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RENEWABLE ENERGY PROSPECTS FOR **CENTRAL AND SOUTH-EASTERN EUROPE ENERGY CONNECTIVITY**

CESEC

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The International Renewable Energy Agency (IRENA) serves as the principal platform for international co-operation, a centre of excellence, a repository of policy, technology, resource and financial knowledge, and a driver of action on the ground to advance the transformation of the global energy system. An intergovernmental organisation established in 2011, 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 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.

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ABBREVIATIONS

CESEC	Central and South-Eastern Europe Energy Connectivity
CHP	Combined heat and power
CO_2	Carbon dioxide
EC	European Commission
ENTSO-E	European Transmission System Operator
ETS	Emissions Trading Scheme
EJ	Exajoule
EU	European Union
EV	Electric vehicle
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross domestic product
GHG	Greenhouse gas
GJ	Gigajoule
GW	Gigawatt
GWh	Gigawatt-hour
ICE	Internal combustion engine
IRENA	International Renewable Energy Agency
LCOE	Levelised cost of electricity/energy
m^2	Square metre
MSW	Municipal solid waste
Mt	Megatonne
MW	Megawatt
MWh	Megawatt-hour
NECP	National Energy and Climate Plan
NTC	Net power transfer capacity
OCGT	Open-cycle gas turbine
PJ	Petajoule
PPA	Power purchase agreement
PV	Photovoltaic
t	Tonne
TPES	Total primary energy supply
TWh	Terawatt-hour
UN	United Nations
USD	United States dollar
VRE	Variable renewable energy

COUNTRY CODES

CESEC members

Country code	Official short country name (UN)	Official full country name (UN)
AL	Albania	Republic of Albania
AT	Austria	Republic of Austria
BA	Bosnia and Herzegovina	Bosnia and Herzegovina
BG	Bulgaria	Republic of Bulgaria
HR	Croatia	Republic of Croatia
GR	Greece	Hellenic Republic
HU	Hungary	Hungary
IT	Italy	Republic of Italy
MK	North Macedonia	Republic of North Macedonia
MD	Republic of Moldova	Republic of Moldova
ME	Montenegro	Montenegro
RO	Romania	Romania
RS	Serbia	Republic of Serbia
SK	Slovakia	Slovak Republic
SI	Slovenia	Republic of Slovenia
UA	Ukraine	Ukraine
XK	Kosovo*	Republic of Kosovo*
CY	Cyprus	Republic of Cyprus

Non-CESEC countries

Country code	Official short country name (UN)	Official full country name (UN)
CH	Switzerland	Swiss Confederation
CZ	Czech Republic	Czech Republic
DE	Germany	Federal Republic of Germany
FR	France	Republic of France
MT	Malta	Republic of Malta
PL	Poland	Republic of Poland

* *The designation Kosovo* is without prejudice to positions on status and in line with the United Nations Security Council Resolution 1244 (1999).*

SUMMARY FOR POLICY MAKERS

CONTEXT

The International Renewable Energy Agency (IRENA), at the request of the European Commission (EC), has developed a Renewable Energy Roadmap (REmap) analysis for the Central and South-Eastern Europe Energy Connectivity (CESEC) area. This study assesses the potential for renewable energy deployment in the CESEC region by 2030, beyond existing plans. It also analyses how an accelerated uptake of renewables would affect energy costs, investments, fossil-fuel consumption, greenhouse gas (GHG) emissions, the environment and people's health. The results can contribute to strengthening energy and climate planning processes in European Union (EU) member states and in Energy Community Contracting Parties.

The CESEC initiative spans nine EU member states (Austria, Bulgaria, Croatia, Greece, Hungary, Italy, Romania, Slovakia and Slovenia) and eight Contracting Parties of the Energy Community (Albania, Bosnia and Herzegovina, Kosovo[*], Montenegro, North Macedonia, the Republic of Moldova, Serbia and Ukraine). This represents a heterogenous group in terms of economic development, per capita energy consumption, energy sources and current levels of renewable energy use.

EU member states account for roughly three-quarters of CESEC energy consumption. Among the other eight parties, Ukraine accounts for more than two-thirds of final energy consumption.

The region remains highly dependent on fossil fuel (mainly oil and gas) imports and has proved to be highly exposed to cuts in gas supply in past years. CESEC members also share the need for thorough modernisation in the energy sector, with numerous fossil fuel-fired generation assets due for retirement within a decade.

CESEC members also suffer from poor air quality due to fossil fuel combustion, which represents a real and significant threat to the health of citizens. South-Eastern European cities have some of Europe's highest levels of air pollution.

RENEWABLE ENERGY ROADMAP APPROACH

The REmap study first analyses the expected deployment of renewables in the CESEC region by 2030 under a Reference Case, which assumes the implementation of existing plans, agreed policies and targets, or the continuation of current trends.[1] It then identifies renewable energy options (REmap options) available on a country-by-country basis to accelerate the deployment of renewables by 2030.

This designation is without prejudice to positions on status and in line with the United Nations Security Council Resolution 1244 (1999).

1 For more detail on the sources used to build the Reference Case for each CESEC member, see Annex A.

These renewable-based options can then be compared with conventional technologies in terms of the levelised cost of energy (LCOE) to determine the costs of substitution. This study covers all aspects of energy use, including power and district heat supply as well as end uses in buildings, industry and transport.

The analysis aims to identify a realistic and cost-effective portfolio of options to scale up renewables faster. IRENA's REmap analysis aligns the energy investment and policy agenda with key climate and sustainability goals, including the Paris Agreement, the United Nations Agenda for 2030 and Sustainable Development Goals. The challenges to implement each identified option inevitably vary from country to country.

Country-level assessments are reinforced by the study's broad regional overview. An hourly dispatch simulation for the entire interconnected European power system in 2030 helps to evaluate the technical feasibility of implementing REmap options in the electricity sector at the regional and national levels.

HOW CESEC MEMBERS COULD SCALE UP RENEWABLES

Energy demand in the CESEC region is expected to increase slightly by 2030, about 5% above levels in 2015, the base year for this analysis.[2] For the Energy Community Contracting Parties, this increase is expected to be substantially larger – about 26% above 2015 consumption – according to existing projections.

In the Reference Case, the share of renewable energy in CESEC members is expected to show slow growth over the decade, rising from 16% of gross final energy consumption in 2015 to about 24% in 2030. In CESEC's eight Contracting Parties of the Energy Community, the share of renewables in the energy mix is expected to grow from 10% in 2015 to about 19% in 2030.

