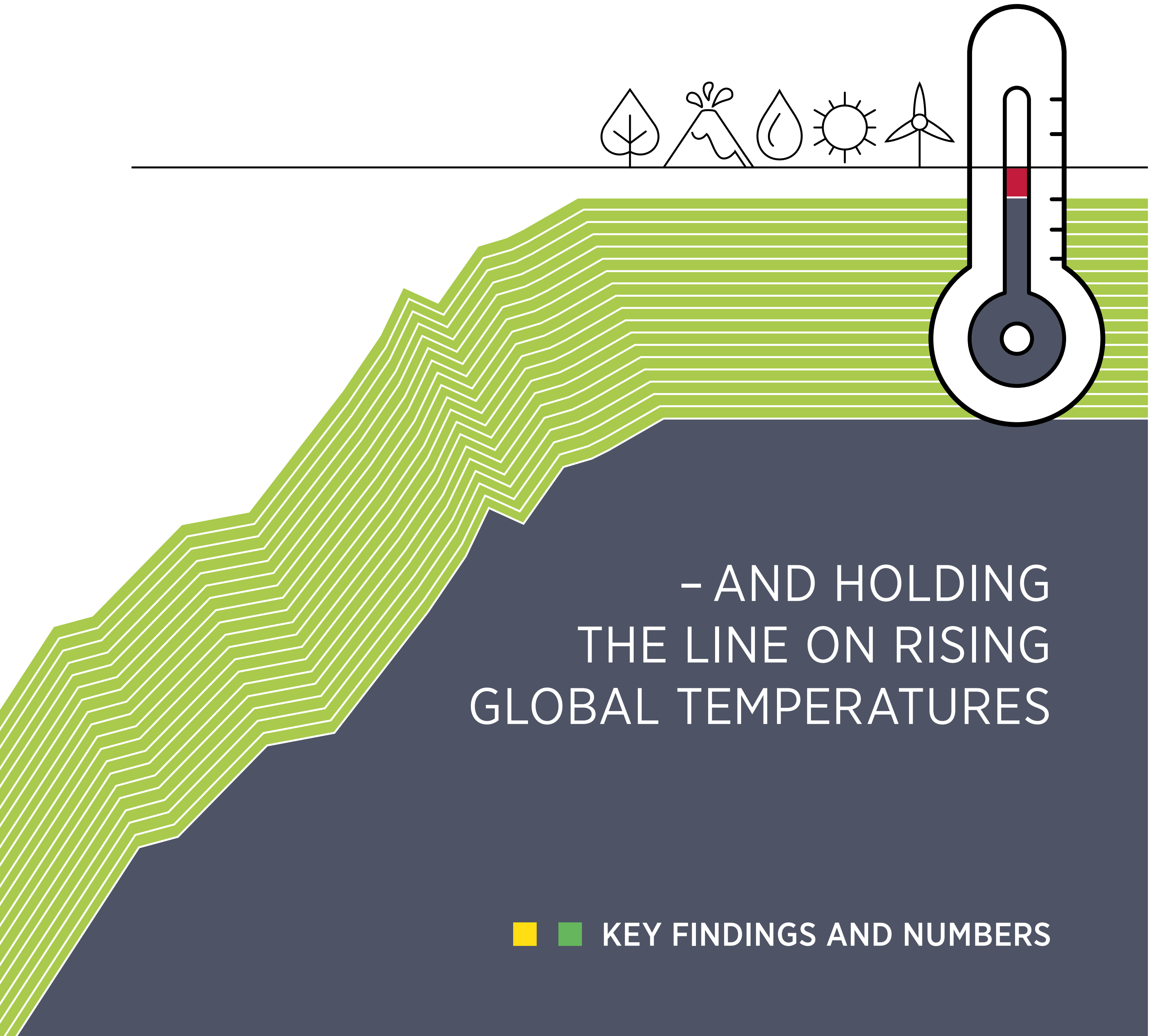
IRENA
International Renewable Energy Agency

TRANSFORMING THE ENERGY SYSTEM



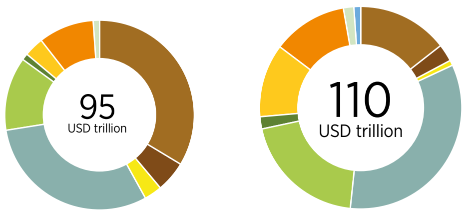
– AND HOLDING THE LINE ON RISING GLOBAL TEMPERATURES

