

Measuring the Socio-economics of Transition: **FOCUS ON JOBS**

STAFF TECHNICAL PAPER
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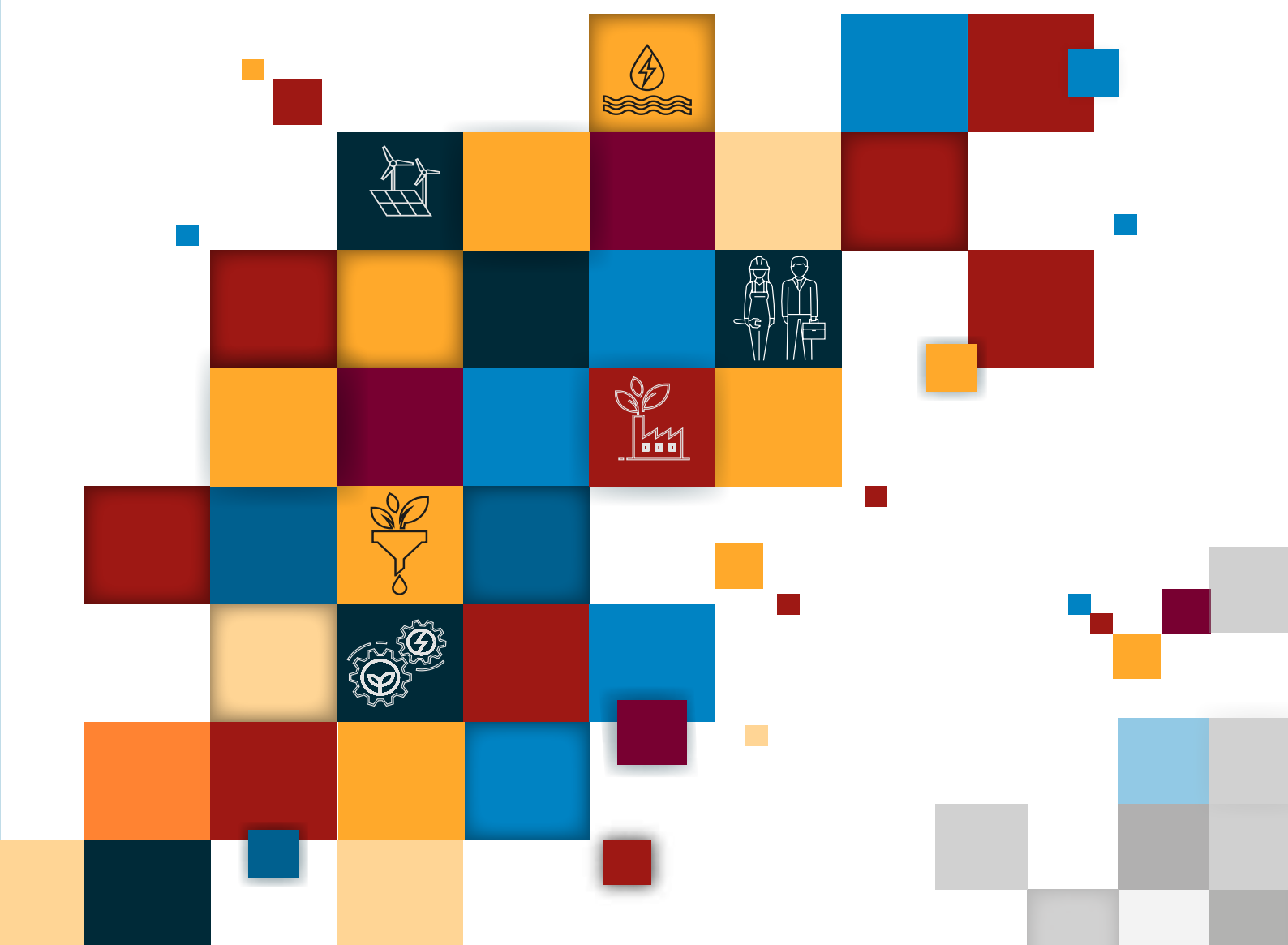
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Measuring the Socio-economics of Transition: Focus on Jobs



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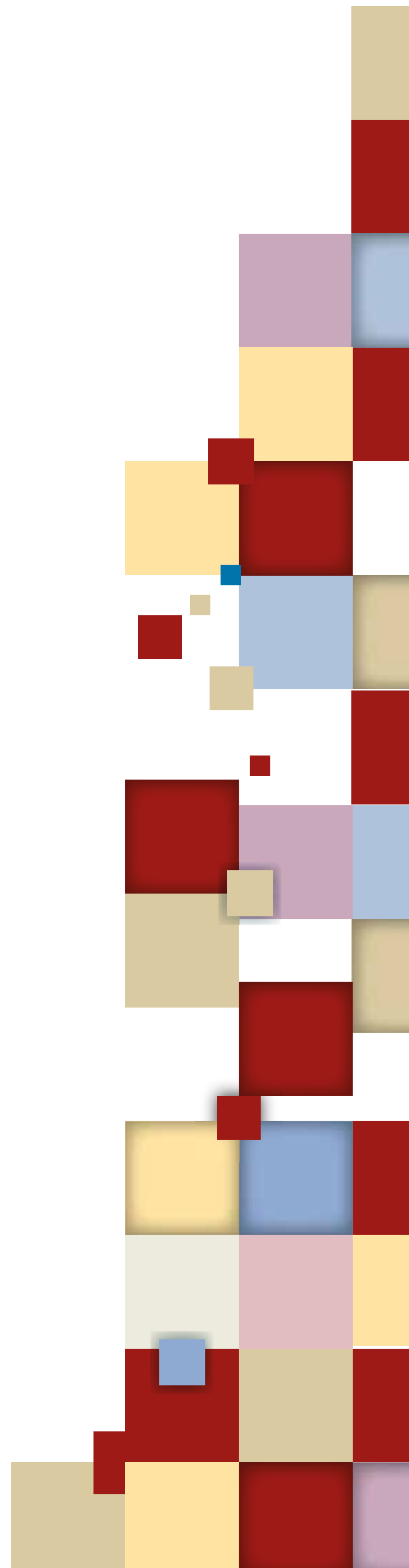
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1 Assessing the Impact of the Energy Transition

Renewable energy jobs (in million)

11
in 2018

42
in 2050

Background

Jobs are instrumental in achieving economic and social development, as well as in helping to achieve broad societal goals such as poverty alleviation, increased well-being and social cohesion in a sustainable manner. Beyond their obvious importance for individuals and families, jobs also play a critical role in education and skills acquisition, as well as in realising greater gender equality. Given their contribution to ensuring a well-functioning economy and, ultimately, societal stability, jobs are of critical interest to governments and policy makers.

To support policy makers and other stakeholders, IRENA monitors the evolution of renewable energy jobs, forecasts employment in renewables and evaluates the wider impact of transition roadmaps on overall and sectorial jobs.

IRENA's *Renewable energy and jobs: Annual review* reports provide regular assessments of overall employment generation along the renewable energy value chain.

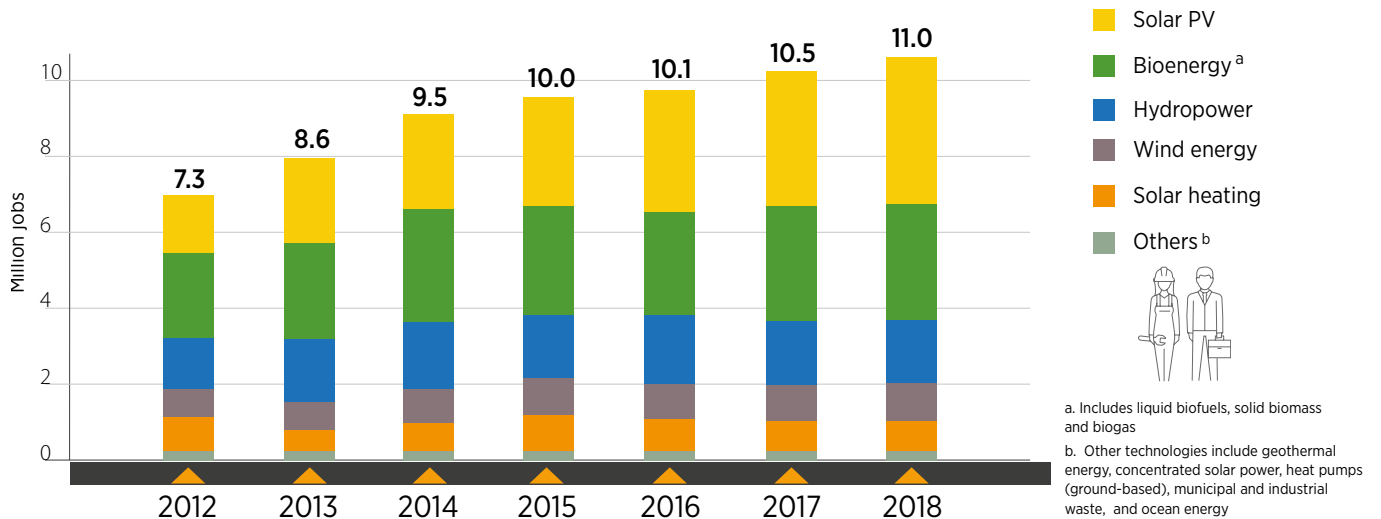
The latest edition estimates that in 2018 some 11 million people were employed worldwide in the renewables sector, up from 7.3 million in 2012 (IRENA, 2019a).¹ The most rapid expansion has occurred in the solar photovoltaic (PV) industry, which now employs over 3.6 million people, putting it ahead of bioenergy, hydropower and wind power (Figure 1).

Looking forward, IRENA's socio-economic footprint work (IRENA, 2016a, 2017a, 2018a, 2019b, 2019c), based on integrated macroeconomic models, analyses the jobs footprint of transition roadmaps, exploring its sectorial distribution (renewables, energy sector, economy-wide) and associated misalignments, thereby informing policies for a just transition. By 2050, the number of people employed in renewable energy could reach 42 million worldwide (see section 2.1). This report will examine the likely implications of IRENA's energy transition roadmap (IRENA, 2019b) on jobs, including from the perspective of selected regions and countries.

¹ The monitored jobs estimate is primarily obtained from data collection, which can lead to underestimation, given the lack of data for certain countries and renewable technologies. IRENA's monitored renewable energy jobs estimate (10.3 million jobs in 2017) was used to calibrate the macro econometric model (E3ME from Cambridge Econometrics). After calibration, the model has been used to fill the gaps in the monitoring process (regions and technologies without available data), providing an estimate of 12.3 million renewable energy jobs in 2017. The calibrated E3ME model is then used to forecast the socio-economic implications (jobs included) from energy transition roadmaps.



Figure 1: Renewable energy jobs, 2012–2018



Source: IRENA, 2019a.

The growth in renewable energy jobs is the logical result of the increasing deployment of renewables – a development underpinned by falling costs and supportive policies. Renewables account for more than half of all capacity additions in the global power sector since 2011 and their share in total power generation has steadily increased. Total renewable power capacity in 2018 exceeded 2300 gigawatts (GW) globally (IRENA, 2019d), with most growth coming from new installations of wind and solar energy. More progress has been achieved in the power sector than for end uses in heating/cooling and transportation, and the expansion of renewable electricity is taking on even greater importance as electrification strategies are pursued. For example, electric cars and buses are

beginning to make inroads into the vehicle market and key enabling technologies such as batteries are experiencing rapid cost reductions.

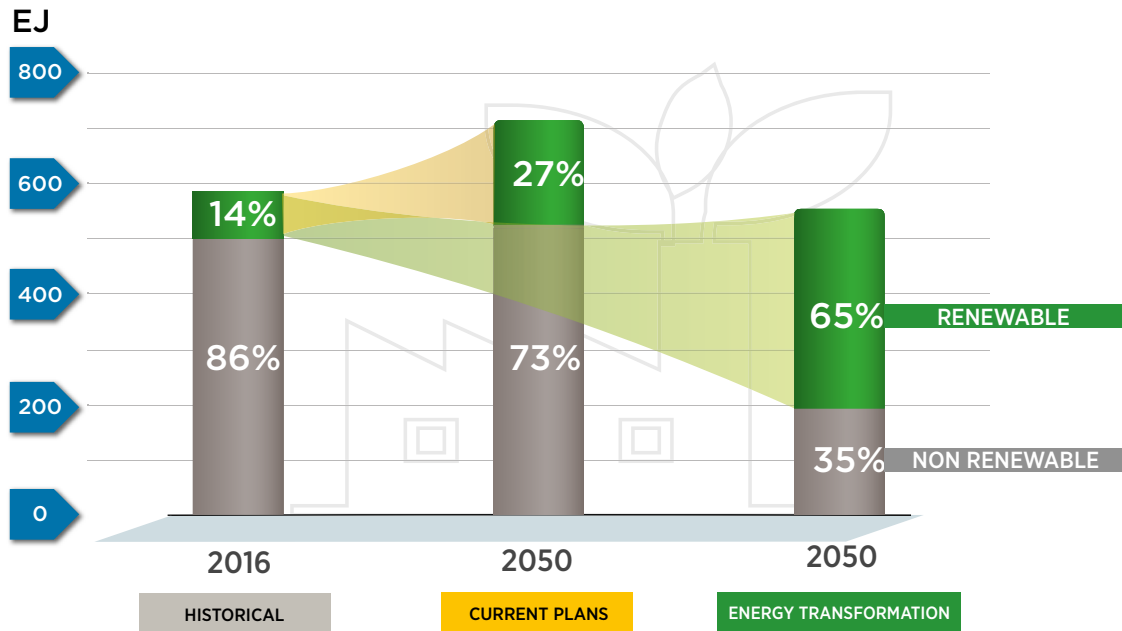
Notwithstanding the promising changes that have taken place in the past few years, climate objectives necessitate a restructuring of the energy system on a much greater scale, led by a combination of renewable energy technologies, greater energy efficiency, increasing flexibility and grid modernisation. Keeping global average temperatures from rising above the 1.5°C threshold (as recommended by the Intergovernmental Panel on Climate Change [IPCC] and endorsed by the 2015 Paris Agreement on climate change) requires significant and timely reductions in energy-related (and other) emissions.

Under the 2019 REmap energy transition roadmap, IRENA has explored two energy scenarios (IRENA, 2019b):

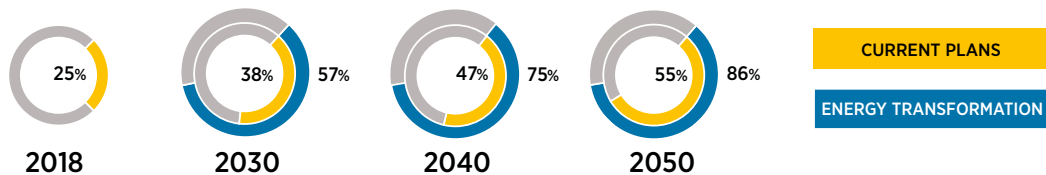
Current Plans: A scenario based on governments' current energy plans and other planned targets and policies, including climate commitments made since 2015 in Nationally Determined Contributions under the Paris Agreement.

Energy Transformation: A more climate-resilient course that entails a large-scale shift to renewable energy, electrification and ramped-up energy efficiency in the period to 2050 (see Figure 2). The power sector sees the wide-scale deployment of renewables, enabled by increasingly flexible power systems that support the integration of variable renewable energy (VRE), and is spurred by sector coupling via electrification. In this pathway, the share of renewables in the power sector increases from 24% today to 86% in 2050 (IRENA, 2019a). The *Global Renewables Outlook* (IRENA, 2020) calls this the "Transforming Energy Scenario".

**Figure 2: Share of renewables in total primary energy supply;
Current Plans and Energy Transformation scenarios, 2016 and 2050**



Renewable energy share in power generation

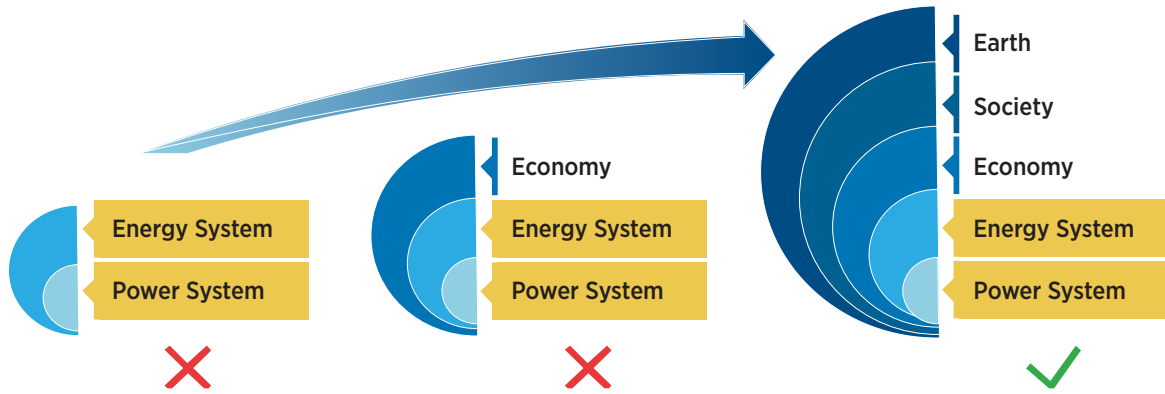


A large-scale shift to renewable energy, electrification and ramped-up energy efficiency is prompting a profound restructuring of the energy system; but for the transition to succeed, policies must be based on a more integrated assessment of the interactions between the evolving energy sector and wider economic and social systems. In an age that requires urgent climate and sustainability action, these

interlinkages extend to the many ways in which human economic activity relates to the planet's natural systems. **Figure 3** illustrates the different dimensions of a more holistic approach. Ultimately, the energy transition cannot be considered in isolation from the broader socio-economic system; in fact, changes in the energy system have profound impacts throughout the economy and society.



Figure 3: The embedded nature of the energy system.



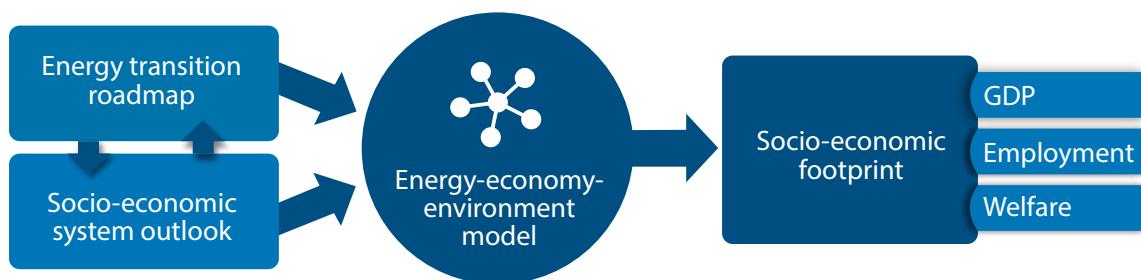
Source: IRENA, 2019

The chances of successfully implementing an energy transition roadmap, and its ultimate implications, both depend on the multiple interactions between the energy and socio-economic systems. Insights on the outcomes of these interactions are necessary to support policy making to enable and facilitate the transition. IRENA's socio-economic footprint analysis provides a comprehensive view of the transition process, capturing the interactions between the

different systems during the transition. It uses integrated models and indicators to measure the likely impacts on gross domestic product (GDP), employment and human welfare (see Figure 4).

Analysis of the drivers and dynamics affecting these outcomes provide valuable insights into how the overall transition process can be shaped to maximise benefits and reduce the costs of adjustment.

Figure 4: The energy transition and its socio-economic footprint.



Note: GDP = gross domestic product.

Source: IRENA, 2018a.

Studies of socio-economic impacts have typically focused either at the global level (e.g. IRENA, 2016a, 2017a, 2018a, 2019b and 2019c) or non-integrated national level.^{2,3} In contrast, very little attention has been paid to understanding regional and integrated country level impacts. IRENA's socio-economic analyses have revealed very important differences between global and regional or country-level socio-economic footprint results (IRENA, 2018a, 2019b, 2019c). However, additional detail at regional/country level is needed to gain insight on the drivers of these different outcomes and to inform policies that enable different regions/countries to reap the potential benefits from the transition.

Such regional/country level integrated assessments can highlight similarities in the challenges and capabilities among neighbouring countries, with potential advantages for collaborative deployment decisions and market creation efforts. Furthermore, lessons may emerge from similarities and differences between the institutional set-ups chosen in a given region, and with regard to comparable socio-economic structures. Such parallels allow for sharing knowledge more readily, enabling learning of policy relevance and effectiveness, and improving understanding of socio-economic impacts.

This study, therefore, aims to fill the gap by assessing the regional employment impacts of the energy transition using an integrated global macro-econometric model that links the world's energy, environment and economy in a single quantitative framework with high regional and sectorial resolution.

SECTION 2

of this report presents the global results in terms of renewable energy jobs, energy sector jobs and economy-wide employment.

SECTION 3

provides a high-level description of the regional distribution of renewable energy jobs, energy sector jobs and economy-wide jobs for ten regions encompassing the whole world. A special "in focus" segment offers a breakdown of job findings for five renewable energy technologies along different segments of the value chain and for major occupational groups.

SECTION 4

presents detailed jobs footprint results (renewables, energy sector and economy-wide) for selected economic and regional groupings and countries



SECTION 5

discusses a holistic policy framework for addressing the identified challenges and incorporating the just transition dimension. It first discusses the structural realities of many economies that governments should study closely as they formulate transition policies. It also considers potential misalignments that may emerge in the labour market during the energy transition; and proposes the contours of a comprehensive policy framework capable of addressing the challenges and capturing the opportunities that the transition offers.

ANNEX 1 discusses some methodological elements adopted for the modelling and assessment of jobs impacts.⁴

² See, for example, Hillebrand et al. (2006) and Lehr et al. (2012) for Germany; Wei et al. (2010) for the US; de Arce et al. (2012) for Morocco; and IASS et al. (2019a and 2019b) for India and South Africa.
³ 'Non-integrated national level' makes reference to those socio-economic impact analyses performed at national level without capturing the interactions with other countries and the global economic system.
⁴ Additional details on the methodology can be found in (IRENA, 2016).



2 Global Employment Results

Additional jobs in 2050 (in million)



The importance of the energy transition reaches well beyond the energy sector itself, given the numerous interlinkages and synergies with the broader world economy. Although the energy industry itself represents a small share of global GDP and employment, energy use is essential for the economy's functioning and the energy industry relies on a range of inputs from various other sectors.

Transforming the energy sector will therefore have effects both within the sector and in other parts of the economy. While the overall employment outcomes of the energy transition are positive at the global level (gains in renewable energy, energy efficiency, energy flexibility and grid upgrades outweigh losses in the fossil fuel industries), they are not uniformly positive across regions and countries.

IRENA has thus adopted an integrated macro-econometric approach to better understand the impacts. Comparisons in this report are between two scenarios, one based on Current Plans and the other on Energy Transformation. The latter will expand the economy by 2.5% over the former in 2050 and create many jobs in the process. This is underpinned by three main drivers: changes in investment; changes in trade flows and patterns; and both indirect and induced effects, including those triggered by fiscal policy changes (IRENA, 2019a).

This section briefly outlines the main global results of the analysis for the jobs footprint of the Energy transition, presenting the evolution of jobs in renewables, in the energy sector and economy-wide. Sections 3 and 4 subsequently apply this analysis at the regional level.





