

ROADMAP FOR A RENEWABLE ENERGY FUTURE

EXECUTIVE SUMMARY



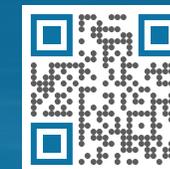
About IRENA

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.

The full version of this report can be downloaded through www.irena.org/publications. All REmap related publications and other supporting material are available at www.irena.org/remap

For further information or to provide feedback, please contact the REmap team at remap@irena.org or secretariat@irena.org

The level and scope of REmap and IRENA's ability to engage with countries benefited greatly from the voluntary contributions provided by Germany and Japan.



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THE WORLD CAN REACH ITS SUSTAINABLE ENERGY AND CLIMATE CHANGE OBJECTIVES BY DOUBLING THE SHARE OF RENEWABLE ENERGY BY 2030

The 2015 United Nations Climate Conference in Paris was a watershed moment for renewable energy. It reinforced what advocates have long argued: that a rapid and global transition to renewable energy technologies offers a realistic means to achieve sustainable development and avoid catastrophic climate change. Now that renewable energy is recognised as central to achieving climate and sustainability objectives, the challenge facing governments has shifted: from identifying what needs to be done, to how best to achieve it.

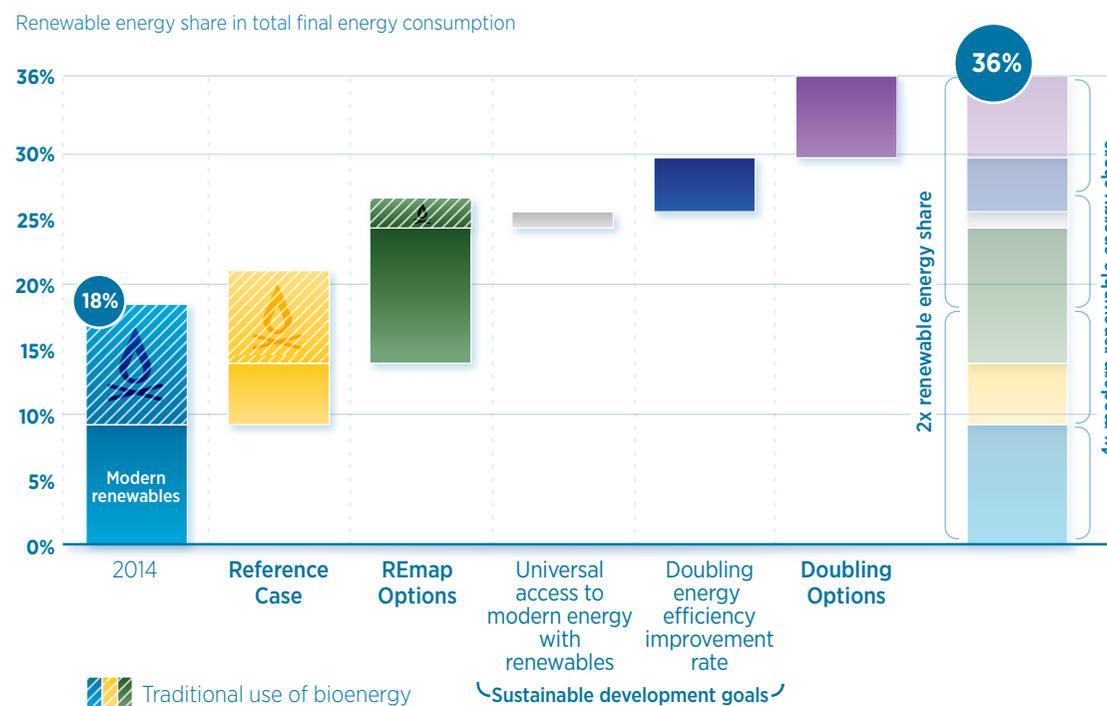
REmap offers a global plan to double the share of renewables in the world's energy mix by 2030. This edition updates some of the key findings of its 2014 predecessor. Yet the core message remains consistent: doubling the share of renewables is possible, cost-effective and economically beneficial, even as global energy demand grows. Doing so is one of the main ways countries can meet their international climate-change targets, as well as the Sustainable Development Goals.