KEY FINDINGS AND NUMBERS

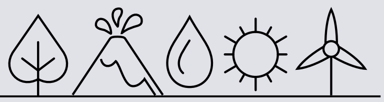
KEY NUMBERS

110 USD trillion investments in the sector by 2050 to achieve **ENERGY TRANSFORMATION**

+15 USD trillion compared to **CURRENT PLANS**

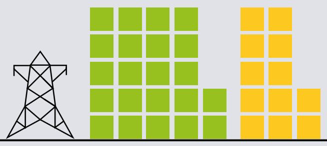


Increased investment and **changing energy mix**



Investment in Renewable Energy: **27 USD trillion** vs. USD 12 trillion

Power

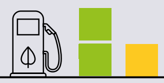


22.5 USD trillion vs. USD 12 trillion

End uses

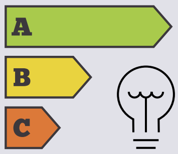
2.5 USD trillion vs. USD 1 trillion

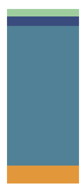
Biofuels



2 USD trillion vs. USD 1 trillion

Investment in Energy Efficiency: **37 USD trillion** vs. USD 29 trillion





Changing **trade**, **spending** and **investment** patterns

2.5% higher GDP

7 million more jobs*

* Estimated 0.15% higher economy-wide net employment in 2050 with ENERGY TRANSFORMATION compared to CURRENT PLANS

KEY FINDINGS

The Paris Agreement sets a goal of *"[h]olding the increase in the global average temperature to well below 2°C above pre-industrial levels and pursuing efforts to limit the temperature increase to 1.5°C above pre-industrial levels"* to significantly reduce the risks and impacts of climate change. The world today has less than two decades to make serious cuts in carbon emissions. If we fail, according to the Intergovernmental Panel on Climate Change (IPCC, 2018), we may cross the tipping point into a future of catastrophic climate change.[1]

Ambitious investments in the energy sector – reshaping power generation, transport and other energy uses on both the supply and demand sides – can provide many of the quick wins needed for a sustainable future. Renewable energy sources, coupled with steadily improving energy efficiency, offer the most practical and readily available solution within the timeframe set by the IPCC. By embarking upon a comprehensive energy transformation today, we can start to create a better energy system – one capable of ensuring that average global temperatures at the end of the century are no more than 1.5°C above pre-industrial levels.

Around the world today, national energy plans and Nationally Determined Contributions (NDCs) fall far short of the emissions reductions needed. Currently, the world may exhaust its "carbon budget" for energy-related emissions until the end of the century in as few as ten years. To hold the line at 1.5°C, cumulative energy-related carbon-dioxide (CO_2) emissions must be 400 gigatons (Gt) lower by 2050 than current policies and plans indicate.

The International Renewable Energy Agency (IRENA) has explored two broad future paths: **Current Plans** (meaning the course set by current and planned policies); and the path for a clean, climate-resilient **Energy Transformation**.[2] Building such a low-carbon, climate-safe future can deliver a broad array of socio-economic benefits, IRENA's analysis shows. But to make this happen, the pace and depth of investments in renewables must be accelerated without delay.

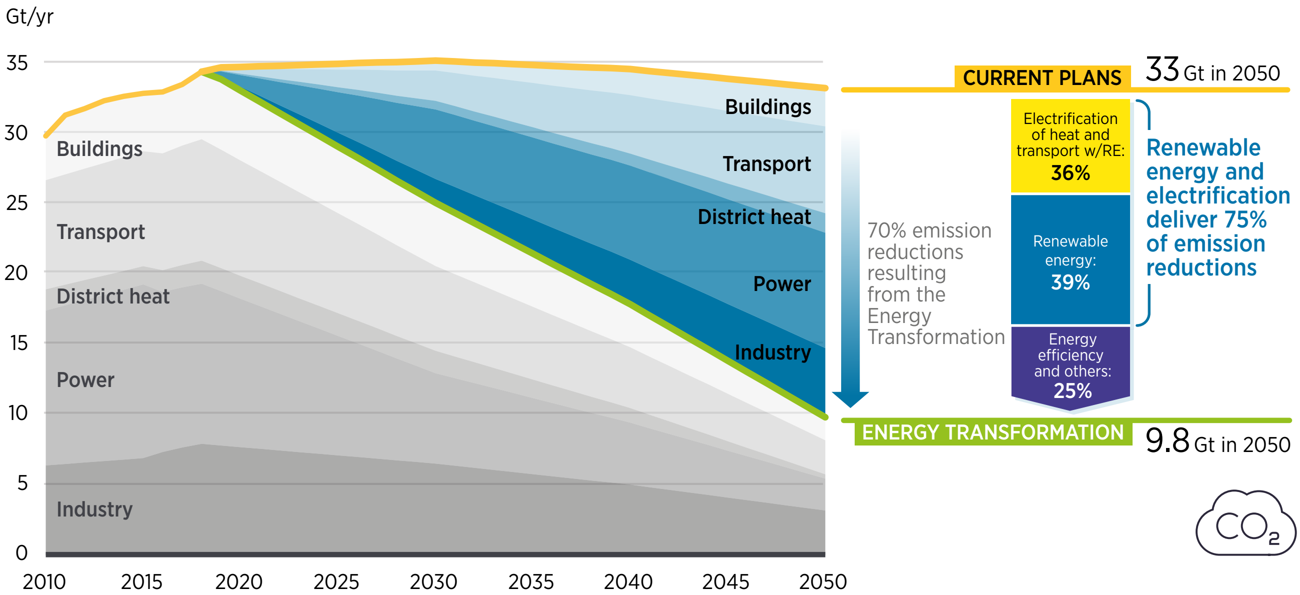
Renewable energy technologies alone are not enough to achieve massive decarbonisation. The future energy system encompasses three inter-related elements: one, renewable energy, would rely on steady improvements to energy efficiency and increased electrification of end-use sectors. The cost equation also matters, with affordable renewable power allowing faster, more viable displacement of conventional coal- and oil-burning systems.

