IRENA
International Renewable Energy Agency

GLOBAL RENEWABLES OUTLOOK

SUMMARY
EDITION: 2020

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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, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. **www.irena.org**

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FOREWORD

This first *Global Renewables Outlook* arrives while the world suffers through the COVID-19 pandemic, which brings dramatic numbers of people infected, a mounting death toll, and social and economic disruption for regions, countries and communities.

The priority now remains to save as many lives as possible, bring the health emergency under control and alleviate hardship. At the same time, governments are embarking on the monumental task of devising stimulus and recovery packages. These are at a scale to shape societies and economies for years to come.

This response must align with medium- and long-term priorities. The goals set out in the United Nations 2030 Agenda and the Paris Agreement can serve as a compass to keep us on course during this disorienting period. They can help to ensure that the short-term solutions adopted in the face of COVID-19 are in line with medium- and long-term development and climate objectives.

Stimulus and recovery packages should accelerate the shift to sustainable, decarbonised economies and resilient inclusive societies. The Nationally Determied Contributions (NDCs) to be presented by the end of this year, as required under the Paris Agreement, should be the backbone of the stimulus package.

In this respect, the *Global Renewables Outlook* shows the path to create a sustainable future energy system. It highlights climate-safe investment options until 2050 and the policy framework needed to manage the transition. Building on earlier *Global Energy Transformation* reports, it also grapples with the decarbonisation of challenging industry and transport sectors and presents a perspective on deeper decarbonisation.

Raising regional and country-level ambitions will be crucial to meet interlinked energy and climate objectives. Renewables, efficiency and electrification provide a clear focus for action until mid-century. Several regions are poised to reach 70-80% renewable energy use in this outlook. Electrification of heat and transport would similarly rise across the board.

The nature of this crisis calls for a major state role in the response. This involves defining the strategies and initiating direct interventions for the way out. Expansionary budget policies may be envisaged to support this effort.

Economies need more than a kick-start. They need stable assets, including an inclusive energy system that supports low-carbon development. Otherwise, even with the global slowdown momentarily reducing carbon dioxide (CO_2) emissions, the eventual rebound may restore the long-term trend. Fossil-fuel investments would continue polluting the air, adding to healthcare costs and locking in unsustainable practices.

Although renewable energy technologies may be affected by the pandemic just like other investments, energy market dynamics are unlikely to disrupt investments in renewables. Price volatility undermines the viability of unconventional oil and gas resources, as well as long-term contracts, making the business case for renewables even stronger. One further result would be the ability to reduce or redirect fossil-fuel subsidies towards clean energy without adding to social disruptions.

Francesco La Camera

Director-General, IRENA

A renewable energy roadmap

Economic recovery packages must serve to accelerate a just transition. The European Green Deal, to take an existing example, shows how energy investments could align with global climate goals. The time has come to invest trillions, not into fossil fuels, but into sustainable energy infrastructure.

Recovery measures could help to install flexible power grids, efficiency solutions, electric vehicle (EV) charging systems, energy storage, interconnected hydropower, green hydrogen and multiple other clean energy technologies. With the need for energy decarbonisation unchanged, such investments can safeguard against short-sighted decisions and greater accumulation of stranded assets.

COVID-19 does not change the existential path required to decarbonise our societies and meet sustainability goals. By making the energy transition an integral part of the wider recovery, governments can achieve a step change in the pursuit of a healthy, inclusive, prosperous, just and resilient future.

While each country must work with a different resource mix, all of them need a 21st-century energy system. The response must provide more than just a bail-out for existing socio-economic structures.

Now, more than ever, public policies and investment decisions must align with the vision of a sustainable and just future. Making this happen requires a broad policy package – one that tackles energy and climate goals hand in hand with socio-economic challenges at every level. A just transition should leave no one behind.

I hope sincerely that this new publication helps to show the way.

ABBREVIATIONS

°C	degrees Celsius
bcm	billion cubic metres
BES	Baseline Energy Scenario
bln	billion
CCS	carbon capture and storage
CDR	carbon dioxide removal
CIP	Climate Investment Platform
CO_2	carbon dioxide
CSP	concentrating solar power
CCUS	carbon capture, utilisation and storage
DDP	Deeper Decarbonisation Perspective
DH	district heat
EJ	exajoule
EV	electric vehicle
G20	Group of Twenty
GDP	gross domestic product
GJ	gigajoule
Gt	gigatonne
GW	gigawatt
GWEC	Global Wind Energy Council
GWh	gigawatt-hour
H_2	Hydrogen
IEA	International Energy Agency
IMF	International Monetary Fund
IRENA	International Renewable Energy Agency
kg	kilogram
kWh	kilowatt-hour
LCOE	levelised cost of energy
LULUCF	land use, land-use change and forestry
m^2	square metre
MENA	Middle East and North Africa
mln	million
Mt	megatonne
Mtce	megatonne of coal equivalent
Mtoe	million tonnes of oil equivalent
MW	megawatt
MWh	megawatt-hour
NDC	Nationally Determined Contribution
OECD	Organisation for Economic Co-operation and Development
PES	Planned Energy Scenario
ppt	percentage point
PV	photovoltaic
RE	renewable energy
REmap	renewable energy roadmap analysis by IRENA
SDG	Sustainable Development Goal
t	tonne
TES	Transforming Energy Scenario
TFEC	total final energy consumption
toe	tonne of oil equivalent
TPES	total primary energy supply
TWh	terawatt-hour
USD	US dollar
VRE	variable renewable energy
WHO	World Health Organization
yr	year

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FIGURES

THIS REPORT AND ITS FOCUS

The International Renewable Energy Agency (IRENA) has produced a succession of studies aiming to quantify and guide the transformation of the world's energy system. These roadmaps provide an ambitious, yet technically and economically feasible, pathway for deploying low-carbon technologies to create a clean, sustainable energy future.

One of IRENA's initial studies, outlined in a key chapter of *Perspectives for the Energy Transition* (IEA and IRENA, 2017), focused on the technical feasibility and socio-economic benefits of long-term global decarbonisation. The subsequent *Global Energy Transformation: A Roadmap to 2050* (IRENA, 2018a), expanded on the implications of accelerated uptake of renewables and investigated the associated investment needs, examined key transition requirements by sector, and offered further insights into the socio-economic implications.

The second edition of the *Global Energy Transformation* roadmap (IRENA, 2019a) updated IRENA's analysis of key countries and regions and underlined the role of renewables-based electrification as a key enabling solution. The report also offered new findings on the costs, subsidies and investment needs of the transition. IRENA's socio-economic analysis delved into the effects of the global transition in terms of gross domestic product (GDP) and jobs as well as an assessment of potential impacts of climate damages.

This *Global Renewables Outlook* reviews the ongoing energy transformation with closer examination of needs and impacts at the regional level, in both energy and socio-economic terms. Going further than the previous studies, this report also outlines a vision for transformative energy policies as the conduit to the creation of a deeply decarbonised global society. On the innovation and technology side, the study grapples with reducing carbon dioxide (CO_2) emissions in challenging sectors, such as shipping, aviation and heavy industry. Addressing such challenges soon will be crucial to achieve net-zero emissions in the second half of the century.

Chapter 1 provides an overview of IRENA's Renewable Energy Roadmap (REmap) energy transformation analysis, highlighting key technology solutions and a vision for a global energy pathway to 2050. Chapter 2 highlights the global socio-economic implications of the energy transformation using the indicators GDP, employment and welfare. Chapter 3 outlines regional techno-economic transformation pathways to 2050, while Chapter 4 describes regional variations in the socio-economic indicators. Chapter 5 explains how to reduce energy and industrial process-related CO_2 emissions to zero and offers solutions for challenging sectors. Chapter 6 discusses the comprehensive policy package, massive resource mobilisation and enhanced international co-operation needed to accelerate the transformative decarbonisation for a sustainable society and to ensure a just transition. In addition, key data and indicators for 10 regions are provided at the end of the report.

SCENARIOS AND PERSPECTIVES IN THIS OUTLOOK

This outlook report presents several scenarios and their socio-economic outcomes:

The **“Planned Energy Scenario (PES)”** is the primary reference case for this study, providing a perspective on energy system developments based on governments’ current energy plans and other planned targets and policies (as of 2019), including Nationally Determined Contributions under the Paris Agreement unless the country has more recent climate and energy targets or plans.

The **“Transforming Energy Scenario (TES)”** describes an ambitious, yet realistic, energy transformation pathway based largely on renewable energy sources and steadily improved energy efficiency (though not limited exclusively to these technologies). This would set the energy system on the path needed to keep the rise in global temperatures to well below 2 degree Celsius (°C) and towards 1.5°C during this century.

The **“Deeper Decarbonisation Perspective (DDP)”** provides views on additional options to further reduce energy-related and industrial process CO_2 emissions beyond the Transforming Energy Scenario. It suggests possibilities for accelerated action in specific areas to reduce energy and process-related CO_2 emissions to zero in 2050-2060.

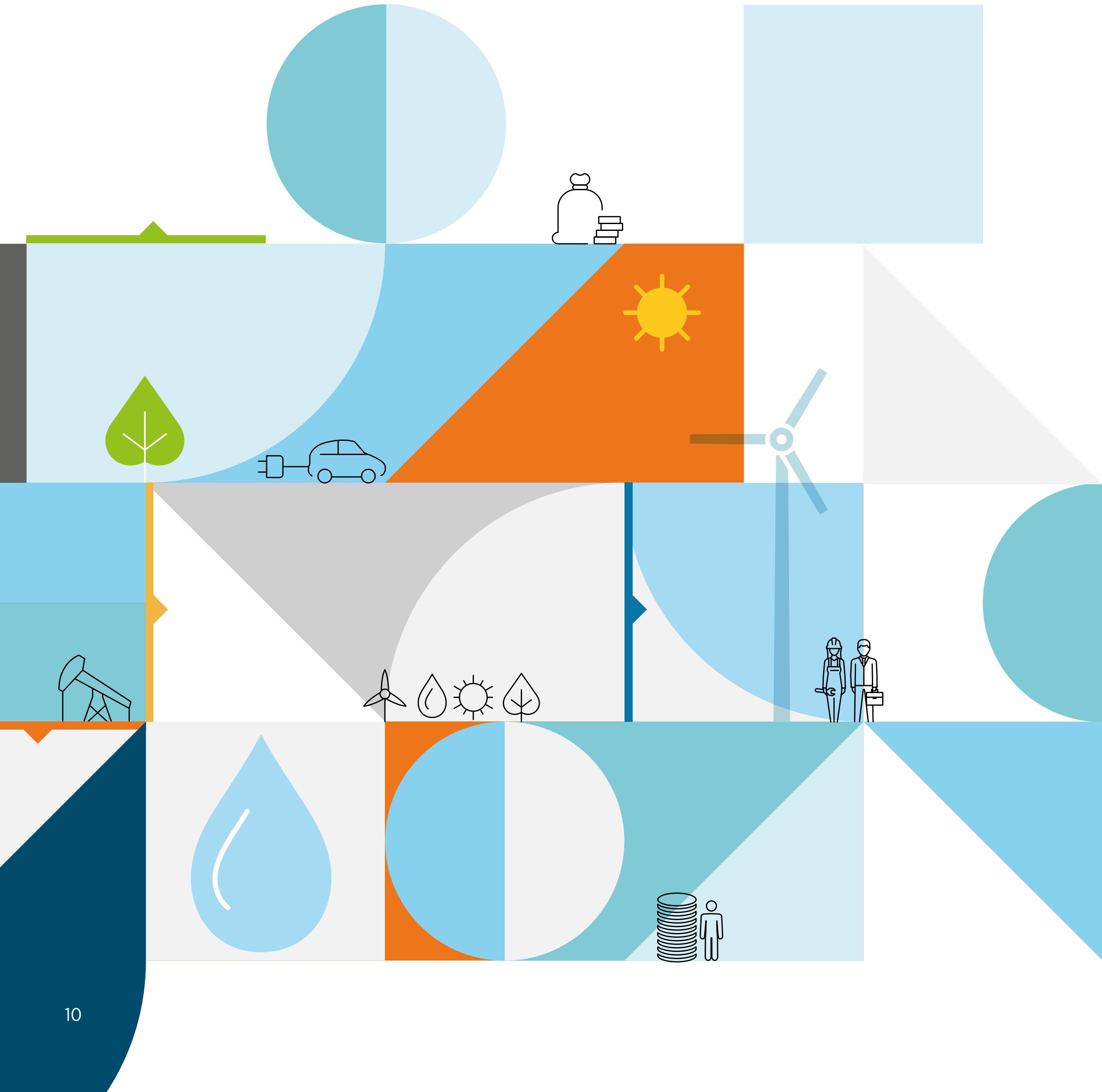
The **“Baseline Energy Scenario (BES)”** reflects policies that were in place around the time of the Paris Agreement in 2015, adding a recent historical view on energy developments where needed.

The **socio-economic analysis** of these scenarios is carried out with a macro-econometric model (via E3ME model) that links the energy system and the world’s economies within a single and consistent quantitative framework. It analyses the impact of the energy transition on variables such as GDP, employment and welfare to inform energy system planning, economic policy making, and other measures undertaken to ensure a just and inclusive energy transition at the global, regional and national level.

These various possible paths for energy investment and broader socio-economic development are explored over the crucial three-decade time frame remaining until mid-century. This report considers policy targets and developments until April 2019. Policy changes and targets announced since then are not considered in the present analysis.

The report builds on IRENA’s REmap (Renewable Energy Roadmap) approach, which has formed the basis for a succession of global regional, country-level and sector-specific analyses since 2014 as well as IRENA’s socio-economic analysis that captures an increasingly comprehensive picture of the impact of the energy transition on economies and societies.

KEY FINDINGS



GLOBAL RENEWABLES OUTLOOK
EDITION: 2020

- **The health, humanitarian, social and economic crises set off by the COVID-19 pandemic requires a decisive, large-scale response guided by appropriate social and economic measures.** As countries consider their economic stimulus options, they must still confront the challenge of ensuring sustainability and strengthening resilience while improving people's health and welfare. The need remains for an accelerated path to meet global climate goals through the decarbonisation of our societies.

- **The Transforming Energy Scenario outlined here – coupled with an additional Deeper Decarbonisation Perspective – offers a sustainable, low-carbon climate-safe foundation for stable, long-term economic development.** It promises more jobs, higher economic growth, cleaner living conditions and significantly improved welfare. This ambitious outlook would also cut 70% of the world's energy-related carbon dioxide (CO_2) emissions by 2050. Over 90% of this reduction would be achieved through renewables and energy efficiency measures.

- **The energy transition can drive broad socio-economic development, guided by comprehensive policies to foster the transformative decarbonisation of societies.** This holistic approach would align energy decarbonisation with economic, environmental and social goals. The proposed European Green Deal – including international support for clean energy – provides an example. Economic stimuli after the 2020 health crisis could move many societies in a similar direction.

