IRENA
International Renewable Energy Agency

REmap 2030
A Renewable Energy Roadmap

EXECUTIVE SUMMARY

RENEWABLE ENERGY PROSPECTS:

GERMANY

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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.

The full report *Renewable Energy Prospects: Germany, REmap 2030 analysis* and other material is available at www.irena.org/remap

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

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EXECUTIVE SUMMARY

Germany is a world leader in its level of renewable energy deployment. Driven by a long-term renewable energy policy that dates back to the 1970s and, more recently, a nuclear power phase-out, the country is spearheading a transition to renewable energy that is commonly known as the *Energiewende* ("energy transition"). The *Energiewende* has gained broad political consensus in recent years. Its main drivers are climate change mitigation, improved energy security and industrial development.

Germany's experience continues to attract interest in the global renewable energy community and among national policy makers, and has inspired action in many countries around the world. The German Federal Ministry for Economic Affairs and Energy (BMWi) requested the preparation of this *REmap Germany* roadmap by the International Renewable Energy Agency (IRENA).

REmap is IRENA's analytical approach for assessing how, by 2030, to close the gap between current national renewable energy plans and the realistic potential of renewable energy beyond those plans. As an intergovernmental agency with broad membership, IRENA is uniquely positioned to promote widespread adoption and sustainable use of all forms or renewable energy worldwide. To date, 38 countries participate in the REmap 2030 programme. Together, these countries represent 80% of total global energy demand.

REmap Germany highlights best practice policy and technology experiences from which others can learn. It also identifies areas where the *Energiewende* can be expanded, in order for Germany's ambitious targets for renewable energy, energy efficiency and greenhouse gas emission reduction to be met by 2030. In addition, the report goes into depth on the integration of Europe's energy markets.

