IRENA
International Renewable Energy Agency

WORLD ENERGY TRANSITIONS OUTLOOK 2023

1.5°C PATHWAY

VOLUME 2

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ABOUT IRENA

The International Renewable Energy Agency (IRENA) serves as the principal platform for international co-operation; a centre of excellence; a repository of policy, technology, resource and financial knowledge; and a driver of action on the ground to advance the transformation of the global energy system. An intergovernmental organisation established in 2011, IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy and geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity.

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WORLD ENERGY TRANSITIONS OUTLOOK 2023

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FOREWORD

As the world prepares for the 28th Conference of the Parties to the UNFCCC (COP28), ever more frequent and devastating weather events leave no doubt that the energy transition must accelerate immediately to avoid the catastrophic effects of climate change. Volume 1 of the *World Energy Transitions Outlook 2023*, released earlier this year, illustrated the pathway to a 1.5°C future in detail, and identified both progress and gaps across sectors and geographies.

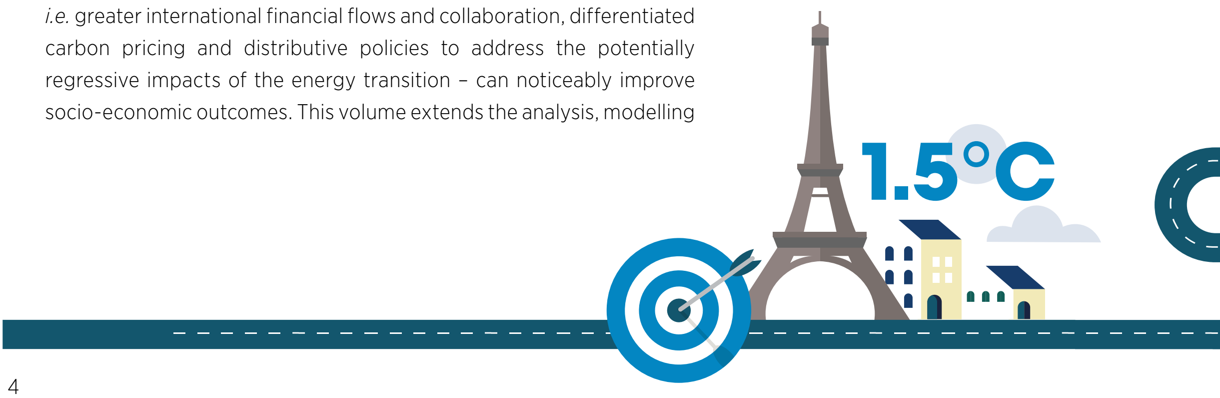
IRENA's work has long emphasised the need for a holistic approach to the energy transition, encompassing not only technological developments, but also socio-economic aspects. This requires an understanding of the far-ranging transformations that will unfold as the world moves from fossil fuels to renewables and greater energy efficiency.

This volume discusses the socio-economic impacts of IRENA's Paris Agreement-compliant 1.5˚C Scenario, compared to the Planned Energy Scenario, using the scenario roadmaps from Volume 1. It is based on IRENA's macro-econometric modelling work and provides policy makers with insights into how economic activity, employment and wellbeing may be affected under the 1.5°C pathway, compared to current policy settings. This analysis can assist countries to design policies that maximise the benefits of the energy transition and minimise adjustment burdens.

Any structural economic change will result in winners and losers; therefore, securing beneficial outcomes for all regions and peoples will require a broad set of policies. These must be guided by an understanding that the energy sector is essential to all human activity across the economy; that the economy ultimately exists to serve human well-being; and that economies and societies depend on the integrity of the planet's ecosystems.

Successful policy making must not be restricted to the energy sector alone; different government ministries and diverse stakeholders should be involved in decision making concerning the energy transition. Echoing the messages from previous editions of the Outlook, this volume outlines the comprehensive holistic policy framework required to deliver a just and effective energy transition.

In the 2022 edition, IRENA explored how progressive policies – *i.e.* greater international financial flows and collaboration, differentiated carbon pricing and distributive policies to address the potentially regressive impacts of the energy transition – can noticeably improve socio-economic outcomes. This volume extends the analysis, modelling



the effects of greater international collaboration, while a sensitivity analysis assesses the generation of additional transition revenues.

These measures can offer significant further improvements in GDP, job creation and welfare globally, but among poorer countries and regions in particular. Between 2023 and 2050, under the 1.5°C Scenario, global GDP and economy-wide employment could see an average annual increase of 4.3% and 2.1%, respectively. By 2050, the energy transition will increase energy sector jobs by 73 million compared to the current level.

We already have most of the tools we need to advance the energy transition, backed by extensive experience in designing policies to support the scale-up of renewable energy. Together with its companion Volume 1, this edition of the *World Energy Transitions Outlook 2023* provides critical insights on what lies ahead if we choose action. What is needed now is to translate this knowledge into urgent and ambitious policy making. It is my hope that the report will inspire policy makers and stakeholders to agree positive outcomes at COP28.

WORLD ENERGY TRANSITIONS OUTLOOK 2023

Francesco La Camera
Director-General
International Renewable Energy Agency

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ABBREVIATIONS

CAGR	compound annual growth rate
COP28	28th Conference of the Parties
CO_2	carbon dioxide
CSP	concentrated solar power
EU	European Union
G20	Group of Twenty
GDP	gross domestic product
GHG	greenhouse gas
Gt	gigatonne
$GtCO_2$	gigatonne of carbon dioxide
GW	gigawatt
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
IRQD	income relative quintile difference
kWh/p-d	kilowatt hours per person-day
MW	mining wages
OPEC	Organization of the Petroleum Exporting Countries
PES	Planned Energy Scenario
PB-A	Policy Basket A
PB-B	Policy Basket B
PV	photovoltaic
QR	quintile ratio
RCI	Responsibility Capacity Index
RQD	relative quintile difference
tCO_2	tonne of carbon dioxide
TFEC	total final energy consumption
USD	United States dollar
WRQD	wealth relative quintile difference

KEY MESSAGES

The socio-economic dimension of the energy transition is critical to its success. Achieving this transition hinges on three fundamental pillars: (1) physical infrastructure: (2) policy and regulatory enablers; and (3) skills and capacities. These elements are deeply interconnected and engage in continuous feedback loops with both the economy and societal structures. A thorough understanding of these interactions - particularly in terms of socio-economic factors like development, employment and social welfare - is critical for informed decision-making by policy makers across the world.

The energy transition presents a historic opportunity to address disparities in economic development. The adoption of domestically available resources and a transition in accordance with the 1.5°C Scenario, will result in a more inclusive and balanced development path for countries that have little or no fossil fuel resources. Progressive fiscal policies - such as carbon pricing differentiated by countries' income levels or greater international collaboration to support poorer countries - can bring about more equitable outcomes, as growth rates have traditionally varied significantly across different regions and countries.

The 1.5°C Scenario offers substantial GDP gains over a business-as-usual scenario, with the majority of developing countries advancing at a faster rate. Under the Planned Energy Scenario (PES) and following the repercussions of the COVID-19 pandemic, the world's real GDP would increase at a compound annual growth rate of 2.8% per year between 2023 and 2050. During the same period, under the 1.5°C Scenario, the world could witness an average additional annual GDP growth of 1.5% compared to the PES. Public investment plays a key role in driving the positive economic impact. The majority of developing countries would witness faster economic growth compared to advanced economies.

The energy transition brings employment gains across the economy. In the PES, economy-wide employment is expected to steadily increase, with an estimated average compound annual growth rate (CAGR) of 0.4%. The 1.5°C Scenario is expected to lead (in average annual terms) to 1.7% higher economy-wide employment than under the PES over the 2023-2050 period. The energy transition is also expected to increase energy sector employment, with renewable energy jobs potentially tripling from 2021 levels to about 40 million by 2050.

By 2050, alignment with the 1.5°C energy transition goal is projected to create an impressive 140 million jobs in the energy sector, a significant increase from the current 67 million. This is 40 million higher than under the PES in 2050. Under the 1.5°C Scenario, employment in the renewable energy sector is predicted to grow significantly, from the current 13.7 million jobs to 40 million by 2050. Over the same period, investments in other transition-related technologies (*i.e.* energy efficiency, power grids and energy flexibility, vehicle charging infrastructure, and hydrogen) could result in a substantial increase in job opportunities, with the sector expanding from today's 15 million jobs to an impressive 81 million. In stark contrast, jobs in the conventional energy sector are expected to half from the present 38 million to just 19 million by 2050.

Progressive policies are necessary to boost socio-economic benefits and spread them broadly. Substantial inequality prevails in the world economy. Achieving greater equity will require intensified international collaboration and structural change to ensure the benefits of the energy transition are distributed broadly and that burdens do not fall disproportionately on the poor. Recognising that priorities across countries may vary widely, the modelling exercise in this report assumes that governments' greater discretionary spending power will be directed towards public and personal services. Private investment – stimulated in part by greater public expenditure – is significantly higher between 2023 and 2030 under the 1.5°C Scenario than under the PES, accounting for 37.5% of the difference in GDP between the two scenarios.

Structural and systemic changes are needed for greater equity and welfare. Greater equity requires structural and systemic changes beyond the energy sector, addressing decades of unequal development. International financial flows – especially from the economically-advanced economies to emerging and developing economies – are essential in rectifying these imbalances, along with long-term commitments in terms of industrial policy, labour market measures, etc. Some recent approaches, such as The Bridgetown Initiative, are aligned with the projected positive impacts of the energy transition on GDP, employment and welfare. These policies are instrumental in transforming historical unequal development and relations, as corroborated by anticipated economic and welfare improvements.

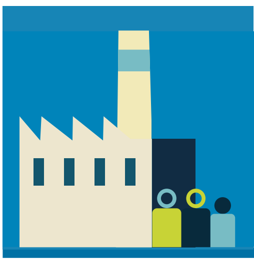
KEY NUMBERS

Improvement in global **gross domestic product (GDP)** compared to the PES's expected compound annual growth rate of 2.8%

An average annual additional GDP of

+1.5%

between 2023 and 2050 under the 1.5°C scenario



Average annual additional **economy-wide employment** compared to PES's expected compound annual growth rate of 0.4%

An average annual additional employment of

+1.7%

over the 2023-2050 period under the 1.5°C Scenario

Jobs in the energy sector under the 1.5°C Scenario

140 million

jobs in 2050 compared to today's 67 million

+40 million

additional jobs compared to the PES in 2050

Fossil-fuel job losses would require re-training and re-skilling for transition-related jobs.

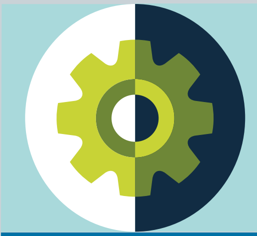
19 million
fossil fuel jobs in 2050 under the 1.5°C Scenario compared to today's 38 million

-17 million
fossil fuel jobs losses compared to the PES in 2050

Jobs in the renewable energy sector under the 1.5°C Scenario

39 million
jobs in 2050 compared to today's 13.7 million

+18 million
additional jobs compared to the PES in 2050



Jobs in other energy transition-related sectors under the 1.5°C Scenario

81 million
jobs in 2050 compared to today's 15 million

+38 million
additional jobs compared to the PES in 2050

Global welfare improvement in 2050 compared to the PES

+15%
under the 1.5°C Scenario

Significant
potential for improvement in social and distributional dimensions at the global level

EXECUTIVE SUMMARY

The world faces a number of interconnected crises of unparalleled magnitude. Climate change, biodiversity loss, volatile energy prices, lack of energy access and socio-economic inequality all present formidable challenges; combined, however, their effects intensify. Consequently, the pressing need to rapidly transition to a more sustainable energy sector and global economy has never been clearer.

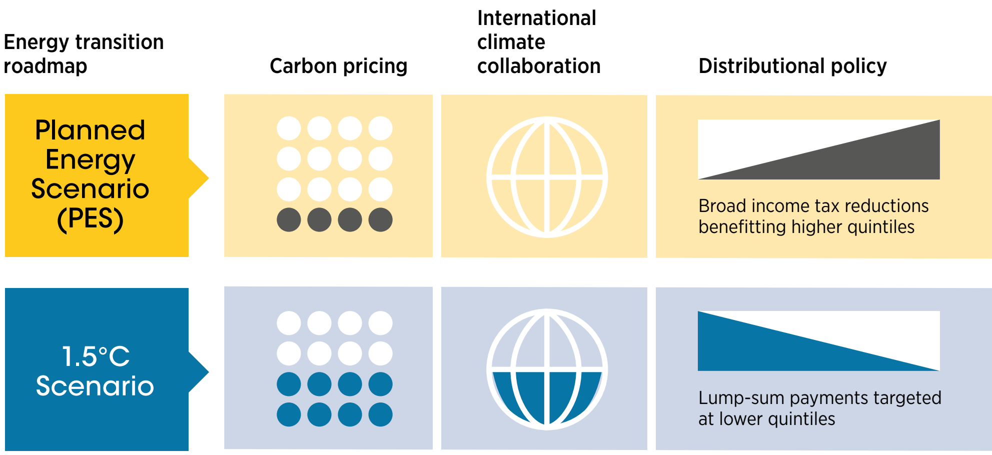
To date, policy makers have predominantly concentrated on the technological, institutional, regulatory and policy facets of the energy transition, with less attention to its socio-economic implications. This report contends that current transition narratives may not resonate with all stakeholders, largely due to their omission of central socio-economic dimensions. Whilst not exclusive to the energy transition, distributional issues (regarding income, wealth, investment and social expenditure, energy and materials use, climate change impacts, and others) should be addressed to maximise socio-economic benefits, and strengthen acceptance and support for the transition. Bridging gaps in climate policy ambition and fostering essential structural changes necessitate unparallel global collaboration.

IRENA's transition scenarios position renewables as the main energy source, with a rise in the global share from 16% in 2020 to 77% by 2050. Electrification of end-use sectors, energy efficiency improvements and renewable energy deployment would contribute to stabilising global energy consumption by 2050 compared to current levels. Volume 2 of the *World Energy Transitions Outlook: 1.5°C Pathway* analyses two energy roadmaps for the period to 2050: (1) a scenario based on current plans, the Planned Energy Scenario (PES); and (2) an ambitious energy transition scenario (1.5°C Scenario) that aims to achieve the 1.5˚C goal of the Paris Climate Agreement. IRENA's 1.5°C Scenario sees a rise in the share of renewable energy in the global primary energy supply mix from 16% in 2020 to 77% by 2050.

Climate change, biodiversity loss and socio-economic inequality demonstrate the urgency of the global energy transition.

IRENA's analysis shows that international financial collaboration can be a central factor in improving the socio-economic outcomes of the transition. This report discusses the socio-economic impacts of the IRENA 1.5°C Scenario compared to the Planned Energy Scenario (PES) and provides an update of the socio-economic results presented in the 2022 edition of the Outlook (Figure S1).

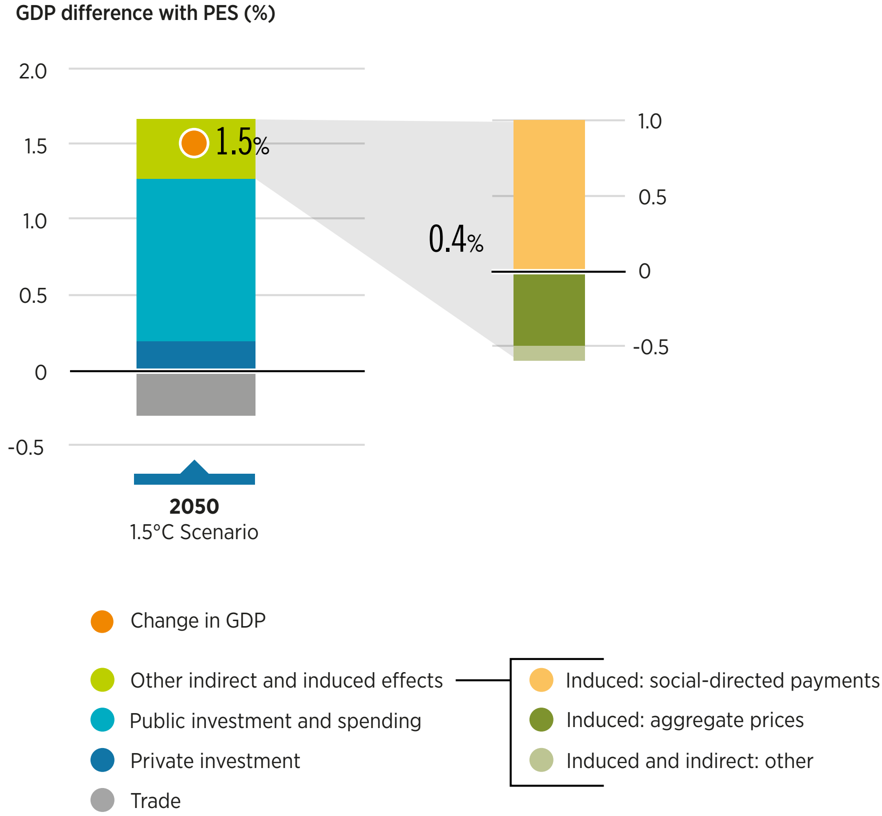
FIGURE S1 **Policy assumptions underlying the analysis of IRENA's energy transition scenarios.**



An ambitious energy transition holds great promise for boosting the global economy. Compared to the PES, between 2023 and 2050, global GDP would see an average annual increase of 1.5% under the 1.5°C Scenario (Figure S2). Public investment plays a key role in driving the positive economic impact. Investment – together with other indirect and induced effects are the main macroeconomic drivers that generate differences in GDP growth throughout the transition period (*i.e.* 2023–2050).

Public Investment in the energy transition drives robust GDP growth and paves the way for a just and inclusive transition.

FIGURE S2 **Global GDP, average percentage difference between the PES and 1.5°C scenario, 2023-2050.**

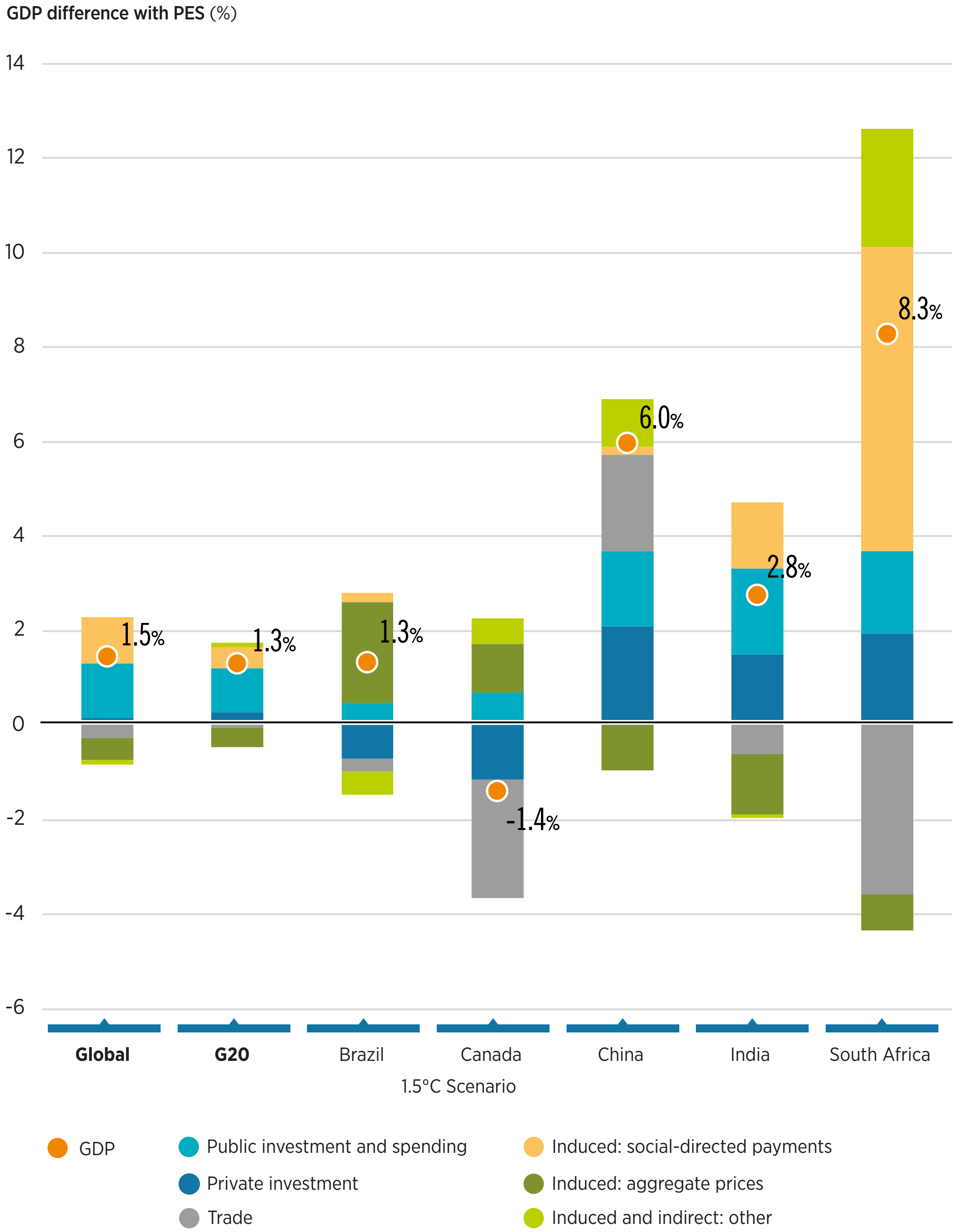


Note: GDP = gross domestic product; PES = Planned Energy Scenario.

However, growth rates vary markedly across regions and countries, highlighting disparities in economic development and underscoring the imperative for inclusive economic strategies. While Africa's per capita GDP is set to double, the continent's resource-rich countries will likely see faster growth, exacerbating regional inequalities. In Europe, economic disparities may also be amplified. Meanwhile, emerging economies like India and China are poised for significant growth, potentially reshaping the global economic landscape. This analysis explores the outcomes of diverse progressive policies designed to address mounting global concerns, including fairness, justice and equality, while advancing the global energy transition.

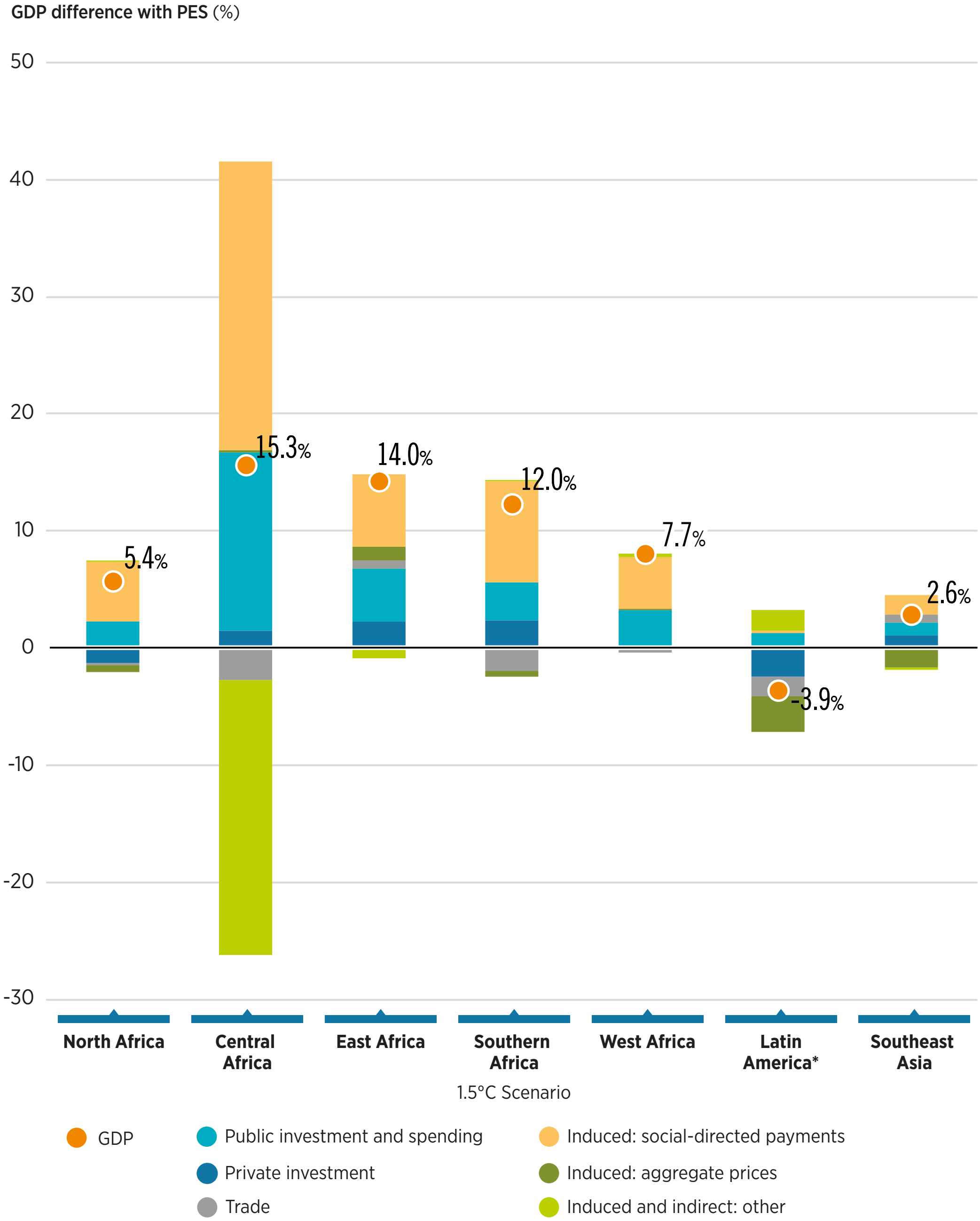
Drivers for economic outcomes differ. For a few G20 countries, such as India and China, the investment driver is the strongest factor boosting results over the PES (Figure S3). Trade is also an important driver in countries such as Canada, China and South Africa, due to their economic structures. For the vast majority of developing countries, induced social-directed payments are an important, and sometimes dominant, factor in GDP differences between the scenarios.