- **The ultimate global climate goal would be to reach zero emissions.** This outlook also explores ways to cut CO_2 emissions beyond 2050 to net-zero and potentially even zero. Hydrogen and synthetic fuels, direct electrification, advanced biofuels and carbon management will be crucial, along with innovative business models, structural changes and behavioural adaptation.

- **Still, the last portion of the world's CO_2 emissions will be the hardest and most expensive to eliminate.** An ambitious energy transition would still leave global emissions at about one-third of their current levels, with energy-intensive industries, shipping and aviation still emitting heavily in 2050. The Deeper Decarbonisation Perspective highlights options to get such sectors to zero. While much remains to be seen, an estimated 60% of the reductions in this final stretch could come from renewables, "green hydrogen" and renewable-based electrification.

Low-carbon investment options

- **Energy-related CO_2 emissions have risen by 1% per year over the past decade.** While the health shock and oil slump may suppress emissions in 2020, a rebound would restore the long-term trend.

- **The Transforming Energy Scenario instead offers a climate-safe path, sufficient to keep global warming this century "well below 2°C" in line with the Paris Agreement.** It could also help to guide continual updates of national climate pledges, which can be strengthened with enhanced renewable energy targets.

- **This outlook for the transformation of the energy system also indicates higher GDP growth, achieving 2.4% more by mid-century than current plans would achieve.** The cumulative gain between now and 2050 amounts to USD 98 trillion, greatly exceeding the additional investments needed for transforming the energy system.

- **The envisaged transformation would effectively pay for itself, with every dollar spent bringing returns between three and eight dollars.** The Transforming Energy Scenario would cost USD 19 trillion more than the Planned Energy Scenario, while bringing benefits worth at least USD 50 trillion by 2050. The Deeper Decarbonisation Perspective would cost another USD 16 trillion to achieve net-zero emissions, or another USD 26 trillion to fully eliminate CO_2 emissions, for a total cost of USD 45 trillion, yet cumulative savings would still be higher at USD 62 trillion or more.

- **Along with a sustainable energy future, the transition promises new patterns of socio-economic development.** The changing investment focus in this outlook would increase jobs in renewables to 42 million globally by 2050, four times more than today. Energy jobs overall would reach 100 million by 2050, about 40 million more than today. The transition would result in 7 million more jobs economy-wide compared to current plans. Environmental and health benefits, along with broad improvements in people's welfare, would be felt in every region of the world.

- **People's well-being would improve faster and further, with a 13.5% higher welfare indicator under the Transforming Energy Scenario by 2050.** The divergence mainly reflects of lower air pollution, which would result in better health across every region. Everywhere, the transition promises to improve people's welfare.

Co-ordination for a smooth transition

- **Ramping up regional ambitions will be crucial to meet interlinked energy and climate goals.** Renewables, efficiency and electrification provide a clear focus for action to cut the bulk of emissions at the regional and country levels. Despite varied transition paths, all regions would see higher shares of renewable energy use, with Southeast Asia, Latin America, the European Union and Sub-Saharan Africa poised to reach 70-80% shares in their total energy mixes by 2050. Similarity, electrification of end uses like heat and transport would rise everywhere, exceeding 50% in East Asia, North America and much of Europe.

- **Despite clear global gains, the transition's structural and labour-market impacts will vary among locations, job types and sectors.** As renewables, energy efficiency and other transition-related sectors grow, other energy jobs will decline. But strategies to ensure a just transition could help to minimise dislocations for individuals and communities.

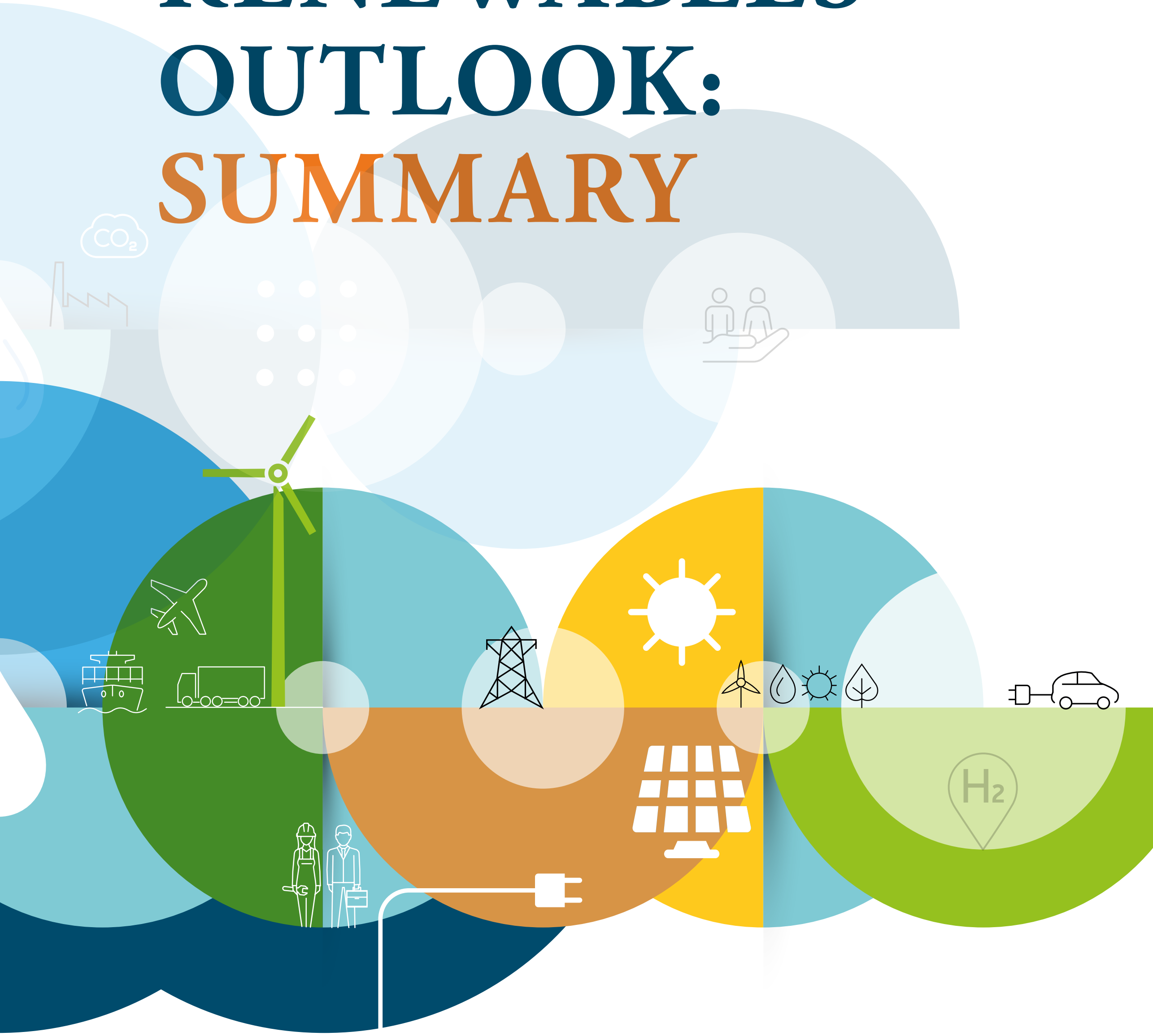
- **Different socio-economic starting points will contribute to different regional energy transitions.** On-the-ground impact will stem from dependence on fossil fuels and other commodities, pre-existing industrial productivity, evolving technology choices, and the depth and diversity of domestic supply chains. Regional and national transition plans, institutional structures, capabilities and policy ambitions also vary, bringing different results in 2050.

- **Rapid decarbonisation calls for unprecedented policy initiatives and investments.** The Climate Investment Platform announced in 2019 aims to drive clean energy uptake in line with Paris Agreement goals. Sub-regional investment forums will help to create the right conditions, improve access to finance and prepare bankable projects.

- **Completing the global energy transition in time to stave off catastrophic climate change requires intensified international co-operation.** The aim is to enable governments and other institutions to adopt a wide array of ambitious policies, all aimed at strengthening public resolve and ensuring that no one is left behind.

- **Ultimately, success in mitigating the climate threat will depend on the policies adopted, the speed of their implementation and the level of resources committed.** Moving forward, investment decisions could be assessed based on their compatibility with building an inclusive low-carbon economy. Anything less would hinder the transformative decarbonisation of societies.

GLOBAL RENEWABLES OUTLOOK: SUMMARY



A WIDENING GAP BETWEEN RHETORIC AND ACTION

Main report **Chapters 1 and 5**

The gap between aspiration and the reality in tackling climate change remains as significant as ever, despite mounting evidence of the harm that climate change is causing. Negative effects of climate change are becoming more evident year by year (NASA, WMO, 2020). Yet global energy-related CO_2 emissions, despite levelling off periodically, have risen by 1% per year on average over the last decade.

The distribution of efforts among countries remains uneven, with certain countries pursuing net-zero emissions while others continue to lack policy targets. Government plans have yet to fully capture the reality of the markets. Nationally Determined Contributions (NDCs) within the Paris Agreement framework are in many cases less ambitious than the latest energy plans and market developments. According to IRENA estimates, current NDC power targets only cover 40% of the renewable electricity deployment needed by 2030 to set the world on course to meet key climate goals (IRENA, 2019b).

The health, humanitarian, social and economic crises set off by the current COVID-19 pandemic could either widen the gap or accelerate the decarbonisation of our societies. Much will depend on how countries respond in terms of economic stimulus. The challenges of ensuring sustainability, strengthening resilience and improving people's health and welfare will be paramount. The **Transforming Energy Scenario** (TES) identified in this report shows how to achieve stable, climate-safe, sustainable long-term energy and economic development. The resulting outlook – further enhanced by the **Deeper Decarbonisation Perspective** (DDP) – could guide low-carbon policy measures, helping to ensure coherence between rhetoric and action in tackling climate change.

This report presents several possible scenarios for the evolution of energy-related CO_2 emissions. In the Baseline Energy Scenario (BES), energy-related emissions increase by a compound annual rate of 0.7% per year to 43 gigatonnes (Gt) by 2050 (up from 34 Gt in 2019), resulting in a likely temperature rise of 3°C or more in the second half of this century. The Planned Energy Scenario (PES), or main reference case, sees emissions increase slightly by 2030 and then decline to 33 Gt, roughly today's level, by 2050. This would result in a likely global temperature rise of 2.5°C in the second half of this century. IRENA's **Transforming Energy Scenario**, in contrast, sees emissions fall at a compound rate of 3.8% per year to some 10 Gt, or 70% less than today's level, by 2050, keeping the expected temperature rise well below 2°C.

The **Deeper Decarbonisation Perspective** would reduce emissions to zero by as early as 2050 or latest by 2060, consistent with holding the line at 1.5°C.

Recent energy trends confirm the need to accelerate a reduction in CO_2 emissions. Renewable energy forms a key part of any viable solution. Renewable energy shares, the energy intensity of GDP and the electrification of final uses of energy have all shown improvements in recent years, yet the pace of those improvements does not put the world on track to meet the goals of the Paris Agreement. Efforts are also needed to reduce emissions outside the energy sector.

Fossil fuels continue producing negative effects in many parts of the world. These include high levels of air, water and soil pollution, and persistent energy-import dependence. Currently, air pollution causes 7 million premature deaths per year (WHO, 2020). With an estimated 840 million people still lacking access to electricity and 2.6 billion lacking access to clean cooking fuels, the world has a pressing need for clean, sustainable energy solutions. For now, some regions are increasing their dependency on energy imports (IEA, IRENA, UNSD, World Bank, WHO, 2019).

The Transforming Energy Scenario would cut fossil-fuel use by about 75% by mid-century. Looking ahead under the Planned Energy Scenario, primary energy demand increases from around 600 exajoules (EJ) today to 710 EJ by 2050 (see Figure S.1), yet the amount of fossil fuels remains roughly similar to today's level, showing the increasing role renewable energy plays. However, given the need to reduce emissions, fossil-fuel consumption cannot stay at today's level. In the Transforming Energy Scenario it declines by 75% compared to today's level, to 130 EJ by 2050 – roughly equivalent to just the energy demand of China today. The largest consumption declines would take place in coal, down by 41% and 87% in 2030 and 2050, respectively. Oil would see the second largest declines, of 31% and 70% in 2030 and 2050, respectively. Natural gas would have an increase of 3% by 2030 (the Planned Energy Scenario has natural gas growth of over 40% by 2030), but it would decline 41% by 2050.

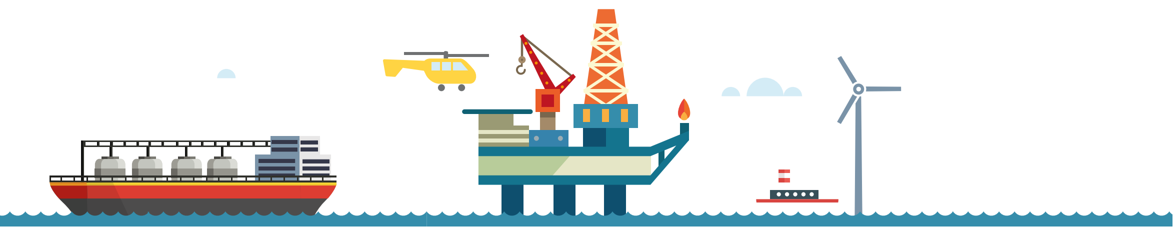
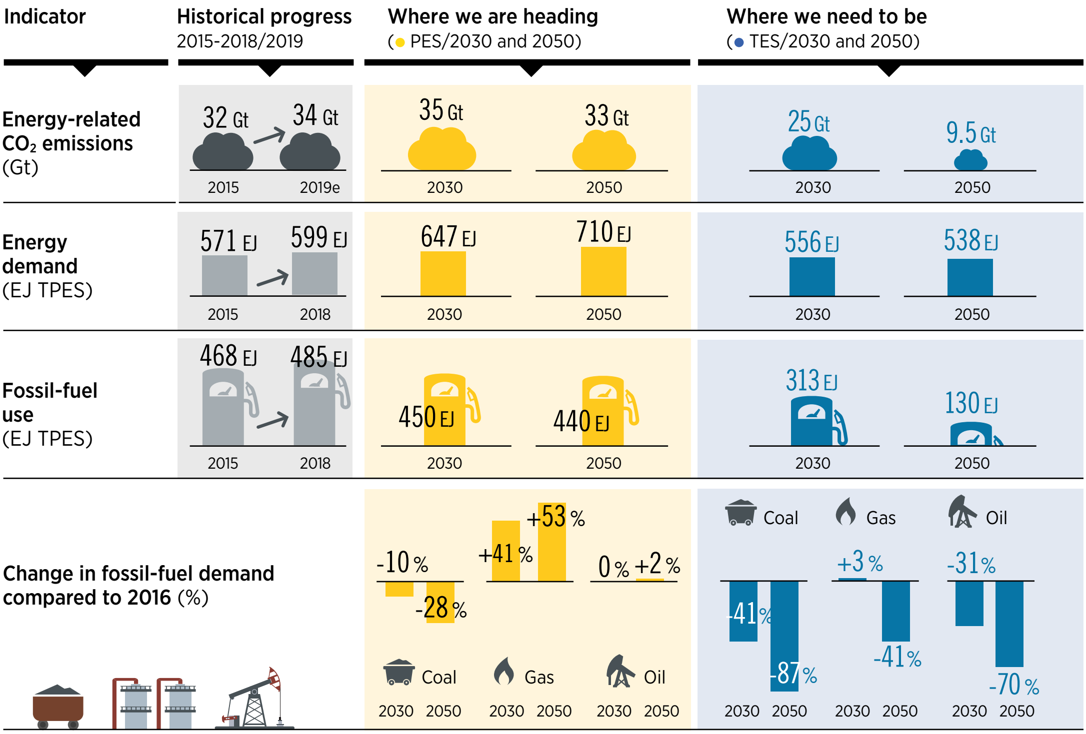


