Labour demand in the energy transition

Projections for EU27

CE Delft

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Content

Summary

The purpose of this study is to provide the Joint Research Centre (JRC) with a preliminary assessment of the labour demand associated with the EU energy transition, complemented by specific assessments for each EU Member State. The study focusses on direct labour demand linked to the deployment of key decarbonisation technologies and shows how labour intensities can be used to estimate total workforce needs.

The study is based on two main objectives:

1. To assess and summarise the labour intensities of key decarbonisation technologies, differentiated by job type or skill level.
2. To develop a case study demonstrating how labour intensities can be applied to estimate total labour demand in the EU energy transition.

Labour intensities

To support this assessment, a comprehensive database of labour intensities was developed for all Member States in 2030. It provides estimates of labour intensities by project phase, job type, and skill level for a broad set of technologies.[1] For industrial heat pumps and building energy efficiency measures, the labour intensities in the database are less granular, as labour demand by job type and skill level is less well covered in the literature.

Table 1 - Labour intensities for 2030 and EU27, per technology

Technology	Subgroup	Unit	Manuf.	T&I	O&M	Granularity	
						Job types*	Skill levels**
Solar PV	Utility	Job(-year)s/MW_{el}	2.3	1.2	0.1	✓	✓
	Rooftop	Job(-year)s/MW_{el}	3.1	4.6	0.2	✓	✓
Wind	Onshore	Job(-year)s/MW_{el}	1.3	2.4	0.2	✓	✓
	Offshore	Job(-year)s/MW_{el}	12.6	1.4	0.2	✓	✓
Electrolysers (hydrogen)	-	Job(-year)s/MW_{el}	0.3	0.5	0.1	✓	✓
Hydropower/Storage	-	Job(-year)s/MW_{el}	2.3	7.4	0.1	✓***	✓***

1 As shown in Table 1, only for industrial heat pumps and building energy efficiency measures, detailed skill information is not available.

Technology	Subgroup	Unit	Manuf.	T&I	O&M	Granularity	
						Job types*	Skill levels**
Heat Pumps	Residential	Job(-year)s/MW_{th}	2.7	3.6	0.2	✓	✓
	Industrial	Job(-year)s/MW_{th}	5.5	3.1	1.7		
Power grid	-	Job(-year)s/mln. $€_{2024}$ capex	2.9	3.2	0.2	✓	✓
Efficiency/Renov in buildings	-	Job(-year)s/mln. $€_{2024}$ capex	2.6	10.2	-		
Biogas	-	Job(-year)s/ktoe	3.7	10.5	0.7	✓	✓
Charging infrastructure	Private	Job(-year)s/1,000 units	8.3	1.9	2.4	✓	✓
	Public	Job(-year)s/1,000 units	11.7	8.8	10.1	✓	✓

* Job types are specified at two levels of detail: broad categories (e.g. managers, trades and technicians, labourers) and more detailed occupations (e.g. business managers, plumbers, concreters).

** Skill levels are defined as low, medium, high (trades), and high (tertiary), corresponding to primary or lower, upper secondary, post-secondary vocational, and tertiary education levels.

*** Excluding manufacturing phase

Direct labour demand projections

Based on the Clean Energy Technology Observatory (CETO) 2025 scenario[2], the deployment of decarbonisation technologies in the EU27 between 2026 and 2030 is associated with substantial labour demand, amounting to approximately 4.5 million job-years in manufacturing and 6.6 million job-years in transport and installation, largely reflecting short-term deployment-related employment.[3] When expressed as indicative annual figures, this corresponds to around 0.9 million manufacturing jobs and 1.3 million transport and installation jobs per year, although the manufacturing figure represents an upper-bound estimate given the EU's reliance on imports. In contrast, operation and maintenance activities account for around 330,000 ongoing jobs[4], while the number of additional jobs required (compared to current employment levels) is lower.

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[2] See POTEnCIA CETO 2025 Scenario

[3] While partial labour intensity approaches provide insight into short-term job creation, they are not suitable for assessing long-term employment impacts, as they ignore key macroeconomic feedbacks such as labour supply constraints, wage pressures, inter-sectoral labour reallocation, and budget effects, and do not account for the fact that part of the required workforce is already employed in relevant sectors. As a result, such approaches are likely to overestimate overall employment impacts.

[4] This figure presents the O&M jobs associated with technologies deployed between 2026 and 2030. The total O&M workforce for these technologies is larger and should be determined based on the total installed capacity in 2030.

Labour demand across decarbonisation technologies differs in labour intensity and deployment scale. Building efficiency and renovation measures account for around 35% of total job-years due to their labour-intensive, on-site nature and the large number of buildings at stake. Technologies such as electrolysers, biogas, hydropower and storage, and industrial heat pumps contribute more modestly to labour demand. Installation activities dominate in buildings, hydropower, and biogas, while manufacturing is more prominent in offshore wind.

Operation and maintenance labour demand is driven by the new installed technology base and is highest for charging infrastructure (around 110,000 jobs), followed by residential and industrial heat pumps (72,000 and 26,000 jobs, respectively) and power-grids (53,000 yearly jobs), providing a sustained source of employment once technologies are operational.

Skills and occupations

Gaining insight into the skills and occupations required for the energy transition is essential for developing a human capital agenda and for identifying and addressing barriers related to training opportunities and required qualifications. The skills analysis indicates that labour demand in the energy transition is predominantly high-skilled, accounting for around 56% of total labour demand, while 44% relates to low- and medium-skilled workers. The largest occupational groups are labourers (31%), professionals such as engineers and IT specialists (30%), and trades and technicians (25%).

In manufacturing, labour demand is more evenly distributed, with 57% low- and medium-skilled and 43% high-skilled workers, and is dominated by assembly roles (over 50%). In contrast, transport and installation are highly skill-intensive, with around 85% of labour demand in high-skilled roles. Operation and maintenance similarly rely mainly on higher skills, with nearly two-thirds of labour demand in high-skilled occupations and about 30% in medium-skilled roles, reflecting strong demand for IT professionals and electricians.

Limitations and further research

This study focusses on labour demand and does not assess labour supply or whether the available workforce is sufficient to meet projected needs. The analysis reflects gross direct labour demand only, without accounting for the share of labour sourced from outside the EU, potential job losses in fossil-based industries, or for indirect and induced employment effects along supply chains.

Based on the findings of this study, several recommendations can be made for further research:

- conduct dedicated EU-level research on labour demand for energy efficiency in buildings;
- update and expand research on labour demand for heat pumps;

- update labour demand studies for technologies based on outdated data (such as biogas and power grids);
- Conduct ex post, historically based analyses of labour coefficients and learning effects for mature technologies.
- apply year-specific labour intensities in future labour demand projections.

← Content

1 Introduction

1.1 Background

With the European Green Deal, the EU strives to be the first climate-neutral continent by 2050.[5] That means net-zero emissions of greenhouse gases, economic growth decoupled from resource use, and a modern, resource-efficient and competitive economy.
The EU has adopted legislation to achieve its target of 55% reduction in greenhouse gas emissions by 2030, compared to 1990 levels, in line with the European Climate Law (see Text box 1).

Text box 1 – The EU commitment to renewable energy and energy efficiency

In order to achieve the goals of the Green Deal, a transition of all economic sectors is necessary. As such, several EU Directives outline the pivotal steps to be taken in each sector. The Renewable Energy Directive (RED)[6] establishes targets for increased energy use. By 2030, at least 42.5% of energy should come from renewable sources.
The directive introduces measures for various sectors, e.g. heating and cooling and transport, where uptake of renewable energy is slower. The Energy Efficiency Directive (EED)[7] is also a key driver of the energy transition: it helps reduce overall energy consumption, with the aim of contributing to achieving the 2030 target of 55% greenhouse gas emission reduction. The built environment, as the largest energy consumer in the EU, has the Energy Performance of Buildings Directive (EPBD), which helps increase the rate of renovation of buildings in the EU.[8] Moreover, the EU ETS[9] regulates the carbon emissions of industry, electricity and heat generation, and aviation by setting a cap on emissions and providing the possibility of trading emission allowances. Each of these directives provides a link to the various decarbonisation technologies: increasing the deployment of heat pumps, solar PV, wind turbines and more all help to achieve the goals set out in the aforementioned directives. To realise all these investments, additional jobs will be needed. Member States' contribution to the achievement of the various targets is elaborated in, for instance, the National Energy and Climate Plans (NECPs).[10] The NECPs outline how the Member States intend to address the five dimensions of the energy union: decarbonisation, energy efficiency, energy security, internal energy market and research, innovation and competitiveness. These plans provide insight into the public and private investments that will need to be made. These plans are evaluated by the European Commission (both at an aggregated and individual level).

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[5] See: The European Green Deal. Striving to be the first climate-neutral continent. (European Commission)
[6] See: Renewable Energy Directive (European Commission)
[7] See: Energy Efficiency Directive (European Commission)
[8] See: Energy Performance of Buildings Directive (European Commission)
[9] See: EU ETS. EU Emissions Trading System (European Commission)
[10] See: National energy and climate plans (European Commission)

The recent Draghi report on EU competitiveness outlines the challenges faced by industry and companies in the Single Market in a world of slowing productivity growth, as well as a need to improve growth.[11] An important conclusion is that the EU must create a joint plan for decarbonisation and competitiveness to become a leader in clean technology. Given the concerns about industries and competitiveness of the EU economy, the Commission has presented the Competitiveness Compass in January 2025, a new roadmap to restore dynamism and boost economic growth in the EU.[12] The Draghi report also contributed to the development of the new Clean Industrial Deal (CID) for competitive industries and quality jobs.[13] The CID presents measures to turn decarbonisation into a driver of growth for European industries, focusing on energy-intensive industries and the clean-tech sector. Lowering energy prices, creating quality jobs, and providing the right conditions for companies to thrive are vital.