Total jobs in 2050 (in million)

100
Energy sector

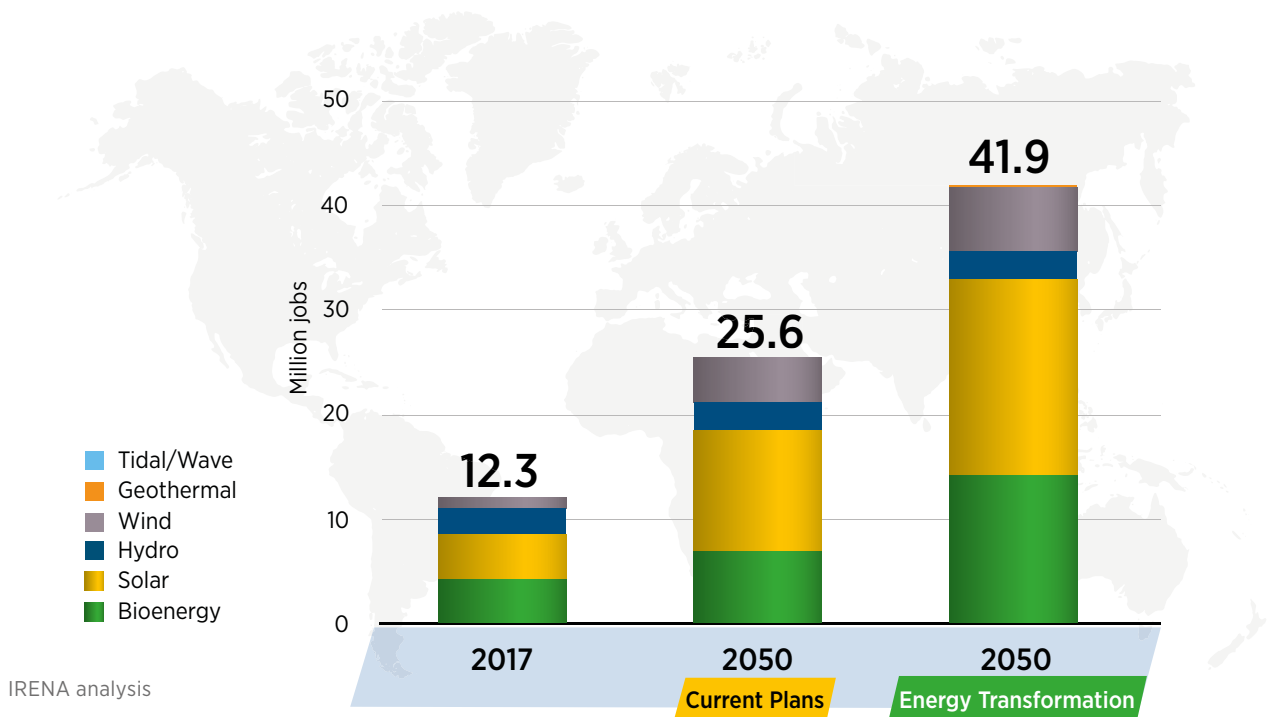
42
Renewable energy sector

2.1 Renewable energy and energy sector jobs

Energy Transformation results in total renewable energy employment of 42 million jobs by 2050, up from about 12 million in 2017 – considerably more than the roughly 26 million expected under Current Plans (Figure 5). The solar workforce will be the sector’s largest, at close to 19 million, enjoying an expansion of 63% over that expected under Current Plans, followed by bioenergy (14 million) and wind (6 million).

Hydropower sees moderate growth of 7% compared to Current Plans, employing under 3 million people. Other renewable technologies are far less prominent but will also expand; jobs in the geothermal energy industry, for example, will increase by almost 60% by 2050 compared to the Current Plans figure (see Table 1). In 2050 overall, Energy Transformation will generate 16 million jobs more than Current Plans in the renewable energy sector.

Figure 5. Global jobs in renewable energy (2017 and 2050)





Energy Transformation results in a total energy sector employment of 100 million jobs by 2050, up from about 58 million today. **Figure 6** shows how jobs in nuclear power, fossil fuels, renewables, energy efficiency, and energy flexibility and grid upgrades stack up at present, and how they will fare in 2050 in both the Current Plans and Energy Transformation scenarios.

Compared to Current Plans, some 8.2 million and 0.3 million of fossil fuel and nuclear jobs, respectively, fall by the wayside with Energy Transformation. Energy efficiency jobs will increase by 21% relative to Current Plans to reach 21 million, while renewables will witness the biggest growth of 64%, reaching 42 million in 2050 (see **Table 1**). Overall, in 2050 the energy sector gains 13 million more jobs with Energy Transformation compared to Current Plans.

Figure 6: Global jobs in the energy sector (2017 and 2050)

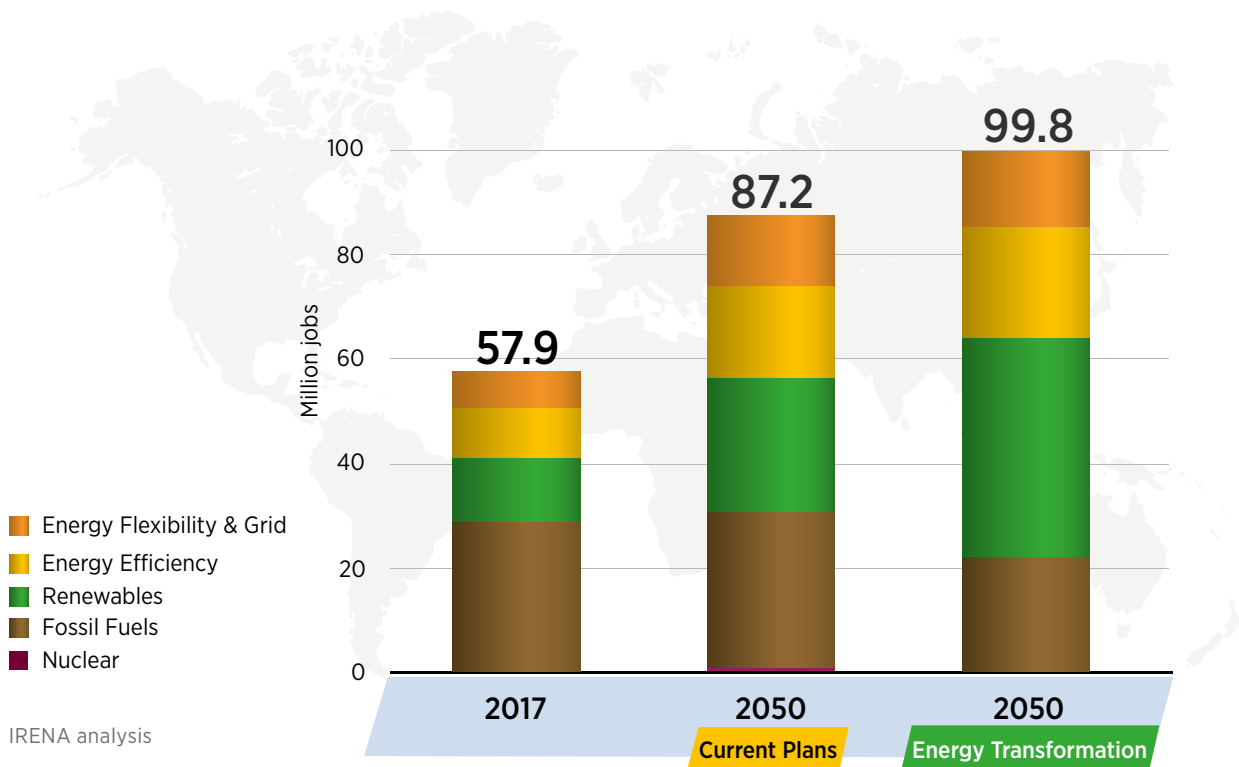




Table 1: Global renewables and energy sector jobs in 2050 with Energy Transformation

Energy Transformation in 2050		
	Million jobs	Increment from Current Plans
Renewables	41.9	64%
Solar	18.7	63%
Bioenergy	14.1	101%
Wind	6.1	39%
Energy sector	99.8	14%
Renewables	41.9	64%
Energy Efficiency	21.3	21%
Energy Flexibility & Grid	14.5	8%
Fossil Fuels	21.7	-27%
Nuclear	0.4	-42%

2.2 Economy-wide jobs

Across the global economy, employment grows slightly faster in the Energy Transition than under Current Plans, with a net positive difference of 0.16% higher employment by 2050. This percentage change may appear marginal but must be seen in context: the energy industry accounts for a relatively small share of the global economy (about 3% of employment and GDP). Thus, the percentage is fairly significant and, indeed, the energy sector's transition translates into a net gain of 7 million additional jobs.

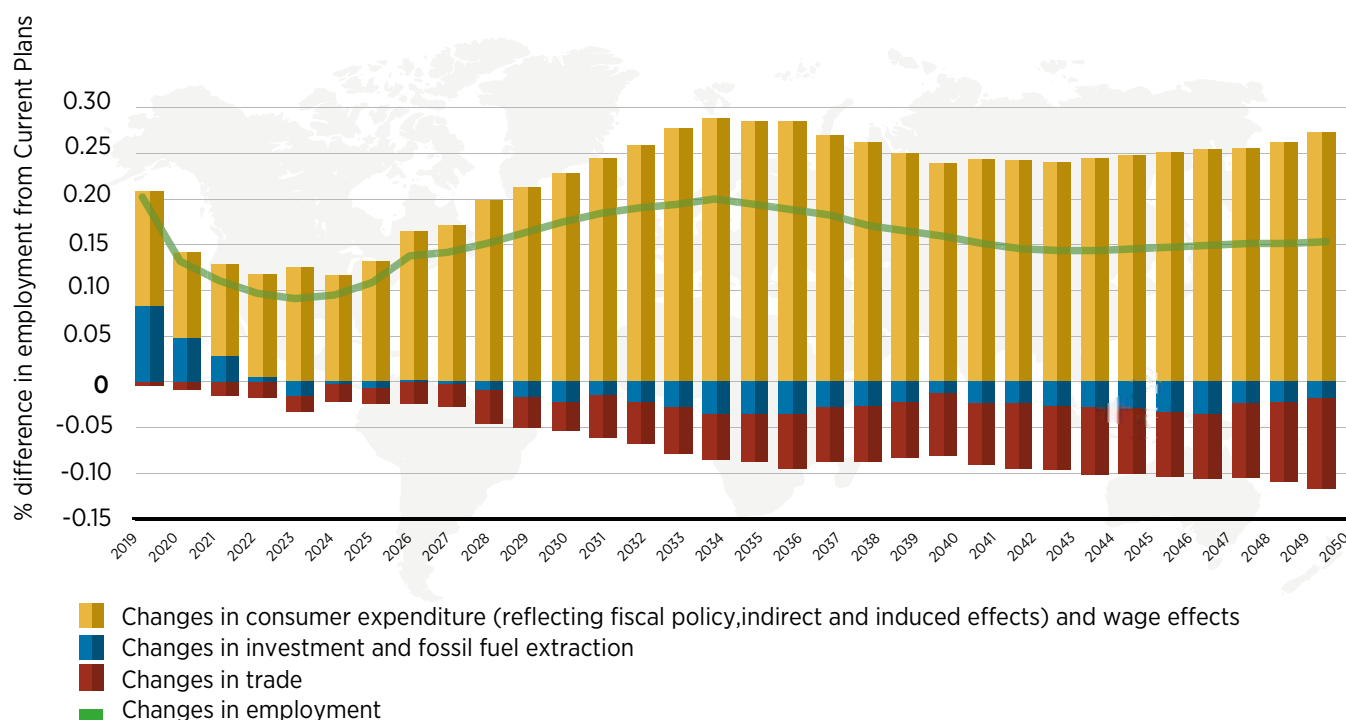
Figure 7 shows how this change unfolds in the period between 2019 and 2050 and indicates the broad change and dynamics that take place as a result of the different drivers (see the Annex for a description of drivers). The investment driver has a positive effect on jobs in the short run.

This is due to front-loaded investment in the Energy Transition and the decreasing relative weight of such investment as the economy grows. In the medium- to long-term, the negative effect of the investment driver is due to the crowding out of other sectors of the economy with higher employment intensities.⁵

The consumer spending driver dominates the impact on global employment. Fiscal policy changes and associated revenue recycling can result in lower income tax, higher disposable incomes and ultimately higher consumer spending. The trade driver has a negative impact on the employment footprint indicator, initially because of changes in net trade in fuels, but after 2035 by changes in non-energy trade.

⁵ A 50% crowding-out effect has been assumed for this analysis, whereby the additional investment required for the energy transition drains investment from other sectors.

Figure 7: Percentage difference in global employment between Energy Transformation and Current Plans, 2019–2050



As a summary of global jobs, **Table 2** presents the CAGR⁶ of renewable, energy sector and economy-wide jobs under Energy Transformation from 2017 to 2050, as well as the increments of jobs in 2050 from Current Plans. The different evolution of jobs in renewable energy, the energy sector and economy-wide reveals sectoral job misalignments (**Figure 8**). The higher increase in jobs in renewable energy than in the energy sector as a whole is a consequence of the jobs being lost mainly in fossil fuels.

The lower increase in economy-wide jobs compared to those in the energy sector indicates a loss of jobs in other economic sectors outside the energy sector. The sectoral job misalignments present a strong regional and country-level dependence, both in qualitative and quantitative terms (see section 4). Just transition policies are needed to properly address these misalignments and prevent them from becoming transition barriers (see section 5).

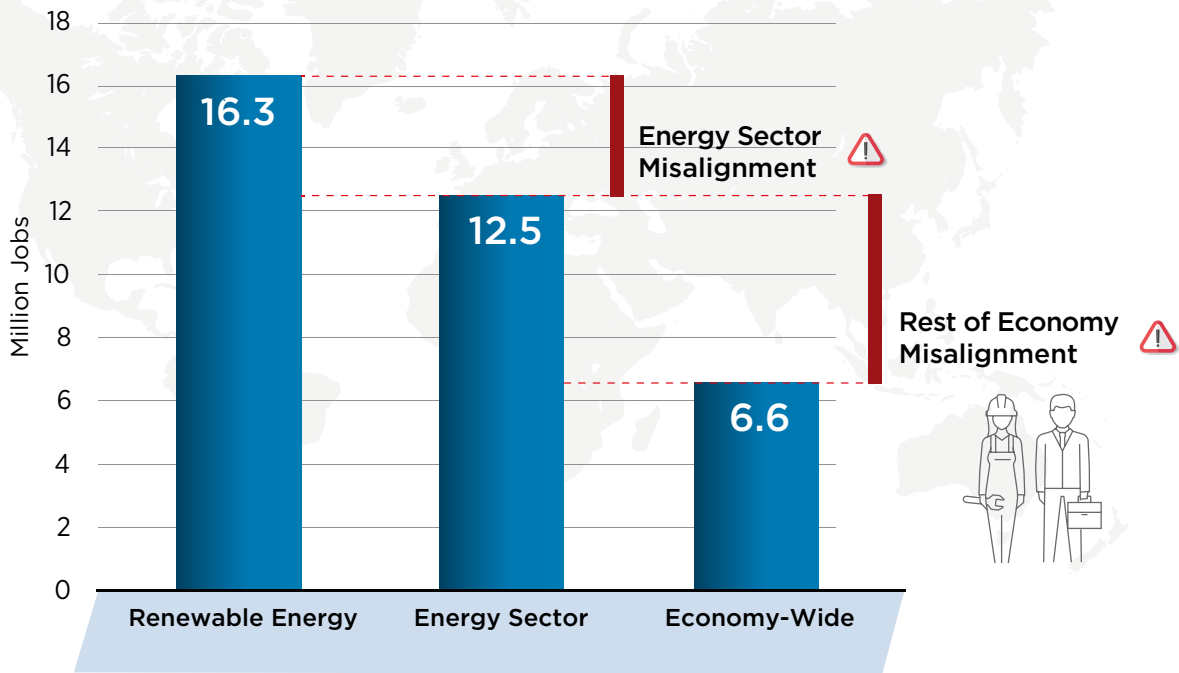
Table 2: Global CAGRs for jobs in renewables, energy sector and economy-wide with Energy Transformation and increment of jobs compared to Current Plans for 2050

	Energy Transformation	Increment of jobs in 2050 from Current Plans	
	CAGR (2017 to 2050)	Million jobs	Percentage
Renewables	3.8%	16.3	63.8%
Energy sector	1.7%	12.5	14.4%
Economy-wide	0.5%	6.6	0.2%

⁶ CAGR = compound annual growth rate. CAGR is a measure of growth over a period (here from 2017 to 2050), and it can be thought of as the constant annual growth rate needed to move from the initial to the final value over that period.



Figure 8: Job misalignments: Increment of global jobs from Current Plans to Energy Transformation in 2050



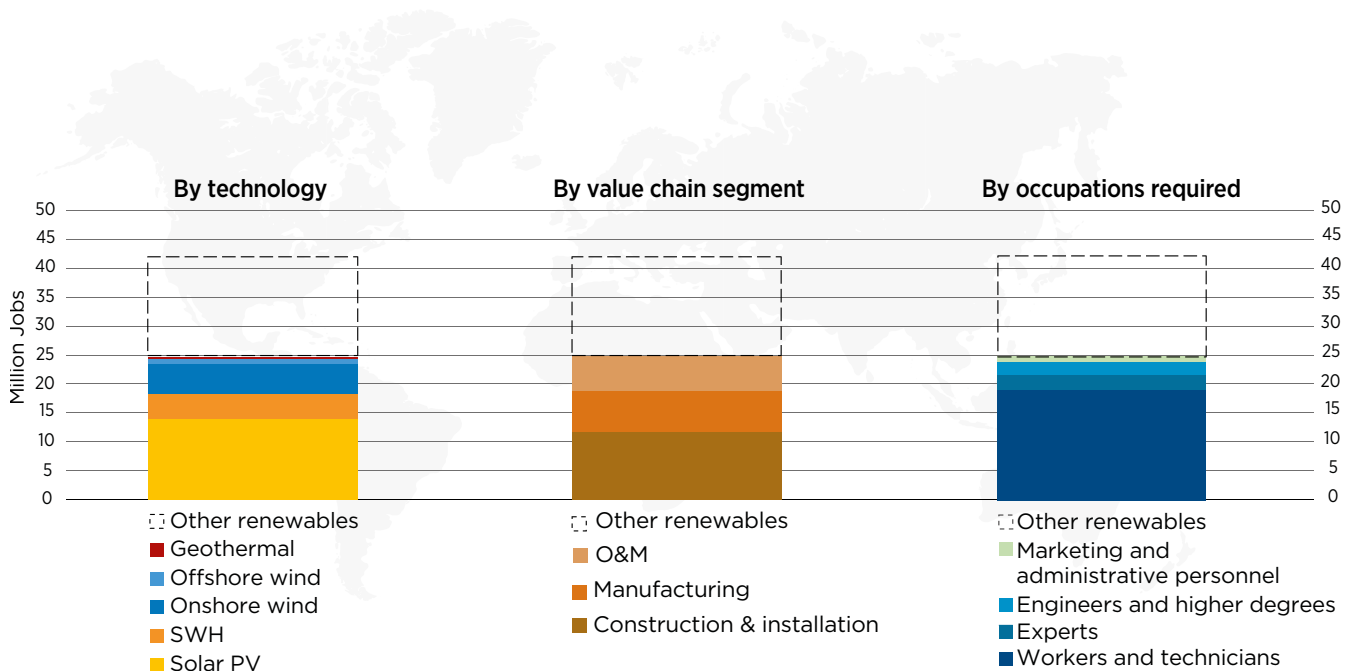
IN FOCUS:

Regional value chains and occupational groups

In addition to the sectoral job findings, IRENA has analysed the jobs impacts of the Energy Transition in a more detailed manner by looking at segments of the value chain and assessing major occupational groups. In large part, this work builds upon insights from IRENA’s Leveraging local capacity report series (IRENA, 2017b, 2017c, 2018b and 2020 [forthcoming]). This section focuses on a subset of five renewable energy technologies– solar PV, onshore and offshore wind, solar water heating and geothermal energy.⁷

Figure 9 shows the results of applying findings from the leveraging local capacity reports to the global modelling results for the year 2050. The first column from the left presents the structure of jobs by renewable technology. The column in the middle groups jobs into key value chain segments, underlining the numerical importance of jobs in construction and installation of projects. The column on the right features major occupational groups, showing that the vast majority of jobs falls into the category of ‘workers and technicians’.

Figure 9: Global employment with Energy Transformation (2050) disaggregated by technology, value-chain segment and occupation for selected technologies



The empty dashed bar shows the balance of total renewable energy jobs (bioenergy, hydro, CSP and tidal/wave).
Source: IRENA analysis

⁷ This subset of technologies is that for which there is current availability of occupational groups data. The renewable technologies outside this subset are: bioenergy, hydro, CSP and tidal/wave. IRENA’s Leveraging Local Capacity workstream aims at filling these knowledge gaps.



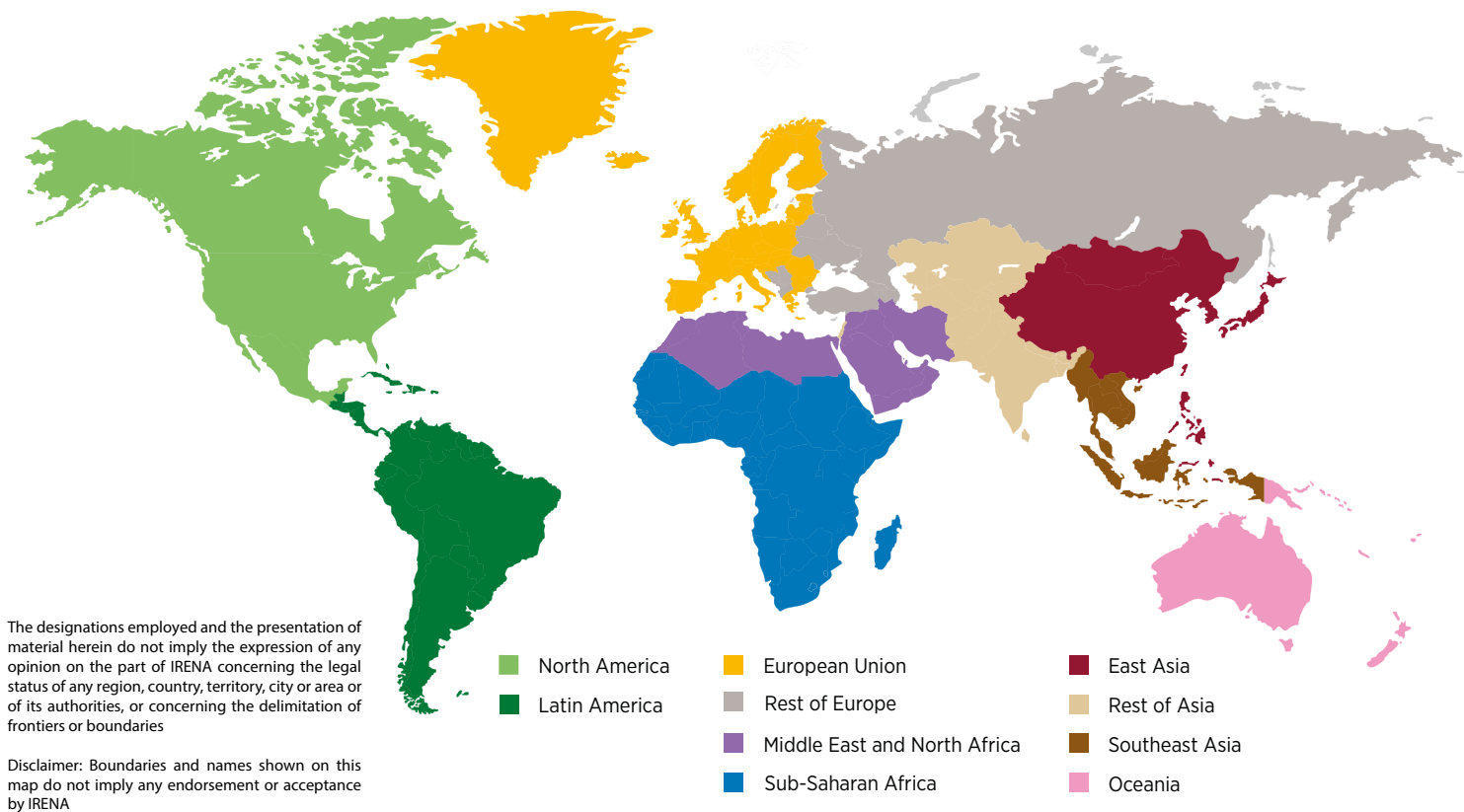
3 Regional Employment Results

The socio-economic footprint of the Energy Transition in any given country or region will vary from the global footprint, owing to a broad range of factors including the volume of investments, the diversity of fundamental socio-economic structures, policies in place and under development, and the complex dynamics and interactions unleashed by the energy transition.

To provide a high-level picture of how the global jobs discussed in Section 2 are distributed across the world, this section presents the world distribution of jobs across ten regions (see Figure 10), for renewable energy, the energy sector and economy-wide.

Further details for specific regions/countries are presented in Section 4.