Renewables and energy efficiency, enhanced through electrification, can achieve over nine-tenths of the cuts needed in energy-related CO_2 emissions

1 Paris Agreement, Art. 2(1)(a).

2 *Global Energy Transformation: A Roadmap to 2050* (IRENA, 2019) analyses and compares these two investment and development pathways as far as mid-century.

Annual energy-related CO_2 emissions and reductions, 2010–2050



Based on *Global Energy Transformation: A Roadmap to 2050* (IRENA, 2019).

Note: "Renewables" in the caption denotes deployment of renewable technologies in the power sector (wind, solar photovoltaic, etc.) and in direct end-use applications (solar thermal, geothermal, biomass). "Energy efficiency" denotes efficiency measures in industry, buildings and transport (e.g. improving insulation of buildings or installing more efficient appliances and equipment). "Electrification" denotes electrification of heat and transport applications, such as heat pumps and electric vehicles. Gt = gigaton; RE = renewable energy.

Practical options for global energy decarbonisation

IRENA has explored global energy development options from two main perspectives: the course set by current and planned policies; and a cleaner, climate-resilient pathway based on more ambitious uptake of renewables and associated technologies. Throughout this report the first, or **Current Plans**, provides a comparative baseline for a more ambitious **Energy Transformation**.

Global Energy Transformation: A Roadmap to 2050 (IRENA, 2019) analyses and compares these two investment and development pathways as far as mid-century.

The ongoing roadmap analysis, updated annually, involves several key steps:

- Identifying the **Current Plans** for global energy development as a baseline scenario (or Reference Case) for comparing investment options worldwide as far as 2050. This presents a scenario based on governments' current energy plans and other planned targets and policies, including climate commitments made since 2015 in Nationally Determined Contributions under the Paris Agreement;
- Assessing the **additional potential** for scaling up or optimising low-carbon technologies and approaches, including renewable energy, energy efficiency and electrification, while also considering the role of other technologies;
- Developing a realistic, practical **Energy Transformation** scenario, referred to in other publications as the REmap Case. This calls for considerably faster deployment of low-carbon technologies, based largely on renewable energy and energy efficiency, resulting in a transformation in energy use to keep the rise in global temperatures this century as low as 1.5°C compared to pre-industrial levels. The scenario focuses primarily on cutting energy-related carbon-dioxide (CO_2) emissions, which make up around two-thirds of global greenhouse gas emissions;
- **Analysis of the cost, benefits and investment needs** for low-carbon technologies worldwide to achieve the envisaged energy transformation.

For more on the global roadmap and its underlying analysis, see **www.irena.org/remap**.

Moreover, falling renewable power costs provide a crucial synergy with electric mobility and heat. Renewables-based heat and transport solutions alone could provide two-thirds of the energy emissions cuts needed to meet agreed international climate goals.

Modern, increasingly "smart" grid infrastructure allows unprecedented flexibility in energy production, distribution and use. But investments are needed to make the most of these gains.

Investment patterns must change

Despite the climate urgency, present investment patterns show a stark mismatch with the pathway to hold the 1.5°C line. Investments in low-carbon energy solutions have stalled over the past three years.

Government plans in place today call for investing at least USD 95 trillion in energy systems over the coming three decades. But those plans and related investments are not always channelled toward climate-proof systems. The investments must be redirected.

To ensure a climate-safe future, they need to flow into an energy system that prioritises renewables, efficiency and associated energy infrastructure. With a different energy investment mix and only USD 15 trillion added to the total investment amount, the global energy system could be largely climate-proof, with cost-effective renewable energy technologies underpinned by efficient use.