Importance of jobs related to the energy transition and well-informed forecasts of labour demand

To follow the roadmaps set out in the Competitiveness Compass and the CID, the development of jobs related to the energy transition is essential. Labour supply shortages, both in terms of overall volume and specific labour qualifications and/or education levels, can act as bottlenecks for this green transition and can slow down the achievement of its objectives.

Analyses of labour demand are key to providing input on the required skills in the labour supply. For example, the Competitiveness Compass highlights the necessity of aligning skills with labour market demands, particularly in the context of the green transition. It proposes measures to promote skills development and quality jobs through a ‘Union of Skills’, ensuring that the workforce is equipped to meet the evolving needs of a decarbonised economy. In order to be able to develop the right set of policy measures to ensure this, detailed information about the labour demand of key decarbonisation technologies is needed.

On the other hand, the green transition can also play an important role in creating new labour opportunities. The Clean Industrial Deal (CID) emphasises the creation of ‘quality jobs’ through the decarbonisation of industries. By focusing on energy-intensive sectors like steel, metals, and chemicals, the CID aims to support these industries in transitioning to clean energy sources, thereby generating employment opportunities in clean manufacturing and related sectors.[14]

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[11] See: The Draghi report on EU competitiveness (European Commission)
[12] See: A Competitiveness Compass for the EU (European Commission, 2025)
[13] See: Clean Industrial Deal (European Commission)
[14] Moreover, the Critical Raw Materials Act (CRMA) establishes, for example, three benchmarks for the EU’s annual consumption of raw materials: 10% from local extraction; 40% to be processed in the EU and 25% to come from recycled materials. This will also have implications for the manufacturing jobs in the EU and, consequently, the labour supply and demand planning.

Given these developments, it is vital to gain a better understanding of the labour demand that comes with the development of a variety of decarbonisation technologies. With this study, we therefore contribute to the assessment of the labour demand entailed by the ongoing energy transition.

1.2 Objectives

The Joint Research Centre (JRC) maintains and employs a range of techno-economic tools for policy analysis, particularly in the context of climate change mitigation and the energy transition. To enhance the granularity and accuracy of labour market representation within these tools, a more detailed characterisation of the labour component of key energy transition technologies is required. This includes estimating the labour intensity of these technologies by skill level and occupation.

The results of this study are useful in two respects: first, they provide a bottom-up characterisation of the additional labour demand generated by the energy transition for each technology; second, they strengthen the JRC's modelling toolbox for assessing the socio-economic impacts of energy and climate policies.

The purpose of this study is to offer the JRC a preliminary assessment of the labour demand associated with the ongoing energy transition at the EU level, complemented by specific assessments for each EU Member State.

The key objectives of the study are:

1. To assess and summarise the labour intensities of key decarbonisation technologies, differentiated by job type or skill level.
2. To develop a case study demonstrating how labour intensities can be applied to estimate total labour demand in the EU energy transition.

1.3 Scope

This study examines the labour demand associated with scaling up a set of decarbonisation technologies (listed in Table 2) in the EU until 2030, focusing on the added capacity between 2026 and 2030. The analysis focuses on direct labour demand, meaning the labour required for the development, installation, and maintenance of these technologies. Indirect employment effects (for example, jobs in the supply chains providing materials for the installations and other services) are not included. In addition, the study considers gross labour demand rather than net labour demand. Accordingly, it accounts for the labour needs of the new technologies but does not factor in potential reductions in labour demand resulting from a decline in conventional technologies and/or a decline in other sectors due to labour substitution.

The activities in the value chain of each technology can broadly be divided into four stages: Research and Development; Manufacturing; Transport and Installation; and Operation and Maintenance. An overview is presented in Figure 1. The first stage, Research and Development (R&D), is typically difficult to quantify, as solid public data are limited, and labour demand estimates rely heavily on interviews. For this reason, R&D was excluded from the scope of this study.

Labour demand for Manufacturing and for Transport and Installation is considered temporary: once an installation becomes operational, the need for these types of jobs ends. Operation and Maintenance, by contrast, largely consists of permanent jobs, as they are required continuously throughout the lifetime of the installed technology, also after technical replacement. Labour demand related to decommissioning activities at the end of asset lifetimes is outside the scope of this analysis.

Table 2 - Scope in terms of decarbonisation technologies and related jobs

Technology	**Subgroup**	**Manufacturing**	**Transport & installation**[15]	**Operation & maintenance**
Solar PV	Utility	✓	✓	✓
	Rooftop	✓	✓	✓
Wind	Onshore	✓	✓	✓
	Offshore	✓	✓	✓
Power grid	-	✓	✓	✓
Biogas	-	✓	✓	✓
Electrolysers (hydrogen)	-	✓	✓	✓
Heat Pumps	Residential	✓	✓	✓
	Industrial	✓	✓	✓
Efficiency/Renovation in buildings[16]	-	✓	✓	
Charging infrastructure	Private	✓	✓	✓
	Public	✓	✓	✓
Hydropower/Storage	-	✓	✓	✓

Figure 1 - Value chain of decarbonisation technologies

[15] In the literature, alternative terminology such as *Design and Installation* or *Construction and Installation* is also used.
[16] Wall and roof insulation, window substitution, radiating floors.

2 Methodology

2.1 General approach

The approach of this study consists of two steps:

1. Collecting **labour intensities** for the decarbonisation technologies per energy functional unit (i.e. job-years per MW, job-years per million euros invested, job-years per ktoe, or job-years per unit) and structuring these in a database.
2. Developing, based on the database with labour intensities, a **baseline scenario** for the potential aggregated direct labour demand for the EU and for each Member State, differentiated by decarbonisation technology and by job type and skill level.

Labour intensities were collected through existing literature and CE Delft's Direct Labour Opportunities (DLO) model. Collecting labour intensities at the most disaggregated level available (covering job types and skill levels) allows to gain insight into the nature of the labour demand required for different technologies, both EU-wide and per Member State. In the model used for constructing the database, input and output parameters were harmonised (having 2030 as the base year, expressing monetary values in euros with price level 2024, etc.) to facilitate a consistent application across technologies and Member States.

To develop a **baseline scenario** for the potential aggregated direct labour demand for the different decarbonization technologies in the EU and for each Member State, the labour intensities were applied to a scenario of aggregated technology deployment projections between 2026 and 2030 in physical terms (capacity installed). This resulted in an estimate of aggregated gross direct labour demand. In addition, low and high labour demand scenarios were derived using lower and upper bounds of the labour intensities included in the database. It should be noted that labour demand for the period 2026-2030 was estimated using labour intensities with a 2030 base year only. As a result, the labour demand estimates presented are likely conservative.

2.2 Data collection

Labour intensities

Table 3 summarises the primary sources used to collect data on labour intensities. For most technologies, several sources were combined. For example, for solar PV, Rutovitz, Langdon, et al. (2025) provides labour intensities for each labour phase and occupational shares for Transport and Installation and for Operation and Maintenance, but not for Manufacturing. As the DLO model, described in Text box 2, provides occupational shares for Manufacturing jobs (and associated skill levels), these shares were applied to the labour intensities presented by Rutovitz, Langdon, et al. (2025). Because the labour intensities for solar PV from Rutovitz, Langdon, et al. (2025) are more recent and differentiated for utility and rooftop, they were preferred over those from the DLO model. For other technologies, such as electrolysers, labour intensities from different sources were combined, typically by taking the average. Annex A provides tables with three scenarios for all labour intensities: low, high, and preferred. The final column of Table 3 specifies the sources used for the preferred labour intensity and provides a rationale for their selection.

In addition to the literature listed in the table below, other sources were consulted to identify labour intensities and to validate the results. However, the sources presented in the table were preferred, based on factors such as the year of the studies and the scope of the labour-intensity estimates (e.g. geographic scope, scope of technologies). In addition, interviews were held with Jay Rutovitz (on the general approach of this study), EHPA (on labour demand for industrial heat pumps), and the IEA (on both labour demand for industrial heat pumps and the general approach of this study).

Table 3 - Main sources used for collecting labour intensities

Technology	Subgroups	Sources used for labour intensities and skills breakdown	Sources used for ‘preferred’ labour intensity (and justification)
Solar PV	Utility, Rooftop	(Rutovitz, Langdon, et al., 2025); DLO model: (CBS, 2022), interviews	Rutovitz (most recent study with labour intensities for utility and rooftop).
Wind	Onshore, Offshore	(Rutovitz, Langdon, et al., 2025); DLO model: (ECN, 2015), (CBS, 2018), (CBS, 2022), interviews	Rutovitz (most recent study).
Power grid	-	(Rutovitz, Langdon, et al., 2025); DLO model: (ECN, 2015), (CBS, 2018), (CBS, 2022), interviews	• Manufacturing, O&M: DLO (only relevant study available). • T&I: average of DLO and Rutovitz (both relevant: DLO better applicable to EU, but Rutovitz more recent).

