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Impacts of a green hydrogen value chain on the labor market in Germany

Abstract

Hydrogen has the potential to play a key role in the energy transition. However, establishing a green hydrogen value chain raises the question of how the labor market will be affected by labor supply and demand changes. Our study analyzes the potential impact of a green hydrogen value chain on employment, occupations and qualifications in Germany until 2045. The forecasts are based on demographic and economic modelling in conjunction with the scenario technique. For the econometric forecasting and simulation, we apply the QINFORGE model with the macroeconomic input-output model INFORGE at its core. The INFORGE model is based on the INFORUM modelling approach. With the extended QINFORGE model, labor market demand and supply can be forecasted disaggregated by 63 economic sectors, 144 occupation groups and four qualification levels. The subsequent scenario analysis shows that establishing a green hydrogen value chain will have an overall positive economic impact and results in a higher level of employment in Germany. However, the development of labor demand differs across economic sectors and occupation groups.

1 Introduction

In 2016, the German Government ratified the Paris Agreement and adopted the Climate Action Plan to become largely greenhouse-gas neutral by 2050 (BMUB, 2016). With the amendment to the Climate Change Act in 2021, the government has set an even more ambitious climate target. Germany is now to become greenhouse-gas neutral by 2045 (German Federal Government , 2021). Hydrogen has the potential to play a key role in the therefore necessary energy transition. It can contribute to decarbonize the industry, transport or heating sector and to achieve the national climate targets. Hydrogen produced via electrolysis from renewable energies is considered «green» hydrogen. The German National Hydrogen Strategy aims to foster the use of green hydrogen, promote its market rollout and establish a green hydrogen value chain (BMWi, 2020). Recently, hydrogen is discussed regarding climate policy and is also evaluated as an option to decrease the dependency on supplier countries for fossil fuels (BMWK, 2022). However, establishing a green hydrogen value chain raises the question of how the labor market will be affected by labor supply and demand changes.

This study analyzes the impacts of establishing a green hydrogen value chain on employment, occupations and qualifications in Germany until 2045. It is embedded within the inter-institutional «QuBe project» (www.qube-projekt.de) conducted by the BIBB (Federal Institute for Vocational Education and Training) and the IAB (Institute for Employment Research) in collaboration with the GWS (Institute of Economic Structures Research). The results are based on demographic and economic modelling in conjunction with the scenario technique. To this end, various assumptions about future developments of a «green hydrogen economy» were made and integrated into a «hydrogen scenario». The comparison with a «baseline projection» allows us to analyze the impacts of a green hydrogen value chain on the overall economy and various aspects of the labor market in Germany.

Results show that the ramp-up of a green hydrogen value chain has an overall positive economic effect over the whole projection horizon. The main drivers are investments in machinery and equipment that lead to a higher GDP level and consequently higher employment levels than in the «baseline projection». Hence, more jobs will be created than lost. In absolute terms, the higher labor demand is especially pronounced in construction as well as in architectural and engineering activities and related technical consultancy. This is due to additional investments in the hydrogen infrastructure and the additional expansion of renewable energies for green hydrogen production. The changing labor demand in the economic sectors is reflected to a certain extent in the demand for different occupations. Regarding qualifications, our computations show a higher demand for skilled labor in absolute terms, while the additional demand is highest for specialists and experts in relative terms.

The structure of this paper is as follows: Chapter 2 explains the underlying methodology of the economic modelling and scenario technique, while chapter 3 describes key assumptions that were integrated into the «hydrogen scenario». Chapter 4 presents the main results of the scenario analysis for GDP, overall deviations of the labor force and employment and main deviations in economic sectors, occupation groups as well as qualification levels. A brief conclusion is presented in chapter 5. The terms «hydrogen» and «green hydrogen» are used analogously in this paper.