The drop in oil prices over the past 18 months has not affected the prospects for renewables. The year 2015 saw record highs in renewable energy investments, with solar photovoltaics (PV) and wind capacity additions at all-time highs. Renewable energy technologies are today among the most cost-competitive options for power generation.

The continued growth of renewables is driven by falling costs. Prices for equipment and installation and project finance all continue to decline. The banking sector has recognised the reliability and

low operational costs of renewables and has responded by offering interest rates at record lows. Investors appreciate that wind and solar power can balance out their energy portfolios and hedge against tightening regulations on fossil fuels.

Figure ES1: Doubling the world's renewable energy share requires concerted action, reinforcing growth in renewables with energy efficiency and universal access.



REFERENCE
CASE: DEPLOYMENT
BASED ON EACH
COUNTRY'S PLANS AND
POLICIES TODAY

REMAP OPTIONS:
THE DEPLOYMENT
POTENTIAL OF ADDITIONAL
RENEWABLE ENERGY
TECHNOLOGIES BY 2030
ON TOP OF TODAY'S
EXISTING POLICIES

DOUBLING OPTIONS:
ADDITIONAL RENEWABLE
ENERGY DEPLOYMENT
COMBINED WITH
DEEPER STRUCTURAL
CHANGES

Doubling the renewable energy share by 2030 will be easier if energy demand growth slows. Greater energy efficiency will rein in demand growth.

Renewables, meanwhile, are essential to extend energy access to all. Off-grid renewable solutions offer the most cost-effective way to expand electricity access. For people in less developed countries, the transition also means replacing traditional, and often unsustainable uses of bioenergy with modern renewable options for cooking and heating.

Doubling the renewable energy share means accelerating the deployment of current technologies as well as investing in innovation. Some 60% of the world's renewable energy potential can be achieved by implementing what this roadmap calls "REmap Options". The remaining 40% can be realised through accelerated energy efficiency along with an investment push to achieve universal energy access with renewables. Described here as the "Doubling Options", these combine new technologies with deeper structural changes.

Doubling the renewable share is vital to achieve a carbon-free energy system in the next 50 years. It would also reduce the challenges of global energy security and risks to the environment and human health.

DOUBLING THE SHARE OF RENEWABLES BY 2030 IS FEASIBLE, BUT ONLY WITH IMMEDIATE, CONCERTED ACTION TO JUMP-START THEIR USE IN TRANSPORT, BUILDINGS AND INDUSTRY

Policies now in place would increase the renewable share in the global energy mix to only 21% by 2030. Starting with the 18.4% renewable share in 2014, average annual growth would amount to 0.17 percentage points, far short of the 1 percentage point a year required. Global energy demand continues to grow – it will rise 30% in 2030 compared to the level today – and the pace of renewable deployment is only slightly higher. To achieve the necessary doubling, therefore, urgent and concerted action is needed, both nationally and through greater international cooperation. REmap aims to equip policy makers, business leaders and civic organisations with the information to make that happen.

Global doubling does not imply doubling in every country. While some countries have raised their outlook for renewable energy adoption in the last two years, others have postponed investments. Projections for many countries show energy demand rising faster than renewable energy adoption. Growth rates and renewable energy deployment potential will always differ, reflecting differences in national circumstances. As of 2010, the modern renewable share in energy consumption in the 40 countries that participate in REmap ranged from a low of 1% to around 50% for modern renewable energy, and up to 90% if traditional use of bioenergy was included. But while the pace varies, every country can achieve some growth.

