GLOBAL ENERGY TRANSFORMATION
A ROADMAP TO 2050
KEY FINDINGS

The transformation of the global energy system needs to accelerate substantially to meet the objectives of the Paris Agreement

- **Energy-related carbon dioxide (CO_2) emissions have increased 1.3% annually, on average, over the last five years.** The gap between observed emissions and the reductions that are needed to meet internationally agreed climate objectives is widening.
- In the last few years the **energy sector has started changing in promising ways.** Renewable power technologies are dominating the global market for new generation capacity, the electrification of transport is showing early signs of disruptive acceleration, and key enabling technologies such as batteries are experiencing rapid reductions in costs.
- Despite these positive developments, **deployment of renewable solutions** in energy consuming sectors, particularly buildings and industry, **is still well below the levels needed, and progress in energy efficiency is lagging.**
- **Structural change also plays a critical role in meeting global climate targets and enabling the high level of energy efficiency that is required.** Changes include modal shifts in transport, as well as efforts in industry such as the circular economy and industry relocation to areas where renewable energy is plentiful.
- **Investment in infrastructure needs to be focused on low-carbon, sustainable and long-term solutions that embrace electrification and decentralisation.** Investment is needed in smart energy systems, power grids, recharging infrastructure, storage, hydrogen, and district heating and cooling in cities.
- **The share of renewable energy in primary energy supply would grow from less than one-sixth today to nearly two-thirds in 2050 in the REmap Case.**
- Energy efficiency must be scaled up substantially; **the rate of energy intensity** improvement **would increase to 3.2% per year,** up from recent historical averages of around 2.0% per year.
- **Electricity would progressively become the central energy carrier,** growing from a 20% share of final consumption to an almost 50% share by 2050, and renewable power would be able to provide the bulk of global power demand (86%) economically. As a result, gross electricity consumption would more than double.

- The transition to increasingly **electrified forms of transport and heat,** when combined with the increases in renewable power generation, **can deliver around 60% of the energy-related CO2 emissions reductions needed** to set the world on a pathway to meeting the Paris Agreement. When these measures are combined with direct use of renewable energy, the share of the emissions reductions from these combined sources reaches 75% of the total required.
- However, emissions will still need to be reduced further, and **bioenergy will play a role in sectors that are hard to electrify, such as shipping, aviation and certain industrial processes.** Biofuel consumption must be scaled up sustainably to meet this demand. Efforts also are needed to reduce non-CO2 greenhouse gas emissions and non-energy use emissions (such as by using waste-to-energy, bioenergy and hydrogen feedstocks); to reduce industrial process emissions; and to reduce fugitive emissions in the coal, oil and gas industries. Efforts are needed outside of the energy sector to reduce greenhouse gas emissions in agriculture and forestry.

The global energy transformation makes economic sense

- According to current and planned policies, the global energy sector will see cumulative investments of USD 95 trillion over the period until 2050. **The transition towards a decarbonised global energy system will require scaling up investments in the energy sector by a further 16% (an additional USD 15 trillion by 2050). In total USD 110 trillion would be invested in the energy system,** representing on average 2% of global gross domestic product (GDP) per year over the period.
- **The types of investments will change, with a shift in the composition of investments away from the fossil fuel sector towards energy efficiency, renewables and enabling infrastructure.** Crucially, the additional investments that are required are 40% lower than was estimated in the previous analysis (IRENA, 2018a), due largely to rapidly falling renewable power costs and the potential for further cost reductions, as well as the emergence of electrification solutions that are getting cheaper and more efficient.
- **The additional investments needs are, however, front loaded.** While additional investments are required in the first period of the transition (to 2030), as the year 2050 approaches, technology progress, better understanding of the power system and increasing electrification of end-use applications result in more optimistic, lower investment estimates.
- Energy sector subsidies totalled at least USD 605 billion in 2015 and are projected to increase to over USD 850 billion annually by 2050 in the Reference Case. In contrast the REmap Case would result in a decline in subsidies to USD 470 billion in 2050. The types of subsidies would change drastically, moving away from fossil fuels and renewable power technologies to technologies needed to decarbonise the transport and industry sectors. **The REmap Case would result in a cumulative reduction in fossil fuel subsidies of USD 15 trillion below**

what would have occurred in the Reference Case by 2050, and in a net reduction of USD 10 trillion when including the increased support needed for renewables in the REmap Case.