Technology	Subgroups	Sources used for labour intensities and skills breakdown	Sources used for 'preferred' labour intensity (and justification)
Biogas	-	(Ram et al., 2022); DLO model: (ECN, 2015), (CBS, 2018), (CBS, 2022), interviews	Average of DLO and Ram (both relevant).
Electrolysers (hydrogen)	-	(Ram et al., 2022); DLO model: (CE Delft, 2021)	Average of DLO and Ram (both relevant).
Heat Pumps	Residential	(Ram et al., 2022), (Rutovitz, Lara, et al., 2025); DLO model: DLO model: (CBS, 2022), interviews	Ram (most relevant study available).
	Industrial	(IEA, 2020b); (EHPA, 2024); (De Boer et al., 2020)	Average of IEA and De Boer et al. (both relevant).
Efficiency/Renovation in buildings	-	(IEA, 2020a); (Hirvonen et al., 2022); (DOE U.S., 2025)	Average of IEA and Hirvonen (both relevant).
Charging infrastructure	Private, Public	(ICCT, 2024); (Rutovitz, Lara, et al., 2025)	• Manufacturing: ICCT (only study available). • T&I, O&M: Rutovitz (more recent and more consistent with other technologies).
Hydropower/Storage	-	(Rutovitz, Langdon, et al., 2025)	Rutovitz (most recent study).

Text box 2 – Direct Labour Opportunities (DLO) model

CE Delft has internally developed a linear model, the DLO model, aimed at estimating direct labour demands for a wide range of energy technologies. The model was initially developed for the Netherlands, but during the course of this study, the model has been updated to cover all EU27 Member States. Based on capacity (MW_{el} or MW_{th}), investment (million $€_{2024}$), output (ktoe), or units (number of chargers), the model estimates temporary direct labour demand (Manufacturing, and Transport & Installation) and permanent direct labour demand (Operation & Maintenance). It does so for both 2020 and 2030, and for a low, high, and 'preferred' scenario. In addition, the model distinguishes labour demand by job type at two levels of granularity and by educational level (CE Delft, 2022).
The model is developed based on literature, public statistical databases, and interviews with industry experts on investments, capacity, costs, direct labour demand, and learning curves of energy technologies. For labour intensities, both in total and by labour phase, the primary sources used are (ECN, 2015), (CBS, 2018), and (CE Delft, 2021). The breakdown by job type and educational level is based on (CBS, 2022), supplemented by interviews with industry experts.

Technology deployment projections

Data on technology deployment projections have been provided by JRC and were shared only for the purpose of this study.[17] The dataset contains trajectories for the deployment of various energy supply and end-use technologies for 2023-2035, broken down to Member State level. Table 4 shows the technologies included in the dataset and the physical unit in which the projections are given.

Table 4 – Technologies included in the deployment projections

Technology	**Unit used for deployment projection**
Electrolysers (hydrogen), Hydropower storage, Solar PV, Wind	MW_{el}
Heat pumps	MW_{th}
Efficiency/Renovation in buildings, Power Grid	$€_{2024}$
Charging infrastructure	Units
Biogas	ktoe

2.3 Data transformations

Transforming the labour intensities to 2030

The focus of this study is to develop labour-demand projections for 2030. Most labour intensities reported in the literature are derived from earlier years. As some decarbonisation technologies are relatively new and expected to benefit from scaling up, learning effects are likely to occur. Learning curves capture the general downward trend in unit costs as cumulative production increases, and improvements in production efficiency in each phase of the value chain may also translate into higher labour productivity.

To account for these learning effects, the labour intensities were multiplied by the unit cost reduction presented in Table 14 in Annex B. The table illustrates that certain technologies, such as hydropower, are already well established and therefore exhibit limited or no expected cost reductions. Other technologies, such as solar PV or electrolysers for hydrogen production, show substantially higher anticipated cost reductions. For power-grid investments, for which no cost-reduction projections were available, we assumed no cost reductions, as this is a well-established and mature technology. For charging infrastructure, we applied learning rates of 7-9% (Tsiropoulos et al., 2022).

[17] Based on POTEnCIA CETO 2025 Scenario

Transforming the labour intensities for cross-country differences

The labour intensities reported in the literature are often specific to a particular country or region. In some cases, the labour demand associated with a specific job can be expected to differ across countries, as reflected in sectoral labour-productivity levels (GDP per FTE). Certain activities, such as the installation of solar panels on residential rooftops or the installation of residential heat pumps, are typically carried out by local or national firms, making cross-country differences in labour intensities likely. For large-scale commercial energy projects, however, activities are more often undertaken by international companies, and differences in labour productivity across countries are therefore expected to be less pronounced for these types of technologies.

As presented in Table 5, part of the labour intensities from the literature were adjusted. This was done by developing, for each Member State, labour-productivity indices that relate national labour productivity to that of the country or region for which the original labour intensity was derived (see Annex C). For the technologies and activities for which labour intensities were adjusted, the adjustment was carried out using labour-productivity data for the NACE sector Construction[18], which has been assumed to serve as a reasonable proxy. As the location of manufacturing activities is uncertain and the manufacturer market is to a large extent global, the labour intensities for manufacturing were not adjusted.

Table 5 – Overview of technologies/activities adjusted for labour productivity differences

Technologies	**Phase**	**Labour productivity adjustment**
Solar PV rooftop; Residential heat pumps; Efficiency/Renovation in buildings; Charging infrastructure	Transport and installation; Operation and maintenance	Yes, based on labour productivity levels in sector Construction
Solar PV utility; Wind; Power grid; Biogas; Electrolysers (hydrogen); Industrial heat pumps; Hydropower/Storage	Transport and installation; Operation and maintenance	No
All	Manufacturing jobs	No

[18] OECD Data Explorer – Productivity database

Harmonisation of job types and educational levels

In the DLO model, a distinction is made based on the Dutch education system (including five levels of education). As educational systems differ across the EU, we have translated these educational levels into four levels based on the International Standard Classification of Education (ISCED):

- **Low skilled level:** Equivalent to ISCED 0-2 (early childhood education, primary educational, or lower as the highest attained educational level).
- **Medium skilled level:** Typically equivalent to ISCED 3 (completing upper secondary education).
- **High skilled level (trades):** Typically equivalent to ISCED 4 (completing post-secondary non-tertiary education). Labourers have the qualifications associated with skilled trades such as electricians, lines workers, metal trades, cable jointers, specialised crane drivers.
- **High skilled level (tertiary):** Equivalent to ISCED 5-8 (completing short-cycle tertiary education, bachelor's degree, master's degree, or doctoral degree).

3 Results

3.1 Database labour intensities

Based on the literature review and the DLO model described in Section 2.2 and the data modifications described in Section 2.3, a database was constructed with labour intensities for 2030 and all EU27 Member States. Table 6 provides an overview of the level of detail of labour intensities for each of the technologies.

Table 6 - Database labour intensities: level of detail per technology

Technology	Subgroup	Total	Labour phases	Job types	Skill levels
Solar PV	Utility	✓	✓	✓	✓
	Rooftop	✓	✓	✓	✓
Wind	Onshore	✓	✓	✓	✓
	Offshore	✓	✓	✓	✓
Power grid	-	✓	✓	✓	✓
Biogas	-	✓	✓	✓	✓
Electrolysers (hydrogen)	-	✓	✓	✓	✓
Heat Pumps	Residential	✓	✓	✓	✓
	Industrial	✓	✓		
Efficiency/Renovation in buildings	-	✓	✓		
Charging infrastructure	Private	✓	✓	✓	✓
	Public	✓	✓	✓	✓
Hydropower/Storage	-	✓	✓	✓*	✓*

* Excluding manufacturing phase

Table 7 provides an overview of the labour intensities at the level of labour phases.
The presented values represent the ‘preferred’ values, as discussed in Section 2.2, which are used for the baseline scenario. Annex A provides on overview of the labour intensities for all scenarios (low, high, preferred).

When comparing labour intensities expressed in **labour demand per MW_{el},** clear differences emerge across technologies. Offshore wind shows the highest manufacturing intensity by a large margin – which, when compared to onshore wind, can be explained by additional components that need to be manufactured for the sub-structures. Solar PV, onshore wind, hydropower, and electrolysers have substantially lower labour intensities for manufacturing. For transport and installation, hydropower exhibits the highest requirements, followed by rooftop solar PV and onshore wind. Electrolysers, utility solar PV, and offshore wind show comparatively lower installation needs. It is notable that the labour demand associated with the installation phase of onshore wind exceeds that of offshore wind. One plausible explanation is that offshore wind projects concentrate a larger share of labour in the manufacturing phase, with a greater proportion of preparatory work undertaken off-site. In addition, offshore wind turbines are generally larger than onshore turbines and are installed using specialised vessels, which may reduce installation labour requirements per unit of installed capacity. Operation and maintenance labour requirements are generally modest across all technologies.

A separate comparison applies to technologies expressed in **labour demand per euro of capital expenditure**. Building efficiency and renovation measures, for which the installation phase represents the largest share of labour demand, show a higher total labour intensity than power-grid investments. For building efficiency and renovation measures, O&M efforts are expected to be close to zero and are not quantified in the literature.