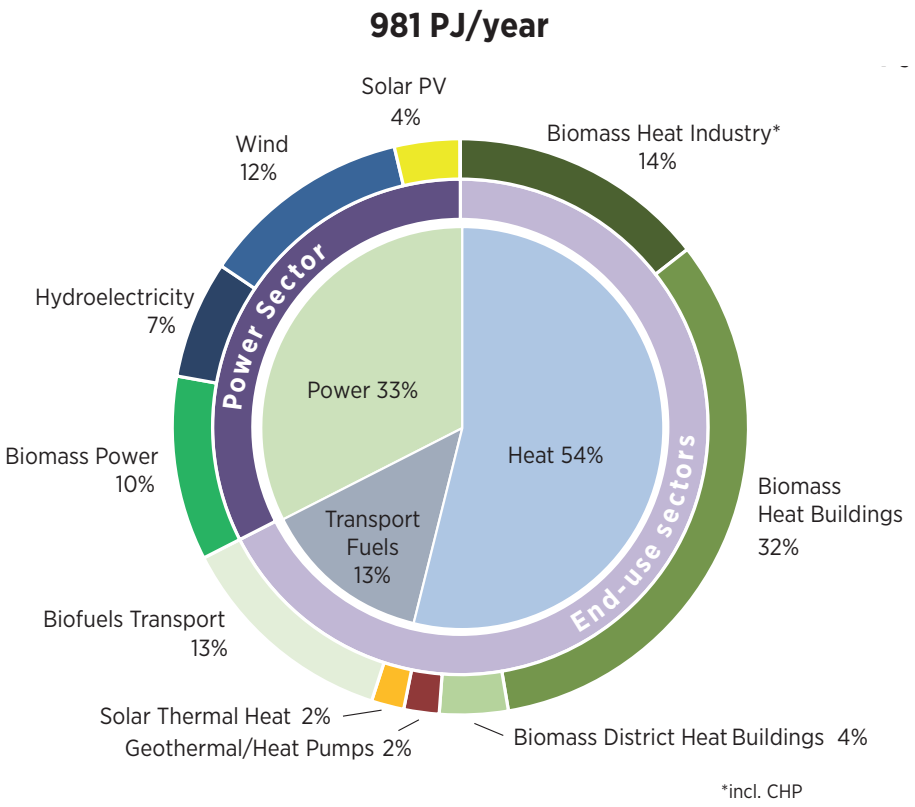
Germany's progress to date

Germany has seen tremendous growth in renewable power generation capacity. For many years, the policy instrument of choice was a feed-in tariff, but the country is now moving to introduce new instruments, including feed-in premium payments and an auctioning system. In the power sector, the development of renewable energy has diversified the energy mix, changed ownership structures and reduced Germany's dependence on fossil fuel imports. In addition, the renewables industry has built up a workforce of over 371 000.

Germany's renewable power share reached more than 25% in 2014, and it exceeded 30% in the first half of 2015. The country has shown the world that such a high level of renewables can be integrated without systemic problems, thanks to strong grid infrastructure and cross-border exchange links. As Germany transitions to ever-higher shares of renewable power, beyond 50% and even higher by 2030, important grid and sector-coupling options must be considered.

For Germany to reach its target of a 30% renewable energy share in total final energy consumption (up from 10% in 2010), a systemic change involving all sectors will be required, as the power sector alone is not sufficient to transition the country's energy system away from fossil fuels.

Figure 1: Breakdown of renewable energy in total final energy consumption, by source and sector, 2010



In the heating and transport sectors, targeted support policies have been less effective in increasing renewable energy technology deployment. Deployment of renewables for transportation has been limited in recent years, with liquid biofuel consumption remaining stable and sales of electric vehicles falling short of earlier forecasts. For industry, which is the second largest energy demand sector in Germany, no specific renewable energy market framework is in place.

The focus with regard to energy use in buildings should first be on improvements in energy efficiency and then on the deployment of renewable systems. Germany has taken considerable steps to improve its energy efficiency and recently introduced a national action plan for energy efficiency to accelerate improvements. However, the yearly energy productivity improvement rate stands at 1.6%, compared to the target rate of 2.1%. In addition, current renovation rates represent roughly half of the 2% per year target. The existing building stock therefore will need to be renovated at a higher rate in order to meet the energy productivity improvement goal, and policies should be considered that also support the installation of renewable heating systems in renovated buildings.

Going forward, the role that renewables will play in both the power and end-use sectors will determine at what rate Germany can continue to progress towards its greenhouse gas emission reductions and ambitious renewable energy targets.

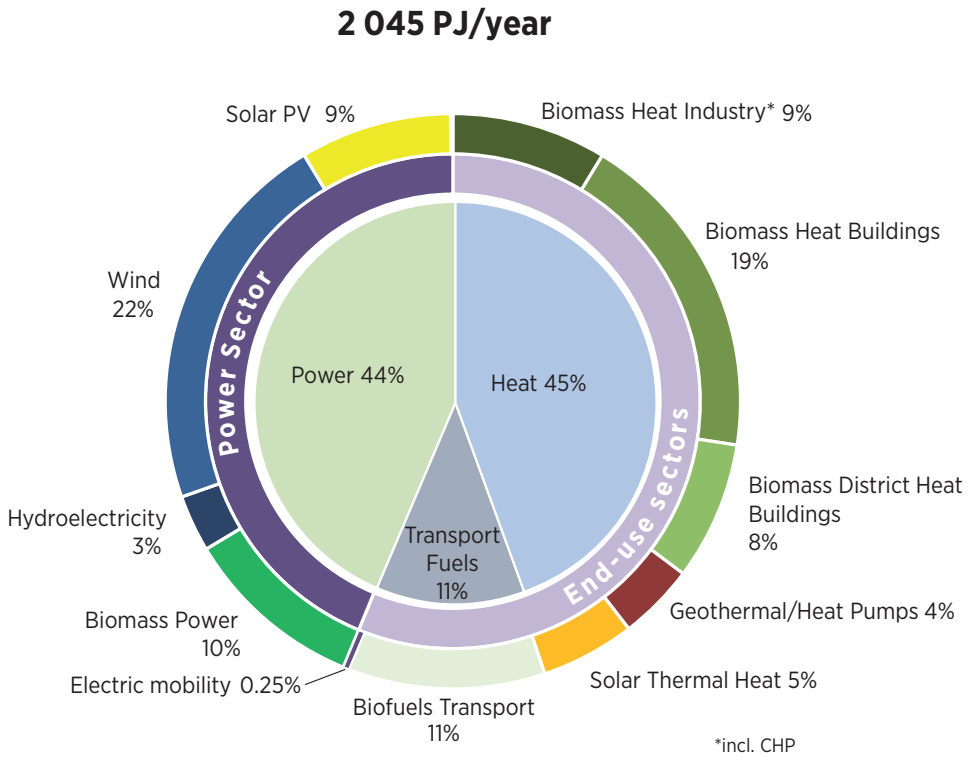
Findings from the *REmap Germany* roadmap to 2030