2 Methodology

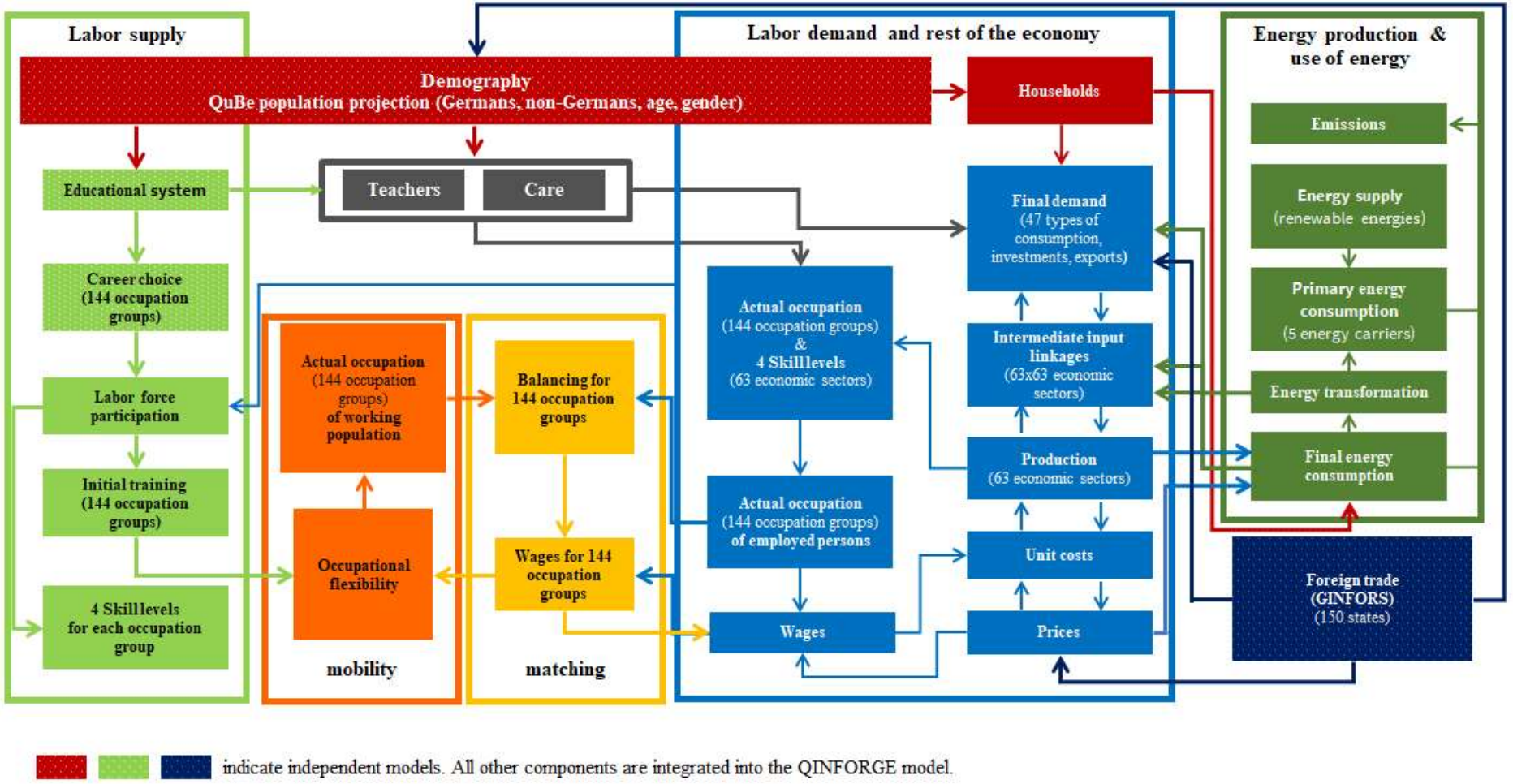
For computing the impacts of establishing a green hydrogen value chain on the economy and the labor market in Germany, it is important to capture the structure of the economy in detail. The envisioned energy transition will influence various economic activities such as construction, exports and imports, cost and production structures or consumption patterns. Thus, an adequate model is required which comprises and depicts these activities as well as their interdependencies.

The econometric forecasting and simulation model QINFORGE (**Q**ualification and Occupation in the **IN**terindustry **FOR**ecasting **GE**rmany) fulfills these requirements. It was developed by the Institute of Economic Structures Research (GWS) and forms part of the model system used in the «QuBe project» (see Figure 1). The economic core of the QINFORGE model is the macroeconomic input-output model INFORGE (**IN**terindustry **FOR**ecasting **GE**rmany). INFORGE enables the analysis of structural changes in the German economy such as changes during energy transition. The model is based on the INFORUM (**IN**terindustrry **FOR**ecasting at the **U**niversity of **M**aryland) modelling approach and follows the principles of «bottom-up construction» and «full integration». In the «bottom-up construction» each economic sector is modelled individually before computing macroeconomic aggregates. This approach ensures that each economic sector is embedded in the economic system and accounts for intersectoral dependencies. «Full integration» describes a highly endogenous and simultaneous model structure which accounts for inter-sectoral linkages, the origin and distribution of incomes, the distribution activities of the state and household spending. INFORGE shares many characteristics with Computable General Equilibrium models but does not presume rational agents or perfect markets converging to equilibrium (Almon, 1991; Becker, et al., 2022; Zika, et al., 2023). The extended QINFORGE model further includes labor market demand and supply, disaggregated by 63 economic sectors, 144 occupation groups and four qualification levels. In a first step, disaggregated labor supply is formed depending on the occupations in which the work force has been trained. In a second step, the potential labor supply that may be available for an occupation is estimated using flexibility matrices. The matrices are stating the extent to which persons who have completed training in a certain occupation remain within this occupation during their working life and how likely they are to switch to other task areas. Interactions between the demand and supply sides are modelled as part of this process to make occupational flexibility modifiable based on wage adjustments and structural changes within the population (Kalinowski, et al., 2021; Zika, et al., 2023). With its detailed, integrated and consistent approach, QINFORGE can be used for the estimation of future economic growth and labor market impacts (Zenk, et al., 2023; Zika, et al., 2022; Mönnig, et al., 2021).