- **In total the savings from avoided subsidies and reduced environmental and health damages are about three to seven times larger than the additional energy system costs.** In monetary terms, total savings resulting from the REmap Case could amount to between USD 65 trillion and USD 160 trillion over the period to 2050. **Viewed differently, for every USD 1 spent, the payoff would be between USD 3 and USD 7.**

The socio-economic footprint of the energy transformation measures the net result of the multiple interactions between the energy transformation and the socio-economic system

- **The energy transition cannot be considered in isolation from the broader socio-economic system.** For the transition to renewable sources and technologies to succeed, policies must be based on a more integrated assessment of the interactions between the evolving energy sector and the wider economy.
- Changes in the energy system have impacts throughout the economy. Globally, **the transition promises GDP, job creation and human welfare benefits.** By year 2050, the REmap energy transition brings about relative improvements of GDP and whole-economy employment of 2.5% and 0.2% respectively. In cumulative terms from 2019 to 2050 the GDP gains of the REmap Case over the Reference Case add up to 99 USD trillion. **The global welfare indicator measuring the improvement of REmap over the Reference Case reaches in 2050 a value of 17%.**
- As is the case with any economic transition, some regions and countries will fare better than others. **Regions with high dependence on fossil fuel exports and/or weak, non-diversified domestic supply chains face an adjustment challenge.** Failure to address distributional aspects can also introduce significant transition barriers.

The socio-economic footprint of the energy transformation is shaped in significant ways by the policy framework

- **Besides the energy transformation characteristics (energy balances and investments), many other policy inputs can have an important impact on the socio-economic footprint.** Carbon taxes and fossil fuel subsidies are among these policy inputs.
- **Carbon taxes** on the level required for a 2°C global warming climate goal can have a **significant socio-economic impact**, which will be positive or negative depending on the policy framework that accompanies the deployment of carbon taxes. Special care needs to be taken concerning the distributional impacts of carbon taxes, both within and between countries, with policy frameworks aiming at reducing inequalities becoming important energy transformation enablers.

A holistic employment policy is required for the energy transformation to have positive contributions in this welfare dimension

- Across the world economy, overall employment increases between 2018 and 2050 for both the Reference and REmap cases, with CAGRi of 0.45% and 0.46% respectively. **The REmap Case produces more jobs than the Reference Case**, with relative gains peaking around 2035 and remaining around 0.2% until 2050.
- The employment impact of the REmap transition in the energy sector is very positive, with **new jobs associated with the transition (i.e., renewable generation, energy efficiency and energy flexibility) significantly outweighing the jobs lost in the fossil fuel sector.**
- The geographic and temporal distribution of energy sector jobs gained and lost is unlikely to be well-aligned, while jobs in other sectors of the economy could decline.

Climate damages will have a significant impact on the socio-economic footprint

- It should be noted that the main socio-economic results presented (GDP and jobs) do not capture the impacts of climate change, the very driver of the energy transition on the economy.
- Climate damage impacts increase with time as the climate system responds to the cumulative GHG emissions. Macroeconomic performance under both the Reference and REmap cases is significantly impacted by climate damages, leading to a global GDP reduction of 15.5% and 13.2%, respectively, by 2050.

Improving the transition's socio-economic footprint

- Modifying the socio-economic structure incorporating fair and just transition elements improves the socio-economic footprint and prevents barriers that could ultimately halt the transition.
- The socio-economic footprint can be substantially improved through greater ambition in all countries and regions. This would reap the benefit of minimizing climate damages, while the associated investment stimulus can produce important socio-economic benefits.
- Negative impacts on low-income countries must be addressed for the transition to be successful.