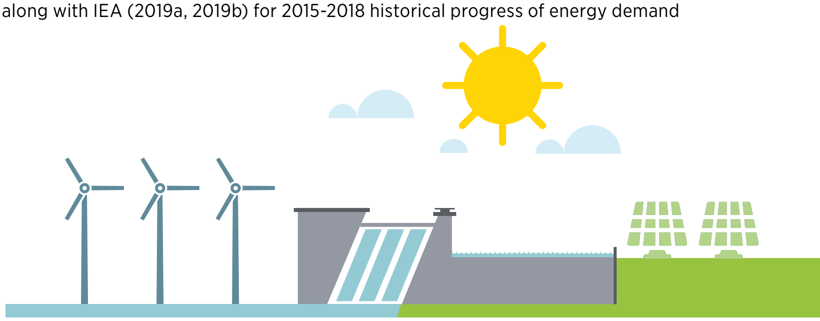
Figure S.1. The changing nature of energy and fossil-fuel use

Energy-related CO_2 emissions, energy demand and fossil-fuel outlook



Note: TPES = total primary energy supply. e = estimate; Gt = gigatonnes; EJ = exajoules.

Based on IRENA scenarios (PES and TES), along with IEA (2019a, 2019b) for 2015-2018 historical progress of energy demand and fossil-fuel use.



Main report **Chapters 1 and 5**

TRANSFORMATIVE ENERGY DEVELOPMENTS

The energy sector has started changing in promising ways, with widespread adoption of renewables and related technologies boding well for a sustainable future. Renewable technologies are dominating the global market for new power generation capacity. Solar PV and wind are increasingly the cheapest source of electricity in many markets, and most renewable power sources will be fully cost competitive within the next decade (IRENA, 2019c).

Renewable power generation is now growing faster than overall power demand. A new milestone was reached in 2019 when renewable electricity generation increased by more than the increase in electricity demand, while fossil-fuel electricity generation decreased. This is the first time in decades that fossil-fuel-based generation declined when overall electricity generation increased (Kåberger, 2019).

The electrification of transport is showing early signs of disruptive acceleration. Progress in accelerating the transition is seen in the rapid cost reductions of solar PV and wind (including offshore), how key enabling technologies such as batteries and electric vehicles are experiencing rapid reductions in costs, and how green hydrogen is viewed as a potential game changer.

Yet renewables are growing too slowly in major energy-consuming sectors like buildings and industry. Deployment in these areas remains well below the levels needed to create a climate-safe energy system. Slowing progress in energy efficiency and biofuels development must be turned around quickly.

The share of modern renewable energy in global final energy consumption has increased only slightly since 2010, staying around a threshold of about 10%.[1] In simple terms, while renewables are increasing, so is energy demand. In the Planned Energy Scenario, the share of modern renewable energy in final energy supply would increase to 17% by 2030 and 25% by 2050. In the Transforming Energy Scenario, this share would increase to 28% by 2030 and 66% by 2050. Therefore, the share would need to increase six-fold compared to today, and two-and-a-half times compared to the Planned Energy Scenario.

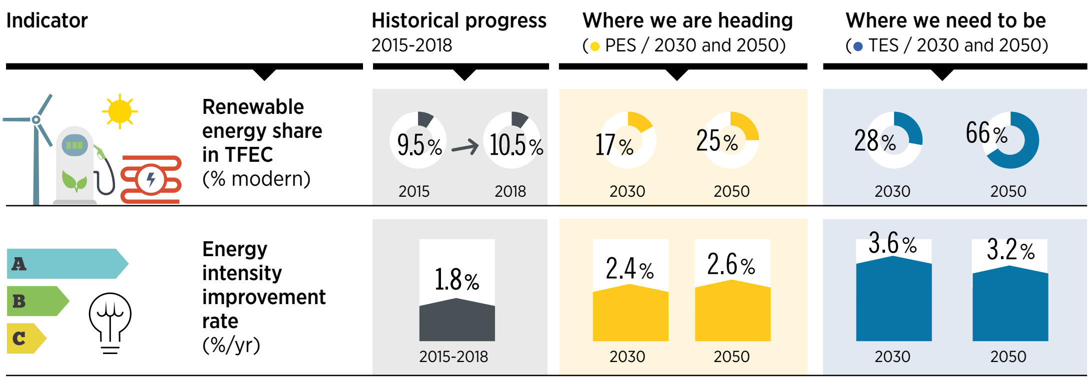
[1] Modern renewable energy excludes traditional uses of bioenergy, which if included in this share would bring the share of all renewable energy in total final energy to 18%.

Energy efficiency improvements must be scaled up rapidly and substantially. Energy efficiency and renewable energy are the two key solutions to enable the global energy transformation. Yet the improvement in energy intensity has slowed. The improvement in 2019 was only an estimated 1.2%, less than the average of 1.8% per year over the last decade (IEA, 2019a). In the Transforming Energy Scenario, the rate of energy intensity improvement needs to increase to 3.2% per year, nearly three times the improvement during 2019 and roughly double compared to recent historical trends. Renewable energy and energy efficiency are "ready-to-go" solutions, available for significant scale-up now.

Renewable energy and energy efficiency together offer over 90% of the mitigation measures needed to reduce energy-related emissions in the Transforming Energy Scenario. To achieve this reduction energy-related CO_2 emissions need to fall by 3.8% per year on average until 2050, to 70% below today's level. That compares to an average annual increase of 1% over the last decade, with a flatlining in 2019. Figure S.2 shows the share of renewable energy and the energy efficiency improvement rate that is needed to achieve the necessary reductions.

Figure S.2. Renewables in the world's energy mix: Six-fold increase needed

Renewable energy share and energy efficiency improvement rate



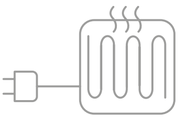
Based on IRENA scenarios (PES and TES), along with IEA (2019a, 2019b) for 2015-2018 historical progress of energy share in total final energy consumption (TFEC).

Five technology pillars for the future of energy

FIRST PILLAR: ELECTRIFICATION

Renewable power generation technologies are setting records for low costs and new capacity despite falling renewable energy subsidies and slowing global GDP growth. In the Transforming Energy Scenario, electricity would become the central energy carrier by 2050, growing from a 20% share of final consumption to an almost 50% share; as a result, gross electricity consumption would more than double.

The rate of growth in the percentage share of electricity (percentage point "ppt") in final energy needs to quadruple, from an increase of 0.25 ppt/yr to 1.0 ppt/yr. To put this into perspective, an additional 1 000 terawatt-hours (TWh) of electricity demand for electrification of end uses has to be added every year on top of current plans – equivalent to adding the entire electricity generation of Japan every year. To supply this additional renewable electricity demand, over 520 gigawatts (GW) of new renewable capacity would need to be added per year. In parallel, the share of renewable electricity in generation has to rise from 26% currently to 57% by 2030 and 86% by 2050. This rise is being accelerated by declining costs: four-fifths of solar PV and wind projects to be commissioned in 2020 will produce electricity cheaper than any fossil-fuel alternative (IRENA, 2019c).



The electrification of end uses will drive increased power demand to be met with renewables. In the transport sector, the number of electric vehicles (EVs) will increase from around 8 million in 2019 to over 1 100 million in the Transforming Energy Scenario by 2050 (see Figure S.3). For heating, heat pumps offer efficiency gains ranging from two to four times higher than conventional heating systems, and the number of heat pumps installed by 2050 would need to increase 10-fold. The shift to these highly efficient electrification technologies also brings increases in energy efficiency.

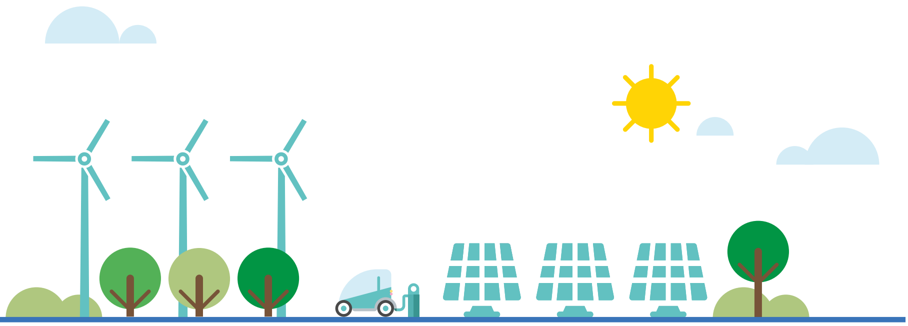


Figure S.3. An increasingly electrified energy system

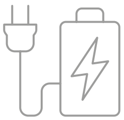
Renewable electricity share in electricity generation, electrification share, and select technologies

Indicator	Historical progress 2015-2018/2019	Where we are heading (PES/2030 and 2050)	Where we need to be (TES/2030 and 2050)
Renewable share in electricity generation (%)	23% (2015) → 26% (2018)	38% (2030), 55% (2050)	57% (2030), 86% (2050)
Electrification share of final energy (%)	19% (2015) → 20% (2017)	24% (2030), 30% (2050)	29% (2030), 49% (2050)
Technologies			
Electric cars (mln units)	1.2 mln (2015) → 7.9 mln (2019e)	269 mln (2030), 627 mln (2050)	379 mln (2030), 1 109 mln (2050)
Heat pumps (mln units)	20 mln (2017) → 38 mln (2019e)	63 mln (2030), 119 mln (2050)	155 mln (2030), 334 mln (2050)

Based on IRENA scenarios (PES and TES), along with Spiegel (2020), IEA (2019a, 2019b), IEA and IRENA (2017) and IRENA (2019a) for 2015-2018 historical progress.

SECOND PILLAR:
INCREASED POWER SYSTEM FLEXIBILITY

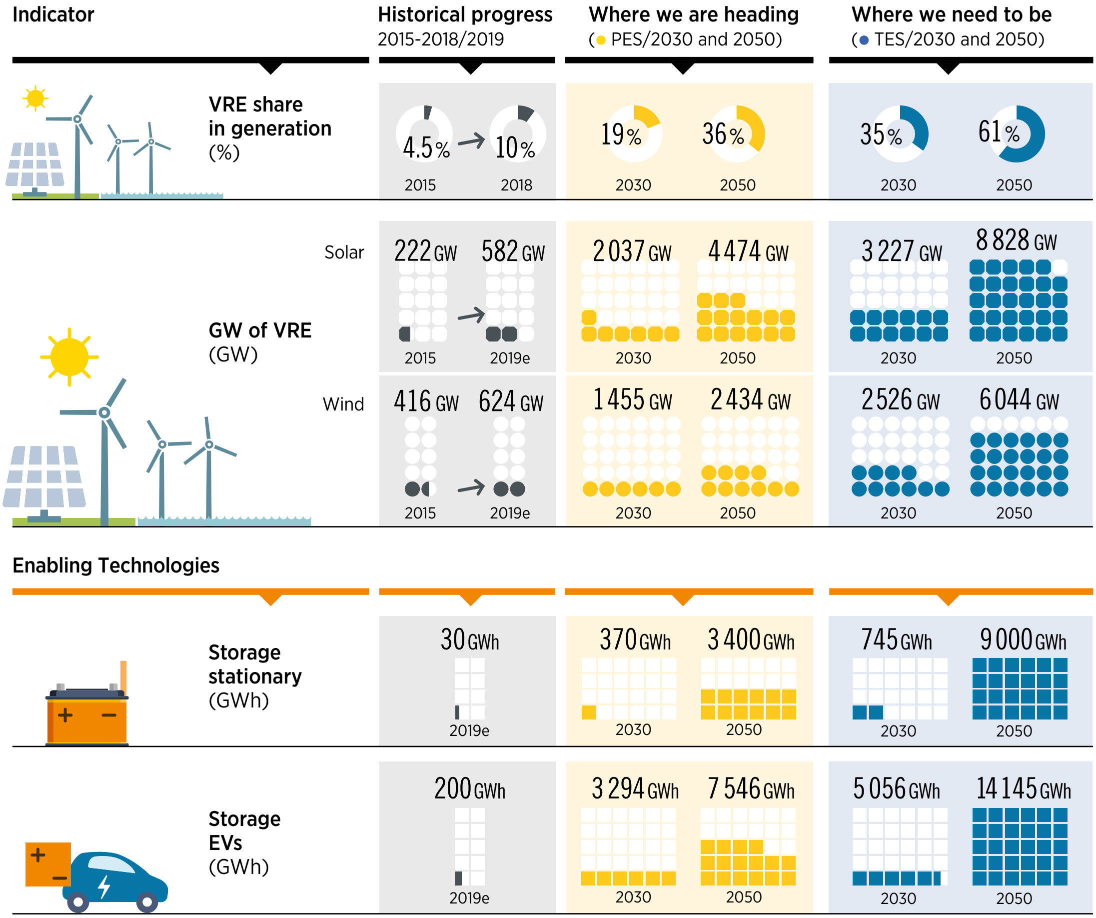
Flexibility in power systems is a key enabler for the integration of high shares of variable renewable electricity – the backbone of the electricity system of the future. A climate-friendly energy system is decentralised, digitalised and electrified. Today, countries are integrating variable renewable energy (VRE) at a share of over 30% on an annual basis (and in some cases much higher), which means that instantaneous penetration of VRE can, at times, approach, or even exceed, electricity demand. These periods of electricity surpluses can then offer new business opportunities for further electrification. In the Transforming Energy Scenario, 73% of the installed capacity and over 60% of all power generation would come from variable resources (solar PV and wind), up from 10% of power generation today.