FIGURE S3 **GDP in selected countries/regions, average percentage difference between PES and 1.5°C Scenario, by driver, 2023-2050**



Note: G20 = Group of Twenty; GDP = gross domestic product; PES = Planned Energy Scenario.

FIGURE S3 **GDP in selected countries/regions, average percentage difference between PES and 1.5°C Scenario, by driver, 2023-2050** (continued)

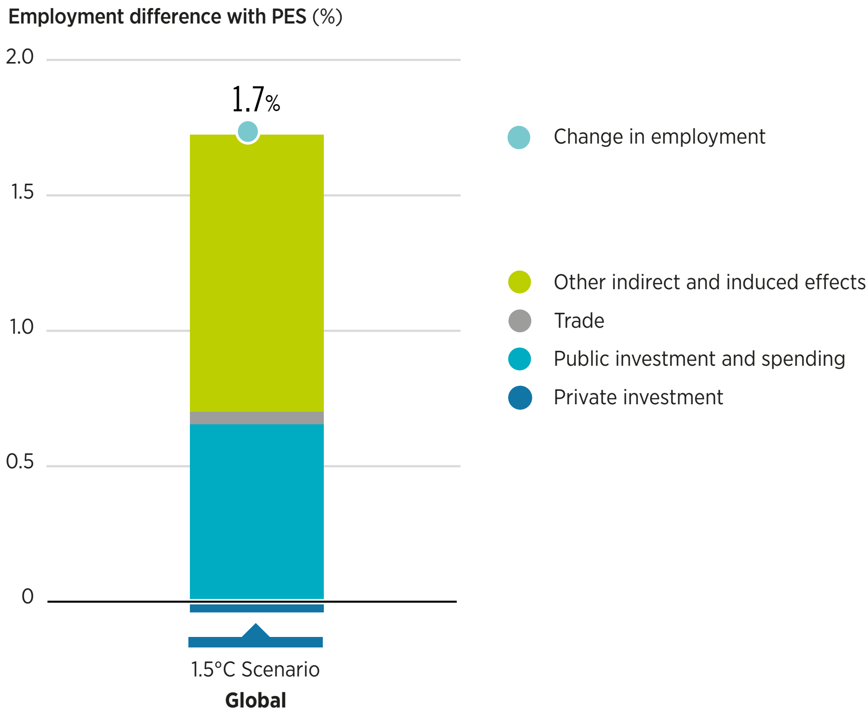


Note: *Excluding Argentina, Brazil and Colombia; G20 = Group of Twenty; GDP = gross domestic product; PES = Planned Energy Scenario.

The 1.5°C pathway would lead to a 1.7% increase in average annual employment over the PES in the 2023-2050 period.

The 1.5°C pathway would create more employment throughout the economy. The 1.5˚C Scenario would lead to, in average annual terms, 1.7% higher economy-wide employment than the PES over the 2023-2050 period (Figure S4). Reflecting front-loaded investments, global economy-wide annual employment would be 1.8% greater on average in the years to 2040, but only 1.5% higher in the final decade (2041-2050).

FIGURE S4 Global economy-wide employment, average percentage difference between PES and 1.5°C Scenario, by driver, 2023-2050

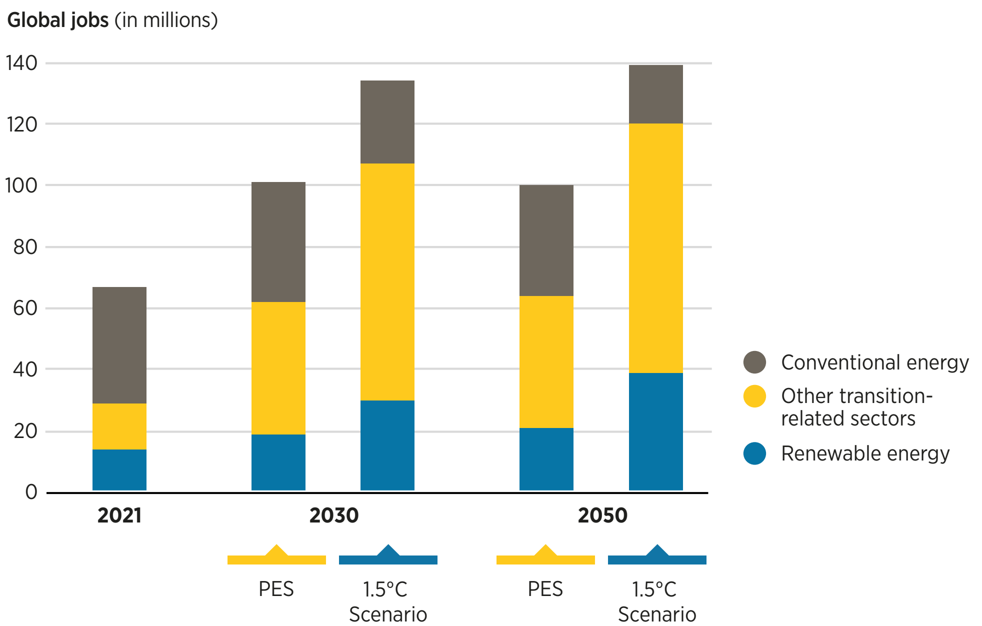


Note: PES = Planned Energy Scenario.

The energy transition will increase energy sector employment. Given front-loaded investments, by 2030 the number of jobs in the energy sector could grow to 101 million under the PES. Under the 1.5°C Scenario, the number would be 134 million – double the current 67 million (Figure S5). Between the PES and 1.5˚C Scenario, substantial job losses in fossil fuels (around 12 million) are more than offset by gains of 45 million jobs in the energy transition – namely in renewables (around 11 million) and other energy transition-related sectors (energy efficiency, power grids and flexibility, vehicle charging infrastructure and hydrogen at around 34 million) by 2030. Employment changes after 2030 are marginal.

Under the 1.5°C Scenario, renewable energy sector employment is expected to triple from 2021 levels to about 40 million jobs worldwide by 2050. Solar energy jobs are expected to rise to around 18 million (*i.e.* around 45% of the total renewable energy jobs) by 2050 under the 1.5°C Scenario, almost a four-fold increase compared to 2021. Wind energy will also see high job creation and is expected to rise five-fold from 2021, reaching over 6 million (around 17% of the total renewable energy jobs). Bioenergy jobs will grow from over 4 million (33% of renewable jobs) in 2021 to over 10 million (27% of renewables jobs) in 2050.

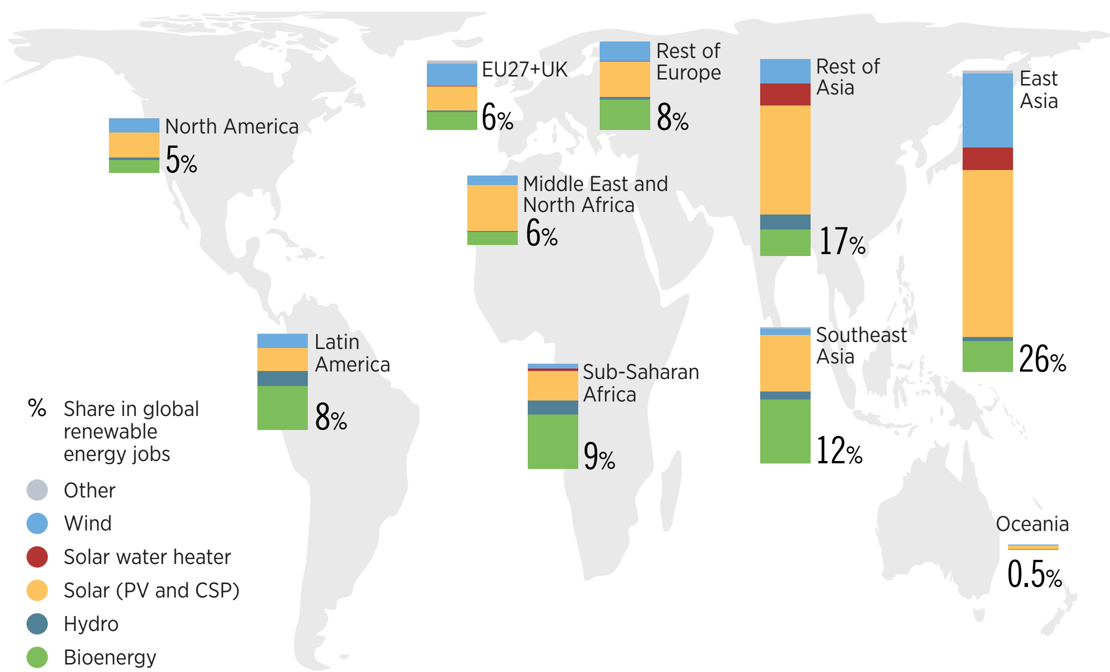
FIGURE S5 **Global energy sector jobs in the PES and 1.5°C Scenario, 2021-2050**



Note: PES = Planned Energy Scenario.

However, these jobs are unevenly distributed across regions. Figure S6 shows the regional and technological distribution of renewables jobs under the 1.5°C Scenario by 2050. Asia is expected to account for a 55% share of global renewable energy jobs, followed by Europe at 14%, the Americas at 13% and Sub-Saharan Africa at 9%. Whilst factors like the size of populations and economies influence regional distribution, these outcomes will also reflect the extent to which countries are able to scale up the deployment of renewable energy and whether they have significant domestic supply chains in place.

FIGURE S6 **Share of renewable energy jobs by region, 2050**

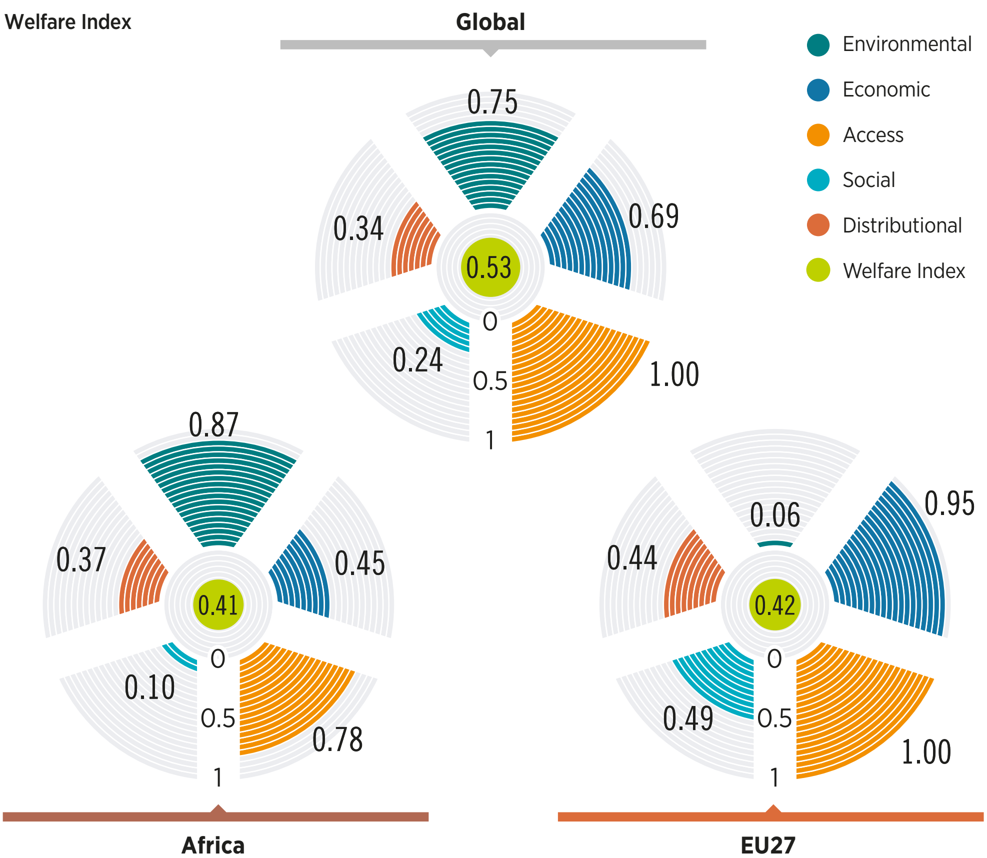


Note: "Other" includes geothermal and tidal/wave. CSP = concentrated solar power; EU = European Union; PV = photovoltaic; UK = United Kingdom.

Connecting the socio-economic and technological/regulatory facets of the energy transition necessitates policy interventions that transcend the shift from fossil fuels to renewables. Policy makers must aim for coherence between energy policy and other national policies over the long term to promote an inclusive and just energy transition. The latter must keep people at its heart and embrace diversity and inclusion across several population demographics (*e.g.* women, youth, older workers, people with disabilities, migrant workers, indigenous people, unemployed people, vulnerable workers). In addition to the specific economic and employment benefits discussed above, a key advantage of the energy transition lies in its ability to improve overall global welfare. IRENA measures potential welfare impacts through its welfare index. The index consists of five dimensions – economic, social, environmental, distributional and access – each one informed by two sub-indicators.

There is significant potential for improvements in the social and distributional dimensions at the global level. Figure S7 shows there is lesser yet noteworthy potential in the economic and environmental dimensions. This remains true even under the 1.5° C Scenario with the implementation of strong policies targeting these dimensions - particularly social and distributional aspects.

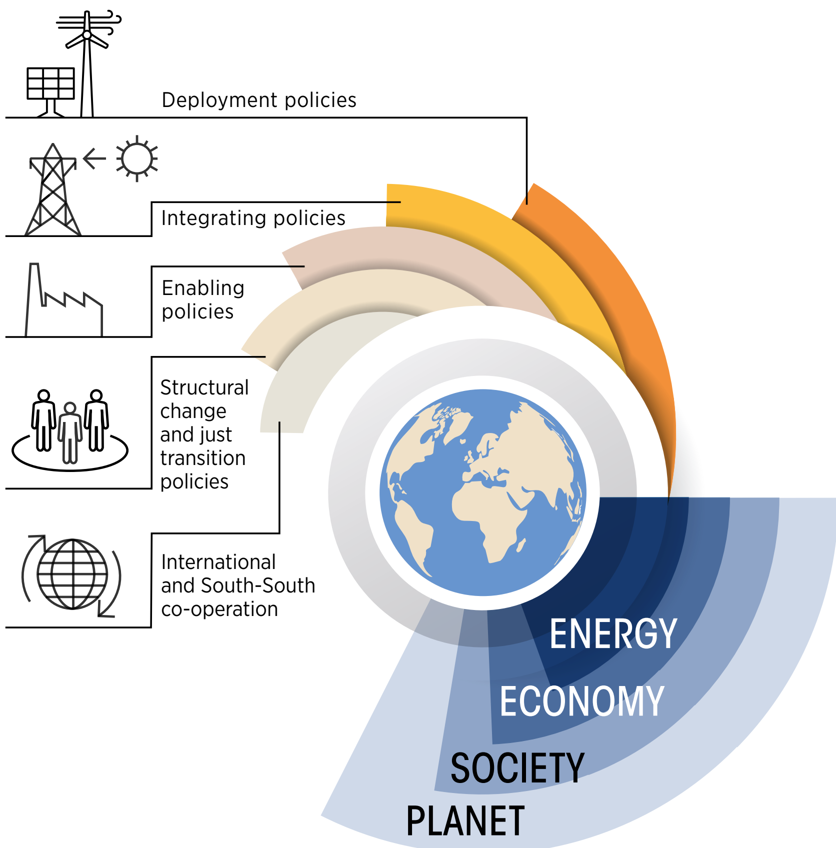
FIGURE S7 **Overall welfare index and dimensional welfare indexes for the 1.5°C Scenario by 2050: Global, Africa and EU27**



Note: The five petals are on a scale from 0 (low performance) to 1 (high performance) and represent the absolute values of the five dimensions of the Welfare Index. The number in the centre is also on a scale from 0 to 1 and represents the absolute value of the overall Welfare Index.

Achieving a just, inclusive and more sustainable world cannot be solely entrusted to market forces. Priorities must be determined in open debate, with policy choices guided by social dialogue. Governments and stakeholders must actively partake in reshaping economic and social structures. This reiterates a foundational premise in IRENA's socio-economic reports: policy making must be inspired by a holistic framework that balances technological considerations with social, economic and environmental imperatives (Figure S8).

FIGURE S8 **A comprehensive policy framework for the energy transition**



CHAPTER 01

INTRODUCTION

Current pledges and plans fall far short of IRENA's 1.5°C pathway, and will result in a 16 $GtCO_2$ emissions deficit by 2050.

The world faces a series of unprecedented and intertwined crises that pose serious challenges for the stability of economies and societies. Individually, fossil fuel price shocks, climate change, biodiversity loss and socio-economic inequality are all serious problems; but the interactions among them amplify their effects. It is becoming increasingly urgent to accelerate the transition to a more sustainable energy sector and global economy. A range of mature, competitive and commercially viable technological options are available, with others in development, and the policies required to facilitate renewable energy deployment are well understood, yet this acceleration has not occurred.

This report contends that an essential element remains largely absent in transition planning and policy making; the socio-economic dimension – ensuring widespread sharing of benefits – is critical to the success of the transition, yet to date limited attention has been paid to it in most settings, with a tendency to focus on technological and some microeconomic aspects.

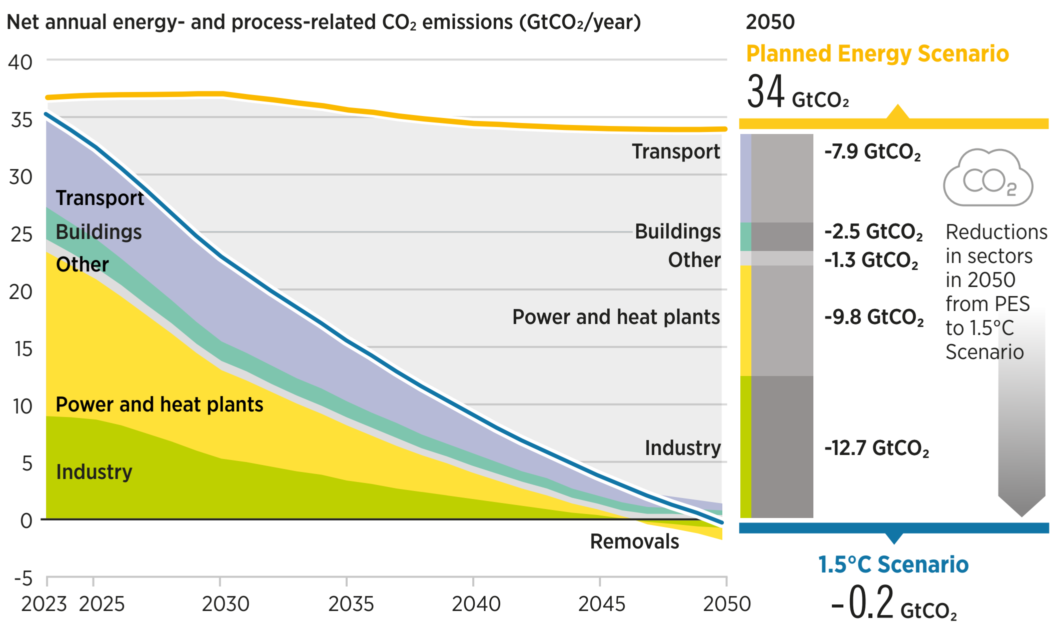
This report presents the socio-economic impacts of the energy transition scenarios detailed in Volume 1 of the *World Energy Transitions Outlook 2023* (IRENA, 2023a). Two energy roadmaps for the period to 2050 are analysed: (1) a scenario based on current plans, the Planned Energy Scenario (PES)[1]; and (2) an ambitious energy transition scenario (1.5°C Scenario)[2] that aims to achieve the 1.5˚C goal consistent with the Paris Climate Agreement. The analysis provides a pathway to limiting global warming by reducing carbon dioxide (CO_2) emissions by 37 gigatonnes ($GtCO_2$) from estimated levels in 2022 and attaining net-zero energy sector emissions by 2050 (Figure 1.1). Current pledges and plans fall short of IRENA's 1.5°C pathway, resulting in a 16 $GtCO_2$ emissions deficit by 2050.

[1] *This is the reference case, providing a perspective on energy system developments based on based on governments' energy plans and other planned targets and policies in place at the time of analysis, with a focus on G20 countries.*

[2] *This scenario describes an energy transition pathway aligned with the 1.5°C climate goal to limit global average temperature increase by the end of the present century to 1.5°C, relative to pre-industrial levels. It prioritises readily available technology solutions, which can be scaled up to meet the 1.5°C goal.*

Annual deployment of 1000 GW of renewable power is needed, each and every year, to stay on a 1.5°C pathway. Globally, 300 GW of renewables were installed in 2022, making up 83% of new capacity, while fossil fuel and nuclear additions made up only 17%. IRENA's 1.5°C scenario sees a rise in renewable energy in terms of primary energy supply from 16% in 2020 to 77% by 2050. Electrification of end-use sectors, energy efficiency improvements and renewable energy deployment would contribute to stabilise global energy consumption by 2050 compared to current levels. Expressed in 2021 values,[3] investments of over USD 5 trillion per year are needed to achieve the 1.5°C climate target by 2050, totalling USD 150 trillion cumulatively. The global energy system must be entirely transformed over the course of 30 years. To maximise energy transition benefits, countries need a comprehensive policy framework that transforms energy systems while protecting people, livelihoods and jobs.

FIGURE 1.1 **Estimated trends in global CO_2 emissions under the Planned Energy Scenario and 1.5°C Scenario, 2023-2050**



Source: (IRENA, 2023a).

Note: $GtCO_2$ = gigatonne of carbon dioxide; PES = Planned Energy Scenario.

[3] *Throughout this report, dollar values are expressed in 2021 terms.*

IRENA analyses the socio-economic footprint of its energy transition scenarios with the help of a methodology developed and refined over several years (IRENA, 2016, 2018, 2019a, 2020, 2021a, 2022a, 2022b, 2023b, 2023c).

In the 2021 edition of the *World Energy Transitions Outlook*, IRENA explored how progressive policies – international collaboration informed by equity and justice considerations, differentiated carbon pricing and redistribution to address the potentially regressive impacts of the energy transition – can improve socio-economic outcomes (IRENA, 2021a). The analysis showed that international financial flows far greater than current pledges are needed to improve welfare results, which in turn may be assumed to raise the acceptance of transition measures among the general public.

IRENA explored the impact of heightened international collaboration, finding that it leads to very significant improvements for regions and countries that otherwise would experience the least benefits (or even suffer negative impacts) from the transition (IRENA, 2022c; IRENA and AfDB, 2022a). At the same time, the effects were almost neutral for the regions and countries expected to benefit more from the energy transition - an outcome that could greatly contribute to the political feasibility of a successful transition. Significant gaps persist nonetheless, with some regions still scoring very low on several welfare dimensions.

To illustrate potential further improvements in the socio-economic outcomes of the energy transition, the modelling exercise underlying this report makes a number of assumptions relating to the use of expanded public sector revenues. The report does so with the understanding that actual policy choices and decision-making processes in countries around the world tend to vary widely, driven by a complex set of social, economic and political contexts. At the individual national level, these choices may or may not be aligned with the broad assumptions underlying the modelling work. At the international level, the modelling presupposes a high degree of co-operation but it should be noted that this report is not intended to engage the important question of whether – or how – sovereign actors might implement such policies in diverse and potentially challenging political circumstances. Instead, it seeks to illustrate the extent to which such measures can, in principle, broaden the manoeuvring space and contribute to improved socio-economic outcomes.

The remainder of this chapter summarises the key policy measures associated with IRENA's 1.5°C Scenario. Chapter 2 examines socio-economic impacts under these conditions, analysing modelling results in terms of GDP and employment. Chapter 3 offers a detailed analysis of IRENA's multi-dimensional welfare index results. Chapter 4 addresses the need for a broad framework of common policies that could help bring about these positive changes.

The negative impacts of climate change are likely to be greater in developing countries.

In exploring the impact of policies designed to address social and economic structures that affect the way in which the energy sector is reshaped, the goal is to broaden the transition narrative in ways that can yield greater support for a global collaborative effort to address common challenges.

IRENA's Planned Energy Scenario (PES), which sketches the development of the energy sector through 2050 under current policies, acts as a baseline against which to measure the implications and performance of the 1.5°C Scenario. The PES is based on policies that have already been announced by governments or are currently under implementation, whereas the 1.5°C Scenario rests on a basket of more ambitious policies.

International collaboration is an important component of the policy basket in the 1.5°C Scenario. Although the accumulated carbon in the atmosphere stems mainly from emissions by developed countries, the effects of climate change are likely to have a greater impact on developing countries owing to their lack of social and physical infrastructure for climate change adaptation and resilience. To build their resilience and advance the energy transition at home, developing countries will require support from economically advanced countries. One source of funding is incorporated into the model's framework for international co-operation[4] *i.e.* government contributions. Table 1.1 provides a summary of the scenarios analysed in this report.

TABLE 1.1 IRENA energy transition scenarios and their policy measures

	PES	1.5°C Scenario
Policy basket	Energy and socio-economic policies already announced or currently under implementation	Supportive policies with international collaboration and redistribution

[4] *In cumulative terms these sources produce the same finance resources in the 2023-2050 period.*

Bridging gaps in climate policy ambition will require an unprecedented global collaborative effort. A transition narrative that includes equity, justice and inclusive development as fundamental objectives may be able to mobilise broad social and political support. This is essential given that societies will need to accelerate climate action to make up for past inaction. With global warming having already passed 1.2°C (Forster *et al.*, 2023; Sanderson, 2023) every fraction of a degree matters in mitigation efforts. It is ironic that societies may be caught between rising climate impacts from limited ambition in the past and the socio-economic disruptions of accelerated transition action undertaken now. The task at hand is daunting but achievable.

