CSH Study

Expected Workforce Requirements for the Green Transition

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Complexity Science Hub Vienna im Auftrag des Rates für Forschung und Technologieentwicklung

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About the Complexity Science Hub Vienna

The Complexity Science Hub Vienna was founded with the vision to become the focal point of complexity science in Europe. The aim is to provide an exciting, creative environment free of bureaucratic constraints for open-minded visionaries who are brave enough to step out of mainstream science. The Hub will be an incubator and playground for radically new ideas. It is a node in a network of international partner institutions, including the Santa Fe Institute, the Complexity Institute at Nanyang Technological University Singapore, Arizona State University, and the Institute for Advanced Study Amsterdam. Through this network a lively exchange of scientists, question posers, students, and postdocs is envisioned, enabling the most important exchange – that of ideas.

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Introduction

The transition to a carbon neutral economy is the main challenge of our time. It entails on the one hand the decarbonization of existing means of production, and on the other hand it requires promoting new, green technologies and products. Due to path dependencies and compounding effects, a fast transition to the manufacture of green products helps to establish market leadership in green technologies (Mealy & Teytelboym 2022). In a recent study (Reisch et al. 2022) commissioned by the Austrian Research Council (RFTE), the Complexity Science Hub Vienna (CSH) identified green products that Austria currently produces competitively, and a set of green products that are promising diversification opportunities for Austria. These green diversification opportunities are on the one hand identified based on Austria's current set of economic and industrial capabilities, and on the other hand by their global market size.

One of the main challenges on the path to a sustainable economy is the shortage of an appropriately trained labor force. The lack of skilled workers already presents an enormous challenge to the Austrian economy. As of April 2023, firms in a wide range of sectors report problems finding skilled workers (Dornmayr & Riepl 2022, Lehner 2023). The occupations in highest demand are handcraft occupations and Technicians outside of the IT sector (Dornmayr & Riepl 2022). Without preventive countermeasures, this tendency will amplify when more skilled labor will be required for the diversification into green products in the course of the green transition. In this study we estimate the labor demand of green products to anticipate changing workforce requirements. In particular, we identify in which industries to expect increased labor demand, in what type of occupation the workers will need to be trained, and what type of education the workers will need to have.

The project consists of the following steps. First, we look at the products in the Green Adjacent Possible (GAP), identified in the previous study (Reisch et al. 2022), and identify the sectors that produce them. Second, we use data from Statistics Austria to calculate the number of jobs we expect to be created as a result of an increase in production of a given green good. The results shown in this report assume a growth of production of €1 million, but we allow the reader to explore different production increases in a dashboard provided with this report.. Third, we use industry-occupation matrices based on data provided by the US Bureau of Labor Statistics to break down sectoral employment growth by specific occupation. Fourth, we use employment statistics collected by Statistics Austria to estimate the increase in demand for labor by field and level of education (e.g., "business, administration, and law" or "engineering, manufacturing, and construction" and "apprenticeship" or "secondary school", respectively).

We find that for an increase of production of €1 million in the top five in products in the GAP identified in (Reisch et al. 2022) there will be an additional demand of 6.3 workers. These workers will be needed mostly in the sectors "Machinery and equipment", "Repair and installation services of machinery and equipment" and "Employment services". In terms of occupations, demand will be highest for general occupation categories, in particular "Laborers and material movers" and "Miscellaneous assemblers and fabricators". However, there is also a significant amount of demand for specialized occupations, such as "General and Operations Managers", "Welding, soldering and brazing workers", or "Electricians". The education fields for which a high labor demand is anticipated are "Engineering, manufacturing and construction" and "Business, administration and law". For both, the demand is highest for workers with vocational training in the mentioned fields.

Our results are made available via an interactive dashboard that is integrated into the visualization of the preceding project (https://ecto.rfte.at/).

Input from the previous project

This study builds on the results of the preceding study "Transformation opportunities for Austria in the Tech for Green sector" (Reisch et al. 2022). There, we identified which products Austria currently exports competitively. Building on the literature of Economic Complexity (Hidalgo & Hausmann 2009), the concept of the Product Space (Hidalgo et al. 2007), and a study on green economic complexity (Mealy & Teytelboym 2022), we then identified a set of green products Austria is in a good position to produce in the future, given its current "capabilities". For details we refer to the report (Reisch et al. 2022) and the associated online dashboard https://ecto.rfte.at/.

The five products that were identified as Austria's main green diversification opportunities, with a high product space density and a large global market volume, are listed in Tab. 1. The products are classified using the Harmonized System product classification (World Customs Organization 1988), and serve as an input for the present study.

