C40 Cities Climate Leadership Group

The employment benefits of a green COVID-19 recovery

cambridge econometrics
clarity from complexity

Technical Report

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1 Introduction

1.1 Background

The COVID-19 pandemic has had a devastating impact on C40 cities' economies and societies, and the negative implications will have a lasting effect for years to come. Following the crisis, there are many calls to rebuild economies with strong sustainability and green principals at the heart of recovery plans. City governments need to continue their work towards meeting the Paris Agreement, to halve emissions by 2030 and reach carbon neutrality by 2050, and cities need to ensure these efforts support a healthy and equitable COVID-19 recovery. On that basis, the C40 Mayoral Taskforce have collectively identified eight key actions that are critical to achieve C40 Cities' vision for a green and just recovery:

1 Create good new green jobs fast

2 Support and lift up essential workers

3 Training and upskilling to enable a just transition to an inclusive economy

4 Deliver a post COVID safe and resilient mass transit system

5 Provide fundamental public services for all

6 Create '15 minute cities'

7 Give streets back to people

8 Build with nature

C40 has estimated how much it will cost to deliver all the necessary climate actions that will contribute to a green and just recovery, and ensure that a typical 'model' city located within most global regions (North America, Europe, East and Southeast Asia, Latin America, South and West Asia and Africa – note due to lack of data for the Pathways tool the Central East Asian region was not included) is on a 1.5^{o}C-compliant emission reduction trajectory between now and 2030. Investment costs have been modelled based on the cities' baseline sectoral profiling data in the Pathways model. The Pathways model assesses what needs to happen across the buildings, energy, transport, waste and industry sectors in order to reduce emissions in line with a 1.5^{o}C trajectory.

C40 has partnered with Cambridge Econometrics (CE) to review and use the results of the cost modelling to estimate the number of jobs investment in these climate actions could generate, and therefore the potential jobs impact a green COVID-19 recovery plan might generate for a given city.

1.2 The scenarios investigated in this study

The aim of this study was to estimate the number of jobs which are assumed to be generated in three separately modelled future scenarios:

- A **business as usual (BAU) scenario** represents the level of investments that will be needed to maintain and enhance existing infrastructure in cities without additional climate actions that reduce urban emissions in line with Paris Agreement commitments.
- The **Green Recovery scenario** represents a scenario in which COVID-19 recovery stimulus funding supports C40 cities to invest in climate actions that prioritizes rapid creation of employment and ensures that C40 cities are on track to limiting warming to 1.5°C[1].
- The **High-carbon Recovery scenario** represents a scenario in which the same amount of COVID-19 recovery stimulus funding goes towards maintaining and enhancing existing infrastructure in cities as in the Green Recovery scenario, but where investments do not focus on achieving 1.5°C-compliant emissions reductions.

Total employment figures were calculated based on the investments included within each scenario.

1.3 Glossary

Several technical terms are used throughout the report, and their meaning is set out in detail in the table below.

Table 1.1 Glossary

Term	Definition
Full-time-employment (FTE)	In this study, the employment results are normalised to full-time employment (FTE). An FTE job represents one person's work for one year at regulated norms (e.g. 40 hours a week for 52 weeks a year, excluding holidays). Using this accounting, two separate, six-month jobs would therefore be counted as one FTE job.
Job-years	Job-years represent the cumulative years of FTE jobs over a period of time, i.e. the total number of jobs for one person for one year. Job-years thus capture total employment created by certain investments in climate actions, allowing comparisons between

[1] Three variations of the Green Recovery scenario were modelled: 1) a "standard" scenario where the stimulus CAPEX is spent over the next 5 years, by end 2025 and climate action and impact occurs over 10 years, 2) an "accelerated" scenario where the stimulus CAPEX is spent at a rapid pace over the next 3 years and climate action and impact occurs over 5 years, and 3) a "slow" scenario where the stimulus CAPEX is spent more slowly over the next 7 years and climate action and impact occurs over 15 years. The purpose of these variations was to see whether the timing of the deployment of stimulus funding has a big impact on emissions, jobs and air quality.

Term	Definition
	employment that may be created during the construction phases of projects with employment that is created in operation and maintenance phases and may continue for ten years or even more.
Total jobs	The number of full-time jobs available in a given year. For example, five job years in one year equals five total jobs; five job years over five years equals one total job.
Climate actions	In this study, climate actions refer to the measures identified within the Pathways model, which are critical to achieve C40 Cities' vision for a green and just recovery. The measures exist within the buildings, transport, energy and waste sectors and in some way contribute to improving energy efficiency, reducing emissions, improving waste management, restoring nature or supporting adaptation to climate change.
Investments	C40 has modelled how much it will cost to deliver each climate actions that will contribute to a green and just recovery, and these costs are referred to as investments. The BAU and High-carbon Recovery scenarios also include other investments which are not typically 'green', such as investment in road infrastructure that may be needed due to a growth in population.

1.4 Report structure

The remainder of this report is structured as follows:

- In Chapter 2, the methodology used for each step of the employment estimation analysis is explained in detail.
- In Chapter 3, the findings of the analysis are presented. A separate Excel file, in which all results are provided, is also available upon request.
- In Chapter 4, additional consideration is given to the potential skills shortages and training needs that might arise as a result of changes in employment caused by a Green Recovery strategy. Consideration is also given to the quality of newly created green jobs compared to non-green jobs in more traditional sectors.

2 Methodology

Our approach to the project consisted of three major steps, which are outlined in detail below. The approach used throughout the study is based upon the use of employment multipliers. Employment multipliers are ratios that describe the relationship between investment within a particular sector and the number of jobs that particular investment creates.

2.1 Identification of employment multipliers

Purpose

In the first stage of the study, we identified employment multipliers relevant to each of the investment types into infrastructure and systems proposed by the C40 Pathways Model, with the purpose of later estimating the number of jobs the specific investment could generate.

Approach

Through desk-based research, we reviewed a range of literature sources including reports by public/private organisations, academic and 'grey' literature, and further publicly available relevant data. The aim of the research was to identify what the known or suggested employment multipliers that are relevant for the investigated set of investments. C40 also purchased a dataset from the International Energy Agency (IEA) consisting of regional employment multipliers. Individual employment multipliers were required to represent both the individual Green Recovery or BAU actions/ investments, and for each global region. It is important to highlight that the Green Recovery, the High-carbon Recovery and the BAU scenarios have overlapping investment types, but are differentiated in terms of the levels of investment into each of these investment types. Also, there are some areas where they do not overlap – that is, certain investment types are assumed to take place in the Green Recovery but are not assumed to happen in the BAU scenario, such as investment into new waste composting facility or energy efficient streetlights.

The key sources for the literature review included:

- The International Energy Agency (IEA)
- The International Labour Organisation (ILO)
- United Nations
- International Renewable Energy Agency (IRENA)
- World Bank
- Academic research[2]

A full list of literature included in the review is available in a separate Excel workbook.

Granularity of employment multipliers

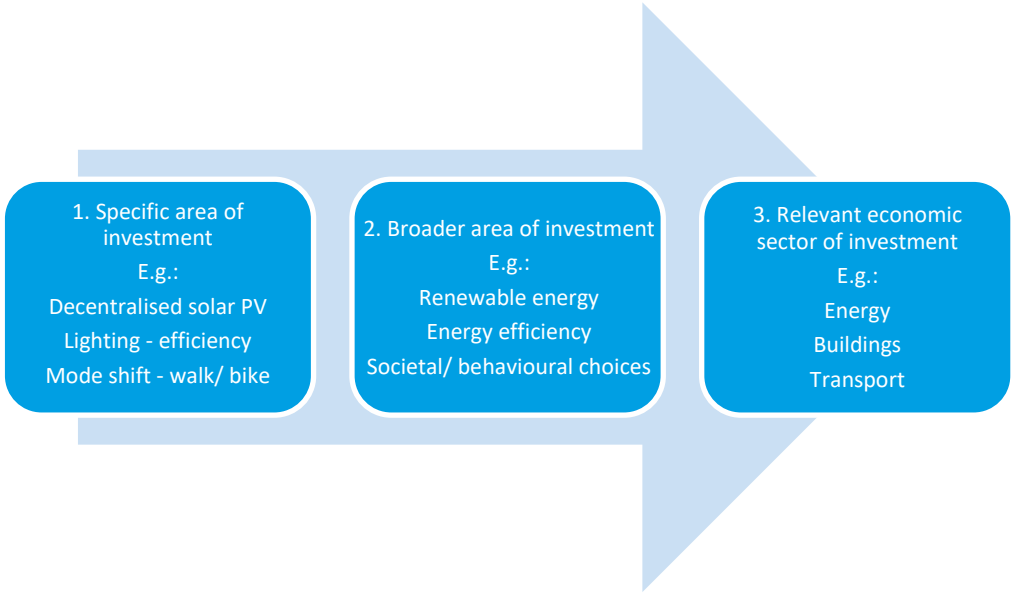
In many cases, it was difficult to obtain investment type-specific employment multipliers in the literature, and in those cases, it was necessary to consider

[2] More specifically, scholarly articles were searched and reviewed using databases such as Google Scholar, JSTOR, EBSCO or EconLit.

using employment multipliers representative of the broader area of investment or the broader economic sector relevant to the specific investment type.

Figure 2.1 below demonstrates the order of the preferred granularity of employment multipliers, starting from 1. Employment multipliers related to investment into specific areas identified under the BAU and the Green Recovery scenario, through 2. Employment multipliers related to broader area of investment, ending with 3. Employment multipliers related to relevant broader economic sector of investment.

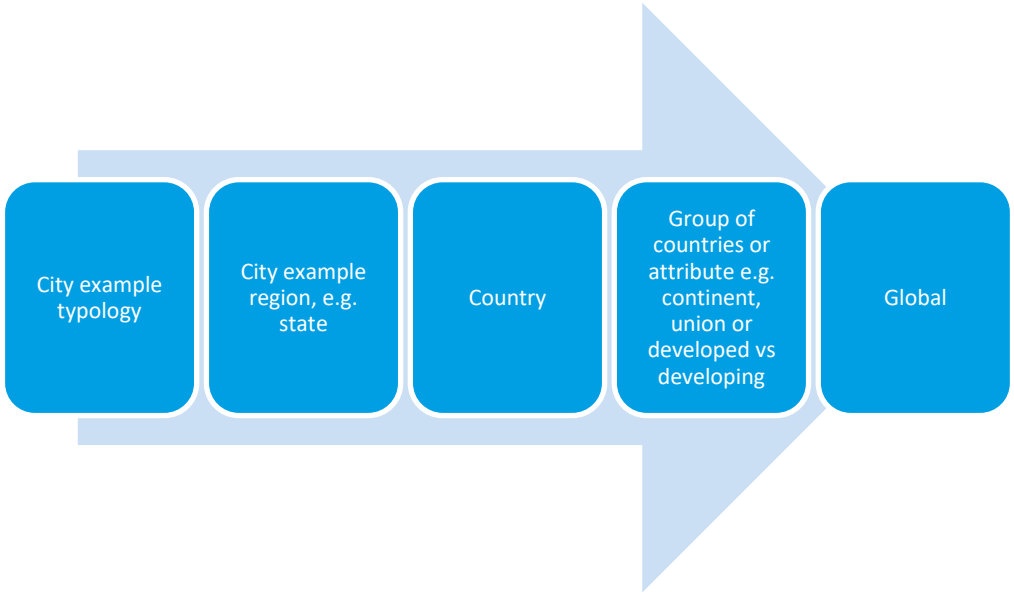
Figure 2.1 Hierarchy of preferred granularity of employment multipliers



For example, when considering the specific investment area 'Lighting – Efficiency', in the event that there was no robust data, it was necessary to use an employment multiplier related to investment in energy efficiency improvements in general or, in the worst-case scenario, an employment multiplier related to investment into equipment replacement or upgrades within the buildings sector in general.

While ideally, the employment multipliers would be representative of the regional model city being investigated, in many cases a lack of available data meant that we needed to use an employment multiplier that was specific to a country, region or continent, or for some other defining feature such as developed vs. developing countries. For instance, it might be the case that the evidence provides us with a multiplier for jobs created by a certain amount of investment into the energy sector in developed countries, in which case we will propose to use that multiplier for the relevant model cities that are located in developed countries. A hierarchy of preferred spatial granularity was applied, as demonstrated in Figure 2.2.

