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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 economy as a whole and the labor market will be affected. Our study analyzes the potential impact of a green hydrogen value chain on GDP, 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 use the QINFORGE model with the macroeconomic input-output model INFORGE which is based on the INFORUM modelling approach, at its core. With the 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 mostly positive economic impact and results in a strictly 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 economy and labor market are affected.

This study analyzes the impacts of establishing a green hydrogen value chain on GDP, employment, occupations and qualifications in Germany until 2045. It is a condensed version of the detailed report by Ronsiek, et al. (2024). The project is funded by the Federal Ministry of Education and Research, and it is embedded within the inter-institutional 'QuBe project' 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 a positive economic effect at first, mostly due to investments in construction, equipment and machinery. However, in the later years of the projection period, the effect becomes slightly negative, as investment activities decrease while import costs are still higher than in the baseline projection. This is due to the expectation of higher prices for green hydrogen compared to fossil fuels. When shifting the focus to the labor market, a higher demand for labor can be observed up to the end of the projection horizon, what is mainly attributed to the increased investment activities, particularly in the construction sector. The changing labor demand in the economic sectors is reflected to a certain extent in the demand for different occupations.

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 as well as main deviations in economic sectors, occupation group and qualification levels. A brief conclusion containing an outlook is presented in chapter 5. The terms 'hydrogen' and 'green hydrogen' are used analogously in this paper.