Region-wide potential

The full deployment of renewable options identified in this study could raise the 2030 renewables share to 34%, cost-effectively, for the whole CESEC region, compared to 24% in the Reference Case. In CESEC's eight Contracting Parties of the Energy Community, the REmap scenario could boost renewables to 30% by 2030, compared to 19% in the Reference Case.

2 *The year 2015 is the most recent year for which a comprehensive historic dataset was available for all CESEC members. Demand projections to 2030 reflect the Reference Case with information available to IRENA as of September 2019. Further commitments on energy efficiency improvements potentially adopted by CESEC members could have a positive effect in terms of demand reduction and renewables share by 2030, both in the Reference Case and the REmap scenarios. For more detail on the sources used to build the Reference Case for each CESEC member, see Annex A.*

In the REmap scenario, the overall consumption of renewables in the CESEC region roughly doubles by 2030 compared to 2015. Renewable power and the electrification options to replace fossil fuels for heating and transport would together account for about two-thirds of the additional potential identified. Biomass-based district heating, solar thermal and liquid biofuels would account for the bulk of the remainder.

In absolute terms, renewable power would account for 51% of total gross final renewable energy consumption, renewable heat for 42% and liquid biofuels for the remaining 7%. Hydro, solar and wind would account for around 30%, 27% and 22% of the renewable power generation, respectively, with the bulk of the remainder being bioenergy. The renewable heat sector would be dominated by solid biomass. Overall, bioenergy (solid biomass, biofuels and biogas) would account for about half of total renewables consumption by 2030.

Potential for different CESEC members

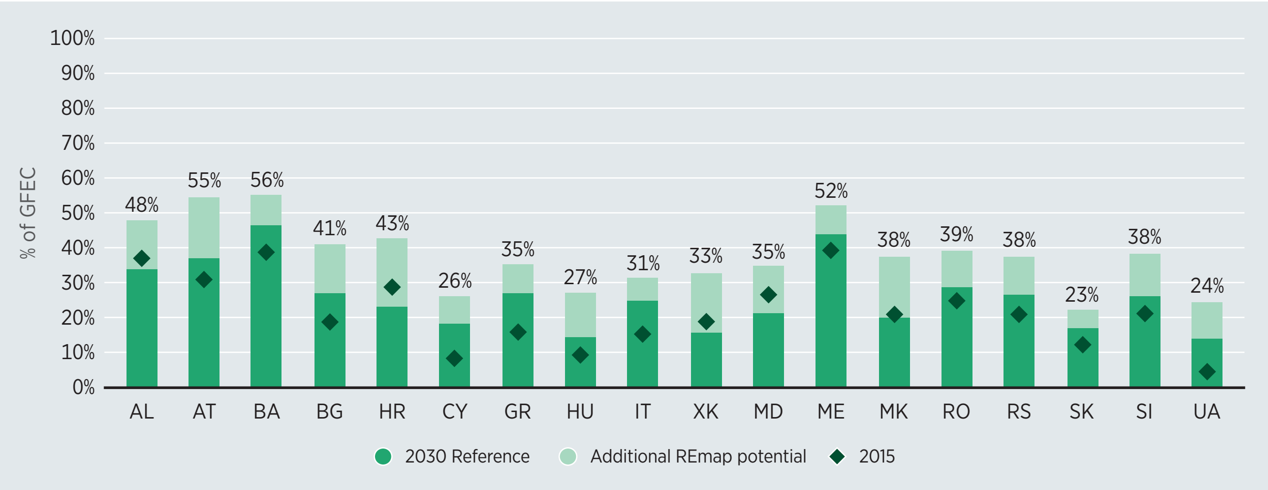
A wide range of factors influences the realistic, cost-effective potential for growth in renewable share for each CESEC member. These include the technical potential and expected costs of realising such potential, the economic and energy market conditions of the country, the current energy mix and age profile of existing generation assets, and the pipeline for new developments, among others.

While the conditions for deployment vary significantly across the region, IRENA estimates that all CESEC members have potential to increase their renewable energy shares beyond the Reference Case by 2030. Country-specific economic potential would support overall renewable shares ranging from 23% to 56%. The additional potential identified, compared to the Reference Case, ranges from 6% to 20%.

Renewables in the power sector

With the continuation of current trends reflected in the Reference Case, by 2030 the power systems of the CESEC region would still rely heavily on fossil-based generation. Coal generation would still represent almost one-sixth of overall generation in CESEC, and almost one-third of the generation in the eight Contracting Parties of the Energy Community. The REmap Case presents a cost-effective way to replace coal and set the course for a sustainable energy future.

Figure ES.1 Share of renewables in gross final energy consumption by CESEC member (%)



Based on IRENA analysis

Note: Excludes end-use sectors other than buildings, industry, transport. Excludes final non-energy use. AL: Albania; AT: Austria; BA: Bosnia and Herzegovina; BG: Bulgaria; HR: Croatia; CY: Cyprus (while not part of CESEC, Cyprus is included in the scope of this study); GR: Greece; HU: Hungary; IT: Italy; XK: Kosovo; MD: Republic of Moldova; ME: Montenegro; MK: North Macedonia; RO: Romania; RS: Serbia; SK: Slovakia; SI: Slovenia; UA: Ukraine.*

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In the REmap Case, renewable power capacity grows from 109 gigawatts (GW) in 2015 to 265 GW in 2030. This includes 116 GW of solar photovoltaic (PV), 58 GW of wind, 67 GW of hydro and 22 GW of biomass power. With the appropriate policies in place, about 55% of the electricity consumed by CESEC members could come from renewable sources (around 620 terawatt-hours [TWh] of renewable power generation in 2030, compared to 253 TWh in 2015).

The hourly simulations of the REmap scenario indicate that such a power generation mix could be feasible at a regional level if CESEC members use interconnections (existing and already planned) efficiently. The REmap capacity mix would also result in a reduced need for electricity imports to the region. At the same time, further integration of power systems needs to be linked to progressive pricing of externalities to avoid carbon leakage.

Regional co-operation in planning for the security of supply and power sector adequacy will be fundamental to realising the regional vision for the power sector laid out in the REmap scenario. This will be particularly important for countries with limited experience and incipient domestic renewable energy markets. Replacing large volumes of conventional generation with renewables would be facilitated by a concerted effort. Closer co-operation with neighbours will likely result in lower energy costs than a purely national approach.