- The *inclusive development* component stands for globally shared prosperity. Structural changes in the economy are a key component for opening up space for inclusive development within planetary boundaries[5] (Brand *et al.*, 2021; Ensor and Hoddy, 2021; Richardson *et al.*, 2023; Rockstrom *et al.*, 2023) and limiting global warming so that it does not jeopardise development itself.
- The *justice* component concerns not leaving anyone behind. One aspect addresses the challenges that fossil-fuel-dependent workers, communities and countries encounter, including misalignments in the labour market. A second aspect concerns limiting the regressive impacts of otherwise positive transition policies such as carbon pricing, or energy efficiency standards and building mandates that raise housing costs for people with low incomes.
- The *equity* component focuses on how to equitably address the burdens and benefits stemming from the transition while contributing to globally shared prosperity. It accounts for distributional aspects of emissions, energy, income, wealth, and opportunities.

A holistic approach to the transition brings together the physical and technological dimension of the transition (with the aim of deploying renewables and other energy transition solutions in responsible, sustainable and clean ways) with the socio-economic dimension.

[5] *The latest scientific assessment of nine planetary boundaries finds that six of them have already been crossed. In addition to climate change, they concern biosphere integrity, land systems, freshwater, biogeochemical flows, and novel entities. The remaining three boundaries our ocean acidification, atmospheric aerosol loading, and stratospheric ozone depletion (Richardson et al., 2023).*

CHAPTER 02

TRANSITION SCENARIOS AND THEIR ECONOMIC IMPACTS

The energy transition encompasses far more than just technological developments and the policies to drive the transformation of the energy system; it signals profound shifts that will affect global economies and societies. Grasping the nature and extent of these changes is vital for effective policy making and for ensuring a fair and inclusive transition. Countries are making progress toward the 1.5°C goal in different contexts and at different speeds, with diverse societal and economic implications.

To assess how the energy transition will affect gross domestic product (GDP), employment and welfare, IRENA uses a modelling framework to connect the world's energy systems and economies. Results of previous analyses suggest that transitioning to a 1.5°C Scenario would boost economic activity, job opportunities and welfare more than the Planned Energy Scenario (PES), assuming an appropriate policy framework were in place (IRENA, 2021b, 2022d, 2022c; IRENA and AfDB, 2022a; IRENA and ILO, 2022, 2023a, 2021).

IRENA's analysis explores the socio-economic outcomes resulting from the assumptions contained in its scenarios (see Box 2.1). Those scenarios include a range of measures to support a just and inclusive transition. Among them are carbon pricing, international collaboration, subsidies, progressive fiscal regimes to address distributional aspects, investments in public infrastructure, and spending on social initiatives.

This chapter provides insights into how certain policies can deliver the highest possible benefits. It also shows how results vary according to policy measures and underlying economic structures and dependencies. These findings delineate the substantial differences between the 1.5°C Scenario and the PES. Section 2.1 explains the basic indicators of the PES.

Transitioning to a 1.5°C Scenario would boost economic activity, job opportunities and welfare.

BOX 2.1 IRENA's climate policy assumptions

Holistic planning and synergistic implementation can address the multiple interactions between the energy, economy and social systems more successfully than an approach that relies on a limited number of disconnected interventions. IRENA's socio-economic footprint analysis includes in its modelling a very diverse set of policies to enable and support a fair, equitable and sustainable energy transition.

Carbon pricing provides a powerful example. The level of carbon pricing needed to bring about a successful energy transition depends on the effective implementation of accompanying policies. Since IRENA's analysis includes a diverse set of policies, transition goals can be achieved with significantly lower carbon prices than might otherwise be required.

IRENA's socio-economic analysis assesses the following set of policies:

- Mandates to phase out the subsidisation and use of fossil fuels.
- Carbon pricing that evolves over time, differentiates prices by each country's income level and accords special treatment to sectors having high direct impacts on people (such as household power and road transport).
- Policies to link international development co-operation with transition requirements (*e.g.* earmarking aid funds for transition-related investments or greater social spending).
- Direct public investment and spending to support the transition, with a special focus on enabling infrastructure (electric vehicle charging stations, hydrogen infrastructure, smart meters, and so on) and energy efficiency.
- Domestic progressive redistributive policies.
- Public involvement in addressing stranded assets, both domestically and internationally.
- Policies to align government fiscal balances with transition requirements and to address domestic distributional issues.

2.1 The Planned Energy Scenario (PES)

From the perspective of macroeconomic indicators

Under the PES, the world's economy is expected to experience strong economic growth, as envisioned in the baseline assumption of the E3ME model, a global, macro-econometric model owned and maintained by Cambridge Econometrics.[6] Under this baseline and following the repercussions of the COVID-19 pandemic, the world's real GDP would increase at a compound annual growth rate of 2.8% per year between 2023 and 2050. This expansion rate has significant negative consequences for the planet's resources and ecosystems, given current policy settings. The PES underscores that, although there will be a substantial reduction in the energy and carbon intensity of the global economy relative to current levels, these reductions will not be enough to meet the challenges of climate change.

[6] *In the E3ME model (www.e3me.com), baseline forecasts are constructed using a comprehensive set of international data sources. The main source for population data is the United Nations (World Population Prospects); for GDP forecasts, the main sources are the International Monetary Fund for short-term forecasts and, for long-term forecasts, the European Commission (Annual Ageing Report) and International Energy Agency (World Energy Outlook). These are applied to historical data from the World Bank, International Monetary Fund and European Commission (AMECO, Eurostat).*

TABLE 2.1 Assumptions on GDP, labour force and population growth under the Planned Energy Scenario

	Compound annual growth rate (%)		
	2023-2030	**2031-2040**	**2041-2050**
Real gross domestic product	2.4	3.2	2.7
Economy-wide employment	0.5	0.4	0.2
Total population	0.9	0.7	0.6

The world's population is projected in the baseline to grow at a compound annual growth rate of 0.7% over the 2023-2050 period, to reach 9.7 billion by 2050 (Table 2.1). Economy-wide employment is also expected to rise by an average of around 0.4% per year over the same period.

From the sectoral perspective

Changes under the PES in the sectoral distribution of gross value added at the global level between 2023 and 2050 are shown in Figure 2.1. Basic manufacturing remains a leading industry due to the abiding need for manufactured goods. Distribution and retail show consistent growth, reflecting a growing consumer market, while the construction industry also shows a major upswing, particularly in the last years of the PES. Also on the rise is transport, which bodes well for developing worldwide transport infrastructure in anticipation of electric vehicles. By 2050, business services will have made the most significant contribution to global value added, highlighting the growing importance of the service sector to the global economy. As a result of the global movement away from coal and the pledges made by various countries to phase out coal altogether, the coal sector experiences a steep fall after 2022. The similar trajectories of oil, gas and manufactured fuels suggest a peak in the mid-2020s.

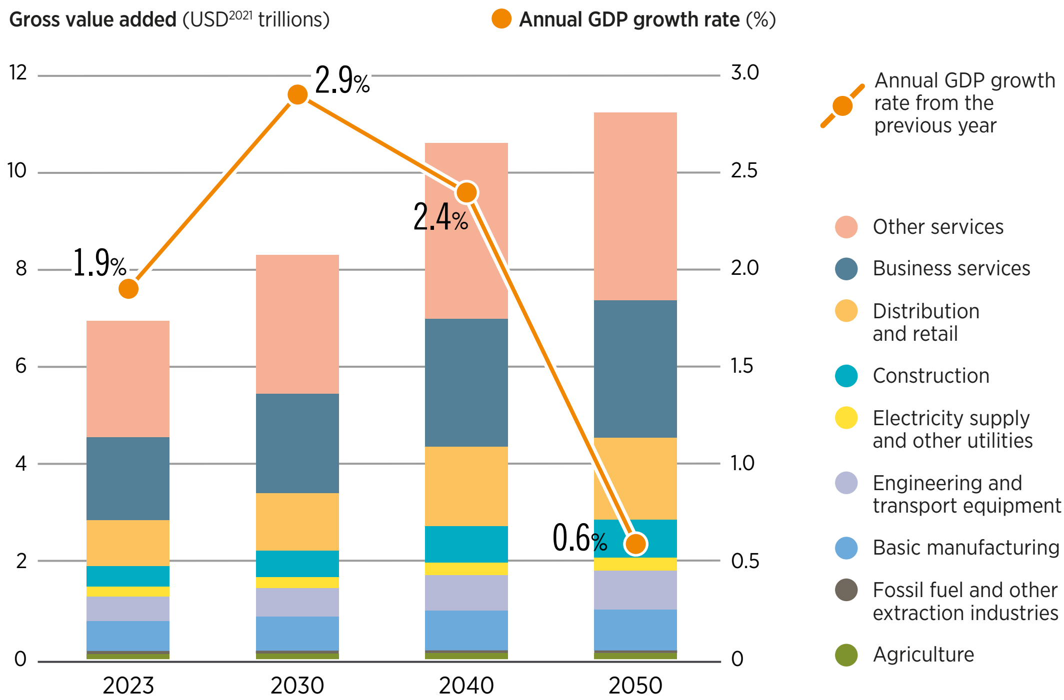
Growth under current policies can have significant negative consequences for the planet's resources and ecosystems, and further exacerbate the issue of unequal development.

2.2 The 1.5°C Scenario

This edition of the *World Energy Transitions Outlook* builds on analysis from previous years. The PES and the 1.5°C Scenario were introduced and analysed in the 2021 edition (IRENA, 2021b). The two scenarios were analysed together with a set of policy measures. We will refer to the set of policy assumptions from the 2021 edition as Policy Basket A (PB-A). Building on the 2021 edition, the 1.5°C Scenario's socio-economic outcomes were analysed in the 2022 edition (IRENA, 2022c) with additional policy elements (Policy Basket B). PB-B mandated a low carbon price – yet higher than real-world levels – in conjunction with greater international co-operative assistance, while PB-A (from WETO 2021) implied a high carbon tax and low international collaboration (*i.e.* limited flows, albeit higher than present pledges).

Under PB-B, the carbon tax was half that of PB-A, with some adjustment made for differences in national income. In PB-A, the 2030 carbon price for high-income countries was USD 300/tonne of carbon dioxide (tCO_2), compared with USD 150 /tCO_2 in PB-B (both in 2019 USD). For low-income countries, the values were USD 60 /tCO_2 and USD 30 /tCO_2, respectively. PB-A encouraged more international collaboration to enable

FIGURE 2.1 Sectoral evolution under the Planned Energy Scenario between 2023 and 2050



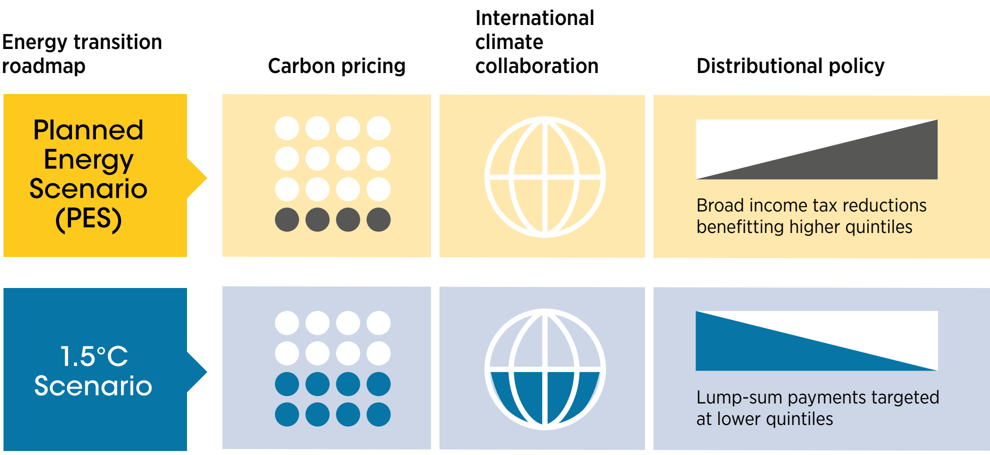
Notes: "Other services" include hotels and catering; communications, publishing and television; public and personal services; and transportation services. GDP = gross domestic product.

an equitable transition and address international distribution, mitigating governments' loss of revenue from decreased carbon pricing. As a percentage of global GDP, these inflows were 0.7%, or an annual average of USD 918 billion (2019 USD). This is roughly three times the international collaboration inflows included in PB-A (USD 290 billion/year, or three times present promises).

As a result, lower-income regions that are home to most of the world's population experience significant benefits when switching to PB-B, indicating a more equal distribution of transition benefits compared with PB-A. Most places that experience lower GDP growth after changing to PB-B nevertheless outperform the PES. In the European Union, the 2030 GDP in the 1.5°C Scenario is 0.4% higher than in the PES; it is 1.9% higher in East Asia. These regions gain in PB-B from hosting supply chains and exporting several energy-transition-related technologies. In general, PB-B improves equity and makes the energy transition more just. For wealthy countries highly reliant on fossil resources, PB-B cannot reverse negative GDP results compared with the PES (a result also observed in the 2021 edition). Countries may therefore need to undertake measures beyond greater international collaboration to promote fundamental changes in their economies and improve the socio-economic footprint of their energy transition efforts.

This year's report compares the Planned Energy Scenario (PES) to the 1.5°C Scenario with a supportive policy layer, equivalent to the PB-B scenario in the 2022 edition (IRENA, 2022b). It also adds a sensitivity analysis to compare an additional policy dimension – a redistributive wealth tax - and investigate its potential socio-economic outcomes (See Appendix). The findings delineate more clearly than ever the differences between the PES and the 1.5°C Scenario.

FIGURE 2.2 **Policy assumptions underlying the analysis of IRENA's energy transition scenarios.**



2.3 Principal assumptions of the scenarios

Carbon pricing

Carbon taxes, a form of carbon pricing, make the external costs of greenhouse gas (GHG) emissions visible by taxing fossil fuels on the basis of their CO_2 emissions, thus giving GHG emitters the incentive to reduce emissions. Considered an effective tool with a low likelihood of causing economic harm, carbon taxes are now being implemented across the globe, albeit unevenly and often at rates well below the true damage costs (Dumoulin, 2023; Santos, 2023). Global revenue from carbon taxes and the Emission Trading Scheme have reached USD 95 billion while covering 23% of global GHG emissions (World Bank, 2023). However, the potential inequity of the distributional impacts of carbon taxes must be considered while planning the allocation of the revenue they generate (Boyce, 2018).

IRENA has studied the weight of carbon pricing policies on the socio-economic footprint by modelling the following suppositions:

- Utilising existing fiscal policies to reduce the burdens of carbon taxes on end consumers.
- Assigning the revenue from carbon pricing to public investment in a just energy transition and to subsidies.

The macroeconomic modelling assumes revenue neutrality in governments' fiscal balances. Revenue recycling[7] is at the heart of the model's hypothesis. However, the progressiveness of the result depends on the policies used to implement revenue neutrality. For instance, in the PES, when government revenues increase (for instance through carbon prices), income taxes are reduced, while they are increased when government revenues decrease. This approach has regressive implications, however, as the wealthiest households generally pay the lion's share of income taxes and benefit accordingly from the tax cuts. By contrast, in the 1.5°C Scenario, revenues are assumed to be recycled through social-directed payments that target lower-income households progressively, assuming the adoption of distributional policies to mitigate any regressive effects of the energy transition – not only carbon pricing but also climate change itself. The social-directed payments assume 60% of the payments going to the lowest-income quintile, 30% to the second quintile and 10% to the third quintile.

Supportive fiscal policies

As countries move away from fossil fuels, one fiscal policy that needs to be rolled back is the fossil fuel subsidy; but the fact that energy prices have a significant impact on overall cost of living makes it harder for countries to phase out both fossil fuels and associated subsidies (IMF, n.d.). However, many fossil fuel subsidies are in the form of foregone revenue in tax breaks to fossil fuel companies or energy intensive industries – these can be more easily rolled back without impacting the least-well-off in society. With the upward trend both in overall cost of living and energy prices, removing consumer subsidies without careful policy design and a sensitive implementation strategy will hit the poorest members of society hardest, which in turn could cause social unrest (Horowitz, 2022).

[7] *From a modelling perspective, revenue recycling is not only a policy instrument for addressing distributional issues in the context of scenarios; it is also a way to avoid assuming that in the case where large investments must be made to finance the transition, governments would increase borrowing without any quantified impact on the economy and society.*

Careful design of policies and implementation strategies is crucial to ensure that the most vulnerable in society are protected, not burdened.

Fossil fuel subsidies are an important part of the assumptions underpinning the analysis presented here. There are varying assumptions for advanced economies, the members of the Organization of the Petroleum Exporting Countries (OPEC) and emerging/developing economies. In the PES, advanced economies are expected to eliminate subsidies by the early 2030s at a rate of approximately 5% per year. OPEC countries will follow suit by the 2050s (with a slower rate of around 3%), while emerging and developing economies are aiming for the late 2030s (with a 4% rate).

The more ambitious 1.5°C Scenario accelerates these timelines. Advanced economies would reach zero subsidies by 2030, OPEC countries by the mid-2040s, and emerging and developing economies by the early 2030s. The rate of reduction is not specified for the 1.5°C Scenario. Overall, the data suggest that advanced economies are leading the charge in subsidy reduction, followed by emerging economies and then the OPEC countries. Table 2.2 provides a summary of the assumptions.

TABLE 2.2 Assumptions on fossil fuel subsidies

	Zero subsidies reached under	
	Planned Energy Scenario	**1.5°C Scenario**
Advanced economies	Early 2030s	2030
OPEC countries	2050s	Mid-2040s
Emerging and developing economies	Late 2030s	Early 2030s

Note: OPEC = Organization of the Petroleum Exporting Countries.

International collaboration

Greater international collaboration between the developing and developed countries will be essential to achieve global climate goals. International collaboration takes various forms: monetary support, technology transfer, technical assistance, and capacity building. International collaboration helps countries strengthen their capacities in critical areas such as institutional development, economic structures, social cohesion, and research and innovation to promote sustainable development and reduce inequity. Prominent examples of blended co-operation are the Energy Transition Mechanism of the Asian Development Bank and the Just Energy Transition Partnership of the European Union.

Previous editions of the Outlook assumed that developed economies contribute 0.7% of their national income to official development assistance, by far the best known international target in the aid field assistance (UNFCCC, 2016). This represents around USD 1 trillion per year (2021 USD).

International collaboration funds are distributed to governments through three pillars. The enabling and social pillar considers inclusive development; the international justice pillar addresses aspects of fossil fuel dependency; and the international equity pillar focuses on the equity dimension of the energy transition. Additional policies are included to direct the use of these funds towards social value creation and support for the energy transition in recipient countries. To explore the option of intensified international collaboration in the 1.5°C Scenario, a sensitivity analysis is conducted to assess the effect of boosting collaboration through changes in distributional policies (see Appendix).

The next section presents the results in terms of economic gains, as measured by GDP under the 1.5˚C Scenario at the global and regional levels, and in selected countries. It finds that international financial collaboration flows would facilitate more equitable outcomes. By disaggregating the GDP results by drivers, this section further clarifies the structural aspects behind the socio-economic footprint.

2.4 GDP results at the global and regional levels, and in selected countries

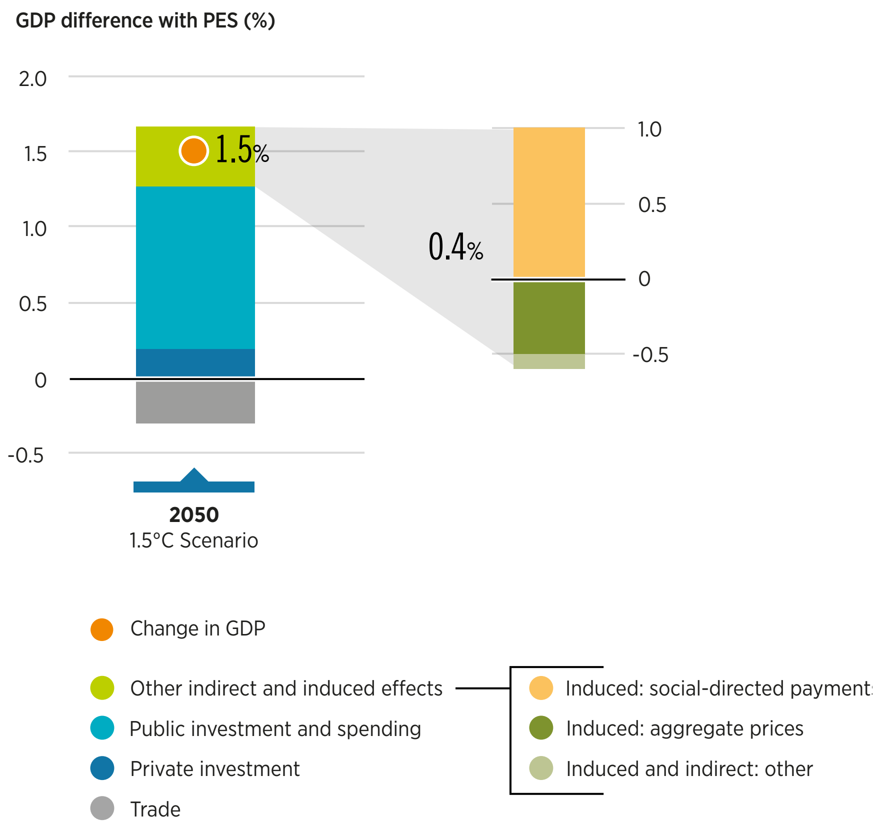
The systematic adoption of renewables and improvements in energy efficiency, combined with progressive policies, hold great promise for boosting global socio-economic indicators as the energy transition progresses. Between 2023 and 2050, the world could see an average annual increase in GDP of 1.5% over the PES under the 1.5°C Scenario (Figure 2.3, left panel).

The chief macroeconomic drivers of GDP differences throughout the transition period (*i.e.* 2023-2050) are shown in Figure 2.3. Public investment is the most powerful of these.

Investment in transition activities encompasses all spending on renewable energy in both the power and end-use sectors, along with investments in energy efficiency, grid and electric vehicle (EV) infrastructure, energy flexibility and system integration, including hydrogen. Such investments generate increased demand in various economic sectors, including equipment manufacturing, construction, and services like retail, business, and IT. This results in a positive overall impact, making a significant contribution to GDP growth. Government expenditures play a crucial role in supporting this energy transition by addressing specific transition needs, encouraging private sector investments, and ensuring expenditures are directed towards a just and equitable transition. Public investment can also be used as a tool for economic stabilisation. During economic downturns, the government can increase its spending to counteract reduced private sector spending, helping to maintain employment and economic activity. This is a key aspect of Keynesian economic theory (and also the theory the model is based on).

Public investment – supported by greater private spending – plays a pivotal role in driving GDP growth, aligning with the collective vision for sustainable economic development.

FIGURE 2.3 Global GDP, average percentage difference between the PES and 1.5°C Scenario, 2023-2050

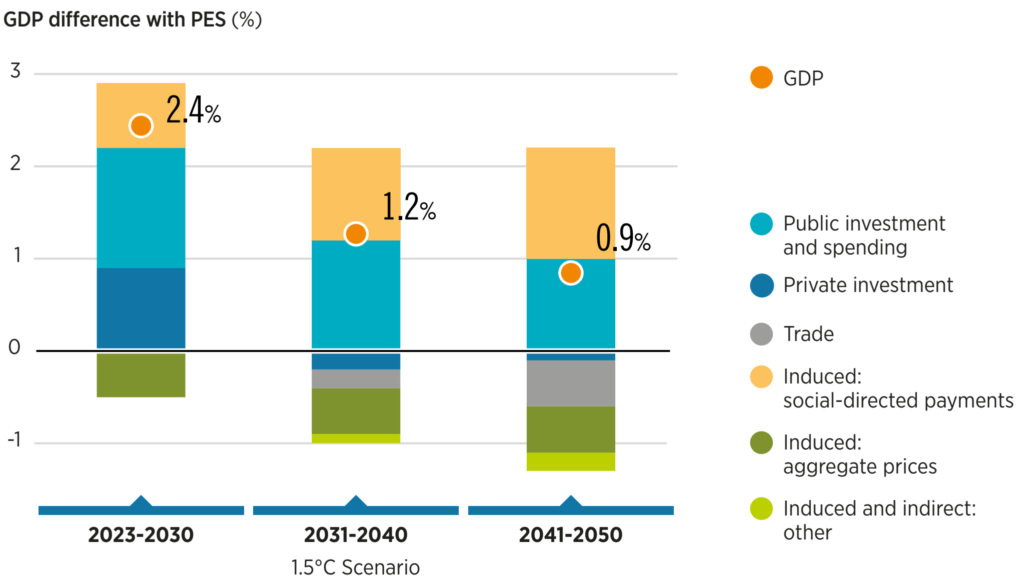


Note: GDP = gross domestic product; PES = Planned Energy Scenario.

Under the 1.5°C Scenario, global GDP gains would not be as significant over time after the initial boost from front-loaded investments, but in the last decade of the period (*i.e.* 2041-2050), GDP would still be 0.9% greater than in the PES (Figure 2.4). The average annual amount of additional private investment generated through 2030 by the 1.5°C Scenario works out to USD 100 per capita; but soon after the first decade, this effect dissipates as the relative impact of private front-loaded transition-related investments tapers off, in addition to the drop in investment in fossil fuel supply and its negative impact on other sectors.