Product name	**HS Code**
Automatic regulating instruments	9032
Pumps for liquids	8413
Pumps, compressors, fans, etc.	8414
Appliances for thermostatically controlled valves	8481
Instruments for measuring properties of liquids	9036

Tab. 1. *The most attractive green diversification opportunities for Austria, as identified in (Reisch et al. 2022).*

Labor demand by sector

The first step in this project is to calculate the expected increase of labor demand if the demand for, and hence the production of a green product increases. First, we calculate the direct increase in labor demand due to the increased production of the green product. Second, we account for indirect effects, i.e. production increases of the suppliers of the industries producing the goods and their suppliers and so forth. We report the total and sectoral expected labor demand resulting from an increase in production of €1 million per product. Due to the linearity of the model used, the expected labor demand for an arbitrary production increase can be calculated by linearly scaling the result.

Which sectors manufacture which products? Mapping HS to NACE codes

Our scenarios are specified by an increase in production of green products, classified using the Harmonized System (HS) classification. As a first step, we need to identify the industry sectors which produce these products. We use the NACE rev. 2 classification (french: "Nomenclature statistique des activités économiques dans la Communauté européenne") to categorize industries.

There is no direct correspondence table between HS 2012 (at the 4 digit level), and NACE rev. 2 available. For this reason, we used a mapping that proceeded across multiple steps, building a chain of one-to-one correspondence tables starting from the HS 2012 code to the desired NACE rev. 2 nomenclature. On the whole, the chain is composed of the following six nomenclatures: HS 2012, SITC rev. 3, ISIC rev. 3, ISIC rev. 3.1., NACE rev. 1.1, NACE rev. 2. The correspondence tables were downloaded from Eurostat's website "Reference and Management of Nomenclatures" (Eurostat 2022) and were merged together. Once we established the path between the two nomenclatures, we identified which HS codes were grouped in which NACE rev. 2 codes. Across all products, a total of 1109 HS 2012 codes were mapped to 282 NACE rev. 2 codes. When considering the environmental goods alone, 133 HS 2012 codes were linked to a total of 154 NACE rev. 2 codes. Using the mapping from HS to NACE we map the products identified in the GAP to industries. If multiple industries produce the same good, we distribute the additional demand equivalently.

The mapping results in a correspondence matrix, C, that allows us to turn a vector of final demand for products, f_p, into a vector of final demand for industry sectors, f, via matrix multiplication, $f = C f_p$.

Direct effects — employment changes due to direct demand

To assess the direct effects of an increased production in a green good on employment, we merge data on employment and output per sector. Both can be obtained from Statistik Austria (www.statistik.at). The Structural Business Statistics (SBS) (Statistik Austria 2023a) contains, among other information, the number of employees per NACE 2-digit sector. For a few sectors the information is secret, due to anonymity constraints, but can be imputed using the number of employees at the next aggregate level, the number of firms per sector, and a proportionality assumption. Following (Miller & Blair 2009) we call the vector of employees per sector h'. For the output per sector, we use data provided in the Input-Output tables (Statistik Austria, 2023b). We call the vector of output per sector x.

Now, using $h_c = h' x^{-1}$ we get the labor coefficients. This is the additional unit of labor for an additional Euro of output (Miller & Blair 2009, p. 244ff) Using h_c we can calculate the direct labor demand as $\Delta h'_d = h_c \Delta f$, where Δf is the change in final demand and $\Delta h'_d$ the change in employment due to direct effects.

As an example, we calculate the additional employees required for an increase of 1 Mio. € in final demand HS 8413 "Pumps for liquids". The increase in labor demand due to total effects is 2.24 workers. In Fig. 1 we show the change in employment per sector due to direct effects, $\Delta h'_d$, in orange. To keep this report readable we show only the labor increase due to one product, and refer to the tables provided as supplementary material and the interactive online visualization, https://ecto.rfte.at/.

Indirect effects — employment changes due to intermediate demand

If an economic sector increases its production, it not only increases its demand for labor, but also needs additional intermediate inputs from other sectors. In this way, if an economy wants to increase the amount of final goods produced by, e.g., the sector „C28 Machinery and equipment", the firms in sector C28 are required to buy more inputs from sector „C25 Fabricated metal products", which in turn increases the demand for „C24 Basic metals". To take all indirect effects of this kind into account, we use the Austrian Input-Output table (AIOT) for 2019, which is the latest available. The AIOT contains economic linkages for 63 economic sectors. In general, the increase in output of a sector will be larger than the amount of its products that are available for final consumption. In the following, we will always discuss an increase in goods available for final consumption, and use the terms "goods available for final consumption", "final demand", "additional production", and "additional turnover" interchangeably in that sense.

Mathematically, the indirect effects can be accounted for using the Leontief inverse, $L = (1\text{-}A)^{-1}$, where A are the technical coefficients of the economy and 1 is the unit matrix. The matrix of technical coefficients, A, can be calculated by normalizing the AIOT row-wise with the sector's output x. While an economy is a constantly evolving system, the technical coefficients are assumed to be fixed for the purpose of this study. With the Leontief inverse, L, we can calculate changes in demand for labor, per sector, by multiplying it with the change in final demand, $\Delta h' = h_c L \Delta f$. For a detailed discussion of (labor) output multipliers, see (Miller & Blair 2009, p. 244ff).

