REmap
A Renewable Energy Roadmap

IRENA
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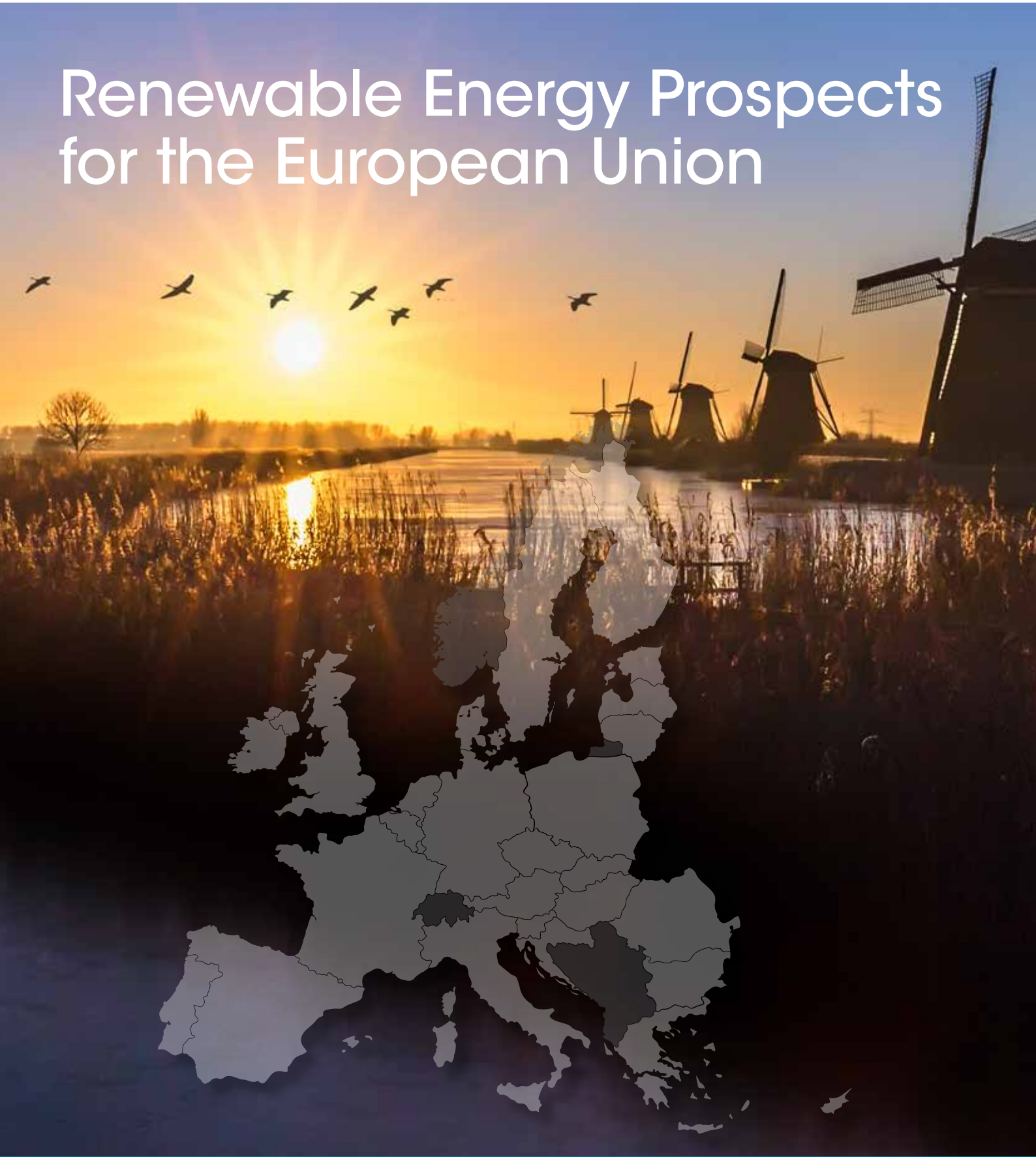
Renewable Energy Prospects for the European Union



PREVIEW FOR POLICY MAKERS
Based on REmap analysis

January 2018

KEY FINDINGS

- The EU could double the renewable share in its energy mix, cost effectively, from 17% in 2015 to 34% in 2030.
- All EU countries have cost-effective potential to use more renewables.
- Renewables are vital for long-term decarbonisation of the EU energy system.
- The European electricity sector can accommodate large shares of solar PV and wind power generation.
- Heating and cooling solutions account for more than one third of the EU's untapped renewable energy potential.
- All renewable transport options are needed to realise long-term EU decarbonisation objectives.
- Biomass will remain a key renewable energy source in 2030 and beyond.