Figure 2.2 Hierarchy of preferred spatial granularity



Differentiation between jobs created during investment stage and jobs created for ongoing O&M

The cost modelling carried out by C40 produced capital expenditure (CAPEX) and operation and maintenance-related (O&M) costs in USD as outputs for the investments under each of the specified scenarios. On that basis, the initial aim was to obtain employment multipliers that are related either to the initial investment or to operation and maintenance (O&M) costs (e.g. the employment multiplier associated with an additional 1 million USD investment in energy-efficient lighting). While for some of the investment types (primarily in the case of different energy generation technologies), it was possible to collect CAPEX-relevant and O&M-relevant multipliers separately, in the majority of cases we were not able to obtain separate multipliers, thus in these cases a general multiplier was used for both cost types.

Robustness of evidence

To determine the robustness of the employment multipliers collected, we assigned a score to each multiplier based on the quality considerations set out in the table below:

Table 2.1 Robustness scoring

Robustness	Not fit for purpose (robustness scoring of 0)	Low (robustness scoring of 1)	Medium (robustness scoring of 2)	High (robustness scoring of 3)
Source of data	Cannot determine author or credibility of author	Not published by sources listed to the right	National non-governmental organisation/ industry data/ grey literature	Academic/ government/ internationally recognised organisation
Relevance to investment	General employment multiplier for investment of any kind	Relates to jobs created in the relevant sector, e.g. transport	Relates to broader area of investment, e.g. energy efficiency measures	Relates to specific investment area

Robustness	Not fit for purpose (robustness scoring of 0)	Low (robustness scoring of 1)	Medium (robustness scoring of 2)	High (robustness scoring of 3)
Spatial granularity		Global/ country grouping	Country-specific	City typology specific/ province within which city typology is found/ comparable city or region
Reporting year		Before 2000	2000-2009	2010-2020

Task outcomes

The outcome of the literature review was a summary Excel spreadsheet that gathered and clearly presented the employment multipliers associated with each types of investment into infrastructure and system, for each global region.

2.2 Estimation of employment benefits

Purpose

In the second stage of the project, the employment multipliers identified in the literature review and the cost data modelled by C40 for each scenario were combined to calculate the job creation potential within each scenario.

The cities analysed in this study

The employment results presented in this report are based on a detailed analysis undertaken on six C40 cities. The selected cities represent most of the regions covered by the C40 cities membership, specifically North America, Europe, Latin America, East and Southeast Asia, South and West Asia and Africa. More details on the characteristics of each city are provided in the table below.

Table 2.2 Model cities analysed in this study

Model cities	Features
North American city	Characterized by urban sprawl, a low transit mode share and a relatively carbon-intensive grid
European city	Characterized by a medium-density, with a lower transit mode-share than the European average as well as a grid that is still relatively carbon-intensive.
East and Southeast Asian city	Characterised by high-density, significant building and waste emissions and a fairly carbon-intensive grid mix.
Latin American city	Characterized by semi-density, a relatively high share of renewables in the grid mix and a high transit and active mobility mode share.
South and West Asian city	Characterized by high-density, a carbon-intensive electricity grid, low private automobile mode share and a rapidly growing building stock.
African city	Characterised by semi-density, a carbon-intensive grid mix and a low active transport mode share.

Approach

Using the Pathways model, C40 developed CAPEX and O&M costs associated with each of the investments included within the three scenarios. Simultaneously, CE collected relevant employment multipliers within the literature review described above. The associated costs and employment multipliers were multiplied to provide an estimation of the employment benefits each investment might generate between 2021 and 2030.

Results reported as job-years

Jobs are normalised to full-time employment (FTE). An FTE job represents one person's work for one year at regulated norms (e.g. 40 hours a week for 52 weeks a year, excluding holidays). Using this accounting, two separate, six-month jobs would therefore be counted as one FTE job. More specifically, and for the sake of consistency, in calculating employment benefits, we report the results in terms of job-years to be created (see Section 1.3 for a detailed definition).

The applied employment multiplier figures were also expressed in the unit of job-years, and wherever it was not specified by the data source, we have

assumed that this is the unit of measurement. In this way, the total number of job-years was then provided for each scenario, by summing together all job-years associated with the BAU, the High-carbon Recovery and the Green Recovery scenarios.

The scenarios and their limitations

As described in Section 1.2, three scenarios were investigated in this analysis; a BAU scenario, a Green Recovery scenario and a High-carbon Recovery scenario.

In all the three scenarios, costs (and the related jobs) have been associated to specific cost categories, which can be grouped under broader activity areas, which have been further grouped together under broader 'sectors' of interest. A detailed breakdown of this categorisation is provided in Annex.

In the High-carbon Recovery scenario, investment was uplifted to match the total investment level assumed in the Green Recovery scenario. The ratio of Green Recovery to BAU scenario was calculated for all costs except urban nature-based solutions, and applied to all costs that have been included under the BAU scenario. In this way, the High-carbon Recovery reflects the same profile of investments as under the BAU, but their levels are scaled to match the total recovery expenditure assumed under a Green Recovery. An important limitation of this approach is that the High-carbon Recovery scenario, in this context, is a strongly hypothetical, hybrid scenario, in the sense that the level of investment is derived backwards, based on the incentivizing policy measures that are assumed to take place under the Green Recovery scenario.

Further breakdown of employment estimations

While the literature review attempted to identify employment multipliers specific to direct, indirect and induced jobs impacts, and whether jobs are typically created locally, nationally or internationally, a lack of available data was often a constraint. In both cases, where we could not provide a quantified estimate, we provide a qualitative assessment of the extent to which additional jobs are created in associated supply chains and the extent to which jobs are likely to remain local, in the 'Findings' chapter of this report.

Similarly, employment multipliers related to CAPEX and O&M are rarely specified in the literature. Therefore, some assumptions were made to separate job creation at the investment stage, when typically short-term jobs are created in planning and development and installation stages of projects (CAPEX-related jobs), from job creation in the operation and maintenance phase of a project (O&M-related jobs). Jobs in the latter stage tend to be more long-term.

In line with these assumptions, variants of the Green Recovery scenario ('Accelerated' and 'Slow' scenarios) were carried out as sensitivity analyses to explore the difference in CAPEX job-years created between the 'Standard' Green Recovery, and its 'Accelerated' and 'Slow' versions. With regards to CAPEX-related job creation, the following simple assumptions were made: in a 'Standard' Green Recovery, all CAPEX jobs were assumed to be produced in five years, while the same job creation was assumed to happen two and a half years earlier / later for the 'Accelerated' and 'Slow' scenarios (hence CAPEX jobs were assumed to be produced over 2.5 and 7.5 years

respectively). It is important to note that when results have been scaled up to the global level we have revised the scenario to two years earlier / later (instead of the two and a half years used in this report), to create a more conservative/realistic timeframe for CAPEX spend over 3 years (vs the 2.5 years' timeframe if spend is brought forward by 2.5 years instead of 2 years). The annual number of O&M job-years were assumed to be created equally across the ten years investigated in all the scenarios.

Quality of jobs and skills needs

In a final sub-task we build upon the literature review carried out earlier in the study to qualitatively consider first the potential skills shortages and training needs for the jobs being created related to various investments, and second the difference in job quality between 'green' and 'non-green' jobs. The assessment of these aspects of job creation are included in Chapter 4 of this technical report.

2.3 Sense checking of employment estimations

The following sense checks were carried out on the final employment estimations:

- Identifying anomalies within the employment multipliers: where employment multipliers seemed unusually high or low (compared to other employment multipliers in the scenario for a given city, or compared to employment multipliers for the same investment carried out in another city), these were investigated further. The robustness of the multiplier was checked by revisiting the robustness scoring criteria set out in Table 2.1, and alternative sources were investigated if necessary.
- Identifying anomalies in the final employment estimation: where employment estimates seemed unusually high or low (compared to other employment estimates in the scenario for a given city or compared to employment estimates for the same investment carried out in another city), the calculations and inputs to the calculations were checked for errors. Similarly, the total employment estimations per city were compared against one another, and it was ensured that there were reasonable explanations for any vast differences (e.g. the characteristics of that city, or the investment required to remain on track to reach the 1.5^{o}C target).
- Checking the ratio between population and employment: spot checks were carried out on the ratio between the population of the city and the total increase in employment to ensure the number of jobs created is plausible given the size of the city's population. An important aspect to note again is that not all jobs are assumed to be created locally, thus, this was taken into account when carrying out the spot checks.
- Increase in employment has been compared to two recent, external data sources: the IEA's Sustainable Recovery Report[3] and a McKinsey and Co.'s analysis for a European Green Recovery to 2030.[4]

[3] IEA (2020) Sustainable Recovery, IEA, Paris https://www.iea.org/reports/sustainable-recovery

[4] Hengel et al. (2020) How a post-pandemic stimulus can both create jobs and help the climate

- External review of results: a final sense-check and critique of the results was carried out by external reviewers from both the International Energy Agency (IEA) and International Labour Organization (ILO).

2.4 Key assumptions and limitations to the approach

The following various limitations to the approach presented above apply, and should be considered when interpreting the results:

- The approach to the analysis attempts to identify the most relevant employment multipliers for each investment, and for each location. However, as noted above, the employment multipliers used within the analysis were not always at the most desired level of granularity. The approach therefore means that the final employment calculations may sometimes under- or overestimate the jobs impact of each investment flows, or may not always be based on location-specific underpinning data.
- More specifically, there are gaps for local multipliers for investments related to urban nature-based solutions for all the model cities except for the North American model city, therefore the North America multipliers have been used for all the other model cities.
- Another major sector-specific limitation is related to initial gaps in multipliers for different investment types within a specific sector. This was a limitation in particular for the waste sector, as the same employment multiplier was applied to all waste management solutions (such as to recycling, composting and landfill). Importantly, due to this lack of different multipliers for both high- and low-carbon investment types within the waste sector, and due to the use of a broad sector multiplier, the differences between the High-Carbon Recovery and the Green Recovery scenarios are not fully captured. As a result, differences in employment impacts between the High-Carbon Recovery and the Green Recovery scenarios may have been over- or underestimated. This is not applicable for the other sectors, where different multipliers could be found for different investment types.
- In the majority of cases, it was not possible to collect separate employment multipliers related to CAPEX and O&M, therefore it is possible that there are overestimates and underestimates in the resulting employment figures (partly depending on the investment costs' distribution across CAPEX and O&M costs).
- In some cases, it was possible to collect different employment multipliers related to CAPEX and O&M-type of investments; however different sources have been used in case of one or the other investment areas. While we have accepted the CAPEX / O&M distinction that the relevant sources have made, it might be the case that different sources have used slightly different methodologies in assessing the CAPEX and O&M-related job multipliers and that the categories do not capture the exact same jobs in one or the other categorisation. Nevertheless, it has been checked that

https://www.mckinsey.com/business-functions/sustainability/our-insights/how-a-post-pandemic-stimulus-can-both-create-jobs-and-help-the-climate#

the overall methodology of their calculation and the relative size of the multipliers allow for using them in parallel.

- Employment multipliers were collated from varied reporting years as far back as 2013 and may have changed over time.
- Employment multipliers were taken from a range of sources that used different methods to calculate the multipliers (for example ex-post assessment based on industry employment figures and investment data, ex-ante assessment based on national input-output tables, industry survey method, etc.).
- Furthermore, it was not always possible to get details of the methodology used to calculate multipliers from the identified sources (especially with regards to the unit of measurement), which means that multipliers cannot be considered standard across the dataset - this may introduce variation into results. For the sake of consistency, we overcome this variation by assuming a universal unit in measuring jobs, by calculating with FTE job-years created.

Related to the limitations of the approach, we consider that the following are relevant areas for future research:

- Based on the review, only limited data is available on the absolute number or ratio of direct vs. indirect vs. induced types of jobs generated. This may be a relevant focus of future research efforts.
- Also more could be done to analyse net job effects (as our approach only considers job gains in the quantitative analysis section and only discusses job losses in the qualitative section). For this further investigation of 'high-carbon' and 'green' employment multipliers is recommended.
- This review exercise further strengthened the observation that the lack of more sophisticated or detailed data on other descriptive aspects of the job (e.g. duration, terms of the job, the pace of actually creating the jobs, etc.) is clearly a challenge in assessing and measuring the job creation (potential) of specific climate investments made.