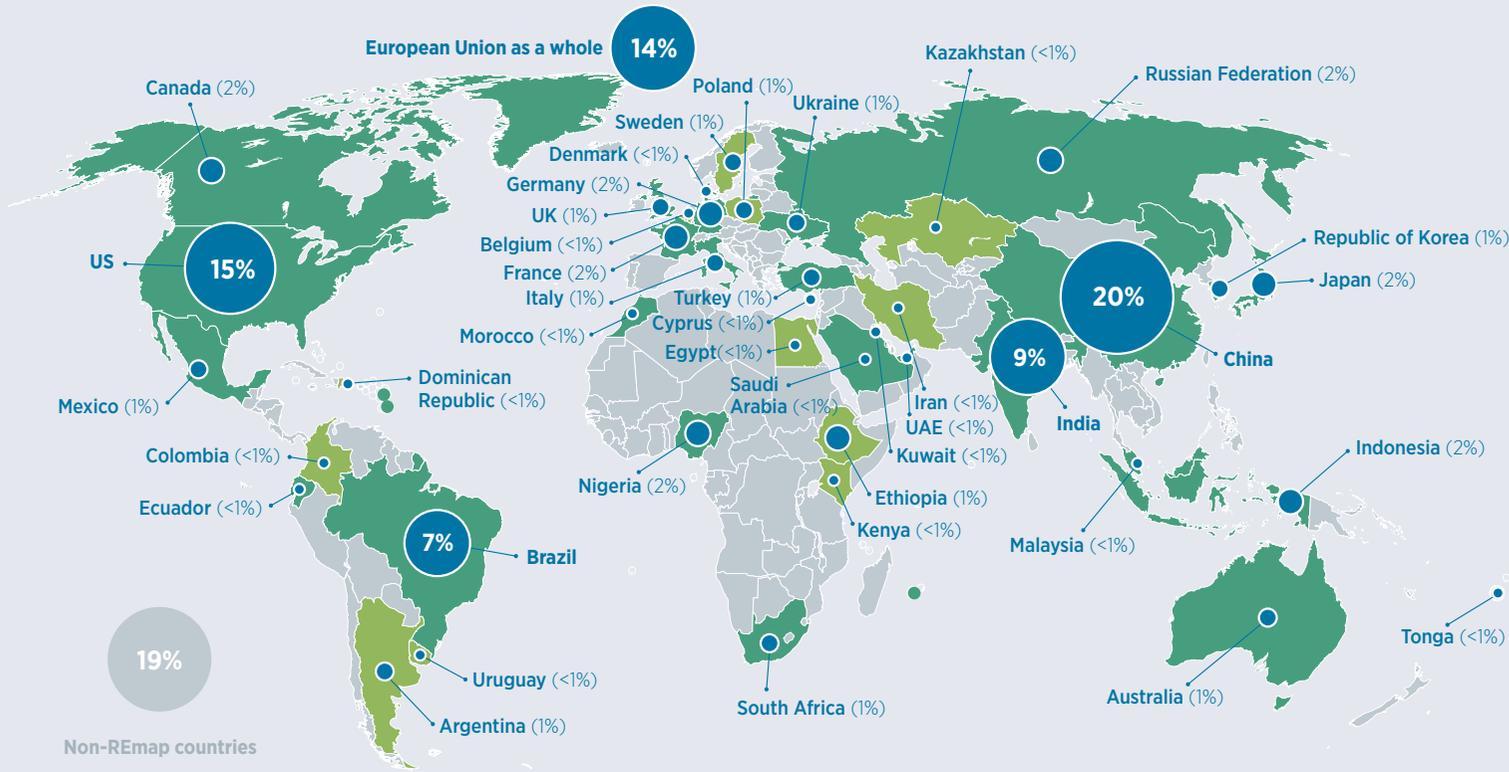
Implementation of all REmap Options would increase the renewable share between 20% and 70% in most countries by 2030.

In several developed countries, renewables have grown because of successful policies, and most have the potential for significant growth. Energy demand in developing countries is growing faster, creating many opportunities for deployment.

The share of renewables in the energy consumption of REmap countries in 2030 varies, from just 10% to over 60%.

REmap takes a country-specific approach to doubling the global share, and addressing the specifics of each market or region. Nonetheless, a global energy transformation requires targeted action by all.

