acosta-Fernández, J., Usubiaga, A., Simas, M., Ivanova, O., Weinzettel, J., Schmidt, J.H., Merciai, S., Tukker, A., 2015. Global Sustainability Accounting—Developing EXIOBASE for Multi-Regional Footprint Analysis. Sustainability 7, 138–163. https://doi.org/10.3390/su7010138

Wüste, A., Schmuck, P., 2013. Social Acceptance of Bioenergy Use and the Success Factors of Communal Bioenergy Projects, in: Ruppert, H., Kappas, M., Ibendorf, J. (Eds.), Sustainable Bioenergy Production - An Integrated Approach. Springer Netherlands, Dordrecht, pp. 293–318. https://doi.org/10.1007/978-94-007-6642-6_10

Wüstenhagen, R., Wolsink, M., Bürer, M.J., 2007. Social acceptance of renewable energy innovation: An introduction to the concept. Energy Policy 35, 2683–2691. https://doi.org/10.1016/j.enpol.2006.12.001

Zafar, R., Mahmood, A., Razzaq, S., Ali, W., Naeem, U., Shehzad, K., 2018. Prosumer based energy management and sharing in smart grid. Renew. Sustain. Energy Rev. 82, 1675–1684. https://doi.org/10.1016/j.rser.2017.07.018

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