Figure 10: Geographical definition of the ten world regions



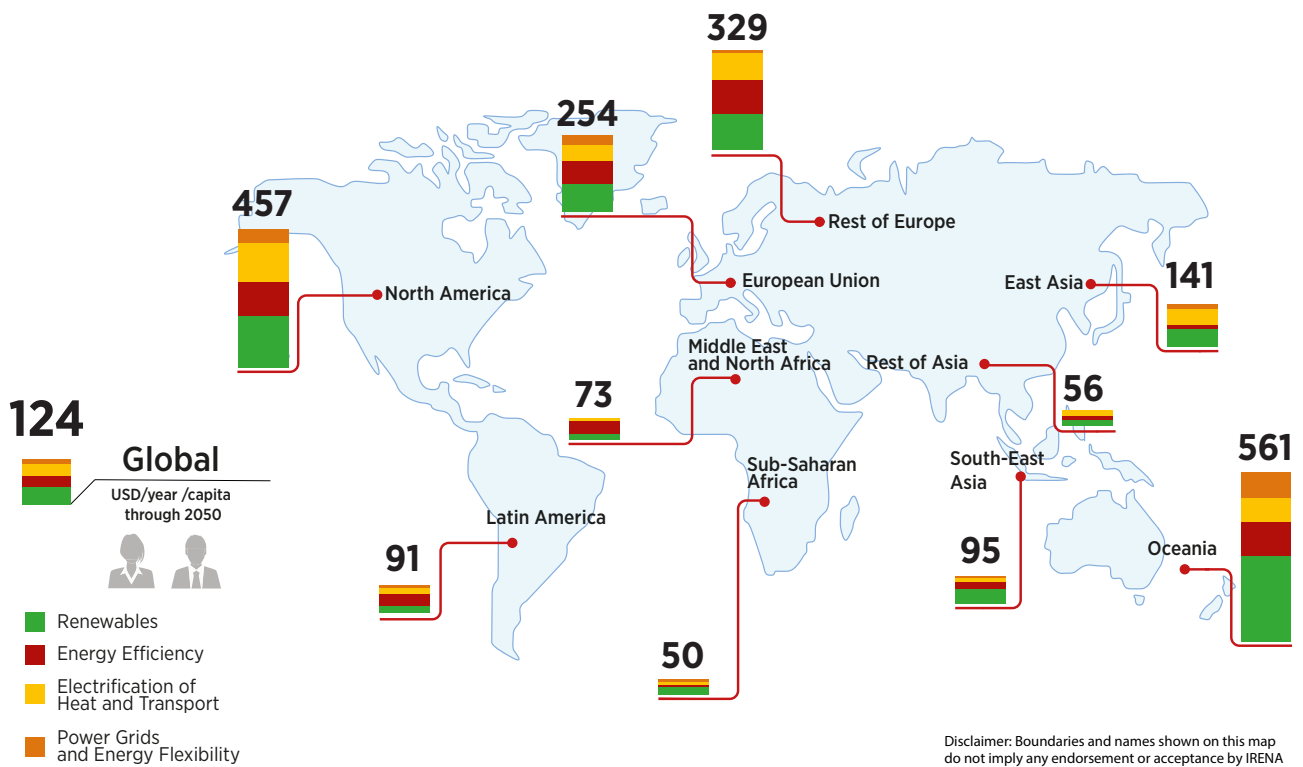


The transition's socio-economic footprint is driven by changes in investment, trade and consumer expenditure due to indirect and induced effects, with complex dynamics at play and strong feedback between these drivers. The total additional cumulative investment needed to move from Current Plans to the Energy Transition is USD 15 trillion between 2016 and 2050 (IRENA, 2019b).

Besides the amount to be invested, the way in which it is invested also impacts the socio-economic footprint.

In per capita and average annual terms, this required total additional investment is 55 USD per person per year over the period to 2050 and has an uneven distribution across the different regions (Figure 11).⁸ Notably, this figure presents the regional distribution of per capita additional clean energy investments. The global value (USD 124 /year/capita) is higher than the total additional investment (USD 55/year/capita) because of the reduction in fossil fuel investment in the energy transition.

Figure 11: Annual per capita additional clean energy investments with Energy Transformation by region through 2050; average population between 2016 and 2050



Source: IRENA analysis.

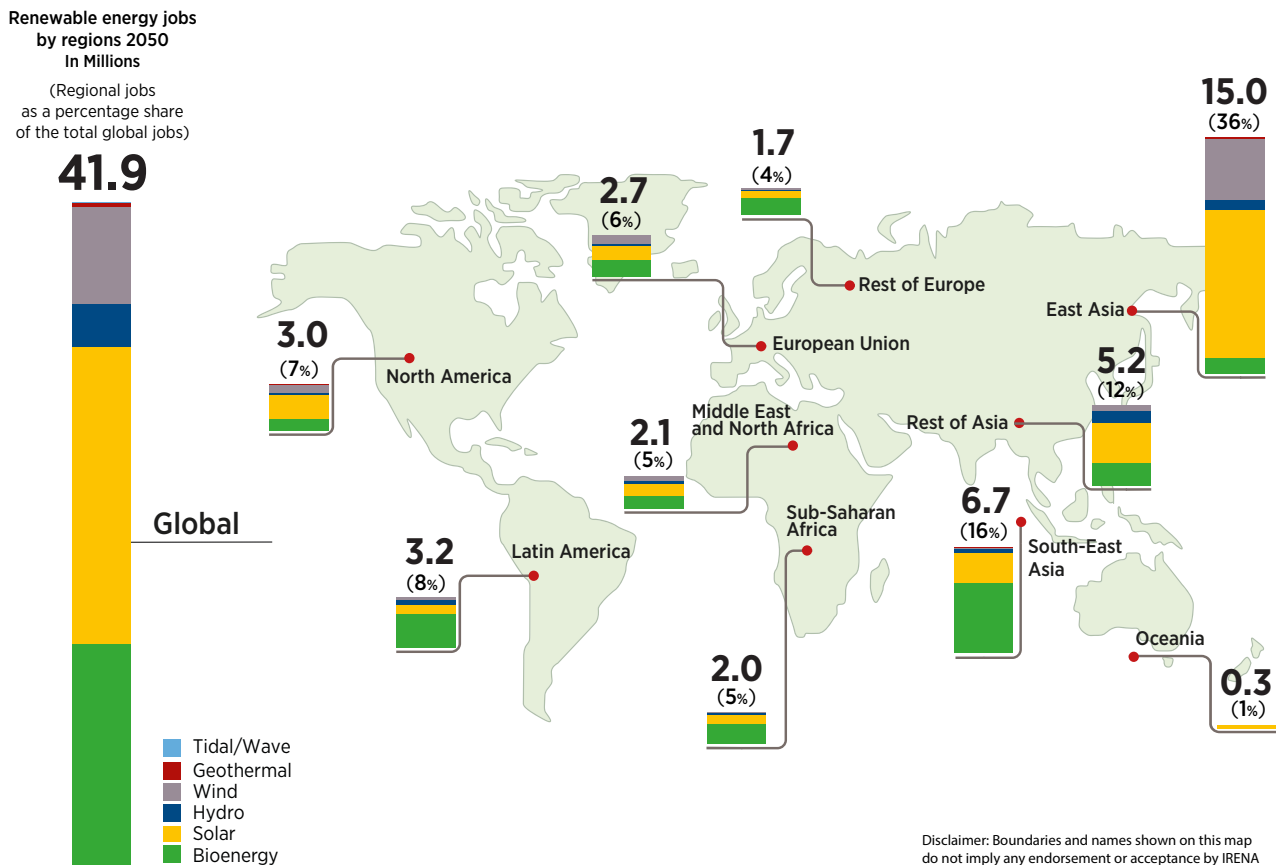
⁸ Considering the average population in the 2016–2050 period as per the socio-economic outlook from the E3ME macroeconomic model, which is aligned with the UN population prospects and with the SSP2 Shared Socio-economic Pathway (Samir and Lutz, 2017). The average world population over this period is 8 501 million. The average population has been used to factor in the inter-generational equity dimension.

3.1 Regional renewable energy and energy sector jobs

The Energy Transition will employ an estimated 42 million people globally in renewables by 2050, 16 million more than under Current Plans. The regional and technological distribution of jobs in the Energy Transition in 2050 is presented in Figure 12. Asia accounts for about 64% of global renewable energy jobs in 2050, the Americas for 15% and Europe for 10%.

Regarding the relative weight of the different renewable technologies, by 2050 for the Energy Transition, solar will account for over 50% of renewable energy jobs in Asia, 34% in the Americas and 30% in Europe. Bioenergy provides under 50% of the renewable energy jobs in America and Europe, and about 25% in Asia. Wind contributes above 15% of renewable energy jobs in Asia and Europe, a share that is reduced to around 10% in America.

Figure 12: Renewable energy jobs by region with Energy Transformation in 2050



Source: IRENA analysis.

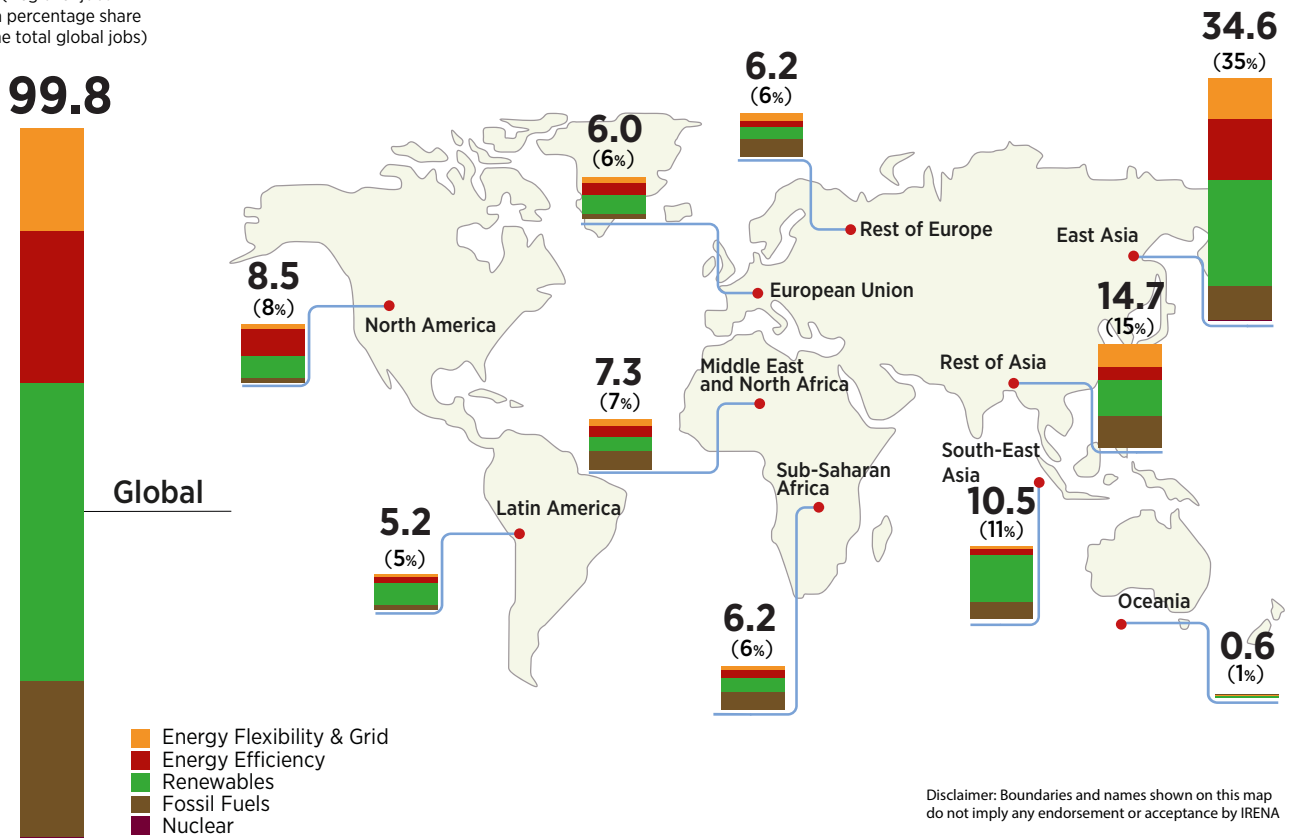


The Energy Transition is estimated to employ 100 million people globally in the energy sector by 2050 – 13 million more than under Current Plans. The regional and technological distribution of these jobs in 2050 is presented in Figure 13. Asia accounts for over 60% of the global energy sector jobs in 2050, America for 13% and Europe for 12%.

Regarding the relative weight of the different energy sector technologies, by 2050 in the Energy Transition, renewables account for about 45% of the energy sector jobs in Asia and the Americas and 36% in Europe. Energy efficiency provides 34% of the energy sector jobs in America, 22% in Europe and 19% in Asia. By 2050, under the Energy Transition, fossil fuels still contribute 26% of energy sector jobs in Europe, 19% in Asia and 11% in the Americas.

Figure 13: Energy sector jobs by region with Energy Transformation in 2050

**Energy Sectors 2050
Jobs In Millions**
(Regional jobs as a percentage share of the total global jobs)



Disclaimer: Boundaries and names shown on this map do not imply any endorsement or acceptance by IRENA

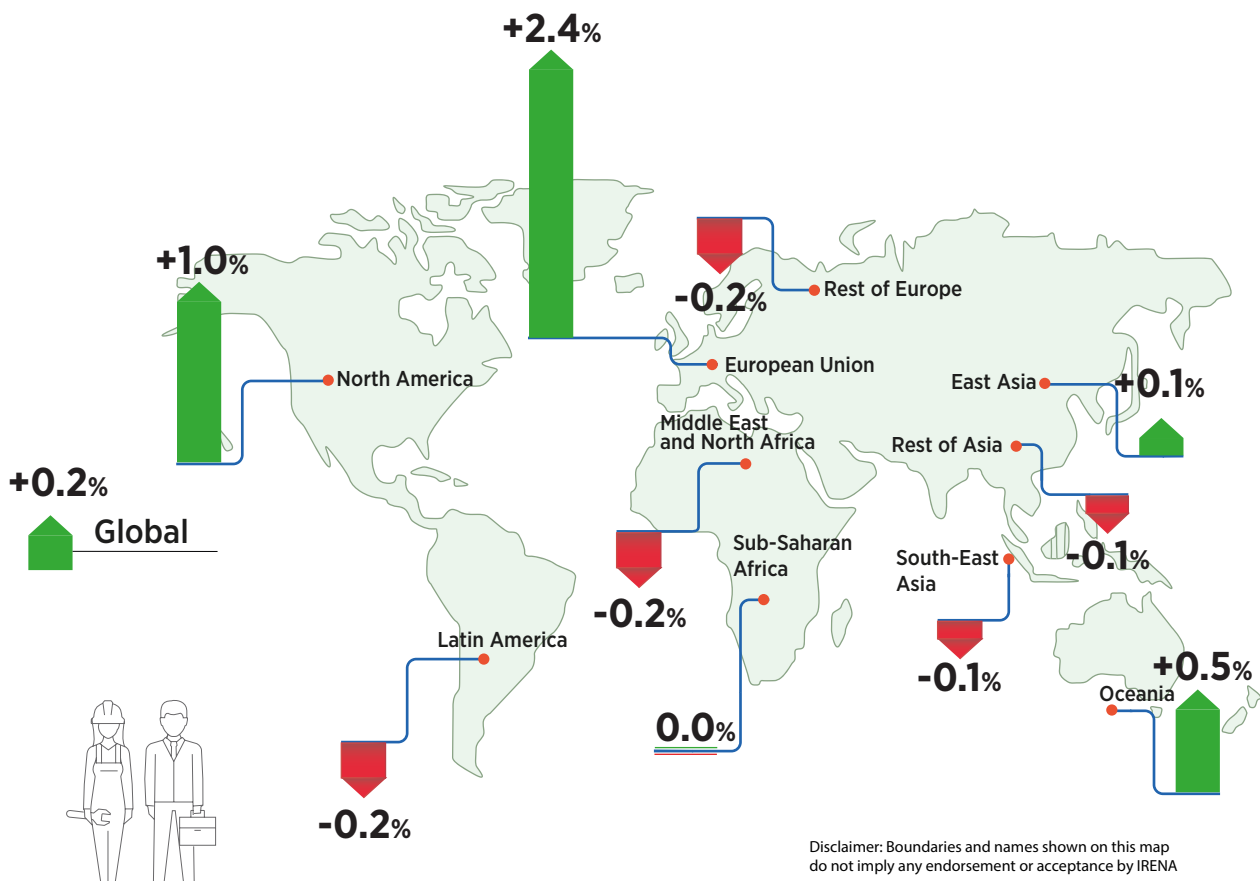
Source: IRENA analysis.

3.2 Regional economy-wide employment

The changes in economy-wide employment are unevenly distributed across geographies, as illustrated in **Figure 14**. Large gains in certain regions of the world contrast with negative or zero growth in over half of regions. These outcomes depend on the close interplay between different drivers, which is largely influenced by transition ambition, dependency

on fossil fuels, institutional and industrial fabric, and current socio-economic structures (and related supply chains). Therefore, a greater understanding of the role of drivers can provide insights on the impact of the Energy Transition on economy-wide jobs. Section 4 delves into the drivers of the economy-wide jobs footprint for different regions/countries.

Figure 14: Percentage difference in regional employment between Energy Transformation and Current Plans, 2050



Source: IRENA analysis.



4 Selected Economic, Regional and Country Analyses



Results from Section 3 show the significant regional spread of the socio-economic footprint of energy transition jobs, with some regions performing better than others, reinforcing the results from previous analyses for different regions, countries and country groupings (IRENA, 2018a, 2019b). The role played by socio-economic footprint drivers also presents a country-level dependency resulting from the combination of the existing socio-economic context and the ambitions of the energy transition.

To better understand the underlying dynamics of job creation in the energy transition, more granular analysis is required at the levels of geography and drivers. In this section, the socio-economic results for four countries/sub-regions are presented with a homogeneous format.⁹

Table 3 presents an overview of the jobs footprints for these regions.

Table 3: Overview of Energy Transformation jobs results for the countries/regions documented in this section.

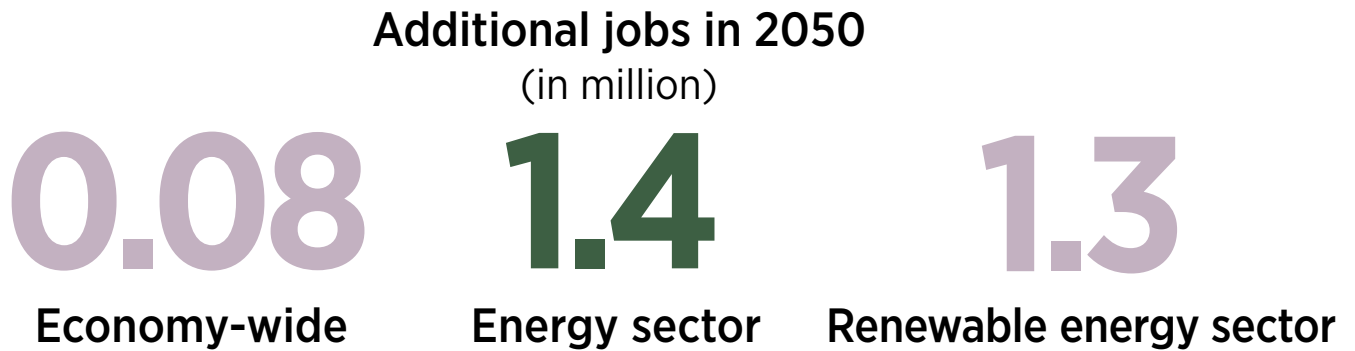
Country/Region	Increment from Current Plans in 2050 thousand jobs		
	Renewable	Energy	Economy-wide
African continent except South Africa and Africa OPEC	1224	1469	81
China	2249	783	184
Middle East OPEC	513	360	-189
Southern Europe	326	274	1650

⁹ The selected groupings aim to illustrate interactions between the different drivers, covering the spread of overall results and providing a reasonable geographic and economic coverage.



4.1 African continent

(except South Africa and Africa OPEC¹⁰)

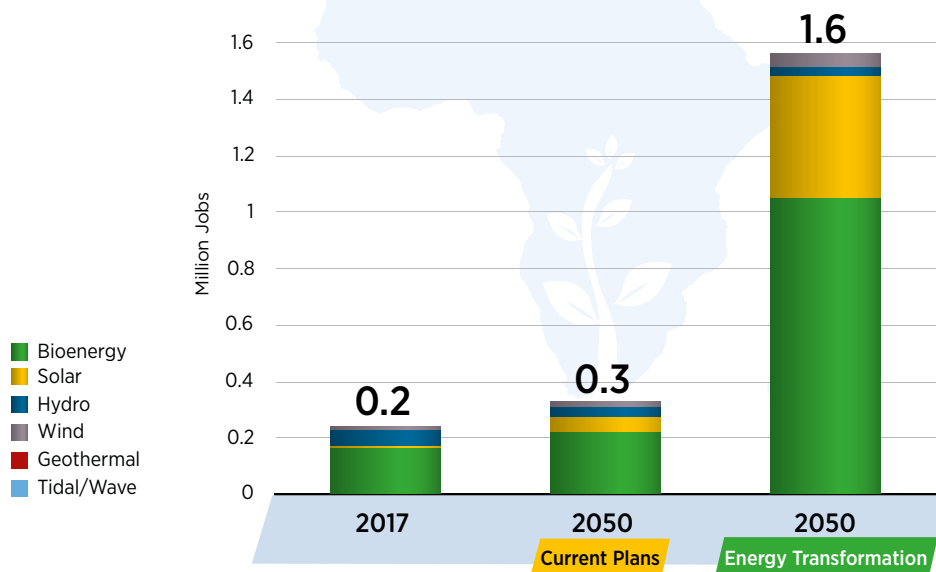


Jobs footprint: Renewables and the energy sector

The energy transition results in a total renewable energy employment of 1.6 million jobs by 2050 – up from about 0.2 million in 2017 and representing a 361% increase from the roughly 0.3 million expected under Current Plans (Figure 15). The bioenergy workforce will be the sector's largest, at close to 1.1 million, enjoying an expansion of 381% through pursuing Energy Transformation compared to Current Plans.

Bioenergy is followed by solar (0.4 million), which experiences the highest increase (698%). Wind also undergoes a significant expansion (96%) reaching 0.05 million jobs (see Table 4). Overall, in 2050, the Energy Transformation scenario foresees 1.2 million more renewable energy jobs than the Current Plans scenario does.

Figure 15: Renewable energy jobs (African continent except South Africa and Africa OPEC)



¹⁰ Africa OPEC: Algeria, Angola, Congo, Equatorial Guinea, Gabon, Libya and Nigeria

Energy Transformation results in a total energy sector employment of 3.8 million jobs by 2050, up from about 2.9 million today. **Figure 16** shows how jobs in nuclear power, fossil fuels, renewables, energy efficiency, and energy flexibility and grid upgrades stack up at present, and how they will fare in 2050 in both Current Plans and Energy Transformation. Compared to Current Plans, 0.2 million of fossil fuel jobs fall by the wayside in Energy Transformation. Energy efficiency jobs will increase by 38% relative to Current Plans to reach 0.7 million, while renewables will witness the biggest growth (361%), reaching 1.6 million in 2050 (see **Table 4**).

Overall, in 2050 the energy sector gains 1.5 million jobs with Energy Transformation compared to Current Plans. The reduction in energy sector jobs by 2050 experienced under Current Plans (**Figure 16**) is mainly driven by the historic trend of reducing fossil fuel exports in this region. The higher absolute increase in energy sector jobs (1.5 million) compared to renewable energy jobs (1.2 million) is a consequence of the lost fossil fuels jobs being compensated for by increases in jobs in energy efficiency, energy flexibility and grids (**Table 4**).