Renewable heating systems

The REmap analysis suggests that a transition to biomass-based district heating systems is among the largest options to accelerate renewables in the region and reduce dependence on imported fossil fuels. Efficient electrification of district heating systems – possibly connected to geothermal sources – can further contribute to improving efficiency and introducing renewables in the sector. In the REmap Case for the CESEC region, the overall share of renewable energy in district heating systems grows to almost half of total generation by 2030.

This measure alone could reduce fossil fuel demand by 251 petajoules (PJ), an amount comparable to the natural gas consumption of Austria.

Besides district heating, accelerating electrification with heat pumps in buildings and industry could reduce fossil fuel consumption by about 11% (or 583 PJ) in 2030, below the Reference Case. The electrification of buildings needs to be considered in conjunction with improvements in the overall energy performance of the building envelope – for new construction as well as renovations – to tap the full potential for fuel demand reductions.

In addition to increased electrification, solar thermal can provide affordable hot water in residential and commercial buildings as well as competitive low temperature heat for certain industry sub-sectors. Most CESEC members can substantially scale up deployment of this technology, which has the potential to reduce demand for fossil fuels in the region's heat sector by about 3% in 2030 compared to the Reference Case.

Renewables in transport

Electrification with renewable power is a key option for the decarbonisation of the transport sector. Electric vehicles (EVs) are typically three to four times more energy efficient than internal combustion vehicles. In addition, the use of electricity enables an easier shift to renewables, as renewable power options are already cost-effective.

The REmap analysis for the CESEC region suggests that with appropriate policies in place, most sales of light duty vehicles could be EVs by 2030. Overall, about 20% of the vehicle stock could potentially be replaced by 2030. Accelerating the electrification of road transport could reduce fossil fuel demand in CESEC by about 294 PJ below the Reference Case in 2030, an amount comparable to the total energy consumption in the transport sector of Ukraine.

Liquid biofuels – both advanced and conventional – can also be significantly scaled up in CESEC countries to supply the existing stock of vehicles with internal combustion engines (ICEs) and to be used in transport modes where electrification is still not viable. The use of blended liquid biofuels could roughly triple by 2030 with sustainable feedstocks available in the region, compared to 2015. By 2030, biofuels could account for about 9% of energy consumption for transport in CESEC countries (or 306 PJ, an amount larger than twice the total energy consumption for transport in Bulgaria).

BENEFITS OF THE REMAP SCENARIO

CESEC members will need to scale up investments to modernise their energy systems over the next decade regardless of the choice of technologies. IRENA estimates the cumulative energy sector investments[3] required in the Reference Case in the CESEC region at EUR (euro) 303 billion (about USD [US dollars] 336 billion) over the period 2015-2030. In the REmap Case, CESEC members would invest about an additional EUR 78 billion cumulative until 2030, compared to the Reference Case.

With these additional investments, CESEC members can build an energy system that is substantially less reliant on imported natural gas and oil while delivering energy at competitive costs. Such reduced reliance on (imported) fossil fuels brings multiple benefits, including not only a significantly reduced negative impact on the environment and the health of citizens, but also improved sector stability as countries are progressively less exposed to unforeseeable swings in the international prices of energy commodities.

The COVID-19 pandemic has devastated people's lives around the world and thrown economies into severe crises – including those of CESEC members. The energy sector is at the centre of the economy and will be a crucial element of the recovery post-COVID-19.

An energy system fuelled primarily by renewable sources in the CESEC region is technically feasible and economically desirable. By placing energy transition investments, regulations and policies at the centre of recovery plans, policy makers can simultaneously alleviate the economic impacts of the COVID-19 crisis, stimulate economic growth and create jobs, while accelerating the transformation of the energy sector.

Deploying all the additional renewable options identified in the REmap scenario could deliver savings for CESEC members in terms of LCOE of energy services, estimated at EUR 3.4 billion/year in 2030, compared to the Reference Case. Several factors could reduce these estimated savings,[4] including high costs of capital or persistently low international fossil fuel prices. Similarly, additional grid infrastructure investments not accounted for in this study – where needed in addition to the Reference Case – could reduce the estimated cost advantage of renewables. Conversely, faster than expected technology improvements could further improve the economics of renewables.

In terms of the impact on fossil fuel import dependency, the REmap scenario would result in natural gas demand reductions estimated at 18% (about 893 PJ) below levels in the Reference Case, an amount comparable to the annual gas demand in Ukraine. Oil demand reductions are also substantial, estimated at 14% (about 564 PJ), comparable to today's annual oil consumption of Croatia and Greece combined.

Accelerating a transformation towards a renewables-based energy system is one of the key cost-effective actions available for CESEC members to meet the goals of the Paris Agreement. The full deployment of REmap options identified in this study would deliver additional emissions reductions estimated at 165 megatonnes (Mt) of carbon dioxide (CO_2)/year, 21% below the Reference Case in 2030. This amount is comparable to today's total emissions of Romania and Bulgaria combined. Of these additional emissions reductions, an estimated 51 Mt CO_2/year (20% below the Reference Case), could be realised in CESEC's eight Contracting Parties of the Energy Community.

Renewables, in combination with energy efficiency and electrification of heat and transport, reduce the need for combustion of polluting fossil fuels and contribute to a substantial improvement in air quality and the health of citizens in the region. The economic value of avoided air pollution with the deployment of the REmap scenario in the CESEC region is estimated at between EUR 5 billion and EUR 20 billion per year in 2030.

3 Including power and distributed heat generation assets as well as heat production equipment in buildings and industry. Excluding infrastructure investments.

4 A sensitivity analysis evaluating the impact of these factors in the estimated savings can be found in Annex B.

Similarly, the externality costs related to carbon emissions that can be avoided by transitioning to renewables are substantial, ranging between EUR 2 billion and EUR 12 billion per year in 2030.[5]

Overall, IRENA estimates the economic value of avoided energy sector externalities with the deployment of the REmap scenario in the CESEC region at between EUR 8 billion and EUR 32 billion per year by 2030.

When the savings calculated by a pure cost-benefit analysis of technologies are added to the estimated economic value of the avoided health and environmental damages, the REmap scenario delivers total benefits to society estimated at between EUR 11 billion and EUR 35 billion per year by 2030.

