IRENA
International Renewable Energy Agency

GLOBAL ENERGY TRANSFORMATION

A ROADMAP TO 2050

EXECUTIVE SUMMARY

This document summarises IRENA (2018), *Global Energy Transformation: A Roadmap to 2050*, International Renewable Energy Agency, Abu Dhabi (ISBN 978-92-9260-059-4).

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. 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**

The full report is available for download: **www.irena.org/publications**

For further information or to provide feedback: **info@irena.org**

Disclaimer

EXECUTIVE SUMMARY

Renewable energy needs to be scaled up at least six times faster for the world to start to meet the goals set out in the Paris Agreement.

The historic climate accord from 2015 seeks, at minimum, to limit average global temperature rise to "well below 2°C" in the present century, compared to pre-industrial levels. Renewables, in combination with rapidly improving energy efficiency, form the cornerstone of a viable climate solution.

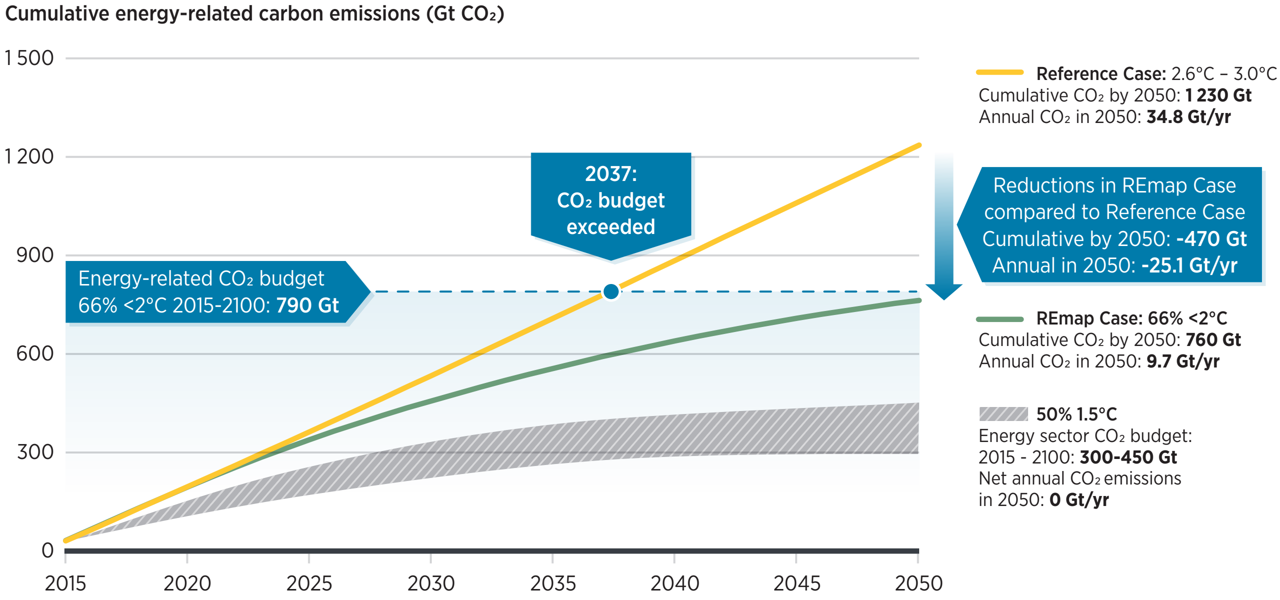
Keeping the global temperature rise below 2 degrees Celsius (°C) is technically feasible. It would also be more economically, socially and environmentally beneficial than the path resulting from current plans and policies. However, the global energy system must undergo a profound transformation, from one largely based on fossil fuels to one that enhances efficiency and is based on renewable energy. Such a global energy transformation – seen as the culmination of the "energy transition" that is already happening in many countries – can create a world that is more prosperous and inclusive.