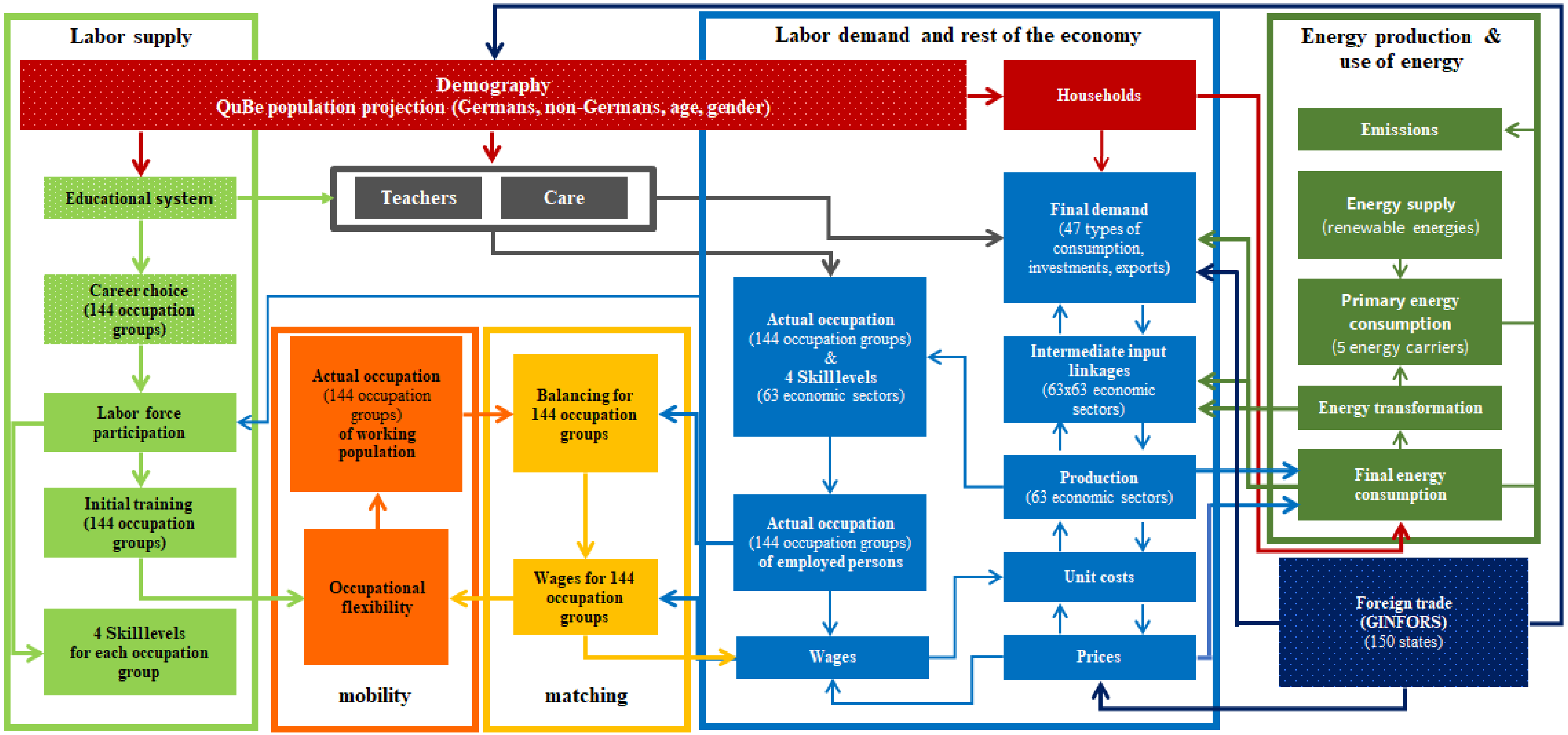
2 Methodology

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 – 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. 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*



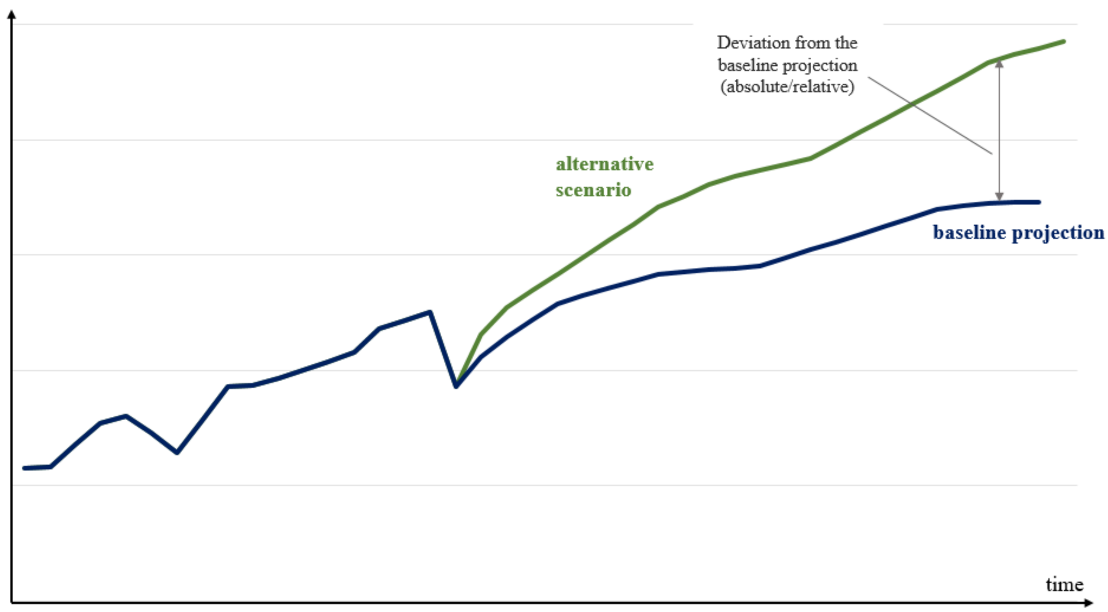
indicate independent models. All other components are integrated into the QINFORGE model.

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 and its update (BMWi, 2020; BMWK, 2023) 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 106 TWh until 2030 and of 501 TWh until 2045