3 Findings

Within this chapter, results of the jobs analysis are reported for each model city. In all charts, the employment results are in order of the GDP per capita (according to World Bank[5] data) of the global region the model city is located in, which results in the following ordering:

- North American model city
- European model city
- East and South East Asian model city
- Latin American model city
- South and South West model Asian city
- African model city

As described above, employment impacts have been calculated based on assumed total investment levels occurring between 2021-2030 in association with the identified scenarios, which have been matched to specific cost categories within the Buildings, Transport, Energy, Waste and Urban nature-based solutions (NBS) sectors. Results of the employment assessment are also presented for these sectors.

3.1 Headline results on job creation potential and the permanency of jobs

The following key insights can be drawn from the employment analysis carried out, with regards to the anticipated job-years created within our scenarios.

While it was not possible to quantify the extent to which the jobs created are located within the city, or the extent to which they are created regionally, nationally or internationally using the employment multipliers methodology (i.e. overall employment impacts have been calculated), a few general observations can be made based on the literature review conducted. Firstly, the extent of local versus non-local job-creation is strongly sector-specific: for example, energy efficiency actions[6] and smaller-scale grid investments are often carried out by local installers[7], while larger-scale renewable infrastructure (such as sustainable biofuel production) is manufactured by non-local, often international firms with facilities that are mainly located in rural, lower labour cost-areas[8]. On the contrary, infrastructure-related jobs, such as those created in new road construction / road reconstruction, or in building cycle lanes and walkways tend to be more local in nature.[9] Secondly, there may be a large variation in the extent of local versus non-local job creation

[5] World Bank (2020) GDP per capita (current US$) https://data.worldbank.org/indicator/NY.GDP.PCAP.CD

[6] IEA (2020) Sustainable Recovery, IEA, Paris https://www.iea.org/reports/sustainable-recovery p108

[7] IEA (2020) Sustainable Recovery, IEA, Paris https://www.iea.org/reports/sustainable-recovery p47, p49

[8] IEA (2020) Sustainable Recovery, IEA, Paris https://www.iea.org/reports/sustainable-recovery p86

[9] IEA (2020) Sustainable Recovery, IEA, Paris https://www.iea.org/reports/sustainable-recovery p67

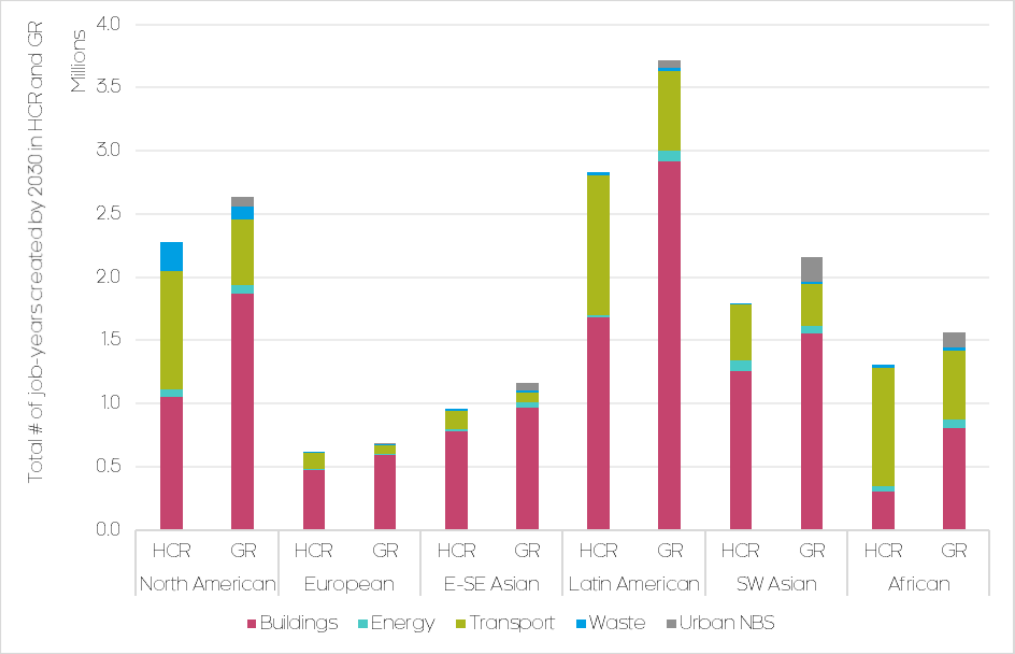
depending on the phase of investment related to a specific scenario: for example, investment in EV (electric vehicle) infrastructure in a city will result in more local jobs created in the installation and O&M of the charging stations, while the production related, induced jobs will be created internationally (as currently EV battery production is geographically highly concentrated).

The results presented below thus show total job creation potential of a Green Recovery versus a BAU scenario.

Total no. of job-years created across cities and sectors

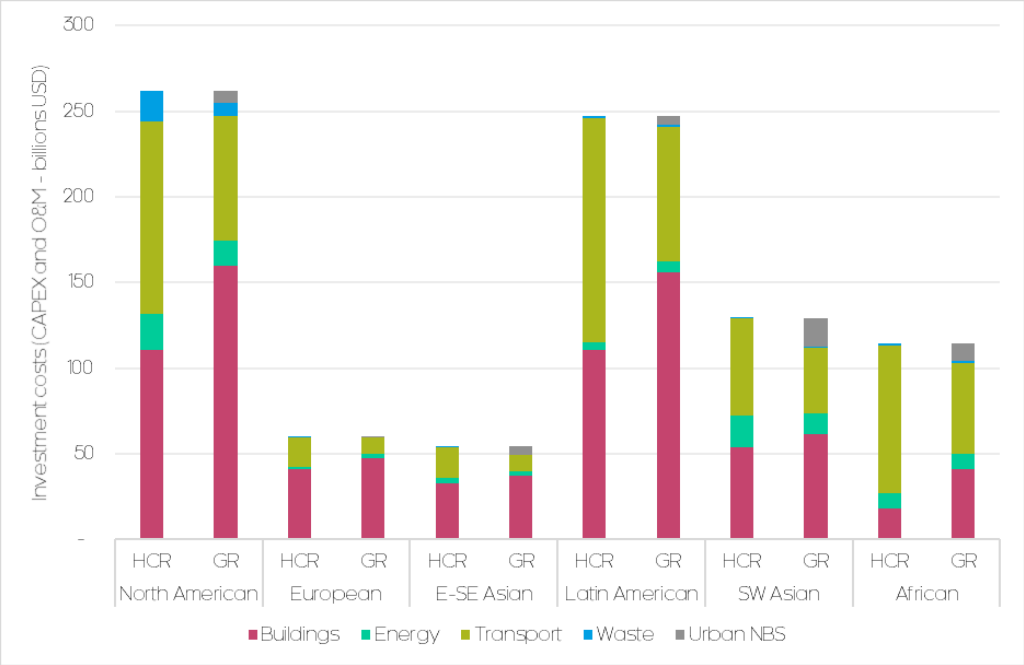
A major finding of our analysis is that generally, a Green Recovery scenario is anticipated to create more jobs than a High-carbon Recovery (where the same amount of investment is assumed). The chart below summarizes our results with regards to job creation in these two scenarios.

Figure 3.1 Total no. of job-years created by 2030 per model city region, per broad sectors in the High-carbon Recovery (HCR) and the Green Recovery (GR) scenario (millions)



The related total level of investment costs (both CAPEX and O&M-type of investment costs) that were used in modelling both the Green Recovery and the High-carbon Recovery scenarios are presented below – their level is the same, but the distribution across sectors is rather different for the example cities.

Figure 3.2 Total investment assumed up to 2030 per model city region, per broad sectors in the High-carbon Recovery (HCR) and the Green Recovery (GR) scenario (billions USD)



While employment results by sectors are largely driven by the size of the underlying investment costs (hence the distributional similarities between the charts), in some cases larger investment costs result in relatively lower employment impact (e.g. Waste) and vice versa (e.g. Buildings) due to employment multipliers being lower on average for Waste-related cost categories.

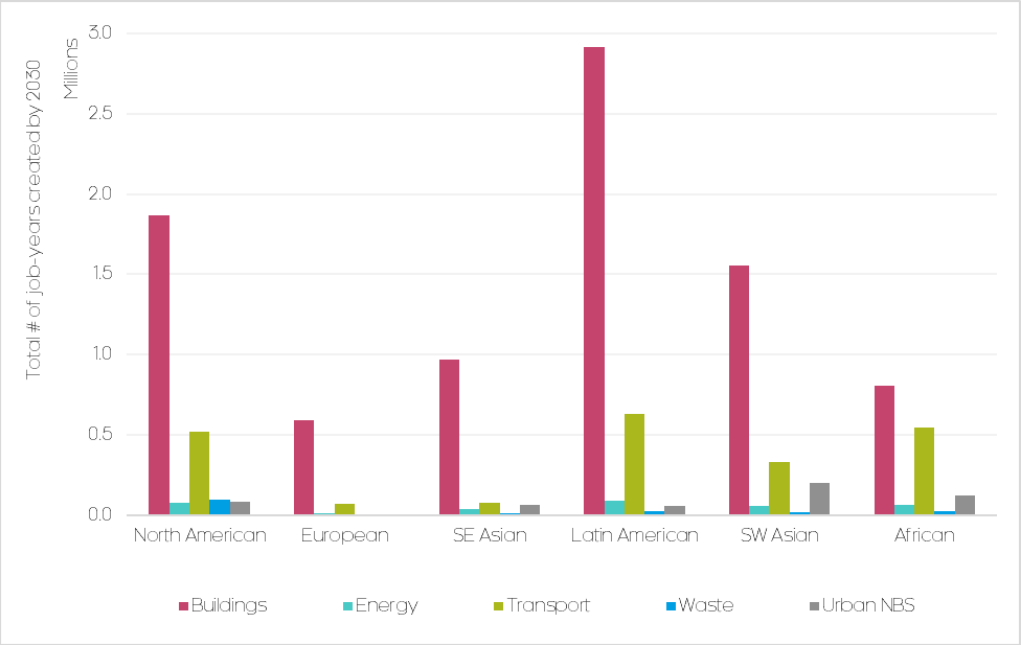
Of the six model cities, which are broadly representative of six global regions (North America, Europe, East and Southeast Asia, Latin America, South and West Asia and Africa), results suggest that a Green Recovery scenario would have a range of positive employment impacts. It is important to note that direct comparison across model cities of varying size (both in terms of population and GDP) would not be valid because of the variation in these attributes. Relative differences in the distribution of investment across sectors of the city examples, however, provide important insights with regards to regional specificities.

Therefore, a considerable part of the variation across total job impact in the regions is explained by the different amount of underlying investment (see chart above). When looking at the unit job creation potential of a million USD spent, however, cities become comparable in terms of the investment levels and the jobs generated.

A more insightful component of the variance is the regional differences in the employment multipliers applied to certain sectors. A key example for this is the buildings sector, where almost twice as many job-years are expected to be created with the same level of investment in developing regions (East and Southeast Asia, Latin America, South and West Asia and Africa) than in developed regions (North America and Europe).

With regards to broader economic sectors, the buildings sector is expected to experience by far the largest job impact across the investigated sectors, in all the model cities; while the second largest number of job-years generated occurs in the transport sector in all model cities.