We return to our example and calculate the increase in labor demand caused by an increase in final demand for goods classified as HS 8413 „Pumps for liquids and gases" by 1 Mio.€. In total, 7.90 extra workers are needed. In Fig. 1 we show the labor demand per sector, direct impacts are shown in orange and indirect impacts are stacked on top in blue. The sector „C28 Machinery and equipment, n.e.c." increases the largest demand for labor, with approximately 2.07 additional workers required, followed by „N78 Employment services" (1.04 additional worker) and „C33 Repair and installation services of machinery and equipment" (0.75 additional workers). Note that the total demand for labor was increased by a factor of 7.90 / 2.24 = 3.5 compared to the direct impacts. We show the results for increases in demand for other products in the online visualization described later in this report, which can be found at https://ecto.rfte.at/.

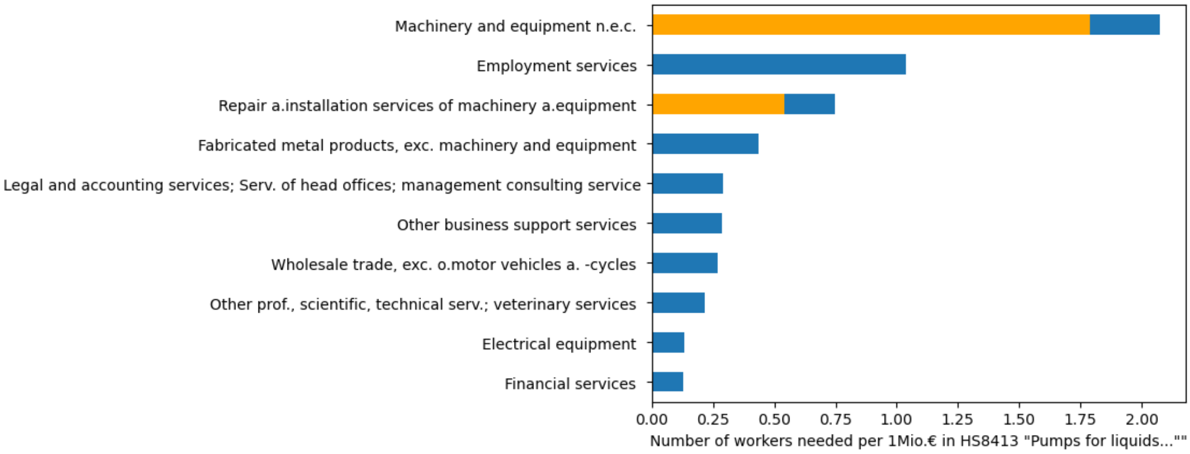

Fig. 1. *Labor demand for the production of 1Mio. € of HS8414 "Pumps for liquids and gases". We calculate the number of additional workers needed to satisfy an increase of 1 Mio. € of final products. The impact due to the production of final goods is shown in orange, indirect effects are shown in blue. Due to the linearity of the model the number of workers can be scaled linearly to smaller/larger increases in final demand.*

To assess the increase in labor demand for the green transition, we consider the labor demand after a 1 M€ increase of final demand spread over all five high-potential green products shown in Tab. 1. We expect the largest demand of 1.39 additional workers in sector „C28 Machinery and equipment", followed by „C33 Repair and installation services of machinery and equipment" and „N78 Employment services", with 0.88 and 0.83 workers, respectively. The total increase of labor demand is 6.30 employees, with 2.31 employees due to direct impacts.

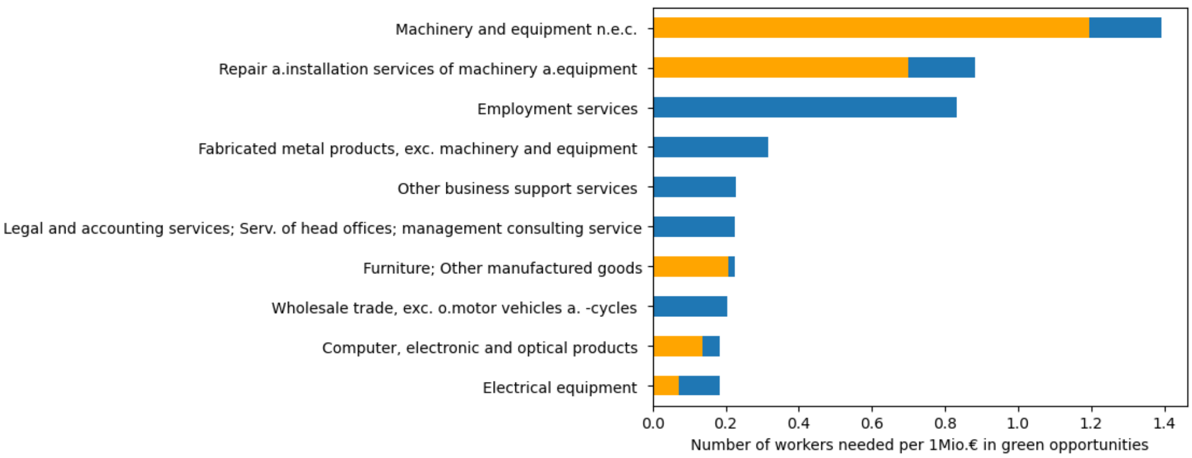

Fig. 2. *Labor demand for the production of 1Mio. € of the top 5 green products in the GAP. We calculate the number of additional workers needed to satisfy an increase of 1 Mio. € of final products. The impact due to the production of final goods is shown in orange, indirect effects are shown in blue. Due to the*