By investing in renewables, CESEC members can build an energy system that is substantially less reliant on imported fossil fuels while delivering energy at competitive costs

KEY ACTIONS TO ENABLE THE TRANSFORMATION

Achieving the shift to modern, clean, competitive and regionally integrated energy systems in the CESEC region will require decisive policy action at the national and regional levels. Developing a long-term vision in national plans is a key and important first step. However, the necessary investments will also depend on adopting appropriate regulatory and market frameworks. Neighbours can work closely with each other to reduce costs and tap the synergies of a regional approach.

At the national level, CESEC members are advised to prioritise the improvement of investment conditions for renewables in their respective markets.

- Although renewables are ready to compete, they need a level playing field, with open, stable and transparent regulatory frameworks to enable fair competition with fossil technologies. Key elements of such a level playing field are a progressive elimination of remaining subsidies to fossil fuels – including through indirect mechanisms, such as below-market regulated energy prices – and a fair set of market and operation rules, adapted to the intrinsic variable nature of renewable technologies.

Table ES.1 Investment needs and economic benefits of the REmap scenario

Accumulated, incremental investments until 2030 (Δ REmap vs Reference)	**EUR 78 billion**
Estimated LCOE savings	EUR 3.4 billion/year in 2030
Estimated avoided air pollution damages	EUR 5-20 billion/year in 2030
Estimated avoided environmental costs related to climate change	EUR 2-12 billion/year in 2030
Total savings and avoided externality costs REmap vs Reference Case	**EUR 11-35 billion/year in 2030**

Based on IRENA analysis. For more detail on the definitions of the metrics for investments and savings, please consult the appendix of REmap methodology and data in REmap: Roadmap for a renewable energy future (IRENA, 2016c).

5 *A range of USD 17 to USD 80 per t of CO_2 is assumed for carbon costs, and a wide range of unit external costs is assumed for air pollutants (IRENA, 2016d).*

- The energy supply sector provides an immediate opportunity for scaling up renewable investments in the region, as renewable technologies are cost-competitive, and there is a need to replace obsolete fossil generation assets. However, policy makers need to foster the transition towards renewables in end-use sectors as well. Planning for an acceleration of renewable electrification of heat and transport is fundamental to developing the markets and the infrastructure as quickly as possible and to tapping the large potential benefits.

- The high cost of capital has been an important barrier for renewable investment in several CESEC member countries. Even under challenging macroeconomic conditions, national energy policy can go a long way in reducing perceived risks for investors, for example by adopting best practices in auctions[6] and administrative procedures. Additionally, CESEC members can work together with the EU, the Energy Community Secretariat, as well as with multilateral financial institutions to develop risk-mitigation mechanisms tailored to the specific conditions and needs of the region.

- Cities in the region will benefit from a cleaner energy system and can also play an important role in driving the transformation. Co-ordination of national energy planning with subnational entities can accelerate the transition in areas such as electromobility and the adoption of distributed renewables. Additionally, decentralised structures such as renewable energy communities have a role to play in mobilising private investment and securing public acceptance.

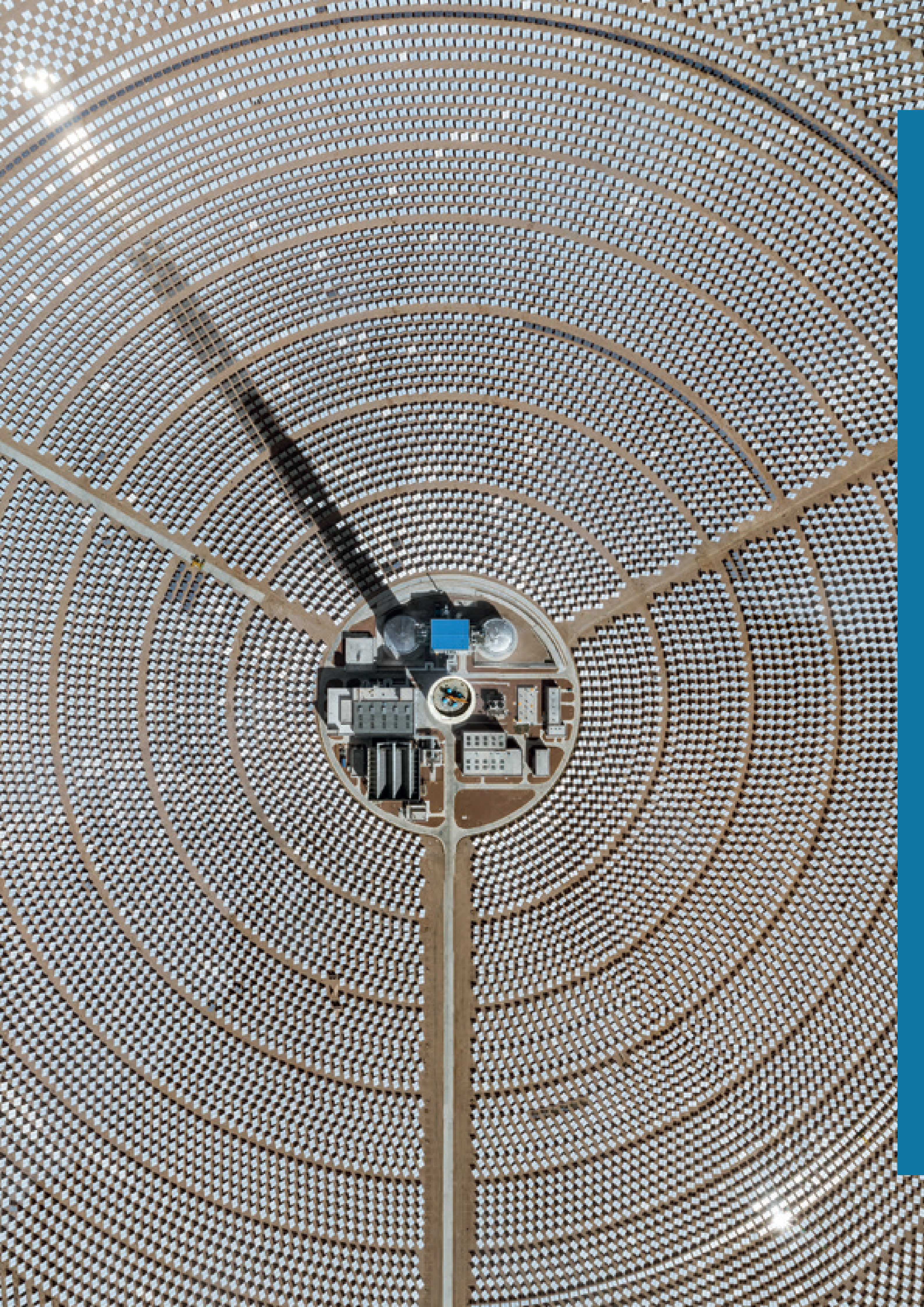
At the regional level, CESEC members should work closely with neighbours to tap the synergies of regional co-operation. Co-operation can happen at multiple levels involving both the *software* and the *hardware* of energy systems. This can accelerate the transition by mutual experience-sharing in developing and implementing policies and regulations and by reducing the costs of balancing energy systems and security of supply. Open co-operation at the regional level can also increase the attractiveness of renewable energy in individual countries – particularly for smaller CESEC members – by reducing the risk perception for investors and increasing addressable market size for developers.