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INTRODUCTION

For more than two decades, the European Union (EU) has been at the forefront of global renewable energy deployment. The adoption of long-term targets and supporting policy measures has resulted in strong growth in renewable energy consumption across the region, from a 9% share in 2005 to 16.7% in 2015. Currently, the EU is on track to meet its 20% target established for 2020.

In October 2014, the European Council agreed on a new set of energy and climate targets for the period up to 2030 (European Council, 2014), including a minimum target of 27% for the share of renewable energy consumed in the EU. This agreement was followed by the Energy Union framework strategy of February 2015, which aims to make the EU "the world leader in renewable energy" (European Commission, 2015).

The European Union ratified the Paris Agreement, which established the goal to limit the rise in global temperatures this century to "well below 2°C" compared to pre-industrial levels. In practice, this entails reducing global carbon emissions from energy use to zero by 2060 and maintaining that level until the end of the century. This long-term decarbonisation objective has profound implications for European climate and energy objectives in the 2030 timeframe. Early climate action is key to ensure an efficient transition in all aspects of energy use, avoiding the need for more dramatic emission reductions after 2030, and minimising stranded assets. Accelerated deployment of renewables can play a key role towards this transition.

For the crucial 2020–2030 period, the European Commission tabled the "Clean Energy for All Europeans" package in November 2016. The package proposes a regulatory framework to support renewable energy deployment (European Commission, 2016a). The International Renewable Energy Agency (IRENA), at the Commission's request, has carried out an assessment of the renewable energy prospects of the European Union to 2030 to support discussion on this proposal. The study, conducted in close collaboration with the Commission, also forms part of REmap – IRENAs' renewable energy roadmap.

The resulting REmap EU study aims to identify cost-effective renewable energy options across all Member States, sectors, and technologies, in order to meet – and potentially exceed – the proposed 27% renewables target for 2030.

IRENA's analysis, furthermore, aims to provide an open platform for EU Member States to assess at an aggregated level the impacts of their national renewable energy plans; to provide insights into the environmental and economic impacts of further deployment of renewables in the EU; and to further highlight the role that renewables could play in the long-term decarbonisation of the European energy system.

APPROACH AND SCOPE

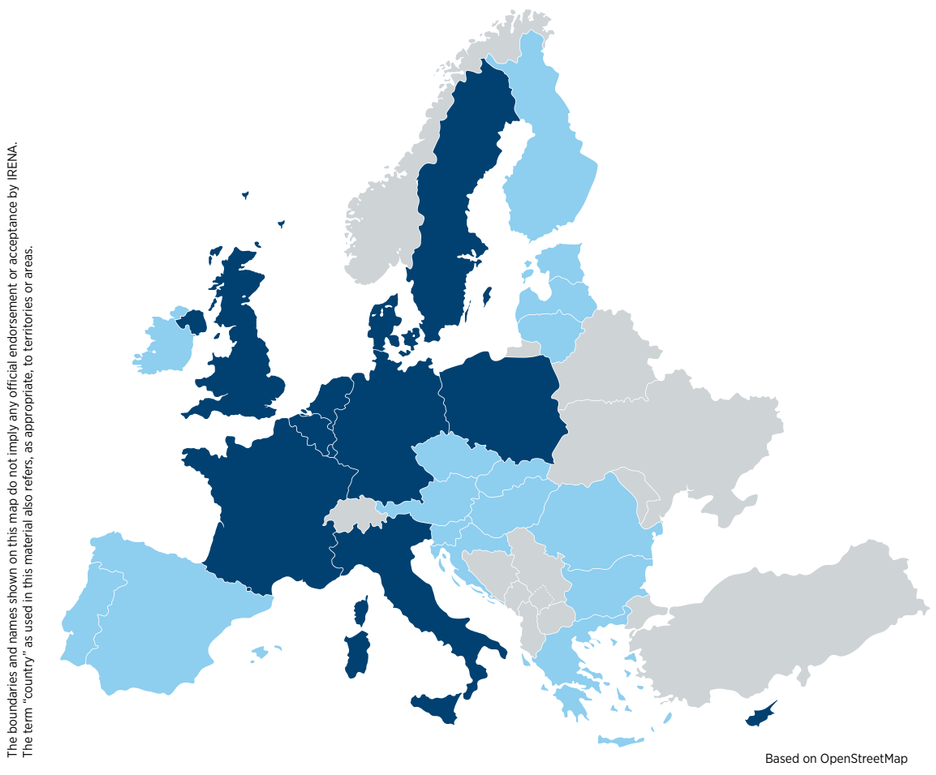
REmap is IRENA's methodology to assess the potential for scaling up renewables in countries, across regions and around the world. The REmap analysis identifies renewable technology options in all sectors of the energy system, assessing them both in terms of costs and required investments as well as their contribution to climate and environmental objectives.