Currently, emission trends are not on track to meet that goal. Government plans still fall far short of emission reduction needs. Under current and planned policies, the world would exhaust its energy-related "carbon budget" (CO_2) in under 20 years to keep the global temperate rise to well below 2°C (with 66% probability), while fossil fuels such as oil, natural gas and coal would continue to dominate the global energy mix for decades to come.

To meet the below 2°C goal, immediate action will be crucial. Cumulative emissions must at least be reduced by a further 470 gigatons (Gt) by 2050 compared to current and planned policies (business-as-usual) to meet that goal.

Figure 1. **In under 20 years, the global energy-related CO_2 emissions budget to keep warming below 2°C would be exhausted**

Emissions and the emissions gap, 2015-2050



Energy efficiency and renewable energy are the main pillars of the energy transition. While different paths can mitigate climate change, renewable energy and energy efficiency provide the optimal pathway to deliver the majority of the emission cuts needed at the necessary speed. Together they can provide over 90% of the energy-related CO_2 emission reductions that are required, using technologies that are safe, reliable, affordable and widely available.

Renewable energy and energy efficiency need to expand in all sectors. The total share of renewable energy must rise from around 15% of the total primary energy supply (TPES) in 2015 to around two-thirds by 2050. To meet climate targets, the energy intensity of the global economy will need to fall by about two-thirds by 2050, lowering the total primary energy supply in that year to slightly less than 2015 levels. This can be achieved, despite significant population and economic growth, by substantially improving energy efficiency.

By 2050, all countries can substantially increase the proportion of renewable energy in their total energy use. REmap, a global roadmap prepared by the International Renewable Energy Agency (IRENA), suggests that renewables can make up 60% or more of many countries' total final energy consumption (TFEC). For instance, China could increase the share of renewable energy in its energy use from 7% in 2015 to 67% in 2050. In the European Union (EU), the share could grow from about 17% to over 70%. India and the United States could see shares increase to two-thirds or more.

A decarbonised power sector, dominated by renewable sources, is at the core of the transition to a sustainable energy future. The share of renewable energy in the power sector would increase from 25% in 2017 to 85% by 2050, mostly through growth in solar and wind power generation. This transformation would require new approaches to power system planning, system and market operations, and regulation and public policy. As low-carbon electricity becomes the main energy carrier, the share of electricity consumed in end-use sectors would need to double from approximately 20% in 2015 to 40% in 2050. Electric vehicles (EVs) and heat pumps would become more common in most parts of the world. In terms of final energy, renewable electricity would provide just under 60% of total renewable energy use, two and a half times its contribution to overall renewable energy consumption today.

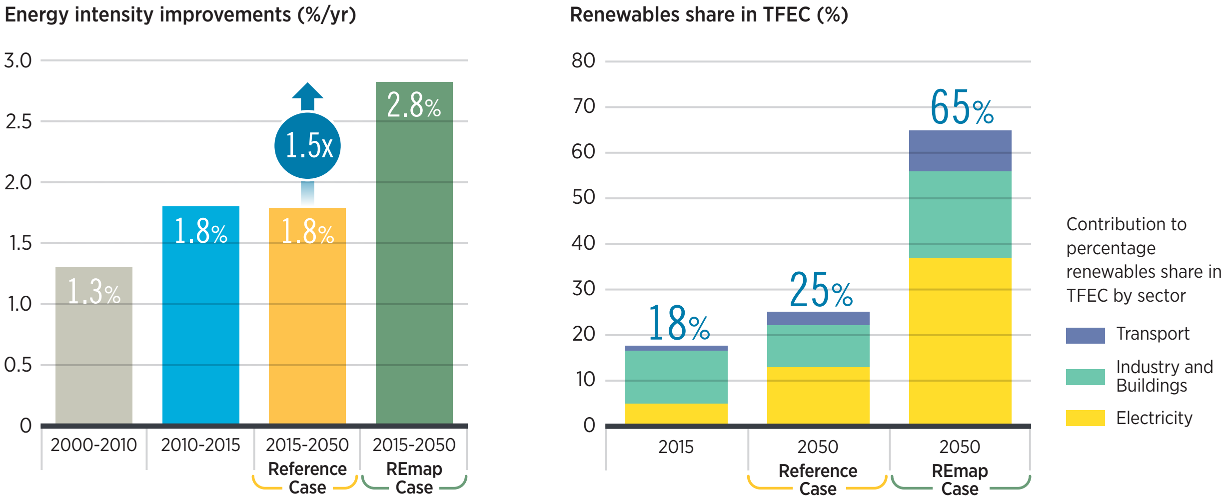
The power sector has made significant progress in recent years, but the speed of progress must be accelerated. In 2017 the power sector added 167 gigawatts (GW) of renewable energy capacity globally, a robust growth of 8.3% over the previous year and a continuation of previous growth rates since 2010 averaging 8% per year. Renewable power generation accounted for an estimated quarter of total global power generation, a new record. New records were also set for solar and wind installation, with additions of 94 GW in solar photovoltaic (PV) and 47 GW wind power, including 4 GW of offshore wind power. Renewable power generation costs continue to fall. There is ample evidence that power systems dominated by renewables can be a reality, so the scale and speed of renewable energy deployment can be accelerated with confidence.