Power systems must achieve maximum flexibility, based on current and ongoing innovations in enabling technologies, business models, market design and system operation. On a technology level, both long-term and short-term storage will be important for adding flexibility, and the amount of stationary storage (which excludes EVs) would need to expand from around 30 gigawatt-hours (GWh) today to over 9 000 GWh by 2050 (see Figure S.4). When storage available to the grid from the EV fleet is included, this value will increase by over 14 000 GWh to 23 000 GWh. However, most flexibility will still be achieved through other measures, including grid expansion and operational measures, demand-side flexibility and sector coupling. IRENA estimates that smart solutions, such as smart charging of EVs, can significantly facilitate the integration of VRE by leveraging storage capacity and the flexibility potential of the demand side. Investment in end-use electrification, power grids and flexibility will need to increase from USD 13 trillion in the Planned Energy Scenario to USD 26 trillion in the Transforming Energy Scenario over the period to 2050.

Figure S.4. The need for power system flexibility

VRE share in generation and capacity, storage technologies



Based on IRENA scenarios (PES and TES), along with Bohlsen (2020), GWEC (2020), IEA (2019a) and IRENA analysis and IRENA (2019d, 2019f) for 2015-2018 historical progress.

THIRD PILLAR: CONVENTIONAL RENEWABLE SOURCES

Hydropower, bioenergy, solar thermal and geothermal renewable energy all have significant scale-up potential and represent over one-quarter of the mitigation potential in the Transforming Energy Scenario. Two technologies that can play particularly important roles are hydropower and bioenergy.

Hydropower can bring important synergies to the energy system of the future. In the Transforming Energy Scenario, hydropower capacity would need to increase 25% by 2030, and 60% by 2050, while pumped hydro storage capacity would need to double. When including both types of hydropower, around 850 GW of newly installed capacity is required in the next 30 years – or roughly adding the entire power system capacity of the European Union in 2020. The synergies between hydropower and other renewable energy technologies in power system operation include the cost effectiveness of using hydropower to counteract the short-term variability of wind and solar generation, and seasonal complementarities in resource patterns. Multi-purpose hydropower infrastructure also can provide co-benefits such as regulating river flows and reducing flooding.

Increasing hydropower capacity does not specifically entail only building new dams: options also exist to upgrade turbines and systems in existing plants, utilise run-of-river designs and electrify non-power dams. Yet for new hydropower plants, planners need to consider local environmental impacts, and engage in discussions with communities in the impacted areas. Hydropower plants will also need operational changes that reflect changing power system needs, including faster and more frequent ramping, and planning practices that include evaluating the impacts of climate change on water supply and reservoir storage requirements. Due to longer planning cycles for new hydropower dam construction, policy makers and planners need to start thinking now about new projects. For existing dams, investments are needed to modernise old hydro plants.

Bioenergy will become increasingly vital in end-use sectors. Bioenergy makes up a large share of renewable energy use today and will remain a significant source of fuel for power and heat generation in industry and as a fuel used in transport. The share of primary energy that is met with modern bioenergy (which excludes traditional uses of biofuel) will increase from 5% today to 10% in the Planned Energy Scenario. In the Transforming Energy Scenario, bioenergy plays an important role, particularly in sectors that are hard to electrify, such as in shipping and aviation and in industry, both for process heat and use as a feedstock. In the Transforming Energy Scenario, the share of primary energy met with modern bioenergy increases to 23% (see Figure S.5). Meanwhile, traditional uses of bioenergy, which cover a large share of bioenergy demand today, must be phased out and replaced with cleaner options, including modern bioenergy and other renewables.

Bioenergy must be produced in ways that are environmentally, socially and economically sustainable. The potential is enormous to produce bioenergy cost effectively and sustainably on existing farmlands and grasslands, and to use residues from existing production forests without encroaching upon rainforests. Bioenergy from such sources would make use of surplus crop potential and not threaten food production (IRENA, 2016a).

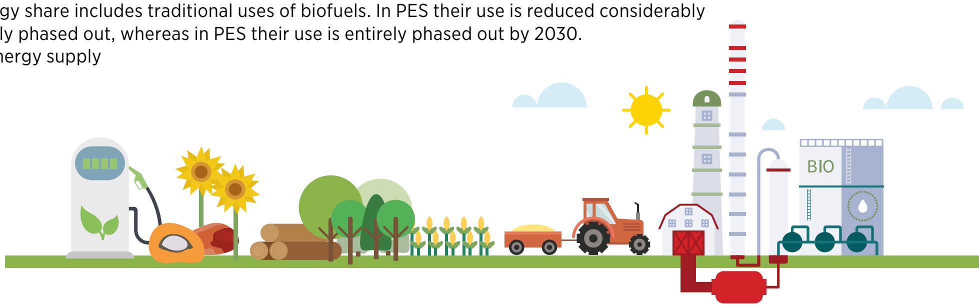
Figure S.5. Vital to any future energy system: Hydropower and bioenergy

Hydropower capacity, bioenergy shares, and liquid biofuel production

Indicator	Historical progress 2015-2017/2018/2019		Where we are heading (PES/2030 and 2050)		Where we need to be (TES/2030 and 2050)	
Hydropower (GW)	1 099 GW (2015)	1 189 GW (2019)	1 356 GW (2030)	1 626 GW (2050)	1 444 GW (2030)	1 822 GW (2050)
Pumped hydro storage (GW)	112 GW (2015)	121 GW (2019)	200 GW (2030)	300 GW (2050)	225 GW (2030)	325 GW (2050)
Share of TPES provided by bioenergy (%) **(total)**	8.7% (2015)	9.5% (2018)	9% (2030)	10% (2050)	12% (2030)	23% (2050)
Share of TPES provided by bioenergy (%) **(modern)**	4.1% (2015)	5.1% (2018)	8% (2030)	10% (2050)	12% (2030)	23% (2050)
Liquid biofuel production (bln litres)	129 bln ltr (2015)	136 bln ltr (2017)	285 bln ltr (2030)	393 bln ltr (2050)	378 bln ltr (2030)	652 bln ltr (2050)

Based on IRENA scenarios (PES and TES), along with Bohlsen (2020), IEA (2019s), IRENA (2019d, 2019e, 2019f) and IRENA analysis for 2015-2018 historical progress.

Note: The total bioenergy share includes traditional uses of biofuels. In PES their use is reduced considerably by 2030, but not entirely phased out, whereas in PES their use is entirely phased out by 2030.
TPES = total primary energy supply



FOURTH PILLAR: GREEN HYDROGEN

Hydrogen can offer a solution for types of energy demand that are hard to directly electrify. Today, around 120 megatonnes (Mt) (14 EJ) of hydrogen is produced per year (IRENA, 2019g). But almost all of this comes from fossil fuels or from electricity generated by fossil fuels, with a high carbon footprint; less than 1% is "green" hydrogen. Yet progress is being made and in early 2020 the world's largest green hydrogen production plant with 10 MW electrolyser capacity began operation in Japan (Recharge, 2020).

Green hydrogen is produced by renewable electricity through electrolysis, and costs are falling fast. Green hydrogen will become cost competitive with "blue" hydrogen (produced from fossil fuels combined with carbon capture and storage [CCS]) in the next few years in locations with favourable low-cost renewable electricity. As costs fall further, green hydrogen will be cheaper than blue hydrogen in many locations within the next 5 to 15 years. Certain energy-intensive industries may in the future relocate to areas with good renewable energy resources to tap this potential to produce cheap green hydrogen; examples include iron making and ammonia. The first plant producing ammonia from green hydrogen is expected to open in 2020 (Yara, 2019).

Hydrogen can be processed further into hydrocarbons or ammonia, which can then help reduce emissions in shipping and aviation. The natural gas industry is also looking at hydrogen as a promising solution for greening the gas system and extending the life of existing infrastructure. However, this approach must be viewed with caution in light of unclear prospects of actually being able to significantly reduce emissions of the gas system and the potential to lock in carbon-intensive infrastructure. A hydrogen commodity trade is nascent, but hydrogen could become the clean energy vector that makes it possible to tap into ample remote, low-cost renewable energy resources – a development that could have important geopolitical implications as well as further accelerating the demand for renewable power generation. By 2050, there would be 160 Mt (19 EJ) of green hydrogen produced annually in the Transforming Energy Scenario (see Figure S.6). That amount, however, would only cover 5% of global energy demand today, with an additional 2.5% being met with blue hydrogen. Significant scale-up of electrolysers is necessary to produce that amount, requiring additions of between 50 GW and 60 GW per year of new capacity from now until 2050.

Figure S.6. Hydrogen: A key part of future energy systems

Evolving hydrogen production, costs and electrolyser capacity

Indicator	Historical progress 2015-2018	Where we are heading (PES / 2030 and 2050)		Where we need to be (TES / 2030 and 2050)	
		2030	2050	2030	2050
Blue H_2 (Mt and EJ)	0.6 Mt / 0.08 EJ (2015 - 2018)	10 Mt 1.25 EJ	40 Mt / 5 EJ	30 Mt 3.75 EJ	80 Mt / 10 EJ
Green H_2 (Mt and EJ)	1.2 Mt / 0.16 EJ (2015 - 2018)	9 Mt 1.1 EJ	25 Mt / 3 EJ	25 Mt / 3 EJ	160 Mt / 19 EJ
Green H_2 production costs (USD/kg)	4.0 - 8.0 USD/kg (2015 - 2018)	2.5 - 5.0 USD/kg	1.6 - 3.3 USD/kg	1.8 - 3.2 USD/kg	0.9 - 2.0 USD/kg
Electrolysers (GW)	0.04 GW (2016)	100 GW	270 GW	270 GW	1 700 GW
Electricity demand to produce H_2 from renewables (GW)	0.26 TWh (2016)	450 TWh	1 200 TWh	1 200 TWh	7 500 TWh

Based on IRENA analysis

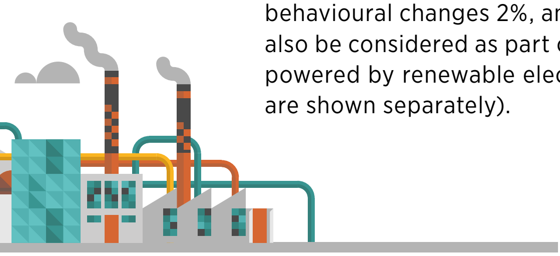
Note: Hydrogen produced from fossil fuels without CCS is called grey hydrogen, with CCS is called blue hydrogen, and if made from renewable power through electrolysis it is called green hydrogen. RE = Renewable Energy

FIFTH PILLAR:
FOSTER INNOVATION TO ADDRESS CHALLENGING SECTORS

In the Transforming Energy Scenario, half of energy demand could be supplied by electricity by 2050, but the remaining half must also be considered. Of this, one-third is already supplied by end-use renewable sources, with the remaining two-thirds by fossil fuels. Solutions to further reduce fossil-fuel use include increased direct use of renewable energy (bioenergy, solar thermal, geothermal heat), energy efficiency and structural changes that can reduce energy demand, and deeper electrification. However, more will still be needed, in particular for sectors such as shipping, aviation and heavy industry. To put it in perspective, three-quarters of the remaining emissions in the Transforming Energy Scenario in 2050 are from the aviation, shipping and heavy industry sectors.

This report presents views on how reduce these remaining emissions in the Deeper Decarbonisation Perspective (DDP). The Deeper Decarbonisation Perspective is not a scenario in itself, rather it is an enhancement of additional technology options on top of the Transforming Energy Scenario. In challenging sectors such as freight, shipping, aviation and heavy industry, advances in biofuels, synthetic fuels, new materials and the circular economy will all be necessary. Industry is the dominant energy consumption sector in many countries such as China, where the sector consumes around half of final energy. There is an urgent need to find solutions for key sectors, such as iron and steel, cement and petrochemicals, which make up the bulk of industry energy demand. Innovation is also needed to find zero CO_2 emission solutions for industrial process emissions and for non-energy uses in these sectors. Innovation will also continue to be crucial to address transport modes that are hard to electrify, namely aviation and shipping.

The Deeper Decarbonisation Perspective shows how the remaining energy and industrial process-related CO_2 emissions in the Transforming Energy Scenario can be cut to zero. Renewable energy provides 60% of the reduction needed when including renewables, green hydrogen and renewables-based electrification; 37% of reductions come from energy efficiency and other structural and behavioral changes; and the remaining 3% of reductions come from carbon capture, utilisation and storage (CCUS) and nuclear. Overall, when considering reductions in energy and industrial process-related CO_2 emissions from the Baseline Energy Scenario to zero, renewables make up 43% of the reductions, energy efficiency 26%, EVs 12%, green hydrogen 9%, blue hydrogen and CCS/Carbon dioxide removal (CDR) 7%, behavioural changes 2%, and nuclear under 1% (EVs and behavioural changes could also be considered as part of energy efficiency, or for the case of EVs, renewables if powered by renewable electricity. However, to show their relative importance they are shown separately).



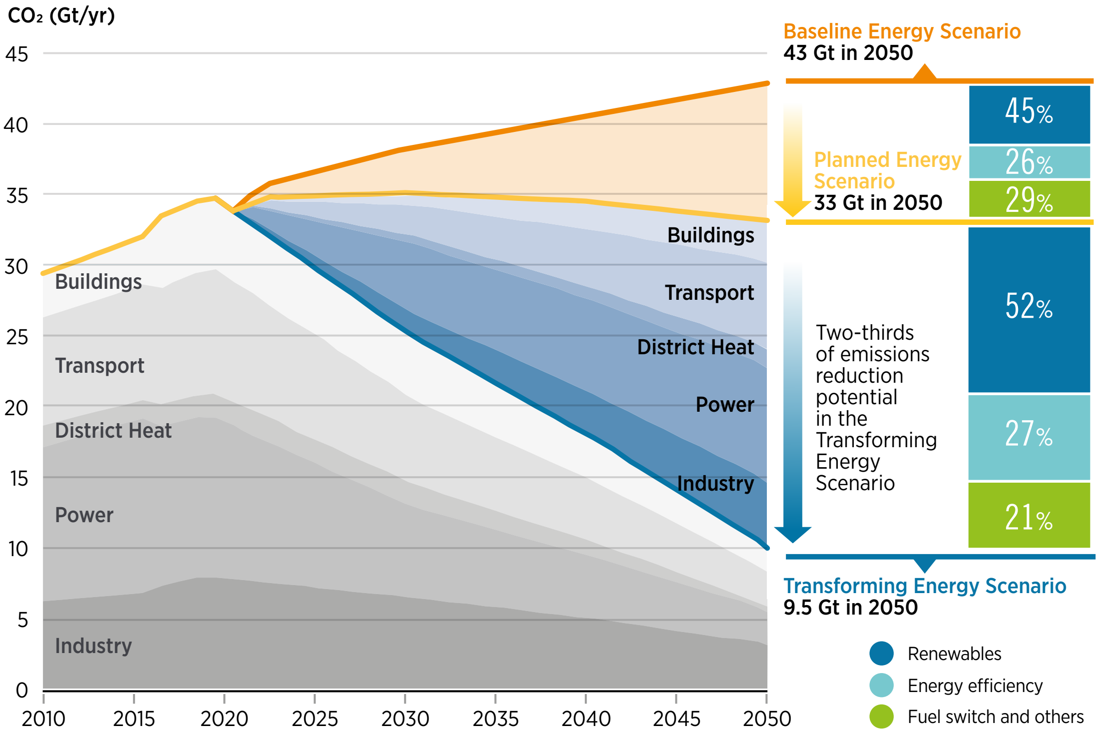
PLANNING FOR THE LONG TERM

Main report **Chapter 1, 3 and 5**

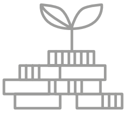
To achieve the Energy Transformation Scenario, energy-related CO_2 emissions need to fall by 3.8% per year on average until 2050. Annual energy-related CO_2 emissions would need to decline by 70% below today's level by 2050. In the Transforming Energy Scenario by 2050, over half of the necessary reductions in emissions come from renewable energy (both power and end use), followed by around one-quarter coming from energy efficiency (see Figure S.7). When including direct and indirect electrification (such as green hydrogen and technologies like EVs), the total reductions increase to over 90% of what is required. The Deeper Decarbonisation Perspective then describes how reducing the remaining emissions to zero – over two-thirds of which come from challenging sectors such as aviation, shipping and heavy industry – will require additional renewable energy, electrification (both direct use and green hydrogen), energy efficiency, carbon management, and other structural and habit changes. Outside the energy sector, efforts also are needed to reduce emissions from non-energy use, emissions from land use, land-use change and forestry (LULUCF), and fugitive gases in the coal, oil and gas industries.