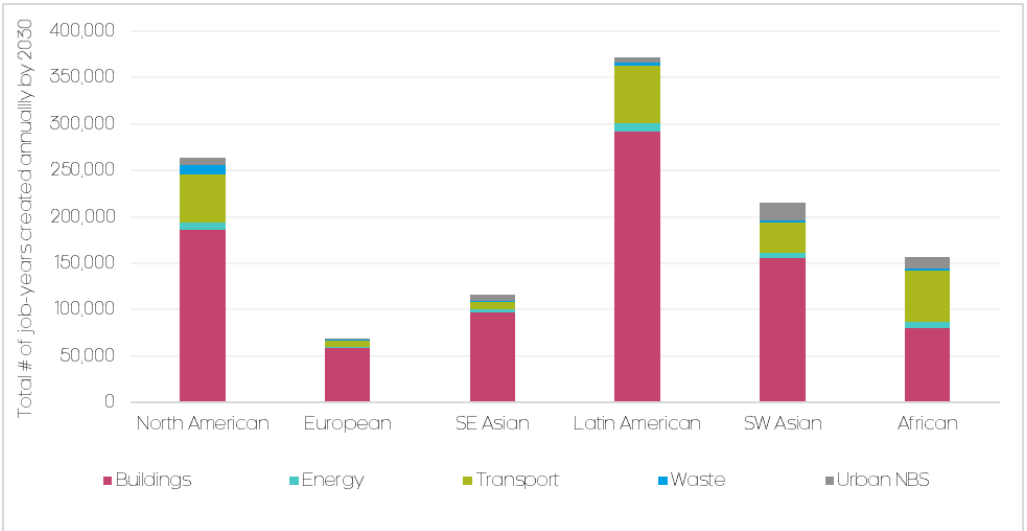
Figure 3.3 Total no. of job-years created by 2030 per model city region, per broad sectors in Green Recovery scenario (millions)



Yearly job creation and the permanency of jobs

In terms of the number of job-years created annually in the six model cities over the period investigated (between 2021-2030), this would result in between 65,000 and 370,000 job-years created annually in the assessed model cities. The distribution of job-years across sectors is the same as in the case of total job-years created.

Figure 3.4 Total no. of job-years created yearly by 2030 per model city region, per broad sectors in the Green Recovery scenario



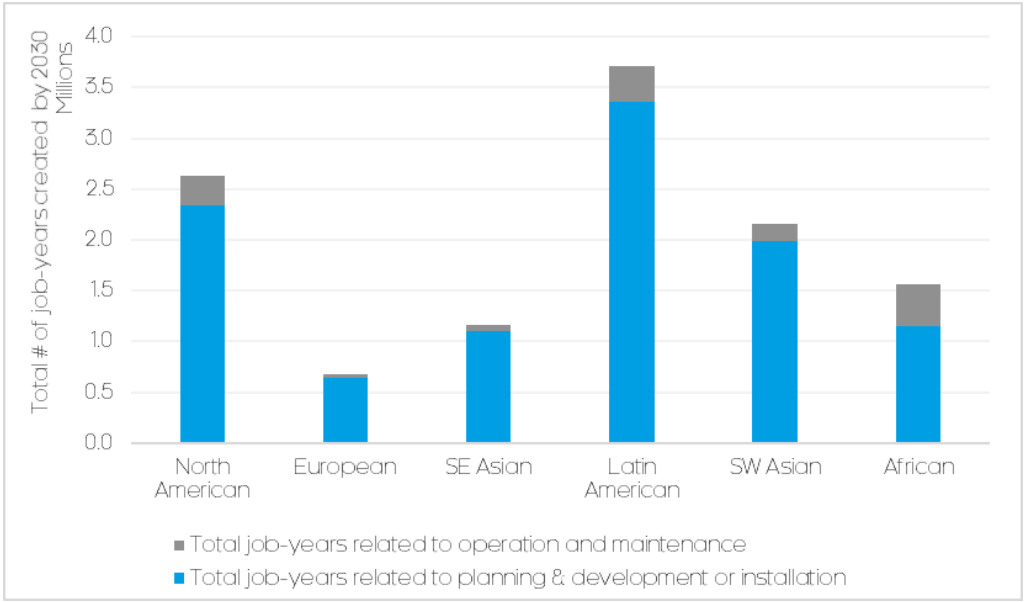
With regards to the permanency of jobs (i.e. with regards to the creation of either more short-term jobs, related to the investment phase of project, or

more long-term jobs that are related to the operations and maintenance phases or projects), it is envisaged that under both a Green Recovery and a High-carbon scenario, a considerably larger amount of job-years are created during the planning and development or installation phases of projects (i.e. related to CAPEX) than in the operation and maintenance phase of a project (i.e. related to O&M). This is due to high CAPEX costs that are assumed to be needed to finance the specific investments for both scenarios over the investigated time period. It is important to note that jobs generated by CAPEX investment would be in the economy for the duration of the investment (5 years for the 'Standard', 3 years for the 'Accelerated' and 7 years for the 'Slow' Green Recovery. Overall, given that the aim - in many ways - is immediate job creation to aid post-COVID19 recovery, the 'Standard' or the 'Accelerated' Green Recovery can be considered ideal strategies.

Job creation potential of 1 million USD invested

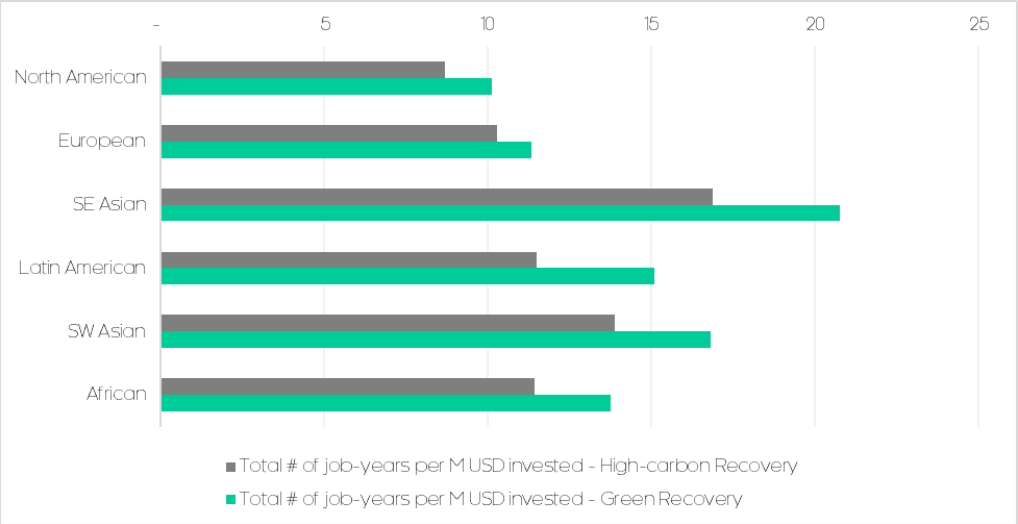
The results of the employment analysis also indicate the number of job-years that may be generated by a million USD invested under specific scenarios, or looking at another dimension, in the sectors investigated. On the chart below, the job-creation potential of 1 million USD spent is compared under the Green Recovery scenario and the High-carbon Recovery scenario (in which the same total amount of investment is assumed, but with a different distribution across the various actions, with less focus on cleaner areas).

Figure 3.5 Total no. of job-years created by 2030 per model city region, by the permanency of jobs in the Green Recovery scenario (millions)



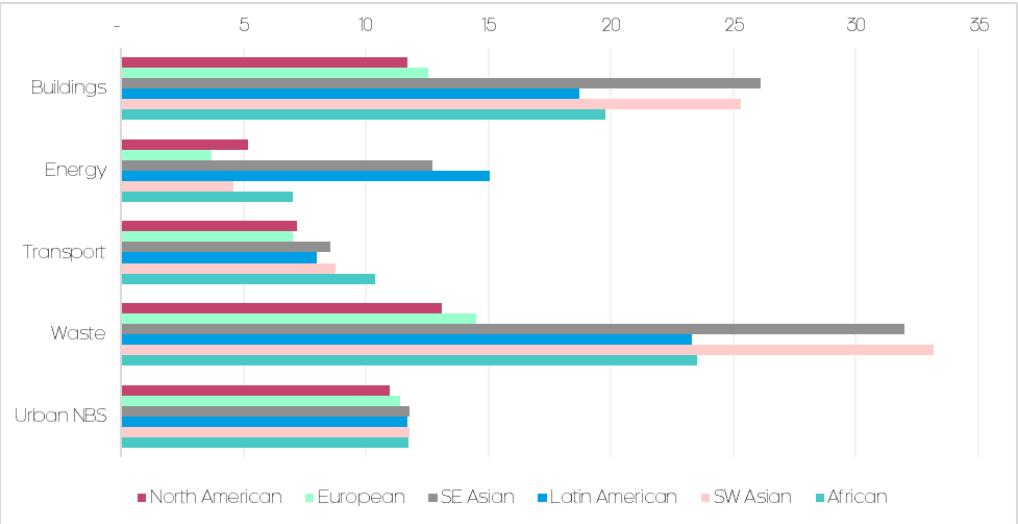
On average, 8-17 job-years are expected to be created by 1 million USD of investment in the High-carbon Recovery scenario, while 10-21 job-years are anticipated for the same level of investment under the Green Recovery scenario. The key explanation behind these results is that the Green Recovery scenario assumed relatively more investment flowing into areas which, based on the reviewed employment literature, also have higher employment-creation potential than the BAU scenario (and the High-carbon Recovery scenario).

Figure 3.6 Job-years created per million USD invested under the standard Green Recovery scenario and the High-carbon Recovery scenario per model city



Looking at the same metric from a different angle and focusing more on the sectoral distribution of job impacts under the standard Green Recovery scenario, there is large variance across the number of job-years that may potentially be created by a million USD invested across sectors (depending on the model city region). The considerable regional differences are driven by the relatively large variation in the size of the underlying employment multipliers, for example, the same robust source of multipliers suggest applying almost twice as large multipliers for the Buildings and for the Waste sectors' investments in the East and Southeast Asian and the South and West Asian model cities as for the same sectors in some of the other regions.

Figure 3.7 Job-years created per million USD invested under the standard Green Recovery scenario per model city, per sectors



In general, the Buildings and Waste sectors see the largest employment impacts for one million USD invested. The absolute largest job-generation potential of one million USD of investment is observed in the South and West Asian country's Waste sector (where over 30 job-years are created by a million USD), while the return is anticipated to be the lowest in the European model city's Energy sector (~3.5 job-years created with the same investment).

An intuitive explanation for these observations may be that less developed countries will likely have relatively fewer automated processes in the same industries compared to developed economies, leading to higher demand for manual labour to achieve the same results.

Job creation under 'Accelerated' and 'Slow' implementation of Green Recovery measures

Finally, there are a few selected investment areas (and the related cost categories modelled), which are presented here to assess how 'Accelerated' and 'Slow' implementation of the Green Recovery measures may impact the number of job-years created annually, on average.

To this, the following simple assumptions were made: in a 'Standard' Green Recovery, all CAPEX jobs were assumed to be produced in five years, while the same job creation was assumed to happen two and a half years earlier / later for the 'Accelerated' and 'Slow' scenarios. It is important to note that when the regional results have been scaled up to the global level we have revised the scenario to two years earlier / later (instead of the two and a half years used in this report), to create a more conservative/realistic timeframe for CAPEX spend over 3 years (vs the 2.5 years timeframe if spend is brought forward by 2.5 years instead of 2 years). The annual number of O&M job-years were assumed to be created equally across the ten years investigated in all the scenarios.

The metric of 'annual job creation potential' refers to the number of job-years that are created in each year, on average, during the whole period considered. The 'Accelerated' variant of the Green Recovery has the largest annual job-creation potential in all model city regions and in all the selected investment areas, the reason for this is that accelerated spend of capital investment generates a higher number of job-years over a shorter period of time, which is beneficial for immediate employment prospects.