REmap includes 70 countries worldwide, accounting for around 90% of global energy use. It is unique in that participating countries nominate national experts to work jointly with IRENA to determine their renewable energy potential, resulting in roadmaps developed in close consultation with countries themselves.

In recent years, IRENA has applied the REmap approach in several regional analyses.[1] A regional approach is useful to assess the aggregated impact of multiple national efforts, as well as in identifying synergies for cost effective renewable deployment and opportunities for co-operation.

The REmap study for the EU is based on deeper analysis of existing REmap studies for 10 EU Member States (accounting for 73% of EU energy use), complemented and aggregated with high-level analyses for the other 18 EU Member States.

Participation of EU Member States in IRENA's REmap programme[2]



The boundaries and names shown on this map do not imply any official endorsement or acceptance by IRENA. The term "country" as used in this material also refers, as appropriate, to territories or areas.

Based on OpenStreetMap

1 *A first regional REmap report looked at Africa (IRENA, 2015). This was followed by an analysis of Southeast Asia in co-operation with the ASEAN Centre for Energy (IRENA and ACE, 2016).*
2 *Countries in dark blue have joined the REmap programme and have an existing detailed REmap analysis; those in light blue comprise the rest of the EU-28, which are not part of the REmap programme but have been added as part of the EU study. (Spain is a REmap country but the REmap analysis is not yet complete.)*

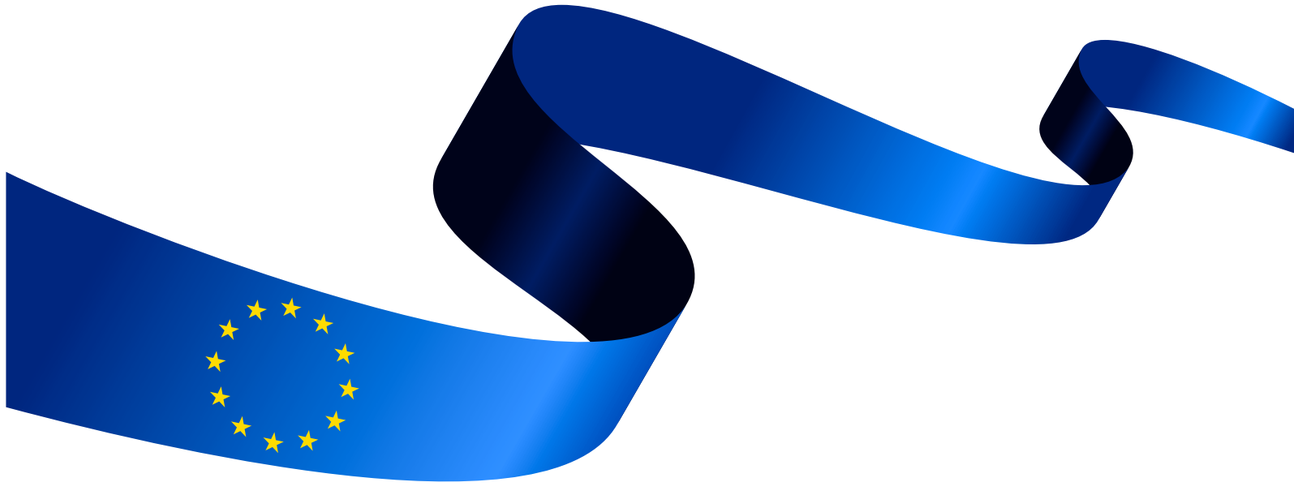
The study analyses the expected deployment of renewables in the EU by 2030 under a Reference Case scenario (which assumes the continuation of existing and planned policies) and through REmap Options (i.e. realisable renewable-based technology potential) at a country level, aiming to identify what is possible beyond the Reference Case.