Figure ES2: Country opportunities vary, but each country has a role to play in scaling up renewables.



Note: Percentage indicates how much renewable energy each country consumes in 2030 if the REmap Options are deployed.



While the outlook for renewables in the power sector is highly positive, advances in transport, heating and industry have been slower. An electric-transport revolution may be drawing closer, but liquid biofuel uptake is hurt by low oil prices. Renewable energy adoption for buildings has also slowed, and industry, in particular, is often overlooked in country plans. To accelerate overall uptake enough, renewable power generation will have to increase still more. The electrification of heating and transport will further boost power demand.



Countries must accelerate their uptake of renewables in buildings, industry and transport without delay. Consumption of renewable power will account for around half of the total renewable energy use in 2030, while the rest would come from direct uses, such as biofuel-based heating, cooking, cooling and transport, as well as district heating.

Planning must start now to ensure the successful integration of variable renewable power. Wind and solar PV power generation are influenced by weather and daylight patterns, resulting in variable output. With higher shares of wind and solar, the power system needs more flexibility. Coupling excess renewable power generation with heating and transport demand is one way to provide such flexibility.



Limited deployment in some government projections stems from a lack of incentives for renewables in buildings and industry. Renewable-heat policies often receive less attention than those for electricity, in part because renewables are more easily deployed in new buildings. Standing capital stock with long lifespans is an impediment to change. Renewable energy is more difficult to deploy in refurbishment and renovation schemes than in new buildings. Other barriers can also play a role. For example, in the aviation sector, the use of renewable fuel is negligible, because price plays a bigger

role in competition between airlines compared to environmental performance.

Bioenergy will have to account for half of renewable energy use in 2030 for a high enough renewable share overall. Bioenergy must be reinvigorated in all its forms, including advanced liquid biofuels for aviation, freight and shipping applications. Enough sustainable bioenergy is available to reach this target. Consistent with many other global estimates, IRENA finds that sustainable primary bioenergy use can increase by nearly 70% between today and 2030.

For renewables other than bioenergy, the growth potential is even higher. Solar PV power generation can grow sevenfold, from 230 gigawatts (GW) of capacity at the end of 2015 to between 1 600 GW and 2 000 GW by 2030. Wind power can more than quadruple, from 400 GW in 2015 to over 1 800 GW.

If the steps outlined in this roadmap are followed, nearly half of global power generation will be renewable by 2030, compared to less than a quarter in 2015. The renewable energy share would also surge in others, with increases to as high as 57% in buildings, 35% in industry and, 16% in transport.

DOUBLING RENEWABLES WILL SAVE UP TO 15 TIMES MORE THAN IT COSTS

Doubling the renewable energy share requires annual investments in power generation, heating, cooling and biofuel capacity to rise from USD 360 billion in 2015 to USD 1 300 billion by 2030.

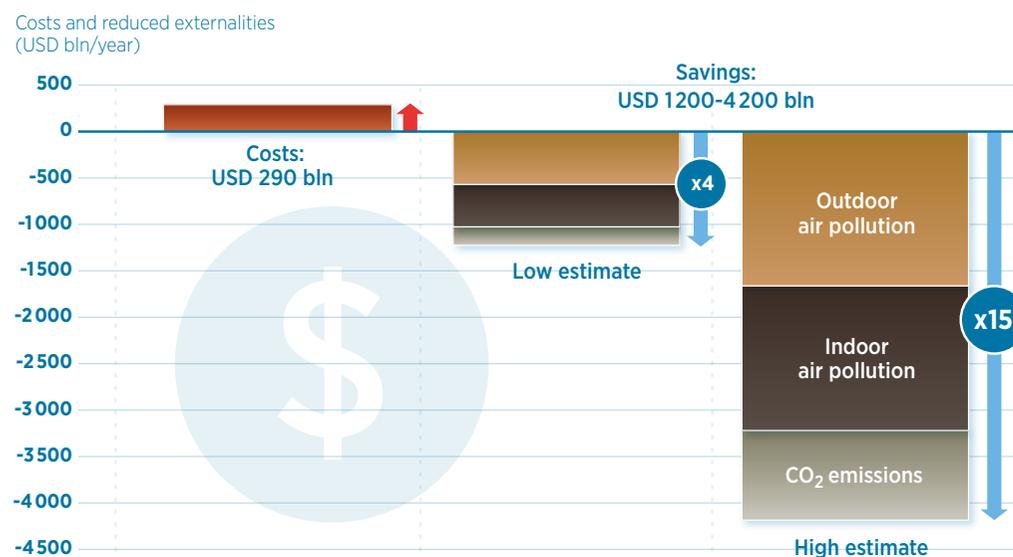
Renewables generally require steeper upfront investment than non-renewable energy technologies, but without ongoing fuel costs later. After those factors are taken into account, REmap Options require USD 100 billion more of investments each year in 2015-2030 compared to a business as usual (the Reference Case in this report). In terms of the global economy, this equals 0.1% of annual investment.