Industry, transport and the building sectors will need to use more renewable energy. In these sectors, renewable sources including increased renewable electricity supply, but also solar thermal, geothermal energy and bioenergy, must play important roles. Renewable electricity will play an increasingly important role but a large contribution are renewable fuels and direct-uses that are needed for heat and transport. For these the use of biomass could provide a little under two-thirds of renewable energy used for heat and fuel; solar thermal could provide around one-quarter; and geothermal and other renewable sources the remainder.

Energy efficiency is critical in the building sector. However, the slow rate at which energy efficiency in the sector is improving, due in part to the low building renovation rates of just 1% per year of existing building stock, remains a major issue. A three-fold increase in this renovation rate is necessary. In industry, the high energy demand of certain industries, the high carbon content of certain products, and high emission processes, require novel solutions and lifecycle thinking.

Figure 2. Significant improvements in energy intensity are needed, and the share of renewable energy must rise to two-thirds

Energy intensity improvement rate (%/yr) and renewable energy share in TFEC (%), Reference and REmap cases, 2015-2050

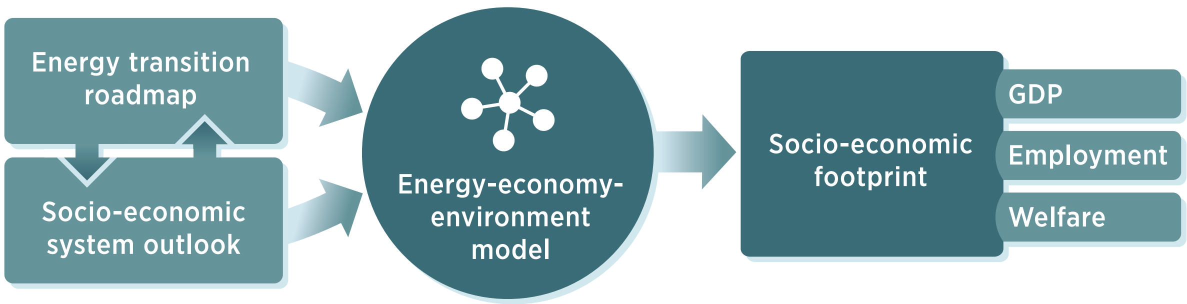


The global energy transformation makes economic sense. The additional costs of the comprehensive, long-term energy transition would amount to USD (United States Dollars) 1.7 trillion annually in 2050. However, cost-savings from reduced air pollution, better health and lower environmental damage would far outweigh these costs. The REmap Case suggests that savings in these three areas alone would average USD 6 trillion annually by 2050. In addition, the energy transition would significantly improve the energy system's global socio-economic footprint compared with business-as-usual, improving global welfare, GDP (Gross Domestic Product) and employment. Across the world economy, GDP increases by 2050 in both the reference and transition scenarios. The energy transition stimulates economic activity additional to the growth that could be expected under a business as usual approach. The cumulative gain through increased GDP from 2018 until 2050 would amount to USD 52 trillion