Table 7 - Labour intensities for 2030 and EU27, per technology

Technology	Subgroup	Unit	Manuf.	T&I	O&M	Source(s)
Solar PV	Utility	Job(-year)s/MW_{el}	2.3	1.2	0.1	(Rutovitz, Langdon, et al., 2025)
	Rooftop	Job(-year)s/MW_{el}	3.1	4.6	0.2	(Rutovitz, Langdon, et al., 2025)
Wind	Onshore	Job(-year)s/MW_{el}	1.3	2.4	0.2	(Rutovitz, Langdon, et al., 2025)
	Offshore	Job(-year)s/MW_{el}	12.6	1.4	0.2	(Rutovitz, Langdon, et al., 2025)
Electrolysers (hydrogen)	-	Job(-year)s/MW_{el}	0.3	0.5	0.1	(Ram et al., 2022), DLO model
Hydropower/Storage	-	Job(-year)s/MW_{el}	2.3	7.4	0.1	(Rutovitz, Langdon, et al., 2025)
Heat Pumps	Residential	Job(-year)s/MW_{th}	2.7	3.6	0.2	(Ram et al., 2022)
	Industrial	Job(-year)s/MW_{th}	5.5	3.1	1.9	(IEA, 2020b), (EHPA, 2024), (De Boer et al., 2020)

Technology	Subgroup	Unit	Manuf.	T&I	O&M	Source(s)
Power grid	-	Job(-year)s/mln. €2024 capex	2.9	3.2	0.2	(Rutovitz, Langdon, et al., 2025), DLO model
Efficiency/Renovation in buildings	-	Job(-year)s/mln. €2024 capex	2.6	10.2	-	(IEA, 2020a), (Hirvonen et al., 2022), (DOE U.S., 2025)[19]
Biogas	-	Job(-year)s/ktoe	3.7	10.5	0.7	(Ram et al., 2022), DLO model
Charging infrastructure	Private	Job(-year)s/1,000 units	8.3	1.9	2.4	(ICCT, 2024), (Rutovitz, Lara, et al., 2025)
	Public	Job(-year)s/1,000 units	11.7	8.8	10.1	(ICCT, 2024), (Rutovitz, Lara, et al., 2025)

3.2 Labour demand projections

3.2.1 EU27 labour demand

Table 8 shows that the labour demand in the EU27 associated with the deployment of decarbonisation technologies between 2026 and 2030 amounts to approximately 4.5 million job-years in manufacturing and 6.6 million job-years in transport and installation. As these figures are expressed in job-years, they do not directly indicate the number of workers required. To provide an illustrative indication, one could assume that manufacturing and transport and installation activities take place in the year preceding deployment. Under this simplifying assumption, the implied average annual labour demand over the period 2026-2030 would be around 0.9 million jobs in manufacturing and 1.3 million jobs in transport and installation. However, this represents an upper-bound scenario in which all manufacturing of clean technologies occurs within the EU. In practice, the EU relies heavily on imported technologies, implying that actual manufacturing-related labour demand within the EU is likely to be substantially lower.

The projected figures therefore reflect significant short-term labour demand during the deployment phase of clean technologies. In addition, operation and maintenance activities account for approximately 330,000 jobs[20], representing ongoing annual labour demand once technologies are operational rather than temporary, deployment-related employment.

Finally, it should be noted that a portion of the required labour is already employed in relevant sectors; consequently, the number of additional jobs that would need to be

[19] The distribution between manufacturing and transport and installation is based on the U.S. Energy Employment Report and is used as a proxy. It should be noted, however, that energy efficiency activities in buildings in the United States may differ significantly from those in the EU due to differences in building characteristics.

[20] This figure presents the O&M jobs associated with technologies deployed between 2026 and 2030. The total O&M workforce for these technologies is larger and should be determined based on the total installed capacity in 2030.

created beyond existing jobs is likely to be considerably lower, although this has not been quantified in the present study.

Table 8 – Total labour demand for EU27, based on projected technology deployment between 2026 and 2030

	Manufacturing (million job-years)	Transport and installation (million job-years)	Operation and maintenance (million jobs)
Baseline scenario	4.5	6.6	0.33

Text box 3 – Validation of numbers

The number of studies providing direct labour demand projections for 2030 across a comparably comprehensive set of technologies is limited. To assess the robustness of the results, a comparison was therefore made with recent studies that estimate current workforce levels.

For wind energy, WindEurope estimates that the sector currently supports 168,800 jobs across EU27 (WindEurope, 2025), while the World Energy Employment Report suggests a lower figure of approximately 141,000 jobs[21] (IEA, 2025). Applying the labour intensities used in this study to 2023, after adjusting the intensities to reflect that year and assuming 50% of the manufacturing takes place within the EU, yields an estimate of around 105,000 jobs. For solar PV, the CETO report estimates the current workforce at roughly 280,000 jobs (JRC, 2023), compared with an estimated 160,000 jobs based on this study's methodology (assuming only 10% of manufacturing takes place within the EU). These differences can be considered modest and within a reasonable range. For heat pumps, however, the discrepancy is considerably larger. While the CETO report estimates current employment in the total heat pump market at around 170,000 jobs (JRC, 2024), the application of this study's approach results in an estimate exceeding 500,000 jobs (assuming 50% of manufacturing takes place within the EU). This indicates a substantial divergence between estimates, highlighting uncertainty in current labour demand figures for this technology.

The observed, and in some cases substantial, variation in employment estimates is likely driven by differences in estimation methods and analytical scope. One important distinction concerns the use of reported workforce statistics from industry associations, compared with the approach adopted in this study, which applies labour intensities to capacity additions. These methodological differences are often accompanied by varying interpretations of what constitutes direct versus indirect labour demand, particularly for technologies such as heat pumps, where building-level installation activities may or may not be included. Additional variation may arise, for example, from differences in the range of components considered within the manufacturing phase. Furthermore, discrepancies in technology definitions and scope, can further contribute to divergent employment estimates. Finally, assumptions regarding the share of manufacturing taking place within the EU differ across studies; in the analysis above, we have assumed that 50% of manufacturing occurs domestically.

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[21] The World Energy Employment Report 2025 reports total employment of approximately 300,000 in the wind sector. As this figure includes both direct and indirect employment, and WindEurope indicates that 47% of the wind workforce is directly employed, we applied this share to derive an estimate of around 141,000 direct jobs.

Table 9 presents labour demand projections across the different scenarios, based on the labour intensities outlined in Annex A. The results indicate that labour demand in the transport and installation and operation and maintenance phases is substantially higher in the high scenario. This increase is primarily driven by higher labour demand associated with charging infrastructure, reflecting labour intensity assumptions derived from an (ICCT, 2024) labour market study, which reports significantly higher values than those used in Rutovitz, Lara, et al. (2025).

Table 9 – Total labour demand for EU27, based on projected technology deployment between 2026 and 2030 (all scenarios)

	Manufacturing (million job-years)	Transport and installation (million job-years)	Operation and maintenance (million jobs)
Baseline scenario	**4.5**	**6.6**	**0.33**
Low scenario	4.0	5.3	0.32
High scenario	4.8	11.2	0.72

3.2.2 Labour demand by technology

Figure 2 illustrates how these labour requirements are distributed across technologies. Labour demand is a result of labour productivity and demand for the technology (deployment rate). Efficiency and renovation measures in buildings (wall and roof insulation, window substitution, radiating floors) create the highest overall labour demand (35% of total), followed by residential heat pumps, and power grids. Building efficiency and renovation measures create the highest labour demand because they involve extensive, hands-on, and highly customisable onsite construction work. Unlike the manufacturing and installation of standardised equipment, which can be highly automated or quick to deploy, building retrofits are resource-intensive and time-consuming processes that require a diverse range of skilled workers for each unique project. In contrast, electrolysers, biogas, hydropower/storage, and industrial heat pumps are a relatively modest contribution to labour needs, as, compared to other technologies, the quantities deployed are rather small in the CETO scenario. The composition of labour demand also varies: rooftop solar PV, charging infrastructure, and heat pumps are installation-intensive, while offshore wind is dominated by manufacturing.

Figure 2 – Labour demand in job-years for EU27, **manufacturing**, **transport and installation**, based on projected technology deployment between 2026 and 2030