As discussed in the previous section, the 1.5°C Scenario supports international collaboration financed by countries commensurate with their contribution to climate change[8] and their wealth, as in previous IRENA reports (IRENA, 2021b, 2022c; IRENA and AfDB, 2022a). The financial flows generated support transition-related public investment and expenditure to boost domestic social spending and address inequality (IRENA, 2022c). Benefitting from larger flows, worldwide governmental social spending rises over the transition period (*i.e.* 2023-2050) compared with the PES, increasing by an annual average of USD 422 billion (2021 USD). Because of this, public and personal services like health care, education and public administration benefit from governments' greater discretionary spending power. Over the first decade of the transition (2023-2030), private investment – stimulated in part by greater public spending – is significantly higher under the 1.5°C Scenario than under the PES, with an annual average differential in 2021 USD of around USD 820 billion, equivalent to around 37.5% of the difference in GDP between the two scenarios (see Figure 2.4).

FIGURE 2.4 Average percentage difference in global GDP between the PES and 1.5°C Scenario, by driver and by decade



Note: GDP = gross domestic product; PES = Planned Energy Scenario.

[8] *Based on the Climate Equity Reference Calculator (https://calculator.climateequityreference.org/).*

Other indirect and induced effects, broken down in the right-hand panel of Figure 2.3, together form the second-strongest factor in driving differences in GDP throughout the transition period. The social-directed payments (revenue recycling) to address the "distributional" dimension are the most influential, followed by *induced aggregate prices*. The *induced and indirect: other* component has a mild negative impact on GDP difference. The effects of these indirect and induced effects are discussed in greater detail below.

Induced social-directed payments have a positive impact over the entire transition period (see Figure 2.4). In the 1.5°C Scenario, tax revenues left over after covering transition-related investment and other policy expenses are assumed to be redistributed to households in the form of payments under a revenue recycling approach, thereby raising household consumption. Domestic responses to shifts in carbon prices, technology prices, power sector capacity, fossil fuel subsidies and investment expenditures are all reflected in the role of *induced aggregate prices*. Due to front-loaded investment in renewables and the [still] significant role of increasingly expensive fossil fuels in power generation, higher electricity prices would counter some of the benefits from *induced social-directed payments*.

Trade impacts on GDP are shaped by changes in fuel trade and responses to trade on other commodities. While these effects are minor globally, balancing out between regions, they can be significant at the national or regional level. Net fuel trade negatively impacts the global economy for most of the forecast period. Under the 1.5°C Scenario, lower consumption of manufactured fuels leads to varied impacts: some countries see reduced fuel export revenues, while others benefit from decreased fossil fuel imports, boosting their GDP. Over the transition period, fuel trade's contribution to GDP growth becomes negative. In contrast, the 1.5°C Scenario affects non-fuel trade by altering price-driven competitiveness and trade dynamics, with global changes in non-fuel trade expected to be positive throughout the forecast period. However, it is not large enough to offset the negative impact of fuel trade, resulting in a net negative impact from trade.

It is important to highlight that the socio-economic outcomes discussed here do not account for the effects of climate change – a crucial factor driving the energy transition. The macroeconomic model used in this analysis operates under the assumption that climate change does not affect economic activity. Consequently, both the scenarios continue on their respective macroeconomic trajectories without considering climate change effects. Elsewhere, IRENA has incorporated into its macroeconomic modelling a climate damage methodology based on Burke *et al.* (2015, 2018) (see Box 2.2).

The global analysis, however, hides huge geographical disparities. For the countries of the Group of Twenty (G20) the investment driver is generally the strongest factor in GDP differences by scenario (Figure 2.7a). This is true for several important G20 countries, notably India and China. In some G20 countries (Canada, China and South Africa), the impact of the trade driver on GDP differences is as, or more, important than investment, due to their economic structures.

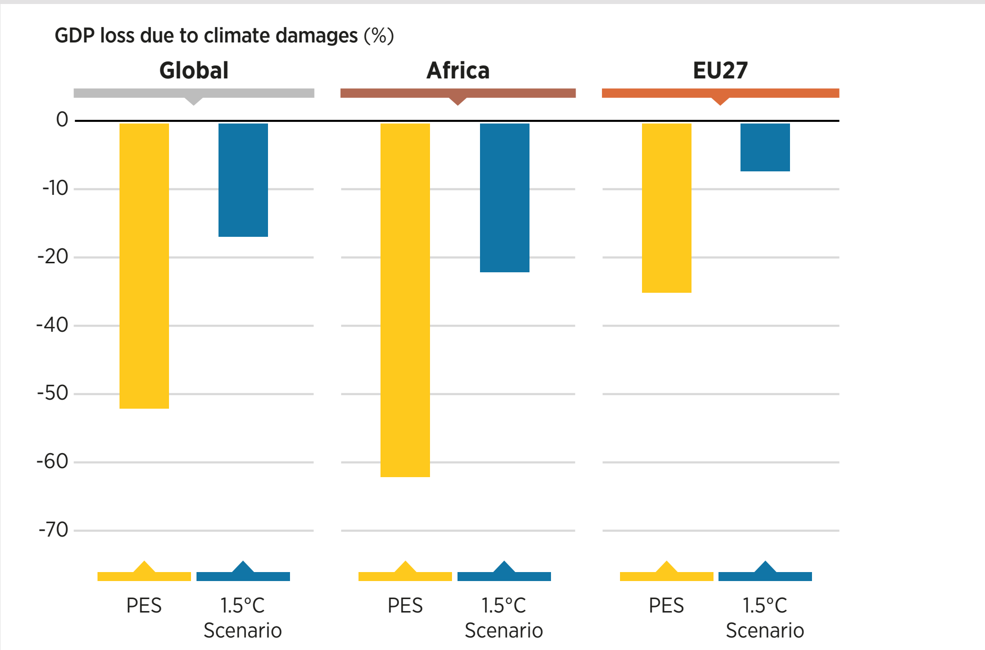
Contrary to results obtained in most of the advanced economies *induced social-directed payments* are becoming more important in emerging and developing countries, where they are sometimes the dominant factor in modelled GDP differences (Figure 2.7b). The cause is international financial resources under the 1.5°C to address the welfare gaps identified in previous modelling exercises. They occur mainly in the social dimension (social expenditure) and the distributional dimension, and to a lesser extent in the economic dimension (consumption and investment).

BOX 2.2 The impact of climate damage on the economy

The GDP results presented in this chapter do not factor in the impact of climate change on aggregated economic activity. But climate change will have negative impacts, varying across locations due to differing climate vulnerabilities and regional distribution of warming, and these will increase over time. Past emissions force a certain degree of climate change already, but the higher the mitigation of future greenhouse gas emissions, the lower the level of additional global warming and associated climate damage. Hence, climate damage will be higher under the Planned Energy Scenario (PES) than under the 1.5°C Scenario, but significant in both cases.

IRENA started exploring the implications of climate damage on overall economic activity in *Global Energy Transformation* (IRENA, 2019b). Subsequently, the agency published global results incorporating updates to the methodology, including additional data on the impact of temperature changes on economic performance (IRENA, 2021b).[a] The estimate is considered conservative because some effects are not yet prominent or measurable in historical data, such as the intensification of extreme events (wildfires, flooding and tropical storms), sea level rise, tipping points, trade disruptions and knock-on political and social effects (*e.g.* mass migration) (IRENA, 2019b).

FIGURE 2.5 Climate damage by 2100 under the PES and 1.5°C Scenario: Global, Africa and EU27



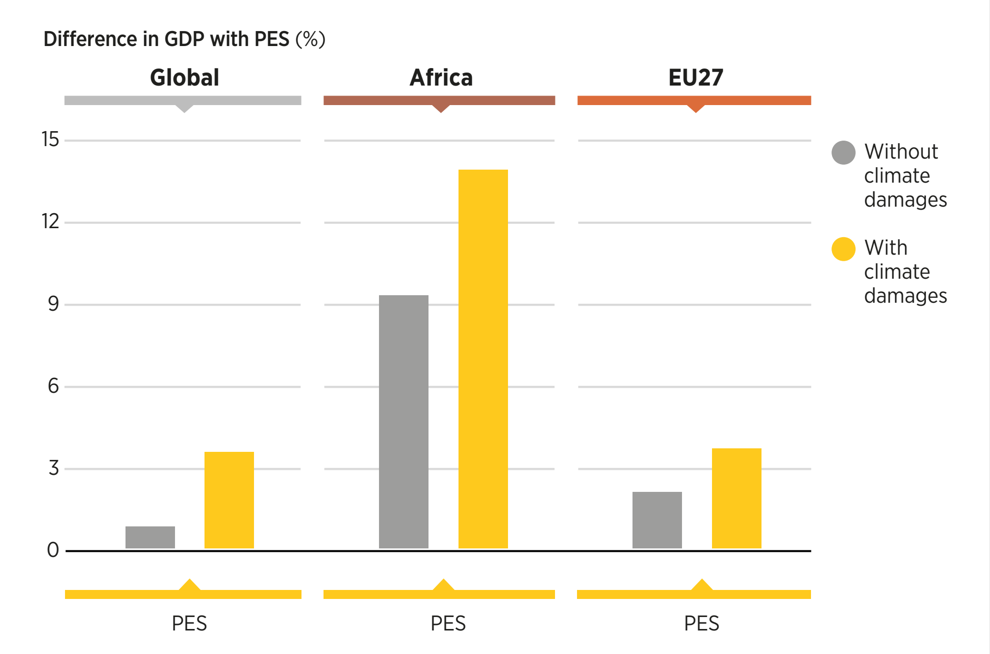
Note: 1.5S = 1.5°C Scenario; EU = European Union; GDP = gross domestic product; PES = Planned Energy Scenario.

Figure 2.5 presents the GDP loss due to climate damage that could be expected by 2100 under the PES and 1.5°C Scenario at the global level as well as for Africa and the EU27, two regions with highly diverging levels of economic development and emissions. Although climate damage under the 1.5°C Scenario are significant (representing a 26% loss of GDP in Africa), following the PES emissions trajectory would lead to a catastrophic loss of more than 60% of Africa's GDP by 2100. Figure 2.5 also reinforces the point on climate inequality discussed in Chapter 3 of this report, with climate damage in emerging and developing countries being much higher in relative terms than those experienced in advanced economies.

Climate damage is much higher under the PES than under the 1.5°C Scenario. Figure 2.6 presents the difference in GDP between the 1.5°C Scenario and PES by 2050, first without accounting for the impact of climate damage (as in this chapter), and then factoring them in. At the global level, the incorporation of climate damage widens the GDP benefit of transitioning from 0.9% to 3.6%.

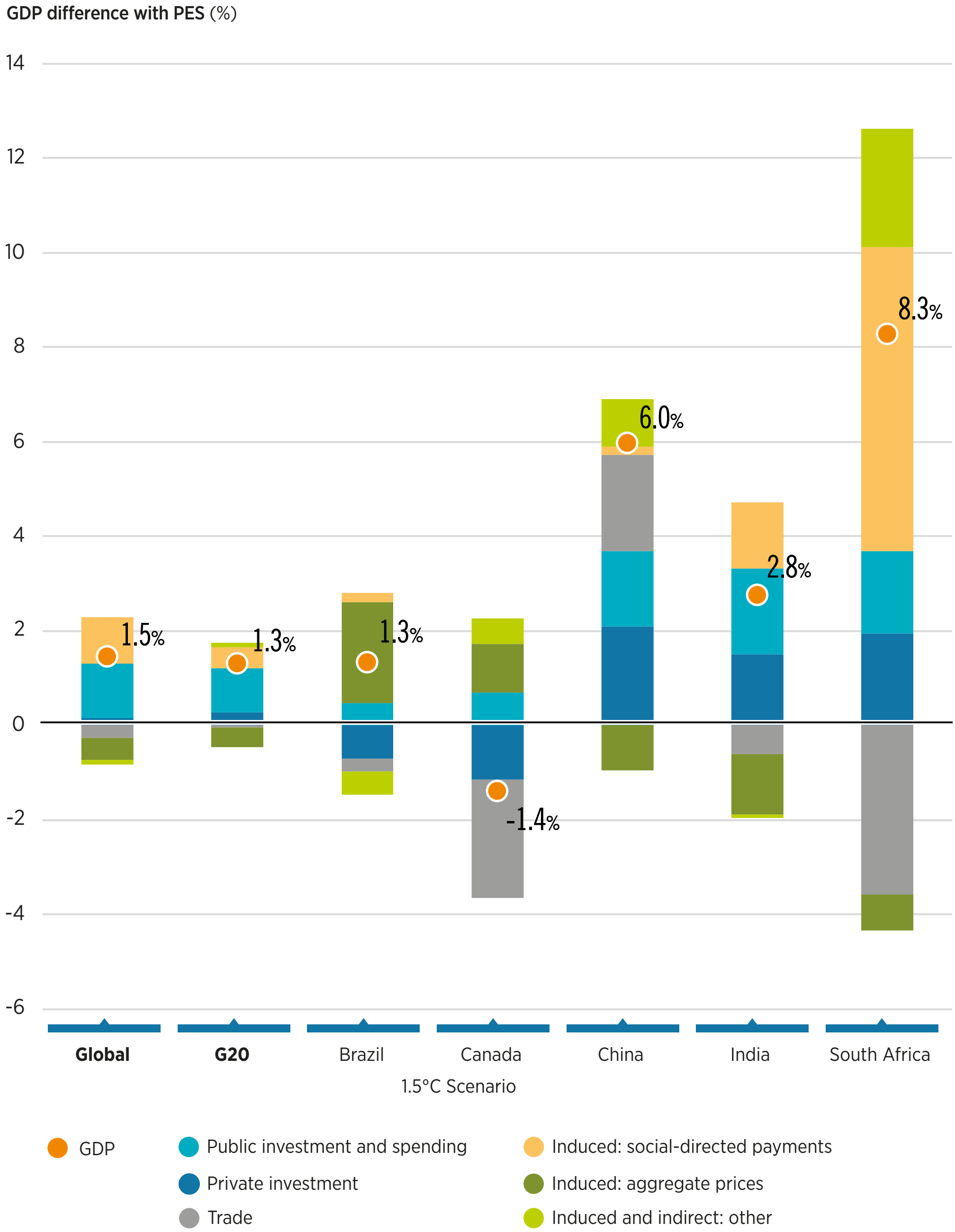
[a] *The methodology is based on a statistical analysis to derive a non-linear damage function that maps temperature changes to economic losses, providing geographical details of climate damage (Burke et al., 2015, 2018). The work was informed by an extended dataset at a subnational level involving over 11 000 districts (Burke and Tanutama, 2019)*

FIGURE 2.6 GDP benefits of the transition by 2050, with and without accounting for climate damage: Global, Africa and EU27



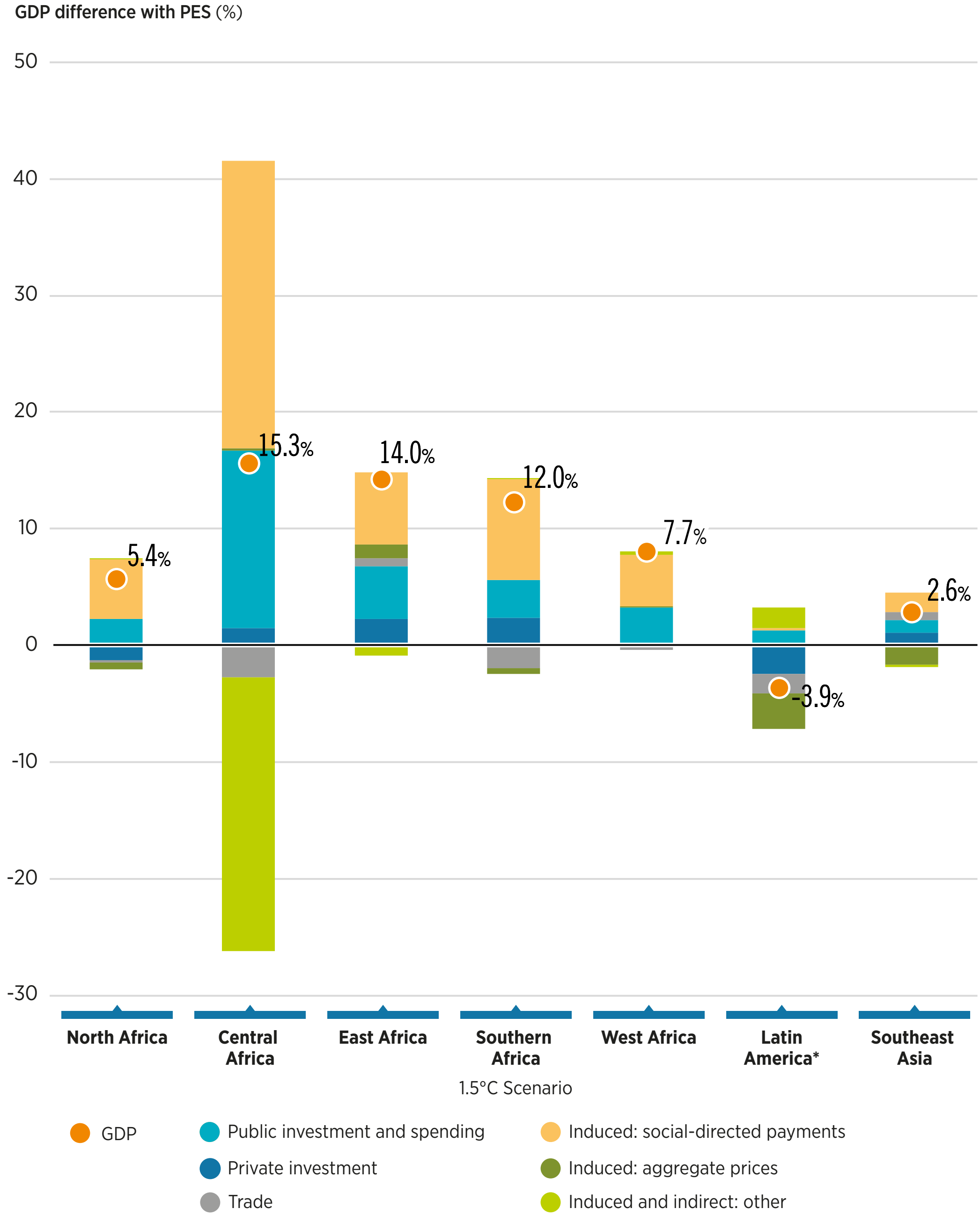
Note: EU = European Union; GDP = gross domestic product; PES = Planned Energy Scenario.

FIGURE 2.7 **GDP in selected countries/regions, average percentage difference between PES and 1.5°C Scenario, by driver, 2023-2050**



Note: G20 = Group of Twenty; GDP = gross domestic product; PES = Planned Energy Scenario.

FIGURE 2.7 GDP in selected countries/regions, average percentage difference between PES and 1.5˚C Scenario, by driver, 2023-2050 (continued)



Note: *Excluding Argentina, Brazil and Colombia; G20 = Group of Twenty; GDP = gross domestic product; PES = Planned Energy Scenario.

2.5 Employment at the global and regional levels

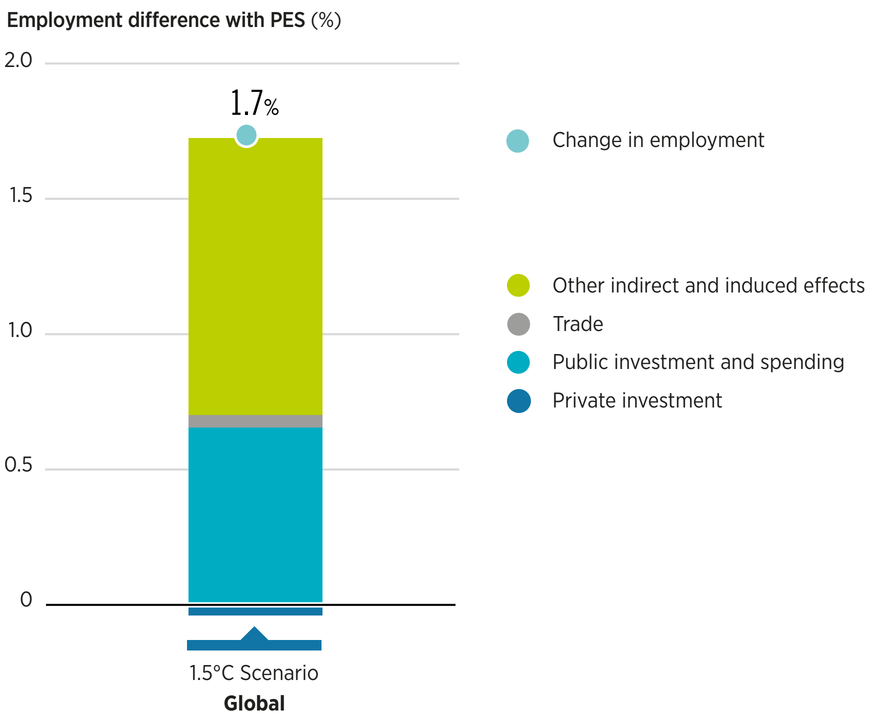
This section provides in-depth findings from modelling of the employment impact of renewables in the energy sector and the economy as a whole. The findings are presented at the global and regional levels and for selected countries within regions. They highlight potential labour market misalignments across the energy transition.

Economy-wide employment

The 1.5°C Scenario would lead to, on average annual terms, 1.7% higher employment than the PES over the 2023-2050 period (Figure 2.8). Globally, economy-wide employment would be 1.8% greater on average in the years to 2040, but only 1.5% higher in the final decade (2041-2050) (Figure 2.9).

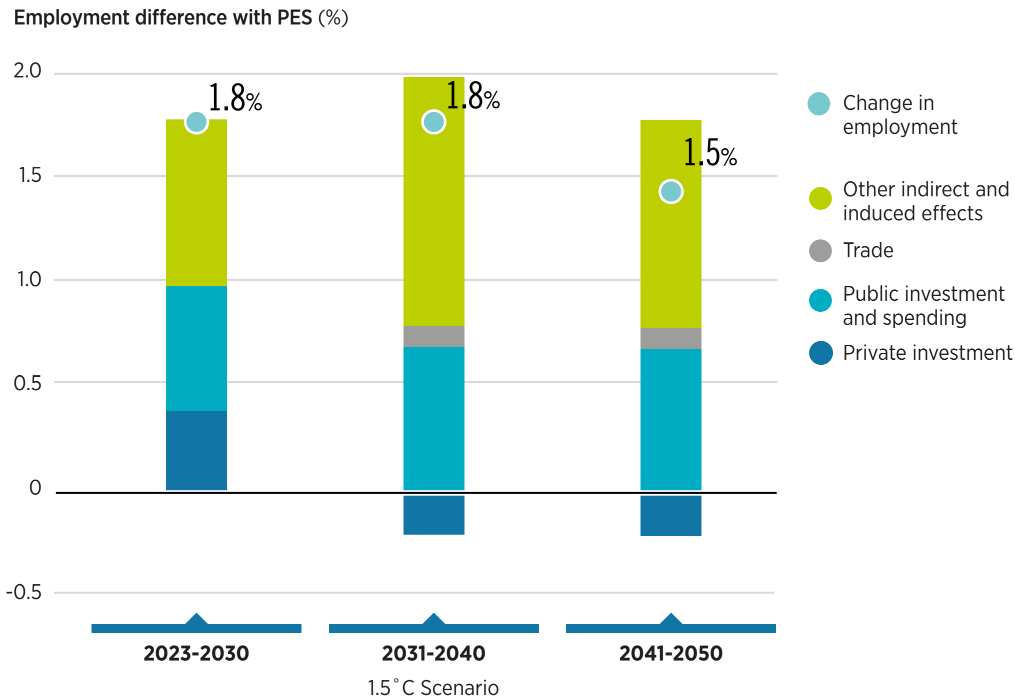
The economy-wide employment differences would be mainly driven by investment and other indirect and induced effects, while trade would have a minor impact (Figure 2.8). In the years to 2030, the investment driver plays the most important role in the differences in employment, while other indirect and induced effects become the main driver from the second decade (2031-2040) (Figure 2.9).

FIGURE 2.8 Global economy-wide employment, average percentage difference between the PES and 1.5°C Scenario, by driver, 2023-2050



Note: PES = Planned Energy Scenario.

FIGURE 2.9 Average percentage difference in global economy-wide employment between the PES and 1.5°C Scenario, by driver and by decade



Note: PES = Planned Energy Scenario.

Other indirect and induced effects boost job creation during the transition period, reaching 35 million in 2050 under the 1.5°C Scenario. The effect is driven by rising wages in non-energy sectors in the years before 2030 because of labour shortages caused by increased demand.

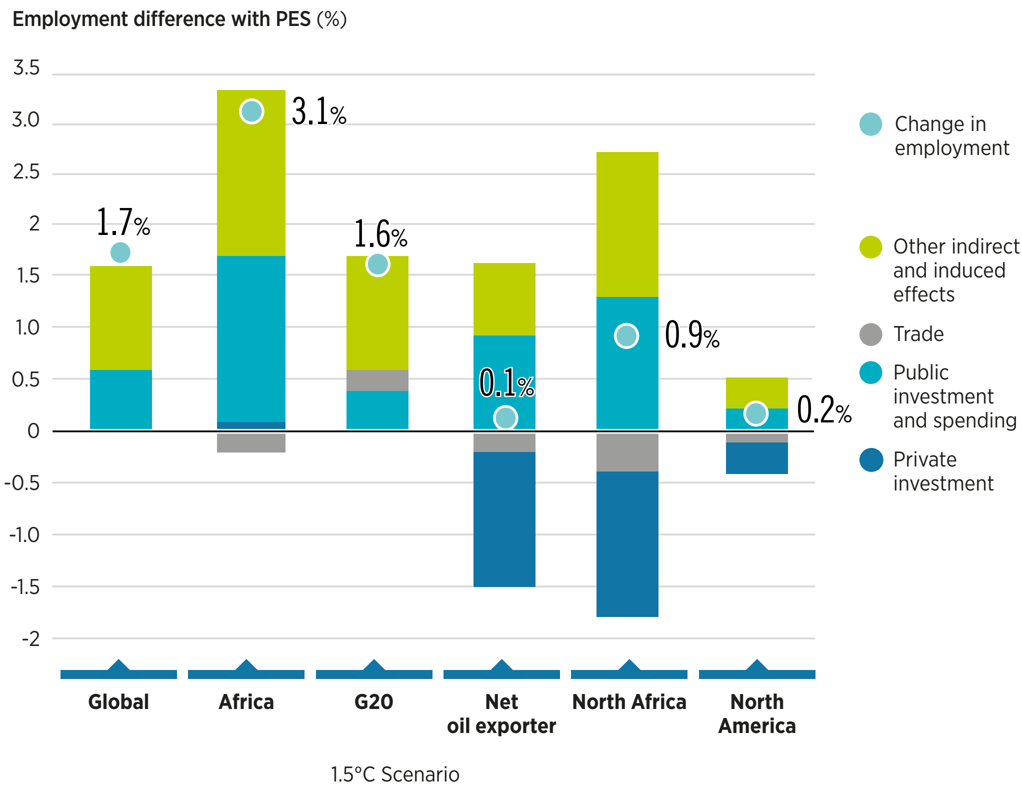
In the second decade (2031-2040), consumer spending will be the main factor among the other indirect and induced effects, driven by ripple effects from front-loaded transition-related investment and social-directed payments used for consumer spending. Compared to the PES, consumer spending is expected to create around 22 million jobs in the 1.5°C Scenario by 2050. Consumption would move from fuels to restaurants, hotels, and other goods and services, such as education, personal costs and financial services. Higher consumer spending and changes in its patterns will produce more job creation than job loss in certain sectors, including fuel extraction activities.