For the Reference Case, this roadmap builds on the 2014 report *Energy Reference Forecasts*, prepared for BMWi by Prognos AG, the Institute of Energy Economics at the University of Cologne, and the Institute of Economic Structures Research (GWS mbh).

For REmap, which aims to determine the feasible potential of renewable energy deployment, this baseline is combined with an analysis of technology options derived from a comprehensive set of data, including reports and information provided by the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB), BMWi, IRENA and others.

The REmap analysis shows that in the Reference Case, Germany reaches a 27% renewable energy share in the total energy mix by 2030. The Reference Case technology deployment is driven largely by renewable power generation. Solar photovoltaic (PV) applications at the utility scale and on rooftops would increase threefold, and installed wind capacity would double between 2010 and 2030. These are outcomes of policies that are focused primarily on the power sector, but that devote less attention to renewables in end-use applications for heating and cooling, as well as the transport sector.

Figure 2: Breakdown of renewable energy in total final energy consumption, by source and sector, Reference Case 2030



REmap shows the potential for additional renewable deployment utilising technologies available today. Deploying higher levels of renewable power technologies, as detailed in REmap, will ensure that Germany can realise its renewable energy target of 30%. In REmap 2030, two-thirds of Germany's total power generation is from renewables, and, even more importantly, half is from the variable renewable energy sources of solar and wind. Installed wind capacity reaches 88 gigawatts (GW), split between 72 GW onshore and 16 GW offshore. Solar PV reaches 75 GW, with more than three-quarters coming from distributed generation and over 10 GW coming from decentralised generation coupled with storage.

Importantly, REmap illustrates that there is a potential for renewables in end-use applications that is not yet fully captured by the *Energiewende*. If the potentials in heating and transport are utilised, Germany can increase its total renewable energy share beyond 30% of final energy. Increasing this share to between 30% and 37% will be cost-optimal depending on how the environmental benefits of individual technologies are valued and if costs are viewed from a business or a government perspective.

The technology options that enable these higher renewable shares are identified largely in the end-use sectors. Some of these technologies are more expensive than their fossil fuel counterparts when viewed from a levelised cost of energy perspective. However, these technologies (*e.g.*, heat pumps, electric vehicles) are also enablers. They allow end-use and power sector coupling to accommodate higher shares of variable renewable power, thereby reducing the need for other flexibility measures. They also ensure the development of heating and transport systems that are smart and sustainable, more affordable in the long-run, and a source of future knowledge and industrial growth. Germany will need to forge new ways of valuing the costs of these energy services by taking a holistic view that includes the economy-wide and energy system benefits of these services.

