IRENA
International Renewable Energy Agency

RENEWABLE ENERGY: A KEY CLIMATE SOLUTION

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» **Energy decarbonisation is vital to keep the rise in global temperatures well below 2°C, in line with the aims of the Paris Agreement. This requires raising the share of renewables to 65% of the world's primary energy supply by 2050, up from 15% today**

The year 2016 was the world's hottest on record, surpassing 2015 and marking the third consecutive year of record average temperatures. In fact, of the 17 hottest years on record, 16 have occurred in the 21st century (NOAA, 2016). As it stands, the world is on track to massively miss the goals set forth in the Paris Agreement,[1] with nearly 1°C of global average temperature rise already witnessed since the pre-industrial era (WMO, 2016). To stay within the agreed Paris Agreement boundaries, the world can only afford 0.6°C to 1.1°C of additional average warming (NOAA, 2016). Current country pledges, or nationally determined contributions (NDCs), could initiate an emission decline in the coming years, but they are not sufficient to reach climate goals. Efforts must be strengthened.

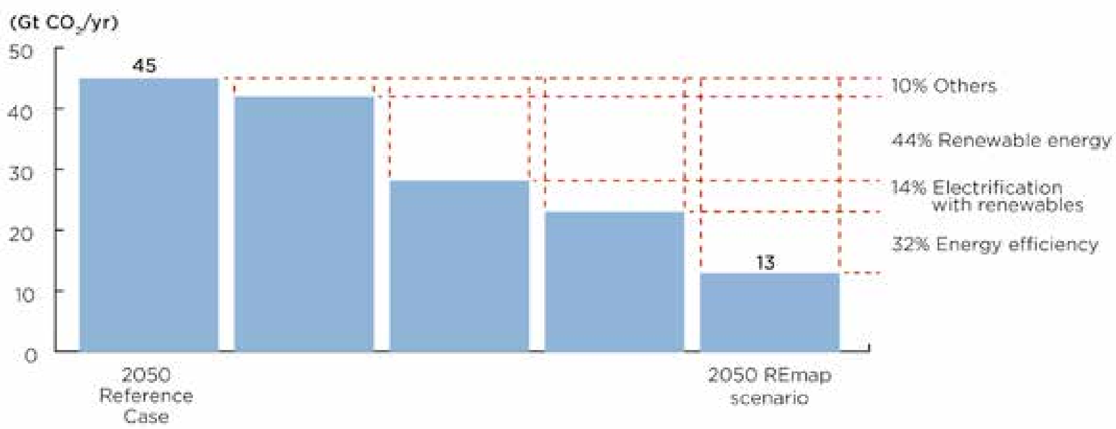
Around two-thirds of GHG emissions stem from energy production and use, which puts the energy sector at the core of efforts to combat climate change. The largest CO_2-emitting sectors are electricity generation and industry, together responsible for about 65% of all energy-related CO_2 emissions today. The remaining 35% comes from transport, buildings and district heating (IRENA, 2017c).

[1] *To limit global temperature increase to well below 2 degrees Celsius (2°C) above preindustrial levels.*

The energy sector needs a total overhaul, with a transformation from fossil-based to zero-carbon energy production by the second half of this century. Today, 84% of energy use comes from fossil fuels, with 16% derived from renewables (IRENA, 2017c). Analysis by the International Renewable Energy Agency (IRENA) shows how, through accelerated uptake, 65% of energy use could come from renewables by 2050. This would be enough for countries to meet the Paris Agreement climate goals. Renewable energy currently represents about 25% of global electricity generation, with the rest generated by fossil fuels, according to IRENA's global energy roadmap, known as "REmap". Around 80% of all electricity in 2050 could be generated by renewable energy (IRENA, 2017c).

The transformation to a sustainable energy system with high shares of renewables would meet climate goals and pay for itself. It would lead to USD trillions in economic growth between now and 2050, and the health, environmental and climate benefits would save up to six times more than the additional costs associated with reconfiguring the energy sector, all while creating millions of jobs in the process (IRENA, 2017c).