The German national accounts – including the input-output-tables (currently until 2021) – are the basic data for QINFORGE. They depict the macroeconomic level including macroeconomic interrelationships between private households, non-governmental institutions, businesses and the government. Private and government spending is highly dependent on the population development and the labor force (Becker, et al., 2022). To this end, the integrated labor supply and population model developed by the Institute for Employment Research (IAB model) forms part of the model system used in the «QuBe project» (Zika, et al., 2023). The data for the demographic modelling is based, amongst others, on the German Microcensus (last survey year 2019). It is an official representative statistic of the Federal Statistical Office - involving one percent of all households in Germany each year - and provides information on the economic and social situation of the population as well as on the labor market. The Federal Employment

Agency's data register of employees, subject to social insurance contributions and of those in marginal employment provides additional information on the employed population by occupation and the corresponding wages paid (until 2020) (Maier, et al., 2022).

Figure 1. Structure of the QuBe model system

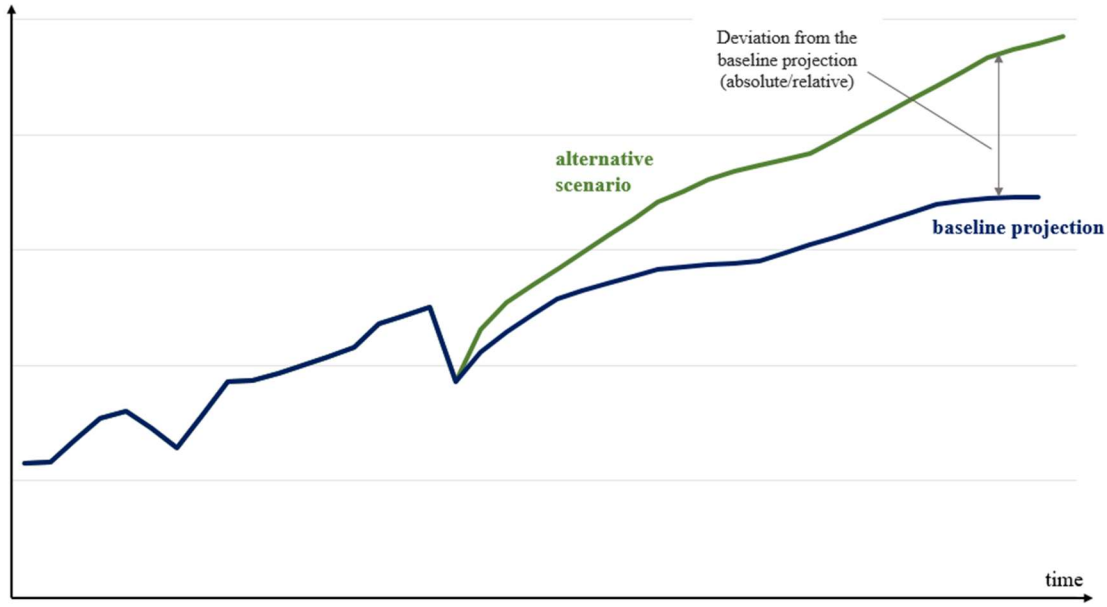


Source: QuBe project, 7th wave (Zika, et al., 2023)

To identify the impacts of a green hydrogen value chain on the economy and labor market, two scenarios are computed using the QINFORGE analytical tool. The first scenario is a «baseline projection» which extrapolates past trends and behaviors in the educational system, the labor market and economic development but neglects the development of a green hydrogen value chain. The second, alternative scenario assumes the development of a green hydrogen value chain according to assumptions derived from a broad literature review (see chapter 3). The model relationships remain unchanged in both scenarios. Thus, differences in the results lead to direct, indirect, and induced overall impacts to the economy and labor market entailed by the development of a green hydrogen value chain (Becker, et al., 2022; Mönnig, et al., 2019).

The results in chapter 4 can thus be interpreted as the deviation between the «baseline projection» and the alternative «hydrogen scenario» (see Figure 2 for a schematic depiction). The analysis is based on the seventh wave of the «QuBe project» and reflects the state of data as of summer 2022.

Figure 2. Application of the scenario technique, schematic depiction



Source: Zika, et al., 2023

3 Assumptions on the establishment of a hydrogen value chain

Since a «green hydrogen economy» is yet to be developed on a larger scale, various assumptions must be made for modelling its development path in the alternative scenario. These are partly based on the goals of the National Hydrogen Strategy (BMWi, 2020) and further extended with assumptions derived from a broad literature review as well as expert interviews. In many cases, the assumptions build upon one another or influence each other. Table 1 gives an overview of the main assumptions formulating the «hydrogen scenario».