Figure S.7. The bulk of emission reductions: Renewables and efficiency

Energy-related CO_2 emissions, 2010-2050



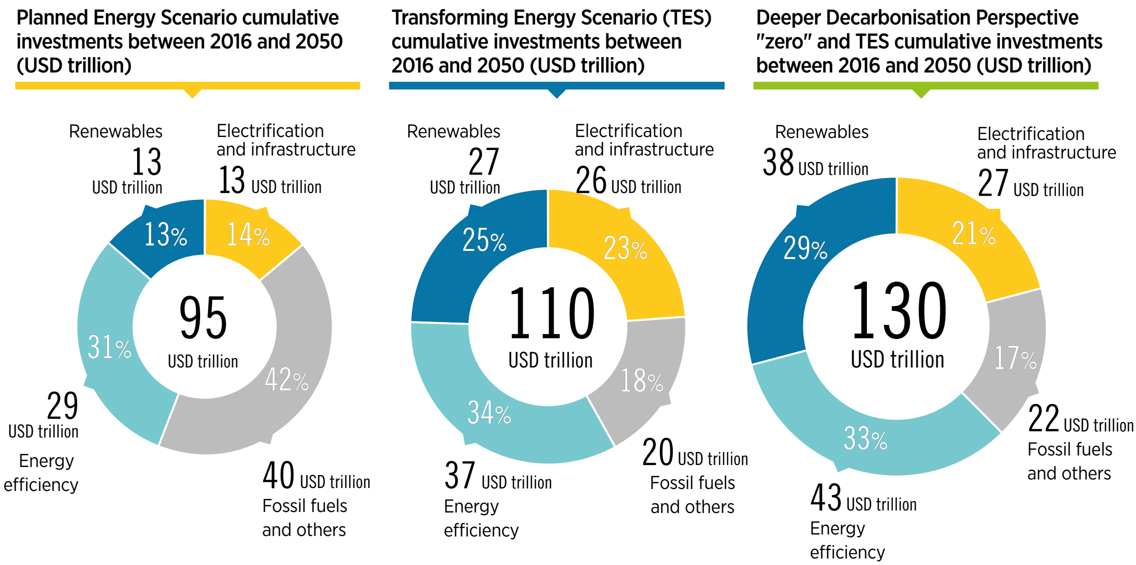
Based on IRENA analysis



A climate-safe future calls for the scale-up, and redirection, of investment to clean energy technologies. Fossil-fuel investments need to be shifted to renewables and energy efficiency instead, while subsidies to fossil fuels must be phased out. Overall, total investment in the energy system in the Transforming Energy Scenario would need to reach USD 110 trillion by 2050, or around 2% of average annual GDP over the period (see Figure S.8). Of that total, over 80% needs to be invested in renewables, energy efficiency, end-use electrification, and power grids and flexibility. If viewed in annual terms, USD 3.2 trillion needs to be invested in the global energy system every year to 2050. That compares to recent historical investment (2014-2018) in the energy system of around USD 1.8 trillion per year (IEA, 2019c), and USD 2.9 trillion per year in the Planned Energy Scenario.

The Deeper Decarbonisation Perspective would require additional investment of USD 20 trillion over the USD 110 trillion of investments in the Transforming Energy Scenario, for a total investment need of USD 130 trillion to reach zero emissions. To help navigate these new investment "waters", and to accelerate a shift of finance into climate-friendly technologies, IRENA is working with partners on the Climate Investment Platform (CIP) to unlock financial resources for the clean energy transition, particularly in developing countries. By addressing the key risks and barriers that hinder the scale-up of renewable investment, CIP will accelerate the low-carbon energy transition and promote sustainable growth.

Figure S.8. New investment priorities: Renewables, efficiency and electrification of heat and transport



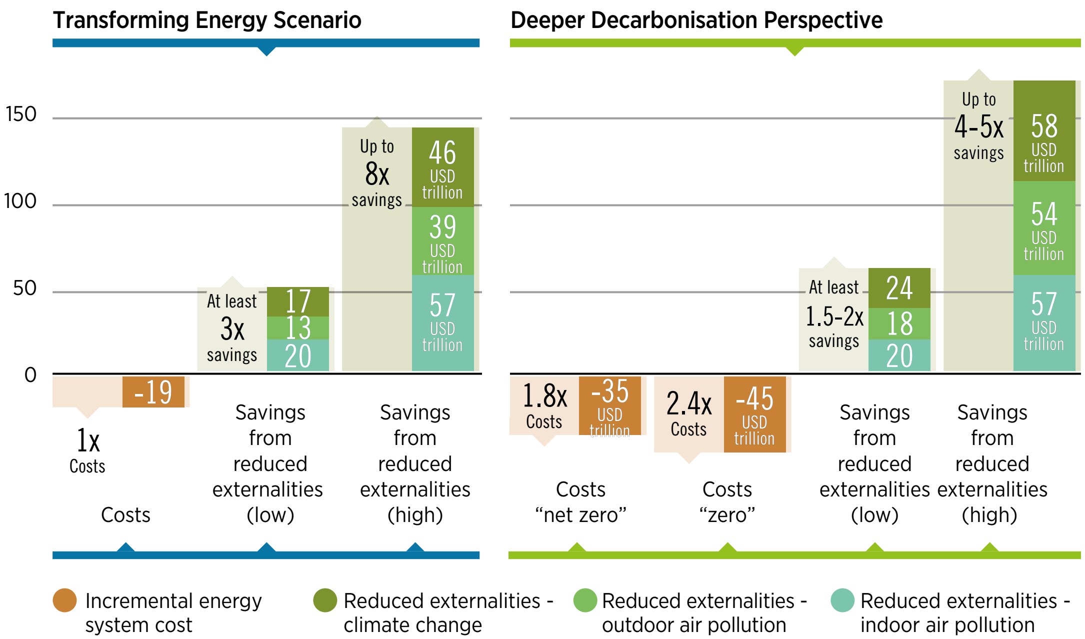
Based on IRENA analysis

The payback for accelerating renewables deployment and efficiency measures is many times larger than the costs. In the Transforming Energy Scenario, every USD 1 spent for the energy transition would bring a payback of between USD 3 and USD 8 (see Figure S.9). Or to put it in cumulative terms, the Transforming Energy Scenario would have an additional cost of USD 19 trillion over the period to 2050 but would result in a payback of between USD 50 trillion and USD 142 trillion in reduced environmental and health externalities. The Deeper Decarbonisation Perspective would cost an additional USD 16 trillion to achieve net-zero emissions, or an additional USD 26 trillion to achieve fully zero emissions (with no carbon offsets).

Therefore, the total additional costs to reach zero range from USD 35 to USD 45 trillion. Yet these higher costs are still significantly lower than the USD 62 to USD 169 trillion in savings from reduced externalities that would result from reaching zero emissions. Another way to look at costs is how much it takes to mitigate one tonne of CO_2 over the period. For the Transforming Energy Scenario, this cost would be USD 34/t CO_2. For the DDP net-zero, the cost would be USD 100/t CO_2, and for DDP fully zero, it would be USD 156/t CO_2.

Figure S.9. The energy transition: Benefits compared to costs

Cumulative system costs and savings from reduced externalities for Transforming Energy Scenario for the period to 2050, and DDP for the period to 2060 (USD trillion)

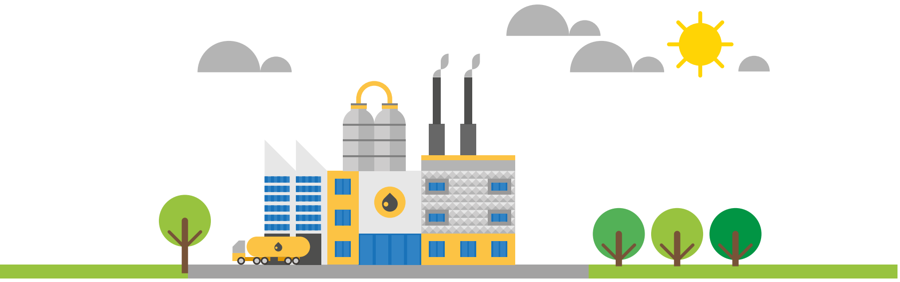


Based on IRENA analysis

Climate change may have significant detrimental and destabilising effects on the world's financial system. Fires, floods, drought, extreme weather, rising seas and other impacts of climate change will take an increasing economic, environmental and human toll – which must be borne in the end by taxpayers, governments and communities (IMF, 2019). In addition, the health costs of pollution are increasingly of major concern for many cities, particularly in the developing world. Central banks, financial institutions and insurance companies are starting to take note and to incorporate assessments of climate risk into their financial planning. Key institutions that have announced steps to incorporate climate risk include the International Monetary Fund, Blackrock, Norway's sovereign wealth fund and KfW Group.

Investments that continue to expand fossil-fuel supply infrastructure are short-sighted and increasingly risky. Such investments will lead to significant stranded assets and will lock in fossil-fuel emissions for decades to come that will also risk achieving the aims of the Paris Agreement (Tong *et al.*, 2019). Recent low oil prices serve as a reminder of the volatility of markets for oil – and other fossil fuels – and of the geopolitics associated with our current energy system. Existing renewable technologies, energy efficiency and some emerging renewables-based technologies can take the reins instead and supply energy across a wide range of energy services at lower cost than fossil fuels, especially when they are coupled with expensive, and often unproven, carbon removal or recycling technologies. While some action is necessary to explore opportunities to make existing fossil-fuel assets cleaner and lower carbon, particularly in sectors such as in industry, where some CCS may be necessary, governments and investors should generally avoid investments into new fossil-fuel supply infrastructure.

Due to the slow progress to date in reducing emissions from the energy sector, already USD 11.8 trillion in assets will need to be stranded by 2050 in the Transforming Energy Scenario. Moreover, further delaying action for another 10 years would result in an additional USD 7.7 trillion in stranded assets by 2050. Limiting the amount of future stranded assets requires greater attention today on the risks that companies, banks and investors face from climate change and the response to climate change. One effort to make those risks more visible is the Task Force on Climate-Related Financial Disclosure, which is helping to develop voluntary climate-related financial risk disclosures.



Policy makers need to establish long-term integrated energy planning strategies, define targets, and adapt policies and regulations that promote and shape a climate-friendly energy system. To capture the overarching impacts of the energy transformation, an integrated energy planning approach is required that combines a holistic, energy system-wide and long-term planning perspective. Long-term energy scenarios have a multiplicity of uses that can support planning for a climate friendly energy system. They can be used to open the dialogue needed among stakeholders to reach consensus, or to raise ambitions of roadmaps for long-term targets and identify short-term challenges when planning the clean energy transition. The boundaries of scenarios need to be expanded beyond the power sector to also integrate traditional fuels, industrial processes, LULUCF and other economy-wide impacts. Overall, there needs to be broader participation and stronger co-ordination across different stakeholders and government institutions involved in the energy scenario building and energy planning process. This should also contribute to setting long-term strategies that consider both energy and climate needs (coupled with the Sustainable Development Goals and the NDCs).

REGIONS PROVIDE THE LINK BETWEEN GLOBAL ASPIRATIONS AND LOCAL ACTION

While climate change is a global threat, transforming the energy sector involves different paths for different regions. Energy transition plans and priorities inevitably differ from country to country. Still, countries within a region also tend to face similar challenges, which can facilitate regional approaches. It may be easier for regions to co-operate and act together on regional energy transition goals than for countries to act alone. Energy transition actions at the regional and country levels must be aligned and consistent with global climate objectives. The inter-regional collaborations must also explicitly address issues of fairness and justice. Ramping up country and regional ambition and interlinking energy and climate is key for the energy transition. IRENA is committed to that effort and will be starting a series of regional investment forums to discuss opportunities with countries in those regions to accelerate the energy transformation. The results of this report will be used to facilitate discussions. A regional focus allows for better "action on the ground".

Figure S.10 **Different transition paths for different regions**

Regional indicators including emissions, energy demand and electrification shares in the Transforming Energy Scenario

Transforming Energy Scenario (TES)

Regions	Emissions: Energy-related CO_2 ($Gt\ CO_2/yr$) 2017	2030	2050	Electrification in end-use consumption (% in TFEC) 2017	2030	2050
East Asia	11.2 $Gt\ CO_2/yr$	8.4 $Gt\ CO_2/yr$	2.2 $Gt\ CO_2/yr$	25%	37%	58%
European Union	3.4 $Gt\ CO_2/yr$	1.9 $Gt\ CO_2/yr$	0.6 $Gt\ CO_2/yr$	22%	30%	49%
Latin America and the Caribbean	1.2 $Gt\ CO_2/yr$	1.0 $Gt\ CO_2/yr$	0.6 $Gt\ CO_2/yr$	18%	26%	39%
Middle East and North Africa	2.5 $Gt\ CO_2/yr$	2.0 $Gt\ CO_2/yr$	1.1 $Gt\ CO_2/yr$	19%	20%	38%
North America	6.2 $Gt\ CO_2/yr$	3.7 $Gt\ CO_2/yr$	1.4 $Gt\ CO_2/yr$	20%	28%	52%
Oceania	0.4 $Gt\ CO_2/yr$	0.4 $Gt\ CO_2/yr$	0.1 $Gt\ CO_2/yr$	23%	22%	45%
Rest of Asia	3.5 $Gt\ CO_2/yr$	3.8 $Gt\ CO_2/yr$	2.0 $Gt\ CO_2/yr$	18%	26%	47%
Rest of Europe	2.0 $Gt\ CO_2/yr$	1.6 $Gt\ CO_2/yr$	0.7 $Gt\ CO_2/yr$	18%	23%	38%
Southeast Asia	1.4 $Gt\ CO_2/yr$	1.6 $Gt\ CO_2/yr$	0.8 $Gt\ CO_2/yr$	18%	20%	42%
Sub-Saharan Africa	0.8 $Gt\ CO_2/yr$	0.6 $Gt\ CO_2/yr$	0.3 $Gt\ CO_2/yr$	7%	23%	48%

Note: 2017 data based on IEA (2019b), Global Carbon Atlas (2019) and IRENA analysis.