Figure 1: CO_2 emissions reduction potential from all sectors under current plans and policies vs. accelerated uptake of renewables in 2050



Notes: Gt = gigatonnes; yr = year. CO_2 emissions include energy-related emissions (fossil fuel, waste, gas flaring) and process emissions from industry. If only fossil fuel emissions were displayed in this figure, CO_2 emissions would start from 32 Gt in 2015 and would reach 40.5 Gt and 9.5 Gt per year in 2050 in the Reference Case and REmap, respectively. The Reference Case (also called the baseline or business-as-usual), is the most likely case based on current and planned policies and expected market developments. It reflects NDCs if they are already an integral part of a country's energy plan, which is the case for around 60% of total global primary energy supply. The 2050 REmap scenario is a low-carbon technology pathway that goes beyond the Reference Case for an energy transition in line with the aims of the Paris Agreement. [2]

Accelerated deployment of renewable energy and energy efficiency measures form the key elements of the energy transition. Recent analysis shows that the world can meet around 90% of the decarbonisation needed to stay within the Paris Agreement boundaries through accelerated deployment of renewable energy and energy efficiency, with the remaining 10% to be met by other low-carbon solutions (IRENA, 2017c).

[2] Technologies covered under REmap include: renewable energy technologies for energy and as feedstock for production of chemicals and polymers; energy efficiency measures and widespread electrification that also improves efficiency; carbon capture and storage for industry; material efficiency technologies such as recycling.

Energy-related CO_2 emissions from all sectors totalled 36 Gt in 2015. These need to fall to 13 Gt in 2050 to achieve the REmap scenario, a reduction of 70% compared to the Reference Case, under which emissions are estimated to reach 45 Gt in 2050. Renewable energy could provide 44% of these reductions (20 Gt per year in 2050), as illustrated in Figure 1. To enable this dramatic emissions reduction, the share of renewable energy must rise from around 16% of the primary energy supply in 2015 to around 65% in 2050.

Renewable technologies could generate more than 80% of all electricity by 2050, with the remaining 20% generated by natural gas and nuclear. By 2050, emissions from electricity generation would plummet by 85% in the REmap scenario, despite the fact that electricity generation is expected to increase by nearly 80% (IRENA, 2017c).[3] Coal-based power generation would cease altogether. Besides increasing shares of renewables, the decrease in power sector emissions is also due to energy efficiency measures taken in industry and buildings to reduce electricity use for heating and cooling. Emissions in the buildings sector would decrease by about 70% by 2050. Transport emissions would be halved, while industry would become the largest emitter of CO_2.

» **Two-thirds of global greenhouse gas (GHG) emissions stem from the production and use of energy. This puts the energy sector at the core of efforts to combat climate change**

The current electricity system evolved over many decades with fossil fuels at the centre. New power generation technologies require a new electricity system that is flexible and allows the integration of variable sources, such as solar and wind energy. Electricity generation from these variable renewables fluctuates according to resource availability and may not coincide with demand. This can cause difficulties in matching supply and demand, requiring flexibility to deal with variability. A range of flexibility options exist and will be needed as the role of variable renewables grows.

Under REmap, the share of wind and solar in power generation would increase to 52% by 2050, requiring a range of flexibility options to ensure grid stability, including time-of-use electricity pricing, adaptation of market designs and new business models. Additional interconnectors, flexible fossil fuel generation and demand-side response can also increase flexibility, thus enabling higher shares of variable renewable energy. An often-discussed flexibility option is storage, which comes in many forms. Today, around 4 700 gigawatt hours (GWh) of electricity storage exists, 96% of which comes from pumped hydro (IRENA, 2017b). Under REmap, 11 900-15 300 GWh of electricity storage is expected by 2030, with only 51% from pumped hydro.[4] With an average battery pack of 50 kilowatt hours (kWh) per vehicle, electric vehicles alone could provide about 8 000 GWh of battery storage by 2030.

[3] *Electricity generation is anticipated to increase to 43 000 terawatt hours (TWh) per year by 2050, up from 24 100 TWh in 2015.*

[4] *Reference Case estimates 6 600-7 800 GWh of storage by 2030.*

This would help to accommodate higher shares of wind and solar through flexible charging, when there is surplus generation and electricity prices are low. To achieve the conditions needed for electric vehicles to provide significant benefits to electric power systems by 2030, IRENA estimates that 160 million electric vehicles will be needed worldwide by then (IRENA, 2017a).

While the power sector holds great potential for renewables, electricity accounts only for around 20% of final energy use today. As a result, IRENA analysis points to an essential role for renewable energy technology deployment in end-use sectors. Such a role is especially important because together they account for approximately 80% of all global energy demand today. In the end-use sectors, REmap shows that the renewable energy share can grow to 78% in buildings, 38% in industry and 53% in transport by 2050 (IRENA, 2017c).[5] In transport, the number of electric vehicles needs to grow and new solutions will need to be developed for freight and aviation. New buildings will have to meet the highest efficiency standards, while existing buildings must be rapidly renovated. Buildings and city designs should facilitate renewable energy integration.