- One key area for regional co-operation is the transition towards integrated electricity markets, which will be instrumental for cost-effective decarbonisation of national power systems. Co-operation towards building functional regional markets is also applicable to other renewable carriers with large potential for trade in the CESEC region, such as biomass.

- Integrated markets require integrated infrastructure. In this area there is also significant potential for co-operation. CESEC members could work towards regional or subregional co-ordinated investment plans to share the costs and benefits of key infrastructure for the transition to renewables such as equipment manufacturing facilities, transboundary hydro projects, biofuel conversion plants and EV charging infrastructure.

- Some CESEC members will need external help to develop their national plans, address socio-economic challenges and mobilise the required investments. European institutions, international organisations, development agencies and multilateral banks can and should play important roles in supporting these countries moving forward.

6 *In 2018, the European Bank for Reconstruction and Development and the Energy Community Secretariat, in collaboration with IRENA, issued joint policy guidelines to help countries design and implement competitive selection processes for supporting renewable energy. The guidelines are available from: www.ebrd.com.*



INTRODUCTION

THE CESEC INITIATIVE

The European Commission's (EC) initiative for Central and South-Eastern Europe Energy Connectivity (CESEC) works to accelerate the integration of Central Eastern and South-Eastern European gas and electricity markets. The CESEC High Level Working Group was set up by Austria, Bulgaria, Croatia, Greece, Hungary, Italy, Romania, Slovakia, Slovenia and the European Union (EU) in February 2015. They were joined later by eight Energy Community Contracting Parties: Albania, Bosnia and Herzegovina, Kosovo*, Montenegro, North Macedonia, Republic of Moldova, Serbia and Ukraine (European Commission, 2020).

The initial aim of the group was to co-ordinate efforts to facilitate the swift completion of cross-border and trans-European projects that diversify gas supplies to the region and to develop regional gas markets and implement harmonised EU rules to ensure the optimal functioning of the infrastructure.

At the fourth CESEC ministerial meeting in Bucharest in September 2017, energy ministers signed a memorandum of understanding extending the scope of CESEC co-operation. It now also includes a joint approach on electricity markets, energy efficiency and renewable development; a list of priority projects to build an interconnected regional electricity market; and specific actions to boost renewables and investment in energy efficiency (European Commission, 2020).

IRENA'S ENGAGEMENT IN THE REGION

In January 2017, following the adoption of the Abu Dhabi *Communiqué on accelerating the uptake of renewables in South East Europe* (Albania *et al.*, 2017), the International Renewable Energy Agency (IRENA) set up a regional initiative in South-East Europe to support the growing efforts of countries of the region in creating frameworks conducive to renewable energy investments.

The communiqué and regional initiative were the result of extensive consultation, including a validation meeting co-hosted by the Romanian government in Bucharest in October 2016. Through this process, IRENA was able to better identify the specific needs and priorities of countries in the region and the potential areas where the initiative could add value and impact.

Building on the agreed priority areas for collaboration, IRENA conducted various capacity-building activities and analyses in areas of mapping renewable energy resources, long-term planning for renewable energy deployment, integration of variable renewable energy (VRE) sources and financing renewable energy projects. The report *Cost-competitive renewable power generation: Potential across South East Europe* (IRENA, 2017d), launched in January 2017, quantifies the region's vast and unexploited renewable potential, while the *Renewables readiness assessment for Republic of Moldova* (IRENA, 2019e), completed in 2019, proposes key actions to accelerate renewable energy deployment on a country level.

* *This designation is without prejudice to positions on status and in line with the United Nations Security Council Resolution 1244 (1999).*

Through its South-East Europe Initiative, IRENA has supported various regional processes with analytical input and participation in discussions. For example, to assist the ongoing reforms of renewable energy support schemes, IRENA conducted regional and national workshops and contributed to the development of policy guidelines to help countries design and implement competitive selection processes (EBRD and Energy Community Secretariat, 2018). Also in the context of the South-East Europe Initiative, IRENA has recently published the *Renewable energy market analysis: Southeast Europe* report (IRENA, 2019b) exploring the energy landscape in the region and the socio-economic benefits of transforming the region's energy systems.

IRENA's engagement in the region is aligned with the CESEC initiative's renewable energy action plan. IRENA has been supporting the development and implementation of CESEC's renewable's agenda since its inception and contributes regularly to the discussions in high-level meetings as well as the Renewables Working Groups.

Back in February 2018, IRENA released a study, *Renewable energy prospects for the European Union* (IRENA, 2018c), identifying cost-effective renewable energy options for EU member states up to 2030. The present study updates and deepens the analysis for EU members who are part of CESEC and extends the scope to the Contracting Parties of the Energy Community to reach full CESEC coverage.

CESEC'S ENERGY CHALLENGES

The region that is covered by the CESEC initiative[7] – spanning over nine EU member states and eight Contracting Parties of the Energy Community – is heterogenous in terms of economic development, energy consumption per capita, and supply mix, as well as in current levels of renewable energy development.

EU member states account for roughly three-quarters of the final energy consumption of the CESEC region. Among the Energy Community Contracting Parties, Ukraine is by far the largest consumer, accounting for more than two-thirds of final energy consumption.

Ensuring security of the energy supply has been a key issue of concern shared by Central and South-East European countries, which led to the creation of the CESEC initiative. The region is highly dependent on fossil fuel imports and has been exposed to cuts in natural gas supply in the past, which illustrate the potential vulnerability and impact of external disruptions. Most CESEC members have limited diversity in their natural gas supply (CESEC Members, 2015).