Figure 3.8 Job-years created annually in 'Buildings upgrades and retrofits' under the standard Green Recovery, the Accelerated GR and the Slow GR scenario, per model city

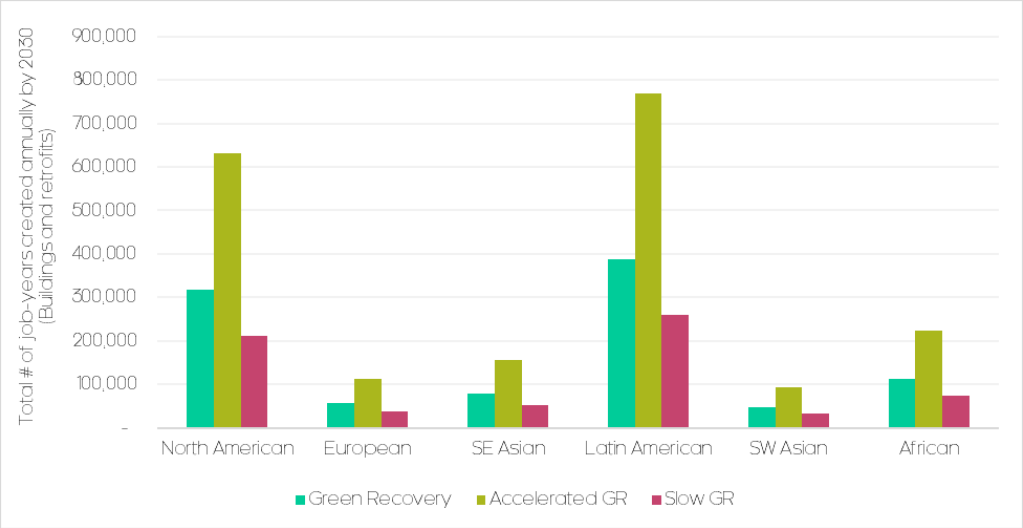


Figure 3.9 Job-years created annually in 'Fuel switch' under the standard Green Recovery, the Accelerated GR and the Slow GR scenario, per model city

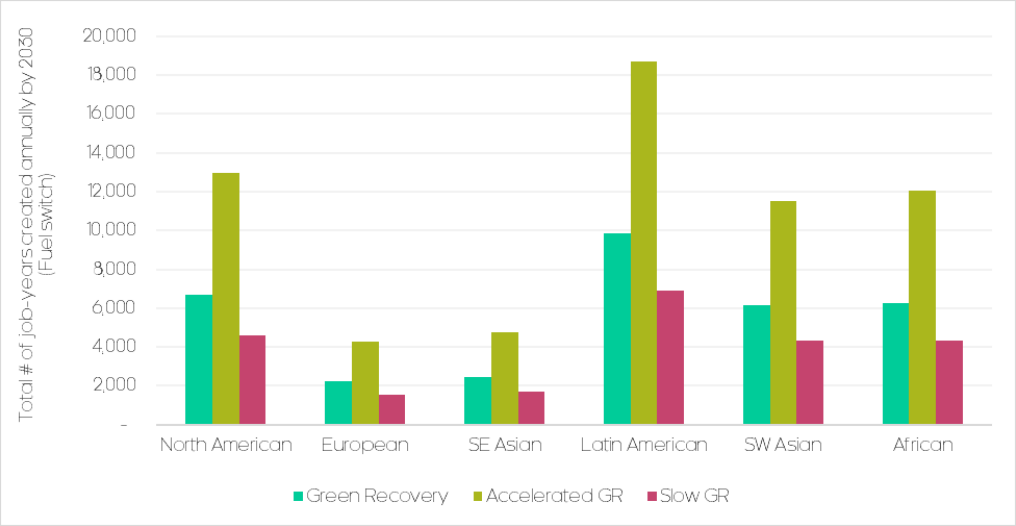


Figure 3.10 Job-years created annually in 'Waste recycling and composting' under the standard Green Recovery, the Accelerated GR and the Slow GR scenario, per model city

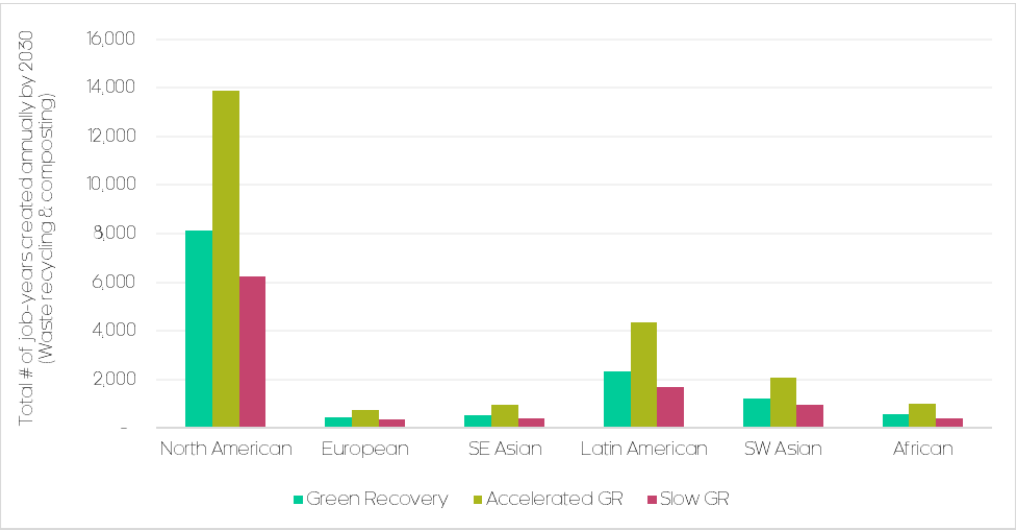
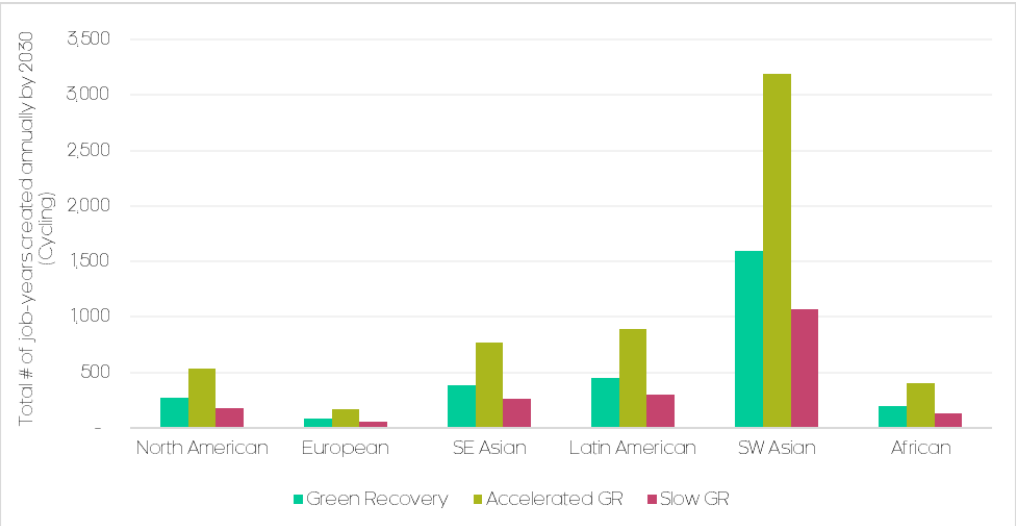


Figure 3.11 Job-years created annually in 'Cycling' under the standard Green Recovery, the Accelerated GR and the Slow GR scenario, per model city



4 Skills and training needs and the quality of jobs

4.1 Introduction

Our analysis clearly shows a more positive employment impact from a Green Recovery strategy, post COVID-19 versus a High-carbon Recovery in which the same level of investments occur as in a Green Recovery, but with less intense climate actions taken across economic sectors. Our findings support the theory that green investment and climate-related actions bring about a net positive change in employment, compared to a High-carbon Recovery scenario. However, beyond the positive employment impacts it is also important that the transition towards a climate-neutral global economy is a socially just process, with appropriate labour market policies focusing on supporting the regions most affected by decarbonisation, including policies focused on reskilling and the active inclusion of regional labour forces. While the support and contribution of the private sector is also important in this process, it is key to stress the decisive role public institutions play in facilitating the adjustments between labour supply and demand by proactively dealing with bottlenecks and mismatches in the labour market.

Following the first part of our analysis on the number of job-years created through a post COVID-19 Green Recovery, this part of the assessment focuses on the anticipated changes in the type of jobs created within the scenario and the anticipated changes in the required skills.

Definition of green jobs

In order to gain a better understanding of what the anticipated employment impacts would mean in terms of skills that will be demanded and the quality of jobs created, it is key to define the term ‘green jobs’ in a general sense.

In line with a recent Cedefop[10] report, the ILO defines green jobs as jobs in agriculture, industry, services or administration that contribute to the preservation or restoration of the quality of the environment, while at the same time, also meet the requirements of decent work (adequate wages, safe work conditions, rights to workers and social protection). In other words, green jobs (and the related occupations) are jobs that reduce the environmental impact of economic activity to levels that are sustainable in the long run.

A recent LSE study[11] concluded that as of 2018, 10.3% of all the jobs in the US was green, and a further 9.1% of the US workforce are in jobs which will be necessary to support the green economy, but which do not directly support green tasks. The definition used in their research builds on that of the US Bureau of Labour Statistics (BLS), in which green jobs are jobs that reduce fossil fuel usage, decrease pollution and greenhouse gas emissions, involve recycling materials, increasing energy efficiency or the development of

[10] Cedefop (2019) Skills for green jobs: 2018 update. European synthesis report. Luxembourg: Publications Office. Cedefop reference series; No 109.
https://www.cedefop.europa.eu/files/3078_en.pdf

[11] Kuralbayeva, K (2018) How many green jobs are there in the US?
https://www.lse.ac.uk/granthaminstitute/news/how-many-green-jobs-in-the-us/

renewable energy sources[12]; but extends that with the inclusion of people doing green tasks in their jobs but less often, for example workers who are urban and regional planners or refuse and recyclable material collectors.

In their recent Policy Responses to Coronavirus (COVID-19) paper series, the OECD[13] suggest that jobs should be considered and labelled as 'green' that are resulting from measures with positive environmental implications and measures directed at supporting the transition to greener economies. Examples for these measures include:

- grants / loans / tax relief directed towards green transport, circular economy and clean energy research and renewables deployment
- financial support to households and businesses to make energy efficiency improvements and support renewable energy installations
- new funding and programmes to stimulate economic activity through ecosystem restoration, and
- control of invasive alien species, forest conservation.

While the majority of the job impacts associated with a Green Recovery are considered to be 'green', not every job created in a Green Recovery scenario will be 'green', as some investment is also assumed to flow into non-green actions and investment areas, such as road infrastructure, or conventional ICE (internal combustion engine) passenger cars. Similarly, 'green' jobs are not necessarily limited to specifically producing a green product or service, but can exist in any sector, be that a clean or more traditional sector, provided that they contribute to improving energy efficiency, reducing emissions, reducing waste, restoring nature and supporting the adaptation to climate change. Therefore, a certain (lower) amount of 'green' jobs will also be created under the High-carbon Recovery scenario.

Definition and scope of employment impacts

When considering the employment impacts of investments, it is important to acknowledge both the gross employment effects and the net employment effects, which can be differentiated as follows:

- *Gross employment effects* account for the total number of new job-years that are created as a result of investment in certain areas (and do not per se account for the job losses), while
- *Net employment effects* also consider the potential job losses occurring as a result of certain investments (for example, investment in renewable energies may have some negative effects on employment in conventional fossil fuel based energy sectors).

Direct calculation of job losses has not been part of our analysis; thus the resulting figures show gross employment impacts.

[12] ibid.

[13] OECD (2020) Making the green recovery work for jobs, income and growth. OECD Policy Responses to Coronavirus (COVID-19), updated 06 Oct 2020. https://www.oecd.org/coronavirus/policy-responses/making-the-green-recovery-work-for-jobs-income-and-growth-a505f3e7/

Furthermore, direct, indirect and induced employment impacts can also be differentiated[14]:

- *Direct jobs* are generated through the actual expansion of production (as a result of investment in certain industries).
- *Indirect jobs* are jobs that are created in supplier industries (of the industries where investment directly flows) due to an increased demand for inputs for the expanded production.
- *Induced jobs* are created because of increased consumer spending by individuals in newly created direct and indirect jobs.

In our analysis, we have considered direct and indirect job creation potential (as the employment multipliers used along the analysis capture these two types of effects), while induced effects[15] are not accounted for (due to the scope of the analysis and the lack of relevant, available data).

Nevertheless, the scope and extent of the employment impacts of a Green Recovery scenario will primarily depend on the climate policies and actions implemented at local, regional, national and global levels. It is important to stress that impacts at the global level will ultimately be built upon local level investments.