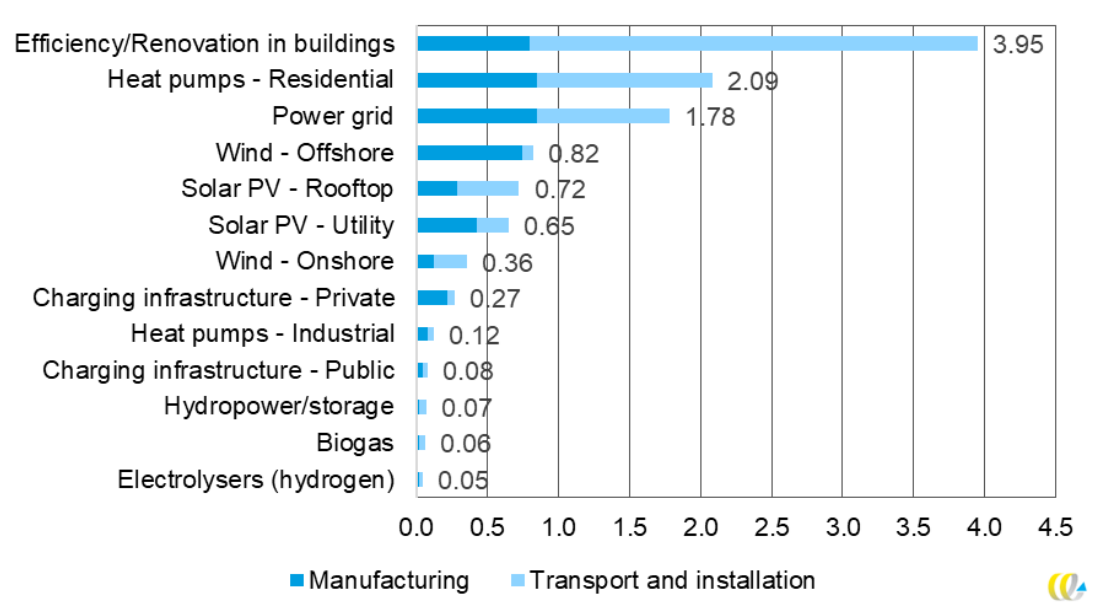
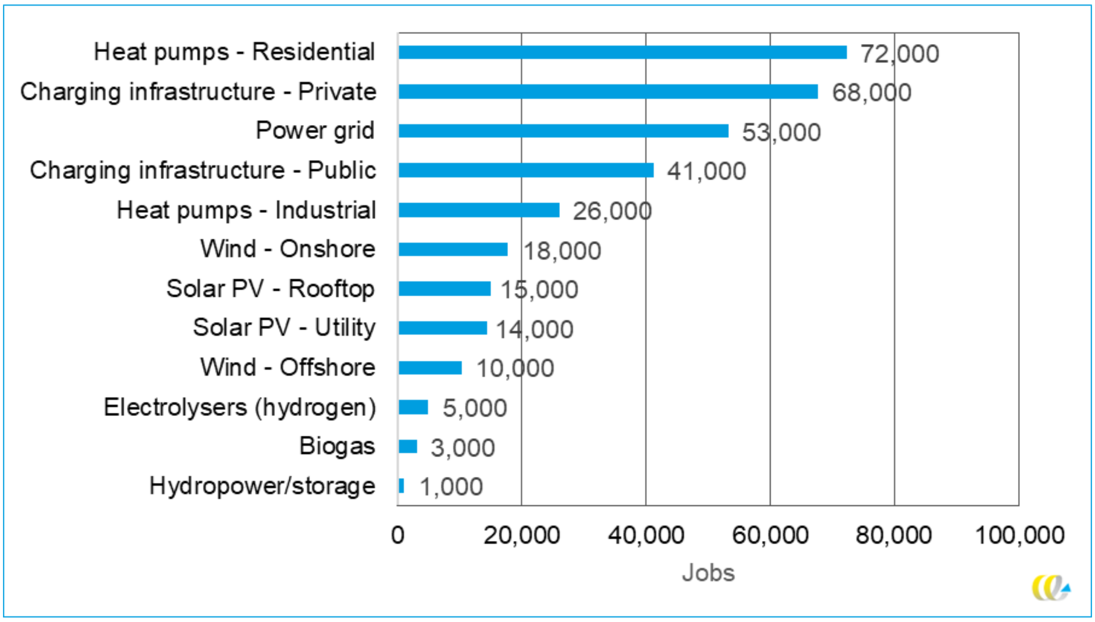


Figure 3 presents the O&M jobs associated with technologies deployed between 2026 and 2030.[22] Charging infrastructure accounts for the largest share of the labour demand with almost 110,000 jobs. The number of private charging points is expected to grow with more than 170% between 2026 and 2030 and the number of public charging points with almost 220%. Other categories that show projections of important labour demand are residential and industrial heat pumps (72,000 and 26,000 jobs, respectively), and power-grids (53,000 yearly jobs).

[22] Accordingly, the *total* O&M workforce for these technologies is larger and should be determined based on the total installed capacity in 2030.

Figure 3 – Yearly labour demand in jobs for EU27, **operation and maintenance**, based on projected technology deployment between 2026 and 2030



3.2.3 Labour demand by Member States

Figure 4 shows that short-term labour demand is highly concentrated in a few Member States. Germany and France account for the largest projected labour needs with almost 2 million job-years each. This is driven in large part by the dominant role of building-efficiency and renovation measures, which account for 23% of total labour demand in Germany and as much as 68% in France. As for the EU as a whole, these measures are the single largest contributor across nearly all Member States.

Italy and Spain follow at a considerable distance, each exceeding 1 million job-years, where building efficiency, residential heat pumps, utility-scale solar PV, and power grids together explain roughly 80% of their totals. Overall, the distribution of labour demand across Member States mirrors differences in population size and energy-system scale, but also structural differences in national transition pathways.

Content

Figure 4 – Labour demand in job-years for EU27, **manufacturing**, **transport and installation**, based on projected technology deployment between 2026 and 2030

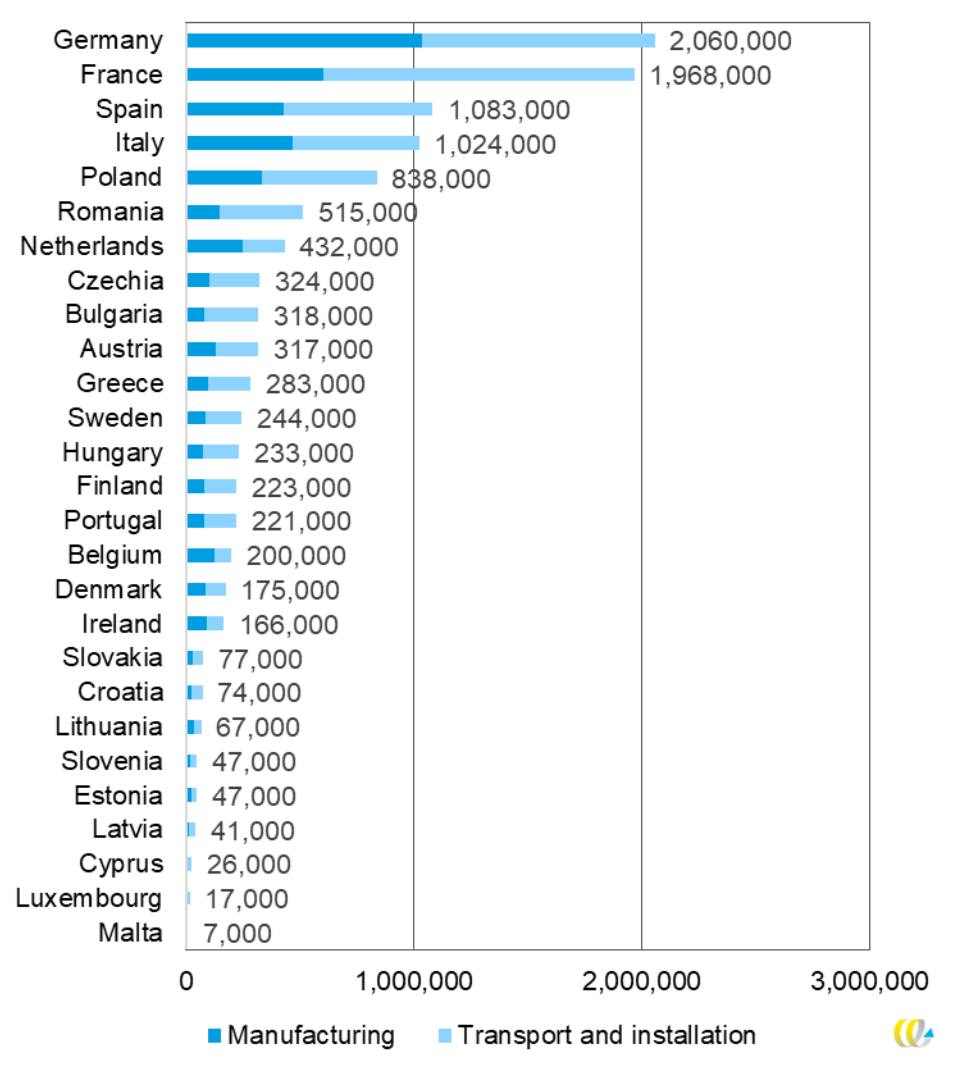
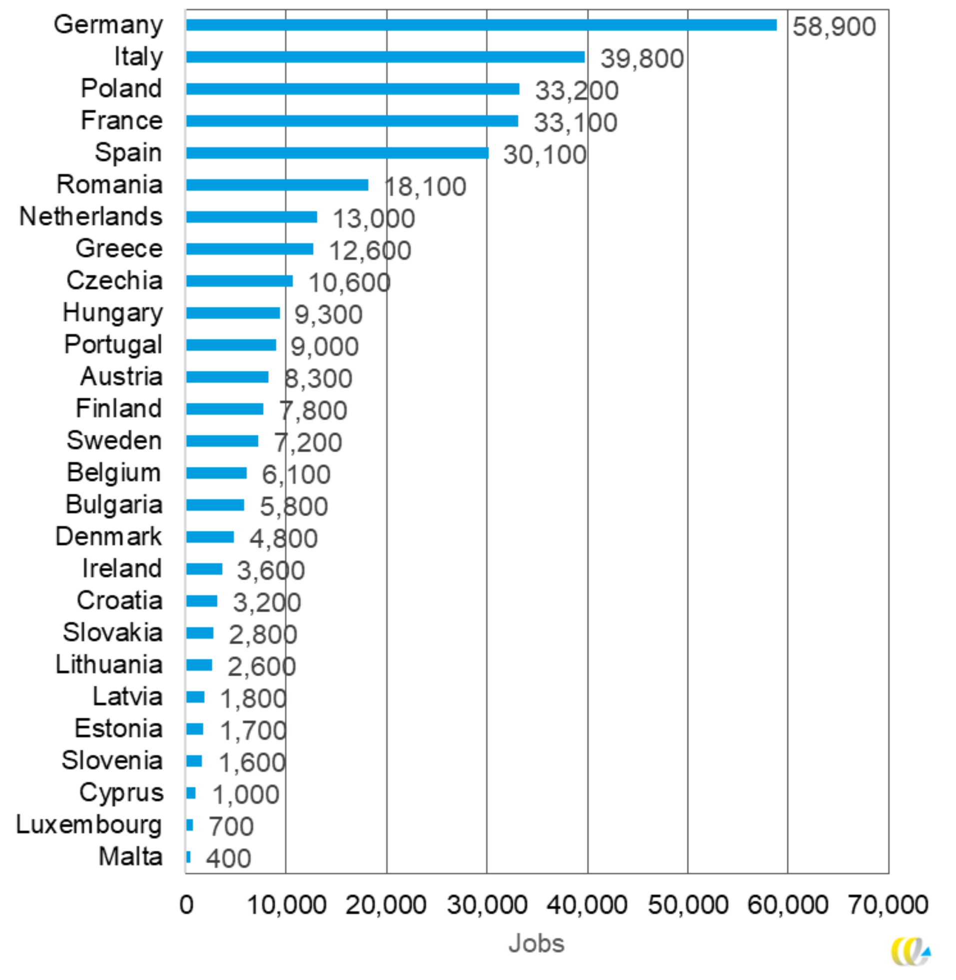