Besides fuel import dependence, another pressing issue for multiple CESEC members is the need for modernisation of the energy sector. A profound transformation will be required over the next decade as a large fraction of the existing fossil fuel-fired power generation assets have reached or are close to reaching the end of their operational lives. For some CESEC members, these assets still represent the bulk of their generation capacity. For these countries, the challenge is greater, as they face the need for an almost complete overhaul of their power systems within the next 10-15 years.

While largely absent from the energy policy debate, the energy sector's impact on health is also an important challenge for the region. Poor air quality driven by the combustion of fossil fuels is a real threat to the health of citizens in the CESEC region. The European Environment Agency estimates that about 400 000 people die prematurely in Europe each year because of air pollution (European Environment Agency, 2019). South-Eastern European cities have some of Europe's highest air pollution levels. Air pollution not only causes adverse human health effects, but can also reduce agricultural yields, cause damage to forests and fisheries, and deteriorate buildings and infrastructure (IRENA, 2019b).

7 The CESEC initiative includes: Albania, Austria, Bosnia and Herzegovina, Bulgaria, Croatia, Greece, Hungary, Italy, Kosovo, Montenegro, North Macedonia, Republic of Moldova. Romania, Serbia, Slovakia, Slovenia and Ukraine. Cyprus, while not part of CESEC, is also included in the scope of this study.*

** The designation Kosovo* is without prejudice to positions on status and in line with the United Nations Security Council Resolution 1244 (1999).*

The socio-economic conditions of some CESEC members – including substantially lower levels of income per capita than the EU average, higher levels of perceived investment risk, and substantial employment related to fossil industries – present additional barriers that need to be overcome to address the above-mentioned challenges while ensuring energy affordability for citizens and improving the countries' economic competitiveness (IRENA, 2019b).

EUROPEAN ENERGY AND CLIMATE POLICY CONTEXT

Following the EU's policies and national targets for renewable energy and energy efficiency in the period from 2009 to 2020, the EU adopted in 2018 and 2019 a new set of regulations and directives that govern Europe's energy transition for the period from 2020 to 2030. This Clean Energy Package includes new EU-binding targets for renewable energy and energy efficiency for 2030, as well as a requirement for EU member states to develop integrated National Energy and Climate Plans (NECPs) addressing all five key dimensions[8] of the Energy Union, to be submitted by January 2020. For some EU member states, draft versions of these plans were available in time to be considered as part of this study.

Similar to EU member states, Energy Community Contracting Parties have adopted energy efficiency and renewable energy policies and targets for 2020 and are committed to monitoring and reporting in the areas of renewables, energy efficiency and GHG emissions as well as other information relevant to climate change. The Paris Agreement further defines the climate change-related reporting obligations for the period after 2020 by establishing an enhanced transparency framework for action and support (Energy Community Secretariat, 2018).

In this context, the Energy Community adopted a recommendation[9] on preparing for the development of NECPs for the period from 2020 to 2030 addressing the five dimensions of the Energy Union by the Contracting Parties of the Energy Community (Energy Community, 2018). The recommendation aims at building the analytical, institutional and regulatory preconditions for the development of integrated NECPs.[10]

OBJECTIVES AND APPROACH TO THIS STUDY

IRENA, at the request of the EC, developed a Renewable Energy Roadmap (REmap study) for the CESEC region. The study aims to assess the potential for renewables deployment in CESEC members by 2030 beyond existing plans. It also analyses the impacts of a scenario with accelerated renewables deployment in terms of costs of energy, investments, fossil fuel consumption, GHG emissions and environmental and health externalities. The results of the study can serve as input to the ongoing planning processes both in EU member states and in Energy Community Contracting Parties.

The REmap study first analyses the expected deployment of renewables in each CESEC member by 2030 under a Reference Case (assuming the implementation of existing plans – where these are in place – or the continuation of recent trends).[11] Then it identifies REmap options, which show the additional renewable technology potential – available on a country-by-country basis – to accelerate renewables deployment by 2030 beyond the Reference Case.

The identified renewable energy options are then characterised in terms of their levelised cost of energy (LCOE) and compared with the conventional technology alternatives to determine the costs of substitution.

8 Energy security; the internal energy market; energy efficiency; decarbonisation of the economy; research, innovation and competitiveness.

9 Recommendation 2018/01/MC-EnC, including Policy Guidelines (PG 03/2018) on the development of NECPs.

10 While not legally binding, Contracting Parties "shall use their best endeavours" to carry it out (as per Article 76 of the Treaty Establishing Energy Community).

11 For more detail on the sources to build the Reference Case for each CESEC member, see Annex A.

The study covers all sectors, including energy supply (power and district heat) and end-use sectors (buildings, industry and transport). The assessment of REmap options for the power sector in each CESEC member is followed by an hourly simulation of the operation of the entire interconnected European power system to evaluate the technical feasibility of the REmap Case at the regional level. This analysis assesses potential flexibility shortages at the regional level and calculates the benefits of regional co-operation in renewable energy integration. It also quantifies expected levels of electricity trade, interconnector congestion, wholesale market price changes, effects on market clearing (*e.g.*, merit order, marginal unit) and other metrics.

For more information about methodology and assumptions, see annexes A and C, which outline the statistical basis, datasets, publications and modelling tools from which the results were derived.

Consultation and engagement are cornerstones of IRENA's REmap approach in both confirming the Reference Case and exploring the realistic potential for accelerating renewables deployment. The process to develop a regional REmap study relies on close consultation with country experts. For this REmap analysis for CESEC, country experts were consulted extensively in multilateral meetings as well as through bilateral communication.

The project kick-off meeting with CESEC members' representatives took place on 25 October 2018 in Brussels, followed by a first sectorial workshop on 31 January 2019 in Vienna and a second workshop on 12 June 2019 in Sarajevo, where preliminary results were discussed. The final stakeholder meeting took place on 3 December 2019 in Brussels.

KEY FINDINGS

REMAP POTENTIAL FOR THE CESEC REGION

The Reference Case for IRENA's analysis of the CESEC region is based on the latest national energy plans – where these are in place – or available studies projecting the status of national energy systems by 2030.[12] The Reference Case assumes the continuation of current trends and the implementation of agreed policies and targets.