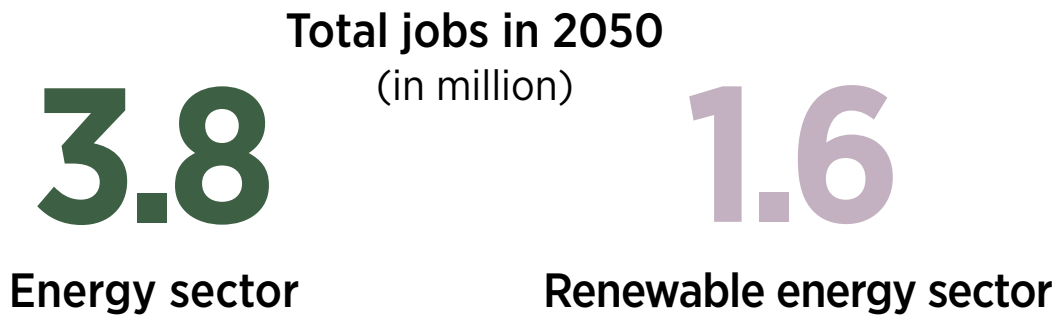


Figure 16: Energy sector jobs (African continent except South Africa and Africa OPEC)

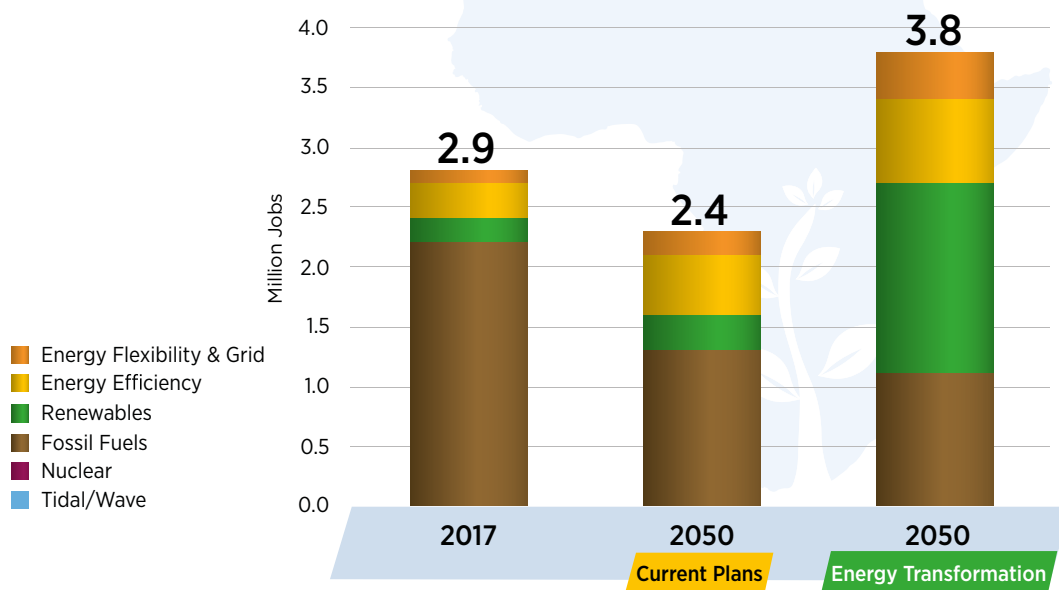




Table 4: Renewables and energy sector jobs in 2050 with Energy Transformation, African continent (except South Africa and Africa OPEC).

Energy Transformation in 2050		
	Thousand jobs	Increment from Current Plans
Renewables	1563	361%
Solar	426	698%
Bioenergy	1052	381%
Wind	48	96%
Energy sector	3822	63%
Renewables	1563	361%
Energy Efficiency	729	38%
Energy Flexibility & Grid	402	113%
Fossil Fuels	1128	-13%
Nuclear	0	-

Figure 17 quantifies the structure of a subset of renewable energy jobs in terms of segments of the value chain and occupational requirements in year 2050 with Energy Transformation.¹¹

Regarding jobs structure in terms of value chain, these results show that there is plenty of room to localise renewable energy jobs in such a way that the transition to renewables and energy efficiency reinforces domestic supply chains. Indeed, manufacturing, which is the segment of the value chain most difficult to localise¹², accounts only for 19% of the jobs in the subset of renewable energy technologies included in this figure, while construction and installation account for 60% of the jobs and O&M for 21%.

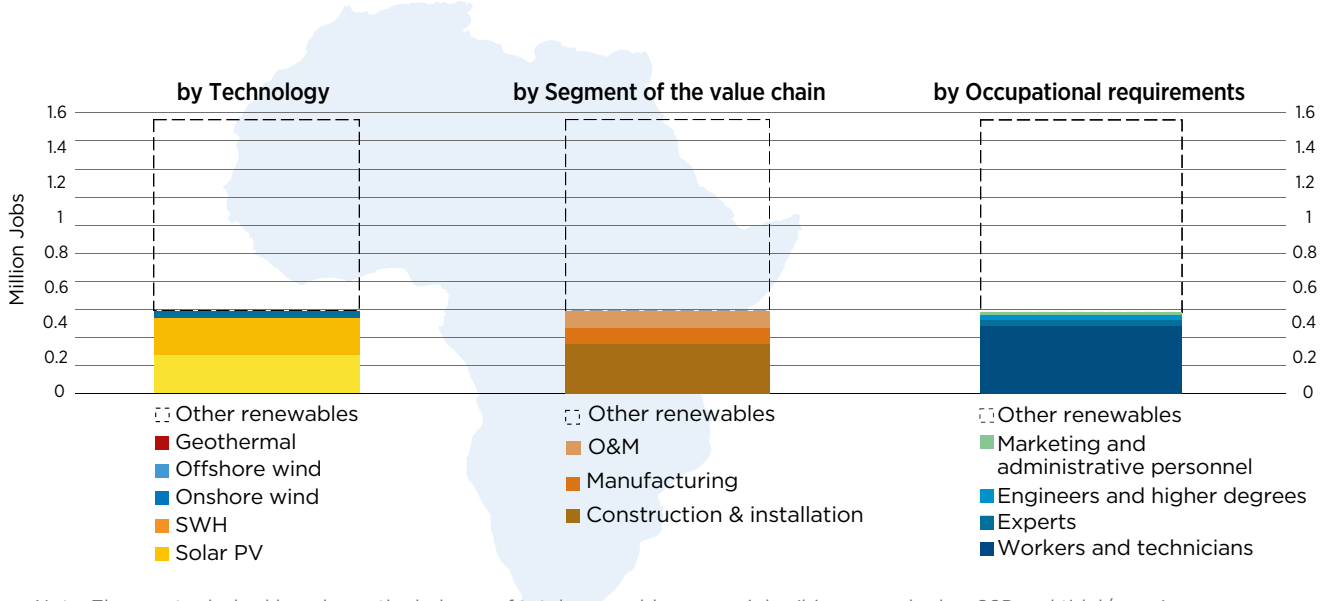
In fact, considering the complete set of renewable technologies, including biomass (which has a large share of jobs required for the production of biomass and biofuels), reduces the weight of the manufacturing jobs segment of the value chain to 7%, with the other more easily localised segments of the value chain accounting for 65% (biomass supply), 19% (construction and installation) and 9% (O&M).

Regarding jobs structure in terms of skills, 83% of the jobs associated with the presented subset of renewable energy technologies corresponds to workers and technicians, while experts are 8%, engineers and other high degrees 7%, and marketing and administrative personnel 2%.

¹¹ The subset of renewable energy technologies used in this figure (PV, wind onshore, wind offshore, solar water heaters and geothermal) is determined by the availability of leveraging information in terms of occupational requirements. Most of this information comes from IRENA's leveraging reports series; as additional technologies are covered in forthcoming reports the analysis will be extended to include more technologies.

¹² Although for renewable energy technologies, localisation of manufacturing is significantly simpler than for fossil fuel or nuclear technologies.

Figure 17: Employment in the African Continent (Except South Africa and Africa OPEC) with Energy Transformation (2050) disaggregated by technology, value-chain segment and occupation for selected technologies



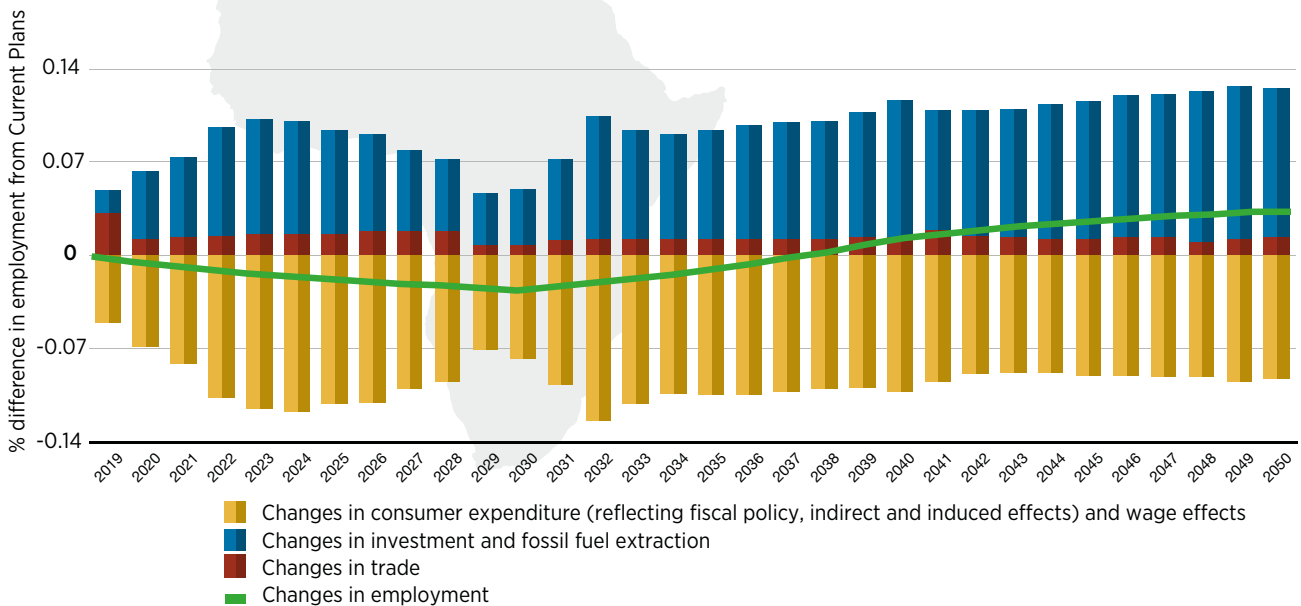
Note: The empty dashed bar shows the balance of total renewable energy jobs (bioenergy, hydro, CSP and tidal/wave).
Source: IRENA analysis

Jobs footprint: Economy-wide

Economy-wide employment can be seen to increase both under Current Plans and Energy Transformation, with an overall 13% increase in 2050 compared to 2017.

Figure 18 may help to see – in terms of the relative performance of Energy Transformation versus Current Plans – the economy-wide jobs footprint and the role played by the different drivers.

Figure 18: Economy-wide employment (African continent except South Africa and Africa OPEC)





The relative evolution of jobs in the economy is almost neutral throughout the period, being slightly negative in the first half of the analysed period and slightly positive in the second half.

The **investment driver** is the main positive contributor to job creation throughout the energy transition. Energy efficiency investment dominates the positive employment impacts, with an initial spike due to front loaded energy efficiency investment. Power sector investment has a negative impact on jobs up to 2030, when it becomes positive thanks to the increase in the ambition of the energy transition in terms of renewables deployment.

Electricity generation also contributes positively to employment after 2030, with an increasing relevance associated with the deployment of grid infrastructure and flexibility capacity.

The impact on job creation from investment in other economic sectors is negative throughout the whole period. While this tends to undermine the positive job impact from the energy sector and reflecting the fact that, in this region, crowding out in other economic sectors is not compensated for by increased economic activity, partly due to the weakness of domestic supply chains.

The **trade driver** has a positive but small impact on the evolution of the job's footprint, mainly due to jobs associated with non-energy trade.

The **indirect and induced effects driver** has an important overall negative impact on jobs, balancing out the positive impacts from the investment and trade drivers. This includes positive but small contributions from consumer expenditure and wage effects in non-energy sectors, and a strong negative impact from dynamic effects attributable to lagged responses in the labour market.¹³

Several insights can be obtained from the analysis of the jobs footprint.

- Increasing the energy transition ambition, especially for the power sector, could push jobs up.
- The negative impact on jobs from other economic sectors due to crowding out must be addressed to improve the jobs footprint. Three sets of complimentary policies could contribute to this purpose:
 - ① reinforcing domestic supply chains in the economy, besides facilitating higher benefits from energy transition-related investment, would allow to capture multiplied effects from economic growth by generating jobs in other sectors of the economy;
 - ② supporting public jobs creation in high-employment-intensity sectors that need to experience significant growth for improving welfare (education, health, care economy, etc.); and
 - ③ addressing the negative impacts of crowding out in this region through international climate finance, thereby sharing the benefits of updated fiscal policies in developed economies.
- Reinforcing domestic supply chains would also address the negative employment impacts due to sluggish responses from the labour market to the demand for jobs.

¹³ Dynamic effects are part of the induced driver considered for the jobs footprint, and in general terms they capture the effect of dynamic responses from the economy, like sluggish responses from the labour market to labour demand.

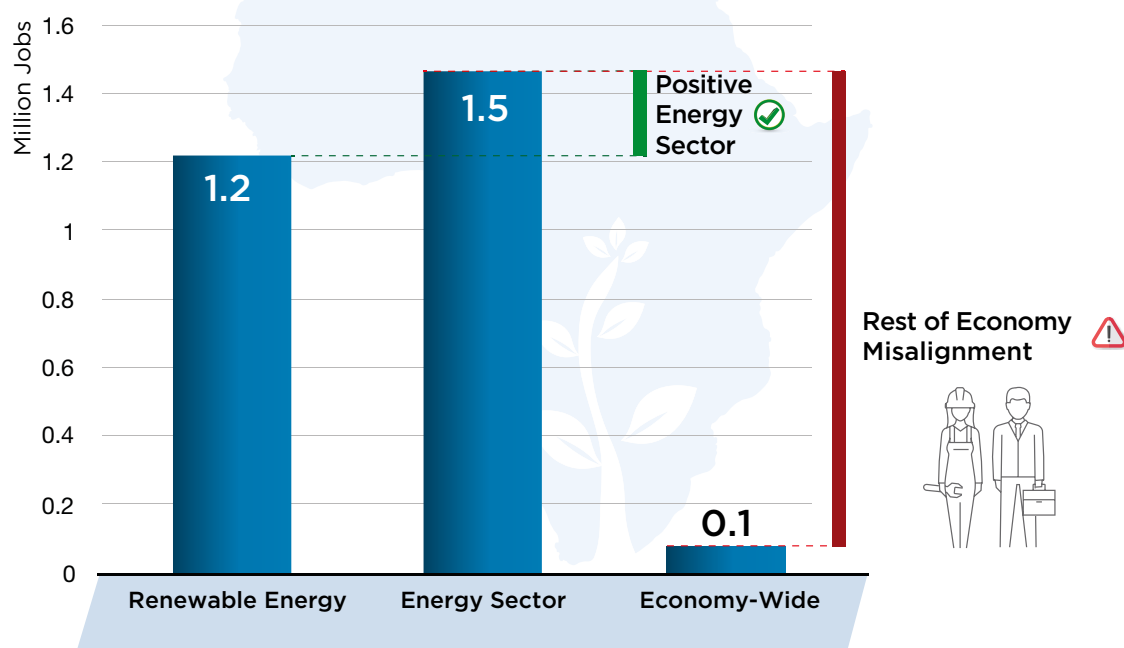
As a summary of the jobs footprint in this region, **Table 5** presents the CAGR¹⁴ of renewable, energy sector and economy-wide jobs under the energy transition from 2017 to 2050, as well as the increments of jobs in 2050 from Current Plans. The different evolution of jobs in renewable energy, the energy sector and economy-wide could produce sectoral job misalignments (**Figure 19**). For most of Africa, energy sector jobs increase more than renewable energy jobs.

This is thanks to energy efficiency and energy flexibility job increases compensating for the reduction in fossil fuel jobs; the lower increase of economy-wide jobs compared to those in the energy sector indicates a loss of jobs in other economic sectors outside the energy sector. Just transition policies are required to properly address these misalignments and to prevent them from becoming transition barriers (see Section 5).

Table 5: CAGRs for jobs in renewables, energy sector and economy-wide with Energy Transformation and increment of jobs compared to the Current Plans in 2050 (African continent except South Africa and Africa OPEC)

	Energy Transformation	Increment of jobs in 2050 from Current Plans	
	CAGR (2017 to 2050)	Thousand jobs	Percentage
Renewables	5.8%	1 224	361%
Energy sector	0.9%	1 470	63%
Economy-wide	0.4%	81	0.03%

Figure 19: Job misalignments: Increment of jobs between Current Plans and Energy Transformation in 2050 (African continent except South Africa and Africa OPEC)



¹⁴ CAGR = compound annual growth rate. CAGR is a measure of growth over a period (here from 2017 to 2050), and it can be thought of as the constant annual growth rate needed to move from the initial to the final value over that period.



4.2 China

Additional jobs in 2050 (in million)

0.2

Economy-wide

0.7

Energy sector

2.2

Renewable energy sector

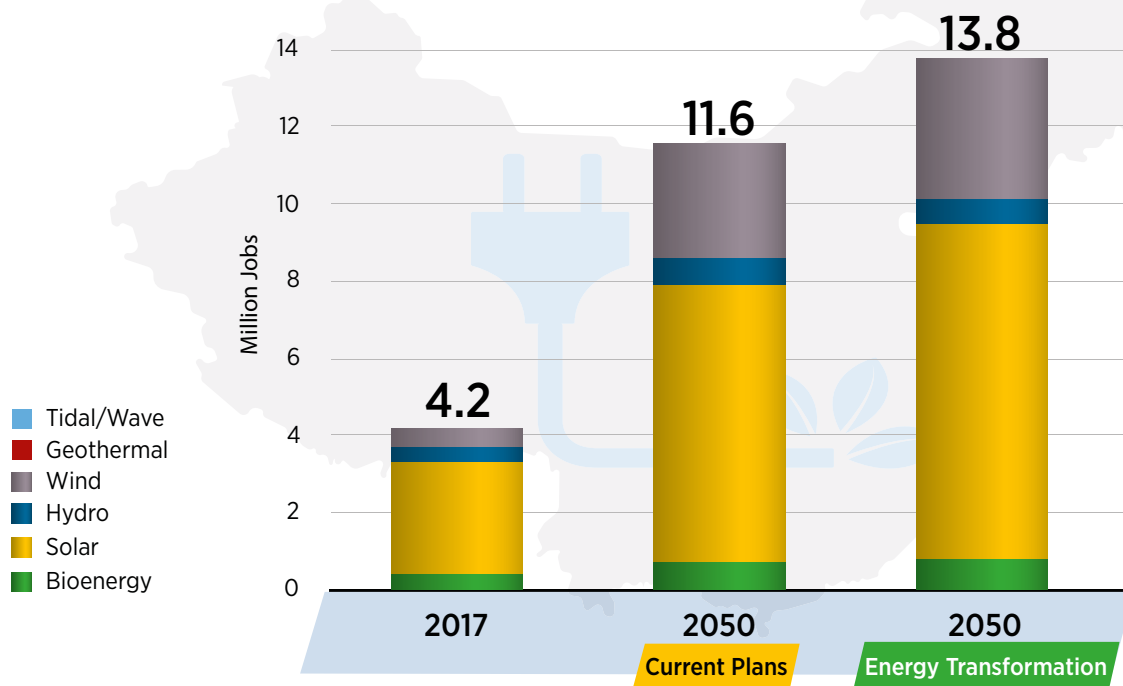
Jobs footprint: Renewables and energy sector

Energy Transformation results in a total renewable energy employment of 14 million jobs by 2050, up from about 4 million in 2017 – a 19% increase from the roughly 12 million expected under Current Plans (Figure 20). The solar workforce will be the sector's largest, at close to 9 million, enjoying an expansion of 20% compared to Current Plans.

Solar jobs are followed by wind (4 million), which experiences the highest increase (25%). Bioenergy undergoes a 9% expansion reaching 0.8 million jobs (see Table 6).

Overall, in 2050, Energy Transformation will create 2.2 million more renewable energy jobs than Current Plans would.

Figure 20: Renewable energy jobs, China



Energy Transformation results in total energy sector employment of 31 million jobs by 2050, up from about 17 million today. Growth in energy sector jobs is higher with Energy Transformation than Current Plans, offering 3% more jobs by 2050 (Table 6), with the decrease in fossil fuel jobs being smaller than the increase in energy transition-related jobs (renewables, energy efficiency and energy flexibility).

Figure 21 shows how jobs in nuclear power, fossil fuels, renewables, energy efficiency, and energy flexibility and grid upgrades stack up at present, and how they will fare in 2050 under both Current Plans and Energy Transformation.

Compared to Current Plans, 3 million fossil fuel jobs will fall by the wayside with Energy Transformation. Energy efficiency jobs will increase by 15% relative to Current Plans to reach 8 million, while renewables will witness the biggest growth (19%), reaching 14 million in 2050 (see Table 6).

Overall, in 2050 the energy sector gains 0.8 million jobs Energy Transformation compared to Current Plans. The lower increase in energy sector jobs (0.8 million) compared to renewable energy jobs (2.2 million) is a consequence of lost fossil fuels jobs (Table 6).

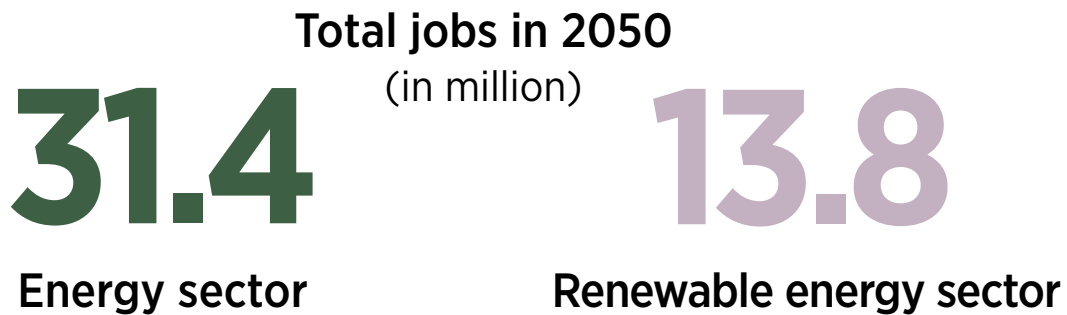


Figure 21: Energy sector jobs, China

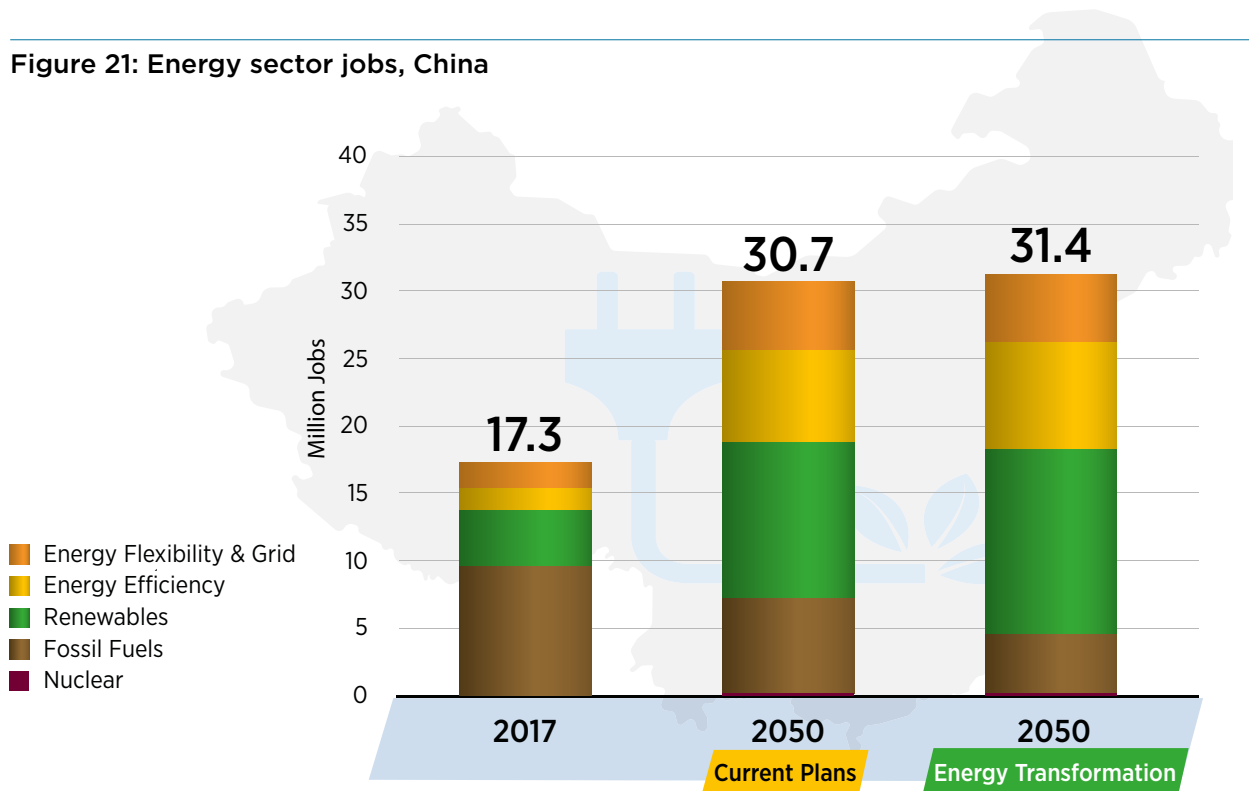




Table 6: Renewables and energy sector jobs in 2050 with Energy Transformation, China

Energy Transformation in 2050		
	Thousand jobs	Increment from Current Plans
Renewables	13 823	19%
Solar	8 677	20%
Bioenergy	769	9%
Wind	3 711	25%
Energy sector	31 382	3%
Renewables	13 823	19%
Energy Efficiency	7 910	15%
Energy Flexibility & Grid	5 147	5%
Fossil Fuels	4 341	-38%
Nuclear	161	-21%

Figure 22 quantifies the structure of a subset of renewable energy jobs in terms of segments of the value chain and occupational requirements in year 2050 for Energy Transformation.¹⁵

Regarding the jobs' structure in terms of the value chain, these results show that there is plenty of room to localise renewable energy jobs in such a way that the transition to renewables and energy efficiency contributes to the reinforcement of domestic supply chains. Indeed, manufacturing, which is the segment of the value chain most difficult to localise¹⁶, in the considered subset of renewable energy technologies, while construction and installation accounts for 44% of the jobs and O&M for 24%.