Cost of doubling the renewable energy share by 2030 would be USD 290 billion per year. According to REmap analysis, this is at least 4 and up to 15 times less than the external costs avoided. In other words, the reduction of CO₂ emissions and air pollution damage on human health and agricultural crops can produce annual net savings between USD 1 200 billion and USD 4 200 billion. Nearly two thirds of the *REmap Options* outlined in this report are already cost-competitive without considering externalities. However, those options result in a share of only 30% for renewables, short of the 36% needed to reach international climate goals. The more costly *Doubling Options*, which would increase renewables to 36%, become competitive when these externalities are accounted for.

The reduction of air pollution both indoors and outdoors promises the largest savings, between USD 1 050 billion and USD 3 200 billion per year in 2030 with the share of renewable energy doubled in the world's energy mix by 2030. Indoor air pollution caused by traditional uses of bioenergy accounts for the largest share

of reduced externalities, followed by outdoor air pollution and climate change. The reduction of air pollution can save up to an estimated 4 million lives per year with the share of renewables doubled in the world's energy mix by 2030. Higher shares of renewable energy will also bring significant energy security benefits, either through reduced import dependence or enhanced trade balances.

Figure ES3: Reducing human health damage and CO₂ emissions would save at least four times more than the cost of doubling renewable energy use.



Fossil-fuel subsidies and taxes continue to distort energy markets. Currently, subsidies and market structures continue to tip the scales in favour of fossil fuels. Encouraging investments through market restructuring should therefore be a priority. Reducing market discrimination against renewables can eliminate the need for investment support, otherwise estimated at USD 400 billion per year in 2030 to implement *REmap Options* and *Doubling Options*.

Renewable energy can sustain 24.4 million jobs worldwide by 2030 if its share in the global energy mix is doubled. Implementing *REmap Options* and *Doubling Options* would increase the number of jobs (direct and indirect) related to renewables from 9.2 million in 2014 to 24.4 million in 2030 – almost 11 million more than business as usual.



RENEWABLES, COUPLED WITH GREATER ENERGY EFFICIENCY, CAN KEEP AVERAGE GLOBAL TEMPERATURES FROM RISING MORE THAN 2°C ABOVE PRE-INDUSTRIAL LEVELS.

Renewables are essential to realise long-term climate targets. Reaching a 30% share by 2030 (*REmap Options*) should be enough to prevent global temperatures from rising more than 2 °C above pre-industrial levels. Going below the 2 °C target called for in the Paris Agreement will require a doubling of renewable energy share to 36%. Investments in renewables and energy efficiency must also accelerate further beyond 2030.