Substantial additional investment in low-carbon technologies will be required compared to current and planned policies. Cumulative investment in the energy system between 2015 and 2050 will need to increase around 30%, from USD 93 trillion according to current and planned policies, to USD 120 trillion to enable the energy transition. Investment in renewable energy and energy efficiency would absorb the bulk of total energy investments. Also included in this total is USD 18 trillion that would need to be invested in power grids and energy flexibility – a doubling over current and planned policies. In total, throughout the period, the global economy would need to invest around 2% of the average global GDP per year in decarbonisation solutions, including renewable energy, energy efficiency, and other enabling technologies.

Understanding the socioeconomic footprint of the energy transition is essential to optimise the outcome. The energy transition cannot be considered in isolation, separate from the socio-economic system[1] in which it is deployed. Different transition pathways can be pursued, as well as different transitions of the socio-economic system. The REmap Case significantly improves the global socioeconomic footprint of the energy system (relative to the Reference Case). By 2050, it generates a 15% increase in welfare, 1% in GDP, and 0.1% in employment. The GDP improvement peaks after about a decade, while welfare continuously improves to 2050 and beyond. The socioeconomic benefits of the transition (welfare) go well beyond GDP improvements, and include marked social and environmental benefits. At the regional level, the outcome of the energy transition depends on regional ambition as well as regional socioeconomic structures. Despite fluctuations in GDP and employment, welfare will improve significantly in all regions.

Figure 3. **Obtaining the socio-economic footprint from a given combination of an energy transition roadmap and a socio-economic system structure and outlook.**