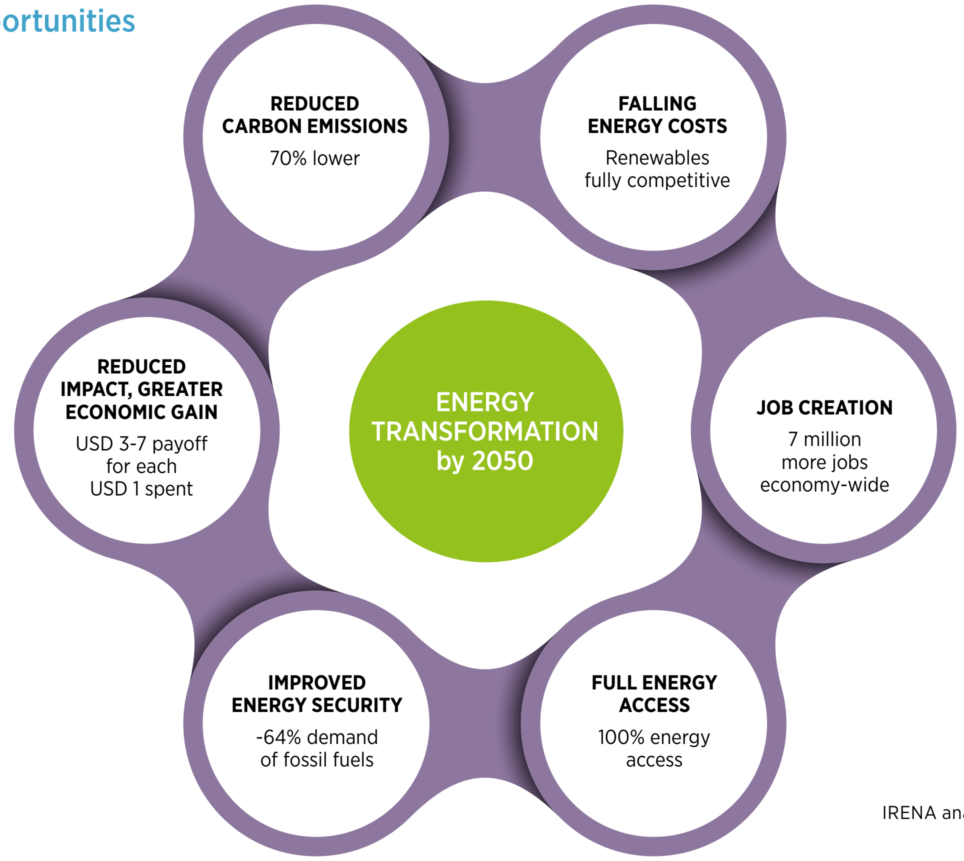
USD 3.2 trillion – representing about 2% of gross domestic product (GDP) worldwide – would have to be invested each year to achieve the low-carbon energy transformation. This is about USD 0.5 trillion more than under current plans. While cumulative global energy investments by 2050 would then be 16% higher, their overall composition would shift decisively away from fossil fuels.

Transforming the energy system means doubling planned investments in renewable power generation over the next three decades

Renewables and associated infrastructure account for nearly half of the difference, with energy efficiency and electrified transport and heat applications absorbing the rest:

- Investment to build up renewable power generation capacity needs to be twice as high as currently foreseen, reaching USD 22.5 trillion by 2050.
- Energy efficiency requires investments of USD 1.1 trillion per year, more than four times their present level.
- With solar and wind power on the rise, grid operators need new equipment to make the whole power system operate flexibly. Some of the solutions are market-based, others require investment in modern technology solutions. Quick-ramping thermal generation backups, pumped hydropower, reinforced transmission and distribution grids, digital control equipment, vastly expanded storage capacity, and demand-side management through heat pumps, electric boilers and behind-the-meter batteries are just some of the areas for power system investment.
- The transformed energy system would include more than a billion electric vehicles worldwide by 2050. Combined investments in charging infrastructure and the electrification of railways could reach USD 298 billion yearly.
- Industry and buildings could incorporate more than 300 million highly efficient heat pumps, more than ten times the number in operation today. This means investments of USD 76 billion each year.
- To deepen the system's synergies even more, nearly 19 exajoules of global energy demand could be met by renewable hydrogen – that is, hydrogen produced from renewable sources. But that means adding nearly 1 terawatt of electrolyser capacity by 2050 at an average investment cost of USD 16 billion per year worldwide.
- Investments in renewable heating, fuels and direct uses, which totalled around USD 25 billion last year (IEA, 2019), must nearly triple to USD 73 billion per year over the coming three decades.
- East Asia would account for the highest annual investments in the energy transformation until 2050, at USD 763 billion, followed by North America at USD 487 billion. Sub-Saharan Africa and Oceania would see the lowest, at some USD 105 billion and USD 34 billion per year, respectively.