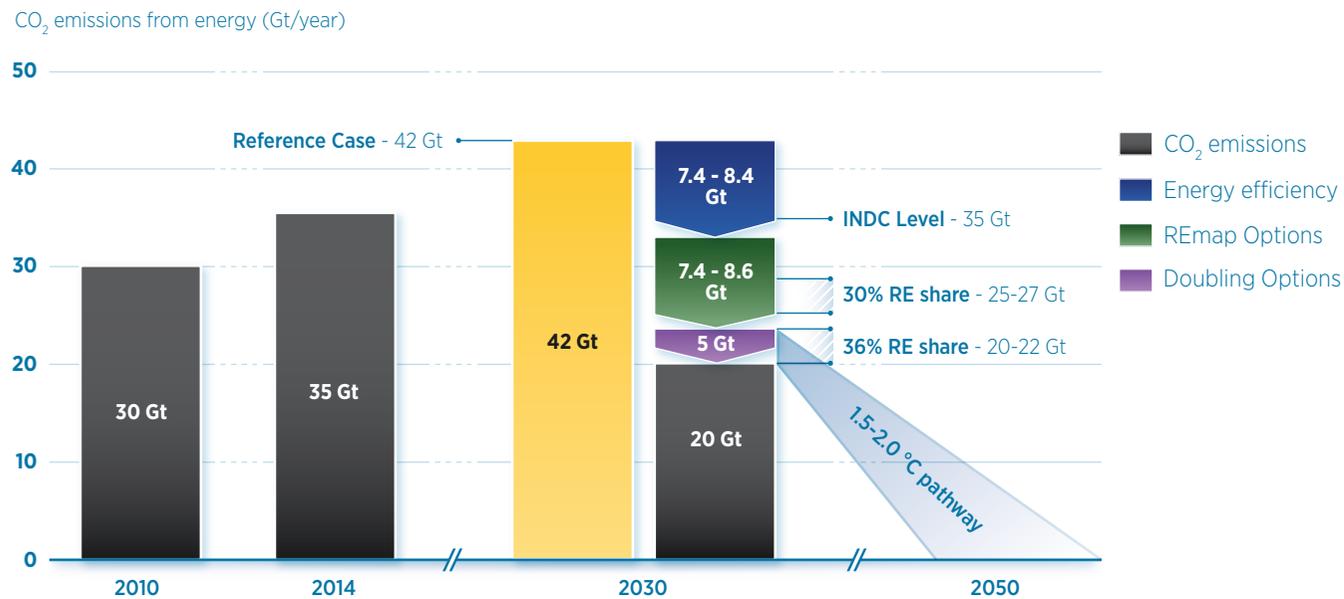
Doubling the share of renewables would avoid up to 12 gigatonnes (Gt) of additional CO₂ emissions per year in 2030 compared to business as usual, while energy efficiency measures would avoid a further 8 Gt. Greenhouse gas emissions in the form of methane and black carbon would also be avoided.

Renewable energy policy needs to be more closely coordinated with climate policy. Although many governments have increased their efforts to promote renewable energy, the Nationally Determined Contributions (NDC) analysed in this roadmap have underestimated the potential for renewable energy in 2030 by a factor of five. To affect change at the national and regional levels, more emphasis must be put on how renewables can mitigate greenhouse gas emissions. Renewables and energy efficiency can end demand growth for coal, oil and gas.

A streamlined system of energy governance is needed at the national level. Currently, the benefits of renewable energy tend to be understood only within specific areas of government. Yet accelerated deployment would address multiple Sustainable Development Goals, from health to resilience and poverty alleviation. For maximum impact, the commitment to renewables must be infused into all dimensions of national planning.

The last two years have seen the emergence of new initiatives, institutions, alliances and centres to promote renewable energy in different countries and regions. Aligning these with global development and climate objectives will strengthen the international-cooperation framework.

Figure ES4: Global energy-related CO₂ emissions between today and 2050



CLIMATE AND SUSTAINABLE ENERGY OBJECTIVES WILL NOT BE MET WITHOUT IMMEDIATE, CONCERTED ACTION TO DOUBLE THE RENEWABLE ENERGY SHARE IN THE GLOBAL ENERGY MIX BY 2030

To double renewable energy share in the global energy mix in the next 14 years, policy makers must accelerate their efforts today and achieve significant progress within five years. Time is running out to achieve the international targets agreed upon in 2015.