Employment impacts in the context of C40 Cities' headline actions

With the goal to support a healthy and equitable COVID-19 recovery, the C40 Mayoral Taskforce have identified eight key actions that are critical to achieve C40 Cities' vision for such a recovery:

1 Create good new green jobs fast
2 Support and lift up essential workers
3 Training and upskilling to enable a just transition to an inclusive economy
4 Deliver a post COVID safe and resilient mass transit system
5 Provide fundamental public services for all
6 Create '15 minute cities'
7 Give streets back to people
8 Build with nature

In relation to these key actions and in line with low-carbon pathways and Green Recovery strategies, specific policies have been assumed within the buildings, transport, energy, waste and urban nature-based solutions (NBS) sectors. Examples of such policies are:

- promotion of investments in renewable energy sources;
- construction of new buildings with high energy efficiency standards;
- electrification of heating (heat pumps, electric heaters, solar thermal);
- electrification of vehicles and of mass transit;
- waste recycling and composting facilities.

[14] International Labour Organization (2013) Methodologies for assessing green jobs. Policy brief. https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_176462.pdf

[15] Evidence of an earlier large-scale US program to support short-term clean energy and jobs suggests that the level of induced jobs can be of around 30% of the sum of direct and indirect jobs created. In: International Labour Organization (2013) Methodologies for assessing green jobs. Policy brief. https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---emp_ent/documents/publication/wcms_176462.pdf

4.2 In which sectors will demand for labour increase and in which sectors will it decrease in a green COVID-19 recovery?

As the positive results of the analysis also support, decarbonisation pathways (and the related investments) are anticipated to have an overall positive job impact in the economy, by creating new job opportunities in energy/ electricity supply, industry, transportation and buildings. Conversely, declines in employment are expected to occur in fossil-fuel based industries and energy-intensive manufacturing. For other sectors (such as agriculture, services and some other energy-intensive sectors), the impacts are ambiguous as countervailing effects are present: the increase in the number of jobs primarily resulting from a promotion of green, climate-neutral policies, and the decrease in the number of jobs which is largely driven by automation, digitalisation and the phase-out of carbon-intensive activities in these sectors. Many of the newly created job-years under a Green Recovery scenario will still be relatively new in the sense that the work area itself is relatively recent (such as certain areas in waste management), therefore it is difficult to determine what jobs, out of these, will still exist ten years from now.

At the same time, it is straightforward to determine which sectors are currently the highest energy users and emitters of greenhouse gases (GHGs), and conclusions can more easily be drawn about how they will be impacted by measures aimed at reducing energy use and GHG emissions (i.e., they are likely to experience relatively larger job losses). As of 2018, the three largest emitter aggregate economic sectors in the EU have been: Energy supply, Industry and Transport[16]. Proper green stimulation packages, as part of the COVID-19 recovery, should promote advanced, climate-neutral technologies and processes in traditional industries, and support the transition of workers in these traditional industries from more carbon-intensive activities towards less carbon-intensive activities (with trainings, vocational programs).

Related to a Green Recovery or the transition to decarbonisation in general, the processes of digitalisation and automation involve the deployment of new technologies across the economy, most of which are aimed at improving efficiency and reducing the amount of time that it takes to complete tasks. Overall, the process of digitalisation and automation are expected to reduce low-skilled job opportunities; the issue then is whether such jobs can be replaced by an increased demand for labour elsewhere in the economy, or by a change in the hours worked (i.e. at least part-time jobs remain), and/or in the level of compensation (pay per hour decreases, but jobs remain). While the effect of reducing demand for low-skilled jobs as a result of digitalisation and automation will be mitigated to some extent organically, e.g. by demographic change (via an increasing demand for electricity supply and health and social care), the combined impact on global employment is yet unclear.

While our analysis shows small net job losses in some of the sectors and regions (e.g. in the Energy sector in the SW Asian model city, or in Transport

[16] European Environment Agency (2019) Greenhouse gas emissions by aggregated sector. https://www.eea.europa.eu/data-and-maps/daviz/ghg-emissions-by-aggregated-sector-5#tab-dashboard-02

in the African model city), in a Green Recovery scenario compared to a High-carbon Recovery scenario, the overall impact is a net employment gain. Beyond the net employment effects (calculated as the number of job-years created), it is also important to note that the assessed investments under the scenarios will likely bring about wider socioeconomic benefits in terms of improved human health and more resilient and sustainable economies, too – however, whether the climate actions lead to such positive impacts depends strongly on how they are undertaken and may vary in sectors.

The table below summarizes our findings regarding the overall sectoral impacts of the assessed sectors under the Green Recovery scenario compared to the High-carbon Recovery scenario.

Table 5.1 Overview of the sectoral employment impacts of the assessed sectors

Sector	General direction / magnitude of employment impact
Total employment	**Overall job impact is higher in a Green Recovery.** Green Recovery is likely to lead to large falls in employment in low- and medium-skilled occupations in transport and its supplier industries, but likely to lead to net job gains in, e.g. the buildings, renewable energy generation, waste and urban nature-based solutions sectors.
Buildings	**Overall job impact is higher in a Green Recovery**. As with all sectors of the economy, parts of many jobs can be automated, potentially leading to some job losses. Improved energy efficiency in buildings and the manufacturing of related appliances will likely lead to large employment gains, even in low-skilled jobs.
Energy generation	**Overall job impact is somewhat higher in a Green Recovery with small, negative impact in one of the regions (South and West Asian)**. Alongside the potential automation of jobs within the electricity sector, greater energy efficiency also has indirect effects on employment within the sector since it can result in less demand for electricity, and thus fewer jobs. Positive impact due to new jobs created in renewable energy generation.
Transport	**Overall job impact is lower in a Green Recovery than in a High-carbon Recovery** (less job-years are created in all regions and in sum as well). Mostly driven by potentially large, negative indirect impact for routine, low- and medium-skilled jobs in the supplier Automotive industry, resulting from a decreasing share of conventional vehicles in transport and an increasing take-up of electric vehicles.
Waste	**Overall job impact is slightly lower in a Green Recovery than in a High-carbon Recovery**. Potentially negative impact for routine, low- and medium-skilled jobs in the sector, but positive impacts under the Green Recovery stemming from a larger emphasis on an increased circularity across the economy, and the related composting and recycling activities.
Urban nature-based solutions	**Overall job impact is higher in a Green Recovery than in a High-carbon Recovery**. Large employment gains due to an increase of jobs related to urban parks and green roofs.

It is key to emphasize that overall job impacts are higher in the investigated Green Recovery scenario than in the High-carbon Recovery. In all potential decarbonisation transition pathways, there will be both employment gains and losses, which also holds true for the employment perspectives of a greener COVID-19 recovery. It is also important to keep in mind that ambitious climate targets can only be achieved with strong emission reductions in the largest emitting sectors (such as Transport), which will likely have adverse effects on employment in the current, traditional parts of the sector.

4.3 What is the evidence regarding the local / non-local split of jobs created?

The employment estimates in our analysis do not make a distinction between local jobs created, and jobs created nationally or internationally. The extent to which jobs will be created within the investigated cities or outside of the cities will primarily depend on the specific scenarios and associated investments that are made.

The extent of local versus non-local job-creation is strongly sector-specific. Some investment areas, such as the construction of new, more energy efficient buildings[17], or smaller-scale grid investments[18] are often carried out by local installers and will likely generate local jobs as customers (councils / businesses / households) also tend to contract with local service providers to carry out these types of work.

Relatedly, several infrastructure-related jobs, e.g. those created in new road construction / road reconstruction, or in building cycle lanes and walkways also tend to be local jobs.[19] Our research thus anticipates that investment in Transport (and specifically, into urban transport solutions) will likely create more jobs locally than outside of the region. While the job impact in Transport is higher in the High-carbon Recovery scenario, than in the Green Recovery, the overall *local* impacts of the investment in Transport under the Green Recovery scenario are also strong and positive.

At the same time, excluding job creation connected to charging infrastructure, investment in new electric vehicles (EVs) will largely generate global jobs as current battery production for EVs is geographically highly concentrated, with China accounting for more than 70% of global battery production capacity.[20]

Regarding local supply chains, dependency on one sector is a more common phenomena in rural areas than in cities, as cities are less dependent on one sector and are more integrated in global supply chains, therefore they are more resilient to changes in sectoral demand.

[17] IEA (2020) Sustainable Recovery, IEA, Paris https://www.iea.org/reports/sustainable-recovery p108

[18] IEA (2020) Sustainable Recovery, IEA, Paris https://www.iea.org/reports/sustainable-recovery p47, p49

[19] IEA (2020) Sustainable Recovery, IEA, Paris https://www.iea.org/reports/sustainable-recovery p67

[20] IEA (2020) Sustainable Recovery, IEA, Paris https://www.iea.org/reports/sustainable-recovery p62

4.4 What changes in the occupational and skills needs are expected to happen?

As a recent labour market study[21] of the University of Cambridge Institute for Sustainability Leadership highlights, rapid advances in technology, in particular automation and robotics are already having a substantial impact on the labour market. A 2017 McKinsey Global Institute[22] study provides similar observations: exponential advancements in computer science, computer power and the availability of big data have dramatically improved the capabilities of technology to perform more and more tasks more efficiently than humans do. According to this study, and based on an assessment of more than 2,000 work activities across 800 occupations, as of 2017 almost half the activities people were paid (almost $16 trillion in wages) to do globally did have the potential to be automated by adapting currently available technologies. While less than 5 percent of all occupations can be fully automated using the current available technologies, the research found that around 60 percent of all occupations did have at least 30 percent of their usual activities that could have been automated. An overall conclusion of that study was that most of the occupations are expected to change rather than being 'automated away' completely.

These advancements have been linked with considerable labour market developments, too, in that skill-biased technological change is increasing demand for high-skilled labour that is capable of working alongside the machine and in parallel, is reducing demand for low-skilled labour[23]. As for a general definition of low-, medium- and high-skilled jobs, the International Labour Organization[24] suggest using the following categorization (based on the ISCO-08, the system of International Standard Classification of Occupation):

- High-skilled jobs: ISCO-08, categories 1-3: managers, professionals, technicians and associate professionals.
- Low-and medium-skilled jobs: ISCO-08, categories 4-9: clerical support workers, service and sales workers, skilled agricultural, forestry and fishery workers, craft and related trades workers, plant and machine operators and assemblers, elementary occupations.

Along this report, low-skilled jobs refers to the above Low- and Medium-skilled jobs group.

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[21] University of Cambridge Institute for Sustainability Leadership (2020) Working towards a climate neutral Europe: Jobs and skills in a changing world. Technical Report. Cambridge, UK: CLG Europe. https://www.corporateleadersgroup.com/reports-evidence-and-insights/publications/publications-pdfs/working-towards-a-climate-neutral-europe/clg-europe-jobs-and-skills-technical-report.pdf

[22] McKinsey Global Institute (2017) A future that works: automation, employment and productivity. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/Digital%20Disruption/Harnessing%20automation%20for%20a%20future%20that%20works/MGI-A-future-that-works-Executive-summary.ashx

[23] University of Cambridge Institute for Sustainability Leadership (2020) Working towards a climate neutral Europe: Jobs and skills in a changing world. Technical Report. Cambridge, UK: CLG Europe. https://www.corporateleadersgroup.com/reports-evidence-and-insights/publications/publications-pdfs/working-towards-a-climate-neutral-europe/clg-europe-jobs-and-skills-technical-report.pdf

[24] International Labour Organization (n.a.) Employment by occupation. https://www.ilo.org/ilostat-files/Documents/description_OCU_EN.pdf

Low-skilled labour makes up a greater proportion of the labour force in less developed countries, and therefore the total labour force in these countries is relatively more affected by technological changes than the total labour force in developed countries. However, cost considerations also play a crucial role in the choice between high-tech or labour-intensive solutions: there are important examples from the past and present for cases when more advanced technologies are not being implemented and deployed as long as the less-efficient, existing technologies are cheaper.

The above referred McKinsey Global Institute[25] study highlights further implications with regards to emerging economies, and argues that emerging economies can further be divided into groups of countries with aging population and with younger population. For emerging countries with aging population (such as Argentina, Brazil or China), automation can provide the productivity injection needed to maintain current GDP per capita; while for emerging countries with heavily growing working-age population (such as India, Indonesia, Mexico, Nigeria, Saudi Arabia or South Africa) may find the generation of new jobs in the age of automation to pose more and more difficult policy challenges.