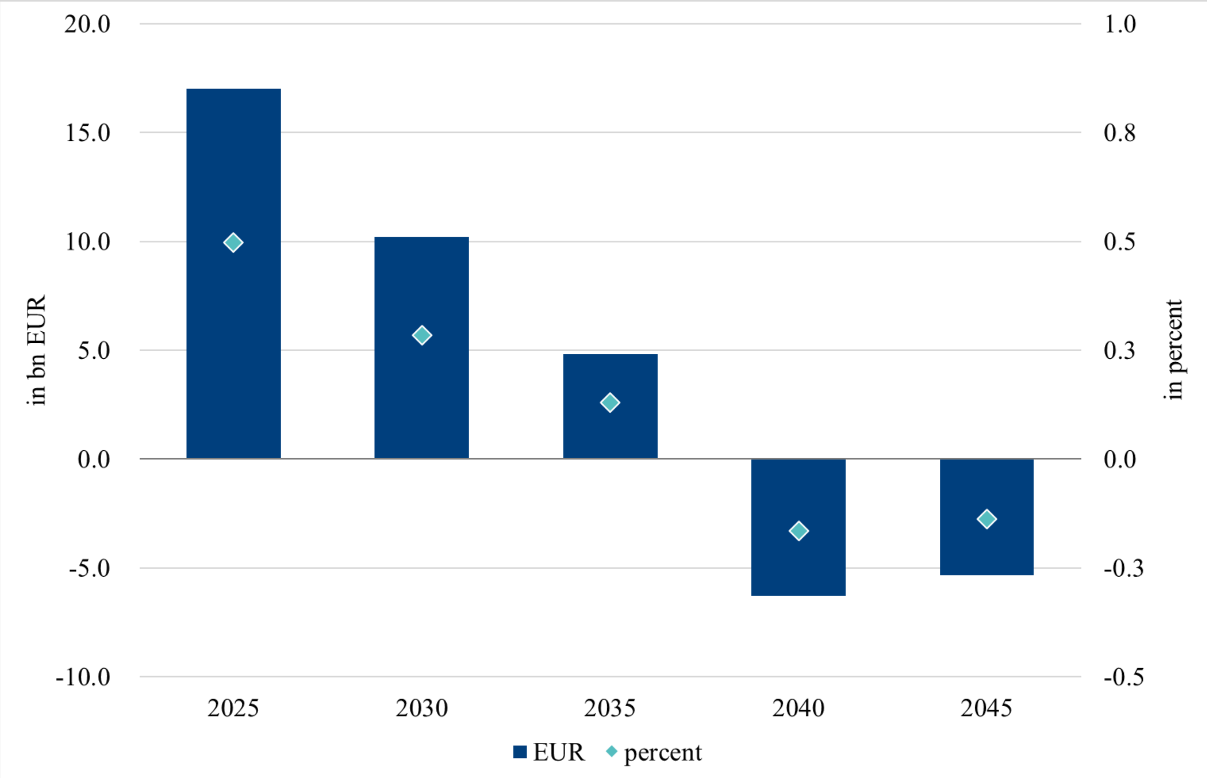
	• Main use in energy-intensive industries and the energy sector • Higher demand than domestic production potential • Import quota on average 61%
2. Expansion of renewable energies	• Electricity from renewable energy sources needed for domestic hydrogen production increases by 40 TWh until 2030 and 171 TWh until 2045
3. Hydrogen infrastructure	• Cumulative cost of 58 bn. Euros by 2045 for repurposing and new construction of pipeline and storage capacities, construction of port terminals for hydrogen import and filling stations for heavy-duty trucks
4. Hydrogen technology	• Upscaling of electrolyzer production with decreasing investment costs and increasing efficiency • Export chances for German hydrogen technologies (presumed world market share of 10%)
5. Hydrogen cost	• Declining production and import cost of hydrogen until 2045 • However, no cost advantage of hydrogen compared to fossil fuels
6. Synthetic fuels	• Total annual demand of 5 TWh until 2030 and of 43 TWh until 2045 for the shipping and aviation sector • Little domestic production
7. Professional training	• Additional training costs • Export of training services

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 construction, equipment and machinery as well as an increase in private consumer spending cause a higher GDP level up to 2035 for the 'hydrogen scenario'. As the investment activity diminishes, the higher import expenditures - due to the cost difference between hydrogen and fossil fuels - weaken the positive impact on GDP to the point that from 2036 on real GDP is lower than in the baseline projection. After 2035 this negative effect is reinforced by lower export revenues as competitiveness decreases with higher production costs for export goods. However, between 2024 and 2045 the German GDP is expected to be 0.1 percent (4.1 billion Euros) higher on average than in the 'baseline projection'.