When the complete set of renewable technologies are considered, owing to the low dependence of the Chinese energy mix on biomass, the weight of the manufacturing segment of the value chain to the total amount of jobs remains almost unaltered (32%)¹⁷, with the other more easily localised segments of the value chain accounting for 4% (biomass supply), 41% (construction and installation) and 23% (O&M).

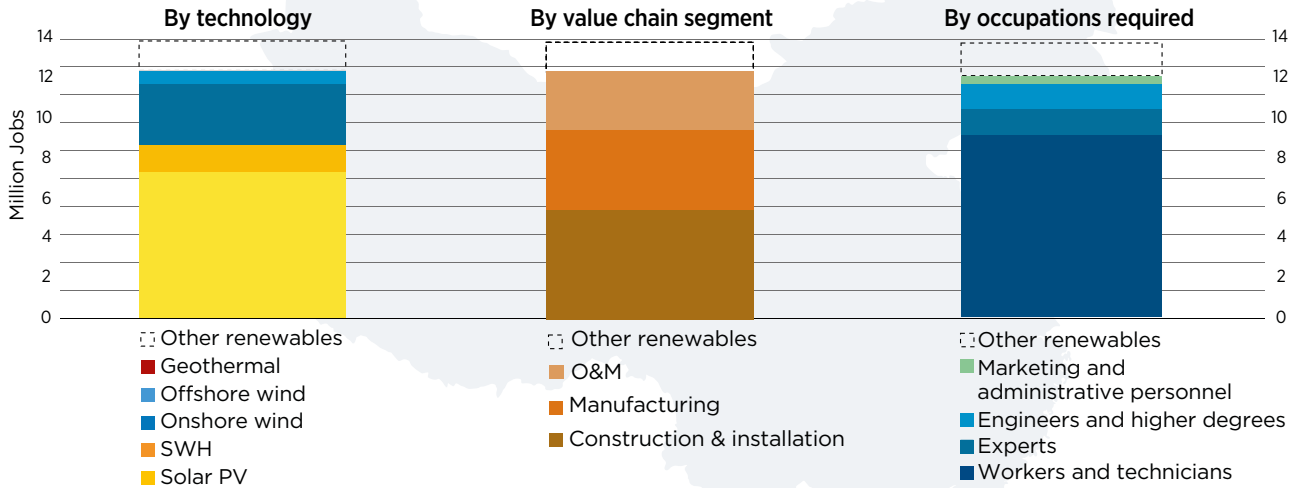
Regarding the jobs' structure in terms of skills, 75% of the jobs associated with this subset of renewable energy technologies corresponds to workers and technicians, while experts account for 11%, engineers and other high degrees for 10%, and marketing and administrative personnel for 4%.

¹⁵The subset of renewable energy technologies used in this figure (PV, wind onshore, wind offshore, SWH and geothermal) is determined by the availability of leveraging information in terms of occupational requirements. Most of this information comes from IRENA's leveraging reports series; as additional technologies are covered in forthcoming reports the analysis will be extended to include more technologies.

¹⁶Although for renewable energy technologies, localisation of the manufacture is significantly simpler than for the fossil fuel or nuclear technologies. In the case of China, domestic supply chains are able to localise manufacturing jobs, allowing the country to reap higher employment benefits

¹⁷The share of manufacturing jobs is 32.4% for the subset of renewable technologies and 31.6% for all renewable energy technologies.

Figure 22: Employment in China with Energy Transformation (2050) disaggregated by technology, value-chain segment and occupation for selected technologies



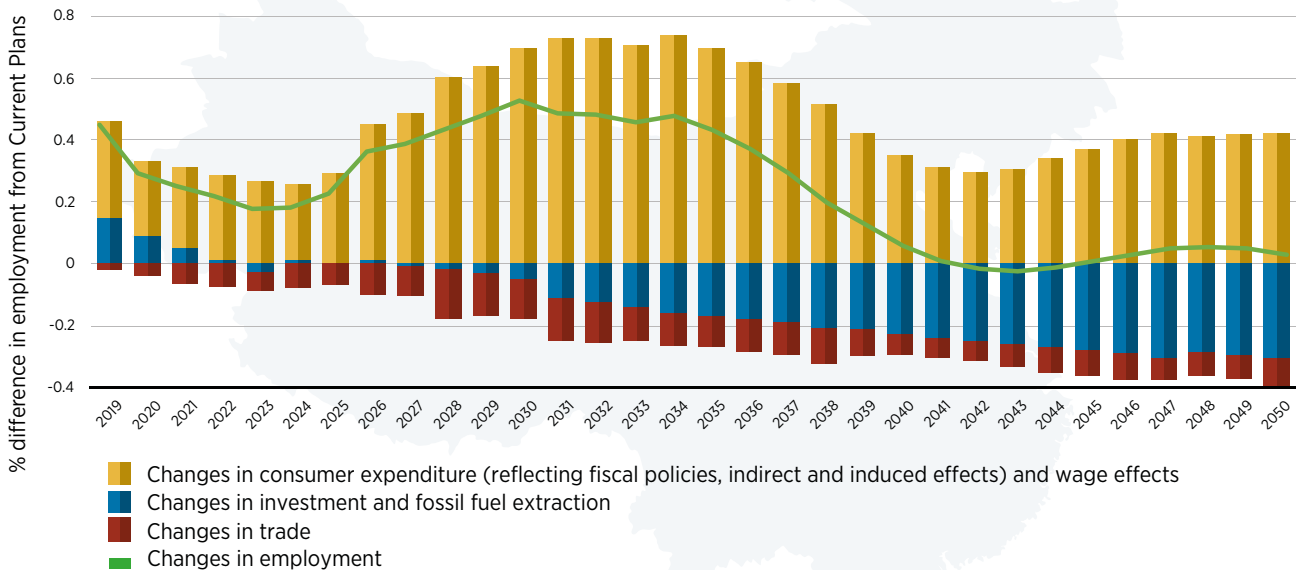
Note: The empty dashed bar shows the balance of total renewable energy jobs (bioenergy, hydro, CSP and tidal/wave).
 Source: IRENA analysis

Jobs footprint: Economy-wide

Economy-wide employment decreases in both the Current Plans and Energy Transformation cases, with an overall 21% reduction in 2050 compared to 2017, which is mainly linked to a demographic-driven reduction of the labour force. Employment in the economy decreases slightly more slowly with Energy Transformation than Current Plans.

In effect, the Energy Transformation case gives 0.03% higher employment in 2050. Figure 23 presents, in terms of the relative performance of Energy Transformation versus Current Plans, the economy-wide jobs footprint and how different drivers influence that footprint.

Figure 23: Economy-wide employment, China





After an initial positive jobs footprint, peaking in around 2030, differential jobs between Energy Transformation and Current Plans quickly fade away to become neutral from 2040 onwards. The main positive contributor to the economy-wide jobs footprint is the induced and indirect driver, with trade and investment providing negative contributions.

The **investment driver**, after an initial positive contribution, becomes neutral in 2025 and from then onwards provides increasingly negative contributions. This net investment driver is compounded by the following sub-drivers:

- 1) the investment in energy efficiency provides a positive impact, peaking around 2023, with values significantly higher than those achieved by the power sector contribution, and then fading away to become almost neutral from 2035 onwards;
- 2) investment in the power sector provides positive contributions driven by investment in renewables, with the changes in investment in the fossil fuel power sector having an almost negligible negative contribution;
- 3) fossil fuel extraction has an increasingly negative contribution as the transition to renewables and energy efficiency progresses (becoming the dominant contributor to the investment driver from 2035 onwards). This is partly due to substantial reductions in jobs in coal mining, and mainly a consequence of a strong reduction in fuel manufacturing jobs because of the lower prices stemming from reduced international demand and the relatively high costs of the Chinese fuel manufacturing industry;

4) investment in other sectors has a negative contribution that closely mirrors the positive contributions from energy transition-related investments, with a very strong negative peak around 2023. This indicates that the impact from crowding out is not being attenuated by additional investment stimulated by economic growth, and that job intensity within the economic sectors experiencing crowding out is similar to that from energy transition-related investments.

The **trade driver** has a negative impact throughout the forecasted period, peaking around 2030 and having a lower negative contribution than the investment driver from 2033 onwards. Trade in fossil fuels has a negative but small impact throughout the energy transition, resulting from the balance of the reduction in imports of oil and gas and the reduction of natural gas exports. Non-energy trade dominates the resulting negative impact from the trade driver and is attributed to the relative increase of imports over Current Plans, triggered by construction activity, economic growth and higher real consumer income.

The **induced and indirect effects driver** has a positive impact on the jobs footprint, peaking in around 2030, compensating for the negative impacts from investment and trade, and driving the positive results up to 2040. This driver is dominated by consumer expenditure and its indirect effects on supply chain employment.

From this jobs footprint analysis, the following insights can be drawn:

- The negative impact from the investment driver, increasing as the transition progresses, could be addressed with appropriate policies:
 - ① negative impacts on jobs from coal mining become the dominant element as the transition advances, requiring focused and long-lasting just transition policies.
 - ② just transition requirements span beyond the energy sector due to investment crowding-out. Public investment could play an important role to support these sectors and the social function they fulfil.
- The negative trade driver impact is associated with a higher increase of imports than exports and is driven by increased economic activity and consumer incomes. Since import intensity through the Chinese economy does not increase, the impact from this driver is a standard leakage from domestic supply chains due to increased economic activity.

As a summary of the jobs footprint in China, **Table 7** presents the CAGR¹⁸ of renewable, energy sector and economy-wide jobs with Energy Transformation in 2017-2050, as well as the increments of jobs in 2050 from Current Plans.

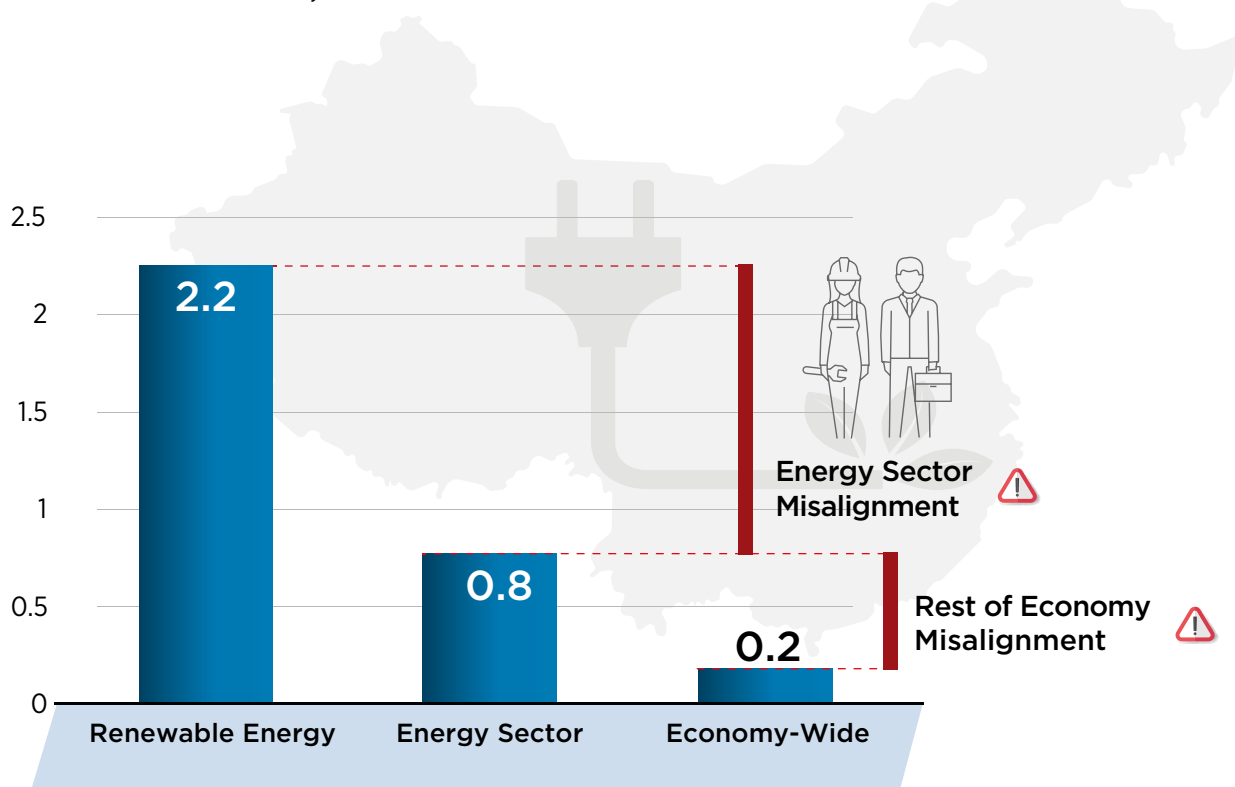
The different evolution of jobs in renewable energy, the energy sector and economy-wide, produces sectoral job misalignments (**Figure 24**).

The higher increase in jobs in renewable energy than in the whole energy sector is a consequence of the jobs being lost mainly in fossil fuels; the lower increase in economy-wide jobs compared to those in the energy sector indicates a loss of jobs in other economic sectors outside the energy sector. Just transition policies are needed to properly address these misalignments and ensure they do not form barriers to the transition (see section-5).

Table 7: CAGRs for jobs in renewable energy, overall energy sector and economy-wide with Energy Transformation and increment of jobs compared to Current Plans for 2050, China

	Energy Transformation	Increment of jobs in 2050 from Current Plans	
	CAGR (2017 to 2050)	Thousand jobs	Percentage
Renewables	3.7%	2 249	19%
Energy sector	1.8%	783	3%
Economy-wide	-0.7%	184	0.03%

Figure 24: Job misalignments: Increment of jobs between Current Plans and Energy Transformation in 2050, China



¹⁸CAGR = compound annual growth rate. The CAGR is a measure of growth over a period (here from 2017 to 2050), and it can be thought of as the constant annual growth rate needed to move from the initial to the final value over that period



4.3 Middle East OPEC¹⁹

Additional jobs in 2050 (in million)

-0.2

Economy-wide

0.4

Energy sector

0.5

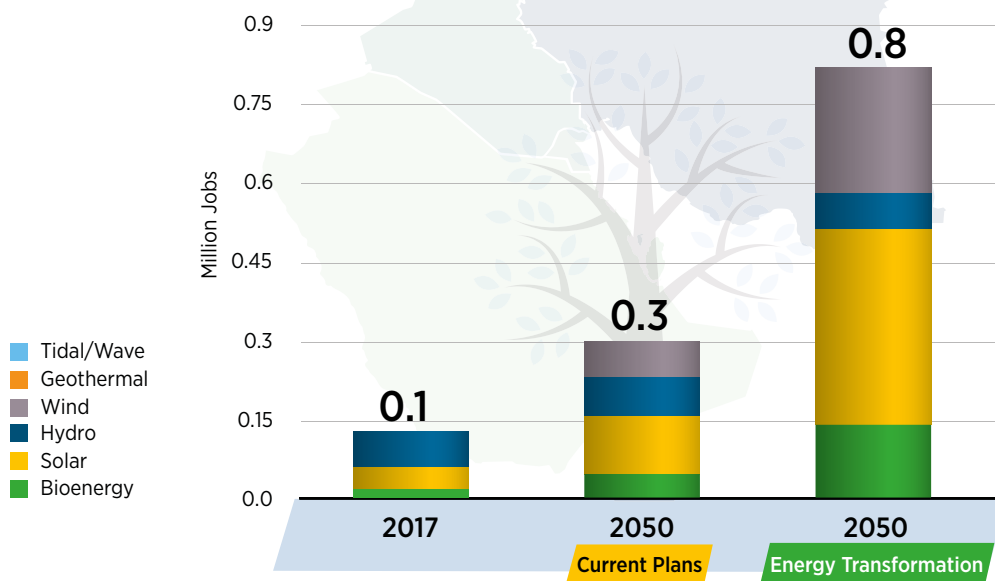
Renewable energy sector

Jobs footprint: Renewables and the energy sector

Energy Transformation results in a total renewable energy employment of 0.8 million jobs by 2050, up from about 0.1 million in 2017 – a 169% increase from the roughly 0.3 million expected under Current Plans (Figure 25). The solar workforce will be the sector's largest at close to 0.4 million, enjoying an expansion of 223% from that expected under Current Plans.

Solar is followed by wind (0.2 million), which experiences the highest increase over Current Plans (259%). Bioenergy undergoes a 14% expansion from Current Plans, reaching 0.1 million jobs (see Table 8). Overall, Energy Transformation will produce 0.5 million more renewable energy jobs than Current Plans would by 2050.

Figure 25: Renewable energy jobs, Middle East OPEC



¹⁹ Saudi Arabia, Islamic Republic of Iran, Iraq, Kuwait, Qatar, United Arab Emirates

Energy Transformation results in a total energy sector employment of 3.3 million jobs by 2050, up from about 2 million today. Growth in energy sector jobs is higher with Energy Transformation than Current Plans, offering 12% more jobs by 2050 (Table 8), with the decrease in fossil fuel jobs being smaller than the increase in energy transition-related jobs (renewables, energy efficiency and energy flexibility).

Figure 26 shows how jobs in nuclear power, fossil fuels, renewables, energy efficiency, and energy flexibility and grid upgrades stack up at present and how they fare in 2050 under both scenarios.

Compared to Current Plans, 0.3 million of fossil fuel jobs will fall by the wayside in Energy Transformation. Energy efficiency jobs will increase by 11% , reaching 1.1 million, while renewables will witness the biggest growth of 169%, amounting to 0.8 million in 2050 (see Table 8).

Overall, in 2050 the energy sector gains 0.4 million jobs with Energy Transformation compared to Current Plans. The lower absolute increase in energy sector jobs (0.4 million) compared to renewable energy jobs (0.5 million) is a consequence of lost fossil fuels jobs (Table 8).

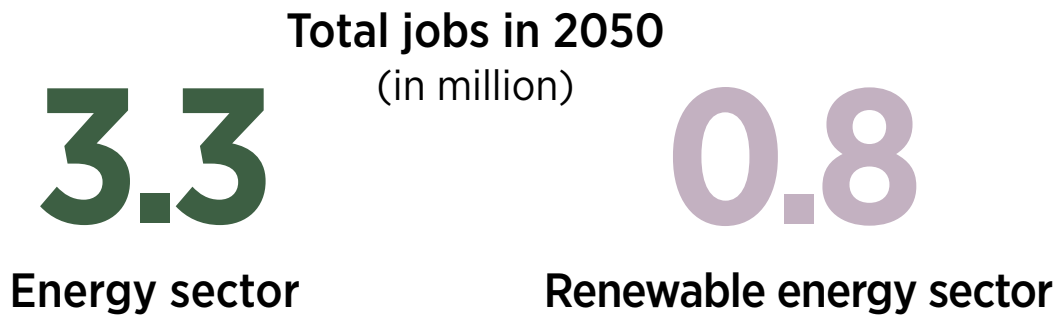


Figure 26: Energy sector jobs, Middle East OPEC

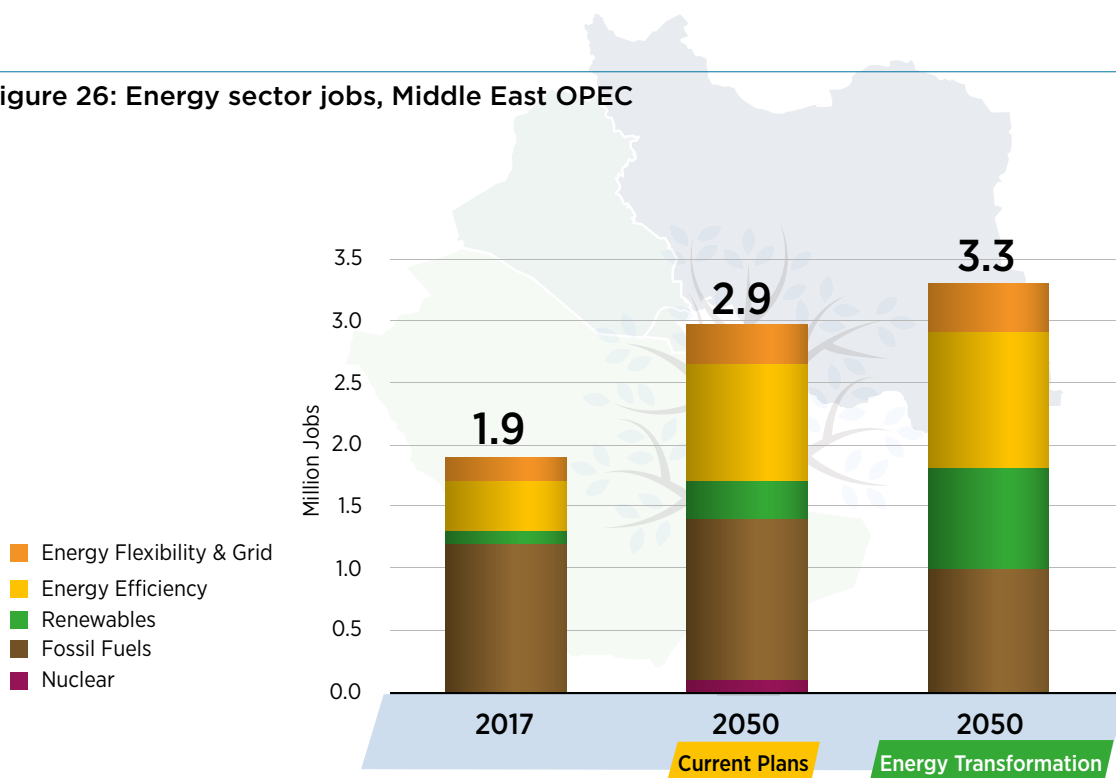




Table 8: Renewables and energy sector jobs in 2050 with Energy Transformation, Middle East OPEC

Energy Transformation in 2050		
	Thousand jobs	Increment from Current Plans
Renewables	816	169%
Solar	365	223%
Bioenergy	139	156%
Wind	236	259%
Energy sector	3 317	12%
Renewables	816	169%
Energy Efficiency	1 059	11%
Energy Flexibility & Grid	433	17%
Fossil Fuels	975	-24%
Nuclear	35	-35%

Figure 27 quantifies the structure of a subset of renewable energy jobs in terms of segments of the value chain and occupational requirements in the year 2050 for Energy Transformation.²⁰

Regarding the jobs structure in terms of value chain, these results show that there is plenty of room to localise renewable energy jobs in such a way that the transition to renewables and energy efficiency contributes to the reinforcement of domestic supply chains. Indeed, manufacturing, which is the segment of the value chain hardest to localise, accounts only for 21% of the jobs in this subset of renewable energy technologies, while construction and installation accounts for 53% of the jobs and O&M for 27%.²¹

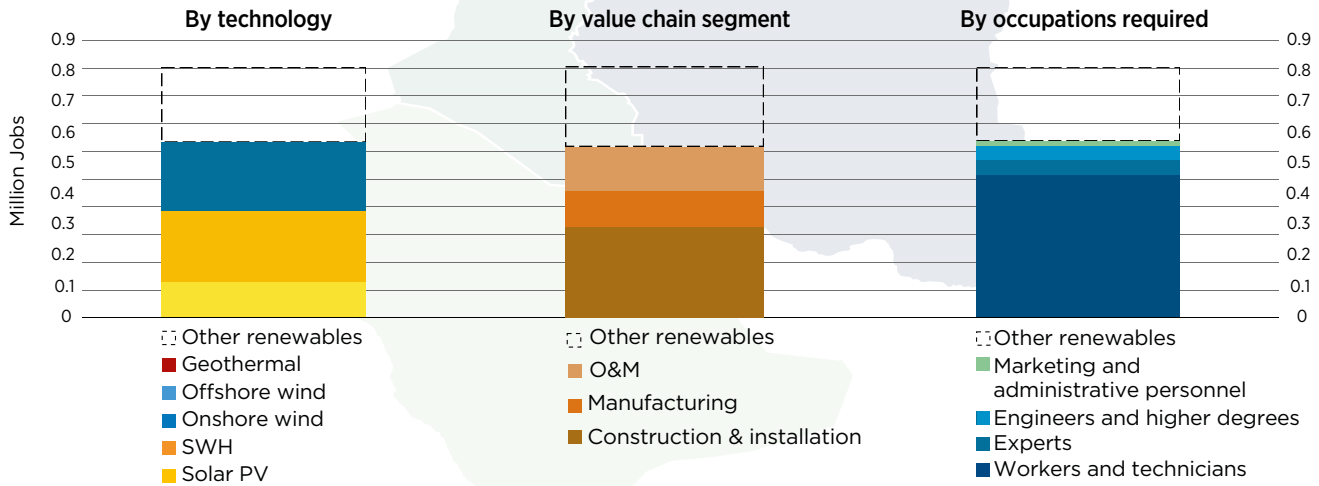
In fact, when the complete set of renewable technologies are considered, the incorporation of biomass (with a large share of jobs required for the production of the biomass and biofuels) reduces the weight of the manufacturing segment of the value chain in the total amount of jobs to 16%, with the other more easily localised segments of the value chain accounting for 16% (biomass supply), 41% (construction and installation) and 27% (O&M).