Greater public investment and spending in transition-related initiatives (*e.g.* energy efficiency, electrification, renewables) leads to more jobs across the transition period. More public investment is allocated to service-oriented sectors, such as building space redesign, energy management system upgrades and retrofits.

Compared with the PES, the transition under the 1.5°C Scenario leads to growing social spending and significant new job creation across the world (Figure 2.10), largely because of increased international financial flows. Job creation would reach 19 million by 2050. This is because a quarter of the revenues from the international financial flows would be used for additional social spending and investment over that occurring under the PES.

Averaged over the entire transition period, private investment has no net influence on economy-wide employment at the global level, primarily because lower investment in fossil fuels in the years after 2030 would offset the positive effect of the front-loaded transition-related investment in the first decade of the period. The effect is significantly negative after 2030, as the fossil fuel phaseout accelerates. Without governmental intervention, 9.1 million jobs will be lost in fossil fuel supply under the 1.5°C Scenario. Some 16 million jobs will be lost in fuel extraction by 2050. Re-training employees for new jobs is necessary to prevent substantial disruptions to living standards. It is important for policy makers to consider the regional impact of these jobs, which are largely concentrated in a few key regions (Figure 2.10).

FIGURE 2.10 Average percentage difference in economy-wide employment in selected regions between the PES and 1.5°C Scenario, by driver, 2023-2050



Note: G20=Group of Twenty; PES=Planned Energy Scenario; Net oil exporter=Denmark, Norway, Canada, Russian Federation, Mexico, Brazil, Argentina, Colombia, Saudi Arabia, Nigeria, Malaysia, Kazakhstan

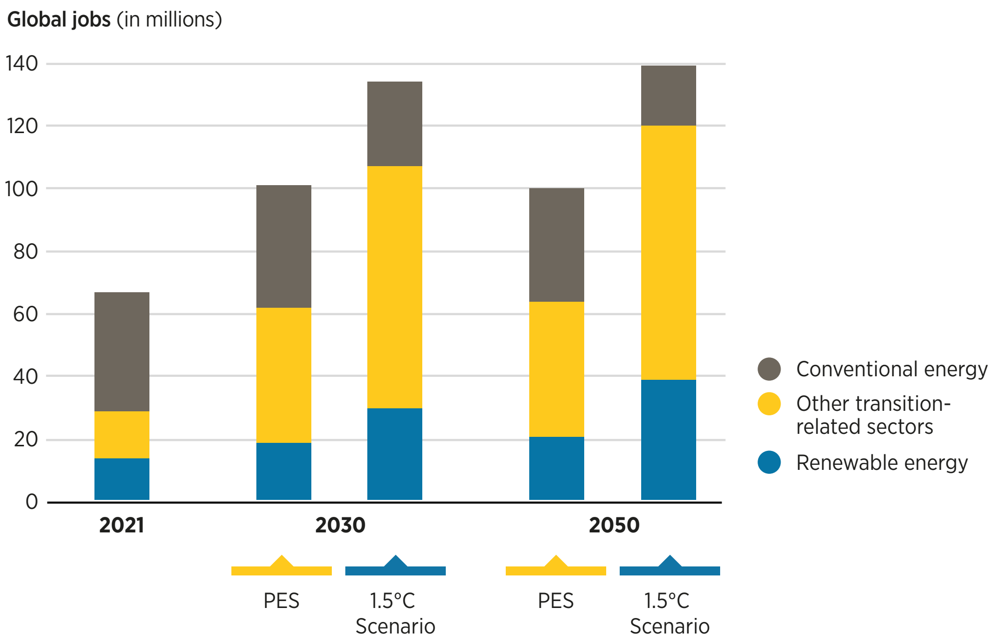
Employment in the energy sector

The analysis of energy sector jobs presented here builds on IRENA's previous research (IRENA, 2016, 2017, 2018, 2019a, 2020, 2021b, 2022d, 2022c; IRENA and AfDB, 2022a). The purpose of much of that previous work has been to inform policies to maximise the employment benefits of the energy transition. These policies would include measures to correct misalignments of skills, timing, geography, and the industries in which jobs are created and lost.

Because the modelling approach used to estimate socio-economic effects holds energy balances and energy-related investments unchanged for the 1.5°C Scenario sensitivity, energy sector jobs are unaffected by the additional policy layers discussed in Appendix. As a result, the 1.5°C Scenario is used for the results reported below. First, findings at the global level are presented, followed by details on certain regions and countries.

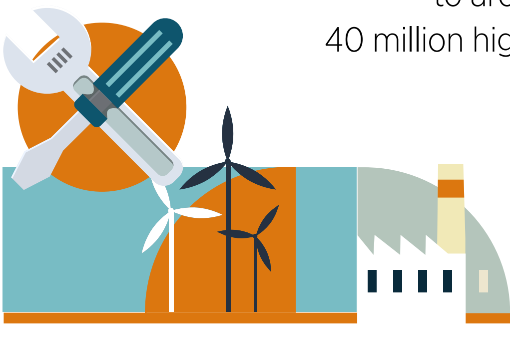
Energy sector jobs could reach 101 million and 134 million in 2030 under the PES and 1.5°C Scenario, respectively, compared with 67 million currently (Figure 2.11). Between the PES and 1.5˚C Scenario, the substantial job losses (around 12 million) in conventional energy jobs (fossil fuels and nuclear) are more than offset by 2030 by gains in renewables (around 11 million) and other energy-transition-related sectors (energy efficiency, power grids and flexibility, vehicle charging infrastructure, and hydrogen, at around 34 million). This is mainly due to the front-loaded investments in transition-related sectors in the first decade of the transition period. Employment in renewables would increase from around 14 million currently (IRENA and ILO, 2023a) to 19 million and 30 million under the PES and 1.5°C Scenario, respectively.

FIGURE 2.11 Energy sector jobs at the global level under the PES and 1.5°C Scenario, 2021-2050



Note: PES = Planned Energy Scenario.

Under the 1.5°C Scenario, energy sector jobs would rise to around 140 million in 2050, 40 million higher than under the PES.



Countries heavily reliant on fossil fuels face various challenges, notably in ensuring that everyone benefits from the transition. The impact on society varies based on how deeply fossil fuels are integrated into an economy. It is essential to address these dependencies, with a special focus on the most vulnerable.

Under the 1.5°C Scenario, energy sector jobs would rise to around 140 million in 2050, 40 million higher than under the PES, owing to growing investments in new transition-related technologies, particularly energy efficiency, power grids and energy flexibility, and renewables.

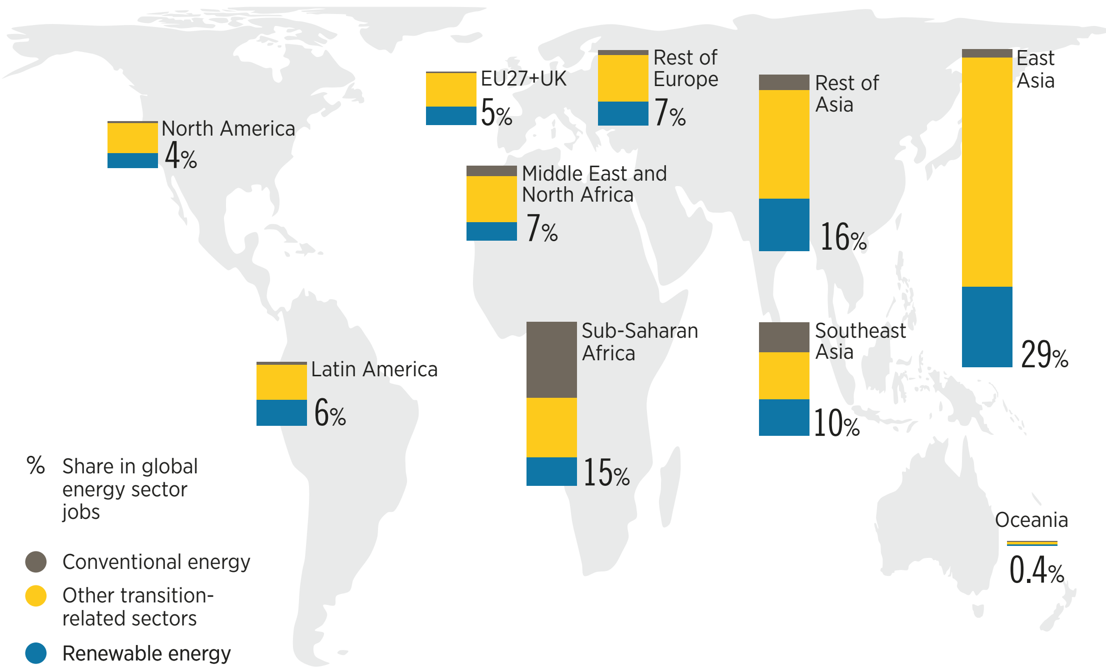
The PES would maintain 36 million energy sector jobs in conventional energy. The 1.5°C Scenario cuts this to 19 million jobs, indicating a big shift towards cleaner energy. Countries heavily reliant on fossil fuels face various challenges, from moving away from fossil fuels to ensuring everyone benefits from the transition. However, if not managed well, some groups might be left behind due to the intricate nature of such changes. The impact on society varies based on how deeply fossil fuels are integrated into the economy.

Following the evolution in public investment and spending outlined in section 2.1, the 1.5°C Scenario boosts other transition-related sector jobs from 43% of energy sector jobs (43 million jobs) under the PES to 58% (81 million jobs). Under the 1.5°C Scenario, 28% of energy sector jobs (39 million jobs) are in renewables in 2050, compared with 21% (21 million jobs) under the PES. Renewable energy occupations would thus grow significantly.

Figure 2.12 shows the regional breakdown of energy sector jobs in the year 2050 under the 1.5°C Scenario. In 2050, around 55% of all jobs in the energy sector would be in Asia, while 15% would be in Sub-Saharan Africa, 12% in Europe and 10% in the Americas (*i.e.* North America and Latin America). Regional variations result from the fact that countries begin the transition from different starting points, as defined not only by their pre-existing socio-economic structures, but also because of the wide differences in their national policies and practices related to the transition.

By 2050, renewables will account for about 28% of Asia's energy sector jobs; the corresponding figures are 36% in the Americas, 33% in Europe and just 25% in Sub-Saharan Africa. In the Americas, 36% of the other transition-related jobs are supported by power grids and energy flexibility efforts (*i.e.* grids, heat pumps, hydrogen, *etc.*). Energy efficiency accounts for 39% of energy sector jobs in Asia and 30% Europe; in Sub-Saharan Africa, the figure is 17%. Under the 1.5°C Scenario by 2050, the fossil fuel industry will still be responsible for 47% of energy sector jobs in Sub-Saharan Africa, 9% in Asia, 5% in Europe and 4% in the Americas.

FIGURE 2.12 Energy sector jobs in the 1.5°C Scenario, by region, 2050



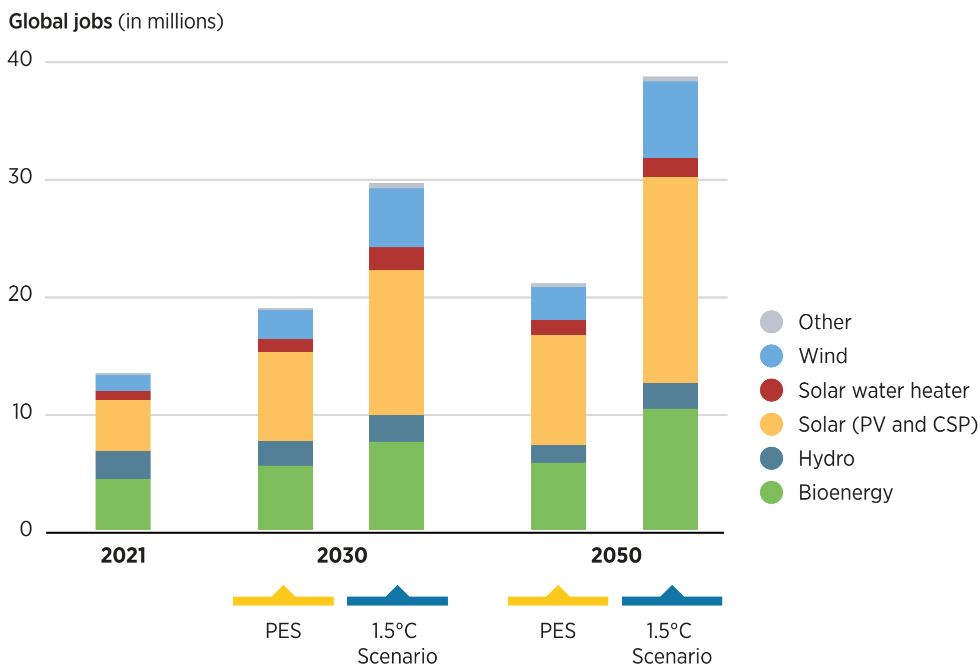
Note: EU = European Union; UK = United Kingdom.

Employment in renewable energy

Under the 1.5°C Scenario, the renewable energy sector is predicted to grow significantly by 2050, creating about 40 million jobs worldwide (Figure 2.13). This remarkable three-fold increase from the 2021 figure of around 13.6 million (IRENA and ILO, 2023b) reflects intensifying efforts to mitigate the effects of climate change by switching to renewable sources. Indeed, the deployment of renewable energy technologies like solar, wind and bioenergy is helping to curb emissions of GHGs, while simultaneously boosting the economy and providing new opportunities for employment in the energy sector.

Solar energy jobs are expected to rise to 18 million (around 45% of renewable energy jobs) by 2050 under the 1.5°C Scenario – almost a four-fold increase from 2021. Wind energy will also see high job creation; employment is expected to rise five-fold from 2021, reaching 6 million (around 17% of all renewable energy jobs) under the 1.5°C Scenario by 2050. The expansion of variable renewable energy (solar and wind) can be attributed to cost reductions, efficiency gains and policy incentives that have made solar energy more accessible and affordable. The spread of utility-scale and rooftop solar systems is predicted to create many jobs, highlighting solar energy's significance in the energy transition and economic development. Bioenergy

FIGURE 2.13 **Renewable energy jobs at the global level in the PES and 1.5°C Scenario, 2021-2050**



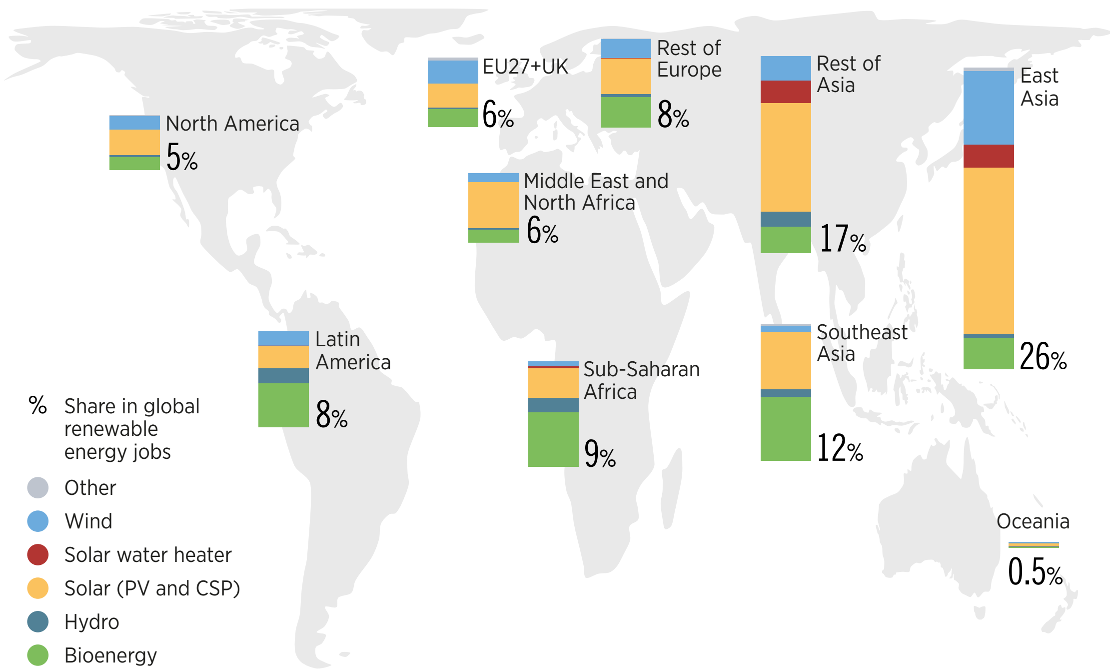
Note: "Other" includes geothermal and tidal/wave. CSP = concentrated solar power; PES = Planned Energy Scenario; PV = photovoltaic.

jobs will grow from 4 million jobs in 2021 (33% of renewable jobs) to more than 10 million in 2050 (27% of renewable jobs). This growth highlights the diverse applications of bioenergy in generating electricity, heating and transportation. Sustainable management and utilisation of biomass resources contribute to a reduction in GHG emissions, while creating jobs in agriculture, processing and energy production.

Figure 2.14 shows the regional and technological distribution of renewable jobs through 2050 under the 1.5°C Scenario. Asia holds 55% of global renewable energy jobs by that year, followed by Europe at 14%, the Americas at 13% and Sub-Saharan Africa at 9%.

Solar energy jobs are expected to rise to 18 million (around 45% of renewable energy jobs) by 2050 under the 1.5°C Scenario.

FIGURE 2.14 Renewable energy jobs in the 1.5°C Scenario, by region, 2050



Note: "Other" includes geothermal and tidal/wave. CSP = concentrated solar power; PES = Planned Energy Scenario; PV = photovoltaic.

By 2050, under the 1.5°C Scenario, solar will make up nearly 66% of renewable energy jobs in the Middle East and North Africa, 52% in Asia and less than 40% in the other regions (38% in Europe, 32% in the Americas and 28% in Sub-Saharan Africa). Bioenergy generates more than 50% of renewable energy jobs in Sub-Saharan Africa. The corresponding figures are 37% and 30% in the Americas and Europe, respectively, and roughly 19% in Asia. Wind energy accounts for almost 27% of renewable energy jobs in Europe, but just 19% and 16% in the Americas and Asia, respectively.

In East Asia, renewable energy employment centres on solar and wind due to substantial investments driven by ambitious electricity goals. Job opportunities span manufacturing, trade and services, but solar manufacturing is increasingly automated, limiting employment prospects. Southeast Asia takes a distinct path, with the emergence of solar manufacturing and a focus on bioenergy driven by domestic inputs and labour-intensive agriculture. The rest of Asia follows a mixed approach, different from East Asia's wind focus. In Latin America and the Caribbean, bioenergy contributes significantly to regional employment due to domestic biomass production, processing and biofuel distribution.

Transition processes, coming on top of pre-existing economic structures, will bring significant changes, including to the labour market. The energy transition may have a positive overall impact on employment, but it is also likely to cause labour market misalignments as old jobs are replaced by new ones and others undergo adjustments. Policy makers must anticipate and address these challenges. IRENA has grouped these challenges into four types of misalignment that need to be closely examined: temporal, spatial, educational and sectoral misalignments (Ferroukhi, Casals and Parajuli, 2020). First, job losses and gains may occur at different times and rates. Second, new jobs may be produced in areas, regions or countries different from those in which most job losses occur. This is especially true in areas with limited economic diversity. Third, although re-training programmes may help, the skills associated with lost jobs may not be what emerging and growing sectors are looking for, leading to educational misalignments. And fourth, those expanding industries may use more raw materials or intermediate inputs from various sectors than those supplying declining industries, generating sectoral misalignments. Just transition policies are required to prevent these misalignments from becoming barriers to the overall energy transition that is so essential to the fight against climate change.

Asia is estimated to spearhead renewable energy job growth, employing 55% of the sector's workforce by 2050.

The results presented in this section provide detailed insights into the energy transition's global and regional impacts on employment. Adequate policies – carbon pricing, fossil fuel subsidy phase-outs, global international climate funds and revenue recycling – can mitigate negative job consequences in the global economy over the course of the energy transition. During that time, governments will need to match labour demand and supply, align unemployed skills with job requirements, and distribute the burdens of technological change on employment (Tirole, 2017; WEF, 2014). Notwithstanding some challenges, the overall employment findings are very encouraging.

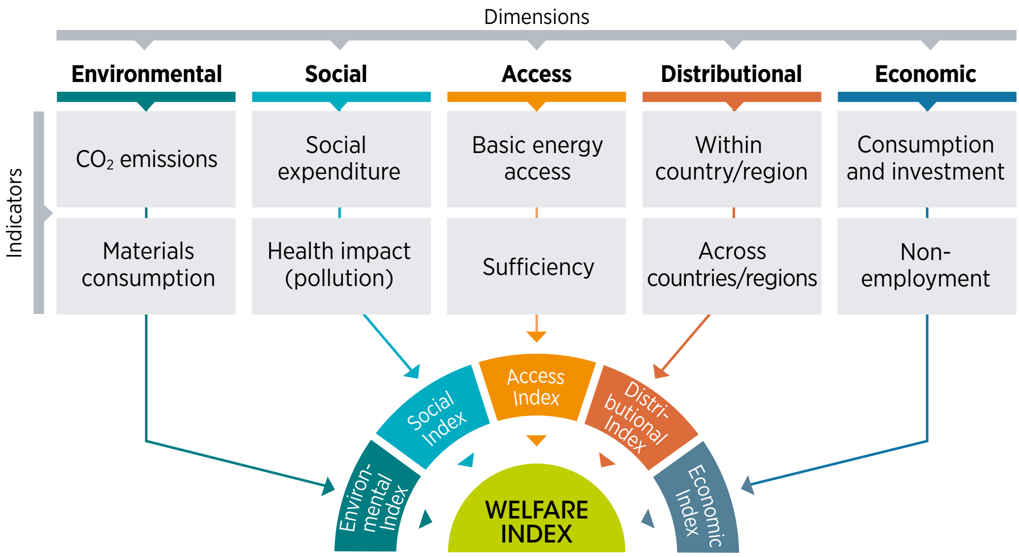
IRENA's socio-economic footprint scheme emphasises welfare as a holistic indicator for transformation roadmaps, beyond GDP and employment. The agency's energy transition welfare index (IRENA, 2021b, 2022c; IRENA and AfDB, 2022b) includes five dimensions of welfare: economic, social, environmental, distributional and energy access. The next section will show that the multiple facets of the energy transition lead to greater welfare for most people in most of the countries and regions of the world.

CHAPTER 03

WELFARE IMPACTS OF THE ENERGY TRANSITION

IRENA uses a welfare index to delve deeper into the socio-economic analysis of the energy transition. The index has five dimensions (economic, social, environmental, distributional and access), each informed by two indicators (Figure 3.1). Socio-economic impacts are quantified to allow a direct comparison of several scenarios. The index's dimensions provide insights into how socio-economic outcomes can be improved through appropriate policy measures (see Chapter 2). Shortcomings point to possible hurdles that policy makers will need to address as they continue to advance the energy transition.

FIGURE 3.1 Five dimensions and 10 indicators of IRENA's welfare index



Note: CO_2 = carbon dioxide.

Enhancing overall welfare requires policy action well beyond the switch from fossil fuels to renewables.

The technological aspects of the energy transition have both direct and indirect impacts on overall welfare. For example, shifting from fossil fuels to renewables directly mitigates carbon dioxide (CO_2) emissions, which has a positive impact on the environment. At the same time, this transformation of the energy system creates jobs (which boost overall consumer spending) and consumes materials (and the resources from which they are produced), and thus has indirect, negative environmental impacts.

Enhancing overall welfare requires policy action well beyond the switch from fossil fuels to renewables. This point has implications for the "how" of the transition. Additional policies are required to sustain otherwise short-term benefits to the economy and environment, boost overall social welfare, distribute benefits equitably and expand access towards the goal of inclusive development.[9]

This chapter forecasts how the dimensions of the IRENA Energy Transition Welfare Index might be affected by the actions taken along several of IRENA's technology transition pathways (section 3.2). It then offers detailed observations about each dimension, and sketches implications for structural policies needed beyond the energy system (3.3).