Renewable energy share in TPES (%)			Renewable energy share in power generation (%)			Clean energy investments (USD billion per year)	
2017	2030	2050	2017	2030	2050	2016-2030	2016-2050
7%	27%	65%	23%	60%	90%	1120 USD bln	763 USD bln
15%	39%	71%	31%	55%	86%	424 USD bln	323 USD bln
30%	53%	73%	65%	85%	93%	154 USD bln	118 USD bln
1%	9%	26%	3%	27%	53%	198 USD bln	148 USD bln
10%	30%	67%	23%	60%	85%	609 USD bln	487 USD bln
10%	39%	85%	25%	66%	93%	37 USD bln	34 USD bln
8%	27%	58%	18%	52%	81%	420 USD bln	376 USD bln
6%	19%	54%	27%	42%	82%	244 USD bln	165 USD bln
13%	41%	75%	20%	53%	85%	143 USD bln	141 USD bln
7%	43%	89%	26%	67%	95%	95 USD bln	105 USD bln

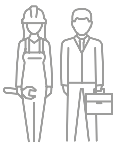
TFEC = total final energy consumption; TPES = total primary energy supply.

Main report
Chapter 2

GLOBAL SOCIO-ECONOMIC IMPACT

Renewable energy technologies lie at the heart of the energy transition. The transition roadmap outlined here points to a more sustainable energy system and lays the foundation for new patterns of socio-economic development. This report examines the transition's likely effects on employment and GDP, while also providing a composite indicator of human welfare. The analysis is based on a model that integrates energy, the economy and the environment. Its results can inform energy system planning, economic policy making, and other policies undertaken to ensure a just and inclusive energy transition at the global, regional and national levels.

JOBS



In the ambitious but achievable Transforming Energy Scenario, jobs in the overall energy sector – comprising transition-related technologies (renewable energy, energy efficiency, and power grids and energy flexibility), fossil fuels and nuclear power – could reach 100 million by 2050. This is 15% more than under the Planned Energy Scenario (which reflects current national commitments and plans) and 72% more than total energy employment at present. Underlying the total are significant changes in the composition of employment. New jobs in transition-related technologies and sectors are expected to outweigh job losses in fossil fuels and nuclear energy. In 2050, energy efficiency alone could employ 21 million people, and power grids and energy flexibility another 14.5 million – 21% and 14% more, respectively, than under the Planned Energy Scenario. By contrast, the 22 million jobs in fossil fuels in 2050 would be 27% fewer than in the Planned Energy Scenario.

Investment projected under the Transforming Energy Scenario would stimulate considerable job growth, most of this directly in renewables, where employment would rise to 42 million jobs by 2050. This is 64% more than expected under the Planned Energy Scenario and close to four times the number of jobs in the sector today. Solar photovoltaic (PV) would account for almost half of these jobs, followed by bioenergy and wind. Among segments of the renewable energy value chain, construction and installation jobs would dominate, accounting for 47% of the total. In terms of occupational profile, construction and factory workers, together with technicians, would hold a 77% share of total employment.

This expanded renewable energy workforce will require specific knowledge and skill sets. The labour market must be able to meet those needs, which would entail education, (re-)training and social policies, among other measures. Beyond the deployment of renewable energy technologies, other sectoral and economy-wide transition trends are sure to affect the evolution of employment in the broader energy sector.

The Transforming Energy Scenario would also achieve a net increase – close to 7 million – in the total number of jobs created economy-wide by 2050, 0.15% more than under the Planned Energy Scenario. The economy-wide employment figure reflects key assumptions and drivers, including not only investments, but also indirect and induced effects across many sectors of the economy, as well as changes in trade patterns. Notwithstanding the overall net job gain, reallocations of investment and changed consumption patterns would trigger job losses in some areas.

Maximising the job creation potential of the energy transition requires a solid understanding of future skill requirements and effective ways to facilitate the corresponding shifts in the labour force. Just and inclusive transition policies can limit labour market disruptions – *i.e.*, the job losses and misalignments that can be expected to occur during the energy transition. Targeted education and capacity-building policies must anticipate impending changes and nurture the diverse and growing labour force required by the transition.

GROSS DOMESTIC PRODUCT

Global GDP in 2050 would be 2.4% higher under the Transforming Energy Scenario than under the Planned Energy Scenario. The cumulative gain would be about USD 98 trillion, a finding shaped by several drivers in the global economy. Front-loaded investments would contribute most to GDP growth during the first years of the transition and retain a positive but relatively small impact thereafter. GDP gains can be explained in great part by changes in consumer spending in response to fiscal policy, as well as other indirect and induced factors. By comparison, trade would add only marginally more to global GDP gains under the Transforming Energy Scenario than under the Planned Energy Scenario, as global trade flows remain broadly balanced in both scenarios.

The cumulative gains in global GDP (USD 98 trillion) would greatly exceed the investment costs of transforming the energy system (USD 15 trillion). The world's GDP would grow by USD 367 per capita per year under the Transforming Energy Scenario, substantially greater than the additional per capita total investment (USD 54) needed to produce those gains. Increased investment and the prospects of economic growth and job creation could all help to obtain political buy-in. Still, the ultimate goal of the transition is to improve people's welfare through clean energy supply, economic and social development, and mitigation of climate change.

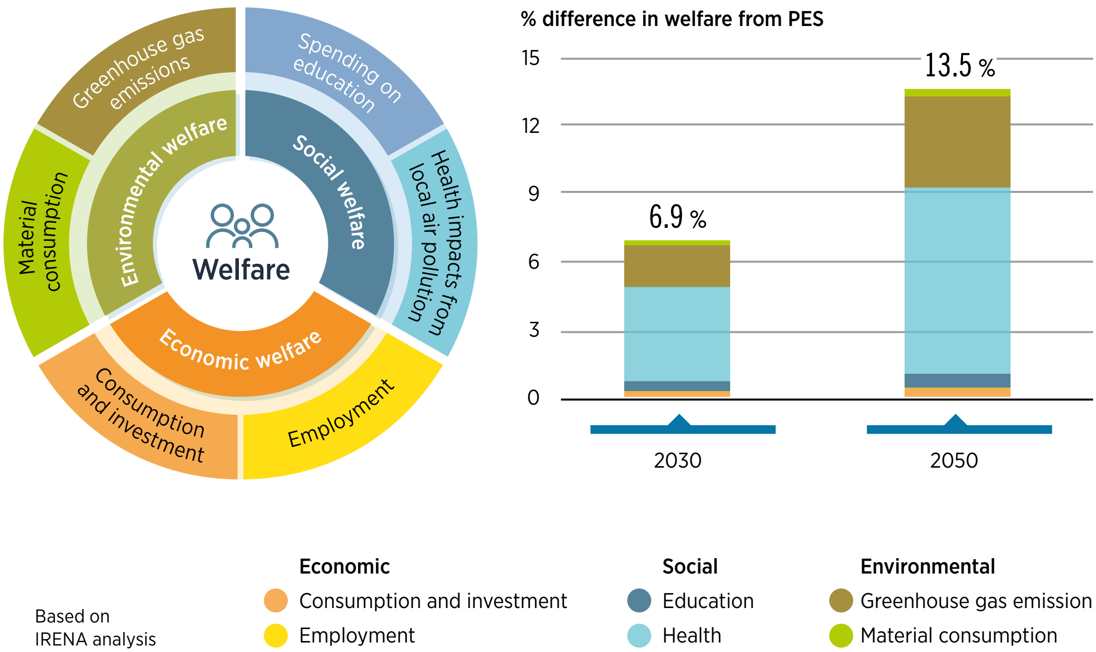
WELFARE

Welfare would improve faster and further under the Transforming Energy Scenario – with global welfare gains estimated at 13.5% by 2050 – than under the Planned Energy Scenario. The composite welfare indicator in the IRENA model reflects the multidimensional nature of human welfare, encompassing economic, social and environmental components (Figure S.11). The economic dimension is measured via household consumption and a composite of total investment and employment. The social dimension reflects spending on education and health. The environmental dimension entails greenhouse gas emissions and the consumption of materials. The bulk of the welfare gains under the Transforming Energy Scenario would take the form of social and environmental gains, reflecting significant health improvements from curbing air pollution and greenhouse gas emissions.

The energy transition would bring substantial socio-economic benefits at the global level. Yet at the country and regional levels, outcomes could vary widely. This is owing to variations in regional and country-specific socio-economic structures and their complex interactions with the energy system. The specific challenges and opportunities in each part of the world call for local solutions.

Figure S.11. Welfare gains: Influenced by health benefits and emission reduction

Global welfare indicator under the Transforming Energy Scenario in 2030 and 2050



Based on IRENA analysis

REGIONAL SOCIO-ECONOMIC IMPACT

Main report **Chapter 4**

The transition will occur in countries and regions at varying stages of development and with different economic structures. Differences include resource endowment, industrial productive capacity, industrial support policies, trade structures and domestic supply chains. All these factors determine the degree to which any economy can take advantage of the opportunities offered by the energy transition. Accordingly, results will vary among individual regions in terms of jobs, GDP and welfare.

The regional impacts of the transition, both in the energy sector as a whole and in its constituent parts, are sure to vary. Careful analysis of the likely outcomes will be required for conventional energy (fossil fuels and nuclear) and transition-related (renewables, energy efficiency, and system flexibility and grid enhancement) industries. The net impact of the Transforming Energy Scenario will depend on the current structure of the energy sector in each region, on regional energy sector roadmaps, and on regional trade patterns associated with transition-related equipment.

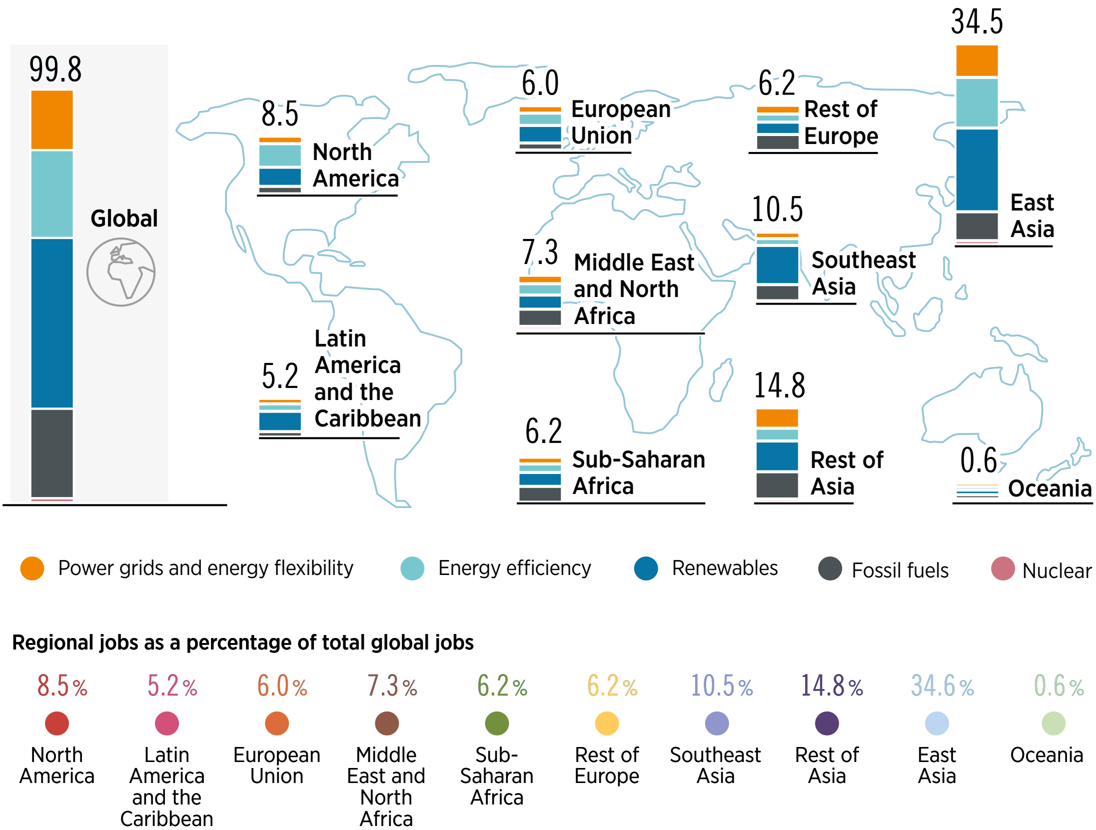
Differences in resource endowment, industrial productive capacity, industrial support policies, trade structures and domestic supply chains determine the degree to which any economy can take advantage of the opportunities offered by the energy transition

ENERGY SECTOR JOBS

The total number of energy sector jobs is expected to expand under the Transforming Energy Scenario to nearly 100 million (up from 58 million in 2017), but their spread will be uneven among regions. Asia dominates with a 60% share of all energy sector jobs in 2050 (Figure S.12). Compared with the Planned Energy Scenario, all regions gain jobs under the Transformed Energy Scenario. But Southeast Asia experiences the largest differential (81%), followed by Oceania (57%), Sub-Saharan Africa (36%) and North America (28%).