These renewable energy options are characterised in terms of their levelised cost of energy (LCOE) and compared with a conventional technology alternative to determine the 'costs of substitution'. The study covers all sectors, including energy supply (power and district heat) and end-use sectors (buildings, industry and transport).

IRENA's REmap study is not intended as a prediction of the expected evolution of the EU's energy system but rather an analysis of what is technically possible and cost-effective from a societal perspective by 2030, based on today's best knowledge. The future of the European energy sector is subject to multiple uncertainties of a technical, economic and social nature. Their impacts on the findings – both positive and negative – have been mapped as part of this study.

Although the total economic and technical potential of renewables identified in the REmap study is considered a robust finding, technology developments are subject to high levels of uncertainty. REmap analysis considers the rising technical potential and falling costs of renewable energy technologies; the additional potential identified, beyond the proposed 27% target for 2030, can be attributed largely to the rapid progress of such technologies, which has occurred faster than expected at the time the target was set in 2014.

IRENA's REmap analysis for the EU was carried out in consultation with Member State representatives by means of several workshops and sectoral webinars. The analysis of the operation of the power sector was carried out in co-operation with University College Cork. The final results of the REmap study were reviewed and benchmarked against other scenarios for the region by the EU Joint Research Centre.



SUMMARY OF RESULTS

Since the adoption of the 27% target in 2014, much has changed in the energy sector. Key renewable technologies such as solar PV and offshore wind have achieved spectacular cost reductions, exceeding expectations both in terms of their speed and extent. As these technologies improve, so does the renewable potential that can be harvested cost-effectively.

Technological development has also accelerated in end-use sectors; for example, electric vehicles are quickly reaching commercial maturity and could play a key role in the deployment of larger shares of renewables in the EU by 2030, both in the transport and power sectors. Meanwhile, new information and communication technologies are revolutionising the way we design and operate our energy systems. **Thanks to these favourable developments, the 27% renewable target agreed in 2014 may be regarded as a conservative objective for the EU.**

The EU could double the renewable share in its energy mix, cost effectively, by 2030

The analysis shows that there are various cost-effective combinations of renewable energy options to meet the 27% target; however, the REmap analysis identifies additional potential to exceed this share. The **full implementation of all renewable energy options** under a reference demand scenario **would increase the share of renewables to 33% by 2030**. If the realisation of the proposed 30% energy efficiency target[3] is considered, the same renewable energy use under the **REmap case would represent a share of 34%.** If more ambitious energy efficiency targets are considered, the resulting share of renewables could be even higher for the same level of deployment.

Renewable energy options to exceed the 27% target for 2030

IRENA analysis

Strong cost savings
- Wind power
- Solar power
- Solar thermal in buildings
- Hydro power
- Geothermal power

Moderate cost savings
- Heat pumps
- Electric vehicles
- Biodiesel
- Geothermal district heating
- Solar thermal in industry

Additional cost
- Biomass in industry
- Conventional bioethanol
- Biomass in power and district heat
- Advanced bioethanol
- Biokerosene

3 As part of the "Clean Energy for All Europeans" package of November 2016, the European Commission proposed a binding EU-wide target of 30% for energy efficiency by 2030 (European Commission, 2016).