Figure 3. Gross domestic product, price-adjusted, deviation from 'baseline projection' in absolute and relative terms, 2025 - 2045



Source: Own calculations.

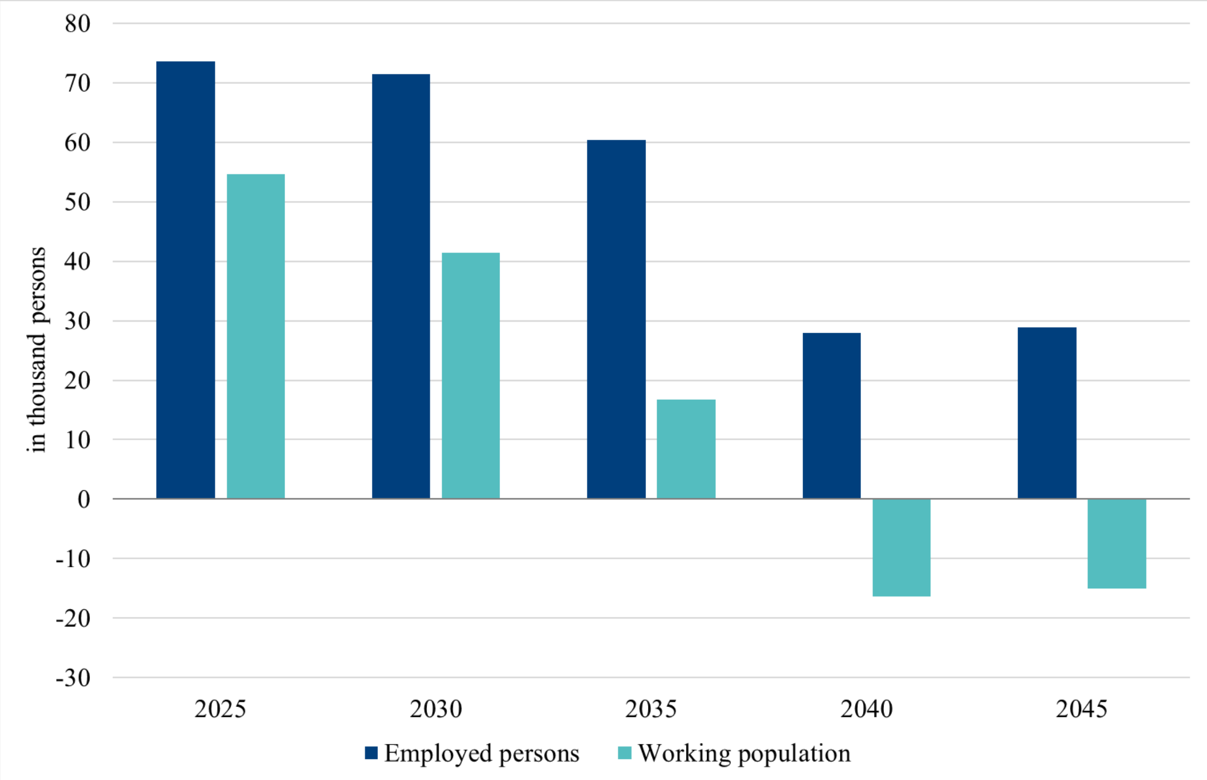
The transition towards a 'green hydrogen economy' will increase the aggregated price level and put additional pressure on the price-adjusted GDP and its components. This phenomenon, denoted as 'greenflation' (Koch, 2022; Saleh, et al., 2022), can be observed in the model calculations which result in 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 based synthetic fuels 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 mostly positive impacts on the labor market. Higher economic performance in the early years of the projection period stimulates employment and activates a larger number of persons to participate in the labor market (see Figure 4). However, as for GDP, the effect weakens. In the later years, after 2035, the working population is smaller than in the baseline projection. The working population denotes the economically active population (employed and unemployed persons). A higher GDP level offers better earning opportunities and vice versa and is therefore the driver behind this development.