linearity of the model the number of workers can be scaled linearly to smaller/larger increases in final demand.

Labor demand by occupation

In the previous section we calculated the number of additional workers needed to produce the products in the Green Adjacent Possible, identified in the preceding study "Transformation opportunities for Austria in the "Tech for Green" sector" (Reisch et al. 2022), and describe the industries in which they would be employed. However, when assessing the expected requirements to the future workforce it is also important to identify the occupations that the new workers will be employed in. In this section we use occupation-industry statistics and the results of the previous section to estimate the labor demand per occupation subsequent to increased production in green products.

Occupation-industry statistics

In Austria, and the EU in general, only very limited statistics on occupations per economic sector are available. Instead we resort to occupation statistics collected by the US Bureau of Labor Statistics (BLS), which is to our knowledge globally the best available data set. Even though the EU and US industrial systems have many differences, it is safe to assume that the production of the same good requires a similar composition of workers; e.g., welders for welding, assembly workers for working on assembly lines, etc..

We use the BLS "Occupational Employment and Wage Statistics (OEWS) Survey 2021". It contains information on the number of employees in an occupation-sector combination. The occupations are classified in the "Standard Occupation Classification" (SOC), of which we use the 455 codes on the 4-digit level. The industries are classified using the "North American Industry Classification System" (NAICS) into 250 sectors that can be mapped to the NACE or AIOT classification using correspondence tables provided by Eurostat (Eurostat 2022).

We show the occupation-sector matrix in Fig. 3. Every row is normalized, to show the share of workers in a sector that work in a given occupation (column). We see that some occupations are needed in most sectors (yellow vertical lines) and that clusters of sectors with similar occupation requirements exist (yellow blocks).

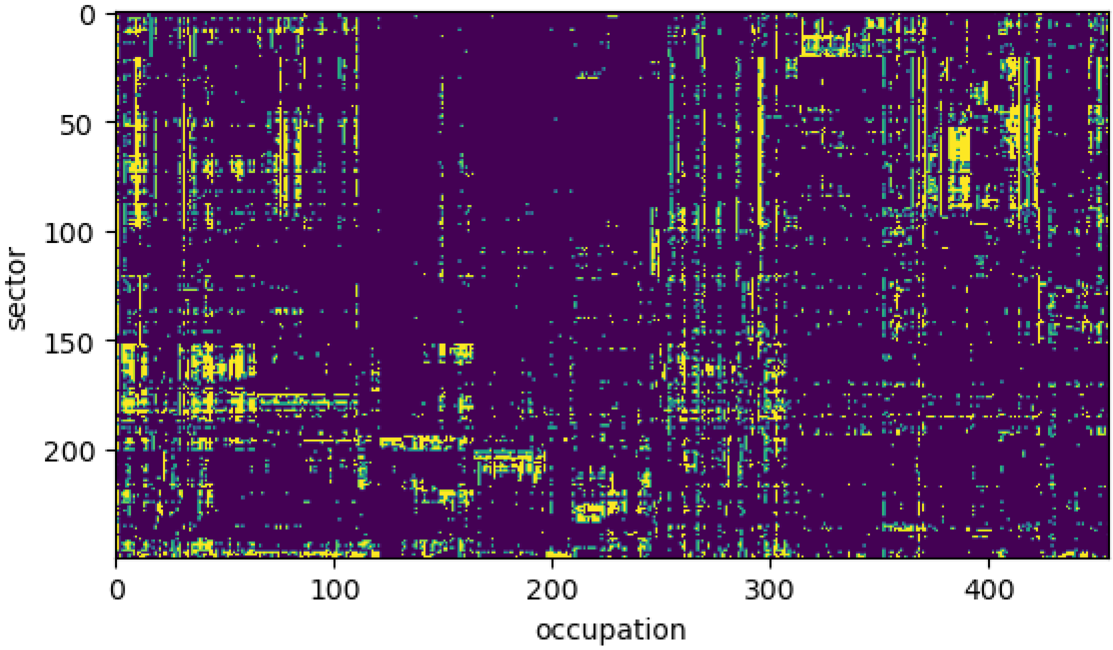

Fig. 3. *Occupation-industry employment requirements. We show the share of workers in a sector (row) that work in a given occupation (column). Some occupations are needed in most sectors (yellow vertical lines), and there are clusters of sectors with similar occupation requirements (yellow blocks).*