Current plans and policies for renewable energy deployment would result in a share of 24% by 2030. The additional potential beyond this Reference Case can be broadly split into three categories: the first category comprises different forms of renewable power generation (wind, solar, hydro, geothermal) as well as solar thermal in buildings. The second category includes electrification of heat and transport by means of heat pumps and electric vehicles (in combination with renewable power generation), as well as biodiesel for transport, solar thermal in industry and geothermal in district heating systems. The third category comprises different forms of biomass use across sectors.

The first category yields strong cost savings compared to conventional technologies, the second delivers cost-neutrality to moderate savings and the third comes at additional cost; however, the **full implementation of all identified options would result in estimated net cost savings of USD 25 billion per year by 2030**, as the savings from the cheapest options outweigh the additional costs of the most expensive ones.

Additional costs for the modernisation of power grids, or a potential scenario of low or stagnating fossil fuel prices, could reduce these estimated savings; however, the potential additional costs are outweighed by the benefits when health and environmental externalities are considered. Today, about 400 000 people die prematurely in Europe each year because of air pollution (EEA, 2017a). The REmap savings from **avoided health damage** alone are estimated at **between USD 19 billion and 71 billion per year** by 2030, while the **environmental costs** avoided with the deployment of REmap options are estimated at **between USD 8 billion and 37 billion per yea**r by 2030. When the savings from a pure cost–benefit analysis are aggregated with avoided health and environmental externality costs, the accelerated deployment of renewables would result in **total savings of between USD 52 billion and USD 133 billion per year** by 2030.

After peaking in 2011, **new investments in renewable energy in Europe have slowed down significantly compared to other major regions around the world**. Reaching a 34% renewable share by 2030 would require an estimated average investment in renewable energy of USD 73 billion per year[4]. The incremental, accumulated investment additional to the Reference Case would amount to **USD 433 billion until 2030, representing an average annual contribution of 0.3% of current EU-28 gross domestic product**, before accounting for additional activity triggered in other sectors. The overall macroeconomic benefits would be more significant because of this multiplier effect. Previous IRENA analysis indicates a multiplier of a factor of two on a global scale, while for fossil-fuel-importing regions such as Europe, the multiplier is probably larger (IRENA, 2017a).

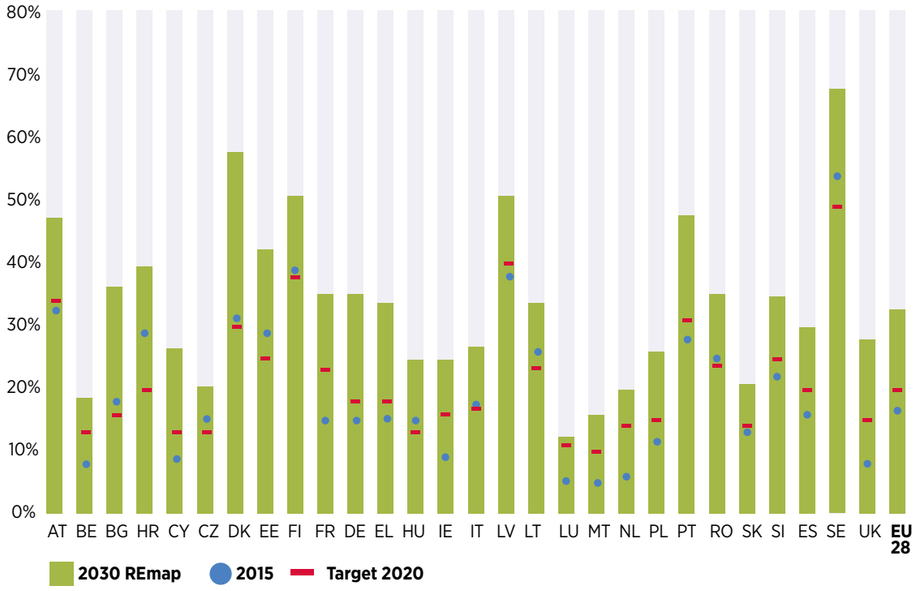
The additional investment in renewables would also have a positive effect in terms of job creation. Today the renewable sector employs about 1.2 million people in Europe (IRENA, 2017b). This figure would increase substantially with a doubling of the renewable share by 2030.