Table 1. Assumptions for the «hydrogen scenario»

Assumption	Description
1. Green hydrogen demand in Germany	• Total annual demand of 96 TWh until 2030 and of 412 TWh until 2045

	• Main use in energy-intensive industries, transport and the energy sector • Higher demand than domestic production potential • Import quota between 53 and 77%
2. Expansion of renewable energies	• Electricity from renewable energy sources needed for domestic hydrogen production increases by 40 TWh until 2030 and 175 TWh until 2045
3. Hydrogen infrastructure	• Gas pipeline repurposing and construction at ratio of 4 to 1 • Storage capacity of up to 16% of total demand • Construction of port terminals for hydrogen import
4. Hydrogen technology	• Upscaling of electrolyzer production with decreasing investment costs and increasing efficiency • Export chances for German hydrogen technologies

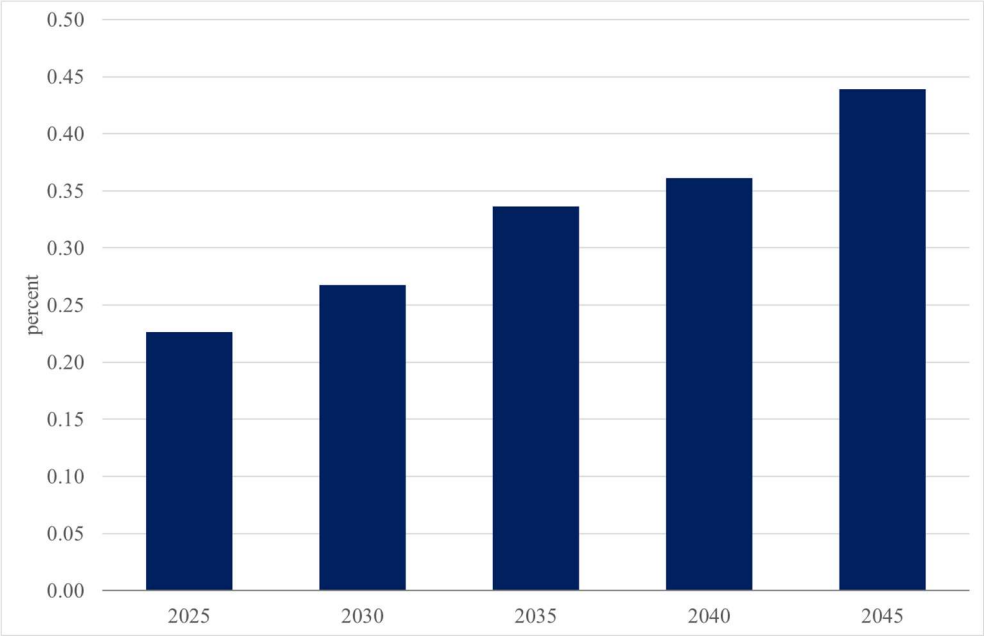
The energy transition leads to a change in the energy mix. Energy demand in the «hydrogen scenario» is kept at the same level as in the «baseline projection». Hence, green hydrogen is replacing fossil fuels and their import to Germany in the «hydrogen scenario». Due to the currently high import costs for green hydrogen, we are not expecting nominal energy import expenditures to fall below the baseline expenditures before 2033. Rising prices for natural gas in 2022 have accelerated the shift in the cost advantage. Without this rise, the cost advantage would have remained with fossil energies for a longer period and beyond 2033. In this sense, the energy crisis in Europe can be considered a driving force for the transition towards a «green hydrogen economy».

4 Results

4.1 Impact on economic output in Germany

The starting point of our analysis is the development of the price-adjusted gross domestic product (GDP) as the overall economic situation influences the labor market. Additional investments in machinery, equipment and construction as well as an increase in private consumer spending lead to a higher GDP level in the model calculation for the «hydrogen scenario». Higher import expenditures slightly weaken the positive impact on GDP. After 2035 this negative effect is reinforced by lower export revenues, as the demand for conventional power plant technology prospectively decreases worldwide. Between 2022 and 2045 the German GDP is expected to be 0.32 percent (11.70 billion Euros) higher on average than in the «baseline projection».

Figure 3. Gross domestic product, price-adjusted, deviation from «baseline projection» in percent, 2025 - 2045



Source: Own calculations.

The transition towards a «green hydrogen economy» will increase the aggregated price level and put additional pressure on the price-adjusted GDP and its components. This phenomenon, denoted as «greenflation» (Koch, 2022; Saleh, et al., 2022), can be observed in the model calculations which result in higher unit costs, especially for intermediate goods, but also in higher amortization costs and wages. Prices are not primarily driven by higher import costs for hydrogen at the beginning of the projection horizon but rather by investments in the production and operation of electrolyzers. Higher costs for hydrogen derivatives in the shipping and aviation sector contribute to the price pressure.