Figure 5 shows that the extra O&M jobs required in 2030 are dominated by more or less the same Member States, with Germany clearly in the lead at around 59,000 ongoing jobs, followed by Italy (40,000), and Poland and France (both 33,000). These high values reflect both the size of their installed technology base and the technologies that are particularly O&M-intensive. In Germany, for example, power grids alone accounts for 22% of O&M labour demand, complemented by residential heat pumps (19%) and private and public charging infrastructure (15 and 10%, respectively).

Figure 5 – Labour demand in yearly jobs for EU27, **operation and maintenance**, based on projected technology deployment between 2026 and 2030

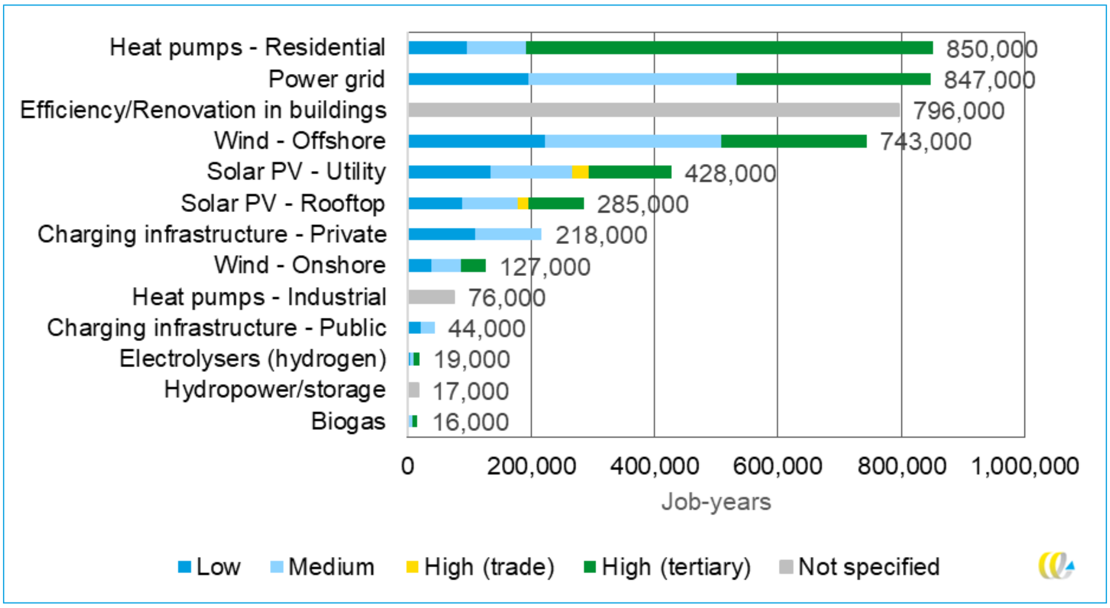


3.2.4 Skills analysis

The database provides detailed information on job categories and educational levels for the technologies listed in Table 6. Overall, the analysis indicates that approximately 56% of total labour demand is associated with high-skilled workers, while 44% corresponds to low- and medium-skilled workers (see Section 2.3 for a discussion of educational levels). The dominant job categories are labourers (e.g. assembly and construction workers; 31%), professionals (e.g. engineers and IT specialists; 30%), and trades and technicians (e.g. plumbers and electricians; 25%). These occupations constitute the core workforce required during the 2026-2030 deployment period, and demand for these skills is expected to persist beyond 2030 as technology deployment continues.

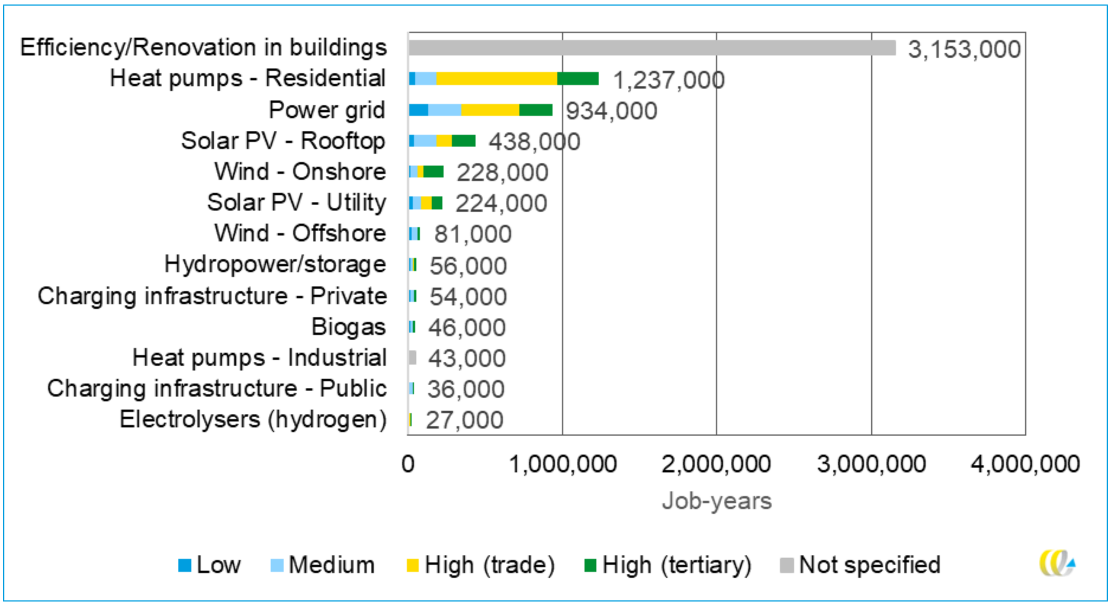
For the **manufacturing phase** specifically, the analysis shows that 57% of labour demand is attributable to low- and medium-skilled workers, while 43% relates to high-skilled workers. In addition, the results indicate particularly strong demand for assembly workers (over 50%), followed by engineers (17%), workers in coordinating roles (10%), and IT professionals (8%).

Figure 6 – Educational levels and labour demand in job-years for EU27, **manufacturing**, based on projected technology deployment between 2026 and 2030



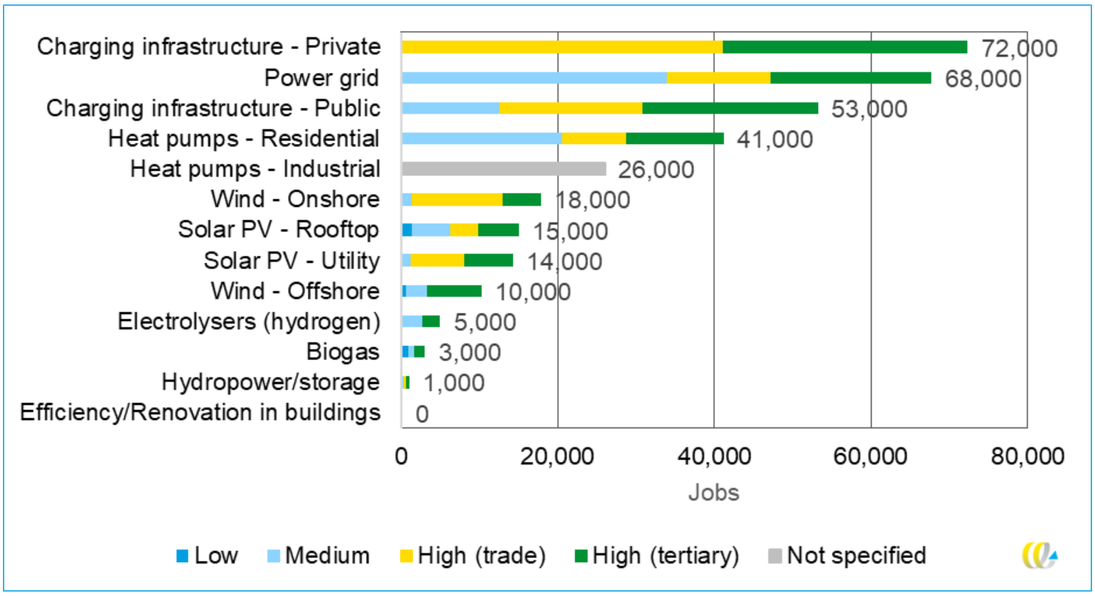
In contrast, the **transport and installation** phase is more skill-intensive, with only 15% of labour demand attributed to low- and medium-skilled workers and 85% to high-skilled workers. The results indicate particularly strong demand for trades and technicians (over 40%), as well as for professional roles such as project estimators (6%), electrical engineers (3%), construction managers (3%), and for workers in coordinating roles (10%). Labourers, such as construction workers, concreters, and riggers and dogmen, account for approximately 15% of total labour demand.