All EU countries have cost-effective potential to use more renewables

In 2015, the renewable energy shares in EU Member States varied from 5% to 54%. Variations will persist to 2030, reflecting multiple factors such as different starting points, available resource potentials, existing and planned policies, as well as the specific market conditions for renewables in each country; however, these differences may narrow by 2030 as Member States with lower initial shares have the potential to grow faster.

4 Current levels of investment in the EU-28 are estimated between USD 50 billion and USD 56 billion in 2016 (Frankfurt School-UNEP Centre/BNEF, 2017).

Renewable energy share in gross final energy consumption – 2015, 2020 target and 2030 potential with accelerated uptake of renewables (REmap)



IRENA analysis

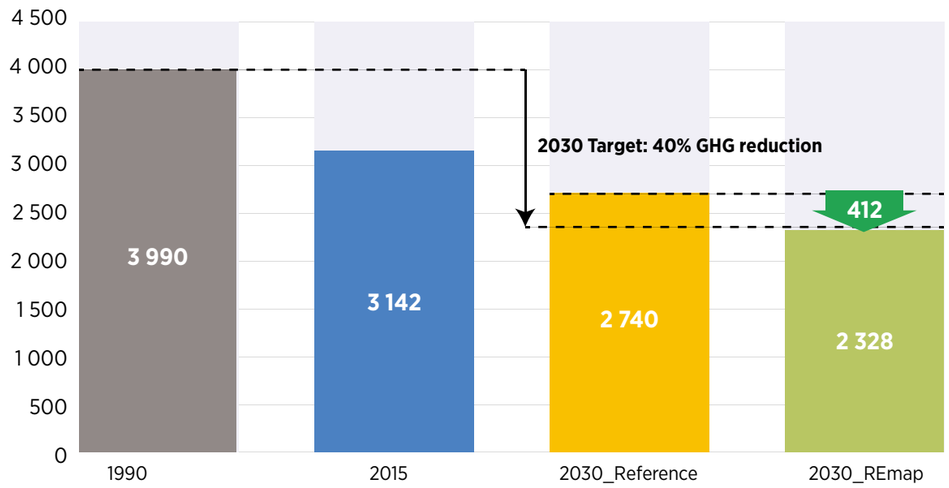
The aggregate share of renewables that would result from existing Member State plans and projections to 2030 falls short of the 27% EU goal; thus, additional commitments will be required from Member States to reach or exceed the proposed 2030 target.

Renewables are vital for long-term decarbonisation of the EU energy system

The EU is well on track to achieve its 2020 emissions reduction target; however, additional effort will be required to align long-term energy system trends with 2050 decarbonisation goals, particularly in end-use sectors (buildings, industry and transport), where progress has been slow in the past. Even if the EU were to realise its 40% emission reduction target by 2030, much deeper reductions (two to three times larger than those required between current and 2030 levels) would be needed between 2030 and 2050 (EEA, 2016).

The full deployment of REmap Options would deliver a reduction of 412 Mt CO_2 (15%) compared to the Reference Case in 2030, an amount comparable to Italy's total emissions today. This scenario would result in a 42% reduction in emissions in the energy sector compared to 1990 levels, in line with the EU's 40% GHG emission reduction objective by 2030 and enabling a deeper decarbonisation pathway conducive to the "well-below" 2°C target in the Paris Agreement (once energy efficiency and other mitigation measures are factored in). This illustrates the key contribution of renewables in meeting EU climate objectives and the need for close alignment between energy and climate policies.

EU energy-related CO_2 emissions (Mt CO_2/year) – 1990, 2015, 2030 Reference Case and 2030 with accelerated uptake of renewables (REmap)



IRENA analysis based on EEA source data for 1990 and 2015 values (EEA, 2017b)

HIGHLIGHTS BY SECTOR

Under the REmap case, the share of renewable energy in the power sector would rise to 50% by 2030 (compared to 29% in 2015), while in end-use sectors renewables would account for shares[5] of 42% in buildings, 36% in industry and 17% in transport.