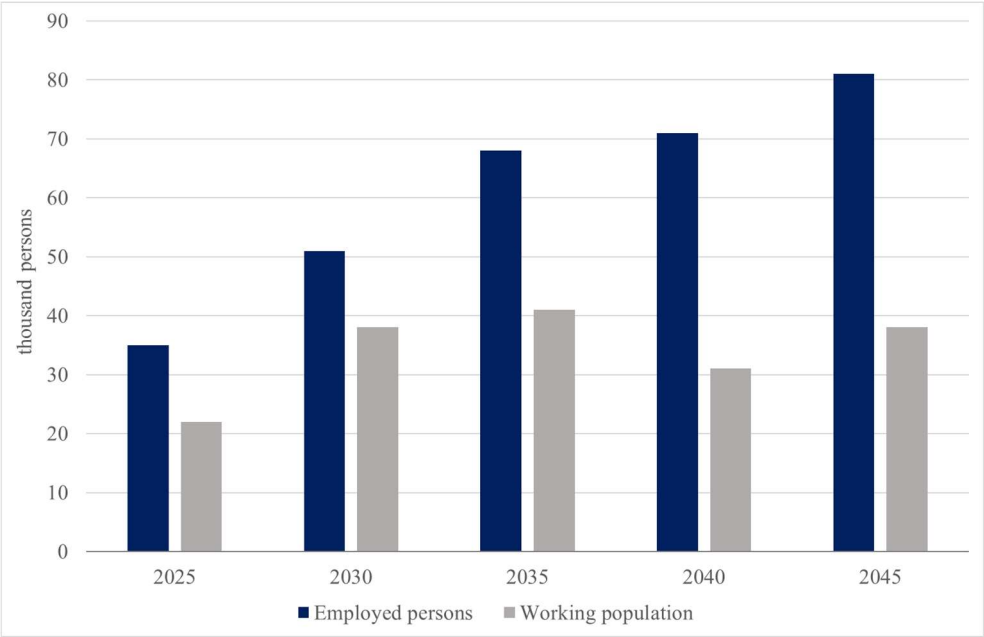
4.2 Employed persons and working population in Germany

The establishment of a «green hydrogen economy» according to the underlying assumptions will have positive impacts on the labor market. Higher economic performance increases employment and activates a larger number of persons to participate in the labor market (see

Figure 4). Between 2022 and 2045 an average of 61,000 additional persons are expected to be employed in comparison to the «baseline projection».

Moreover, also the working population increases in number compared to the «baseline projection». The working population denotes the economically active population (employed and unemployed persons). A higher GDP level offering better earning opportunities is the driver behind this development. Between 2022 and 2045 an average of 34,000 additional persons are expected to be active in the labor market. The higher rise in employed persons in comparison to the working population leads to a lower unemployment level in the «hydrogen scenario».

Figure 4. Number of employed persons and working population, deviation from «baseline projection» in thousand persons, 2025 - 2045



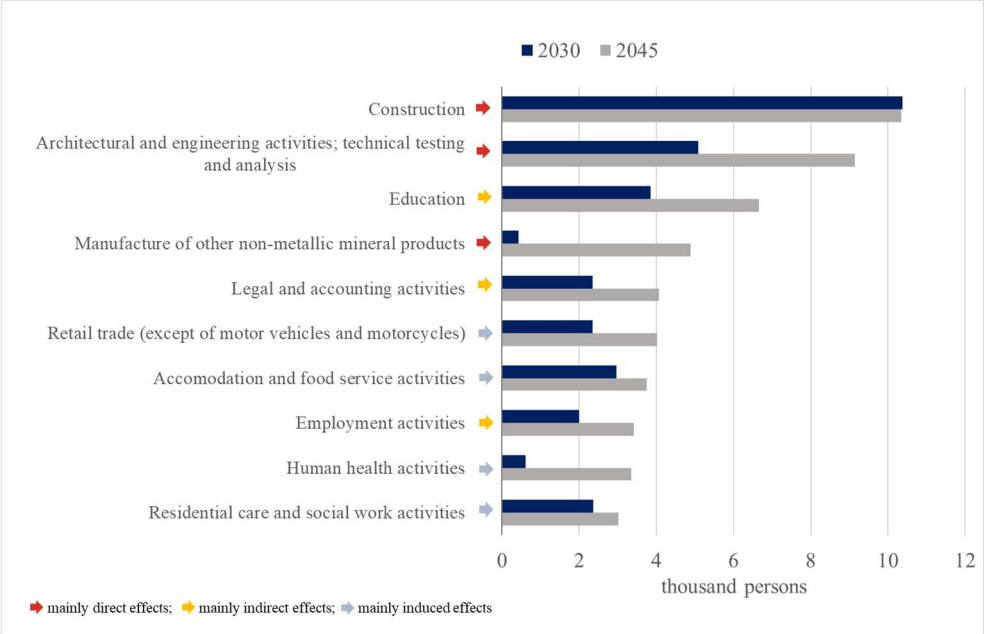
Source: Own calculations.