Between 2024 and 2045 an average of 57,000 additional persons are expected to be employed in comparison to the ‘baseline projection’. Moreover, an average of 17,000 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



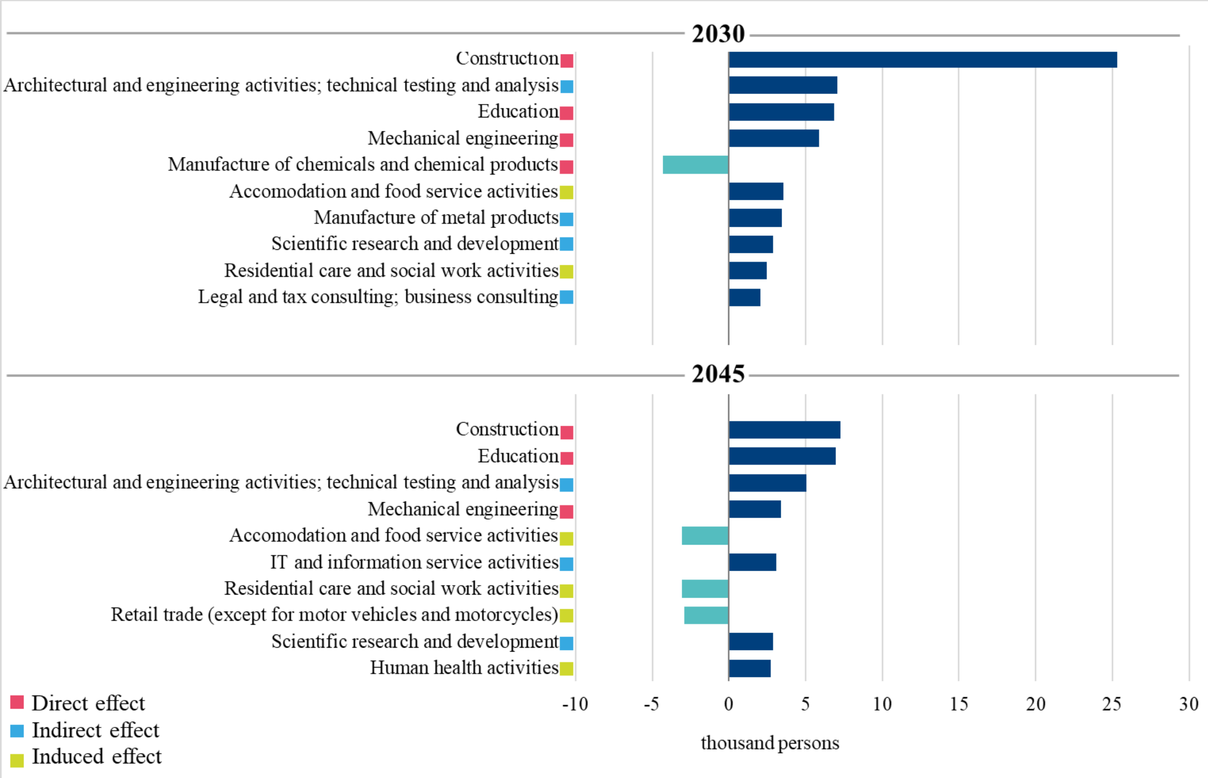
Source: Own calculations.

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. Most of the ten economic sectors with the largest deviations from the ‘baseline projection’ profit from higher employment levels in the ‘hydrogen scenario’.

In absolute terms, construction and the architectural planning sector will have the greatest additional labor demand in 2030 (see Figure 5). The primary reason for this is additional construction investment in the hydrogen infrastructure. Further, the education sector profits from a higher demand for advanced training and mechanical engineering from higher exports of hydrogen technologies. On the other hand, the energy-intensive chemical industry's labor demand is lower in the 'hydrogen scenario' because of the higher cost of hydrogen compared to substituted fossil fuels. Other sectors show induced effects. The rise in accommodation and food service activities in 2030 can be attributed to higher consumer spending as a response to the increase in income. In 2045 the affected sectors are mostly similar, but the effects are smaller and, in some cases, negative – especially, when the impacts are induced by the overall economic activity like in the retail trade sector.