Needs and opportunities



IRENA analysis.

To stay below the IPCC's recommended 1.5°C limit, the world must shift nearly USD 18.6 trillion of its cumulative energy investments until 2050 from fossil fuels to low-carbon technologies. Average annual fossil-fuel investments over the period would then fall to USD 547 billion – about half of what the fossil fuel industry invested in 2017.

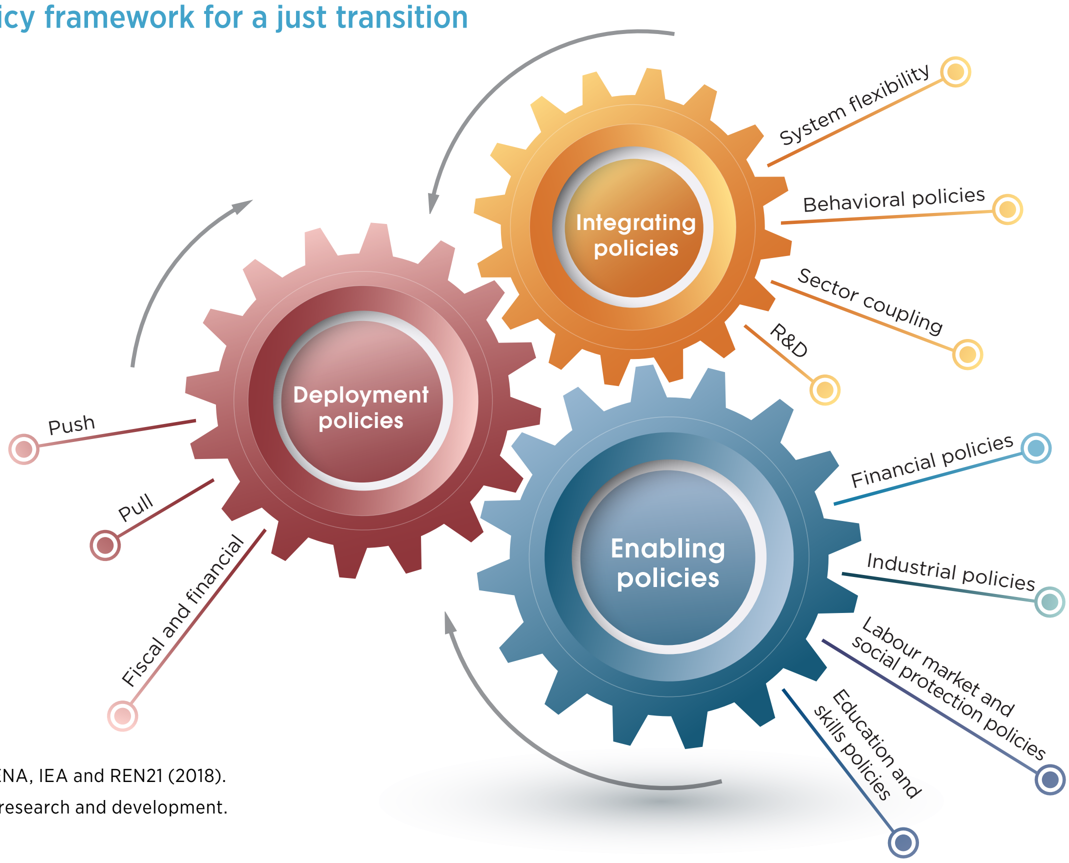
Every dollar spent can bring returns as high as seven dollars in fuel savings, avoided investments and reduced health and environmental damage

By shifting investments, the world can achieve greater gains. Fortunately, transforming the energy system turns out to be less expensive than not doing so. This is true even without factoring in the payoffs of mitigating climate change and achieving long-term sustainability. Through 2050, the amounts saved by reducing net energy subsidies and curtailing environmental health damage would exceed investments by three to seven times.

Investments in the energy transformation could create about 98 trillion in additional GDP gains by 2050 compared to current plans, IRENA's analysis shows.

Jobs in the energy sector would increase by 14% with the transformation. New jobs would outweigh job losses, even with the decline in jobs linked to fossil fuels. Renewable energy jobs would grow an estimated 64% across all technologies by 2050.

The policy framework for a just transition



Based on IRENA, IEA and REN21 (2018).
Note: R&D = research and development.

While such indicators are highly encouraging, energy investment can no longer be pursued in isolation from its broader socio-economic context. As countries turn increasingly to renewables, they will need a comprehensive policy framework for the ensuing transformation. Plans and investment strategies must be accompanied by a clear, integrated assessment of how the energy system interacts with the broader economy for a just and timely transition.