4.3 Employed persons by economic sector in Germany

A more detailed picture of the labor market is given by looking at the deviation of employed persons by economic sector. Applying the QINFORGE model, economic sectors can be affected directly, indirectly and via induced effects when integrating the assumptions on the establishment of a green hydrogen value chain. Among the ten economic sectors with the largest deviations from the «baseline projection» in 2030 and 2045, almost all profit from higher employment levels in the «hydrogen scenario».

In absolute terms, construction, architectural and engineering activities, technical testing and analysis will have the highest additional labor demand (see Figure 5). The primary reason for these deviations is the additional investment in construction and in the hydrogen infrastructure. The energy-intensive manufacture of other non-metallic mineral products can profit from the increasing cost advantage that green hydrogen offers in comparison to fossil fuels over time. Other sectors show indirect or induced effects. The rise in education can be attributed, for example, to further training needs for employees forming part of the hydrogen value chain (indirect effect) while retail trade profits from higher consumer spending as a response to the increase in income (induced effect).

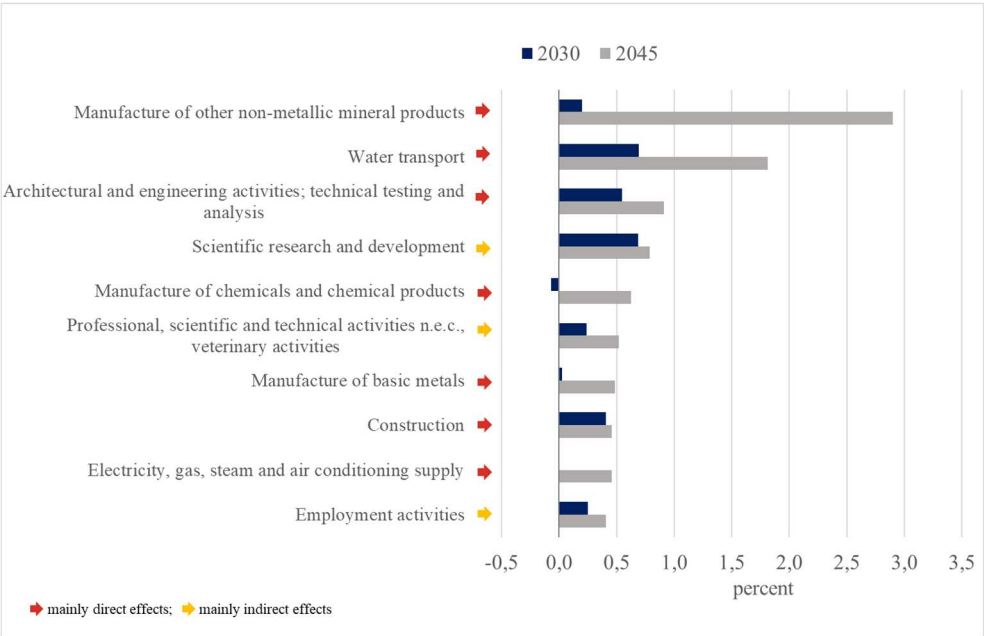
Figure 5. Ten economic sectors with the largest deviations in number of employed persons, 2030 and 2045



Source: Own calculations.

In relative terms, there is a shift in the ranking (see Figure 6). Only economic sectors which are directly or indirectly affected by the transformation towards a «green hydrogen economy» form part of those sectors with the largest deviation in employment numbers. Manufacture of other non-metallic mineral products is leading in the long-term. The same holds true for the manufacture of chemicals and chemical products in the long-term but not the in the short-term. In 2030, the chemical industry is one of the few sectors with a lower employment level when introducing green hydrogen into the energy mix.

Figure 6. Ten economic sectors with the largest relative deviation in employed persons, 2030 and 2045