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



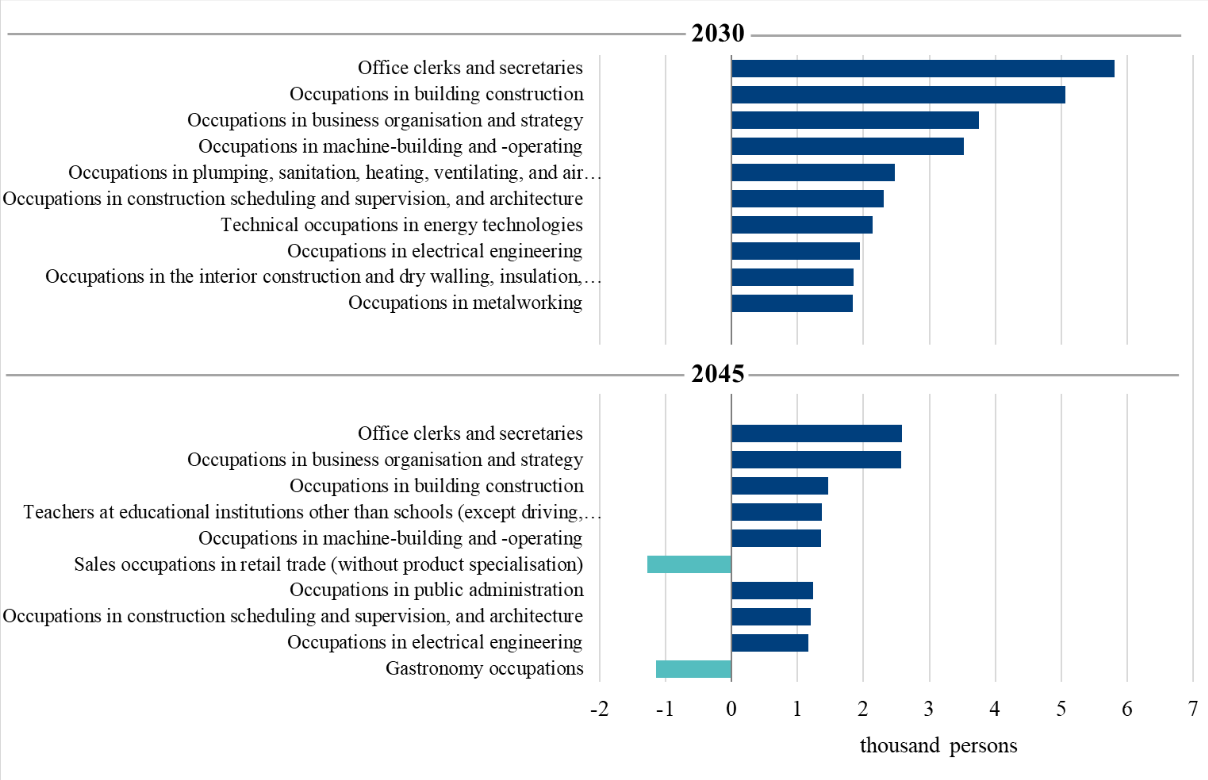
Source: Own calculations.

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 eight of the ten in 2045 profit from higher employment levels in the 'hydrogen scenario'.

Figure 6 shows the ten occupation groups with the largest deviations in number of employed persons in absolute terms for 2030 and 2045 respectively. In absolute terms, office clerks and secretaries lead the ranking. This results from their broad engagement in various economic sectors. Similar applies to occupations in business organization and strategy. 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 building construction, in machine-building and -operating, and construction scheduling, supervision and architecture.