Figure 7 – Educational levels and labour demand in job-years for EU27, **transport and installation**, based on projected technology deployment between 2026 and 2030



For the **operation and maintenance** phase, the majority of labour demand is concentrated among high-skilled workers, with 37% attributed to high-skilled workers with tertiary education and 31% to high-skilled workers with trade qualifications, while 30% corresponds to medium-skilled workers. Low-skilled workers account for only 1% of labour demand. The most prominent occupational groups in this phase are IT professionals (39%) and electricians (34%).

Figure 8 – Educational levels and labour demand in yearly jobs for EU27, **operation and maintenance**, based on projected technology deployment between 2026 and 2030



4 Conclusions

4.1 Key findings

Labour intensities

To support a comparative assessment of employment effects across energy transition technologies, a comprehensive database was constructed containing labour intensity estimates for 2030 for all EU27 Member States. The database provides broad coverage of relevant technologies and includes labour intensities disaggregated by project phase, job type, and skill level. For all technologies covered in this study, this allows a detailed comparison of direct labour demand across manufacturing, transport and installation, and operation and maintenance phases. Information on job types and skill levels is available for all categories except industrial heat pumps and building energy efficiency measures.

Table 10 - Labour intensities for 2030 and EU27, per technology

Technology	Subgroup	Unit	Manuf.	T&I	O&M	Granularity	
						Job types	Skill levels
Solar PV	Utility	Job(-year)s/MW_{el}	2.3	1.2	0.1	✓	✓
	Rooftop	Job(-year)s/MW_{el}	3.1	4.6	0.2	✓	✓
Wind	Onshore	Job(-year)s/MW_{el}	1.3	2.4	0.2	✓	✓
	Offshore	Job(-year)s/MW_{el}	12.6	1.4	0.2	✓	✓
Electrolysers (hydrogen)	-	Job(-year)s/MW_{el}	0.3	0.5	0.1	✓	✓
Hydropower/Storage	-	Job(-year)s/MW_{el}	2.3	7.4	0.1	✓*	✓*
Heat Pumps	Residential	Job(-year)s/MW_{th}	2.7	3.6	0.2	✓	✓
	Industrial	Job(-year)s/MW_{th}	5.5	3.1	1.7		
Power grid	-	Job(-year)s/mln. €$_{2024}$ capex	2.9	3.2	0.2	✓	✓
Efficiency/Renovation in buildings	-	Job(-year)s/mln. €$_{2024}$ capex	2.6	10.2	-		
Biogas	-	Job(-year)s/ktoe	3.7	10.5	0.7	✓	✓
Charging infrastructure	Private	Job(-year)s/1,000 units	8.3	1.9	2.4	✓	✓
	Public	Job(-year)s/1,000 units	11.7	8.8	10.1	✓	✓

* Excluding manufacturing phase.

Comparing labour intensities expressed in job-years or jobs per MW of installed capacity reveals substantial differences across technologies. Offshore wind has by far the highest manufacturing labour intensity, reflecting the need for additional components such as sub-structures, while solar PV, onshore wind, hydropower, and electrolysers show considerably lower manufacturing requirements. For transport and installation, hydropower is the most labour-intensive technology, followed by rooftop solar PV and onshore wind, whereas electrolysers, utility-scale solar PV, and offshore wind exhibit lower installation labour demand. The higher installation labour intensity of onshore wind relative to offshore wind likely reflects a greater concentration of offshore labour in manufacturing and off-site preparation, combined with the use of larger turbines and specialised installation vessels offshore. Operation and maintenance labour demand is generally modest across all technologies.

When labour intensities are expressed per euro of capital expenditure, building efficiency and renovation measures stand out as particularly labour-intensive, driven primarily by installation activities. These measures show higher total labour demand per euro invested than power-grid investments, while operation and maintenance requirements for building efficiency and renovation measures are expected to be negligible and are therefore typically not quantified in the literature.

Direct labour demand projections

EU27 labour demand

Based on the CETO scenario, our analysis shows that the deployment of decarbonisation technologies in the EU27 between 2026 and 2030 is associated with substantial labour demand. The demand amounts to approximately 4.6 million job-years in manufacturing and 6.5 million job-years in transport and installation, reflecting mainly short-term employment during the deployment phase. When translated into indicative annual figures under a simplifying assumption that all activities occur in the year prior to deployment, this corresponds to roughly 0.9 million manufacturing jobs, representing an upper-bound scenario given the EU’s reliance on imported technologies, and 1.3 million transport and installation jobs per year. By contrast, operation and maintenance activities account for around 330,000 ongoing jobs, reflecting sustained annual labour demand once technologies are operational. Finally, as part of the required workforce is already employed in relevant sectors, the number of additional jobs that would need to be created is likely to be lower than these gross estimates, although this has not been quantified in this study.

Labour demand by technology

Labour demand across decarbonisation technologies is shaped by both labour intensity and deployment scale. Building efficiency and renovation measures account for the largest share of overall labour demand, representing around 35% of total job-years, reflecting their labour-intensive and highly customised on-site nature. In contrast, electrolysers, biogas, hydropower and storage, and industrial heat pumps contribute more limited labour demand, mostly because of their relatively smaller deployment. Labour demand profiles also differ by technology, with building efficiency and renovation measures, rooftop solar PV, and charging infrastructure being installation-intensive, while offshore wind is dominated by manufacturing.

Operation and maintenance labour demand reflects the size of the installed technology base rather than deployment activity. Charging infrastructure accounts for the largest share of ongoing employment, with close to 110,000 jobs, followed by residential and industrial heat pumps (72,000 and 26,000 jobs, respectively) and power-grids (53,000 yearly jobs), together representing a substantial and sustained source of labour demand once systems are operational.

Labour demand by Member States

From an EU perspective, labour demand is strongly concentrated in a few Member States, with Germany and France together accounting for almost 4 million job-years for the manufacturing and transport and installation phases between 2026 and 2030. This is largely driven by labour demand in the built environment (i.e. building efficiency and renovation measures, residential heat pumps, rooftop solar PV, private charging points), which represent around 48% of total labour demand in Germany and up to 77% in France. Italy and Spain follow at a considerable distance, each exceeding 1 million job-years, with labour demand primarily driven by building efficiency measures, residential heat pumps, utility-scale solar PV, and power-grid investments. Overall, differences across Member States reflect variations in population size, energy-system scale, and national decarbonisation pathways.

Ongoing operation and maintenance labour demand shows a similar geographical pattern, with Germany leading at around 59,000 jobs, followed by Italy (approximately 40,000), and Poland and France (both 33,000). These levels reflect both the size of the installed technology base and the prominence of O&M-intensive assets, particularly power grids and charging infrastructure, in the largest Member States.

Skills analysis

Across all technologies, the analysis shows that labour demand is predominantly high-skilled, accounting for around 56% of total labour demand, while low- and medium-skilled workers represent 44%. The main occupational groups are labourers (about 31%), professionals such as engineers and IT specialists (30%), and trades and technicians including plumbers and electricians (25%).

In the manufacturing phase, labour demand is more evenly distributed by skill level, with 57% attributed to low- and medium-skilled workers and 43% to high-skilled workers, and is dominated by assembly workers (over 50%), followed by engineers, coordinating roles, and IT professionals.

By contrast, transport and installation activities are highly skill-intensive, with around 85% of labour demand associated with high-skilled workers and only 15% with low- and medium-skilled workers, driven mainly by demand for trades and technicians and specialised professional roles. Operation and maintenance shows a similar emphasis on higher skills, with nearly two-thirds of labour demand concentrated among high-skilled workers, around 30% among medium-skilled workers, and only a marginal share for low-skilled workers, reflecting the prominence of IT professionals and electricians in this phase.

4.2 Limitations and further research

Direct labour demand provides one side of the total picture

A key limitation of this study is that it focuses exclusively on labour demand and does not assess labour supply. The analysis adopts a demand-side perspective to identify the types and scale of labour required in the EU to support the deployment of decarbonisation technologies, but it does not evaluate whether the available workforce is sufficient to meet this demand. In addition, the analysis does not determine the extent to which labour demand would be met by workers within the EU or sourced from outside the EU.
The results therefore reflect gross labour demand only and also do not account for potential job losses in fossil-based industries. Finally, the analysis is limited to direct labour demand and does not capture additional indirect or induced employment effects along the supply chain.

Further research
Based on the findings of this study, several recommendations can be made for further research:

- **Conduct dedicated EU-level research on labour demand for energy efficiency in buildings.** Energy efficiency and renovation measures represent the largest source of labour demand in this study, yet information on required skills, including job types and educational levels, remains limited. The heterogeneity of the sector may partly explain this data gap, underscoring the value of a focused EU-level analysis.

- **Update and expand research on labour demand for heat pumps.** For residential heat pumps, labour demand projections based on the applied labour intensities are substantially higher than those reported in other studies, potentially reflecting reliance on older sources dating back to 2015. In addition, for industrial heat pumps, there is a clear lack of evidence on labour requirements and skill profiles, a gap confirmed through discussions with the EHPA and the IEA.
- **Update labour demand studies for technologies with outdated data.** For technologies such as biogas and power grids, labour demand estimates are currently based on relatively old studies. More recent, technology-specific research would improve the quality and relevance of labour demand projections.
- **Conduct ex post, historically based analyses of labour coefficients and learning effects for mature technologies.** Drawing on historical deployment data for technologies with long rollout histories, such as solar PV, wind energy, and building renovation, such analyses should assess how labour coefficients and labour productivity have evolved over time and the extent to which learning effects have contributed to these changes. The insights gained can then be used to inform expectations for technologies that are currently at an early stage of scale-up, such as charging infrastructure and heat pumps, and to improve forward-looking labour demand projections.
- **Apply year-specific labour intensities in future labour demand projections.** In this study, labour demand for the period 2026–2030 was estimated using labour intensities for 2030 only. This means that the current estimates are likely conservative. Using labour intensities that vary by year would improve accuracy.