The European electricity sector can accommodate large shares of solar PV and wind power generation

Solar PV and wind power account for the bulk of capacity additions in the power sector under the REmap case. The potential identified would result in 327 GW of wind installed capacity (+97 GW compared to the Reference Case) and 272 GW of solar power (+87 GW compared to the Reference Case), while other technologies including biomass, hydro, geothermal and marine contribute a further 22GW.

The REmap case results in a high share of variable renewable generation (29%), which will pose new challenges for the operation of EU power systems. A key question is whether there will be sufficient power system flexibility[6] in 2030 to deal effectively with the increased variability in generation expected. To assess this, an EU-wide model[7] was developed to simulate the operation of the power sector in 2030, assuming full deployment of the generation mix resulting from the REmap case.

5 Expressed in final energy consumption terms, including renewable electricity and district heating.
6 Flexibility in power systems can be defined as the ability to constantly keep power supply and demand in balance, responding to (quick and large) changes in either. Flexibility can be provided by generators (fossil but also dispatchable renewable), consumers, storage systems, networks or even system operation rules.
7 A dispatch model based on Plexos software and developed in co-operation with University College Cork (www.ucc.ie/en)

The modelling simulations indicate that the **REmap scenario could be technically feasible considering the interconnection infrastructure planned for 2030; however, they also reveal challenges that will need to be addressed.** Firstly, multiple EU interconnectors are expected to operate under high levels of congestion by 2030 regardless of the renewable deployment scenario considered. This indicates a need for additional infrastructure and cross-border market integration efforts to enable the efficient trade of electricity, which is a key element for a cost-effective EU-wide deployment of renewables. Secondly, the simulations show that variable renewable generation plants would capture prices lower than the average in wholesale markets, as their low marginal generation costs place downward pressure on prices when they are in operation. This effect is most pronounced for solar PV plants, as their generation concentrates in the central hours of the day and during summer. A decreasing economic value for solar PV generation could be a barrier to investment in new capacity, which could be mitigated by enabling additional energy storage and incentivising demand-side flexibility across EU markets.

The accelerated adoption of heat pumps and electric vehicles would result in a substantial increase in the use of electricity in end-use sectors. Under REmap, electricity would represent 27% of total final energy consumption, up from 24% in the Reference Case. This requires generation of 230 TWh/year of additional power, an amount comparable to Spain's electricity demand today.

Heating and cooling solutions account for more than one third of the additional renewable energy potential identified through IRENA's REmap analysis

Heating and cooling accounts for about half of the energy demand in the EU today; however, progress in the deployment of renewables has been slower than in the power sector. **The share of renewables in heating and cooling could reach 34% by 2030 with faster renewable energy uptake (as per REmap), compared to 25% in the Reference Case.**

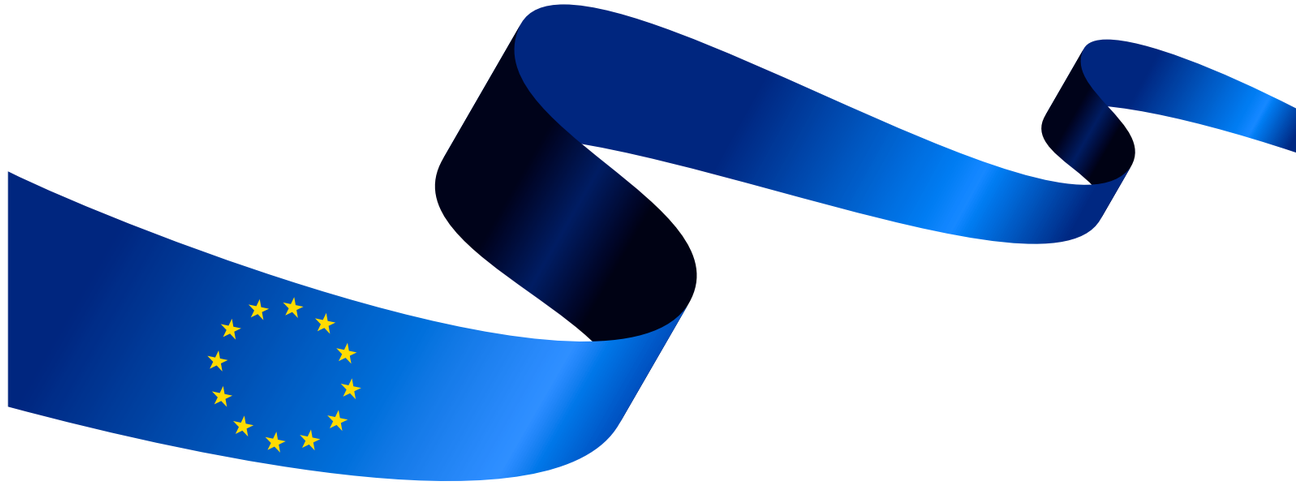
More than two-thirds of the additional renewable heating and cooling options identified are cheaper than the conventional alternative. The REmap analysis reveals significant potential to accelerate the deployment of heat pumps – which could account for about 9% of heating needs – as well as solar water heaters and direct use of biomass in industry and buildings. Today, district heating systems provide about 9% of the EU's heating needs (European Commission, 2016b); however, the bulk is produced with natural gas and coal. The conversion of district heating systems to use renewables is an option to accelerate renewable deployment in the heating and cooling sector.