Figure S.12 A hundred million energy jobs: Regional distribution

Energy sector jobs in 2050 under the Transforming Energy Scenario, by region



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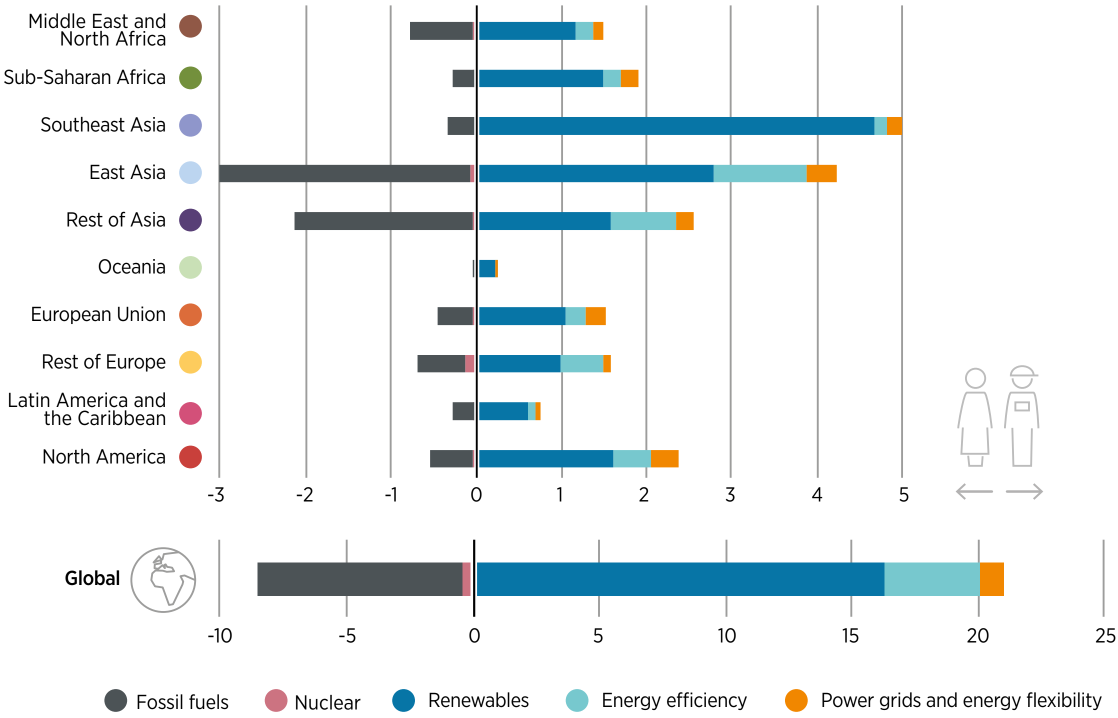
The number of jobs created in the overall energy sector will vary by technology and region. The jobs impacts in absolute numbers are largest in Asia and lowest in Oceania and Latin America. In East Asia and the Rest of Asia region, job losses are the highest of all, yet they are nonetheless surpassed by gains in transition-related technologies (Figure S.13).

Figure S.13 Energy sector job gains: Exceeding losses in every region

Difference in energy sector employment in 2050 between the Transforming Energy and Planned Energy scenarios, by region and sector



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TRANSITION-RELATED JOBS

Jobs intrinsically linked to the transition include those in renewable energy, energy efficiency, power grids and energy flexibility.

Under the Transforming Energy Scenario, **the employment share of transition-related technologies will rise against that of conventional technologies in all regions.** The transition-related share ranges from a high of 85% for North America and the European Union to a low of 60% for Sub-Saharan Africa and Rest of Europe (non-EU). Southeast Asia and Latin America will have the highest shares of jobs in ***renewable energy*** (83% and 72% respectively), while North America and the Middle East and North Africa (MENA) should fall at the lower range (40% and 45% respectively). In ***energy efficiency*** jobs, North America is far ahead of other regions, at 45% of its total energy sector jobs; the share is 29% in the European Union. Southeast Asia has the lowest share of energy efficiency jobs (7%), while the share in other regions lies between 10% and 25%. With respect to ***power grids and energy flexibility***, the share of jobs is highest in the Rest of Asia (22%) and the Rest of Europe (17%) and lowest in Southeast Asia (6%).

Employment gains can be realised in every region by 2050 in all transition-related technologies. In ***renewable energy***, the relative increase in the Transforming Energy Scenario over the Planned Energy Scenario ranges from more than 20% in East Asia and Latin America to 380% in Oceania. In ***energy efficiency***, regions would experience a relative gain ranging from 10% to 115%, with the Rest of Europe and the Rest of Asia regions faring best. In ***power grids and energy flexibility***, the gains will range from about 6% in the Rest of Europe, East Asia and the Rest of Asia to almost 65% in North America.

The regional distribution of renewable energy employment in 2050 varies widely under the Transforming Energy Scenario. The share of the world's renewable energy jobs is as high as 36% in East Asia but as small as 1% in Oceania, which largely reflects the size of populations, workforces and investments (Figure S.14). In terms of technology, solar will account for half of all renewables jobs in North America and in Asia, followed by Europe with 30%. By contrast, bioenergy is most prominent, with a share of over 60% of renewables jobs, in Latin America, Southeast Asia, Sub-Saharan Africa and the Rest of Europe. Wind is strongest in East Asia and the European Union, with about 25% of jobs; the figure is about 15% in North America and the MENA region. Hydro jobs account for 15% of all renewable energy jobs in the Rest of Asia and 10% in Latin America and the MENA region.

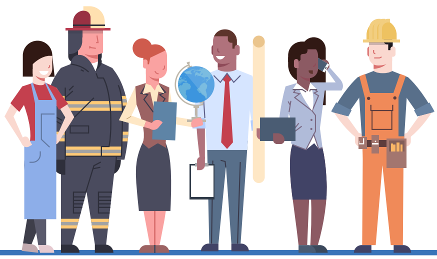
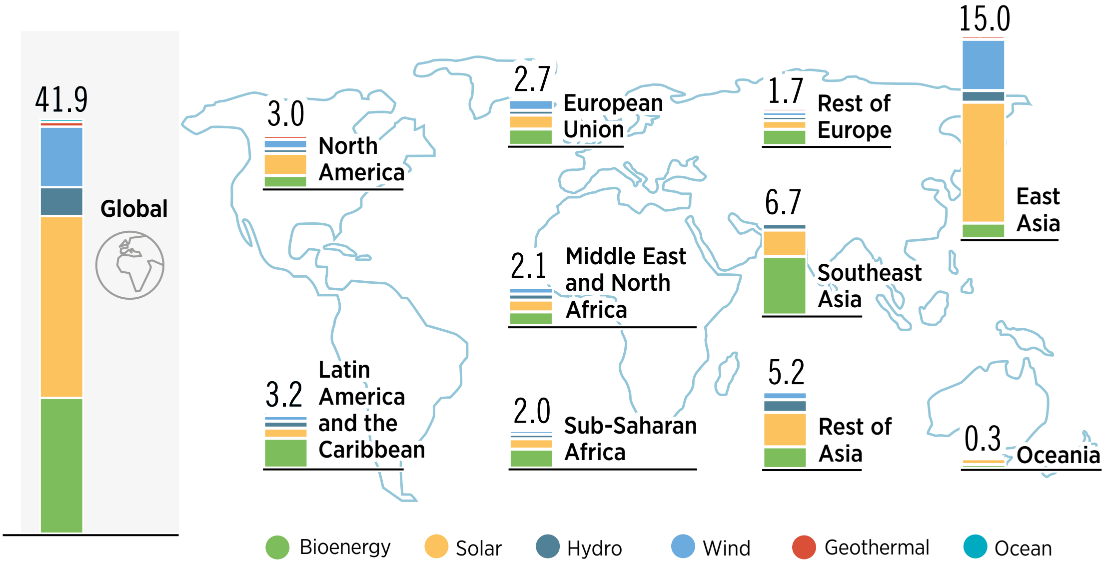


Figure S.14 An estimated 42 million jobs in renewables: Regional distribution

Renewable energy jobs in 2050 under the Transforming Energy Scenario, by region



Regional jobs as a percentage of total global jobs

North America	Latin America and the Caribbean	European Union	Middle East and North Africa	Sub-Saharan Africa	Rest of Europe	Southeast Asia	Rest of Asia	East Asia	Oceania
7.1%	7.7%	6.4%	4.9%	4.8%	4.1%	16%	12.3%	35.8%	0.7%

Based on IRENA analysis

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All regions gain more energy sector jobs than they lose as jobs in transition-related technologies outweigh the loss of jobs in the fossil-fuel sector

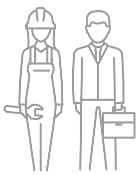
CONVENTIONAL ENERGY JOBS

In contrast to the gains for transition-related technologies, the Transforming Energy Scenario leads to lower projected employment in the conventional energy sector in all regions. For ***fossil fuels***, the largest declines, of around 40%, are projected for North America, East Asia and the European Union. The Rest of Asia follows with a roughly 30% decline, while Latin America and the MENA region would drop about 25% each. Fossil-fuel job losses concern not only exporters but also importers that have built up extensive infrastructure, distribution networks, assets and human know-how around these forms of energy. In ***nuclear energy***, all regions are set to lose jobs as well, with declines ranging from 20% in Latin America, East Asia and the Rest of Asia, to as much as 65% in Europe and North America.

Even as conventional energy employment shrinks overall, the share of conventional energy jobs remains high in some regions. Conventional energy jobs account for up to 40% of energy sector employment in Sub-Saharan Africa, the MENA region and the Rest of Europe compared with 10% to 15% in the European Union, the Americas and East Asia. The remaining conventional energy employment reflects a continuing degree of reliance on these sources.

As the energy transition accelerates, the job loss in conventional technologies becomes more pronounced. For the design of just transition policies that leave no one behind, detailed analysis will be needed to understand the structure of qualifications in the jobs lost and the composition of the labour force.

ECONOMY-WIDE EMPLOYMENT



Energy is an integral part of every economy, interacting with every other sector, affecting relative wages and generating income to be spent in other sectors. The embedded character of the energy sector within the wider socio-economic system, and the complex dynamics of the transition, will induce positive or negative effects in other economic sectors. In turn, other sectors may contribute favourably or adversely to transition challenges within the energy sector. A holistic, just transition policy framework is needed to bring about the best possible outcome.

Whether a region experiences growth or decline in economy-wide jobs depends on various factors, including energy transition roadmaps and regional socio-economic structures. The European Union and North America, respectively, are expected to gain 2.4% and 1% in economy-wide jobs in 2050 over the Planned Energy Scenario. These regional gains are significantly higher than the global average gain of 0.15%. All other regions gain less than 0.5% in economy-wide employment, and some even face a loss of jobs (MENA region, Rest of Europe, Latin America, Southeast Asia and the Rest of Asia). Sub-Saharan Africa shows no significant change.

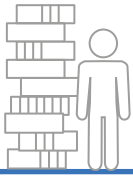
Despite new, transition-related job opportunities, labour market challenges are sure to arise in various sectors of the economy. The loss of jobs in the fossil-fuel sector is the most prominent example of these challenges, but other sectors may also be affected. In fact, the analysis indicates that across entire economies, some regions face the prospect of lower 2050 employment under the Transforming Energy Scenario than under the Planned Energy Scenario. At the economy-wide level, some regions, such as the European Union, North America and East Asia, experience a strong net positive benefit owing to their economies' ability to capitalise on indirect and induced effects of the energy transition. Sub-Saharan Africa and the Rest of Asia lack this ability, given their less diversified and weaker supply chain structures. Others, such as coal and hydrocarbon dependent regions, face a net negative outcome in comparison to the Planned Energy Scenario.

Structural realities may translate into different kinds of labour market misalignments of a temporal, spatial, educational or sectoral nature – a potential in any transition. The quantification of potential sectoral job misalignments, as revealed by the present socio-economic analysis, should inform policy making on the just transition. Because labour challenges are context-specific, a just transition will depend on context-specific policies in each region and country.

GROSS DOMESTIC PRODUCT

In the period 2019-2050, the average difference in GDP between the two scenarios amounts to 2% globally, but the gains in individual regions show considerable variation. The projected results range from a gain of almost 5% in the European Union to a loss of 0.5% in the MENA region. Regions scoring better than the global average include Southeast Asia and East Asia, while the Rest of Europe, North America, the Rest of Asia and Sub-Saharan Africa fall below the average. The MENA region and Oceania are the two exceptions that would experience less GDP growth under the Transforming Energy Scenario than under the Planned Energy Scenario.

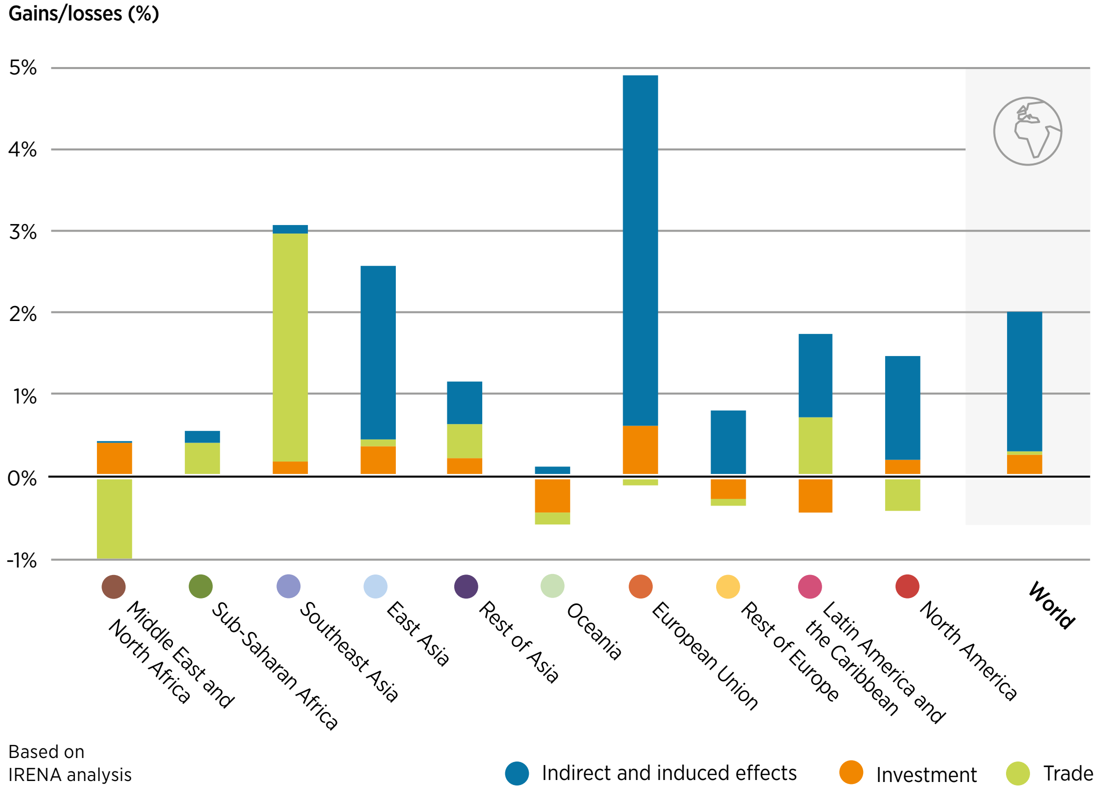
Trade plays a prominent role in shaping the future of some regional economies. The large GDP gains in Southeast Asia and Sub-Saharan Africa are attributable to a strong increase in net exports, whereas the MENA region faces the opposite dynamic, driven by the loss of hydrocarbon exports. The positive trade effect in Latin America and the Rest of Asia is quite pronounced; North America, by contrast, faces a drag from reductions in fossil-fuel trade and even more so trade in other goods and services (Figure S.15).