With regard to the jobs structure in terms of skills, 81% of the jobs associated with this subset of renewable energy technologies corresponds to workers and technicians, while experts are 8%, engineers and other high degrees 8%, marketing and administrative personnel 3%.

²⁰The subset of renewable energy technologies used in this figure (PV, wind onshore, wind offshore, SWH and geothermal) is determined by the availability of leveraging information in terms of occupational requirements. Most of this information comes from IRENA's leveraging reports series; as additional technologies are covered in forthcoming reports the analysis will be extended to more technologies.

²¹ Although for renewable energy technologies localisation of manufacturing is significantly simpler than for fossil fuel or nuclear technologies.

Figure 27: Employment in Middle East OPEC with Energy Transformation (2050) disaggregated by technology, value-chain segment and occupation for selected technologies



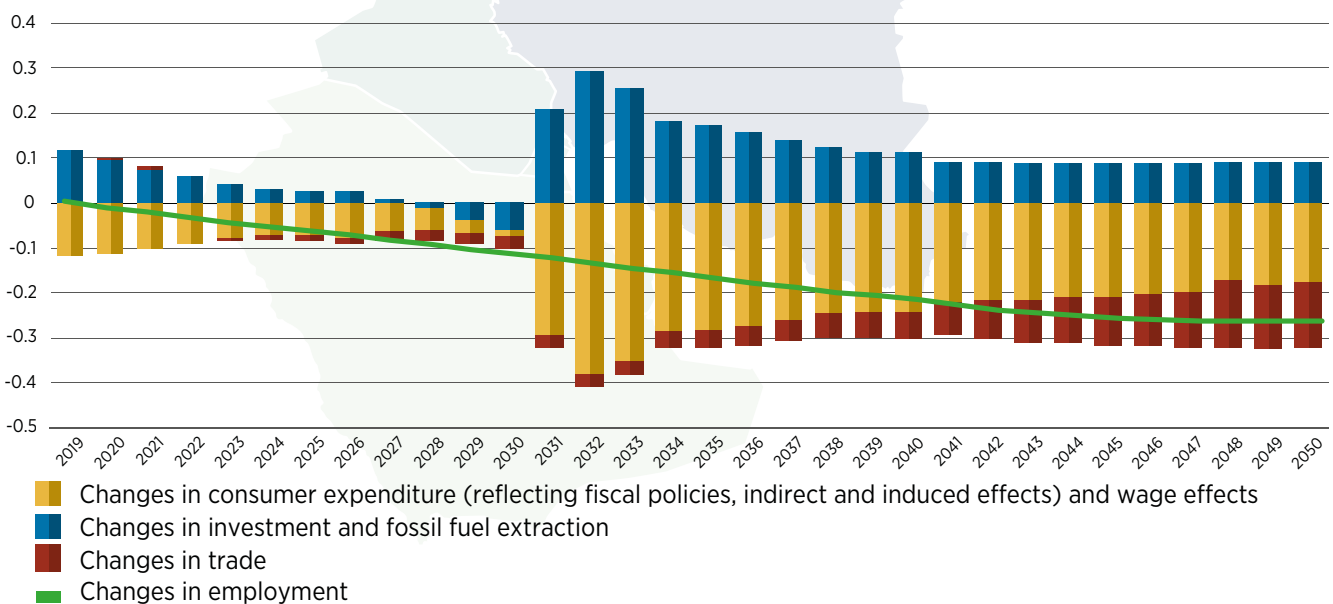
Note: The empty dashed bar shows the balance of total renewable energy jobs (bioenergy, hydro, CSP and tidal/wave).
Source: IRENA analysis

Jobs footprint: Economy-wide

Economy-wide employment would increase by 9% in 2050 compared to 2017 for both Energy Transformation and Current Plans, with Energy Transformation producing 0.23% lower fewer jobs in 2050 than Current Plans would.

Figure 28 presents the economy-wide jobs footprint and the effect that different drivers have upon it.

Figure 28: Economy-wide employment, Middle East OPEC





Middle East OPEC has a negative overall jobs footprint, resulting from positive investment effects being unable to offset negative trade and induced effects.

The **investment driver** has an overall positive impact most of the time, especially after 2030. Energy efficiency investment provides a positive contribution to the jobs footprint throughout the forecast period, decreasing over time due to the front-loaded character of this investment. Regarding the power sector, renewables investment has a negligible effect until 2030, when its positive contribution becomes as important as that from energy efficiency investment and remains at this level until the end of the energy transition. Fossil fuels investment has a negative but small impact throughout the forecast period; it initially cancels-out the positive impact from renewables investment but becomes negligible from 2030 onwards once ambitions for the transition increase.

Fossil fuel extraction provides a negative impact, becoming progressively more negative as the transition continues. However, this negative impact is smaller than what may be expected from the reduced trade in fossil fuels, because the domestic market partly compensates for the reduced exports.

Investment in other economic sectors has a negative impact on the jobs footprint, significantly offsetting the positive effect from energy transition-related investment. This occurs as a consequence of the higher employment intensity in the sectors affected by crowding-out.

The **trade driver** has a negative impact throughout the analysed period, dominated by trade in fossil fuels. It becomes gradually more negative over time. The negative impact of trade in fossil fuels on the jobs footprint is relatively small as a consequence of the low employment intensity of the fossil fuels sector in this region. Non-energy trade is almost neutral in terms of employment.

The **induced and indirect effects driver** is negative throughout the period, dominating the jobs footprint after 2030 and resulting from the balance between different effects: consumer expenditure has a positive impact, increasing as the transition progresses, but does not offset the negative contribution from dynamic effects mainly due to the limited depth and strength of domestic supply chains (preventing the economy from realising more benefits from investment stimulus).

From this job footprint analysis, the following insights can be drawn:

- there is need for employment policies looking beyond the fossil fuels sector and addressing the negative impacts in employment-intensive sectors affected by crowding-out;
- reinforcing domestic supply chains would provide access to more benefits from investment stimulus through increased localised employment across supply chains.



As a summary of the jobs footprint in Middle East OPEC, **Table 9** presents the CAGR²² of renewable, energy sector and economy-wide jobs under the Energy Transformation case from 2017 to 2050, as well as the increments in jobs from Current Plans in 2050. The different evolution of jobs in renewable energy, the energy sector and economy-wide produces sectoral job misalignments (**Figure 29**).

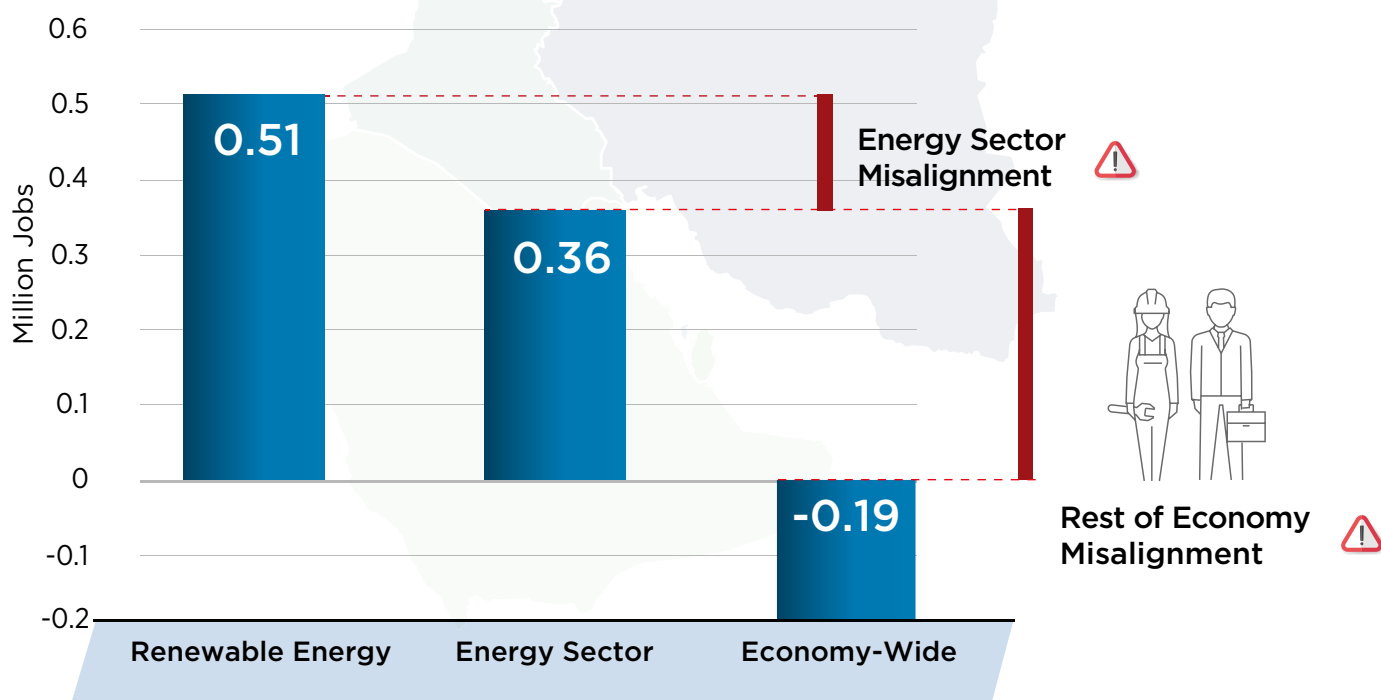
Renewables gain more jobs than the overall energy sector. Where energy jobs are lost, they are mainly in fossil fuels. Economy-wide jobs losses despite net job gains in energy, meanwhile, indicates an important loss of jobs in other economic sectors outside the energy sector.

Just transition policies are needed to properly address these misalignments and avoid that they become transition barriers (see Section 5).

Table 9: CAGRs for jobs in renewable energy, the whole energy sector and economy-wide with Energy Transformation and increment of jobs compared to Current Plans for 2050, Middle East OPEC

	Energy Transformation	Increment of jobs in 2050 from Current Plans	
	CAGR (2017 to 2050)	Thousand jobs	Percentage
Renewables	5.6%	513	169%
Energy sector	1.6%	360	12%
Economy-wide	0.3%	-189	-0.2%

Figure 29: Job misalignments: Increment of jobs from Current Plans to Energy Transformation in 2050, Middle East OPEC



²² CAGR = compound annual growth rate. The CAGR is a measure of growth over a period (here from 2017 to 2050), and it can be thought of as the constant annual growth rate needed to move from the initial to the final value over that period.



4.4 Southern Europe²³

Additional jobs in 2050 (in million)

1.6

Economy-wide

0.3

Energy sector

0.3

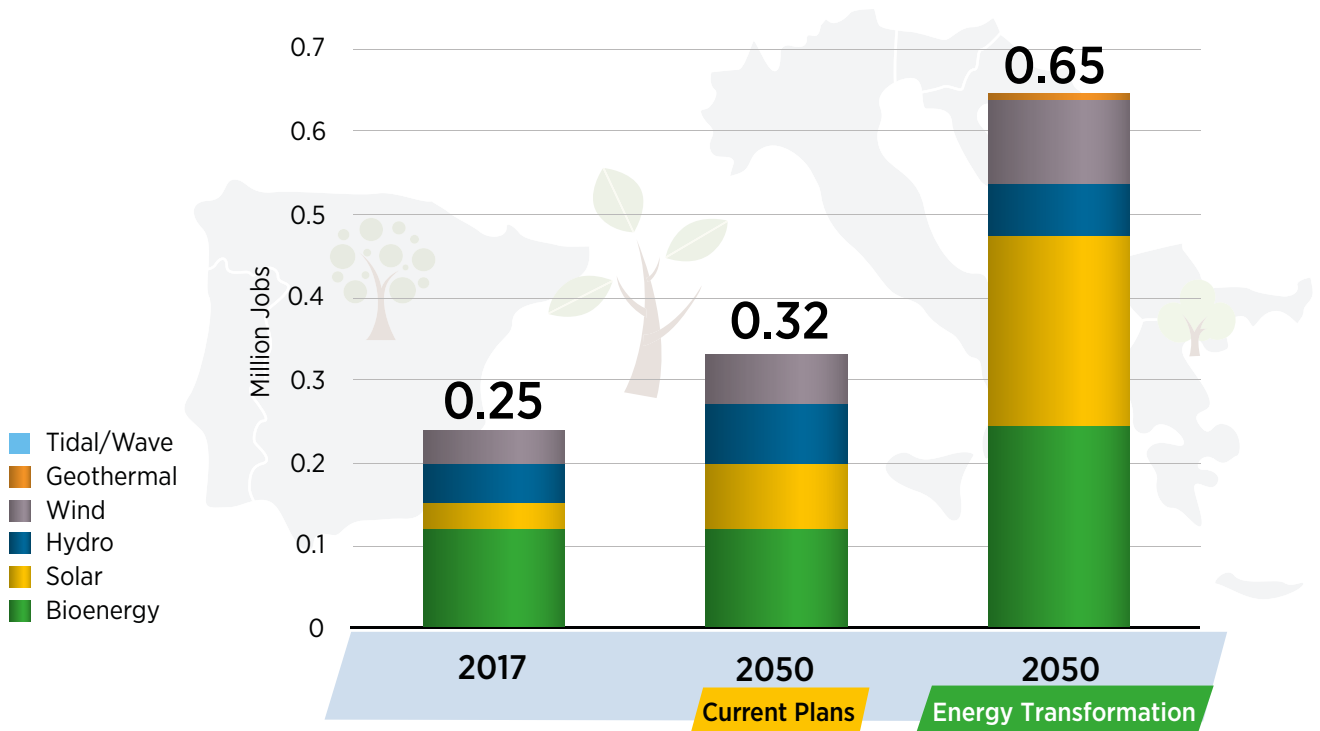
Renewable energy sector

Jobs footprint: Renewables and energy sector

Energy Transformation results in total renewable energy employment of 0.65 million jobs by 2050, up from about 0.25 million in 2017 – a 101% increase from the roughly 0.3 million expected under Current Plans (Figure 30). Bioenergy and solar workforces will be the sector's largest.

At close to 0.25 million each, bioenergy and solar jobs expand 105% and 204%, respectively, followed by wind (0.1 million) with a 72% increase (see Table 10). Overall, in 2050, Energy Transformation foresees 0.3 million more renewable energy jobs than Current Plans.

Figure 30: Renewable energy jobs, Southern Europe



²³ Greece, Spain, Italy, Portugal, Slovenia, Croatia, Macedonia, Cyprus

The transition results in a total energy sector employment of 1.5 million jobs by 2050, up from about 0.6 million today. Growth in energy sector jobs is higher with Energy Transformation than Current Plans, offering 23% more jobs by 2050 (Table 8), with the decrease in fossil fuel jobs being smaller than the increase in energy transition-related jobs (renewables, energy efficiency and energy flexibility).

Figure 31 shows how jobs in nuclear power, fossil fuels, renewables, energy efficiency, and energy flexibility and grid upgrades stack up at present, and how they will fare in 2050 under both Current Plans and Energy Transformation.

Compared to Current Plans, 0.1 million of fossil fuel jobs will fall by the wayside with Energy Transformation. Energy efficiency jobs will increase by 14% relative to Current Plans to reach 0.4 million, while renewables will witness the biggest growth of 101%, reaching 0.7 million in 2050 (see Table 10). Overall, in 2050 the energy sector gains 0.3 million jobs with Energy Transformation versus Current Plans. The slightly lower absolute increase in energy sector jobs (0.27 million) compared to renewable energy jobs (0.33 million) is a consequence of lost fossil fuels jobs (Table 10).

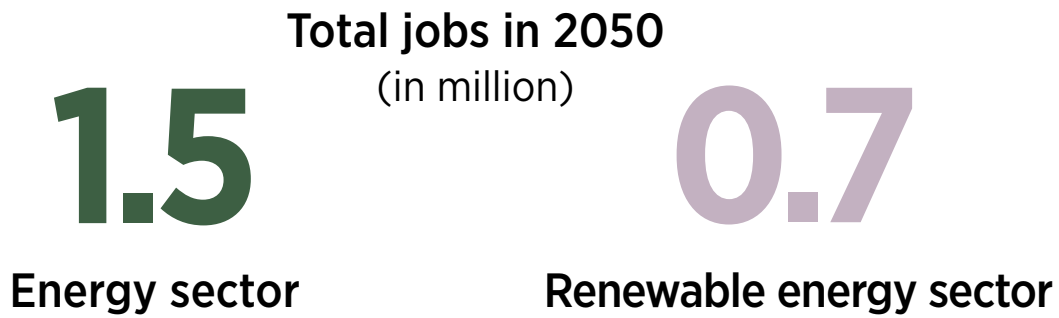


Figure 31: Energy sector jobs, Southern Europe

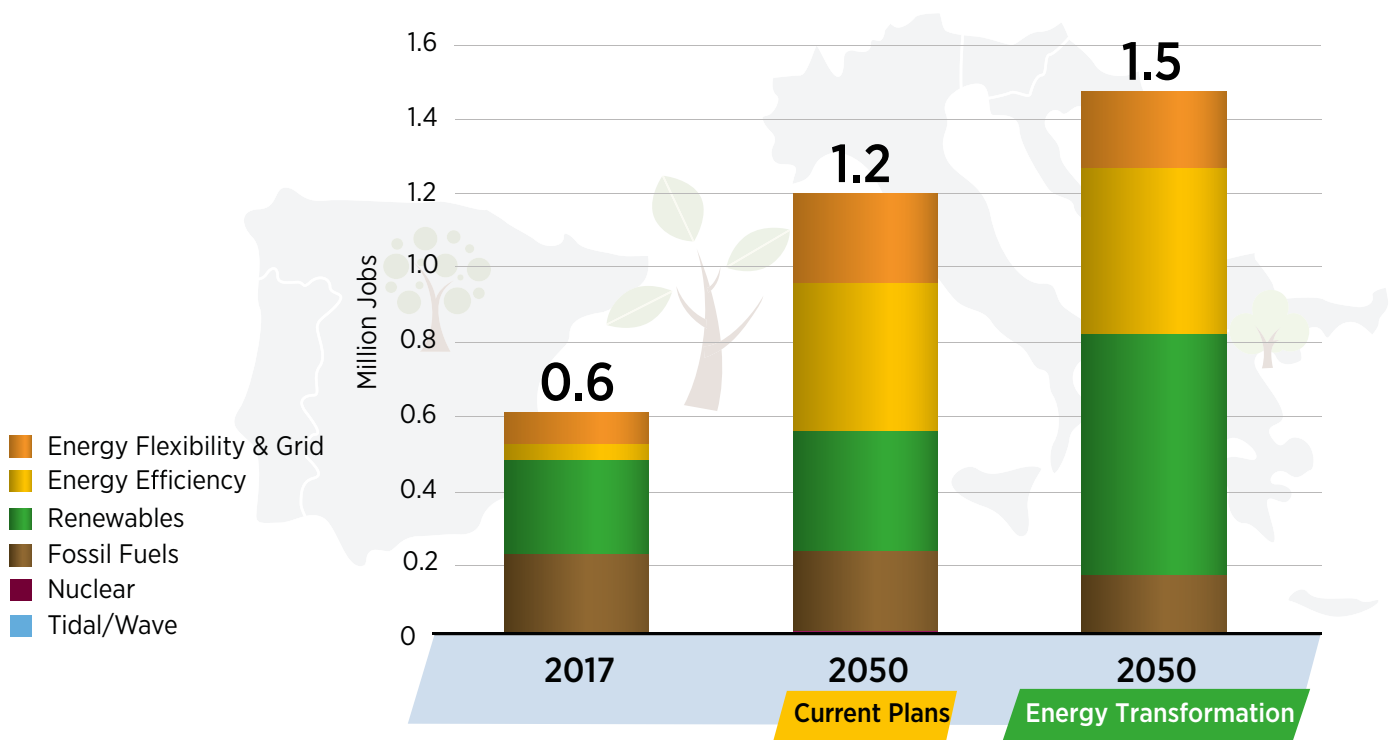




Table 10: Renewables and energy sector jobs in 2050 with Energy Transformation, Southern Europe

Energy Transformation in 2050		
	Thousand jobs	Increment from Current Plans
Renewables	649	101%
Solar	236	204%
Bioenergy	245	105%
Wind	97	72%
Energy sector	1 473	23%
Renewables	649	101%
Energy Efficiency	450	14%
Energy Flexibility & Grid	209	-16%
Fossil Fuels	162	-27%
Nuclear	4	-67%

Figure 32 quantifies the structure of a subset of renewable energy jobs in terms of segments of the value chain and occupational requirements in year 2050 with Energy Transformation.²⁴

Regarding the jobs structure in terms of the value chain, these results show that there is plenty of room to localise renewable energy jobs in such a way that the transition to renewables and energy efficiency contributes to the reinforcement of domestic supply chains. Indeed, manufacturing, which is the segment of the value chain most difficult to localise²⁵, accounts for 44% of the jobs in the subset of renewable energy technologies, while construction and installation accounts for 38% of jobs and O&M for 18%.

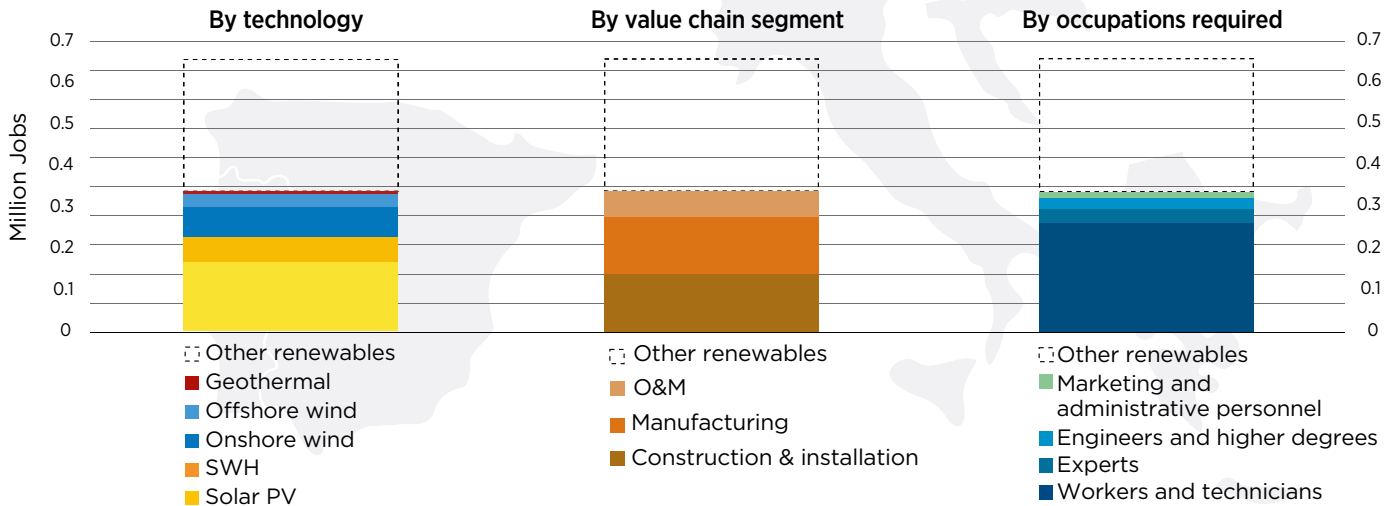
In fact, when the complete set of renewable technologies are considered, the incorporation of biomass – with a large share of jobs required for the production of biomass and biofuels – reduces the weight of the manufacturing segment of the value chain to 28%, with the other more easily localised segments of the value chain accounting for 34% (biomass supply), 24% (construction and installation) and 14% (O&M).