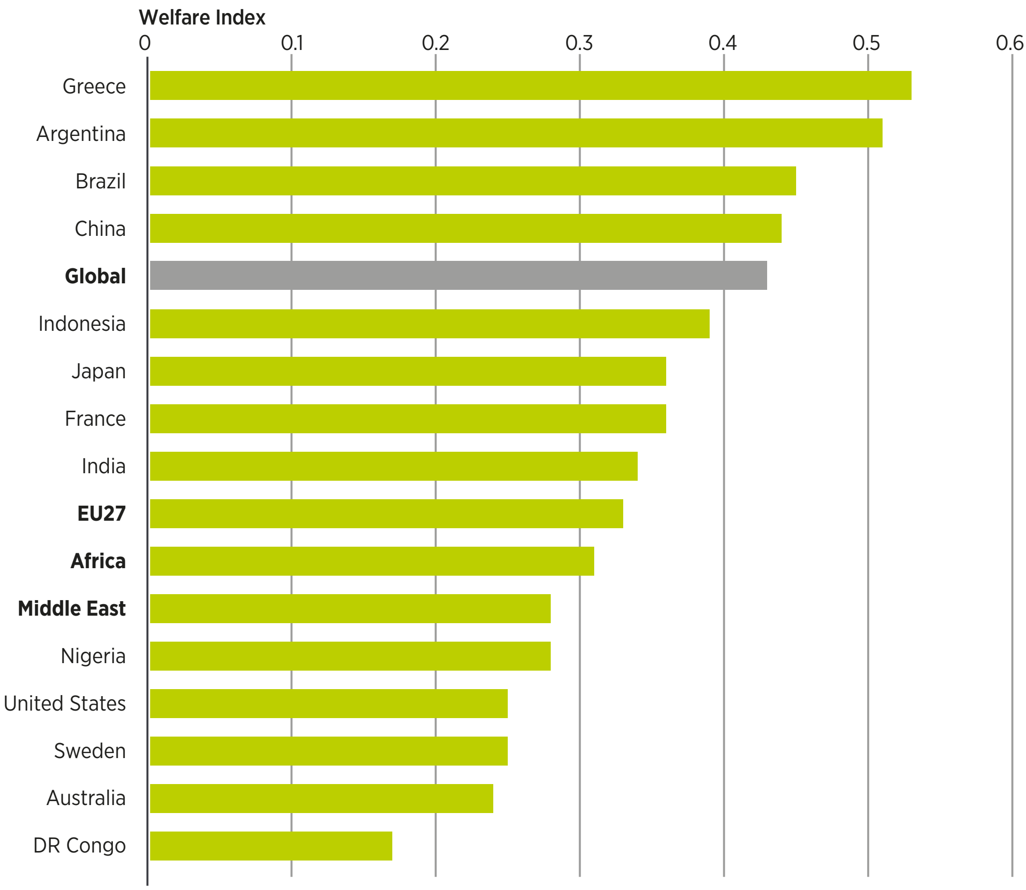
3.1 Overall welfare index under the 1.5°C Scenario

The welfare index and its five dimensions are structured on a scale ranging from 0 (low performance) to 1 (high performance). Figure 3.2 presents average index values for selected countries and regions under the Planned Energy Scenario (PES) throughout the transition the transition period (*i.e.* 2023-2050). The best-performing locations barely reach a value of 0.5, reflecting persistent socio-economic gaps. Interestingly, countries and regions that rank high in the use of energy and materials, or aggregate economic activity, do not necessarily rank the highest in terms of welfare. Once sufficiency levels are reached, human welfare is primarily achieved through policies and social structures that channel resources towards overall well-being.

The shift from fossil fuels to renewables increases social and environmental welfare by reducing pollution and mitigating climate change. To further increase welfare, policies must address gaps in socio-economic structures. Figure 3.3 builds on Figure 3.2 by adding welfare index results for the 1.5°C Scenario, again for the same set of countries and regions. These transition scenarios bring about significant welfare improvements over the PES.

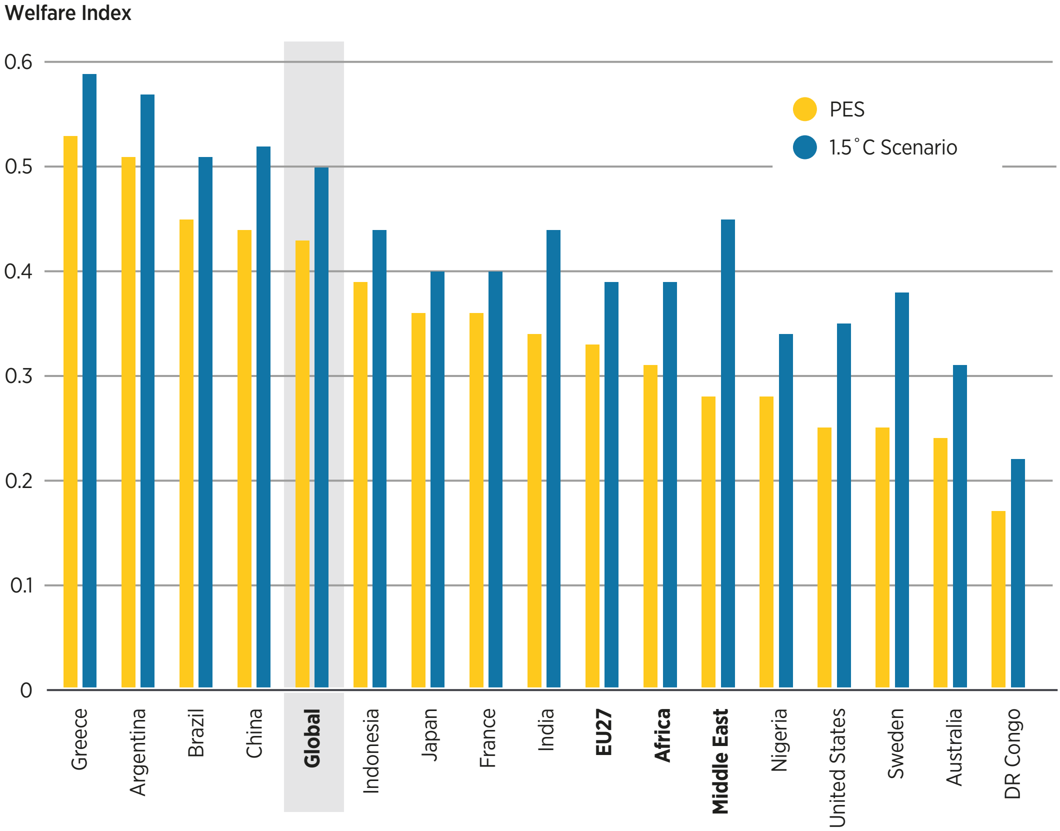
[9] *To accurately assess the socio-economic footprint of a particular course of action, it is important to use tools that capture feedback across systems (energy, economy, society, planet). Otherwise, there may be unintended consequences as the negative feedback from one system cancels out the benefits to another.*

FIGURE 3.2 **Welfare index under the Planned Energy Scenario (PES) in selected countries and regions, 2023-2050**



Note: DR Congo = Democratic Republic of Congo; EU = European Union.

FIGURE 3.3 **Welfare index under the Planned Energy Scenario and 1.5°C Scenario in selected countries and regions, 2023-2050**



Note: PES = Planned Energy Scenario; Congo = Democratic Republic of Congo; EU = European Union.

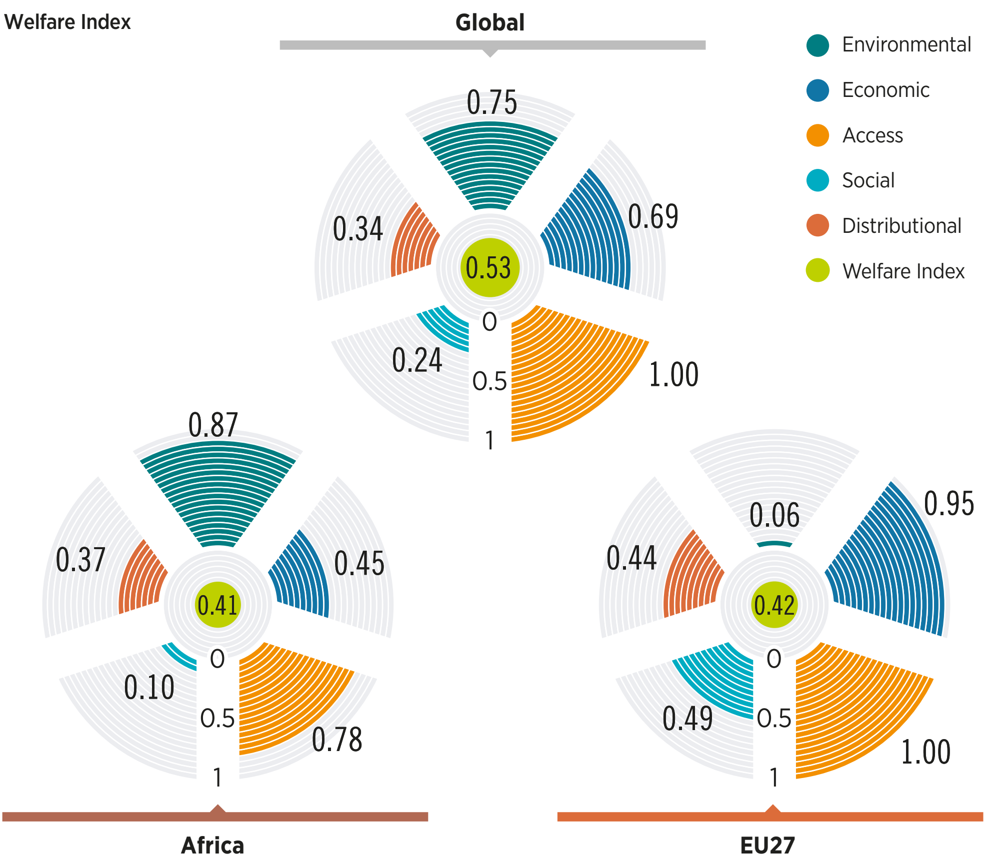
In general, welfare improves over time in the 2022-2050 period across the scenarios. The only exception is under the PES in the early years of the period in question, amid the lingering impacts of COVID-19's onset and the energy price crisis. The 1.5°C Scenario, with its mitigation impacts and policy components fostering international collaboration and redistribution, generates far greater welfare improvements than does the PES in both regions.

While the IRENA Energy Transition Welfare Index allows simple, direct comparisons across scenarios and regions, it does not offer insights into the factors behind results, or into which policy actions would bring further improvements. A separate index, for each of the five dimensions, helps to clarify this. To represent this graphically, IRENA presents the overall welfare index (shown at the centre of a flower-shaped illustration) along with the five-dimensional indices (shown as "petals"). Figure 3.4 presents these five dimensions for the world, and regions (*e.g.* Africa and the EU27) under the 1.5°C Scenario in 2050. While the overall index values in Africa and EU27 (0.41 and 0.42, respectively) are quite similar, their dimensional indices differ. The EU27 performs better in the economic, social and access dimensions. Africa performs significantly better in the environmental dimension – despite its greater vulnerability to climate change – due to its very low consumption of materials.

At the global level, Figure 3.4 shows the significant potential for improvement in the social and distributional dimensions, with less yet still significant potential in the economic and environmental dimensions. This is despite the 1.5°C Scenario's strong policies addressing general welfare, and the social and distributional dimensions in particular.

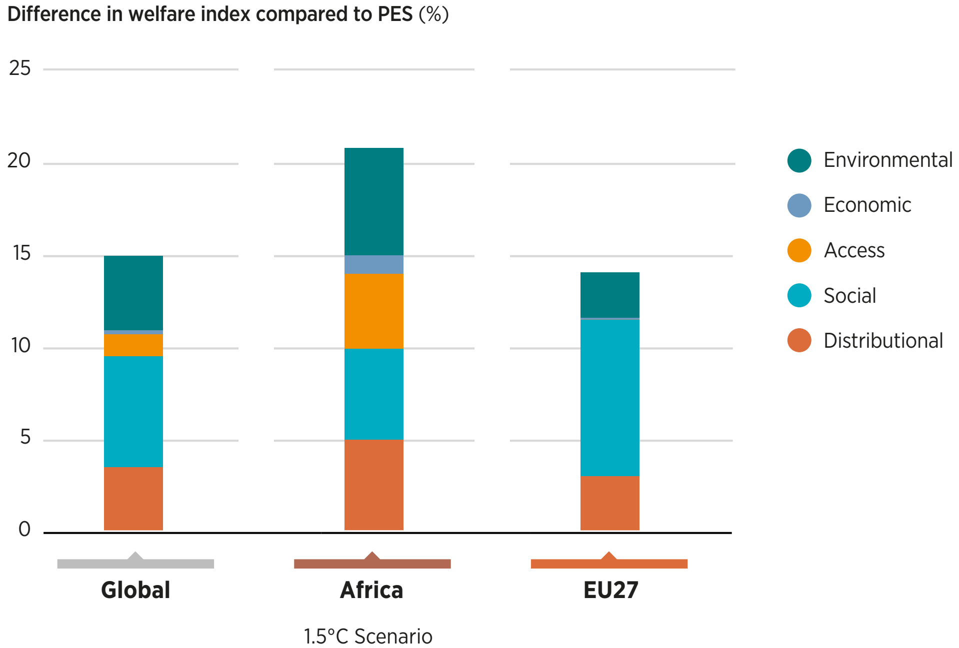
Figure 3.4 illustrates the significant welfare improvements, over the PES, brought about by the transition scenario. Figure 3.5 complements this by providing insights into which welfare dimensions drive these improvements. Across the globe and particularly in Africa, all five welfare dimensions contribute to the improvements. In the EU27, improvements are driven by the social, distributional and environmental dimensions (reflect the already high access and economic indices under the PES). Under the 1.5˚C Scenario the welfare index is around 15% higher than under the PES at the global level (Figure 3.5).

FIGURE 3.4 Overall welfare index and dimensional welfare indices for the 1.5°C Scenario by 2050: Global, Africa and EU27



Note: The five petals are on a scale from 0 (low performance) to 1 (high performance) and represent the absolute values of the five dimensions of the Welfare Index. The number in the centre is also on a scale from 0 to 1 and represents the absolute value of the overall Welfare Index. EU = European Union.

FIGURE 3.5 **Welfare differences between the Planned Energy Scenario and the 1.5°C Scenario, by dimensional contributions, by 2050: Global, Africa and EU27**



Note: PES = Planned Energy Scenario; EU = European Union.

In Africa, the benefits of the 1.5°C Scenario (relative to the PES) are quite balanced across all dimensions except the economic dimension, which makes a smaller contribution. Further improvements would require steps to restructure socio-economic systems, rethinking economic activity and its distribution so that it becomes focused on the creation of shared prosperity.

Rethinking economic structures and activities, and the distribution of its beneficiaries could lead to shared prosperity.

3.2 A deep dive into the welfare index

This section offers observations about the five welfare dimensions: environmental, economic, social, distributional and access.

The economic dimension

The economic dimension of the welfare index is composed of two indicators: (1) per capita consumption and investment and (2) non-employment.

The *per capita consumption and investment* indicator establishes a minimum and an upper threshold for investment. At the minimum, investment covers basic needs, and investment need not extend beyond the upper threshold to reap welfare benefits. A logarithmic scale represents how welfare is improved by higher levels of consumption and investment.

The investments required to transform the energy system have direct, indirect and induced economic effects that impact both indicators. The distribution of these effects depends on existing economic structures. Countries manufacturing the equipment needed for the energy transition will reap greater benefits, while those that depend on fossil fuel technologies that are being phased out are likely to experience negative effects. Policies beyond the energy system can also affect the economic dimension. For instance, international collaboration and redistributive policy measures can significantly improve consumption, investment and employment.

Contrasting two diverse regions of the world, Africa and the EU27, in terms of per capita consumption and investment, Africa derives a greater relative increase than the EU27. Still, Africa's consumption and investment remain well below the minimum threshold of sufficiency and there is limited convergence between the two regions. In 2022, consumption and investment levels in the EU27 were 19 times higher than in Africa; by 2050 this ratio would be reduced to 14 and 13, respectively, under the PES and 1.5°C Scenario. At the level of some individual countries, this gap is even more pronounced.[10] Addressing these staggering inequalities requires fundamental structural changes in the socio-economic system in ways that go far beyond the energy industry.

The second indicator informing the economic dimension is *non-employment*, a term that encompasses the portion of the working-age population that is neither employed nor receiving an education.[11] Demographic dynamics drive up non-employment worldwide in all scenarios. This is because the working-age population increases faster than employment and education/training. Relative to the PES, the 1.5°C scenario dampens this rise, partly because of the additional jobs generated in the energy transition. But this is mainly due to the employment impact of additional public social investment and spending (for instance, in education, health or increased food security) and additional consumption enabled by social-directed payments.

The demographic dynamics vary by country and region. For instance, the growth of the working-age population exceeds employment and education/training in Africa, whereas in the EU27, aging populations and greater availability of jobs and education/training lead to a reduction in overall non-employment. In countries and regions where non-employment is bound to increase over time due to demographic trends, additional policies addressing structural socio-economic issues would be needed.

[10] *Comparing Switzerland and the Democratic Republic of Congo (DR Congo), for example, the ratio rises from 209 in 2022 to 228 under the PES and 226 under the 1.5 °C Scenario in 2050. Or between the United States and DR Congo, the ratio is 155 in 2022, and by 2050 it increases to 165 under the PES, and to 148 under the 1.5 °C Scenario.*

[11] *Non-employment is the share of the working-age population that is neither employed nor in education.*

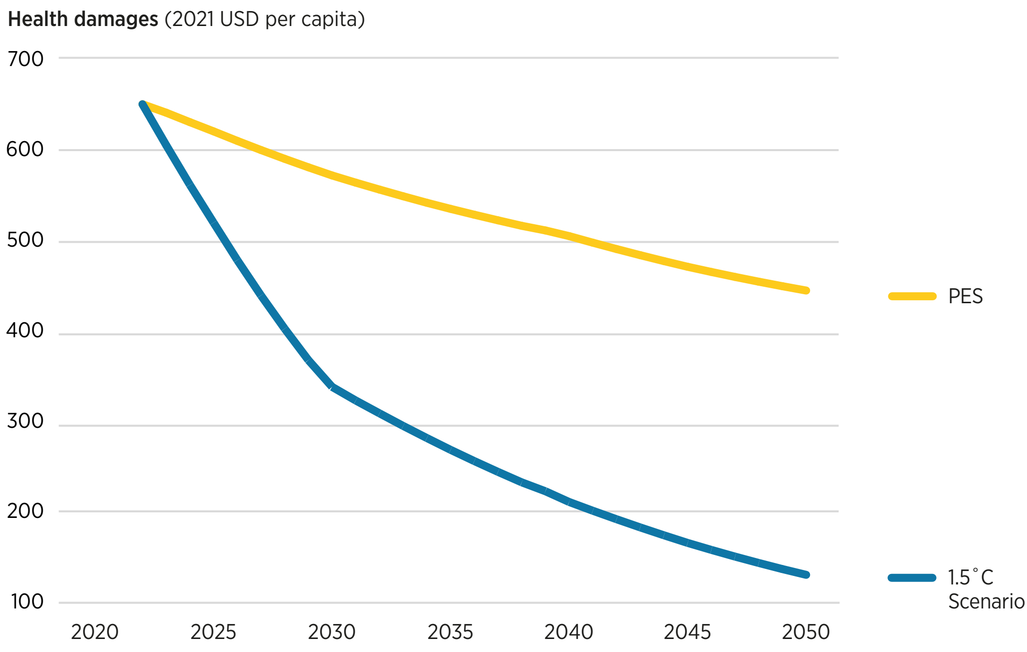
The social dimension

The social dimension of the welfare index is composed of two indicators: (1) social expenditure and (2) the health impacts of pollution.

Social expenditure is expressed as per capita public expenditure providing social value (*i.e.* policies beyond the energy system). Because earlier editions of IRENA's *World Energy Transitions Outlook* (IRENA, 2021b, 2022a) identified huge gaps in this indicator, this report includes policy components intended to improve welfare outcomes. International collaboration plays an important role here, as do policies earmarking and directing public investment and expenditure towards social value creation.

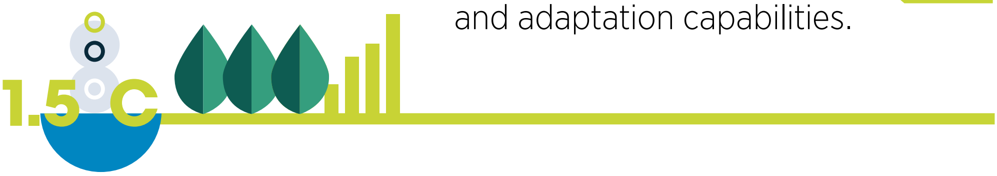
The impact of the transition on the evolution of per capita social expenditure in Africa and the EU27 is positive for both regions, with Africa seeing a greater socio-economic impact. And as is the case for the economic dimension of welfare impacts, there is limited or no convergence between advanced and emerging/developing economies of the world. In 2022, the ratio of per capita social spending in the EU27 to that in Africa was 24, and by 2050 it would rise to 35 under the PES while staying roughly even at 25 under the 1.5°C Scenario. The same trend is observed at the country levels. Hence, the policies introduced in the 1.5°C Scenario help avoid further divergence and even greater inequality.

FIGURE 3.6 Global per capita health damages due to pollutants, 2022-2050



Note: PES = Planned Energy Scenario.

Climate change impacts vary due to regional temperature differences, climate vulnerability, and adaptation capabilities.



The second indicator in the social welfare dimension is *per capita health damages due to pollution*. These are estimated by considering the benefits directly linked to the phaseout of fossil fuels and expansion of energy access (specifically clean cooking). Both the PES and the 1.5°C Scenario present a decline in health damages, but the latter provides much greater benefits (Figure 3.6). By 2050, however, health impacts are still significant. Mitigating them would require a faster transition and fossil fuel phase-out. While results vary across regions and countries (linked to their respective energy balances), they all trend around the global average.

The environmental dimension

The environmental dimension consists of two indicators: (1) cumulative CO_2 emissions[12] and (2) per capita materials consumption.

The effects of a given amount of global warming differ significantly across the globe. This is because of the uneven distribution of regional temperature increases, and differences in both climate vulnerability and ability to address climate change impacts. Therefore, this indicator considers emissions as modulated by each country's degree of vulnerability. Progress on this indicator is linked to both the technological transition (deployment of renewables and efficiency) and the evolution of aggregate economic activity. The level of aggregate economic activity has been assumed to be the same across scenarios.[13] IRENA's Energy Transition Welfare Index considers vulnerability-adjusted cumulative emissions[14] as an indicator (IRENA, 2021a). For a given amount of global cumulative emissions, and hence global warming, countries with relatively high cumulative-adjusted emissions will experience greater impacts than countries with lower values.

Figure 3.7 presents the vulnerability-adjusted cumulative CO_2 emissions in selected countries under the PES and the 1.5°C Scenario.[15] A country like Democratic Republic of Congo (DR Congo) would experience a level almost three times that of Norway. Differing degrees of climate change vulnerability compound imbalances in socio-economic systems, to magnify overall inequality.[16]

[12] *From the energy sector and also from land use, and land use change and forestry.*

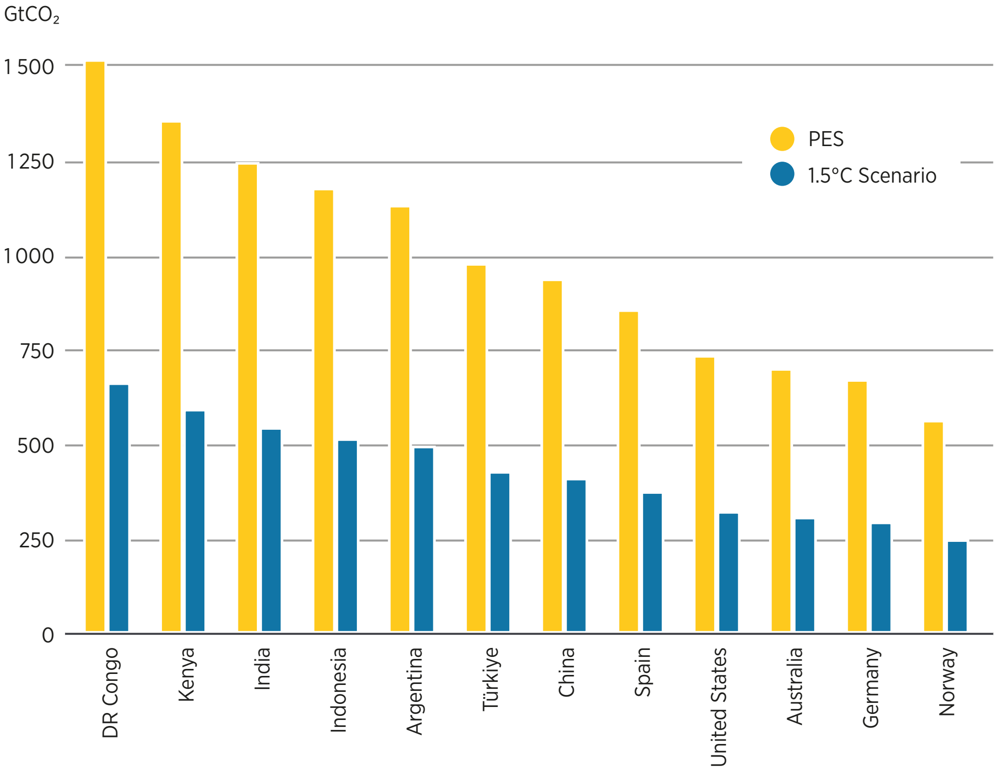
[13] *Indicated by the direct, indirect and induced impacts of increased energy sector investment on overall economic activity, which drive the GDP differences documented in section 3.2.*

[14] *The University of Notre Dame Global Adaptation Initiative Index was used to evaluate vulnerability-adjusted cumulative CO_2 emissions. This index has 36 indicators of vulnerability across health, food, ecosystem, habitat, water and infrastructure dimensions, and 9 indicators of readiness across social, governance and economic dimensions.*

[15] *Emissions for the sensitivities in the 1.5 ˚°C Scenario are the same, since energy balances are unchanged using the current methodology.*

[16] *Distributional impacts are directly embedded in most transition roadmaps. For example, mitigation scenarios with negative emissions could lead to a deterioration of food security since they assume a major share of the emissions mitigation burden would rely on the agriculture, forestry and other land use sector, such as through bioenergy with carbon capture and storage, and afforestation, in Asia and Africa (Fujimori et al., 2022; Hasegawa et al., 2018) .*

FIGURE 3.7 **Vulnerability-adjusted cumulative CO_2 emissions in the Planned Energy Scenario and 1.5°C Scenario in selected countries, 2023-2050**



Note: DR Congo = Democratic Republic of Congo; $GtCO_2$ = gigatonnes of carbon dioxide; PES = Planned Energy Scenario.