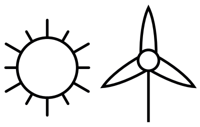
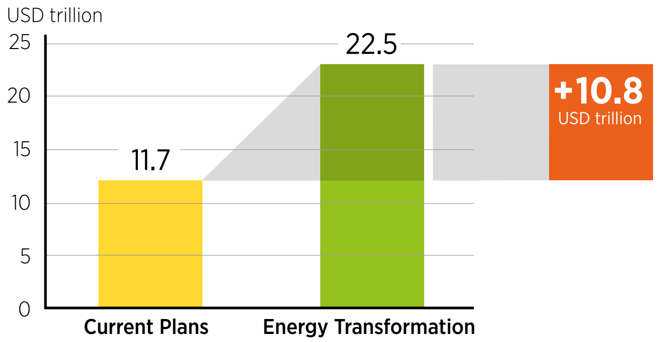
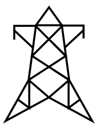
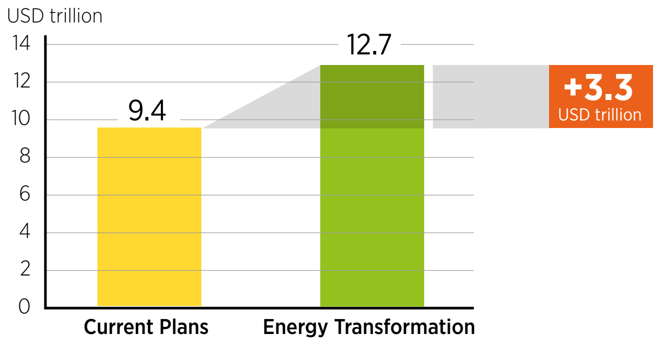
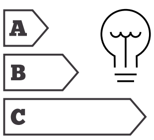
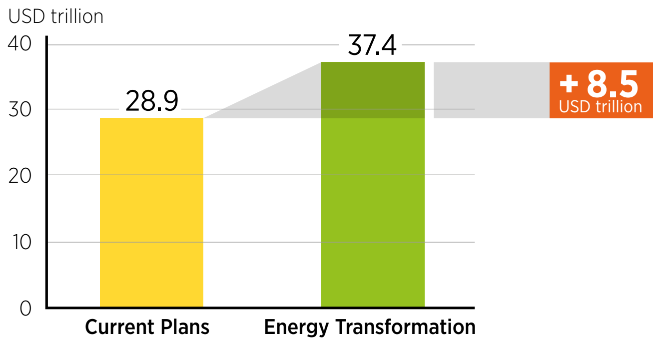
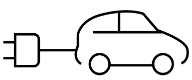
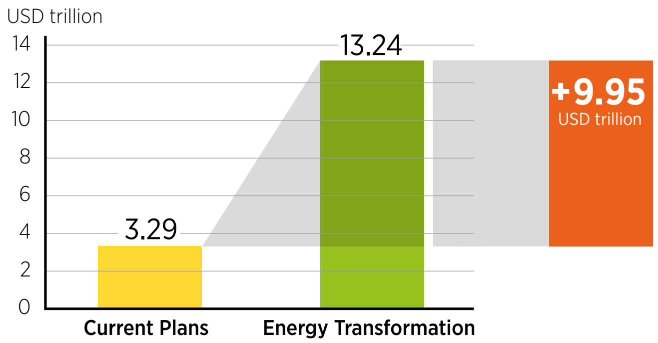
Countries seeking to stimulate economic growth can simultaneously optimise the effects of renewables and minimise the cost of economic and employment adjustments. Far-sighted energy investment policies, when harnessed to savvy socio-economic policies, can help to ensure a just transformation that leaves no one behind.

Through informed investments starting today, countries and communities can scale up renewables cost-effectively, make steady gains in energy efficiency and achieve extraordinary synergies through electrification. The transformed energy system by 2050 should be able to meet the world's needs for the second half of the century.