A Labour intensities

A.1 Manufacturing

Table 11 - Manufacturing: labour intensities for 2030 and EU27, per technology

Technology	Subgroup	Unit	Low	Pref.	High	Source(s)
Solar PV	Utility	Job-years/MW_{el}	2.3	2.3	2.3	(Rutovitz, Langdon, et al., 2025)
	Rooftop	Job-years/MW_{el}	3.1	3.1	3.1	(Rutovitz, Langdon, et al., 2025)
Wind	Onshore	Job-years/MW_{el}	1.3	1.3	3.2	(Rutovitz, Langdon, et al., 2025), DLO model
	Offshore	Job-years/MW_{el}	7.1	12.6	12.6	(Rutovitz, Langdon, et al., 2025), DLO model
Electrolysers (hydrogen)	-	Job-years/MW_{el}	0.2	0.3	0.5	(Ram et al., 2022), DLO model
Hydropower/Storage	-	Job-years/MW_{el}	2.3	2.3	2.3	(Rutovitz, Langdon, et al., 2025)
Heat Pumps	Residential	Job-years/MW_{th}	2.7	2.7	2.7	(Ram et al., 2022)
	Industrial	Job-years/MW_{th}	5.3	5.5	5.6	(IEA, 2020b), (EHPA, 2024), (De Boer et al., 2020)
Power grid	-	Job-years/mln. €$_{2024}$ capex	2.9	2.9	2.9	DLO model
Efficiency/Renovation in buildings	-	Job-years/mln. €$_{2024}$ capex	2.2	2.6	3.0	(IEA, 2020a), (Hirvonen et al., 2022), (DOE U.S., 2025)
Biogas	-	Job-years/ktoe	1.7	3.7	5.8	(Ram et al., 2022), DLO model
Charging infrastructure	Private	Job-years/1,000 units	8.3	8.3	8.3	(ICCT, 2024), (Rutovitz, Lara, et al., 2025)
	Public	Job-years/1,000 units	11.7	11.7	11.7	(ICCT, 2024), (Rutovitz, Lara, et al., 2025)

A.2 Transport and installation

Table 12 - Transport and installation: labour intensities for 2030 and EU27, per technology

Technology	Subgroup	Unit	Low	Pref.	High	Source(s)
Solar PV	Utility	Job-years/MW_{el}	1.2	1.2	1.2	(Rutovitz, Langdon, et al., 2025)
	Rooftop	Job-years/MW_{el}	4.6	4.6	4.6	(Rutovitz, Langdon, et al., 2025)
Wind	Onshore	Job-years/MW_{el}	2.4	2.4	6.3	(Rutovitz, Langdon, et al., 2025), DLO model
	Offshore	Job-years/MW_{el}	1.4	1.4	14.2	(Rutovitz, Langdon, et al., 2025), DLO model
Electrolysers (hydrogen)	-	Job-years/MW_{el}	0.4	0.5	0.6	(Ram et al., 2022), DLO model
Hydropower/Storage	-	Job-years/MW_{el}	7.4	7.4	7.4	(Rutovitz, Langdon, et al., 2025)
Heat Pumps	Residential	Job-years/MW_{th}	3.6	3.6	3.6	(Ram et al., 2022)
	Industrial	Job-years/MW_{th}	3.0	3.1	3.2	(IEA, 2020b), (EHPA, 2024), (De Boer et al., 2020)
Power grid	-	Job-years/mln. $€_{2024}$ capex	0.5	3.2	5.9	(Rutovitz, Langdon, et al., 2025), DLO model
Efficiency/Renovation in buildings	-	Job-years/mln. $€_{2024}$ capex	8.6	10.2	11.7	(IEA, 2020a), (Hirvonen et al., 2022), (DOE U.S., 2025)
Biogas	-	Job-years/ktoe	8.2	10.5	12.8	(Ram et al., 2022), DLO model
Charging infrastructure	Private	Job-years/1,000 units	1.9	1.9	65.9	(ICCT, 2024), (Rutovitz, Lara, et al., 2025)
	Public	Job-years/1,000 units	8.8	8.8	101.9	(ICCT, 2024), (Rutovitz, Lara, et al., 2025)

A.3 Operation and maintenance

Table 13 - Operation and maintenance: labour intensities for 2030 and EU27, per technology

Technology	Subgroup	Unit	Low	Pref.	High	Source(s)
Solar PV	Utility	Jobs/MW_{el}	0.08	0.08	0.08	(Rutovitz, Langdon, et al., 2025)
	Rooftop	Jobs/MW_{el}	0.16	0.16	0.16	(Rutovitz, Langdon, et al., 2025)
Wind	Onshore	Jobs/MW_{el}	0.19	0.19	0.90	(Rutovitz, Langdon, et al., 2025), DLO model
	Offshore	Jobs/MW_{el}	0.17	0.17	2.01	(Rutovitz, Langdon, et al., 2025), DLO model
Electrolysers (hydrogen)	-	Jobs/MW_{el}	0.05	0.09	0.13	(Ram et al., 2022), DLO model
Hydropower/Storage	-	Jobs/MW_{el}	0.14	0.14	0.14	(Rutovitz, Langdon, et al., 2025)
Heat Pumps	Residential	Jobs/MW_{th}	0.21	0.21	0.21	(Ram et al., 2022)
	Industrial	Jobs/MW_{th}	1.82	1.88	1.93	(IEA, 2020b), (EHPA, 2024), (De Boer et al., 2020)
Power grid	-	Jobs/mln. $€_{2024}$ capex	0.18	0.18	0.18	DLO model
Efficiency/Renovation in buildings	-	Jobs/mln. $€_{2024}$ capex	-	-	-	
Biogas	-	Jobs/ktoe	0.25	0.70	1.16	(Ram et al., 2022), DLO model
Charging infrastructure	Private	Jobs/1,000 units	2.36	2.36	9.12	(ICCT, 2024), (Rutovitz, Lara, et al., 2025)
	Public	Jobs/1,000 units	10.10	10.10	13.68	(ICCT, 2024), (Rutovitz, Lara, et al., 2025)

B Cost reductions

Table 14 – Cost reductions per technology

Technology	Sub-group	Costs	2015	2020	2025	2030	2035
Solar PV	Utility	Capex	1.00	0.60	0.48	0.40	0.35
Solar PV	Utility	Opex fix	1.00	0.88	0.78	0.71	0.64
Solar PV	Rooftop	Capex	1.00	0.86	0.71	0.61	0.53
Solar PV	Rooftop	Opex fix	1.00	0.88	0.79	0.71	0.64
Wind	Onshore	Capex	1.00	0.92	0.85	0.80	0.77
Wind	Onshore	Opex fix	1.00	0.92	0.84	0.80	0.76
Wind	Offshore	Capex	1.00	0.89	0.84	0.80	0.76
Wind	Offshore	Opex fix	1.00	0.81	0.74	0.68	0.63
Biogas	-	Capex	1.00	0.95	0.92	0.88	0.85
Biogas	-	Opex fix	1.00	0.95	0.92	0.88	0.85
Electrolysers (hydrogen)	-	Capex	1.00	0.86	0.63	0.45	0.41
Electrolysers (hydrogen)	-	Opex fix	1.00	0.84	0.63	0.40	0.36
Heat Pumps	Residential	Capex	1.00	0.98	0.94	0.91	0.88
Heat Pumps	Residential	Opex fix	1.00	0.98	0.94	0.91	0.88
Heat Pumps	Industrial	Capex	1.00	0.94	0.88	0.84	0.81
Heat Pumps	Industrial	Opex fix	1.00	1.00	1.00	1.00	1.00
Efficiency/Renovation in buildings		Capex	1.00	0.98	0.94	0.91	0.88
Efficiency/Renovation in buildings		Opex fix	1.00	0.98	0.94	0.91	0.88
Hydropower/Storage	-	Capex	1.00	1.00	1.00	1.00	1.00
Hydropower/Storage	-	Opex fix	1.00	1.00	1.00	1.00	1.00

Source: (Bogdanov et al., 2021)

C Labour productivity indices

Table 15 – Labour productivity indices (based on OECD Productivity database)

Country or region	Index (EU27 = 1)
Austria	1,59
Belgium	1,72
Bulgaria	0,31
Cyprus	0,57*
Czechia	0,60
Germany	1,51
Denmark	1,61
Estonia	0,69
Greece	0,32
Spain	0,93
Finland	1,20
France	1,12
Croatia	0,46
Hungary	0,44
Ireland	1,22
Italy	1,00
Lithuania	0,64
Luxembourg	1,40
Latvia	0,61
Malta	0,57*
Netherlands	1,32
Poland	0,59
Portugal	0,45

Country or region	Index (EU27 = 1)
Romania	0,48
Sweden	1,35
Slovenia	0,87
Slovak Republic	0,86
Australia	1,45
United States	1,71
North-America	1,29
Global	1,00**

* Data missing. Assumption: average of Southern European countries.
** Data missing. Assumption: equal to EU27.

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