Whether a region experiences growth or decline in economy-wide jobs depends on various factors, including energy transition roadmaps and regional socio-economic structures

Figure S.15 Largest drivers of GDP gains: Transition effects and trade

Effect of three sets of drivers on the differences in regional GDP between the Transforming Energy and Planned Energy scenarios over the 2019-2050 period



Based on IRENA analysis

Investment levels are another important driver of the transition's regional socio-economic outcomes. At the global level, transition-related clean energy investments average USD 122 per capita per year. Among regions, the amounts vary widely, from about USD 50 per capita per year in Sub-Saharan Africa to more than USD 450 per capita per year in North America. Not only are the macroeconomic impacts consequently higher where investments are larger, but the multipliers in each economy play a significant role in determining the strength of investment effects.

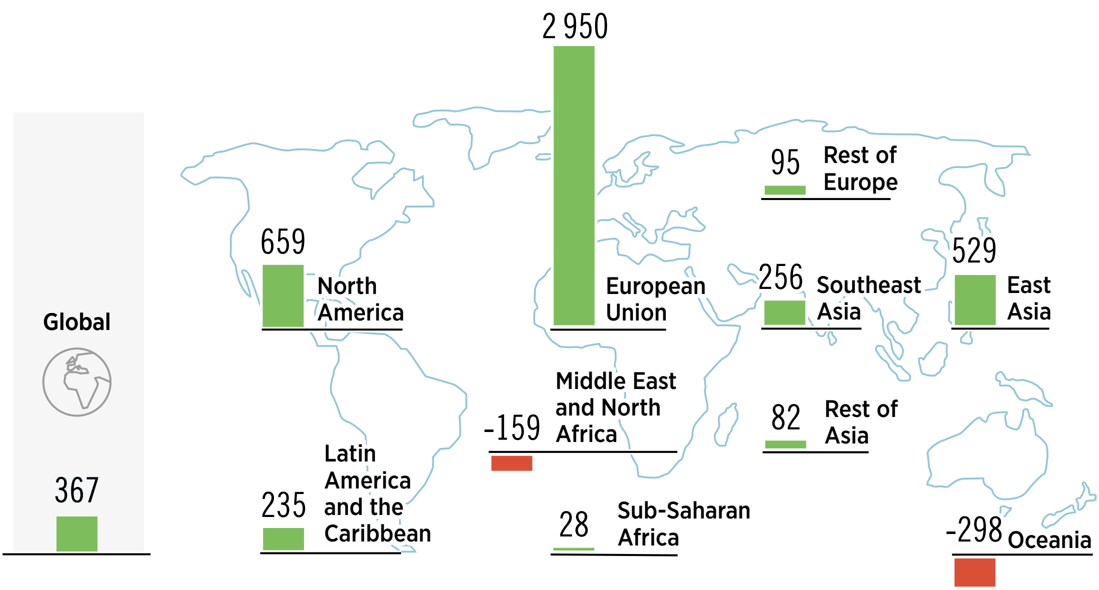
The presence of robust supply chains allows indirect and induced effects to contribute positively to the economy, especially if supported by appropriate fiscal policies. This is particularly the case in some of the major economic regions, such as the European Union, East Asia and North America. Additional employment is a key factor in triggering induced effects, as it leads to additional wage income, which has multiplier effects through increased consumer spending. Fiscal policies are most effective if they are based on a clear understanding of the local socio-economic context in a given region or country. But their successful implementation hinges on the presence of complex administrative infrastructure.

The diverging outcomes of the transition process can be attributed to different regional socio-economic starting points. This means that even if all regions had the same level of ambition and success in implementation, their results would be different. The underlying causes can be traced back to several country factors and structural realities: macroeconomic conditions, fossil fuel and other dependencies, institutional fabrics and capabilities, investment patterns and trade positions.

Under the Transforming Energy Scenario, the cumulative global GDP gains of USD 98 trillion by 2050 translate into an average of USD 367 per capita each year. The distribution of these gains is uneven across the regions. The European Union is expected to gain as much as USD 2 950 per capita per year, reflecting its strong socio-economic structures, but for most regions the gain is between USD 650 to about USD 100. Sub-Saharan Africa is projected to experience a modest increase of about USD 30, while the MENA region and Oceania would see a decline relative to the Planned Energy Scenario (Figure S.16). Variations in economic outcome contribute to the differences in the welfare estimates for these regions.

Figure S.16 Regional differences in GDP gains per capita

Cumulative GDP gains by region under the Transforming Energy Scenario compared with the Planned Energy Scenario (in USD, per person per year)



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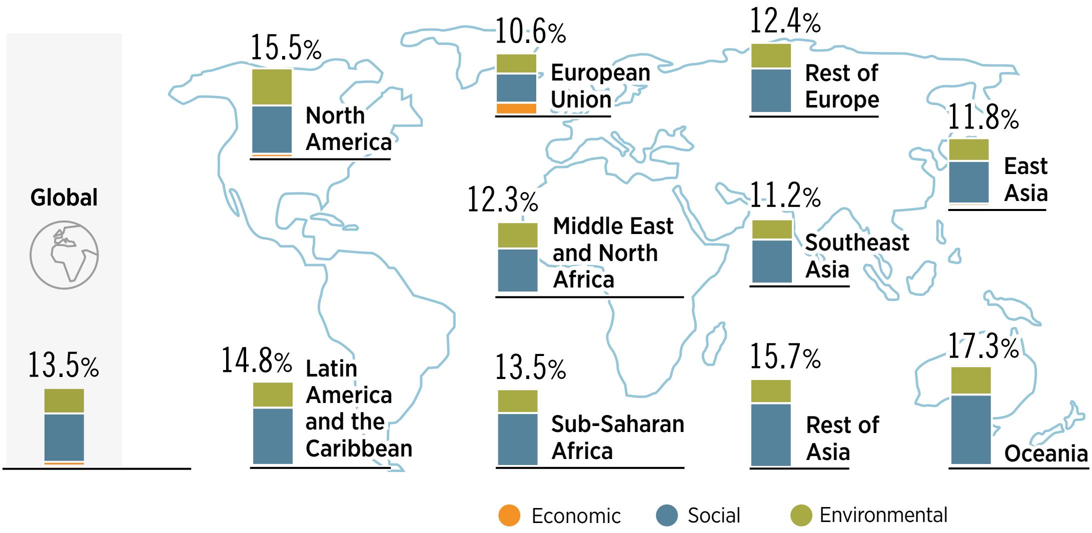
WELFARE

The transition would bring significant improvements in people's welfare in every region. Compared to the Planned Energy Scenario, the Transforming Energy Scenario strengthens the welfare index between 10% in the European Union and 17% in Oceania. The Rest of Asia, the Americas, and Sub-Saharan Africa fare slightly better than the global average, while the remaining regions score slightly lower.

Welfare gains are mostly due to progress in social and (secondarily) environmental indicators. Social indicators include two sub-components: health and education. On the health side, improvements due to reduced air pollution have the strongest effect across all regions, with people suffering most from air pollution achieving the greatest welfare gains. Among the two environmental sub-indicators, the mitigation of greenhouse gas emissions features more prominently than changes in the consumption of materials. Again, this is true across all regions. The economic indicator (composed of employment and consumption and investment) is most evident in the European Union and North America (Figure S.17).

Figure S.17 Regional-level welfare improvements driven by social and environmental gains

Composite welfare indicator in 2050 under the Transforming Energy Scenario, by region



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IMPLICATIONS

All regions of the world can expect to derive benefits from the energy transition, but thorough, granular analysis is needed to understand the reasons for regional differences. Individual regions will not gain equally in the transition-related sectors (renewables, energy efficiency, and power grids and energy flexibility), and they will face losses in the conventional energy sector to different degrees.

Regional outcomes will vary for GDP, employment and human welfare. With regard to jobs, the outcome for different regions will also diverge for the energy sector and its main components (transition-related and conventional energy) and with regard to the economy as a whole.

Differences in regional socio-economic outcomes can be traced back to contrasts in their structural conditions, industrial capacities and trade patterns, and the depth and diversity of domestic supply chains. Existing structures can be altered over time through policy ambition and far-sighted planning. Taking full advantage of the opportunities offered by the energy transition requires that interlinkages between the energy transition and the wider economy be analysed at sub-regional and national levels.

To achieve a successful transition, energy policies must be mainstreamed into economic, industrial, labour, educational and social policies. Cross-cutting and coherent policy making can deliver on climate and energy ambitions; put in place a mix of programmes, projects and initiatives to generate successful outcomes; and avoid or reduce potential misalignments in labour markets as the energy transition unfolds.

Unforeseen developments. The novel coronavirus (COVID-19), its impact on the global economy and the resulting fall in oil prices in early 2020 serve as reminders of how unforeseen factors can disrupt both actual trends and planned processes. These developments confirm the importance of close inter-connections between the energy system and the wider economy. Amid the complexities of the real world, deep-rooted structural dependencies will require persistent efforts to overcome.

Coronavirus is sure to affect the energy transition, too, threatening global supply chains in many sectors. Oil price volatility could have contradictory effects, in part because oil plays a marginal role in the power sector but is much more important in the transport sector, which accounts for half of total demand, and where without low-emission transport policies in place, an extended period of low oil prices may impact the speed of electric vehicle adoption. Conversely, oil price volatility may undermine the viability of unconventional oil and gas resources as well long-term contracts. The severity and duration of such impacts remain to be seen. Yet they will not change the path required to build a low-carbon society.

TOWARDS THE TRANSFORMATIVE DECARBONISATION OF SOCIETIES

Main report **Chapter 6**

Rapidly mounting climate concerns, rampant economic inequality and simmering social justice issues require a comprehensive global economic transformation. These challenges call for holistic solutions, with renewable energy playing a key role. A successful energy transition is central to the achievement of interconnected objectives, such as meeting climate goals, fostering economic development, creating jobs and promoting shared welfare.

The decarbonisation of the global economy in a relatively short time frame calls for unprecedented, large-scale policy interventions and massive resource mobilisation. The confluence of social justice, economic and climate issues has prompted calls for a global "Green New Deal" to bring about massive shifts in the world's energy system and economy, accompanied by measures to ensure a just transition for affected workers and communities through public interventions on an unprecedented scale. The key lies not just in a given set of policies but in the recognition that a transformative decarbonisation of societies is needed.

As countries and regions embark on their transformation pathways, their respective, different starting points reflect their various structural dependencies and the depth of their domestic supply chains. These factors, including dependencies on fossil fuels and other commodities, technologies and trade, will inevitably be reflected in the outcomes of the energy transition in 2050. Despite positive outcomes at the global level, the energy transition is likely to generate very different outcomes for individual regions and countries.

Fossil-fuel dependence is reflected in flows of finance and economic structures. Beyond export revenues for producers (as a share of their GDP or government budgets), dependence extends to the multiple facilities required for extracting, processing and distributing oil, gas and coal. This has implications for the sectors that provide supply chain inputs, and for institutions that educate and train the workforce. However, dependence is hardly limited to energy exporters. Importers, too, have built up extensive infrastructure, distribution networks, assets and human know-how around oil, gas and coal. Such forms of dependence may become a liability as the energy transition unfolds.

In addition to structural factors that need to be addressed, unforeseen developments may well influence the energy transition. The outbreak of the coronavirus is disrupting global supply chains in many sectors, including renewable energy. The oil price volatility observed in early 2020 has contradictory effects. It is unlikely to have a significant impact on renewables in the power sector (where oil plays a limited role) but could affect the speed of electrification in the transport sector. Oil price volatility could also undermine the viability of unconventional oil and gas (Box on "Unforeseen developments"). It is difficult to know how disruptive these developments will prove to be. While the short-term impacts loom large, they seem less likely to alter the long-term planning horizons for decarbonisation and sustainable development.

As countries around the world grapple with the challenge of transforming an energy system – and by extension a global economy – that relies on polluting conventional energy resources, notions of a "Green New Deal" are receiving growing attention in Europe and elsewhere. While this term is inspired by the New Deal of the 1930s, the name chosen for a given set of policy proposals is less important than recognising the need for a holistic approach to the energy transition that simultaneously addresses economic, social and ecological problems.

Market mechanisms alone will not bring about emissions reductions on the scale required in coming decades to transform the energy system and overcome structural dependencies. Alongside private sector financing, much stronger public-sector interventions and global collaborative efforts are needed to ensure the transition to a green, just and inclusive economy. Countries need to acquire or further develop their industrial capabilities and leverage them to take advantage of emerging opportunities in green technology development. Technological transitions, such as the rapid uptake of renewables and energy efficiency measures, can provide a temporary window of opportunity for lagging economies to catch up. Likewise, pre-existing productive capabilities, particularly in manufacturing sectors with high spillovers to the rest of the economy, can provide a promising basis for innovation in green technologies.

A successful energy transition will depend on a package of proactive, coherent public-sector interventions. In addition to measures to support technological innovation, bolstered by knowledge sharing and exchanges of best practices, such a package includes policies on the deployment and integration of renewables into energy distribution systems and end-use applications, as well as measures to ensure sufficient system flexibility as variable renewables (solar and wind) grow in importance. Further, enabling policies include industrial policies, labour-market interventions, educational and skills development, and social protection measures. Strategies for a just and inclusive transition aim to avoid or minimise dislocations for individuals, communities, countries and regions, thus ensuring broad benefits from the energy transition.

Success will depend on the strengthening of institutions, and also on broadening policy co-ordination and cohesion. At the national level, robust institutions can play a key role in accelerating the energy transition and driving change at the scale and magnitude needed. Co-operation is as important at the international level as it is within any country, not least because of tremendous variations in the ability of individual countries to marshal necessary resources, raise institutional capacities and develop technical know-how. A shared willingness to draw on lessons learned and best practices will benefit all and can herald a strengthened multilateralism for decarbonisation. This includes a rethinking of rules governing the global trade system with a view to supporting an ambitious and successful energy transition.

Mobilising resources on a massive scale is indispensable. At the international level, the Climate Investment Platform announced in September 2019 by the International Renewable Energy Agency, the United Nations Development Programme, the multi-partner Sustainable Energy for All initiative, and the Green Climate Fund aims to mobilise energy-transition investments on a scale commensurate with climate goals. Sub-regional investment forums, co-ordinated by IRENA, are intended to create enabling conditions, improve access to finance and assist developers in the preparation of bankable renewable energy projects.[1]

Ultimately, the success of the energy transition in mitigating the climate crisis will depend on the policies adopted, the speed of their implementation and the level of resources committed. In our interconnected world, international co-operation and solidarity are not only desirable, they are a vital condition for addressing climate change, economic inequality and social injustice. Moving forward, investment decisions should be evaluated on the extent to which they accelerate the shift towards an inclusive low-carbon economy. Anything short of that can seriously hamper the path towards a transformative decarbonisation of our societies.

[1] To learn more, see *https://irena.org/irenaforcip*.

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