Calculating the labor demand increase by occupation

We start with the vector of additional employees per industry, $\Delta h'$, calculated in the previous section. From the BLS OEWS we obtain the occupation matrix, O, with elements O_{io}, the number employees in industry i in occupation o. By normalizing every row with the number of employees per sector, $O'_{io} = O_{io} / \sum_o O_{io}$, we arrive at the relative employee-industry matrix O'_{io}. Now, given that an industry i gets an increase of $\Delta h'_i$ new employees, we expect occupation o in industry i to increase its employees like $\Delta O_{io} = O'_{io}\ \Delta h'_i$. We assume that additional labor demand increases linearly according to the weights in the relative employee-industry matrix. This results in the following overall increase in occupation o if one or more industries increase their employment $\Delta O_o = \sum_i O'_{io}\ \ \Delta h'_i$.

Figure 4 shows the 10 largest elements of the occupation vector, ΔO_o , for a 1 Mio. € increase in demand for HS 8413 "Pumps for liquids and gases". Around 0.4 new workers are needed in the categories "Laborers and material movers" and "Miscellaneous assemblers and fabricators. The next two most important occupation categories are "Welding, soldering, and brazing workers" and "General and operations managers" with around 0.2 new workers each. The values for ΔO_o in Fig. 3 are much lower than those for $\Delta h'_i$ in Fig. 1, because here on the one hand the employees are spread out across 455 occupations instead of 63 sectors and on the other hand most industries and products need a broad range of activities and, hence, occupations in their production steps.

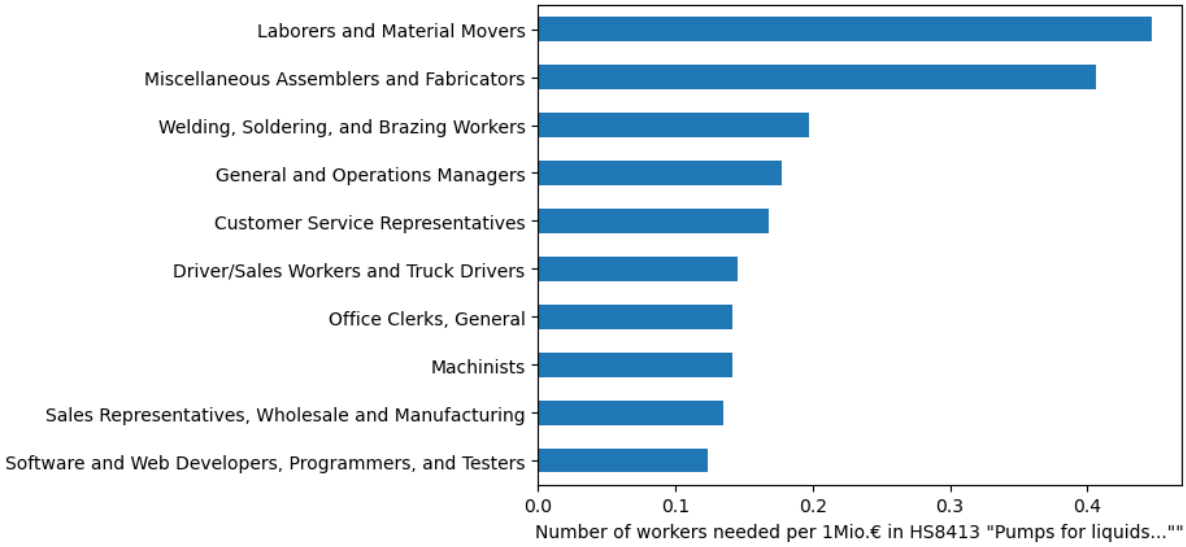

Fig. 4. *Increase in labor demand per occupation for an additional final demand of 1Mio. € of HS8414 "Pumps for liquids and gases". The numbers can be scaled linearly to different final demands. We find the largest demand for generic categories such as "Laborers and movers" and "Misc. Assemblers and Fabricators". However, many other specialized categories are also in high demand, e.g. "Welding, Soldering and Brazing Workers", "General and Operations Managers", or "Customer Service Representatives".*

We also investigate the increase in demand of occupations if there is an increase in all 5 products in the Green Adjacent Possible listed in Tab. 1. We find that "Laborers and Material Movers" is still the most demanded category, with 0.37 workers per 1M €, followed by "Misc. Assemblers and Fabricators" (0.33 workers per 1M€) and "General and Operation Managers" (0.16 workers per 1M€), see Fig. 5. These relatively broad occupations are followed by more specific high-demand occupations such as "Welding, Soldering and Brazing Workers", "Customer service representatives", "Electricians", "Driver/Sales Workers an Truck drives", or "Software and Web Developers, Programmers, and Testers".