All renewable transport options are needed to realise long-term EU decarbonisation objectives

The EU has made limited progress on the deployment of renewable energy in the transport sector over the last decade. **The quick adoption of electric vehicles will be key to accelerating renewable deployment by enabling the use of renewable electricity in road transport.** By 2030 most passenger vehicles sold could be fully electric or hybrids, and electric vehicles could potentially account for 16% of the overall car stock in Europe; however, even with such quick adoption of electric vehicles, renewable power would only account for about 3% of the energy consumption in the sector by 2030. Liquid biofuels – both advanced and conventional – will still be needed for the existing stock of vehicles with internal combustion engines and for transport modes where electrification is still not an option. The use of liquid biofuels could triple by 2030 compared to 2010 levels to reach ~66 billion litres.

Biomass will remain a key renewable energy source

Provided that sustainability concerns are considered, biomass will remain key for the energy transition until 2030 and beyond. This is especially the case for uses that are not easily converted to electricity or other carriers in the short and medium term (e.g. high temperature processes in industry, advanced biofuels for road freight, etc.). Overall deployment of bioenergy in the REmap scenario would double from today's levels; however, its share in the total consumption of renewables would decline from 67% in 2010 to 55% in 2030 as the growing contribution of other renewables outpaces bioenergy.



LOOKING AHEAD

IRENA's REmap analysis identifies significant renewable energy potential beyond the proposed 2030 target of 27%. **Tapping the additional potential to reach 34% is cost-effective**, even before considering the very significant economic value of the associated health and environmental benefits.

A faster deployment of renewables by 2030 is **technically feasible with today's technologies**. All EU Member States have renewable potential beyond the Reference Case that could be harvested economically. While an EU-wide target represents an important declaration of intent, **national-level commitments and implementation will hold the key** to achieving this objective cost-effectively at the regional level.

To fulfil its aspiration to become the global leader in renewables, Europe will need to maintain a growing domestic market. The additional investments required to reach a **34% share by 2030 would help Europe maintain its leading role** while deriving **substantial macroeconomic benefits in terms of growth and balance of trade, as well as creating a new industrial base around the renewables** sector.

Accelerating the deployment of renewables would have much **broader social benefits for the EU** and its Member States. It can boost economic activity and create new jobs. Moreover, the decentralised nature of many renewable energy technologies and the increased uptake of domestic biomass production under the REmap scenario could be a **driver for economic development among structurally weak regions and rural areas**. Combined with energy efficiency measures, renewables can also be a key contributor to **reducing energy poverty in the EU**.

Finally, tapping the additional renewable energy potential identified in the REmap study would bring the EU closer to a **decarbonisation pathway compatible with the "well-below" 2°C objective** established in the Paris Agreement, while substantially **improving the health of citizens**.

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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

About REmap

IRENA's REmap programme determines the potential for countries, regions and the world to scale up renewables. REmap assesses renewable energy potential assembled from the bottom-up, starting with country analyses done in collaboration with country experts, and then aggregating these results to arrive at a global picture.