Regarding the jobs structure in terms of skills, 76% of the jobs associated with this subset of renewable energy technologies corresponds to workers and technicians, while experts are 11%, engineers and other high degrees 8% and marketing and administrative personnel 5%.

²⁴ The subset of renewable energy technologies used in this figure (PV, wind onshore, wind offshore, SWH and geothermal) is determined by the availability of leveraging information in terms of occupational requirements. Most of this information comes from IRENA's leveraging reports series, and as additional technologies are covered in forthcoming reports the analysis will be extended to include more technologies.

²⁵ Although for renewable energy technologies, localisation of the manufacture is significantly simpler than for the fossil fuel or nuclear technologies. In the case of Southern Europe, domestic supply chains are able to localise manufacturing jobs, allowing the region to reap higher employment benefits.

Figure 32: Employment in Southern Europe with Energy Transformation (2050) disaggregated by technology, value-chain segment and occupation for selected technologies



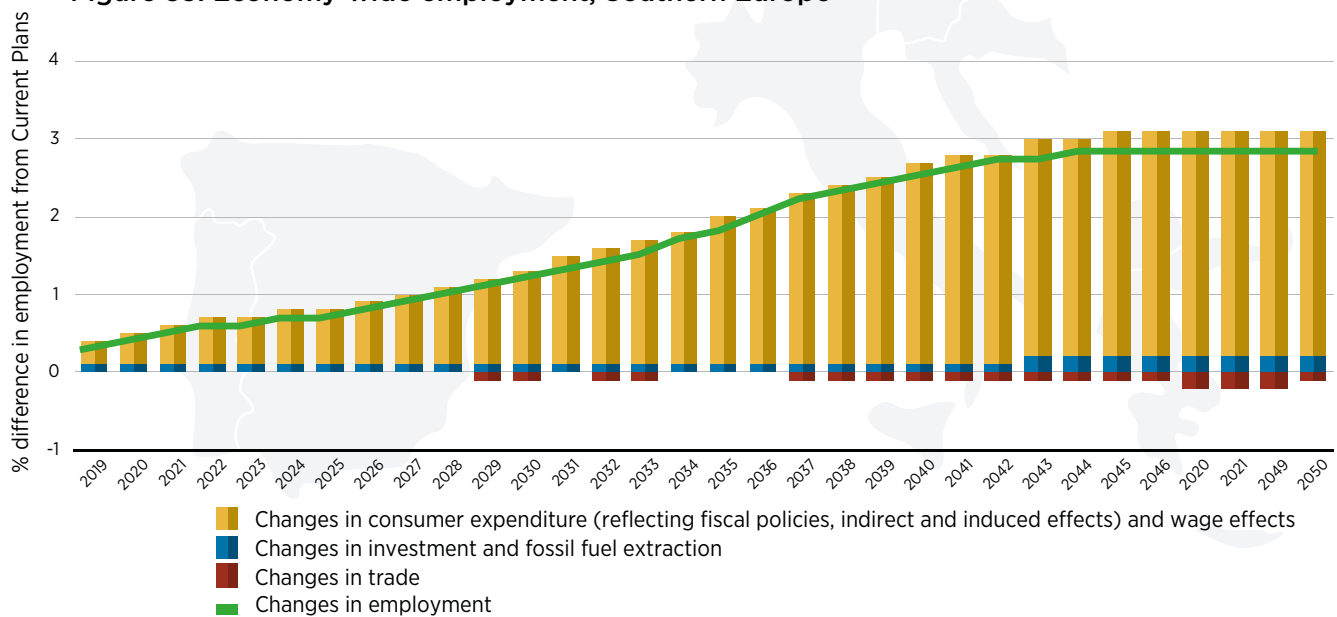
Note: The empty dashed bar shows the balance of total renewable energy jobs (bioenergy, hydro, CSP and tidal/wave).
 Source: IRENA analysis

Jobs footprint: Economy-wide

Economy-wide employment almost stagnates under Current Plans, whereas Energy Transformation brings an overall 3% growth in 2050 compared to 2017, with employment under Energy Transformation being 3% higher in 2050 than in Current Plans.

Figure 33 presents - in terms of the relative performance of the Energy Transformation case versus Current Plans - the economy-wide jobs footprint and the role the different drivers play in shaping it.

Figure 33: Economy-wide employment, Southern Europe





Southern Europe has a very positive jobs footprint, steadily increasing in value as the transition to renewables and energy efficiency reaching as high as almost 3% in job increases over Current Plans in the last decade of the Energy Transformation scenario, mainly driven by induced effects.

The **investment driver** has a positive but relatively small impact that remains rather constant, compounded by several contributions: 1) a front loaded positive impact from energy efficiency investment; 2) an overall positive contribution from the power sector, dominated by investment in renewables that more than outweigh the impact from reduced fossil fuel power generation; 3) a negative impact from investment in other sectors that becomes almost neutral from 2040 onwards.

The **trade driver** is almost neutral up to 2030, and from there on becomes negative.

It remains relatively small but almost cancels out the positive impact from investment during the last decade of the energy transition. The impact from trade in fossil fuels is slightly negative at times, but almost neutral overall. Non-energy trade has a negative impact on employment, stemming from the relative increase in non-energy imports and the associated loss of domestic economic activity and employment.

The **induced and indirect effects driver** has a strong positive impact on employment, dominating the overall outcome. Consumer expenditure and associated labour demand in the corresponding supply chains explain most of the impact from this driver. Wage effects in non-energy sectors have an increasingly negative impact due to the relative reduction of unemployment (higher relative wages) – small in relative terms but capable of cancelling out the positive contributions from the investment driver during the last decade of the energy transition.

From this job footprint analysis, the following insights may be drawn:

- Indirect and induced effects, and especially those driven by fiscal policies and revenue recycling policies, can have a significant positive impact on the jobs footprint, but for this to happen the appropriate socio-economic context needs to be in place. Policies focusing on sharing the benefits from carbon taxation could contribute to a fair and just transition by using international climate finance to support economies experiencing negative impacts from the energy transition.
- In a high differential economic growth context, the negative impacts on jobs from crowding out of investment in other sectors can be compensated by additional economic activity stimulated in these sectors. In the absence of this market driver, public investment concentrated in affected sectors with high social value could play a similar role.



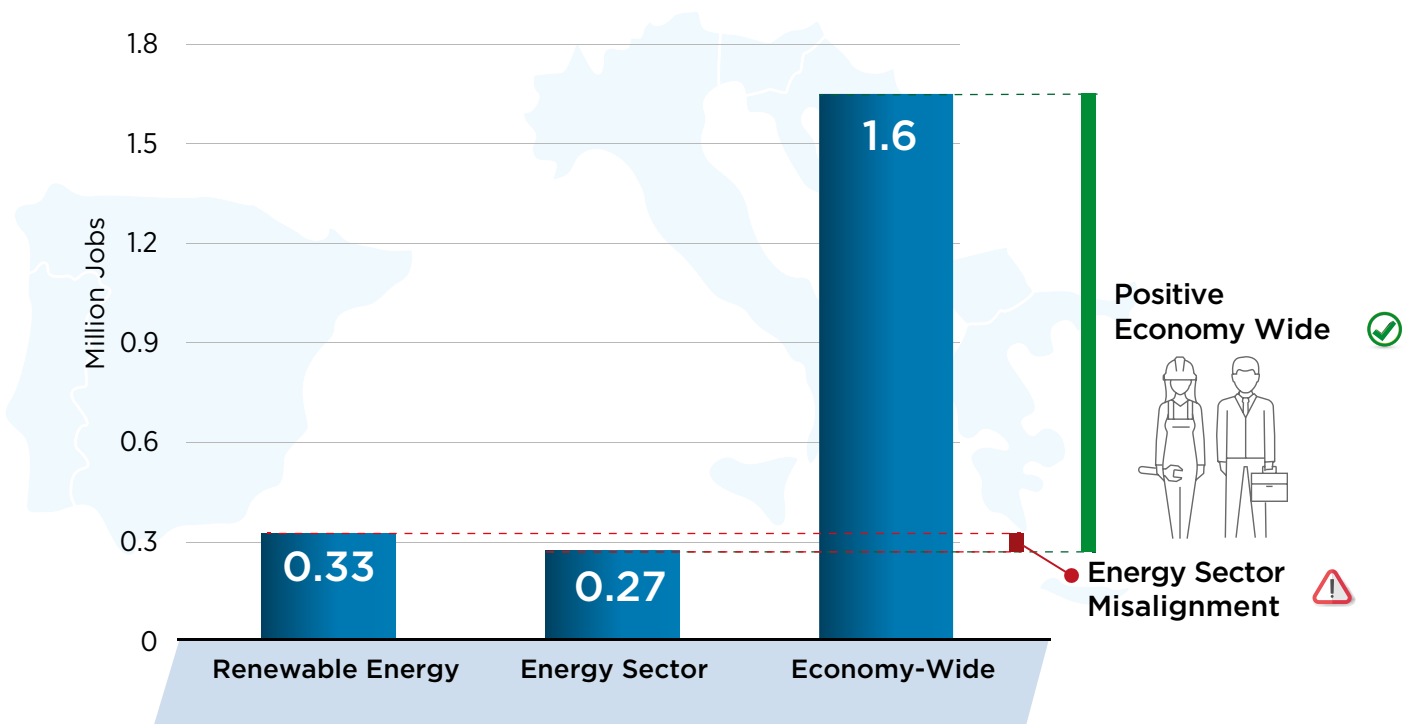
As a summary of the jobs footprint in this region, **Table 11** presents the CAGR²⁶ of renewables, energy sector and economy-wide jobs under the Energy Transformation case in 2017-2050, as well as the increments of jobs in 2050 from Current Plans. The different evolution of jobs in renewable energy, the energy sector and economy-wide may produce sectoral job misalignments.

For Southern Europe, no significant misalignments occur (**Figure 34**). The slightly higher increase in jobs in renewable energy than in the whole energy sector is consequence of the jobs being lost mainly in fossil fuels; the higher increase in economy-wide jobs compared to the increase in the energy sector indicates that during the energy transition, jobs are being created in other sectors of the economy.

Table 11: CAGRs for jobs in renewables, energy sector and economy-wide with Energy Transformation and increment of jobs compared to Current Plans for 2050, Southern Europe

	Energy Transformation	Increment of jobs in 2050 from Current Plans	
	CAGR (2017 to 2050)	Thousand jobs	Percentage
Renewables	3.0%	326	101%
Energy sector	2.7%	274	23%
Economy-wide	0.1%	1650	3%

Figure 34: Job misalignments: Increment of jobs, Current Plans to Energy Transformation in 2050, Southern Europe



²⁶ CAGR = compound annual growth rate. The CAGR is a measure of growth over a period (here from 2017 to 2050), and it can be thought of as the constant annual growth rate needed to move from the initial to the final value over that period.



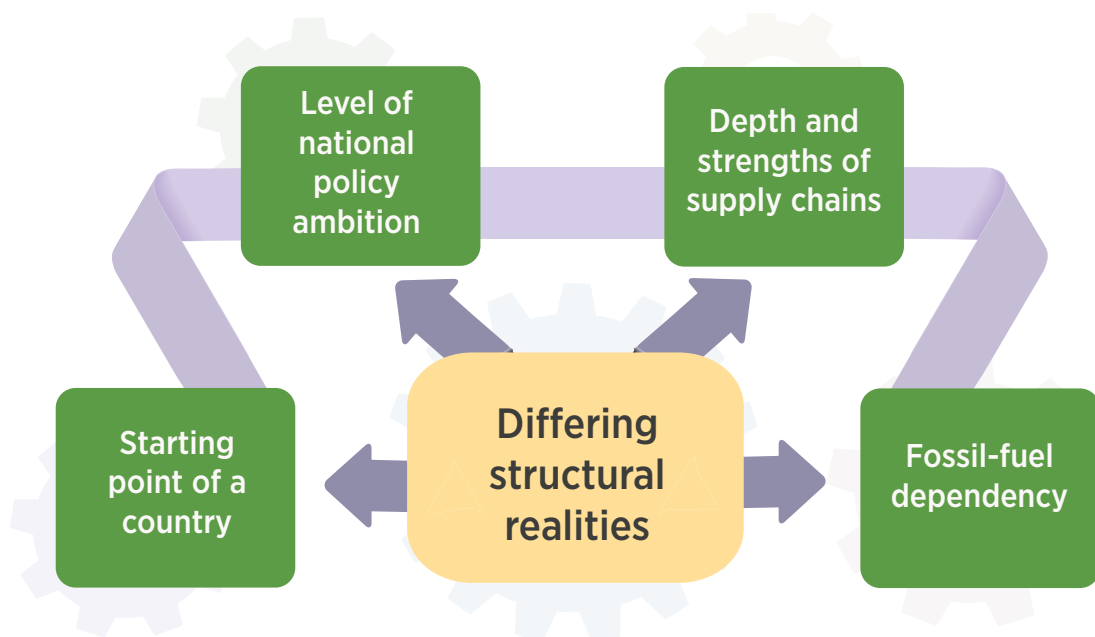
5 Economic Structure, Employment Misalignments and a Just Transition

The results presented in this report offer detailed insights on how the transition will impact employment at the global and regional levels. They show that the energy transition, when accompanied by appropriate policies - such as updated fiscal policies, fossil fuel subsidy phase-out and revenue recycling - can avoid adverse job effects across the global economy. In this analysis, a strong fiscal policy is key. With it, Energy Transformation yields a small economy-wide jobs gain over Current Plans, whereas without it, the result would be a slight loss.

The shift in energy pathways does not occur in isolation. It interacts with underlying socio-economic structures around the world, and has ramifications for macroeconomic stability, trade, investment, supply chains, production capacity and employment. All of

these dynamics affect how different regions/countries fare. Understanding the socio-economic impacts is therefore essential for countries exploring ways to meet multiple objectives such as stimulating economic growth and employment, improving energy security, expanding energy access and mitigating climate change.

This chapter first highlights the importance of underlying economic structures shaping countries' transition adjustment needs (5.1). It then explores potential employment misalignments that may emerge as a result of transition processes (5.2). Finally, the chapter sketches the contours of a comprehensive policy framework, required to address structural realities and misalignments and designed to help bring about a successful energy transition (5.3.).



5.1 Understanding structural realities

A disaggregation of the results at the regional level sheds light on how transition-related trade shifts, investments, and indirect and induced effects affect different parts of the world. Some regions experience a significant loss of economy-wide jobs (relative to Current Plans), while others enjoy gains. However, economy-wide results can mask additional changes across different sectors within each region/country.

Furthermore, within each of the regions analysed in this report, jobs requiring different skill sets will become available depending on the stage of the transition process. These different job impacts raise the question of what can be done to minimise economic and social disruptions as the transition unfolds.



The regional differences are due to the fact that countries embark on the transition from different starting points, defined by their existing socio-economic structures. As such, they will undertake the transition with varying levels of national policy ambition and means of ambition.

Two sets of situations warrant closer examination: (1) the varying depths, strengths, and diversity of national supply chains; and (2) the different degrees to which economies depend on the production and sale of fossil fuels. These structural realities shape the ways in which key drivers of transition affect local economies – triggering challenges or offering new opportunities.

1: Supply chain depth, strength and diversity

Regions with a robust industrial base and diversified economy are best able to localise segments of the value chain, including equipment manufacturing; project planning and development; engineering, construction and installation; and operations and maintenance.

Growing activity along the supply chain triggers demand for more intermediary industrial inputs and services from other sectors of the economy, creating positive feedback loops between energy system changes and the wider economy. This is the case in regions such as North America and the European Union. Thus, transition in energy creates sectoral spill-overs leading to greater production and consumer expenditure, which leads to additional employment in both the energy and non-energy sectors of the economy.

In other regions, such as Sub-Saharan Africa and the MENA, where economic structures are less diversified and weaker in terms of supporting transition-related technologies, modelling results show that effects in the energy supply chains sector are negative, spill overs remain limited, and consumer expenditure and wage effects in the non-energy sectors remain small.

2: Fossil-fuel dependence

While renewable energy jobs are expected to sharply increase compared to Current Plans (64% globally in 2050), fossil fuel industries will experience a significant decrease (-27%).

Regions with a heavy fossil fuel profile will face a considerable adjustment challenge. In the MENA, for example, the modelling results show that the orientation of supply chains towards the fossil fuel sector translates into forgone investment, lower oil and gas revenues, and smaller indirect and induced effects.

Re-orienting and diversifying fossil-fuel-dependent regions is likely to take time, especially in countries where such dependence is high relative to overall GDP and government revenues. Acquiring new skills can be a difficult process ([see Box 1](#)).

In summary, the rise in employment opportunities during the energy transition forecast at the global level is unevenly distributed across different regions – an outcome conditioned by existing structural realities and by fossil fuel dependencies. Appropriate policies addressing these dimensions must be introduced early in the transition.

Box 1: Reorienting economies dependent upon fossil fuels

Overall the transition has the potential to bring about improvements in welfare and prosperity. However, the complex dynamics of structural change can leave some collectives behind if not properly identified and supported. A transition that successfully addresses the climate challenge and spurs resilience, requires an unprecedented collaborative effort, which is contingent on not leaving anyone behind.

Dependencies on fossil fuels exist in all countries, with the share of the society being affected depending on how entrenched fossil fuels are in the economic activity. Just transition elements are needed to address these dependencies, with special attention to the most vulnerable.

Countries with economies dependent upon fossil fuels face a wide spectra of transition challenges, ranging from the need to restructure its economic activity away from fossil fuels, to the just transition elements for not leaving anyone behind. Strong feedbacks can develop among these transition challenges: Failure to timely restructure its economy will increase the vulnerability of its society.

Proactively anticipating and addressing these challenges within a just transition framework is key to facilitate structural changes and overcome potential transition barriers. This can be done by:

- Pursuing pro-active planning and investments to drive economic diversification in support of the energy transition;
- Identifying local economic capacities and seeking ways to leverage them in support of renewable energy development and other transition pillars (energy efficiency, energy flexibility and system integration);
- Foreseeing evolving skills needs in the renewable energy sector and the other transition pillars, and matching them with available skills in the local economy;
- Aligning, to the extent feasible, relevant expertise and skills from the fossil fuel sector (e.g. using offshore oil and gas industry expertise in offshore wind development; reorienting fossil fuel economic structures toward the new fuels of renewable-based energy systems – hydrogen economy) and re-training and re-skilling existing labour in the fossil fuel sector (e.g., coal miners) to integrate them in the renewable energy sector and the other transition pillars;

This proactive and anticipative planning for structural change has to be accompanied by just transition elements, which although common to all the countries, may be amplified in fossil fuel-dependent economies, especially when action for structural change is delayed. These just transition elements include:

- Developing active labour market policies to help individuals who lose their jobs find new livelihoods;
- Introducing adequate measures to manage the transition for fossil-fuel-dependent communities, including social protection measures.
- Governments also may choose to develop public work programmes to bridge the period required for revitalising local and regional economies.

Past economic adjustment processes suggest that re-orienting fossil-fuel-dependent regions is likely to take time and is not always certain to succeed. Acquiring new skills can be a resource-intensive process. Further, new job creation in the renewable energy sector will not necessarily be neatly aligned, temporally or geographically, with fossil fuel job loss – whence the need for appropriate social protection measures for affected communities. This is why a holistic approach and proactive anticipation are crucial: Beyond renewables, the other transition pillars have to be addressed, and the potential of improvements outside the energy sector must be invoked.

Elaborated from: IRENA, 2020 and 2019c; World Bank, 2018; World Bank, ESMAP, and SERIS, 2019.

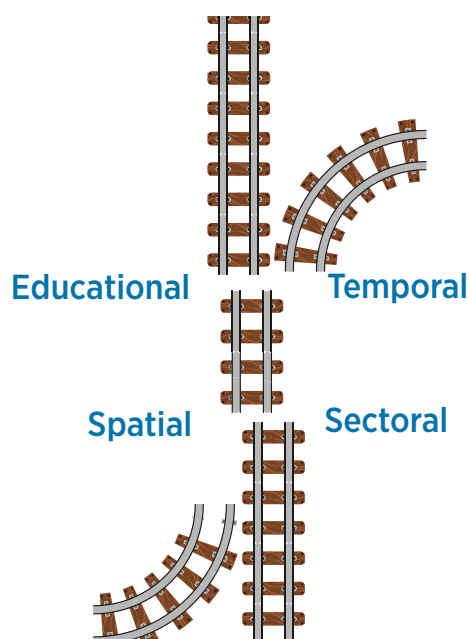


5.2 Job gains, losses and potential misalignments

In addition to the impact of pre-existing economic structures, the transition process itself will bring about profound structural changes. Key among them are labour market impacts. Four types of job effects can be discerned: job creation, elimination, substitution and transformation (UNEP et al., 2008). Given the front-loading of energy transition investments into energy efficiency, many efficiency-related jobs will be created by 2030. In line with scenario assumptions, job creation in the renewables sectors will unfold more gradually and over the entire period to 2050.

On the other hand, some jobs will become redundant, specifically in fossil fuel production but also in other sectors such as conventional automobiles (as electrification of transport takes place). Some of these jobs will be lost but others could be saved through reorientation and retraining measures. Finally, several occupations such as plumbers, electricians and carpenters may undergo a process of transformation, as they refocus toward the particular needs of the renewable energy and energy efficiency sectors.

Even though the overall jobs impacts of the energy transition are likely to be positive, some labour market misalignments may emerge along the way as old jobs fall by the wayside, new ones emerge and others undergo various kinds of shifts. Policy makers, therefore, must anticipate and address the following challenges:



- **Temporal misalignments:** job losses and gains will likely play out over diverging time scales rather than take place in parallel.
- **Spatial misalignments:** new jobs may be created in different communities, regions or countries than those where the principal job losses occur. This is particularly the case in locations that lack economic diversification.
- **Educational misalignments:** although retraining efforts can help to some extent, the skills associated with vanishing jobs do not necessarily match the profiles and occupational patterns of emerging industries.
- **Sectoral misalignments:** rising industries may draw more heavily on raw materials or intermediate inputs from sectors that are quite different from those that supply once-prominent but now declining industries.

Moreover, changes triggered by the transition to renewables and energy efficiency are not the only ones affecting employment across the economy. The potential misalignments discussed above will unfold in the context of broader structural changes affecting economies across the world.

These wider dynamics will place increasing pressure on institutions charged with matching demand and supply of labour; aligning the skills of the unemployed with requirements inherent in emerging jobs; and distributing the burdens of technological change for employment (Tirole, 2017).

The socio-economic results presented in this report assume a ‘business as usual’ evolution of labour productivity; i.e., the kind that is driven mainly by historic learning rates and labour market dynamics like shortages or surpluses of skilled personnel.

But the transition to renewable energy and energy efficiency will be accompanied by megatrends such as the fourth industrial revolution,²⁷ which is expected to transform industries and workplaces through greater connectivity, flexible automation, artificial intelligence and other changes.

These drivers intersect with a global economy characterised by low or stagnating demand growth. Another concern is that poorer and more vulnerable regions will be hard-pressed to derive benefits from these dynamics. Both across and within individual economies, increasing inequality is of concern.