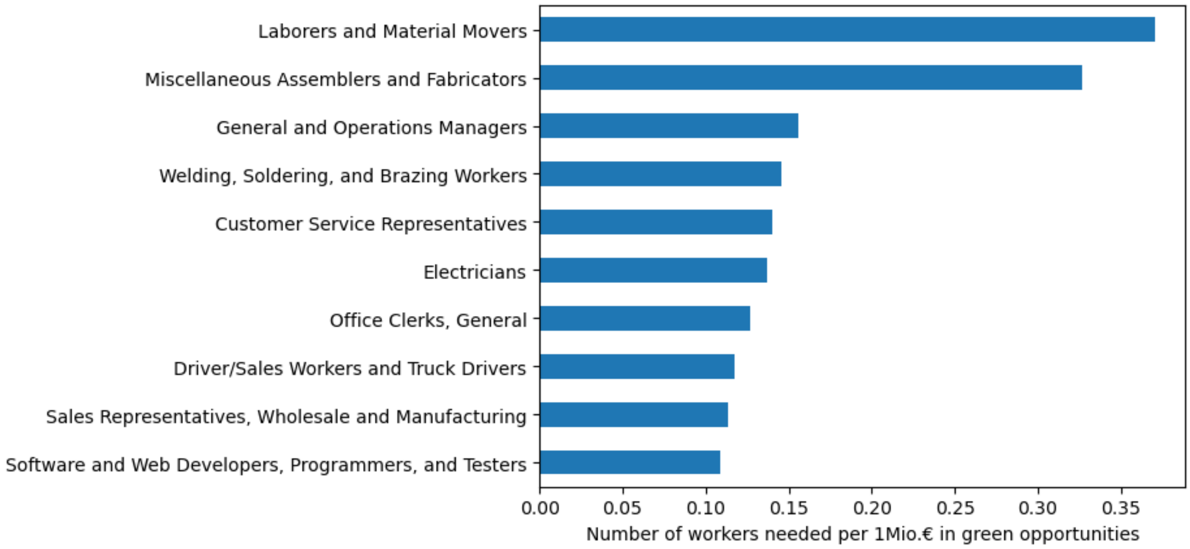

Fig. 5. *Increase in labor demand per occupation for an additional final demand of 1Mio. € for the top 5 GAP products, shown in Tab. 1. The numbers can be scaled linearly to different final demands. We find the largest demand for generic categories such as "Laborers and movers" and "Misc. Assemblers and Fabricators". However, many other specialized categories are also in high demand, e.g. "Welding, Soldering and Brazing Workers" or "Customer Service Representatives".*

Labor demand by education

The third way in which we will characterize the additional required workforce due to growth in green products is the education the future workers will need. Especially in Austria, where the education system provides many options from vocational training (ger. "Lehre") to colleges for higher vocational training (ger. "HTL"), the composition of the workforce requirements can show which education type needs to be strengthened and advertised in the near future. In this section we use education-industry statistics and the results of the previous section to estimate the labor demand per education subsequent to investments in green products.

Education-industry statistics

We use the "Register-based Labour Market Statistics" (LMS) provided by Statistik Austria (Statistik Austria 2023c). It contains information on the field and highest level of education attained by the employees of an industrial sector. The data is provided for NACE 2-digit industry codes, 12 education fields and 8 highest levels of education.

Calculating the labor demand by education

As in the previous section, we start with the vector of additional employees per industry, $\Delta h'$. From the LMS we obtain the education matrix, E, of which the elements, E_{ie}, represent the number of employees in industry *i* in education *e*. By normalizing every row with the number of employees per sector, $E'_{ie} = E_{ie} / \Sigma_e E_{ie}$, we arrive at the relative employee industry matrix E'_{ie}. Now, given that an industry *i* gets an increase of $\Delta h'_i$ new employees, we expect education *e* in industry *i* to increase its employees like $\Delta E_{ie} = E'_{ie}\ \Delta h'_i$. This results in the following overall increase in education *e* if one or more industries increase their employment $\Delta E_e = \sum_i E'_{ie}\ \Delta h'_i$.

In Fig. 6 we show which field and level of education combinations will be in needed the most after a final demand increase of 1 Mio. € in "HS 8413 Pumps for liquids and gases". The most needed education will be an apprenticeship in engineering, manufacturing and construction (1.6 employees), followed by untrained workers having finished a generic compulsory school (1.1 employees), and alumni of schools in higher vocational training in engineering, manufacturing and construction (0.5 employees).