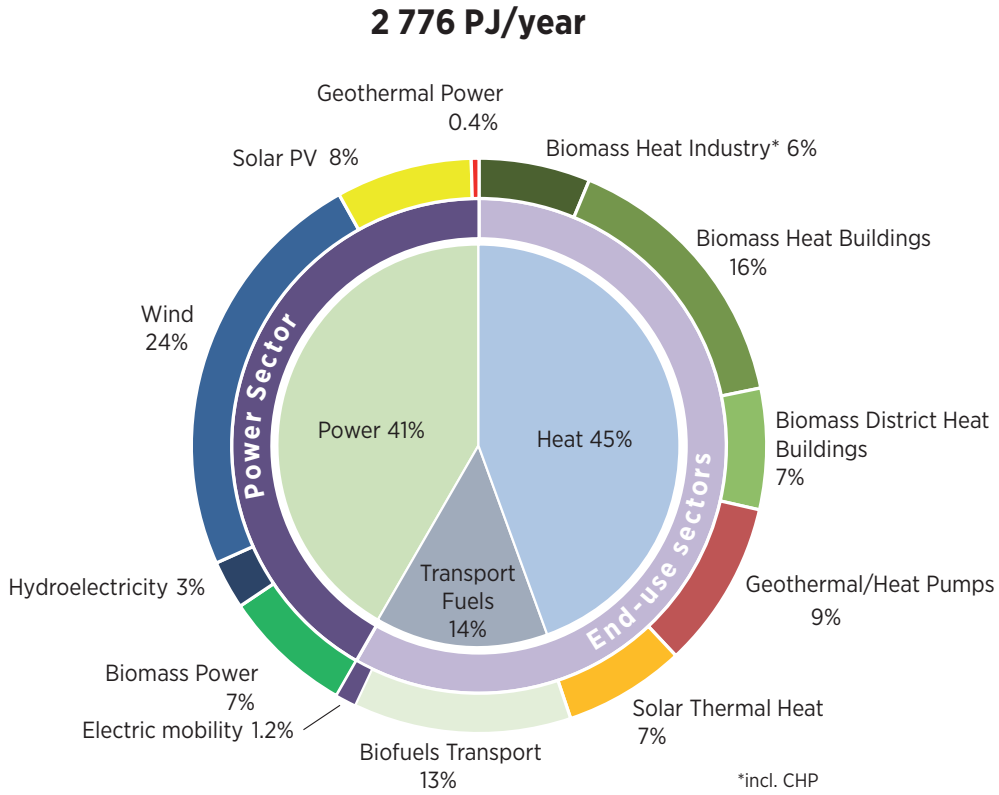
The end-use sectors offer significant additional renewable potential. If all of the technology options identified in REmap are deployed, the total installed heat pump stock can grow to over 6 million units, solar water heaters can exceed 100 million square metres (m^2) and the use of biomass for heating in industry and buildings can increase by 8 million tonnes per year by 2030, compared to the Reference Case. By 2030, the supply of renewable heat can more than double compared to current levels. There also are important benefits from increases in sector coupling, with the introduction of district heating systems that utilise heat pumps and solar thermal.

In the transport sector, where robust biofuel growth occurs in both the Reference Case and REmap, total biodiesel demand reaches nearly 9 billion litres and total ethanol demand reaches 3.4 billion litres, with two-thirds of this total being advanced ethanol. Electric mobility, coupled with renewable power generation, plays an equally important role, reaching 6.5 million electric vehicles by 2030. This includes not only electric vehicles and hybrids, but also e-bikes and electric vehicles used for freight transportation. By 2030, the share of the transport sector's energy consumption that will come from renewable sources will increase fourfold over today's levels, reaching more than 20%.

However, the deployment of many of these technologies is only beginning, and their potential, costs and synergies with other energy sectors is only starting to be understood. Importantly, as the share of electricity in final energy increases,

and as this electricity is increasingly sourced from variable renewable sources, transition costs need to be better understood and analysed. These can include investments in transmission and distribution infrastructure, measures to ensure flexibility in the power system, and the development of district heating systems and charging infrastructure.

Figure 3: Breakdown of renewable energy in total final energy consumption, by source and sector, REmap 2030



What are the cost and benefits of renewables for Germany, according to REmap?