A key issue in today's labour market is thus that advances in technology are creating demand for more high-skilled workers, while there is also a shortage in supply of workers with the right skills. As many actions related to the green recovery are expected to require the same skills that are already required by other trends (such as technological change), these actions will magnify the areas of future jobs and skills already shaped by global drivers, with a shift to high-skilled jobs.[26]

Which specific occupations / skills will be in demand within the green recovery?

Importantly, the green recovery may not result in totally new professions over the next decade: a new job can be something fairly similar to what has existed before (manufacturing lithium-ion EV batteries vs. manufacturing lithium-ion batteries for smart phones), but it may require new processes and skills. The key question is where the areas of job growth will be, and what that implies in terms of anticipated changes in skills need in the future (and especially skills needed in a specific location that may want to capture a share of a growing global market).

Many of the investment types investigated in this study are closely linked to energy efficiency improvements (in buildings and industry), which tend to be labour intensive and typically require technically skilled labour, which includes occupations such as plumbers, electricians, plasterers and window-fitters, as well as buildings maintenance workers that continuously ensure the high-performance of more energy efficient facilities.

[25] McKinsey Global Institute (2017) A future that works: automation, employment and productivity. https://www.mckinsey.com/~/media/mckinsey/featured%20insights/Digital%20Disruption/Harnessing%20automation%20for%20a%20future%20that%20works/MGI-A-future-that-works-Executive-summary.ashx p15

[26] University of Cambridge Institute for Sustainability Leadership (2020) Working towards a climate neutral Europe: Jobs and skills in a changing world. Technical Report. Cambridge, UK: CLG Europe. p30 https://www.corporateleadersgroup.com/reports-evidence-and-insights/publications/publications-pdfs/working-towards-a-climate-neutral-europe/clg-europe-jobs-and-skills-technical-report.pdf

In their recent work Vona et al.[27] identified so-called "Green General Skills", that are potentially used in all occupations, but are in relatively higher demand in jobs that are relevant in a green economy (green jobs), including:

- engineering
- operations management
- monitoring and
- science skills

While such skills are often associated with higher education degrees, the engineering skills required by the green transition, for example, also include building and construction skills (such as certain jobs in buildings' maintenance focused on optimizing building energy efficiency without requiring any advanced degrees). The authors further identify the following green occupations as highly relevant and in high demand:[28]

- construction laborers
- construction equipment operators
- electricians
- roofers
- sheet metal workers
- solar PV installers
- hazardous material removal
- millwrights
- wind turbine service technologists
- refuse and recyclable collectors

Most of these occupations can be linked to one or more types of investment investigated in this study: for example, renewables-related occupations to investments in the Energy sector, recyclable collector jobs to investments in the Waste sector, and construction laborers and operators to several investment types in the Buildings and in the Transport sector.

What are the implications of changes in the occupational and skills needs for training needs?

Greening of the economy is, thus, in many cases interrelated to technological changes and to the use of technologies which require high-skilled professionals in previously untapped job areas (e.g. jobs around renewable generation technologies' installation phases). In some occupations (e.g. several occupations related to urban nature-based solutions, such as city greening), the transition towards green jobs is much easier due to many skills being already present and easily transferable to 'cleaner' activities; in other cases the transition will require more training.

Importantly, recent empirical works – such as recent research[29] on the US labour market - conclude that overall, the retraining needed for many workers to work in the green economy could be much less than was previously

[27] Vona, F. et al (2018) Environmental regulation and green skills: an empirical exploration. Journal of the Association of Environmental and Resource Economists, vol 5, nr 4 (2018). https://www.journals.uchicago.edu/doi/pdf/10.1086/698859

[28] Vona, F. et al (2020) Green Stimulus in a Post-pandemic Recovery: the Role of Skills for a Resilient Recovery. Environmental and Resource Economics 76, 901–911 (2020). https://doi.org/10.1007/s10640-020-00464-7

[29] Kuralbayeva, K (2018) How many green jobs are there in the US? https://www.lse.ac.uk/granthaminstitute/news/how-many-green-jobs-in-the-us/

expected. Yet, there are a few areas where the 'greening' of the labour market will require transitions to directly green jobs which are unique to the green economy and which represent a wider skills gap and, therefore, may require specific training, such as environmental engineer or recycling operator.

There are several dimensions of skills and training requirements that are associated with green-specific occupations. Vona et al.[30] groups these along the above four "Green General Skills" categories, identifies training need around these jobs and concludes that most of the green jobs require over a year of on-the-job training, thus, some training will be required for workers transitioning from currently high-demand, high-carbon jobs to green jobs. The authors also note that there are highly demanded low-skill occupations in traditional industries (e.g. derrick operators in oil and gas, service unit operators in oil, gas and mining, earth drillers and pump operators) the transitioning of which will likely require less time due to the more similar skills and expertise needed for these workers in positions related to the "Green General Skills" as in their original positions.

4.5 What are the implications of changes in the occupational and skills needs for inequality?

While many of the employment impacts of decarbonisation measures lead to positive outcomes, there are some vulnerable sectors or groups of workers who may be negatively affected by the structural changes required to achieve a green transition.

In the context of an overall net positive employment impact of the investigated investments, it is likely that job opportunities will be skewed towards high-skilled/ high-paid occupations, and in the absence of the right training opportunities, some workers in lower-skilled/ lower-paid occupations are at risk of being left behind. Workers negatively affected by a green recovery should be suitably protected by efficient social protection systems and offered training, to ensure that inequality issues are mitigated.

There are differences in the extent of potential inequality impacts across different regions, and there are regions and areas where sectoral employment will likely be more skewed towards high-skill workers and occupations than in others. In general, high dependence on fossil fuels or carbon-intensive processes makes regions and economic sectors (e.g. oil-rich economies such as the Gulf-countries, Venezuela or Indonesia; and coal-rich economies such as South Africa, China, Russia or India[31]) more vulnerable to the potential negative effects of the transition (e.g. increasing inequality). Overall, developed regions are more equipped to design an adequate training system in support of the changing skills needs than developing regions due to greater

[30] Vona, F. et al (2020) Green Stimulus in a Post-pandemic Recovery: the Role of Skills for a Resilient Recovery. Environmental and Resource Economics 76, 901–911 (2020). https://doi.org/10.1007/s10640-020-00464-7, Table 1

[31] Friedrichs, J. – Inderwildi, O.R. (2013) The carbon curse: Are fuel rich countries doomed to high CO_2 intensities? Energy Policy 62:1356–1365 https://www.researchgate.net/publication/257815497_The_carbon_curse_Are_fuel_rich_countries_doomed_to_high_CO_2_intensities

resources available in their vocational education and training systems. With regards to specific occupations, it should be noted that there are several high-demand jobs and related positions in traditional, non-green sectors that have lately become considerably vulnerable due to falling oil prices (rotary drill operators in oil and gas, extraction workers and helpers), which would be in much lower demand, should a true green recovery take place.[32] An important policy implication stemming from all these is that investment in green policies and actions will not in itself provide assistance to workers who have been hurt the most by the pandemic, or workers whose jobs are at highest risk to disappear as a result of a green transition; but a properly designed green stimulus package can provide great assistance and training to those in the highest need. For this to happen, it is really important to raise awareness and resilience of workers locally, cities for example can and should promote the skills that will be needed for the 'greening' jobs and design local training and retraining schemes to support the process of COVID-19 recovery and to enable the process to be a Green Recovery. Municipalities can support career fairs to encourage young people to aspire to jobs of increasing demand, such as green jobs.

The presence of gender issues in the green economy should be acknowledged, as women are currently underrepresented in typically 'green' sectors (agriculture, fishery and forestry)[33] as well as in quite a few key, traditionally non-green sectors: globally, males hold around 93% of construction jobs and more than 60% of manufacturing jobs.[34] These observations raise two important issues: first, it is key to address the gender occupational gap in the process of transition in order to ensure a green and just transition; second, the current high proportion of males in manufacturing / traditional fossil fuel-based industries also mean that they are at relatively higher risk to lose their jobs in the transition process.

If not designed properly, some of the measures ensuring that climate actions do actually occur may raise inequality concerns. For example, carbon taxes can be regressive without the necessary mitigation measures as they are hitting low-income households disproportionately more[35], which observation holds true for all regions globally. Nevertheless, if designed and implemented well, climate policies, and the related changes in demand for labour can also help decrease inequality by acknowledging the potential 'losers' of the climate transition and by providing them with the right incentives and support

[32] Vona, F. et al (2020) Green Stimulus in a Post-pandemic Recovery: the Role of Skills for a Resilient Recovery. Environmental and Resource Economics 76, 901–911 (2020). https://doi.org/10.1007/s10640-020-00464-7

[33] University of Cambridge Institute for Sustainability Leadership (2020) Working towards a climate neutral Europe: Jobs and skills in a changing world. Technical Report. Cambridge, UK: CLG Europe. https://www.corporateleadersgroup.com/reports-evidence-and-insights/publications/publications-pdfs/working-towards-a-climate-neutral-europe/clg-europe-jobs-and-skills-technical-report.pdf

[34] International Energy Agency (2020) Sustainable Recovery, IEA, Paris. https://www.iea.org/reports/sustainable-recovery

[35] Burke et al. (2020) Distributional impacts of a carbon tax in the UK. https://www.lse.ac.uk/granthaminstitute/publication/distributional-impacts-of-a-carbon-tax-in-the-uk/

schemes. As suggested by a related study[36], examples for this include programmes to improve energy efficiency in homes, or renewable systems to improve access to energy in remote communities. The study concludes that best results can be achieved when potential inequality concerns are taken into consideration in all stages of the policy making process: including policy planning, development and implementation (including the jobs created as part of the transition process).

For the reasons discussed above, it is key to promote equal opportunities in technical and vocational education and training and retraining opportunities locally as well as regionally and globally.

4.6 What does the evidence say about the quality of new jobs?

In considering the difference in job quality between green and non-green jobs, it is important to define what job 'quality' captures. The quality of an occupation can be conventionally[37] measured by earnings, education, prestige and job satisfaction; we furthermore consider that other non-economic benefits should be included too, such as the legal conditions of the work (i.e. it is a formal job or part of the informal labour market), the working arrangements and future prospects of an occupation / position.

Will green jobs be of higher / lower quality compared to similar non-green jobs?

The ILO's[38] definition of 'decent' work includes the following:

- Opportunities for work that is productive and delivers a fair income
- Security in the workplace and social protection for families
- Prospects for personal development and social integration
- Freedom for people to express their concerns, organise and participate in the decisions that affect their lives, and
- Equality of opportunity and treatment for all women and men.

Van der Ree[39] enhances that while from an output perspective, green jobs generate goods or services that benefit the environment, it is often the case that outputs are not entirely based on environmentally friendly production processes and do not necessarily grant 'decent' job conditions. For instance, as typical green jobs, recycling and waste management jobs often involve working practices that are dirty and dangerous, causing considerable damage to human health; while workers are often unprotected against these detriments and are not fairly compensated. Similarly, construction workers often face poor working conditions and are among the most hazardous groups in terms of

[36] Sanna Markkanen & Annela Anger-Kraavi (2019) Social impacts of climate change mitigation policies and their implications for inequality, Climate Policy, 19:7, 827-844. https://www.tandfonline.com/doi/full/10.1080/14693062.2019.1596873

[37] University of Cambridge Institute for Sustainability Leadership (2020) Working towards a climate neutral Europe: Jobs and skills in a changing world. Technical Report. Cambridge, UK: CLG Europe. https://www.corporateleadersgroup.com/reports-evidence-and-insights/publications/publications-pdfs/working-towards-a-climate-neutral-europe/clg-europe-jobs-and-skills-technical-report.pdf

[38] van der Ree, K. (2019) Promoting Green Jobs: Decent Work in the Transition to Low-Carbon, Green Economies. International Development Policy, 11 | 2019, 248-271. https://journals.openedition.org/poldev/3107

[39] ibid.

work accidents.[40] Green-economy versions of these jobs should therefore be changed in a way that they provide adequate income, social protection and working conditions**.** Importantly, research indicates that the overall risk of jobs being of a low quality tend to be lower when moving towards a low-carbon economy.[41] For example, an increased deployment of renewable energy sources will avoid the health dangers associated with traditional coal-mining. However, it is also important to emphasise that the jobs in a greener future will not be decent by default, but can be made so by design[42] which requires economic and social policies that help workers to properly adjust, including large-scale investments in the education and training systems, both at the secondary and the tertiary levels.