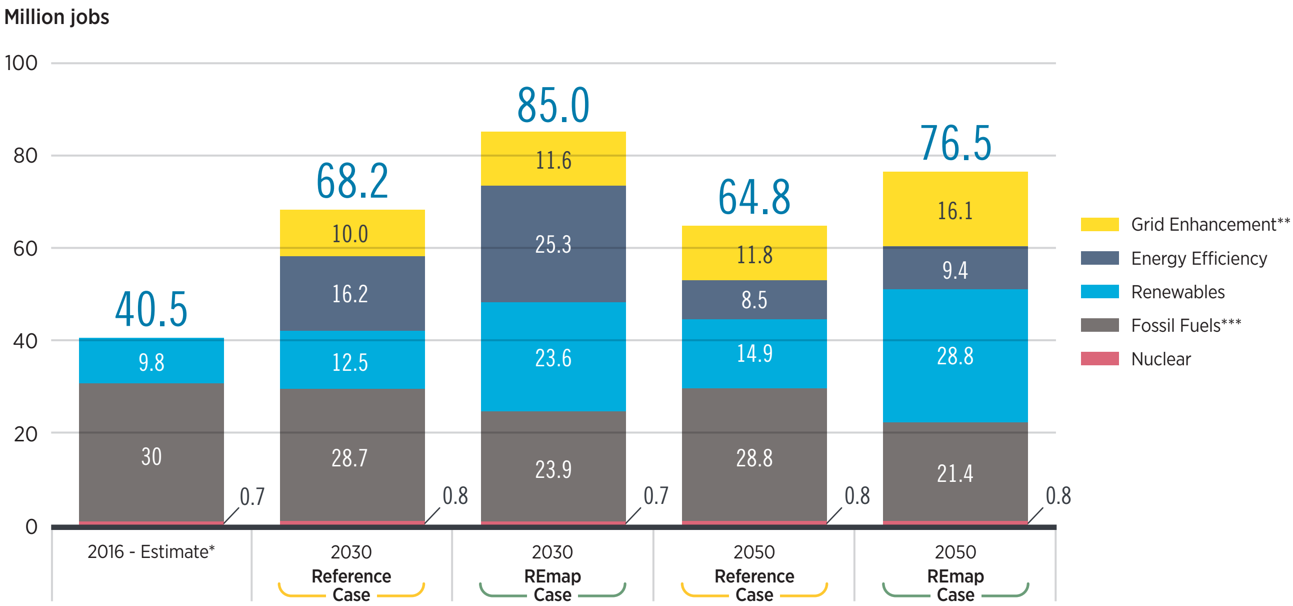


With holistic policies, the transition can greatly boost overall employment in the energy sector. On balance, the shift to renewables would create more jobs in the energy sector than are lost in the fossil fuel industry. The REmap Case would result in the loss of 7.4 million jobs in fossil fuels by 2050, but 19.0 million new jobs would be created in renewable energy, energy efficiency, and grid enhancement and energy flexibility, for a net gain of 11.6 million jobs. To meet the human resource requirements of renewable energy and energy efficiency sectors in rapid expansion, education and training policies would need to meet the skill needs of these sectors and maximising local value creation. A transition that generates fair and just socioeconomic outcomes will avoid resistances that could otherwise derail or halt it. Transforming the socioeconomic system is one of the most important potential benefits.

1 The socio-economic system includes all the social and economic structures and interactions existing within a society. The energy transition is not to be deployed as a standalone component, but within the existing socio-economic system, with many and complex interactions taking place between them. Holistically addressing these interactions from the onset prevents barriers and opens the door to greater and deeper transformational potential. Improvements in both the energy transition and the socio-economic system, enhancing the synergies between them, contributes to boosting the overall transition outcome.

Figure 4. **The transition would generate over 11 million additional energy sector jobs by 2050**

Employment in the overall energy sector in 2016, 2030 and 2050 (in millions of jobs)



* Estimates for jobs in energy efficiency and grid enhancement are not available for 2016.

** The jobs in grid enhancement make reference to the jobs for T&D grids and energy flexibility, created in the development, operation and maintenance of infrastructure to enable the integration of renewable energy systems into the grid.

*** Includes all jobs the fossil fuel industry including in their extraction, processing and consumption

All regions of the world stand to benefit from the energy transformation, although the distribution of benefits varies according to socio-economic context. As expected, socio-economic benefits are not distributed uniformly across countries and regions. This is because the effects play out differently depending on each country's or region's dependence on fossil fuels, ambition in its energy transition, and socio-economic characteristics. In terms of welfare, the strongest overall improvements are found in Mexico, closely followed by Brazil, India and the countries and territories of Oceania. Other regions, including rest of East Asia, Southern Africa, Southern Europe, and Western Europe also record high welfare gains. Environmental benefits are similar in all countries, because they are dominated by reduced greenhouse gas (GHG) emissions given its global nature. Regional net gains in employment fluctuate over time, but the impact is positive in almost all regions and countries.

Accelerated deployment must start now. Early action to channel investments in the right energy technologies is critical to reduce the scale of stranded assets. The slow progress of emission mitigation to date means that the adoption of a mitigation path as envisaged in this study would result in stranded assets worth more than USD 11 trillion. If the world starts to accelerate the energy transition today based largely on renewable energy and energy efficiency, it would limit the unnecessary accumulation of energy assets, which would otherwise have to be stranded; minimise the environmental and health damage caused by fossil fuel use; and reduce the need to resort in the future to environmentally questionable technologies, such as carbon capture and storage or nuclear power.

The financial system should be aligned with broader sustainability and energy transition requirements. Financial constraints and inertia can inhibit the investment required to deliver the energy transition. Increasing access to finance and lowering borrowing costs would increase both GDP and employment further, while also enabling the transition pathway envisaged in this study. Policy measures and structural socioeconomic modifications increase the availability of finance without compromising regional financial stability. Sources of finance that currently contribute little to sustainable energy investment should be unlocked. Potential sources include institutional investors (pension funds, insurance companies, endowments, sovereign wealth funds) and community-based finance. Scarce public finances should be used to mitigate key risks and lower the cost of capital in countries and regions where renewable energy investments are perceived to be high risk. Rapid action is required to remove this potentially significant transition barrier and ensure that the introduction of clean and modern energy sources is not further delayed.