Achieving this transformation will require, on average, USD 15.7 billion per year of investment to 2030 in renewable technologies (including investments for both the power and end-use sectors in both the Reference Case and REmap Options).

REmap assesses the cost of Germany's energy system from two perspectives: business and government. The business perspective annualises renewable energy investments with a national discount rate and accounts for the annual operation and maintenance costs as well as national fuel and carbon costs. It reflects how businesses and investors would perceive the investment opportunity. From this perspective, Germany

would save USD 2.4 billion annually by 2030 for the REmap renewable energy system relative to the Reference Case. This makes for a compelling case for higher renewable deployment. If these investments are viewed from the government perspective, which provides a macro-economic view and includes a higher discount rate of 10% and energy prices that exclude tax effects, renewables would have incremental costs of USD 4 billion per year in 2030.

Complementary infrastructure is not assessed, due to uncertainty about what those actual transition costs could entail. For instance, some of the end-use sector coupling technologies deployed in REmap (heat pumps, electric vehicles) can offer complementary services to the grid. Understanding how these services are provided, and their costs, will be crucial in the coming years to better assess the transition costs, or the savings, that can result from significantly higher renewable shares.

In both the business and government perspectives, however, a portfolio of technology options that permits a renewable share above 30% can be realised cost-optimally, when their benefits are accounted for. At a technology level, each option has the potential to bring important benefits in better energy security, improved human health and greenhouse gas mitigation. If all REmap Options were deployed, the total fossil fuel import costs in Germany would be reduced by almost USD 30 billion per year by 2030. Improved human health, from reduced outdoor air pollution, can save USD 1-2 billion per year in 2030, and climate change benefits in REmap can be valued at USD 2-8 billion per year in 2030. The total of all benefits is USD 33-40 billion per year in 2030, much higher than the total system costs of USD 4 billion when viewed from the government perspective.

In REmap 2030, energy-related carbon dioxide (CO_2) emissions will decline from some 789 million tonnes in 2010 to 540 million tonnes in the Reference Case. The REmap Options result in an additional reduction of 101 million tonnes, to 439 million tonnes in 2030, representing a 55% reduction in CO_2 over 1990 levels for the energy sectors covered in this study.

What are the challenges and solutions?

Generating 50% of electricity from variable renewable energy will require changes in the power system. After intensive discussions, Germany has decided to undertake an electricity market reform, dubbed “electricity market 2.0”, highlighting the importance of flexibility measures, including cross-border exchange, demand-side management (including smart grids/metering that incentivises customers to save energy, and other measures) and sectoral linkages between the power and end-use sectors. In particular, sectoral linkages enable important renewable energy potential and reduce the need for costly measures such as curtailment or battery storage. The use of combined heat and power (CHP) generation coupled with heat storage, heat pumps and electric vehicles all can be scheduled to accommodate the variability in solar and wind power generation.

In this context, *REmap Germany* shows that the largest potential for additional deployment of renewables beyond the Reference Case is in the heating and transport sectors. These sectors also will face the biggest challenges to deployment, especially because the policy focus in these areas is still somewhat limited, and progress is needed to realise further growth in renewables deployment.

The key factor for increasing both the energy efficiency of the building stock, and the deployment

of renewable systems, is the rate at which old buildings are renovated. Even with a 2% per year renovation rate (in 2014, it was under 1.0%), and approximately 10% of the building stock being newly built to 2030, only about 40% of the total building stock in 2030 will have gone through some level of renovation. Therefore, additional efforts will need to be made to expand the rate of energy efficiency retrofits in old buildings, and to link these retrofits with increased renewable energy deployment.

The industry sector has very specific heating supply requirements, and today, renewables play only a modest role in supplying process heat. However, REmap shows that additional potential exists. For low-temperature heating applications, both solar thermal technology and heat pumps offer potential. Biomass is, and will remain, the largest renewable energy source, but it should be allocated primarily to applications that require medium- and high-temperature heat. Additionally, the possibility of further electrification of the sector for heating needs should be considered.