The second indicator, *per capita consumption of materials*[17], depends on the structure of the economy and on the level of aggregate economic activity. It relates to sustainability in terms of how the resources available are being used and is a proxy of impacts on biodiversity. The corresponding index includes a developmental allowance of 2.5 tonnes/person-year, for a minimum amount of materials required for inclusive development. The index also includes an upper threshold for performance in excess of planetary limits; if per capita materials consumption exceeds this value (12.5 tonnes/person-year), the index is zeroed (IRENA, 2021a). The upper threshold is already well surpassed in many countries (Bringezu, 2015; Hickel, 2020), a clear indication of the lack of sustainability embedded in many current transition scenarios. Globally, the sustainable planetary boundary of materials consumption is surpassed before 2035.

[17] *This is currently formulated in terms of Domestic Materials Consumption and includes metals, non-metallic minerals and biomass (wood, food) but excludes fossil fuels. The DMC quantifies the total mass of material extraction within a nation's borders, plus the mass of imports, minus the mass of exports. Although DMC accounts for trade to some degree, it does not include the embedded upstream material extraction required to produce traded goods.*

However, huge disparities exist. Some countries and regions do not even reach the developmental allowance threshold by 2050 while others far overshoot the sustainability limit.[18] For instance, Africa and India barely reach 2 tonnes, while the EU27 is at about 15 tonnes and Australia at close to 40 tonnes. The ratio of per capita materials use between the EU27 and Africa is about 9 over time and across scenarios. For selected countries, these differences are even more pronounced.[19]

The distributional dimension

The distributional dimension consists of two indicators: distribution (1) between countries and (2) within countries/regions. Each one of them is in turn informed by two sub-indicators, namely income distribution and wealth distribution (serious inequalities persist in other aspects as well, including social spending, climate impacts, materials consumption and energy use). Given that tremendous distributional inequalities persist under an energy transition solely focused on a technological pathway, several of the policy components considered in this report directly aim at improving the distributional dimension of welfare.

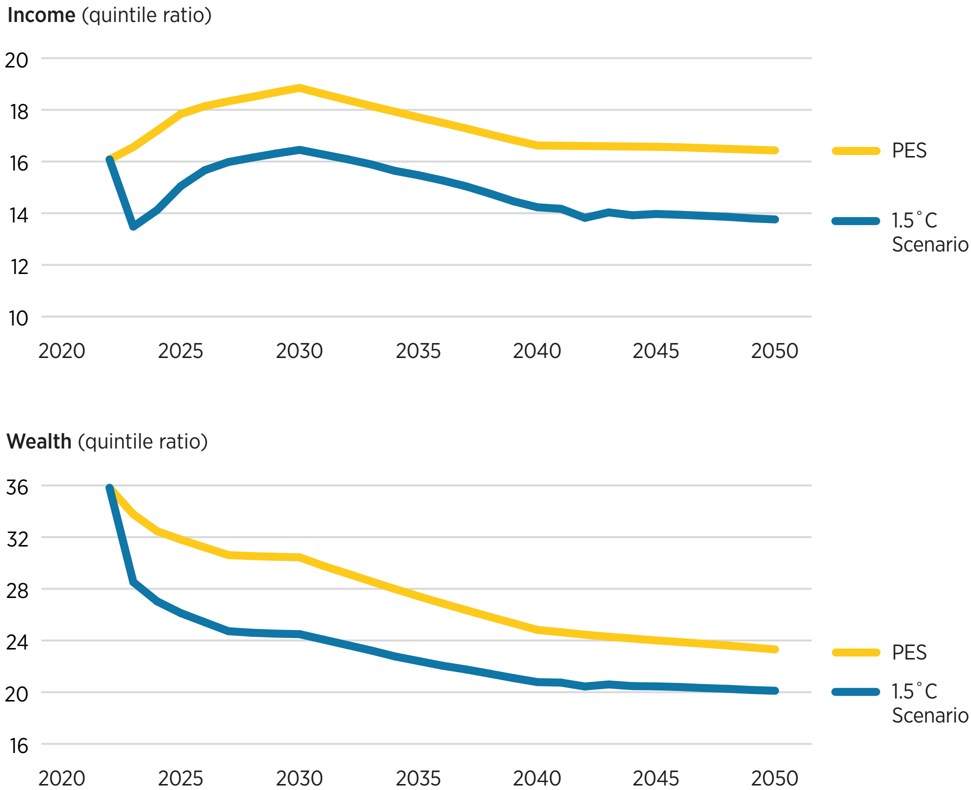
The indicator used to measure the distribution of income and wealth between countries is the quintile ratio (QR). This is the ratio of the average per capita income/wealth in the highest quintile of the world's countries, to the average in the lowest quintile, or – simply put – the richest 20% relative to the poorest 20%. A distributional improvement is characterised by a reduction of the QR. Figure 3.8 presents the evolution of income and wealth QRs across scenarios. The transition scenarios (with their accompanying policy measures) provide important and lasting distributional improvements in both income and wealth.

The increasing income QR under the PES until 2030 is driven by high energy prices and a rising cost of living as a consequence of the COVID-19 recovery and the on-going geopolitical shocks, effects that are assumed to last until 2026-2027. This means that in the years through 2030, inflation remains relatively high, hitting low-income households and countries the hardest. In the transition scenario, this trend is neutralised by a boost in investment from the energy transition and international collaboration financial flows. Energy transition investments are front-loaded; therefore, it is mainly international collaboration that provides the lasting distributional impacts.

[18] The welfare index evaluates domestic materials consumption, which does not account for the materials embodied in imported products. In terms of materials footprint, inequality is still more pronounced.

[19] Between Luxembourg and DR Congo, the ratio was already around 235 in 2022 but would soar to close to 460 by 2050 under the 1.5°C Scenario.

FIGURE 3.8 **Global income and wealth quintile ratios under various scenarios, 2022-2050**



Note: PES = Planned Energy Scenario; QR = quintile ratio.

Despite the significant distributional improvement brought about by international collaboration, income and wealth QRs remain high by 2050 (for an income QR above 10 and wealth QR above 15), and international collaboration levels considered here[20] are already high relative to current standards (Flavelle, 2023).

[20] About 2021 USD 2 trillion/year on average in 2023-2050.

Inclusive development requires providing the space for energy services to increase from basic needs to energy sufficiency.

The access dimension

Access is informed by two indicators: (1) access to basic energy and (2) progression along the energy sufficiency level (assumed at 20 kilowatt hours (kWh)/capita/day in line with the literature (Millward-Hopkins *et al.*, 2020)[21]

Energy access in the transition scenarios is driven by the Sustainable Development Goals agenda, with the assumption that universal basic energy access is indeed achieved by 2030. But the welfare index's access dimension acknowledges that basic energy access is only a first step towards full energy access. The index therefore includes another indicator which measures progress along the energy ladder towards energy sufficiency (necessary for inclusive development). The indicator used to measure progress along the energy ladder is per capita total final energy consumption (TFEC). The ultimate goal is not energy consumption per se, but rather the energy services needed for a decent life. By increasing overall energy efficiency, the same amount of services can be provided using a smaller amount of energy. The energy access index uses a sufficiency limit[22] with an efficiency modulation function that captures the effect of energy efficiency improvements in reducing energy consumption.

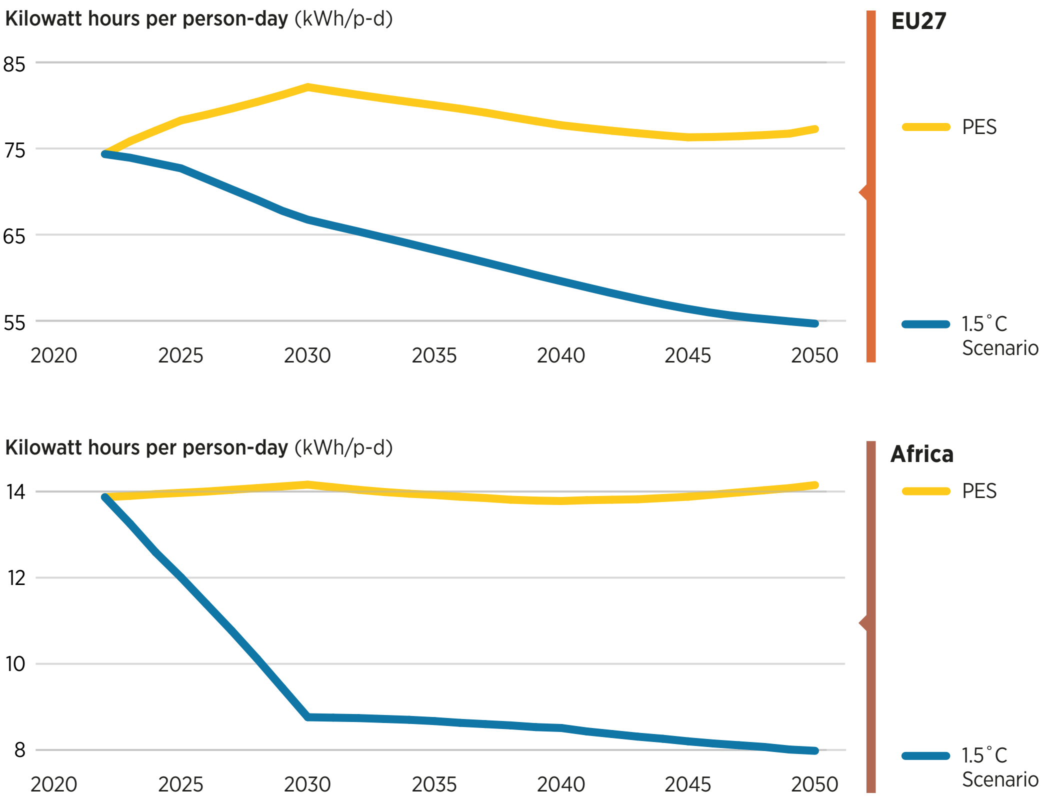
Figure 3.9 presents the evolution of per capita TFEC in Africa and the EU27 across scenarios. Two points can be made: First, energy consumption drops in both regions, but the drop is larger and more immediate in Africa, despite a baseline below sufficiency. This drop in energy consumption can be attributed to greater energy efficiency, and in the emerging and developing countries it should provide an opportunity to progress along the energy ladder. Second, per capita energy consumption does not converge. In fact, the huge disparities at baseline are further amplified over time. As has been noted several times, the persisting inequalities in consumption of energy are directly linked to structural socio-economic conditions.

The lack of convergence and resulting inequalities are more pronounced at the country level. Figure 3.10 presents the ratio of per capita TFEC in selected regions/countries across scenarios, indicating rising divergence over time. The 1.5°C Scenario shows a higher level of divergence than the PES; by 2050 ratios of per capita TFEC in several countries could be as high as 50-100.

[21] *Sufficiency level estimated between 11.6-30.4 kWh/capita/day across all 119 countries depending on the scenarios considered.*

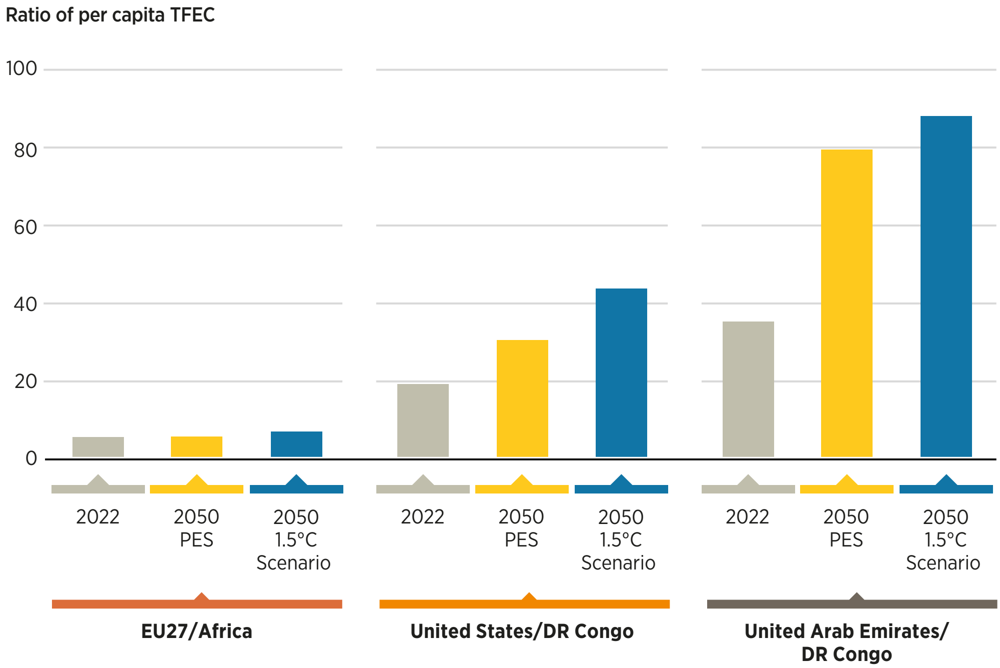
[22] *Per capita TFEC levels above the sufficiency limit do not improve the index value, or overall welfare.*

FIGURE 3.9 **Evolution of per capita total final energy consumption across scenarios in the EU27 and Africa, 2020-2050**



Note: EU = European Union; PES = Planned Energy Scenario.

FIGURE 3.10 **Ratio of per capita total final energy consumption in selected regions/countries, 2022 and 2050**



Note: DR Congo = Democratic Republic of Congo; EU = European Union; PES = Planned Energy Scenario; TFEC = total final energy consumption.

Inclusive development requires providing the space for energy services to increase. Even as energy efficiency improves, per capita consumption could increase. In the emerging and developing countries, consumption is reduced more under the 1.5°C Scenario (*e.g.* by over 50% in DR Congo) than in the advanced economies (*e.g.* by about 20% in Canada), and the requirements for energy reduction are more immediate (*i.e.* by 2030 the difference is even higher).

In today's global economic landscape, it is crucial to tailor policy options to amplify social benefits, including income, health, education, employment and overall well-being. As discussed, welfare, an alternative to GDP, is instrumental in evaluating the impacts of augmented renewable energy use. As outlined in this chapter, the energy transition promises significant benefits beyond an increase in GDP and employment.

For these benefits to persist, however, they will need to be supported over time by comprehensive policies. Many such policies have been discussed across the chapters of this report. The energy transition is a gradual process, and policy makers will need to think holistically and align energy policy with other areas of national policy over an extended period of time to ensure an inclusive and just transition – and to meet a central global objective: energy justice for all.

CHAPTER 04

CONCLUSIONS AND POLICY RECOMMENDATIONS

FOR A JUST, EQUITABLE AND INCLUSIVE ENERGY TRANSITION

4.1 A holistic policy framework

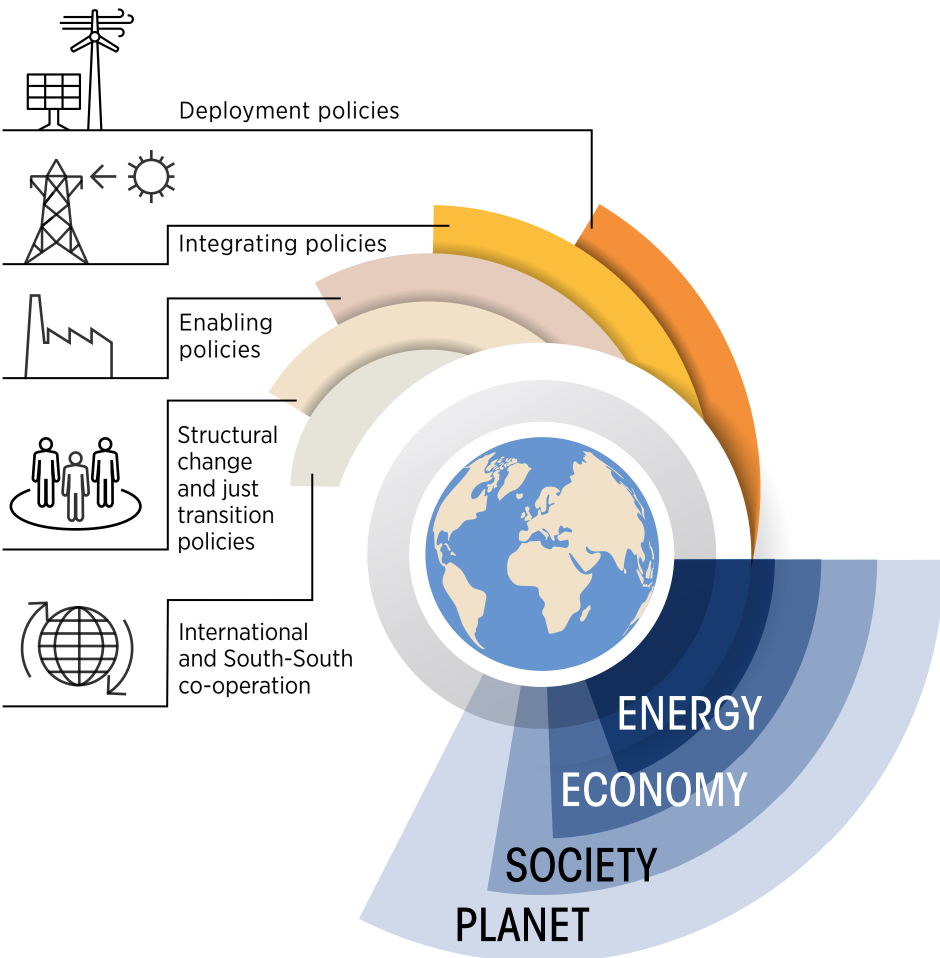
Increasingly refined and mature technologies have made renewable energy not only attractive but also cost-competitive with fossil fuels. Experience in the design and application of policies and regulations supporting the deployment of renewables is now extensive in many parts of the world. These are indeed encouraging developments, yet progress in transitioning to a clean energy system still falls short of the scale and speed needed to adequately address the climate crisis. A central contention of this report is that the socio-economic dimension of the energy transition requires more attention. To win broad support for comprehensive, ambitious policy measures that would not only extend but also increase the transition's socio-economic benefits, policy makers need to disseminate a compelling narrative, using the facts at hand.

Climate ambition abounds in governmental and corporate announcements, particularly in the run-up to the 2023 United Nations Climate Change Conference (COP28). Frequent reference to the need for a just and inclusive transition, and newfound interest among growing numbers of governments in industrial policy to scale up renewable energy, suggest that the world may be on the brink of taking strong action. The next step is to shore up popular and political support for the energy transition, rallying people around the colossal global collective effort needed to address the unfolding "polycrisis." It will not be easy to meet today's intersecting challenges that include those stemming from climate change, the transgression of more and more planetary boundaries, and growing socio-economic imbalances and misalignments, among others.

This report has explored ways in which the present energy transition trajectory can be corrected. The energy transition requires a comprehensive and holistic policy framework (see Figure 4.1). Most immediately, of course, this includes policies that directly advance the generation of renewable energy. Deployment policies facilitate the scale-up of renewable energy capacities. Integrating policies stipulate ways to feed renewables into power grids and integrate them into other energy delivery systems. Public investments can fund infrastructure such as transmission and distribution systems. Under the heading of enabling policies, public funds can support long-term energy planning, capacity building and training, and research and development.

But as IRENA's analysis has demonstrated, successful policy making cannot be restricted to the energy sector alone, given the industry's extensive links to the economy at large, and the ways in which the economy is inextricably connected to broader societal and planetary issues. Ultimately, the energy transition can succeed only if it is seen and experienced as just across different communities, countries and regions. This implies that policy making must be embedded in, or linked to, efforts to: narrow the vast inequities between rich and poor; make economies more sustainable; and mitigate the intensity and frequency of climate and other environmental calamities in the coming decades. The energy transition alone cannot be expected to resolve these long standing and deeply structural problems. But holistic approaches can help to identify ways in which different domains of policy making can be interlinked better. For example, it is commonly accepted that the climate agenda has to go hand in hand with efforts to fulfil the Sustainable Development Goals, and that progress in one can provide positive impetus to the other.

FIGURE 4.1 A comprehensive policy framework for the energy transition



Distilling the discussion in the previous chapters, this chapter first summarises the policy measures needed to bring about a successful energy transition and ensure equitable outcomes (section 4.2). This is followed by a discussion of policies required to promote the broader, structural changes in the economy recommended in earlier chapters (4.3). Finally, the chapter sketches some ideas to bring the global economy more in line with planetary boundaries (4.4).

4.2 Supportive policies for equitable outcomes

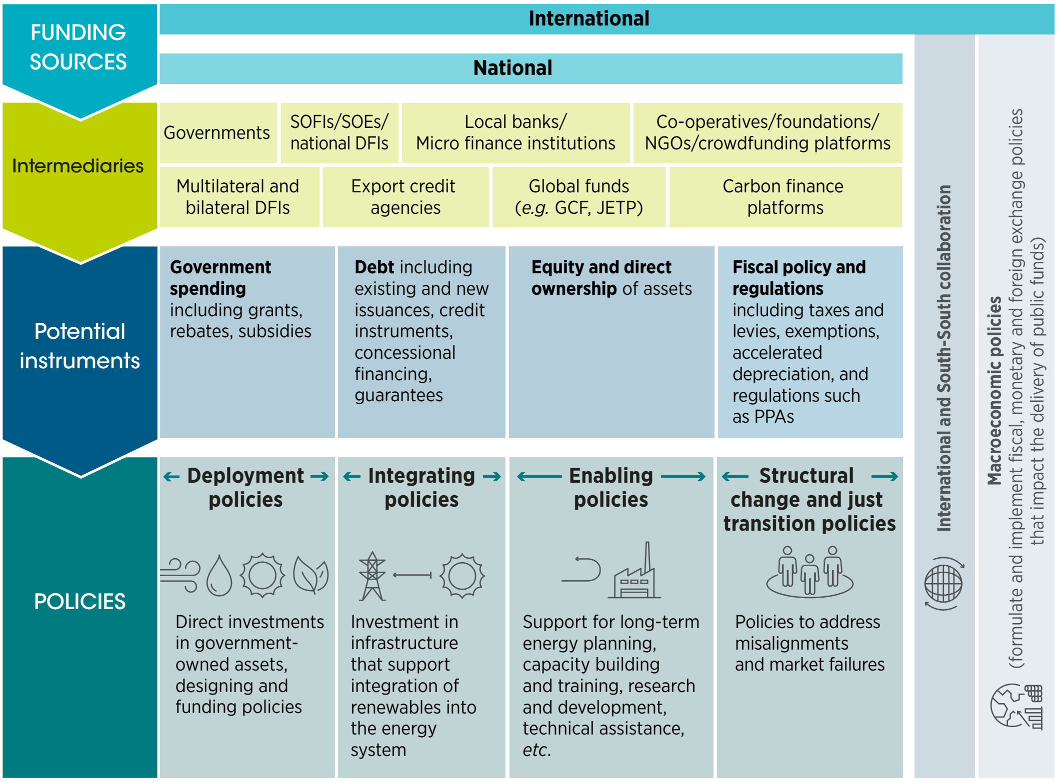
As detailed in Chapter 2 (specifically, Box 1), IRENA's policy measures include an array of measures such as phasing out fossil fuel subsidies while providing subsidies for transition-related technologies where needed; adopting carbon pricing differentiated by each country's income level; implementing regulations and mandates to further facilitate the deployment of renewables, electric vehicles, hydrogen, energy efficiency and other transition-related technologies; and undertaking direct public investment to support the transition. Many of these kinds of policies are the domain of national governments, but some would require a higher level of international co-operation. A differentiated carbon pricing regime that takes into account the diverging economic capabilities of different countries could only come about through intergovernmental negotiations, a challenging process.

Underlying the analysis is the argument that additional measures – beyond those focused on technology development and renewable energy deployment – are required to ensure equitable outcomes. For the purposes of this report, these measures include international collaboration flows of greater magnitude, progressive fiscal policies, along with redistributive policies.

Public funds may flow through intermediaries such as governments, multilateral and bilateral development finance institutions, and global funds such as the Just Energy Transition Partnerships (Figure 4.2). The money can flow as direct investments in public-owned transition assets, or be used to attract and support private investment (*e.g.* through grants, rebates and subsidies; concessional financing and guarantees [IRENA and CPI, 2023]). Importantly, a portion of international collaboration (around 10%) would be directed toward social-directed payments in support of social objectives, including an inclusive transition.

IRENA's policy measures include an array of measures while providing subsidies for transition-related technologies.

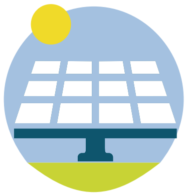
FIGURE 4.2 The flow of public finance for a just and inclusive energy transition



Note: PES = Planned Energy Scenario; Congo = Democratic Republic of Congo; EU = European Union.

Besides the Planned Energy Scenario (PES), with its business-as-usual policy basket, this report has modelled the socio-economic footprint of the 1.5°C Scenario, forecasting their effects on welfare, employment and gross domestic product. The modelling results show that an ambitious approach to the energy transition – one that puts socio-economic objectives at the core of policy making – can yield substantial benefits, advancing progress towards the goal of a just transition for all. Relative to the PES, the global economy is projected to grow annually on average by 1.5% under the 1.5°C Scenario. This difference in gross domestic product is mostly attributable to higher transition-related investment and social-directed payments to low-income households to make the transition more inclusive.