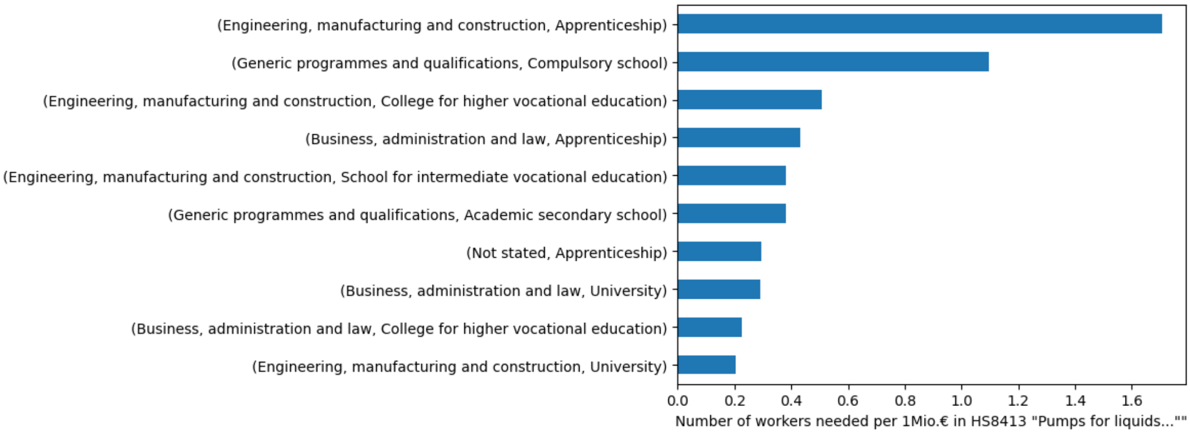

Fig. 6. *Increase in labor demand per occupation for an additional final demand of 1Mio. € of HS8414 "Pumps for liquids and gases". The numbers can be scaled linearly to different final demands. We find the largest demand for vocational training in "Engineering, manufacturing and construction", followed by demand for workers without specialized education who have compulsory school. The two fields in highest demand are "Engineering, manufacturing and construction" and "Business, administration and law", which are in demand for all levels of highest attained level of education.*

Figure 7 shows which education fields and levels are needed for an additional 1 Mio. € in final goods of the five green opportunities listed in Tab. 1. Most workers will be needed with vocational training in Engineering, manufacturing and construction (1.47), followed by workers who have finished compulsory schools without a special focus (0.92), and workers who have finished training in Engineering, manufacturing and construction in Colleges for higher vocational training (0.44). Most other following educations are for other levels of education in the field of "Engineering, manufacturing and construction" or all levels of education in "Business, administration, and law".

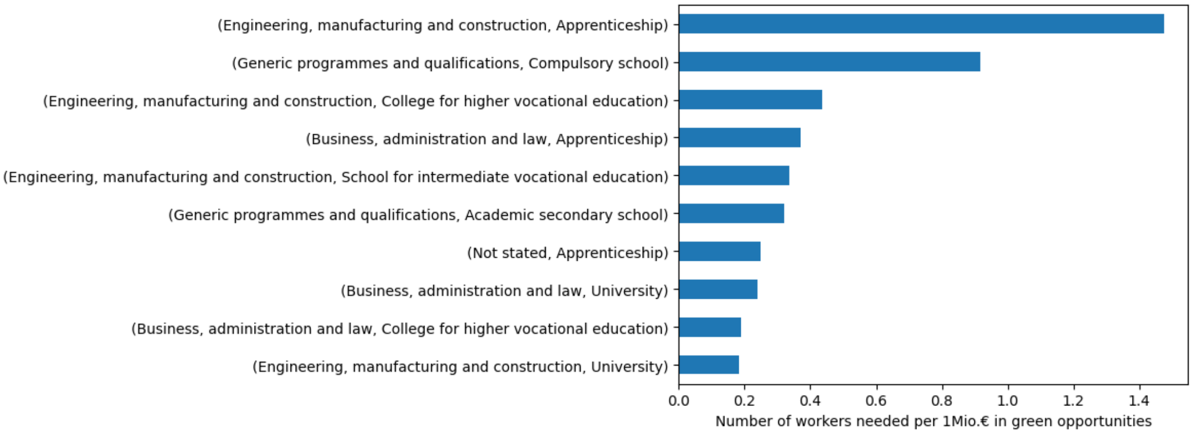

Fig. 7. *Increase in labor demand per occupation for an additional final demand of 1Mio. € for the 5 products in the GAP, shown in Tab. 1. The numbers can be scaled linearly to different final demands. We find the largest demand for vocational training in "Engineering, manufacturing and construction", followed by demand for workers without specialized education who have compulsory school. The two fields in highest demand are "Engineering, manufacturing and construction" and "Business, administration and law", which are in demand for all levels of highest attained level of education.*

Visualization

This work contains many variables and dimensions that are difficult to exhaustively present in a report like the present one. To allow the reader and the public to explore our results in an interactive way, we developed an online dashboard. It will be integrated in the existing dashboard at https://ecto.rfte.at/ to make our work accessible to stakeholders and the general public. Fig. 8 shows the dashboard and explains the different elements of the visualization.