While the energy transition is technically feasible and economically beneficial, it will not happen by itself. Policy action is needed urgently to steer the global energy system towards a sustainable pathway.

FOCUS AREAS

IRENA's report, ***Global Energy Transition: A Roadmap to 2050,*** identifies six focus areas where policy and decision makers need to act:

1. **Tap into the strong synergies between energy efficiency and renewable energy.** This should be among the top priorities of energy policy design because their combined effect can deliver the bulk of energy-related decarbonisation needs by 2050 in a cost-effective manner.

2. **Plan a power sector for which renewables provide a high share of the energy**. Transforming the global energy system will require a fundamental shift in the way energy systems are conceived and operated. This, in turn, requires long-term energy system planning and a shift to more holistic policy-making and more co-ordinated approaches across sectors and countries. This is critical in the power sector, where timely infrastructure deployment and the redesign of sector regulations are essential conditions for cost-effective integration of solar and wind generation on a large scale. These energy sources will become the backbone of power systems by 2050.

3. **Increase use of electricity in transport, building and industry**. Urban planning, building regulations, and other plans and policies must be integrated, particularly to enable deep and cost-effective decarbonisation of the transport and heat sectors through electrification. However, renewable electricity is only part of the solution for these sectors. Where energy services in transport, industry and buildings cannot be electrified, other renewable solutions will need to be deployed, including modern bioenergy, solar thermal, and geothermal. To accelerate deployment of these solutions, an enabling policy framework will be essential.

4. Foster system-wide innovation. Just as the development of new technologies has played a key role in the progress of renewable energy in the past, continued technological innovation will be needed in the future to achieve a successful global energy transition. Efforts to innovate must cover a technology's full life-cycle, including demonstration, deployment and commercialisation. But innovation is much broader than technology research and development (R&D). It should include new approaches to operating energy systems and markets as well as new business models. Delivering the innovations needed for the energy transition will require increased, intensive, focused and co-ordinated action by national governments, international actors and the private sector.

5. Align socio-economic structures and investment with the transition. An integrated and holistic approach is needed by aligning the socio-economic system with the transition requirements. Implementing the energy transition requires significant investments, which adds to the investment required for adaptation to climate change already set to occur. The shorter the time to materialise the energy transition, the lower the climate change adaptation costs and the smaller the socio-economic disruption. The financial system should be aligned with broader sustainability and energy transition requirements. Investment decisions made today define the energy system of decades to come. Capital investment flows should be reallocated urgently to low-carbon solutions, to avoid locking economies into a carbon-intensive energy system and to minimise stranded assets. Regulatory and policy frameworks must be established quickly which give all relevant stakeholders a clear and firm long-term guarantee that energy systems will be transformed to meet climate goals, providing economic incentives that fully reflect the environmental and social costs of fossil fuels and removing barriers to accelerate deployment of low carbon solutions. The increased participation of institutional investors and community-based finance in the transition should be facilitated and incentivised. The specificities of distributed investment needs (energy efficiency and distributed generation) should be addressed.

6. Ensure that transition costs and benefits are fairly distributed. The scope of the transition required is such that it can only be achieved by a collaborative process that involves the whole of society. To generate effective participation, the costs and benefits of the energy transition should be shared fairly, and the transition itself should be implemented justly. Universal energy access is a key component of a fair and just transition. Beyond energy access, huge disparities exist at present in the energy services available in different regions. The transition process will only be complete when energy services converge in all regions. Transition scenarios and planning should incorporate access and convergence considerations. A social accounting framework that enables and visualises the transition contributions and obligations from individuals, communities, countries and regions should be promoted and facilitated. Advances should be made in the definition and implementation of a fair context to share the transition costs, while promoting and facilitating structures that allow a fair distribution of the transition benefits. Just transition considerations should be explicitly addressed from the onset, both at the micro and macro levels, creating the structures that provide alternatives allowing those individuals and regions that have been trapped into the fossil fuel dynamics to participate from the transition benefits.

IRENA

International Renewable Energy Agency

www.irena.org