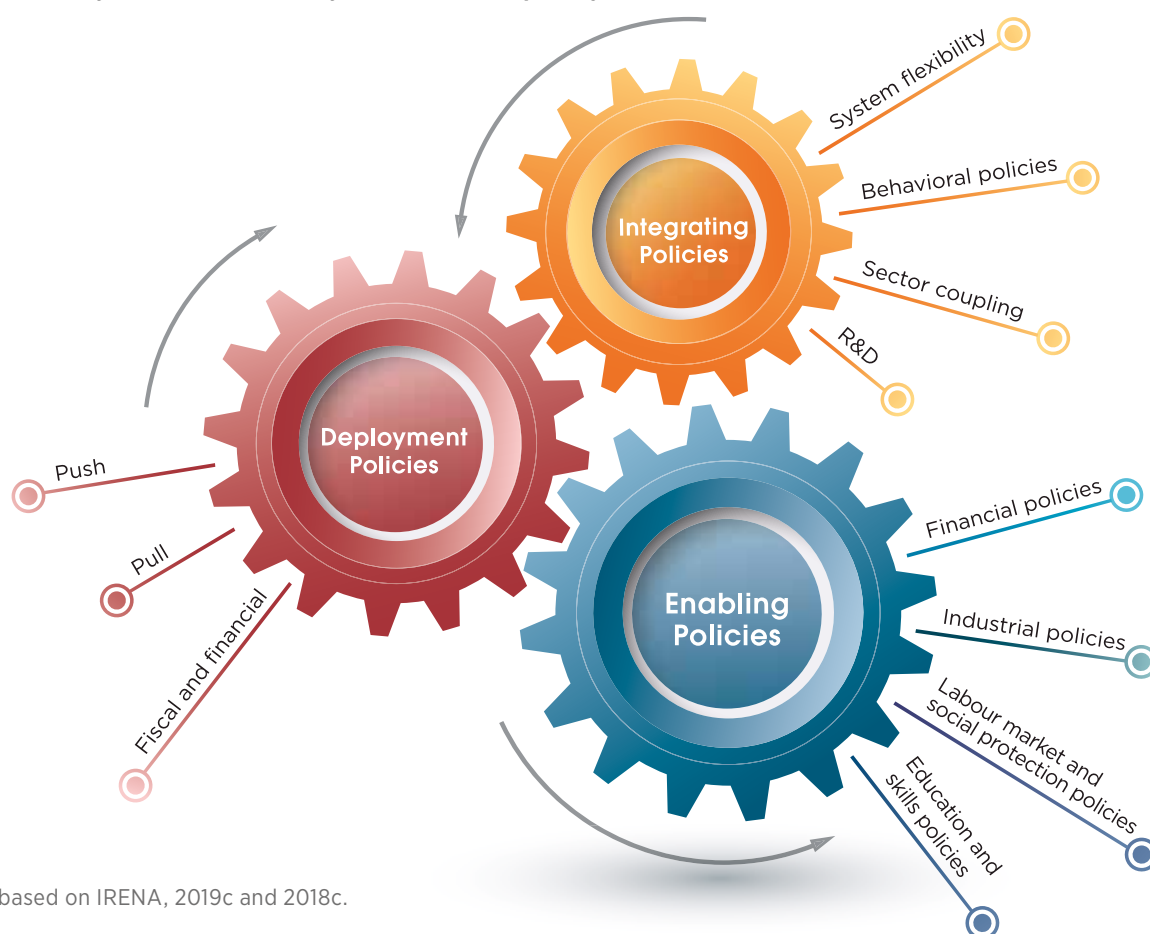
These larger dynamics are beyond the realm of energy policymakers but reinforce the need for a broad approach and cohesion among different government ministries and other stakeholders. The next section addresses core pillars of policy framework in support of just transition objectives.

5.3 Contours of a just transition policy framework

Maximising the employment benefits of renewables and energy efficiency while minimising transition costs requires a comprehensive policy framework to support a just transition.

The required framework rests on three transformative policy pillars – deployment, integration and enabling (see Figure 35) (IRENA, 2019c and 2018c).

Figure 35: Major elements of a just transition policy framework



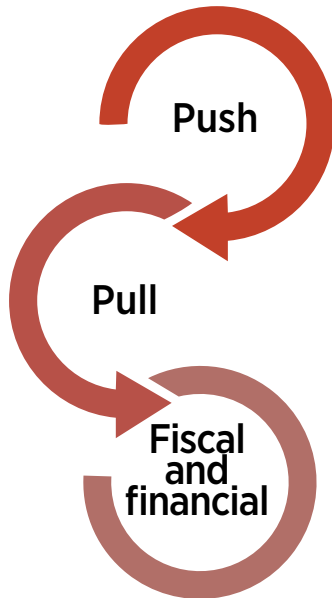
Source: based on IRENA, 2019c and 2018c.

²⁷ See, for example, World Economic Forum, www.weforum.org/agenda/2019/01/3-megatrends-for-the-factories-of-the-future/.



Deployment policies

Deployment policies are designed to support the installation of renewable energy capacities:



- **push policies** such as binding targets, quotas and obligations, as well as building codes and mandates (e.g., for solar water heaters);

- **pull policies** that include regulatory and pricing policies (e.g., feed-in tariffs and auctions), tradable certificates, tools that favour self-consumption (e.g., net billing and net metering), and other measures that help create markets for various types of renewables; and

- **fiscal and financial measures** such as incentives and investment credits, subsidies and grants to accelerate the uptake of renewable energy.

Policies may be undertaken at the national and state/provincial government level. Increasingly, however, cities are also getting involved, particularly where municipal authorities directly own local energy utilities or are otherwise actively engaged in producing or procuring energy.

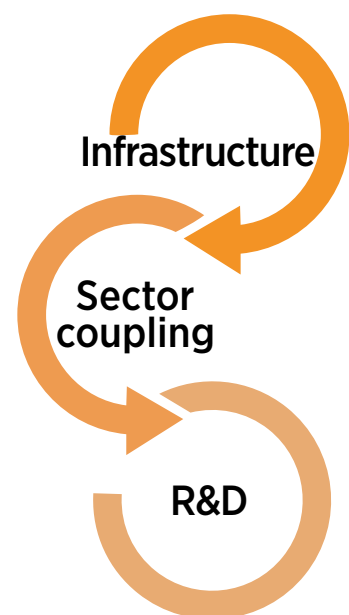
Integration policies

Integration policies facilitate the use of renewable energy in the energy system and enhance system flexibility as the share of variable renewables rises (IRENA, 2018c). This pillar includes the following:

- **National infrastructure policies** that place energy transition planning within a wider process of infrastructure provision. The deployment of renewables serves as a core strategy of infrastructure expansion (e.g., transmission and distribution networks; charging stations for electric vehicles; urban district heating and cooling networks, etc.).

- **Policies for sector coupling** that connect the building, transport and industry sectors with the power producing sector through electrification strategies, helping to generate demand for renewable energy products.

- **R&D policies**, such as those supporting the development of battery storage, are essential for advancing cross-sectoral integration and supporting the wider application of renewable energy technologies across the economy.

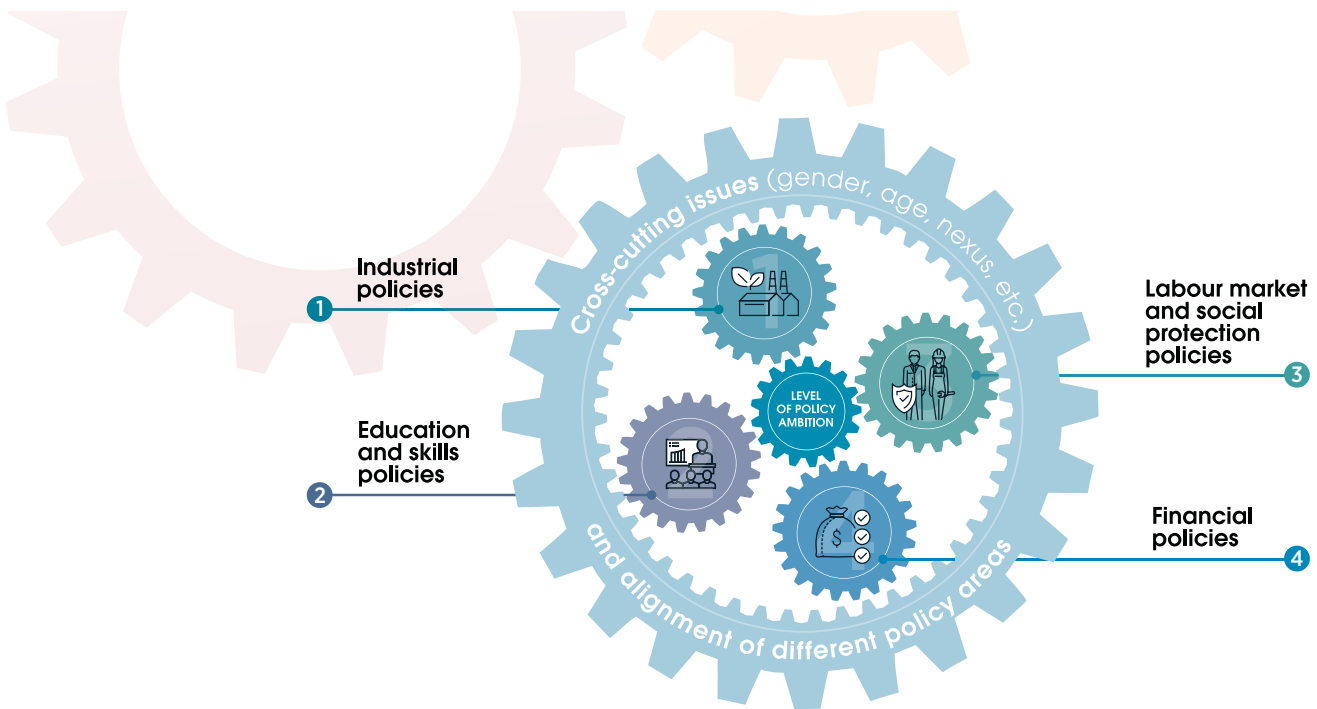


Enabling policies

This pillar's focus reaches far beyond the confines of measures that promote the deployment and integration of renewable energy into the energy system. It is also concerned with efforts to strengthen the alignment between the energy sector and the rest of the economy, so as to generate maximum benefits from the transition to renewables and energy efficiency and avoid or limit the burdens of adjustment.

Such burdens may emerge in light of the structural constraints and potential job misalignments discussed above. **Figure 35** shows enabling policies in the context of the three broad policy pillars, while **Figure 36** delves into the details of this pillar, showing its four components: industrial, labour market and social protection, education and skills, and financial policies (IRENA, 2019c and 2018c).

Figure 36: Enabling policy pillar of the just transition policy framework





(a) Industrial policies

Generally speaking, industrial policies harness, leverage and further enhance domestic capabilities in support of economic development and diversification. They encompass initiatives and programmes to incubate businesses, develop the capabilities of firms in the supply chain by providing low-cost loans and incentivising spill-overs, and promote key industry

clusters. In the context of the energy transition, industrial policy fosters renewable energy technologies as strategic sectors. In addition to pursuing public investment strategies in the renewables sector with the aim of job creation, governments can take a direct role in the following areas:

INDUSTRIAL POLICIES

- Low-cost emission sector focus
- Regional economic development/diversification
- Incentives, low-cost loans, business incubation and clusters
- Domestic supply chain development

- **design renewable-energy-focused research** and development strategies, and promote associated institutions to ensure uptake in the public and private sectors;
- **facilitate the creation of technical capacities** and technological transfer in renewables and energy efficiency through carefully-designed incentives;
- **incentivise supply chain participation** in renewable sectors by local firms, and actively support the creation of partnerships (IRENA, 2019f); and
- **establish direct links** to labour policy to translate targets and support measures into employment creation.

(b) Labour market and social protection policies

Forecasting skills needs (see below) and mapping labour market outcomes are pre-requisites for effective labour market intervention. Offering adequate employment services is essential (matching jobs with qualified applicants; promoting employee wellbeing; facilitating on- and off-job training; and employment safety nets), along with measures to facilitate labour mobility, such as relocation grants.

For workers displaced during the transition, income stability is essential. In part, this means developing policy incentives for employers to retain (and retrain) workers where possible. Flexible, longer-term employment contracts can promote job stability and employee welfare in a manner consistent with the needs of employers. But unemployment insurance and other programmes that offer social protection to those laid off are also important. Social protection measures need to offer support for vulnerable workers and their communities so that they do not shoulder an unfair burden of the energy transition.

Retraining and job facilitation should be closely monitored to regularly assess trends in jobs creation and loss. The created jobs could be inferior or superior in terms of employee satisfaction and pay, for example, and this should be taken into consideration when designing retraining programmes.

LABOUR MARKET AND SOCIAL PROTECTION

- Job shift forecast
- Unemployment insurance (social protection programmes)
- Labour mobility (relocation grant)

(c) Education and skills policies

In order to take full advantage of the job opportunities that emerge from the energy transition, a strong focus on STEM²⁸ education can help build/augment technological learning and know-how in the energy sector and the wider economy. Skills and education efforts should be introduced as part of degree programmes at universities, as well as in the form of short-term and evening certificate courses that help existing workers gain additional skills. Specialised training courses could be offered in collaboration with universities or relevant research labs to provide employees with specialised training opportunities. Governments should also promote collaboration and technology transfer opportunities from foreign suppliers as part of a long-term skill-building strategy.

Coordinated by government, strategic collaboration between universities, other educational institutions and renewable energy industries can help achieve several goals: incubation of knowledge; ensuring the industry relevance of public research; ensuring labour mobility of scientists and researchers as needed; and alerting scientific attention to the needs and opportunities of local production. All of this will be essential in strengthening supply chains for renewable energy sectors.

EDUCATION AND SKILLS POLICIES

- STEM education: on-the-job vocational training
- Skills demand and supply matching
- Re-skilling
- Skills transfer from abroad
- University-Industry collaboration

(d) Financial policies

FINANCIAL POLICIES

- Carbon pricing and revenue recycling
- Public investment strategy
- Sustainable finance initiatives
- New forms of transition cost-sharing

None of these goals can be achieved without adequate funding. The fluctuating amounts invested in renewable energy in recent years indicate the need for strong financial strategies in support of expanded deployment, as well as the broader just energy transition tasks outlined herein. Governments will need to marshal significant revenue streams through a variety of measures, including green bonds and carbon pricing. They will also need to devise revenue recycling schemes so that the revenues from updated fiscal policies can be channelled to support education, healthcare and other societal needs.

Revenues are needed to support strategic energy transition investments and supporting infrastructure, and to limit the financial burdens of carbon pricing on low-income families and small businesses. The “fiscal space” of government varies tremendously and depends on how robust and diversified a country’s economy is. The choice between expanded investments, revenue recycling, reductions of non-energy levies and other options thus depends on each country’s needs and circumstances. Countries without robust economic structures will face considerable challenges in mobilising the financial investments required for the transition.

²⁸ STEM education emphasises the redesign of curricula with a strong focus on four disciplines – science, technology, engineering and mathematics – and promotes the idea of stronger inter-disciplinary and applied approaches to education and training.



Conclusion

Deployment, integrating, enabling and financial policies are often regarded as distinct, unrelated policy areas. They are supported by disparate academic fields, speak different specialist languages and are anchored by separate government institutions and industry associations. Yet these divisions must be bridged in an effort to foster co-ordination and coherence in policy planning, design and implementation between the main policy pillars.

Only then can the requirements of the transition to renewables and energy efficiency be integrated with the economic ambitions of countries and with desired social outcomes such as employment, welfare, inclusion and overall prosperity. Governments must combine measures in these policy pillars in line with the economic and social context of each country or region.

Cross-cutting and coherent policy-making can deliver on climate and energy ambitions, and put in place a mix of programmes, projects and initiatives to generate successful outcomes. IRENA's work indicates that a strategic combination of well-designed deployment, integrating and enabling policies will create many millions of new jobs along the value chains of renewable energy and energy efficiency. The volume of new employment that is expected under an energy transition scenario consistent with commitments under the Paris Agreement surpasses the number of jobs that will be lost in fossil fuel industries.

This is good news, but gross numbers do not tell the full story. The patterns and profiles of job creation do not necessarily match those related to job losses across different geographies and time scales. This is why policymakers and other actors in society need to pay close attention. Misalignments that may emerge during the energy system transition can be avoided or limited with enough foresight and planning.

Looking forward, it is also essential for policies to be attuned to possible additional misalignments in end-use sectors (such as transportation, where shifts – e.g. from internal combustion engines to electric vehicles – are already beginning to make themselves felt). Throughout the wider economy, fundamental changes such as flexible automation and artificial intelligence will affect the creation and loss of jobs. Against this backdrop, efforts to minimise adjustment burdens and maximise broadly-shared gains need to be at the centre of just transition policies.

6

Annex: Methodological elements

Conceptual framework

IRENA's socio-economic footprint analysis of transition roadmaps uses a holistic approach to evaluate the socio-economic implications of specific transition roadmaps. It aims to produce insights that inform policy making to support and facilitate a sustainable and resilient transition.

Using integrated energy economy models allows IRENA to capture the impact of the multiple interactions between energy transition roadmaps and socio-economic outlooks.²⁹

A detailed description of the techno-economic characteristics of the transition roadmaps considered is inputted into the modelling framework and a set of comprehensive indicators is used to characterise the different dimensions of the socio-economic footprint, including welfare and jobs. (See: IRENA, 2016a, 2018a, 2019c for general modelling methodological elements).

A policy-driven analysis

A non-equilibrium and policy driven modelling framework is used because the main goal is to gain insights into what types of policies are required to support and enable the transition.

Different policy inputs are introduced in the analysis, including the phasing out of fossil fuels, fiscal policies and revenue balancing of government budgets.

How government budgets are managed has an important impact on socio-economic results.

The assumption built into the current socio-economic footprint analysis is that of a policy on revenue balancing through income taxes: Revenue gains/losses are recycled back to the population by way of a reduction/increase in income taxes,

which drives up/down households' disposable incomes and consumption, which in turn impacts GDP and labour dynamics. Other government budgetary policies are possible, with potentially significant socio-economic impacts.

Calibrating the modelling framework to monitored renewable energy jobs

The focus of this report is on jobs, which is one of the socio-economic areas most affected by the implications of the energy transition.

IRENA monitors the evolution of renewable energy jobs (IRENA, 2016b, 2019a) and forecasts the job implications of transition roadmaps (IRENA, 2013, 2016a, 2018a, 2019b, 2019c) for all renewables, the energy sector and the wider economy.

The modelling framework is continually being fine-tuned to capture the implications of the transition for the labour market – which are manifold – including in terms of renewables, energy efficiency, energy flexibility, fossil fuels, and impacts in other economic sectors through indirect and induced effects and because of investment crowding out.

Both workstreams (monitoring and forecasting) are brought together by using the monitored renewable energy jobs to calibrate the modelling framework. Once calibrated, the modelling framework allows for the 'filling-in' of monitoring gaps and projections of the implications of the transition on jobs in the future. Forecasting the time and regional dependency of the evolution of jobs in different sectors of the economy provides the data and insight needed to inform policy making for a just transition.

²⁹ The E3ME macroeconomic model developed by Cambridge Econometrics is used: <https://www.e3me.com/>



Measuring the socio-economic footprint as relative performance

The socio-economic footprint of Energy Transformation is defined in relative terms against Current Plans. This approach allows direct conclusions to be drawn on whether the Energy Transformation case performs better or worse than Current Plans, with a focus on the differential performance, which could otherwise be lost because of the high numeric value of absolute performance indicators (GDP, Jobs, Welfare).

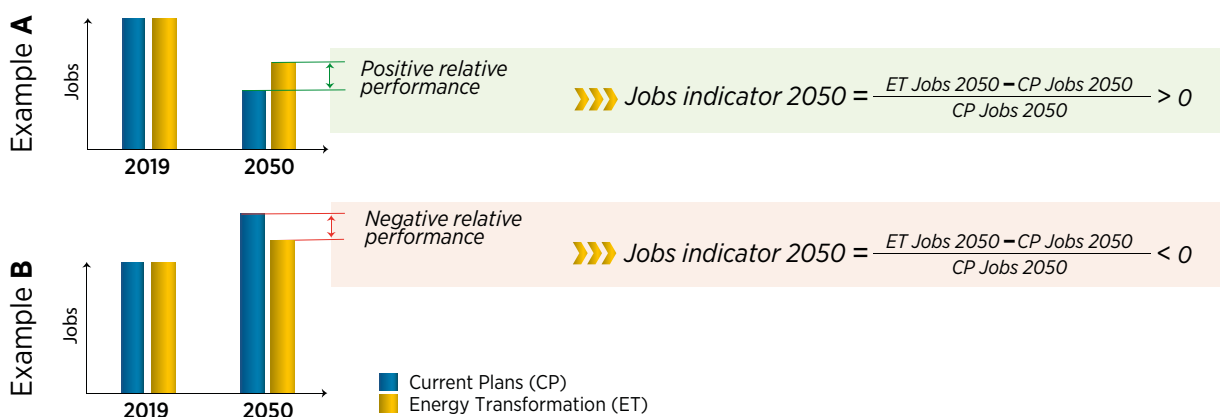
Hence, for any footprint performance indicator like jobs, besides presenting the results in terms of the absolute evolution of jobs in Energy Transformation and Current Plans, a 'jobs indicator' is used which evaluates the relative differential performance of Energy Transformation versus Current Plans, in such a way that at each point in time the jobs indicator is evaluated as:

$$\text{Jobs indicator} = \frac{(\text{Energy Transformation jobs} - \text{Current Plans jobs})}{(\text{Jobs under Current Plans})}$$

Figure A-1 presents two examples to facilitate the interpretation of the footprint indicator and its relationship with absolute performance and time:

- **Example A:** Both Energy Transformation and Current Plans present a negative absolute performance with time (lower number of jobs in 2050 than in 2019). Yet Energy Transformation has a positive relative performance in 2050, because for that year, jobs with Energy Transformation are higher than with Current Plans. Hence, both cases off negative absolute, time-dependent performance, likely due to structural causes. However, the Energy Transformation case still represents an improvement over Current Plans.
- **Example B:** Both Energy Transformation and Current Plans yield positive absolute performance with time (higher number of jobs in 2050 than in 2019). However, Energy Transformation shows negative relative performance in 2050, with lower jobs that year than from Current Plans. Hence, absolute time-dependent performance is positive for both scenarios, likely due to structural causes, yet the Energy Transformation case achieves relatively less than Current Plans.

Figure A-1: Obtaining the jobs footprint indicator from the absolute jobs performance of both Energy Transformation (ET) and Current Plans (CP)



Drivers of the socio-economic footprint

To gain insights on what drives the socio-economic footprint, the overall results are disaggregated in different drivers. The main drivers (investment, trade and induced & indirect effects) are common to the GDP and jobs footprints, so that the appropriate links between both can be made.

As discussed above, the socio-economic footprint is evaluated in terms of the performance of the Energy Transformation case relative to Current Plans. The drivers must be interpreted in this context. Hence, each one of the drivers must be understood as quantifying the differential impact. For instance, the investment driver presents the effect on the incremental Jobs or GDP from the differential investment with Energy Transformation relative to Current Plans.

Each one of the drivers captures the impact on the footprint from the following elements:

Changes in investment: this driver evaluates the impact on the footprints from overall investment in the economy and includes the effect of transition-related investment (renewables, energy efficiency, energy flexibility, grids, etc.), of fossil fuel and nuclear investment, and of investment in other sectors in the economy. Often the differential investment in each one of these investment categories presents different trends (i.e., the transition increasing investment in renewables and reducing investment in fossil fuels). The investment driver presents the net effect from all these trends.

Changes in trade: this driver evaluates the impact on the footprint from overall trade, including the effects of both energy and non-energy trade.

Induced and indirect effects: this driver evaluates the impact on the footprints from indirect and several induced effects, including reallocations of expenditure, fiscal policy effects, other induced effects and supply chain multiplicative effects. For the GDP footprint, this driver is further disaggregated in the following drivers:

- Changes in consumer expenditure due to fiscal policy changes: this captures the induced consumer effects due to changes in fiscal policy and associated government revenue balancing policies. Hence, under a revenue recycling policy like the one considered for this analysis, the increases or decreases in government revenue (due to various fiscal policies, fossil fuel royalties, fossil fuel phase-out, etc.) are balanced through a decrease or increase in consumer income levies that induces an increase or reduction in consumption.
- Aggregated consumer price effects: the relative evolution of the economy brings about a relative modification of aggregated consumer prices (including energy and general prices), which in turn induces changes in economic activity.
- Indirect and other induced effects: this includes indirect effects, which can arise from payments to producers in the supply chain, and other induced effects associated with changes of employment levels or wage rates for existing employees.



7

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