In the transport sector, all options need to be considered to increase the renewables share from what currently is the lowest of all sectors. Importantly, electric mobility will need to be increased, which will allow for better demand-side management of variable electricity generation. However, increased investment in charging infrastructure and incentives for electric vehicles are needed to enable this significant growth.

What does European integration mean for Germany to reach its targets?

Germany consumes approximately 20% of the European Union's (EU) energy, and the country will play a major role in helping the EU realise its regional energy and climate targets. Germany will not achieve its REmap 2030 potential without further market integration with the EU. Germany is at the centre of European energy markets and is linked closely with the electricity markets of its neighbours. Regional integration already is regarded as a core component to strengthen the EU's coupled power markets. Integrated markets offer greater flexibility and balancing potential as well as gains from using smoothing effects. The next steps are finalising and implementing the 10 European network codes, taking a co-ordinated approach to strengthening grid infrastructure at the national level and expanding cross-border trade. Finally, a larger unified European market will help to reduce equipment and project costs.

Expanding the focus of Germany's energy transition

The *Energiewende* is a visionary, long-term and evolving process. Its development will continue, but ensuring Germany's aim to build one of the world's most energy-efficient, sustainable and low-carbon energy systems will require expanding the *Energiewende's* focus beyond the power sector and making deliberate efforts to link sectors that have remained largely separate. In this way, the next step of the *Energiewende* will define what a transition to very high shares of renewables will look like and lead the way in the global energy transition.

In making this new transition, this analysis shows that realising Germany's climate targets and long-term renewable energy goals will require efforts in both improving energy efficiency and deploying additional renewable energy in both the power and end-use sectors.

Efficiency measures and the renewable heating sector are the potential Achilles' heel of the

Energiewende in the medium term. Renovation targets need to be met, and efficiency regulations in the building sector must be harmonised with renewables targets to achieve the best technical and economic solutions. To increase the share of renewables in heating, a combination of building-type specific efficiency and technology-neutral renewable heating targets, supported with continued finance programmes, will help to achieve both goals.

The industry sector is, in large part, not yet part of the *Energiewende*. Therefore, benchmarks and targets need to be established for supplying industrial process heat based on renewable energy. The development of a dedicated programme to increase the uptake of renewables for process heat generation is missing and is required urgently. Innovative policy approaches need to ensure continued competitiveness for the sector.

The transport sector will be among the most challenging areas for the future of the *Energiewende*. The uptake of electric vehicles in Germany is progressing slowly, and specific policy measures for electrification are required that also incentivise investments in charging stations and their access and use by all. Advanced biofuels represent an important enabling technology for applications such as aviation and freight. The technologies exist to use non-food feedstocks to provide biofuels, but costs need to be driven down through economies of scale. To utilise the limited availability of biomass resources in the most sustainable and cost-effective way across competing uses, a Germany-specific bioenergy resource plan needs to be developed.

The new power market design that is being planned in Germany should create business opportunities for heating storage and demand-side management technologies as well as sectoral linkages to support grid integration of renewable power supply. Regular reviews are needed to ensure its effectiveness.

The *Energiewende* in Germany will influence international energy markets. The EU electricity market needs to finalise implementation of the 10 network codes and to facilitate investments in transmission infrastructure. The EU member states need to develop and co-ordinate mechanisms to address energy security situations, update market design to deliver secure and affordable energy supply, and foster research, development and deployment (RD&D) in transmission networks.

To date, Germany has played a remarkable leadership role in the promotion of renewables in the international arena. It now has the opportunity to show the world what the true energy system of the future will be. The country has started on a process that will continue for years to come, and will require constant evolution. In making this contribution to the German debate, it is the hope of IRENA that with the solutions outlined in this report, Germany can realise its full renewable energy potential and, in the process, continue to forge best practices, create awareness and spread knowledge worldwide, and remain a pioneer in the renewable energy field.

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