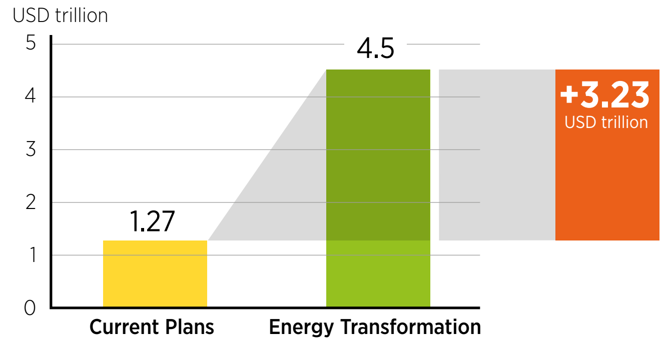
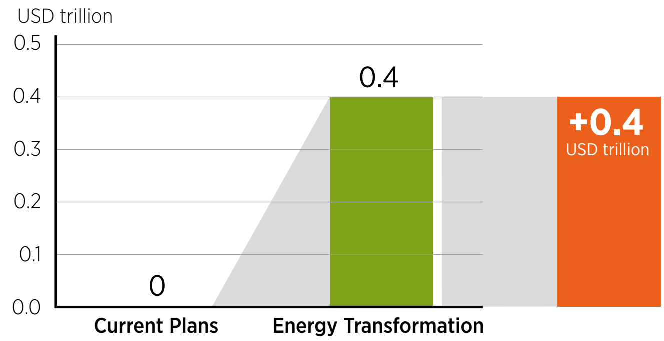
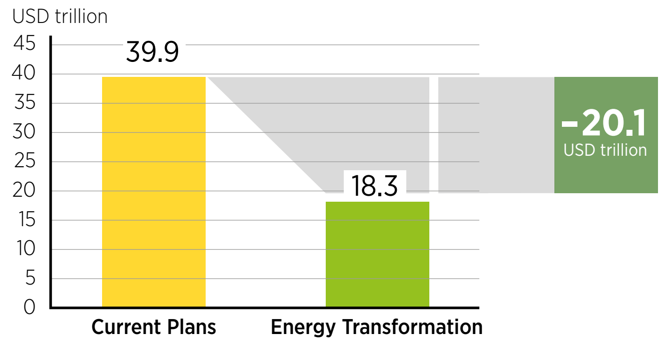
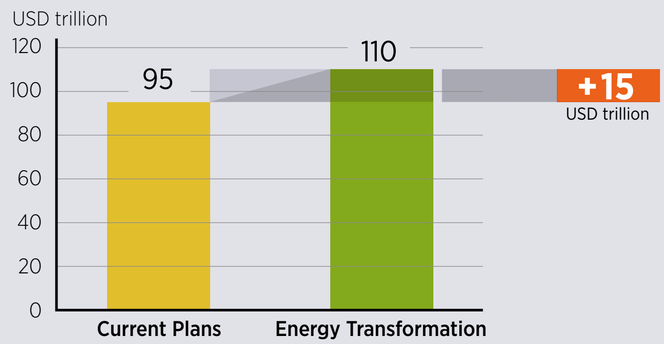
A transformed energy system would help to fulfil the Sustainable Development Goals and stimulate benefits across multiple sectors

If socio-economic needs and aspirations are fulfilled in parallel, such changes are likely to gain acceptance and endure even beyond today's urgent shifts to mitigate climate change. Only then will the global energy transformation be truly sustainable.

Investment needs through 2050 by technology: **Current Plans** vs. **Energy Transformation**