Under the 1.5°C Scenario, on average annual terms, economy-wide employment will be 1.7% higher than under the PES between 2023 and 2050. By 2050, the more ambitious trajectory would yield 140 million jobs in the energy sector. About 40 million people would work in renewable energy by then, which is twice as many as predicted under the PES. When compared to the PES, the 1.5°C Scenario would create 38 million more jobs in other transition-related sectors (*i.e.* energy efficiency and other end-uses, grids and energy flexibility, hydrogen, *etc.*).



Increased international collaboration will help ensure rapid acceleration of the energy transition and improve welfare more equitably.

The overall welfare gains over PES are also significant. The welfare findings emphasise the need for policies and societal institutions that direct resources towards increasing well-being once sufficiency levels have been reached. The transition from fossil fuels to renewable energy sources affects social and environmental welfare dimensions primarily by lowering pollution and slowing global warming. Increased international collaboration flows help redistribute welfare more equitably via social-directed payments to the bottom quintiles, especially in the developing countries.

4.3 Policies to promote structural change

A comprehensive approach to the energy transition needs to include a set of policies to promote structural change and enable countries to take full advantage of socio-economic opportunities that emerge as the energy transition unfolds.

Decades and centuries of unequal development have brought about different patterns of strengths and weaknesses among different countries and regions of the world. These translate into technological, financial, commodity and trade dependencies and misalignments. For example, unequal exchange between the advanced and developing economies amounts to a net drain from the less economically advanced countries of a staggering USD 11 trillion per year (Hickel *et al.*, 2022).

There is a risk that structural dependencies could simply be replicated in the energy transition. As it stands now, very few countries have the ability to produce more than a limited set of components for solar photovoltaic panels, wind turbines, electric vehicles, batteries, or other energy transition technologies. This limits the degree to which they can generate domestic value and create lasting, decent jobs. In fact, if resource-rich countries that are either emerging or developing are unable to pursue green industrial development, they may once more find themselves relegated to the role of mere commodity producers, while the bulk of value added would continue to accrue elsewhere.

Changing these patterns (through key policy measures) is a highly complex undertaking, requiring not only a strong vision of the future, clear-eyed leadership, and engagement with industries, communities and other stakeholders, but also co-ordinated action to marshal human skills and technical competencies, establish competent and dedicated institutions, pursue regional or global co-operation for capacity-building, and mobilise public and private financial resources.

Key policy measures include:

- **Industrial policies.** Many countries do not at present possess the capacity to manufacture the equipment and related services needed for the energy transition and thus remain import dependent. The bulk of the socio-economic benefits to be had in this context thus accrues elsewhere, in a small number of exporting countries. Industrial policy making can leverage existing capabilities and further enhance them so as to form viable domestic supply chains and enhance local value creation. Industrial policy measures may include local content requirements; tax credits, subsidies, grants and loan guarantees for manufacturing; public funds for research and development; inexpensive provision of electricity and land; and infrastructure upgrades.
- **Skills assessments and education and training strategies.** Countries need to undertake detailed assessments of required occupational patterns to create a skilled, capable energy transition workforce. This includes continuous co-ordination between the renewable energy industry and the educational system in an effort to match, as much as possible, industry demand for skills and the supply of skills generated by schools, vocational centres and universities, thus avoiding skill gaps. Given that millions of jobs in the fossil fuel sector will fall by the wayside as the energy transition accelerates, particular emphasis needs to be placed on efforts to retrain workers from that sector. This entails not only an assessment of existing skills that can be adjusted and repurposed, but also programmes to facilitate the necessary re-accreditation of workers.
- **Labour market measures.** These include programmes to provide adequate employment services to assist people in entering the workforce or finding new jobs. During the transition, various types of labour market misalignments may emerge: temporal (job creation and job loss not taking place at the same time); spatial (job creation not necessarily in the same location as job loss); sectoral (job gains and losses affecting different industries); and educational (job creation and job loss marked by different skills profiles). Thus, programmes to facilitate labour mobility and other measures may be needed.
- **Community investment and revitalisation.** Public investments can be tailored in ways to enhance the ability of communities and regions to take advantage of energy transition opportunities. Such measures are best connected to industrial policy making (*e.g.* efforts to modernise or upgrade a region's infrastructure can help attract energy transition investment). There is also a need for social protection programmes to assist fossil fuel-dependent workers and communities to cope with any transition challenges.

The policies sketched above will not generate immediate results. They require the long view, and a long-term commitment of resources, lasting political support and a willingness to adjust policies along the way and to keep learning from experiences around the world. Without doubt, this is a challenge vis-à-vis the short time horizon of electoral cycles and quarterly or annual corporate reporting standards.

Change requires a strong vision of the future, clear-eyed leadership, and engagement with industries, communities and other stakeholders.

4.4 Making the global economy more sustainable

The modelling for this report shows that the 1.5°C Scenario can grow the gross domestic product, the indicator that has been the bellwether of politics and economics around the world for some decades. But even as the poorer segments of humanity have ample reason to seek a larger slice of the economic pie in order to secure a decent life, wealthy countries and communities that consume the majority of the world's resources will need to find ways to moderate their claims. The energy transition needs to be embedded in broader systemic changes to ensure a level of human well-being at lower levels of energy and materials intensity, while overcoming historical disparities.

Ever more frequent climate-related disasters confirm the need to undertake an urgent, fundamental transformation of the economy, beyond a mere switch from fossil fuels to renewable energy. Six of nine planetary boundaries have already been crossed (Richardson *et al.*, 2023); ceaseless economic growth is not possible on a planet with finite resources and increasingly stressed ecosystems. Meanwhile, the dominant economic model fails to bring about universal well-being. It generates wide disparities in wealth and human development between and within countries and exposes the developing countries to the repercussions of resource depletion and to increasing climate vulnerability.

There is now a vibrant discussion of post-growth paradigms that would allow a transition towards more inclusive and sustainable economies. Moving in this direction would require scrutiny of fundamental production and consumption patterns and also efforts to differentiate between human needs and wants. This is not an easy task but could create the space needed by people consuming far less than what is needed to sustain a decent life. Hundreds of millions of people still fall short of the standards of human well-being embodied in the Sustainable Development Goals.

The task cannot be left to markets if a just, inclusive and more sustainable world is to be achieved. Policy priorities must be determined in open debate that includes the communities most affected by current inequities. Governments, acting in accord with stakeholders from across the spectrum of societies, will have to play a proactive role in transforming economic systems, reinforcing an argument that has underpinned IRENA's staple of socio-economic reports: a holistic framework considers technological innovation in conjunction with social, economic and environmental priorities.

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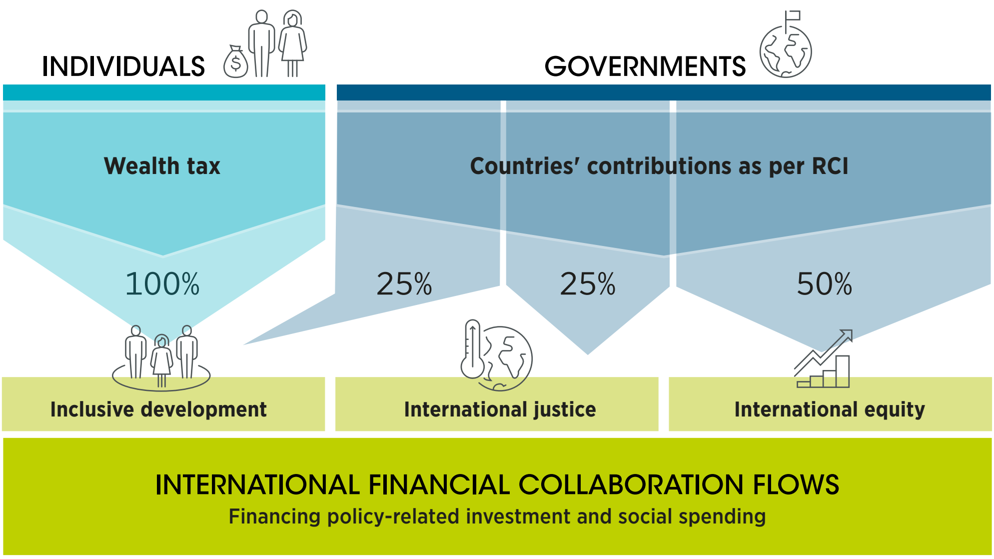
APPENDIX
Assumptions and results of wealth tax sensitivity analysis

In an additional sensitivity analysis under the 1.5°C Scenario, international collaboration is assumed to have two sources of funding, described below and illustrated in Figure A1. The first is country contributions, calculated using the Responsibility Capacity Index (Climate Equity Reference Project, n.d.) – that is, in proportion to countries' roles in producing the climate crisis, and their national wealth. The second is revenues from wealth taxation, a source of funding not considered in previous editions of the *World Energy Transitions Outlook* (IRENA, 2022a).

Derived from one of the scenarios of the World Inequality Report (Chancel *et al.*, 2022), the wealth tax scheme generates revenues for increased social expenditure and investment. Table A1 shows the tax rate assumed for each wealth group.

FIGURE A1 International collaboration funding: Contributions and distribution



Note: GDP = gross domestic product; RCI = Responsibility Capacity Index.

TABLE A1 Wealth tax assumptions

Wealth group (in 2021 USD)	Tax rate (%) per wealth bracket
1 million–10 million	**1%**
10 million–100 million	**1.5%**
100 million–1 billion	**2%**
1 billion–10 billion	**2.5%**
10 billion–100 billion	**3%**
Over 100 billion	**3.5%**

Source: (Chancel *et al.*, 2022).

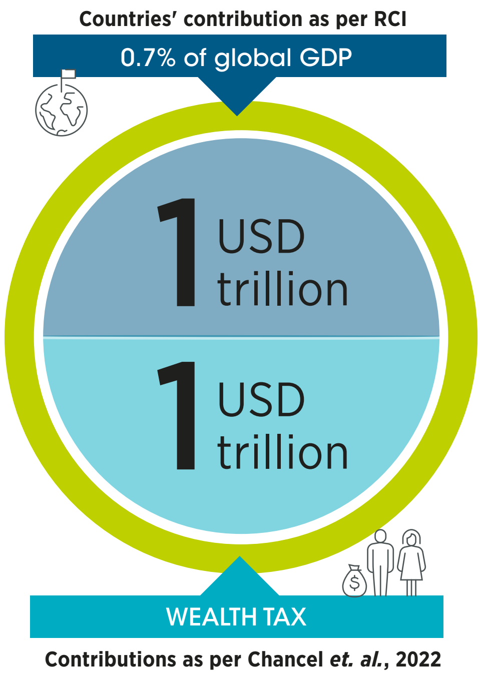
The revenues generated by the additional wealth taxation would provide an annual average of around USD 1 trillion between 2023 and 2050, equivalent to around 0.7% of global GDP in the same period. To put this number in perspective, wealth tax revenues represent an average of around 0.08% of total wealth and 0.09% of fifth quintile wealth over the 2023-2050 period. This would equate to an annual contribution of around USD 15 000 from each of the 62 million people listed in 2021 as having wealth of more than a million dollars.[23]

[23] *At market exchange rates (Chancel et al., 2022).*

Combining both sources of revenue, the total monetary flow of international collaboration amounts to approximately USD 2 trillion[24] per year (Figure A2), with half coming from government contributions and the other half from wealth taxation. The increased amount is used in the sensitivity analysis to bridge the welfare gaps in the developing countries, predominantly in the social and distributional dimensions. To address these gaps, the revenues from the wealth tax are divided as follows:

- 80% is allocated to additional social spending.
- 20% is directed towards improving government fiscal balances, which are assumed to eventually contribute to social-directed payments.

FIGURE A2 **Contributions to the Global Energy Transition Fund from public sector and wealth taxation**



Note: GDP = gross domestic product; RCI = Responsibility Capacity Index.

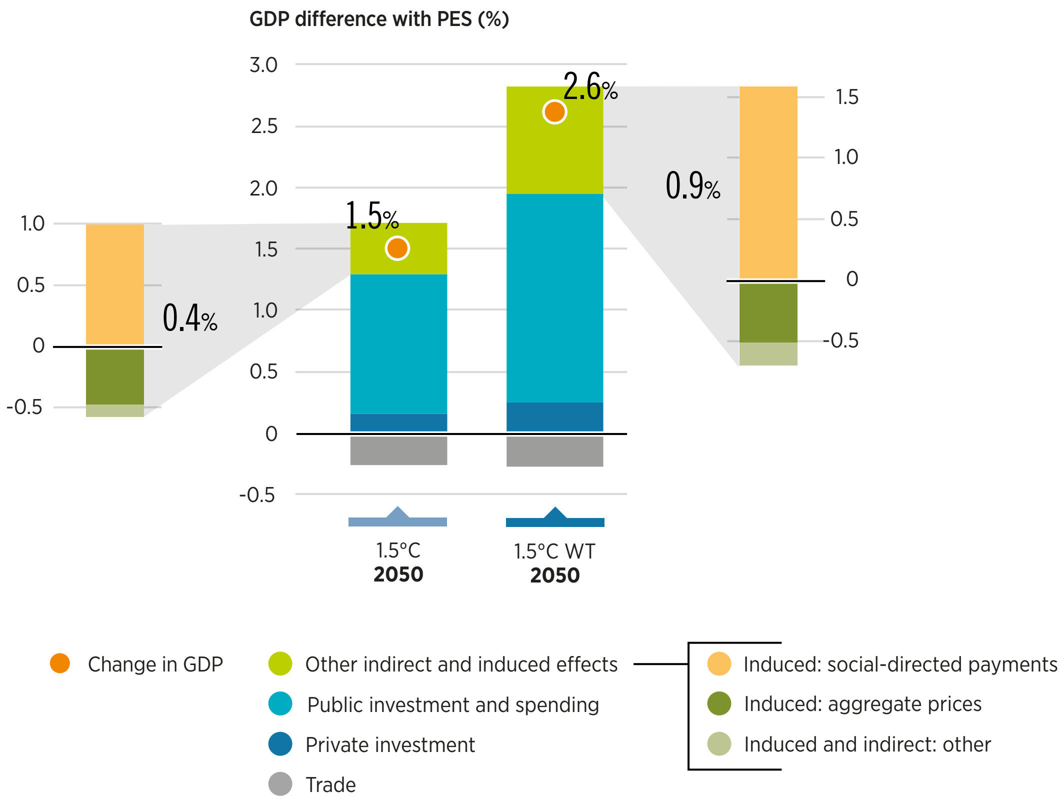
[24] *In 2021 USD.*

GDP results

Between 2023 and 2050, and compared to the 1.5°C Scenario, the introduction of wealth taxation in the 1.5˚C Scenario would see an increase in the annual average in GDP over the PES from 1.5% to 2.6% (Figure A3). Public investment is still the most influential driver throughout the transition period (*i.e.* 2023-2050). Under the wealth taxation sensitivity, a fraction of the wealth taxation revenues flows directly into government fiscal balances, increasing social-directed payments for the bottom quintiles, directly addressing the income distribution dimension and indirectly the economic dimension (consumption and investment).

Under the wealth tax sensitivity, the global analysis also shows large spatial disparities, as in the 1.5˚°C Scenario, with the same trend in GDP differences. The revenues from wealth taxation would address the social, distributional and economic dimensions in most of developing economies.

FIGURE A3 Global GDP average percentage difference between the PES and 1.5°C Scenario sensitivity, 2023-2050

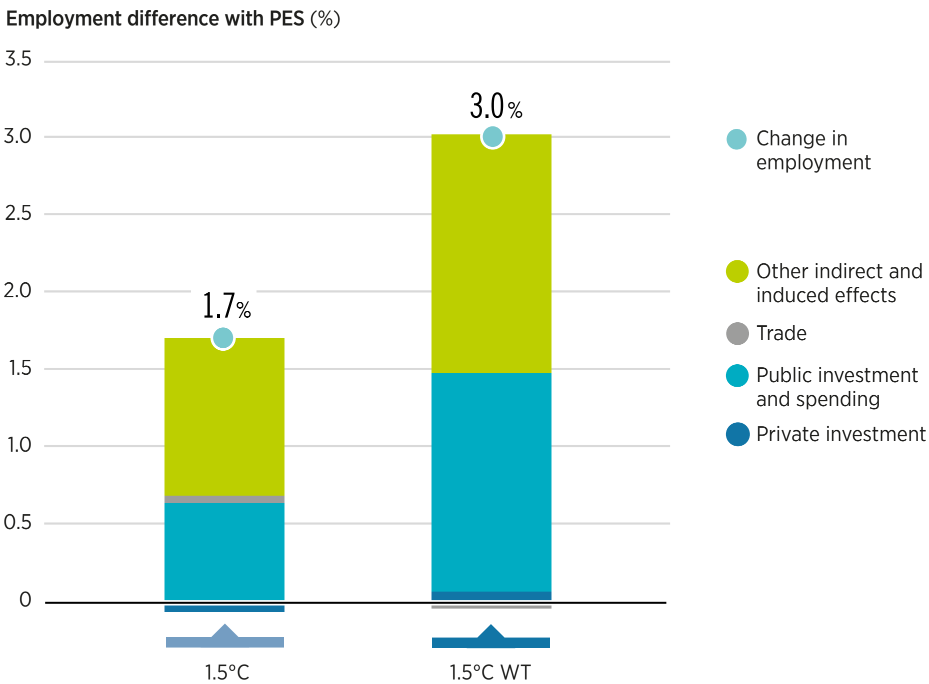


Note: GDP = gross domestic product; PES = Planned Energy Scenario; 1.5˚C= 1.5˚C Scenario; 1.5˚C WT= 1.5˚C Scenario with wealth tax sensitivity.

Employment

The economy-wide employment creation over the PES would be higher under the wealth taxation sensitivity case than in the 1.5°C Scenario. It would be 3.0% higher over the 2023-2050 period (A4). Employment creation would increase over the entire transition period under the sensitivity, strengthened by the implementation of the wealth tax. As in the 1.5°C Scenario, investment and other indirect and induced factors would also drive economy-wide employment variations in the wealth taxation sensitivity, but trade would have a minimal impact (Figure A4). In the second decade (2031-2040), compared to the PES, consumer spending is expected to create around 22 million jobs in the 1.5°C Scenario by 2050, a figure that would more than double to 45 million under the wealth taxation sensitivity.

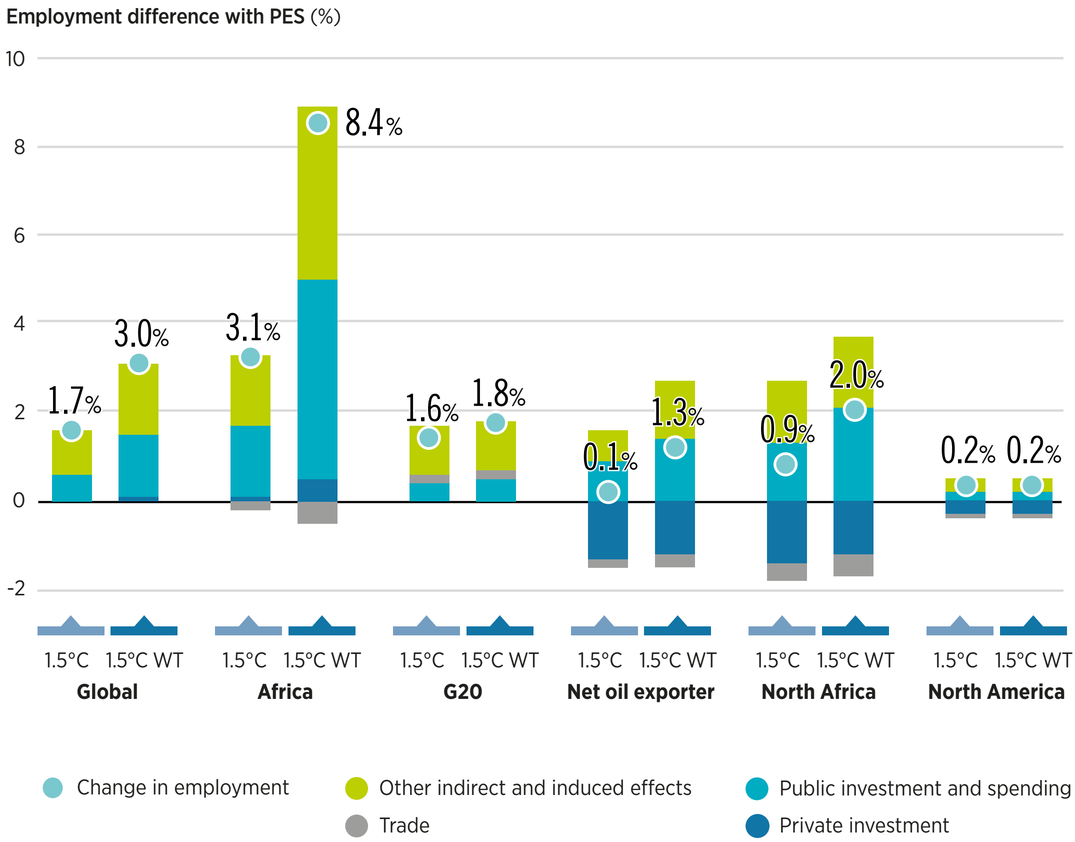
FIGURE A4 **Global economy-wide employment, average percentage difference between the PES and 1.5°C Scenario sensitivity, by driver, 2023-2050**



Note: GDP = gross domestic product; PES = Planned Energy Scenario; 1.5˚C= 1.5˚C Scenario; 1.5˚C WT= 1.5˚C Scenario with wealth tax sensitivity.

Under the wealth taxation sensitivity analysis, we can expect job creation to rise from 19 million to around 81 million by 2050. The impact of wealth taxation on employment creation is expected to be greater in key regions of the developing economies (notably Africa) than in the G20 countries (Figure A5). The reason, of course, is that those regions would be the recipient of increased international aid flows far in excess of their contribution to them.

FIGURE A5 **Average percentage difference in economy-wide employment in selected regions between the PES and 1.5°C Scenario sensitivity, by driver, 2023-2050**

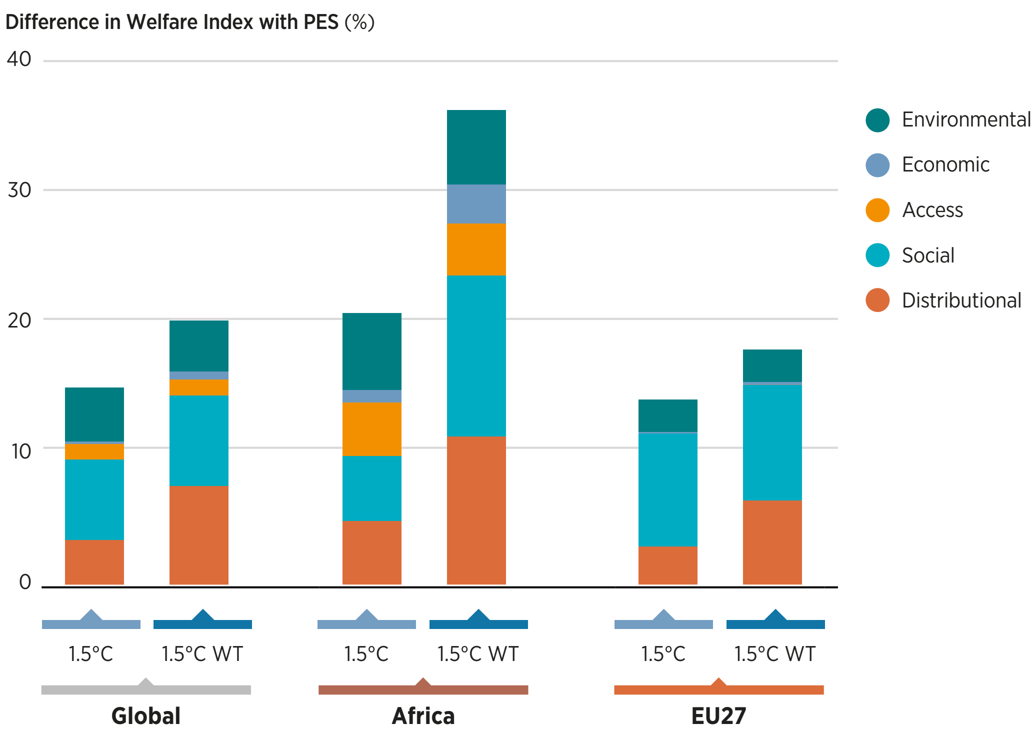


Note: G20 = Group of Twenty; PES = Planned Energy Scenario; 1.5˚C= 1.5˚C Scenario; WT = 1.5˚C Scenario with wealth tax sensitivity; net oil exporter = Denmark, Norway, Canada, Russian Federation, Mexico, Brazil, Argentina, Colombia, Saudi Arabia, Nigeria, Malaysia and Kazakhstan.

Welfare

Figure A6 presents the results of a wealth tax in combination with the 1.5°C Scenario on the overall welfare index for Africa, the EU27 and the world. The social and distributional dimensions boost significantly the improvements already observed under the 1.5°C Scenario. Overall, the improvements to general welfare – again, relative to the PES – are significant. In Africa, the improvement under the 1.5°C Scenario is 21% and rises to 37% under the 1.5°C wealth taxation sensitivity – a good indication of the efficacy of the scenarios' policy measures.

FIGURE A6 **Impact of introducing a wealth tax in the 1.5°C Scenario on the welfare index at the global and regional levels by 2050: Global, Africa and EU27**



Note: PES = Planned Energy Scenario; WT= Wealth Tax; 1.5˚C= 1.5˚C Scenario; 1.5˚C WT= 1.5˚C Scenario with wealth tax sensitivity; EU = European Union.

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