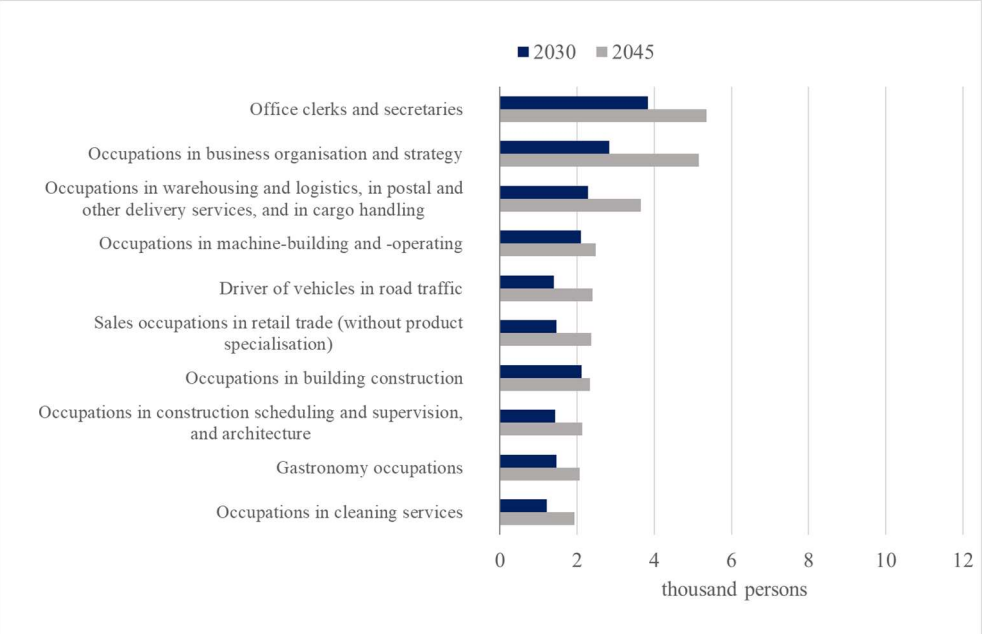
Source: Own calculations.

4.4 Employed persons by occupation group in Germany

As for economic sectors, deviations of employed persons can be analyzed by occupation groups (3 digit-level of the German Classification of Occupations 2010). However, and in contrast to the previous analysis in subchapter 4.3, a classification of direct, indirect and induced effects is hardly possible due to different sector-occupation combinations. All ten occupation groups with the largest deviations from the «baseline projection» in 2030 and 2045 profit from higher employment levels in the «hydrogen scenario». This holds true for absolute and relative deviations.

Figure 7 shows the ten occupation groups with the largest deviations in number of employed persons. In absolute terms office clerks and secretaries lead the ranking, closely followed by occupations in business organization and strategy. The higher employment level results from the broad engagement of these groups in various economic sectors. Nevertheless, we also find occupation groups that can be more closely related to the economic sectors depicted in subchapter 4.3 such as occupations in machine-building and -operating, building construction and construction scheduling, supervision and architecture.

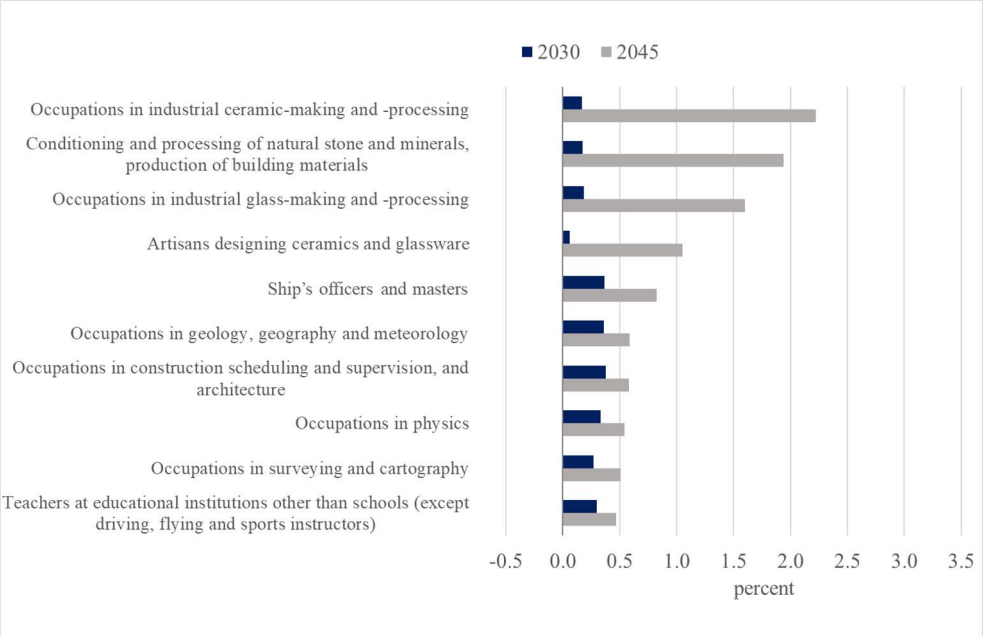
Figure 7. Ten occupation groups with the largest deviations in number of employed persons, 2030 and 2045



Source: Own calculations.

The deviations by occupation groups in relative terms reflect the deviations in the economic sectors (see Figure 8). The top four occupation groups can be closely linked to manufacturing of other non-metallic products, namely ceramic, natural stone, minerals and glass. Fifth in the ranking are ship's officers and masters, followed by occupations linked to construction, architectural and engineering activities, scientific research and development as well as education.