Under the Reference Case, overall energy demand in the CESEC area is expected to increase slightly, by about 5% by 2030 compared to 2015 levels.[13] For the eight Energy Community Contracting Parties which are members of CESEC, this increase is expected to be substantially larger, at about 26% above 2015 consumption.

Under these conditions, the share of renewable energy in CESEC is expected to show slow growth over the next decade, from 16% in 2015 to 24% in 2030. In CESEC's eight Contracting Parties of the Energy Community, renewables are expected to grow from 10% in 2015 to 19% in 2030.

Figure 1 shows the cost-supply curve[14] of available renewable energy options across all sectors (power and district heat, buildings, industry and transport) resulting from the REmap analysis of the CESEC region.

In IRENA's assessment, renewables can grow cost-effectively in the region to deliver more than a third of gross final energy consumption by 2030. The full deployment of REmap options identified in this analysis could lead the CESEC region to reach – cost-effectively – a renewable energy share of 34% by 2030, compared to the 24% expected in the Reference Case and to the 16% in 2015, the base year for this analysis. In the eight Contracting Parties of the Energy Community which are members of CESEC, the deployment of the REmap scenario could raise the renewables share from 19% in the Reference Case to 30% in 2030.

Higher renewable shares could be realised with the same level of renewables deployment proposed in the REmap scenario if the projected demand to 2030 falls short of expectations or if countries improve their energy efficiency compared to Reference Case assumptions. Furthermore, there is additional technical potential to deploy renewables by 2030 beyond the REmap Case, albeit at higher costs.

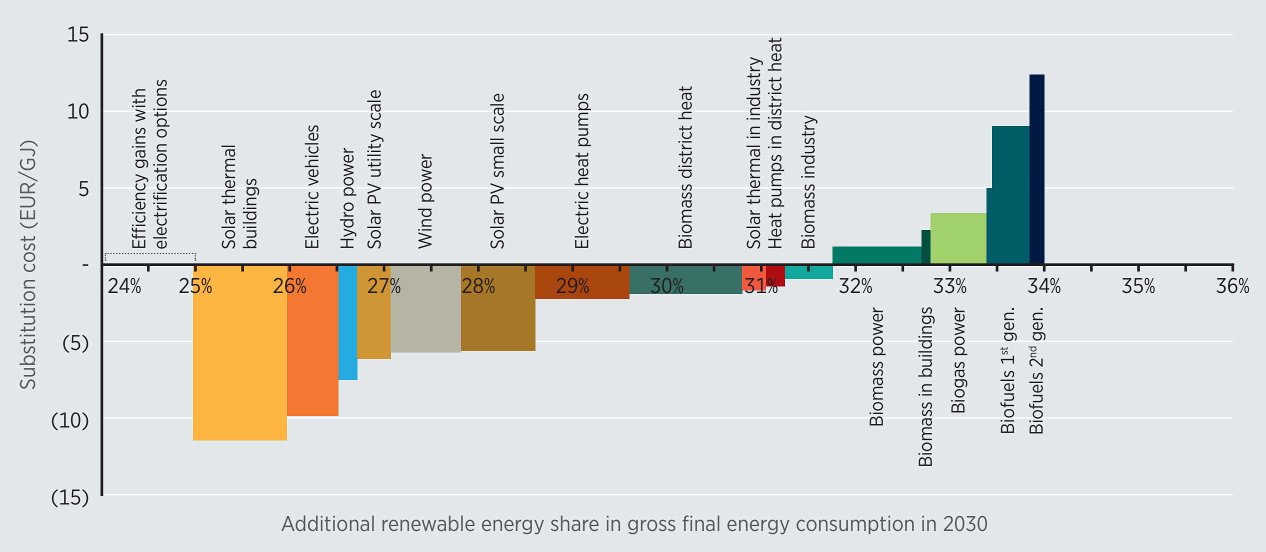
The REmap options with negative substitution costs (coloured areas below the horizontal axis) deliver savings, while the rest of the REmap options (coloured areas above the horizontal axis) result in additional costs. Most of the identified

12 *For more detail on the sources to build the Reference Case for each CESEC member, see Annex A. These demand projections reflect the Reference Case with information available to IRENA as of September 2019. Further commitments on energy efficiency improvements potentially adopted by CESEC members could have a positive effect in terms of demand reduction and renewables share by 2030, both in the Reference Case and REmap scenarios..*

13 *The year 2015 was the most recent year for which a comprehensive dataset could be produced for all CESEC members.*

14 *The horizontal axis represents renewable energy deployment, with REmap options organised by cost from left to right. The vertical axis represents substitution costs, i.e., the differences between the LCOE for the renewable and the conventional technology that the renewable option substitutes. REmap options with negative substitution costs are cheaper than conventional technologies. The calculation of substitution costs excludes externalities.*

Figure 1 Cost-supply curve of REmap options for the CESEC region



Based on IRENA analysis

REmap options for the CESEC region deliver savings compared to the conventional technologies substituted by the REmap options.

Overall, deploying all additional renewable options identified in the REmap study could deliver savings for CESEC citizens in terms of levelised costs of energy services, because the economic savings from the most competitive options are greater than the additional costs of the least competitive ones. With appropriate policies, regulations and financing mechanisms in place, the estimated savings amount to EUR 3.4 billion/year in 2030, compared to the Reference Case.

Several factors could reduce these estimated savings,[15] including high costs of capital or persistently low international fossil fuel prices. Similarly, additional grid infrastructure investments not accounted for in this study – where needed in addition to the Reference Case – could reduce the estimated cost advantage of renewables. Conversely, faster than expected technology improvements could further improve the economics of renewables.

The key cost-effective contributors to the additional renewable potential are: 1) renewable power generation technologies, mainly solar photovoltaic (PV) and wind power; 2) renewable electrification of heat and transport applications; 3) modern biomass for district heating systems; and 4) solar water heating. Additional bioenergy options, such as biomass power, liquid biofuels and biogas, are also available and could be sustainably deployed at similar to moderately higher costs than Reference Case (fossil) technologies.[16] Renewable power in combination with electrification of heat and transport accounts for about two-thirds of the additional renewables' potential identified in the REmap analysis.

Accelerating renewables deployment in line with the REmap scenario simultaneously addresses many of the energy sector challenges facing CESEC members. It reduces import demand for oil and gas, which enhances energy security. It modernises the energy sector by replacing old inefficient generators with modern renewables and reduces air pollution resulting from combustion by meeting heating and transport demand with electricity. It also has many socio-economic benefits derived from significant cost savings and local job creation in the construction and operation of domestic renewable energy resources.