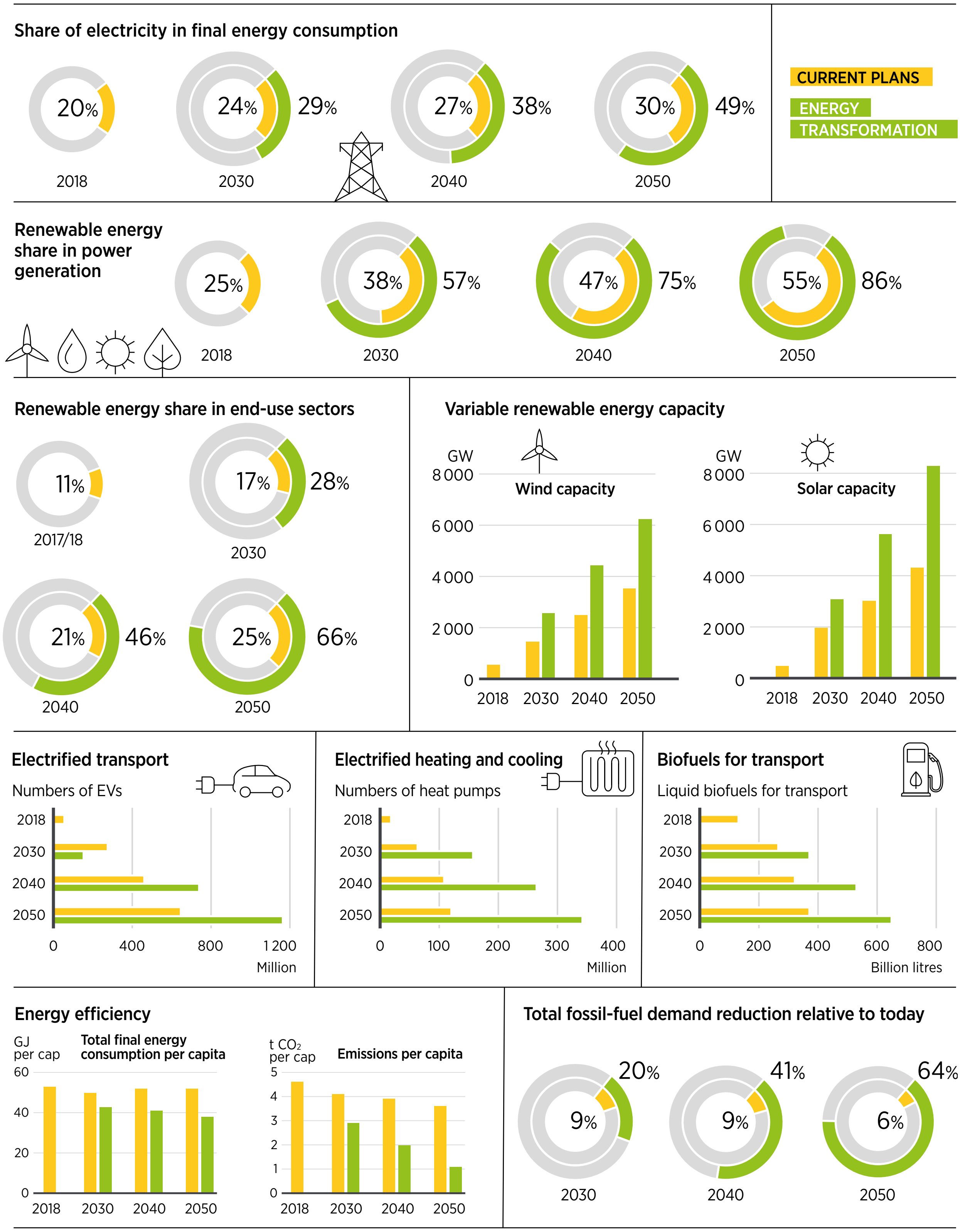
Category	Cumulative investments between 2016 and 2050	Difference	Comments
Renewables-based power generation capacity (excl. electrification) 		**+10.8** USD trillion	• Chiefly, construction of generation capacity fuelled by wind and solar PV
Power grids and flexibility 		**+3.3** USD trillion	• 80% for extension and reinforcement of transmission and distribution networks • Balance for smart meters, energy storage (pumped hydro, battery storage), and retrofitted or new generation capacity to ensure adequate reserve capacity
Energy efficiency in end-use sectors (excluding electrification) 		**+ 8.5** USD trillion	• 50% for building renovations and construction of new efficient buildings • Balance for improvements in transport and industry
Electrification of end-use sectors 		**+9.95** USD trillion	• 80% for charging infrastructure for electric vehicles and electrification of railways • Balance for heat pumps in buildings (12%) and industry (8%) • Fraction of 1% for 1 TW of electrolyser capacity to produce 19 exajoules of hydrogen

Note: EJ = exajoule; PEM = polymer electrolyte membrane; PV = photovoltaic; TW = terawatt.

Category	Cumulative investments between 2016 and 2050	Difference	Comments
Direct applications of renewables			• 42% for biofuel production to decarbonise the transport sector, especially aviation and shipping • 40% for solar thermal deployments in industry (primarily) and buildings • 11% for modern biomass; balance for geothermal deployment
Other			• Includes carbon capture and storage in industry and efficiency improvements in materials
Non-renewables			• More than 90% of change due to lower spending on fossil fuels (upstream supply, generation capacity) • Balance reflects avoided investments in nuclear power generation capacity
Total difference			**Overall incremental investment needs are USD 15 trillion.**

IRENA analysis.

Key indicators for two scenarios: Current Plans vs. Energy Transformation



IRENA analysis.

Note: Total wind capacity includes both onshore and offshore wind; total solar photovoltaic capacity includes both utility and small scale.
EVs = electric vehicles; GJ = gigajoule; GW = gigawatt.

"The market has given the signal with cost competitive technologies. Policy makers must now put the enabling frameworks in place to accelerate climate-proof investments. We must create a low-carbon energy system to hold the line on rising global temperatures. It's possible."

Francesco La Camera

Director-General
International Renewable Energy Agency

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that serves as the principal platform for 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. 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.

This document summarises IRENA (2019), ***Transforming the energy system – and holding the line on the rise of global temperatures***, International Renewable Energy Agency, Abu Dhabi (ISBN 978-92-9260-149-2).

Report and summary available for download: **www.irena.org/publications**

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

TRANSFORMING THE ENERGY SYSTEM

KEY FINDINGS AND NUMBERS

www.irena.org