Transforming the energy system cannot be left to markets and investors alone. In some cases, the main obstacle is policy and regulation; in others, market design, institutional frameworks or local renewable-resource quality. In a few instances, a lack of commercially viable renewable solutions requires technological innovation. The public sector must do its part to surmount all these obstacles.

Legislators and policy makers must lay the necessary foundations. Five areas are especially critical:

- planning transition pathways for development of national plans and targets,
- creating an enabling business environment, with energy prices that recover external costs;
- ensuring the smooth integration of renewables into existing infrastructure;
- creating and managing renewable energy knowledge; and
- promoting continuous innovation.

REmap has identified five key action areas that must be addressed in order to enable the significant scale-up of renewables >>

REMAP IDENTIFIES THE FOLLOWING ACTION AREAS:

1 Correct for market distortions to create a level playing field.

This could be achieved by introducing carbon prices to reflect the external costs of fossil fuels, as well as improving the regulatory framework for the renewable energy market. Governments also need to account for externalities related to human health and climate change in energy pricing. Risk-mitigation mechanisms will be important to mobilise investment.

2 Introduce greater flexibility into energy systems and accommodate the variability of

key renewable energy sources. The availability of solar and wind energy is predictable, despite daily and seasonal variations. Interconnectors between national or regional grids help to balance supply and demand for power. Demand-side management, electricity storage and smart grids also strengthen the integration of variable renewables, while real-time market pricing helps to assess the value of power generation at different times. New regulatory frameworks must allow new entrants into the power market and reflect the evolving roles of utilities and consumers.



3 **Develop and deploy renewable heating and cooling solutions for urban development projects and industry.**

Cities, local governments and municipalities need to encourage the uptake of renewables and adopt efficient, centralised district systems. Sector coupling allows surplus electricity to provide heating and cooling for buildings and industry.



4 **Promote transport based on renewable power and biofuels.**

Urbanisation is occurring rapidly worldwide, and clean transport is necessary to keep cities liveable. Trams, buses, freight and passenger vehicles powered by renewable-based electricity must become the predominant forms of city transport. This can be achieved through smart city planning and the rollout of recharging and supply infrastructure. Government support is needed to commercialise advanced liquid biofuels for widespread use, especially in aviation, freight and shipping.



5 **Ensure the sustainable, affordable and reliable supply of bioenergy feedstocks.**

Bioenergy can come from agricultural and forestry residues, waste and other sustainable feedstocks. It is particularly important in applications for which no other renewable energy technology is suitable, such as high-temperature process heat in industry. Depending on the feedstock type, either markets need to be expanded or vertical integration of the fuel chain is needed to guarantee supply of reliable and affordable bioenergy products. New international trade and infrastructure policies are needed to facilitate local, regional and global trade in bioenergy commodities.



Policy makers are encouraged to consider solutions in these areas as part of a comprehensive approach to enabling the energy transition. If the international community fails to seize the opportunity offered by renewable energy, there is a serious risk that international energy and climate targets will be missed.

This roadmap offers ten technology and innovation solutions (see Chapter 3) that will be crucial to take action in the recommended areas. In sum, this roadmap is meant to foster ambitious, sustainable and commercial-scale renewables growth in a climate-constrained world.

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Doubling renewables in the global energy mix by 2030 is not only feasible, but cheaper than not doing so. Economic savings would far exceed the costs. It would create more jobs, boost economic growth and save millions of lives annually through reduced air pollution. It would also, when coupled with greater energy efficiency, put the world on track to keep the rise of temperatures within 2°C, in line with the Paris Agreement.

But to meet that goal, renewable energy deployment must happen six times faster than today.

This second edition of IRENA's global roadmap provides an in-depth perspective on the energy transition in 40 economies, representing 80% of global energy use. It offers concrete technology options and outlines solutions to accelerate renewable energy growth.

The age of renewables is here. But without concerted action, they cannot reach their potential soon enough to meet international climate and development targets. For decision makers in the public and private sectors alike, this roadmap sends an alert – on the opportunities at hand and the costs of not taking them.

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