The energy transition can fuel economic growth and create new employment opportunities. The renewable energy sector alone could support around 26 million jobs in 2050,[6] with new job creation in renewables and energy efficiency more than offsetting job losses in the conventional energy sector (IRENA, 2017d). In fact, net energy sector employment in the REmap scenario (including in energy efficiency) would be higher by 6 million additional workers in 2050 compared to the Reference Case (IRENA, 2017c). Furthermore, global GDP would be 0.8% higher in 2050 compared to the Reference Case, a cumulative gain of USD 19 trillion from 2015 to 2050.[7] This overall improvement in GDP would induce additional job creation in other economic sectors as well.

The energy transition is technically and economically feasible. Drastic cost reductions have been instrumental in the unprecedented scale-up of renewable energy we are currently witnessing. Among the most transformative developments of the current decade has been the dramatic and sustained improvement in the cost-competitiveness of renewable electricity generation technologies. Technology learning and the opening up of new markets in countries with high resource potential continue to make renewables increasingly attractive.

» Nine-tenths of the necessary emissions reduction can be achieved through accelerated uptake of renewables and energy efficiency

Since the end of 2009, solar photovoltaic (PV) module prices have fallen by around 80% and the price of wind turbines by 30-40% (IRENA, 2016). Biomass for power, hydropower, geothermal and onshore wind technologies can all now provide electricity that is competitively priced compared to fossil fuel-fired electricity generation.

[5] Including the use of electricity and district heat sourced from renewables.

[6] Up from 9.8 million today.

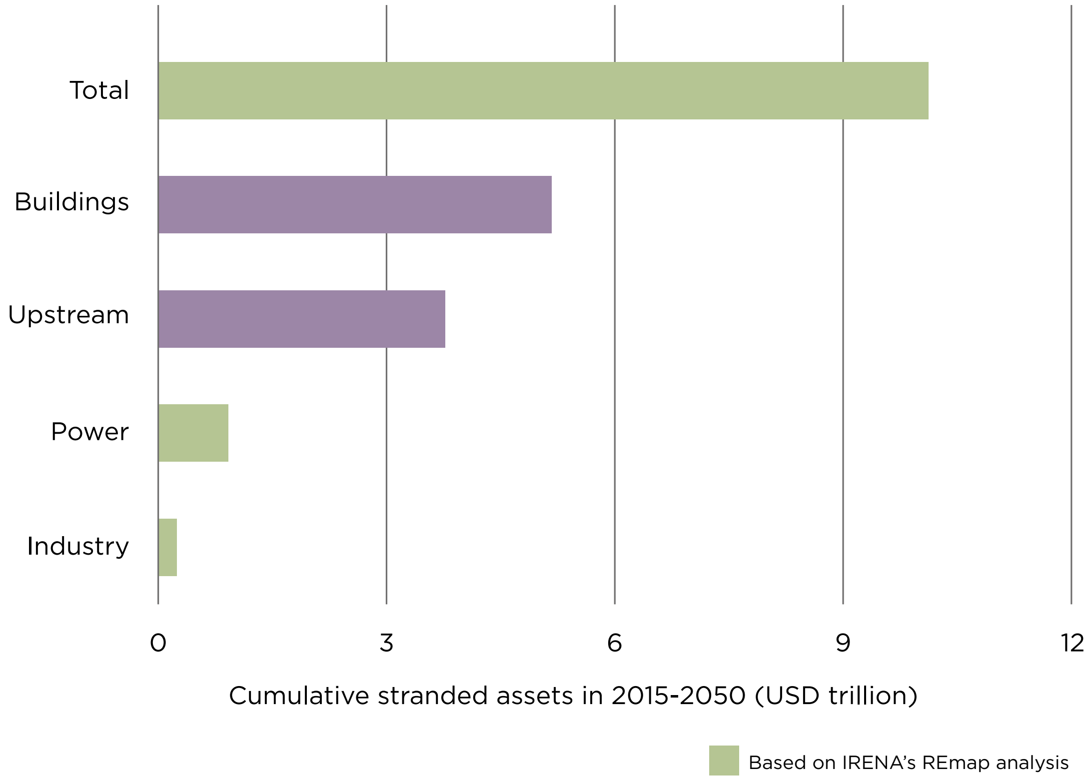
[7] The main driver of the global economic surge is the investment boost from the high capital requirements of renewables and energy efficiency. Upfront investment constitutes, for both, a larger share of total lifetime cost than it does for fossil fuel-based technologies.