Figure 8. Ten occupation groups with the largest relative deviation in employed persons, 2030 and 2045

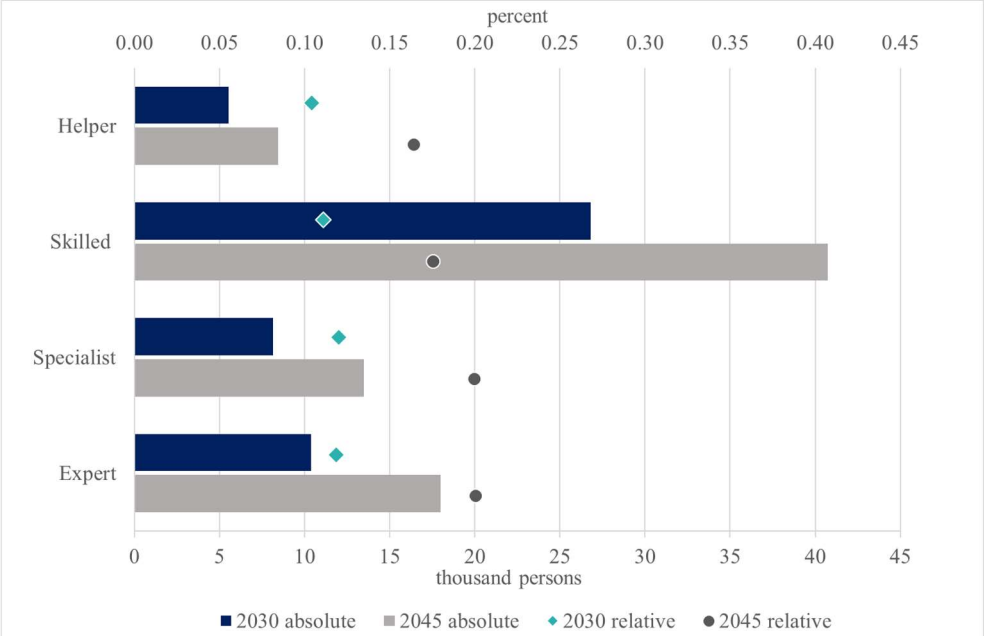


Source: Own calculations.

4.5 Employed persons by qualification level in Germany

Looking at employed persons by qualification level (International Standard Classification of Education (ISCED)), we observe a higher demand for all qualification levels in the «hydrogen scenario» compared to the «baseline projection». In absolute terms, the highest additional demand is recorded for skilled workers (persons with a vocational qualification in the upper secondary and post-secondary, non-tertiary sector). Relative to all persons employed in the respective qualification level, the highest additional demand is recorded for experts (persons with a master's degree, a degree following a diploma or a doctorate) and specialists (persons in possession of upgrading training, a bachelor's degree, or a degree from a university of applied sciences). Thus, the establishment of a green hydrogen value chain is accompanied by higher demands on the competences of employees. Nevertheless, employees in all qualification levels profit from higher employment levels in the «hydrogen scenario».

Figure 9. Employed persons by qualification level, deviation from «baseline projection» in thousand persons and percent, 2030 and 2045



Source: Own calculations.

5 Conclusion

Decarbonization is one of three main drivers (digitalization, demographic change, decarbonization) for transforming the economy and labor market in Germany (Maier, et al., 2022). Recently, it has been shown that hydrogen does not only play a key role in climate policy, but it is also an option to reduce dependencies for fossil fuel supplies (BMWK, 2022).

Establishing a green hydrogen value chain requires extensive research and development activities as well as investments and restructuring in industry, transport and the energy system. The results of the scenario analysis show that a «green hydrogen economy» has positive impacts on GDP and employment. Negative effects in single economic sectors and occupation groups remain small and are outweighed by positive effects in other sectors and occupation groups. Most positive employment effects can be related to the additional expansion of renewable energies necessary for producing green hydrogen as well as to the development of an adequate hydrogen infrastructure. The traditionally labor-intensive construction sector is a main driver for rising the employment level in the «hydrogen scenario». However, indirect and induced effects are also visible. Higher investments and domestic value lead to more employment and improved income opportunities. This in turn stimulates private consumption and increases the demand in different economic sectors and occupation groups.

Rising prices for fossil fuels foster the development towards a «green hydrogen economy». Even energy-intensive industries can profit from the shift to alternative energy carriers in the long-term. Employment in these sectors is expected to decrease less than in the «baseline projection». The yet to be determined market price for green hydrogen as well as import volumes are crucial factors for the magnitude of future impacts on the economy and labor market. Assumptions made in the «hydrogen scenario» are subject to margins of uncertainty and might have to be revised, adjusted or extended in future research. Irrespective of this, the development of a «green hydrogen economy» can only succeed if an adequately qualified

workforce is available. Thus, further efforts in recruitment, training and education will be necessary.

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