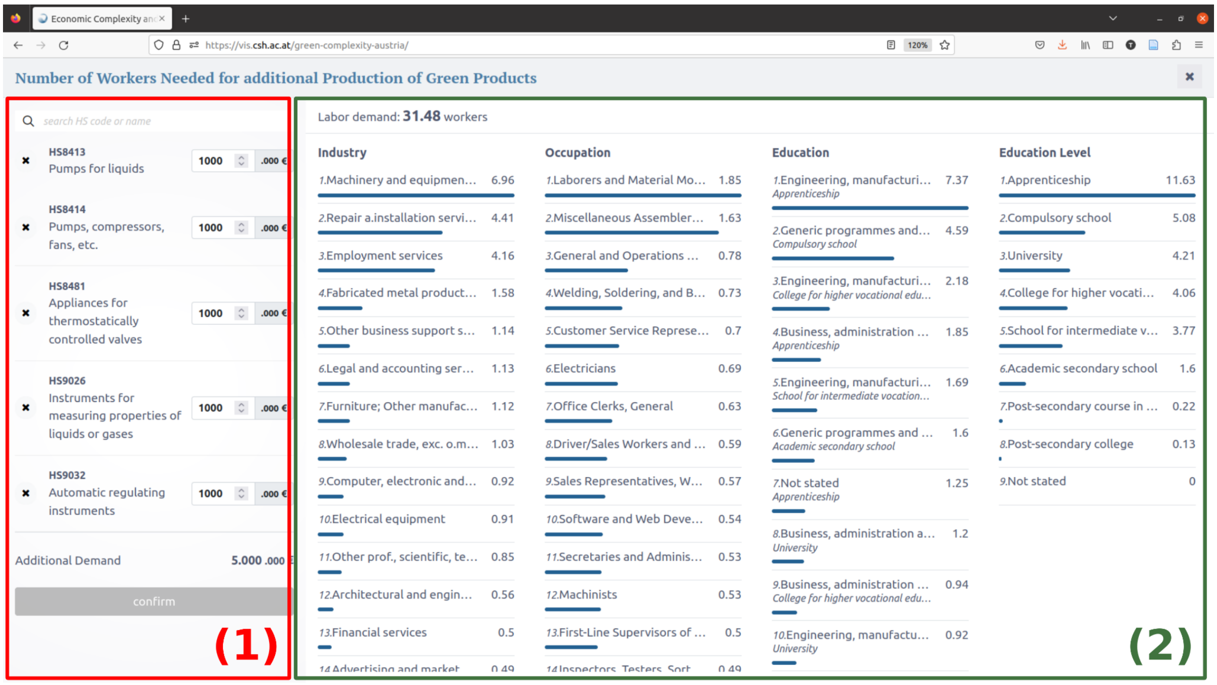

Fig. 8. *Dashboard for the future demand for employment in Austria. (1) Scenario configurator: In this panel the user can configure a custom scenario by choosing the amount of additional green products manufactured. (2) Results panel: In this panel the user can inspect the predicted employment requirements with respect to industry, occupation and sector.*

Conclusion

In this work we explore the expected additional labor demand that will arise due to the growth in production of green products in Austria. The green products for which Austria is in an advantageous position to diversify into, were identified in a preceding study (Reisch et al. 2022). Here, we estimate how many additional employees will be needed, and in which economic sectors they will be employed in order to grow the identified industries. We find that Austria's five most promising green diversification options will cause the largest demand for labor in the sectors "Machinery and Equipment", and "Repair of Machinery and Equipment". The overall increase in labor demand across all sectors is estimated to 6.30 employees.

We analyze which specific occupations will be required. For the same top five green diversification options, the two most needed occupation categories are the categories "Miscellaneous Assemblers and Fabricators" and "Laborers and Material Movers". The large demand increase in these occupation categories is due to their generality. More specialized occupations like "Welding, Soldering and Brazing Workers", "Customer service representatives", or "Electricians" will also see a significant increase.

Finally we investigate which educational backgrounds will be in high demand. The most needed education will be in vocational training for "Engineering, manufacturing and construction". This category will also see an increase in demand in academic training, as will the category "Business, administration and law".

This study has a few shortcomings. First, we are using input-output tables which are aggregated to 63 economic sectors. Our results would highly improve if granular, firm-level information about the production network would be available (Diem et al. 2023). Second, while we could rely on Austrian data for field and highest attained level of education, for occupation data we have to rely on statistics from the US. No equivalent data is collected for Austria or the EU. Third, our results are based on insights based on a Product Space constructed from country-level export statistics (Hidalgo et al. 2007). With the advent of granular data, future iterations of the Product Space should be improved by using firm-level supply chain data (Diem et al. 2022).

In conclusion, this study shows how much and in which sectors, occupations and education fields, the demand for labor will increase due to the additional production of green goods. However, the accuracy of the study would be greatly improved if actual data at the appropriate granularity were available. It is of utmost importance to create data governance structures in Austria that allow for the collection of data on supply chains, occupation, and education.

The results of this study are accessible and explorable through an online dashboard that allows for the study of customized scenarios. The dashboard is published under: https://ecto.rfte.at/

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