The levelised cost of electricity from solar PV fell by more than 68% between 2010 and 2016, meaning it is also increasingly competitive with conventional power generation technologies at utility scale. Onshore wind has witnessed an 18% decline in its levelised cost of electricity since 2010, while offshore wind has seen a 9% decline over the same period. IRENA analysis predicts further substantial cost reductions in the coming decade (IRENA, 2016).

Cost reductions have opened the door to an energy transition that makes economic sense. Early action, however, is essential to capitalise on the economic opportunities available while avoiding the future costs of stranded assets. Delayed policy action would result in significant asset stranding in comparison to an energy transition where accelerated renewable energy and energy efficiency deployment begins today.

Early action is critical to reduce the stranding of economically valuable assets.[8] Delaying decarbonisation of the energy sector would require higher levels of investment to achieve the same objectives and would double stranded assets. In the REmap scenario, cumulative stranded assets from 2015 to 2050 would total USD 10 trillion, coming largely from buildings that need to be replaced because of low energy efficiency, and upstream energy infrastructure and assets (gas, oil and coal that must stay in the ground). This would double to USD 20 trillion to reach the same emissions objective by 2050 if effective mitigation policy was delayed by only one decade (IRENA, 2017e). To put this into context, USD 20 trillion is approximately 4% of global wealth in 2015 terms.[9]

Figure 2 Buildings and upstream fossil reserves and infrastructure will form the lion's share of assets stranded in the energy transformation



[8] Assets that have become obsolete or non-performing, but must be recorded on the balance sheet as a loss of profit.
[9] Estimated at USD 250 trillion (Credit Suisse, 2015).

The buildings sector will be the most affected, experiencing the largest amount of asset stranding on a global scale, at approximately USD 5 trillion under REmap. Upstream energy is the second-largest sector by size of stranded assets, at approximately USD 4 trillion under REmap. In order to avoid stranded assets by accelerating the deployment of renewables and energy efficiency, as envisaged under REmap, sectors will require appropriately low-cost and long-duration financing to realise the required investments and retrofits. Without this finance, delayed action is more likely to prevail, whether there are strong macroeconomic incentives to make such investments or not (IRENA, 2017e).

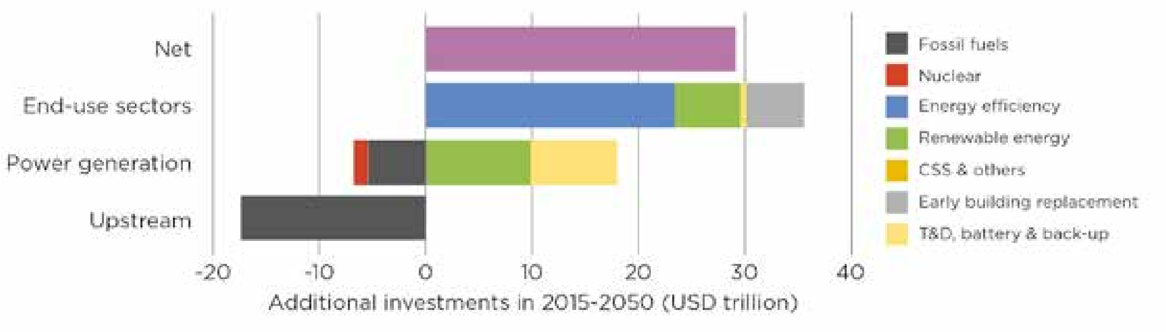
» **The resulting energy transformation would boost global gross domestic product (GDP) by 0.8% in 2050 – a cumulative gain of USD 19 trillion in the period 2015-2050**

The benefits of the energy transition for human health can also be expressed in monetary terms. Reducing human health impacts and CO_2 emissions from the combustion of fossil fuels would save between two and six times more than the costs of decarbonisation, which are estimated at USD 1.8 trillion per year in 2050 (IRENA, 2017c). Reduced outdoor air pollution accounts for two-thirds of the benefits. These numbers demonstrate that investment in decarbonisation would pay for itself purely from the human health benefits, leaving aside the further benefits of reduced climate-related impacts. Welfare gains to society could also come from increased energy access, helping to generate sustainable livelihoods and better quality of life in rural areas.

Realising the energy transition requires increased innovation and investment, along with new business models and market designs. Innovations must be shared, perfected and widely replicated by others. International collaboration can accelerate innovation through increased research and development (R&D) and investment in clean energy. In particular, greater attention needs to be paid to end-use sectors (buildings, industry and transport), where important opportunities exist.