Figure 6. Ten occupation groups with the largest deviations in number of employed persons, 2030 and 2045

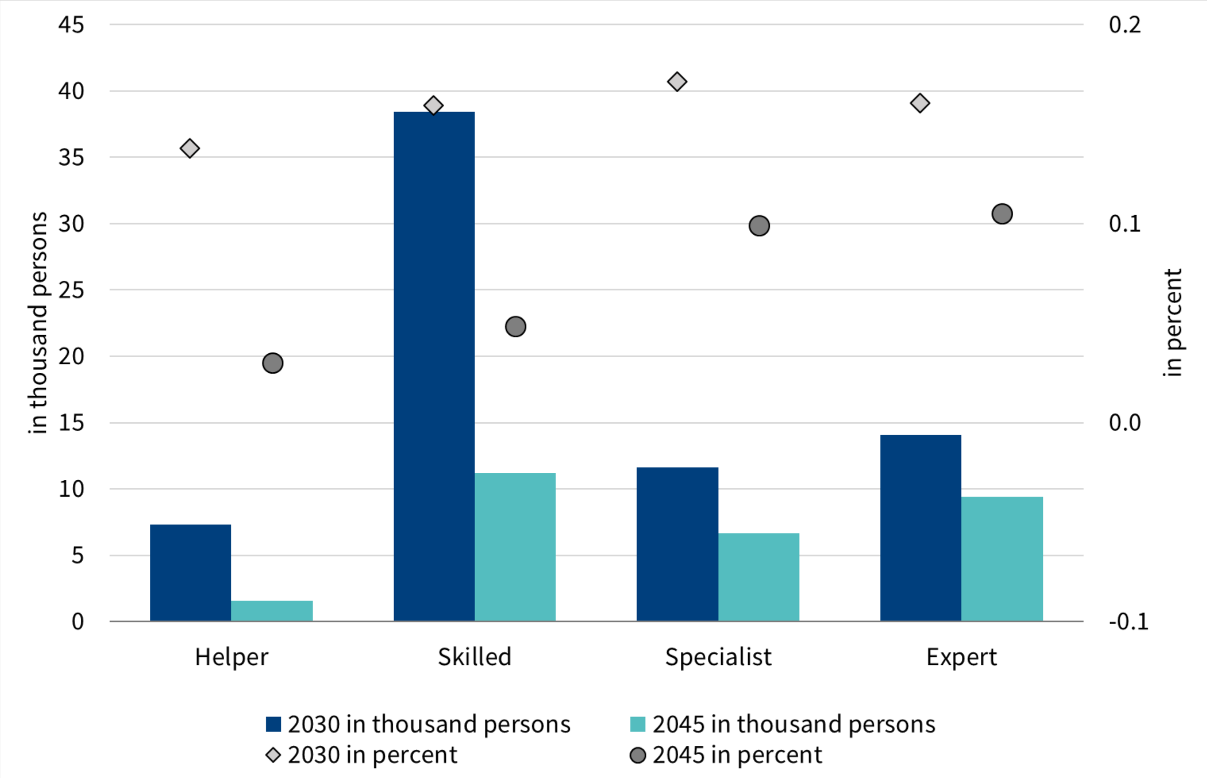


Source: Own calculations.

4.5 Employed persons by qualification level

The additional labor demand in the ‘hydrogen scenario’ varies by qualification level (International Standard Classification of Education (ISCED)). Figure 8 illustrates the deviations in the number of employed persons compared to the ‘baseline projection’ for the years 2030 and 2045, differentiated by qualification level, both in absolute and relative terms. The establishment of a ‘hydrogen economy’ leads to higher employment numbers across all four qualification levels. In absolute terms, the greatest additional demand in 2030 is for skilled workers. In relative terms, the greatest additional demand is for specialists, although the relative deviations in 2030 are close across all four qualification levels. By 2045, the additional demand for skilled workers is less pronounced and the demand for helpers is only slightly higher than in the ‘baseline projection’. The relative comparison particularly shows that, in the long term, more specialists and experts are needed in the ‘hydrogen scenario’.

Figure 8. Number of employed persons by qualification level, deviation from 'baseline projection' in absolute and relative terms, 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). 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 on average small but positive impacts on GDP and employment. The lower GDP level in the later years of the projection period compared to the 'baseline projection' can for the most part be attributed to the higher import cost of hydrogen compared to fossil substitutes. Negative employment 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 investments in infrastructure necessary for producing and distributing green hydrogen. 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 can 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 until the projection year 2036. After that the effect is reversed.

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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