With respect to the longevity of the jobs created, there is no clear evidence as to whether green jobs provide longer-term job opportunities than non-green ones (e.g. jobs related to buildings retrofit or to solar PV installation are typically short-term), but there are a couple of key technologies and industries that are foreseen to be robust for the future and therefore will be continuing to support jobs and a thriving economy in the longer run (such as renewable energy generation, energy efficient buildings and the manufacturing of energy efficient appliances, or waste recycling and composting).

As a key takeaway, at the level of an individual job there is no clear evidence if a 'green' job will necessarily be a more decent job, too; but at an industry and national level, there is clear evidence that some high-carbon industries (coal, mining, conventional ICE vehicles manufacturing) are declining and do not have long-term prospects, while other industries are by all evidence expanding and will be offering long-term employment prospects.

4.7 What skills shortages might exist, and what impact does an inadequately equipped workforce have?

According to the ILO, skills gaps and shortages are a major bottleneck of the transition process in several sectors, such as renewable energy (farm implementation and generation), energy and resource efficiency, the renovation of buildings, or environmental services.[43] Local initiatives of the ILO provide good examples for projects and regions in which skills gaps and shortages proved to be clear bottlenecks of the transition, but where many

[40] International Labour Organization (2016) A just transition to climate-resilient economies and societies: Issues and perspectives for the world of work. https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---gjp/documents/publication/wcms_536552.pdf

[41] Poschen, P. (2015) Sustainable Development, Decent Work and Green Jobs. Sheffield, Greenleaf Publishing; UNEP – ILO – IOE – ITUC (2008) Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon World
in: International Labour Organization – The Green Initiative (2016) A just transition to climate-resilient economies and societies: Issues and perspectives for the world of work. Technical paper.
https://www.ilo.org/wcmsp5/groups/public/---ed_emp/---gjp/documents/publication/wcms_536552.pdf

[42] International Labour Organization (2017a) Work in a changing climate: The Green Initiative, Report of the Director-General, International Labour Conference, 106th Session (Geneva: ILO)
https://www.ilo.org/wcmsp5/groups/public/---ed_norm/---relconf/documents/meetingdocument/wcms_554315.pdf

[43] International Labour Organization (2020) Frequently Asked Questions on green jobs.
https://www.ilo.org/global/topics/green-jobs/WCMS_214247_EN/lang--en/index.htm

decent work opportunities could be created with focussed local actions, for example:

- Training for green entrepreneurship in for example China and Kenya has resulted in new business ideas (particularly among youth).
- Training on solar panel installation and maintenance has proven to be very effective in rural areas in Bangladesh. The training allowed the participants (mainly women) to use solar power in their own home and to start small business ventures by providing installation and maintenance services to other people in the community.

Skills shortages can also arise from demographic changes, for example, as retirement levels in engineering sectors outweighing the number of trained engineers entering the workforce.

Ensuring an adequately skilled workforce is a key issue for policy makers, since skills shortages would mean employment effects cannot be maximised and decarbonisation targets may not be met. While the offshoring of jobs (associated with the phenomena of carbon leakage[44]) and automation can support the accomplishment of the decarbonisation targets, both of these have adverse effects on national employment, mainly in jobs using mid-level skills performing routine tasks. Therefore, this emphasises the strong need to develop skills that are not at extremely high risk of being 'offshored' or automated and to fill in the related skills shortages locally, if there are any present, through the implementation of specific programmes.

The detailed mapping of skills requirements can be very helpful in this process, and greatly supports in elaborating in-depth programs for potential skills upgrading and in redesigning national / regional vocational education and training schemes.[45] The ILO also suggest that environmental awareness needs to be part of education and training at every level; and emphasises that public-private partnerships, the use of governments' and businesses' resources and effective communication between employers and training providers are all key to a successful recovery from COVID-19 that is in line with the transition to a greener economy.

Literature that focuses on the skills implications of a green transition[46] tend to agree that the required topping up of skills is, however, likely to be rather minor, and will focus on core STEM skills (individual skills needed to do science, mathematics, and engineering, and those needed to use technology effectively). This is also true for the construction sector, where a considerable topping up of skills will be necessary for the construction of new, energy

[44] Carbon leakage is a term used to describe the hypothetical situation where stringent climate policies would force companies to move their production abroad to countries with less ambition climate measures to lower their production costs. This can lead to a rise in global GHG emissions. https://carbonmarketwatch.org/wp-content/uploads/2015/10/CMW-Carbon-leakage-myth-buster-WEB-single-final.pdf p3

[45] International Labour Organization (2020) Frequently Asked Questions on green jobs. https://www.ilo.org/global/topics/green-jobs/WCMS_214247_EN/lang--en/index.htm

[46] See for example: Cedefop (2019) Skills for green jobs: 2018 update. European synthesis report. Luxembourg: Publications Office. Cedefop reference series; No 109. https://www.cedefop.europa.eu/files/3078_en.pdf

efficient buildings and the implementation of the related appliances and it is still true that these green occupations will require more green skills than most of the current brown jobs in the sector - yet, recent studies, including Vona et al.[47] conclude that the anticipated skills shortages, even in the construction sector, are relatively small.

The skills required for many new 'green' jobs are not necessarily new, and many green occupations incorporate skills from existing sectors. Policy-makers should hence focus on anticipating the skills implications of decarbonisation policies the most appropriately and identify potential skills gaps in the workforce as quickly as possible. The reviewed literature suggests that the skills implications are relatively minor, so whilst we need to be well prepared to ensure a swift, successful and above all just transition, evidence suggests it is entirely possible to carry out the necessary re-skilling of the workforce.

The provision of re-skilling and training are good strategies in times of high unemployment, so overall these fit well with a post-COVID-19 recovery.

4.8 How can skills shortages be overcome?

Skills shortages can be overcome by applying effective **training and education**, ensuring the mobility of labour between sectors and firms and enabling a city to fully maximise the employment benefits of a green recovery strategy.

The topping up of skills, **initial and continuing vocational education and training** should be promoted by both the public and the private sector, and should focus on allowing workers to migrate between sectors more easily, so that workers from declining sectors have sufficient opportunities for new employment in growing sectors.

To assist policy-makers with creating the most effective policy packages, it is essential that **government and industry work closely together** to ease potential adjustment pressures in the most vulnerable industries, early on. Employers within industries that are vulnerable to green recovery measures should communicate potential skills gaps and identify groups of workers at highest risk of unemployment. Policy-makers should equally respond with appropriate support.

Collaboration between industry and research institutions is also important (and may need to be encouraged by policy-makers), to enable the transfer of knowledge and to allow new clean technologies (supported by workers with the right skills) to come to market. A well-designed policy mix, coupled with effective collaboration between industry, research institutions, civil society and government will allow policy-makers to achieve both positive outcomes for both the environment and labour markets.

[47] Vona, F. et al (2020) Green Stimulus in a Post-pandemic Recovery: the Role of Skills for a Resilient Recovery. Environmental and Resource Economics 76, 901–911 (2020). https://doi.org/10.1007/s10640-020-00464-7

There is a need for **investment opportunities** in the regions affected so jobs are being created for the newly trained workers. Otherwise, outward migration is incentivized to the regions where the new jobs are created.

Finally, it is key that the **continuous anticipation of future green skills** is not ad-hoc, but regular and systematic (digital tools and technologies can largely help this process): it may be beneficial to weigh up the costs and benefits of putting in place permanent mechanisms, such as observatories, to ensure continuous monitoring of the demand for and supply of green skills - even at the city level. The box below briefly presents some best practices based on an earlier work[48] of the C40 Cities Climate Leadership Group.

How to overcome skills shortages: City examples and best practices

The C40 Cities Climate Leadership Group community has collected a couple of pioneer examples of cities that have successfully implemented actions to **accelerate the delivery of upskilling and reskilling programmes** as part of their COVID-19 recovery strategies. Such examples included:

- Amsterdam's 'House of Skills' initiative: a public-private partnership bringing together almost 100 representatives from businesses, employee associations, research institutes, the education sector and local government to facilitate upskilling and skills matching from the circular economy to information and communications technology.
- A retrofit project for low-income communities in Cape Town: a project involving a national agency to deliver training to participants to develop retrofitting skills, increasing economic mobility, which provided nearly 2,350 local people with temporary employment.

[48] C40 Cities Climate Leadership Group (2020) COVID-19 recovery: How cities can rapidly boost good, local employment
https://www.c40knowledgehub.org/s/article/A-green-just-and-job-rich-COVID-19-recovery-How-cities-can-rapidly-boost-good-local-employment?language=en_US

4.9 Concluding remarks

Transitioning towards a greener economy will require structural change. These structural changes will cause shifts in production and consumption throughout all sectors of the economy, particularly shifts from high-carbon-intensive sectors to low-carbon-intensive sectors.

A successful transition to decarbonisation will thus have an impact on a city's labour market. Impacts may be positive or negative, depending on the sectoral structure of the city in question and the decarbonisation policies used; while some policies will create new opportunities for workers in existing or new sectors, others will put jobs within declining sectors at risk. Not only will workers in sectors directly affected by decarbonisation be in need of re-skilling, but also workers in all sectors and occupations, as investments in the energy sector are redirected and the use of green technologies increases.

An important observation is that not all green jobs will be by default decent jobs, there is a great opportunity to make new green jobs decent by design, which emphasises the urgent need of accompanying social and economic policies to achieve a just transition for all that leaves no one behind and promotes decent work. While at the level of an individual job there is no clear evidence if a 'green' job will necessarily be a more decent job, at the same time; but at an industry and at a national level, there is clear evidence that some high-carbon industries (coal, mining, conventional ICE vehicles manufacturing) are declining and do not have long-term prospects, while other industries (such as renewables, the construction of energy efficient buildings and advanced waste management) are expanding and will be offering long-term employment prospects.

A successful transition towards a greener economy means implementing environmental policy that is coupled with complementary labour market and social policies, to ensure that the benefits of the transition are maximised. It is important to ensure workers are able to fully exploit all new opportunities, and those that are displaced as a result of decarbonisation policies are suitably protected and assisted with the transition back into work.

4.10 Future research areas

The evaluation of the employment impacts of a green COVID-19 recovery and the review of related evidence, has highlighted a few areas where related future research efforts might be best focused.

While on the cost side, the modelling approach allowed us to explicitly differentiate the 'Green Recovery' and the 'High-carbon Recovery' scenario by applying different investment assumptions under the two scenarios, the same could not be done in the case of employment multipliers found in the reviewed literature. While the empirical sources suggest using the same employment multiplier in estimating the job generation potential of a 1 million USD investment spent on, e.g. a new landfill site, irrespective of the scenario

investigated, in practice there might be significant efficiency differences between how the same investment amount is used in one or the other scenario. That is, an important future area of research might be to investigate the differences between how efficiently investment is used (what is the expected return, in monetary / production terms, of a certain investment) in case of green and non-green investments.

Another interesting future research area would be a deep-dive into what impacts the green transition will likely have on the key economic sectors to identify important sectoral differences, opportunities and risks the major economic sectors are facing in the transition[49]. While the current research has already provided a few insights in this regard, it is worth further investigating, e.g. to what extent high-emitting sectors have access to promising technologies that can reduce emissions in order for the industry to become green, or identify industries that have limited opportunities to go green and that will likely become stranded industries/assets in the future.

Finally, a more in-depth investigation of the concept of green jobs could be carried out, including a more detailed review of how different international organizations, country-specific institutions define green jobs. Relatedly, a detailed comparison of countries' performance in terms of green job creation, accounting for their past demand for green jobs and the potential future hiring demand to fill green jobs would expand on the current research with further important insights.

[49] One of the key dimensions to investigate in this topic is resource efficiency, and the question of how industries differ in terms of their ability to increase resource efficiency in line with the green transition. An important piece of work that could be used as a starting point in such a research is:
European Commission – DG Environment (2015) The interaction of resource and labour productivity: A scoping study. Authors: Stocker, A. et al.
https://ec.europa.eu/environment/enveco/jobs/pdf/Study%20Resource%20labour%20productivity%20.pdf