Innovation and the accelerated deployment of low-cost renewable energy, energy efficiency, widespread electrification and information and communications technologies are essential to accelerating this energy transition. Investments made in power generation equipment and related infrastructure today, as well as over the coming decades, are going to have to bring deep emissions cuts by 2050. This is especially true for long-lived investments, such as in buildings, industrial production facilities, power plants, transport infrastructure and others. Otherwise, the risks of continued carbon lock-in will be high. Transport and industry will be the two most

Figure 3: Additional investment needs for the energy transition compared to current plans and policies



challenging sectors, with substantial investment and innovation required.

Notes: These components add up to additional investment of USD 54 trillion. However, there are also avoided investments in both fossil fuel and nuclear electricity generation capacity, as well as in the upstream sector (exploration and production steps in the fossil fuel supply chain). Those avoided investments add up to USD 25 trillion, resulting in net investment of USD 29 trillion. T&D = transmission and distribution.

Net additional investment needs for the energy transition are estimated at around USD 29 trillion between 2015 and 2050, on average about USD 830 billion per year. While investment in power generation and upstream fuel supply remains at the same level, additional investment is concentrated in the end-use sectors. Additional R&D efforts in renewables will bring down further the cost of zero-carbon technologies and decrease the overall cost of decarbonisation. Unfortunately, R&D investment in renewable energy technologies has not grown in the last seven years. Moreover, most R&D investment in renewables continues to focus on power sector technologies (such as solar and wind) rather than on technologies for end-use sectors (such as biofuels and biomass), where they are urgently needed. To enable the energy transition, higher R&D investment is needed to find technology solutions for sectors where more innovation is required, such as end use. While overall energy investment requirements are substantial, net positive impacts go beyond the energy sector, from human health and wellbeing, to employment growth in related industries and overall economic growth (IRENA, 2017c).

REFERENCES

» Credit Suisse (2015), Global Wealth Report 2015, Credit Suisse, Zurich, www.credit-suisse.com/ch/en/about-us/research/research-institute/publications.html (accessed 15 September 2017).

» IRENA (International Renewable Energy Agency) (2017a), *Electric Vehicles: Technology Brief*, IRENA Publications, Abu Dhabi, www.irena.org/DocumentDownloads/Publications/IRENA_Electric_Vehicles_2017.pdf (accessed 10 September 2017).

» IRENA (2017b), *Electricity Storage and Renewables: Costs and Markets to 2030*, IRENA Publications, Abu Dhabi, www.irena.org/DocumentDownloads/Publications/IRENA_Electricity_Storage_Costs_2017.pdf (accessed 10 September 2017).

» IRENA (2017c), [Executive Summary/Chapter [3/4]] of *Perspectives for the Energy Transition: Investment Needs for a Low-Carbon Energy System*, IRENA Publications, Abu Dhabi, www.irena.org/DocumentDownloads/Publications/Perspectives_for_the_Energy_Transition_2017.pdf (accessed 10 September 2017).

» IRENA (2017d), *Renewable Energy and Jobs: Annual Review 2017*, IRENA Publications, Abu Dhabi, www.irena.org/DocumentDownloads/Publications/IRENA_RE_Jobs_Annual_Review_2017.pdf (accessed 10 September 2017).

» IRENA (2017e), *Stranded Assets and Renewables: How the Energy Transition Affects the Value of Energy Reserves, Buildings and Capital Stock*, IRENA Publications, Abu Dhabi, www.irena.org/DocumentDownloads/Publications/IRENA_REmap_Stranded_assets_and_renewables_2017.pdf (accessed 10 September 2017).

» IRENA (2016), *The Power to Change: Solar and Wind Cost Reduction Potential to 2025*, IRENA Publications, Abu Dhabi, www.irena.org/DocumentDownloads/Publications/IRENA_Power_to_Change_2016.pdf (accessed 10 September 2017).

» NOAA (National Oceanic and Atmospheric Administration) (2016), Reporting on the State of the Climate in 2016, NOAA, Asheville, NC, www.ncei.noaa.gov/news/reporting-state-climate-2016 (accessed 5 September 2017).

» WMO (World Meteorological Organization) (2016), WMO Provisional Statement on the Status of the Global Climate in 2016, WMO, Geneva, https://ane4bf-datap1.s3-eu-west-1.amazonaws.com/wmocms/s3fs-public/2016_WMO_Statement_on_the_Status_of_the_Global_Climate-14-11-16-ver2.pdf?ZmIaubFZknHEGDBpyxTBpTcrNotiDpDo (accessed 5 September 2017).

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