15 A sensitivity analysis evaluating the impact of these factors in the estimated savings can be found in Annex B.

16 Excluding the additional economic benefits of avoided fossil fuel externalities.

RENEWABLE ENERGY DEPLOYMENT BY SOURCE AND APPLICATION IN 2030

In 2015, the base year for this analysis, solid biomass and hydro power accounted for the bulk of all the renewable energy consumption in the CESEC region. More than half of the renewable consumption was used for heating and cooling applications in buildings and industry. Renewable power accounted for 43% of total renewable use. Biofuels in the transport sector accounted for just 5% of total renewable consumption in the region. Figure 2 shows the breakdown of gross final renewable energy consumption[17] in the CESEC region by source and application in 2015 and 2030 (for both the Reference Case and REmap).

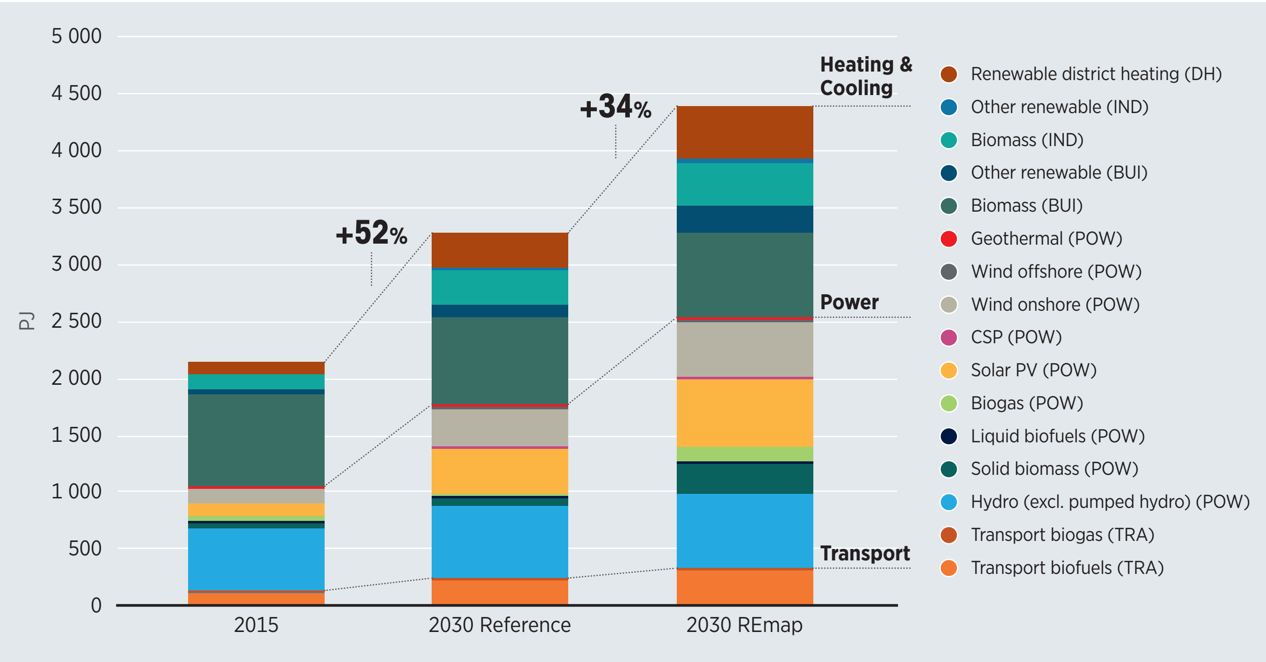
By 2030, in the Reference Case, the overall consumption of renewables is expected to grow by about 52% (or 1 123 petajoules [PJ]), compared to 2015 levels. Solar PV and wind power, as well as solid biomass in industry and district heating systems, account for most of the expected growth. Solar PV and wind power generation are expected to roughly triple compared to 2015, to account for almost half of the renewable power in the region.

In terms of the breakdown per sector, the share of renewable power in overall renewable consumption is expected to increase to reach 48%. The contribution of biofuels in transport would slightly increase to 7% of all renewable consumption, while the share of renewable heat would decrease to 45% of all renewable consumption.

In the REmap scenario, the overall consumption of renewable energy roughly doubles compared to 2015. The largest contributors to the additional potential are renewable power technologies (solar PV, wind, biomass and biogas) followed by renewable heat technologies (solar thermal and biomass in buildings and industry) and liquid biofuels in transport.

In terms of the breakdown per sector, the share of renewable power in overall renewable consumption increases to reach 51%. The contribution of biofuels in transport remains as per the Reference Case at 7% of all renewable consumption, while the share of renewable heat would decrease to 42% of all renewable consumption.

Figure 2 Breakdown of gross final renewable energy consumption in the CESEC area by source and application in 2015 and 2030 (PJ) (Reference Case vs REmap)



Based on IRENA analysis. DH: District heat; IND: Industry; BUI: Buildings; POW: Power generation; TRA: Transport

17 Final energy consumption of all energy carriers (except electricity and derived heat) and gross electricity and derived heat generation.

REMAP POTENTIAL BY CESEC MEMBER

The CESEC region is diverse in terms of the maturity of each of the different domestic renewable markets, as well as the overall penetration of renewable energy deployment. In 2015, the base year for this analysis, the renewable share in final energy consumption ranged from about 4% in Ukraine to about 40% in Montenegro.

Figure 3 compares the expected renewable share in 2030 in the Reference Case and the additional cost-effective potential realisable by 2030 in the REmap analysis. A wide range of factors influence the realistic, cost-effective potential for growth in renewable share in each country within the region. These include the technical renewable potential and the expected costs of realising such potential; the economic and energy market conditions of the country; the current energy mix and age profile of existing generation assets; and the pipeline for new developments (particularly for large projects that can make a big difference for smaller countries).

While these conditions for renewables deployment vary significantly across the region, IRENA estimates that all CESEC members have the potential to increase their renewable energy shares cost-effectively beyond current projections by 2030. Country-specific economic potential would support overall renewable shares ranging from 23% to 56%. The additional potential identified, compared to the Reference Case, ranges from 6% to 20%.

KEY TECHNOLOGY ENABLERS

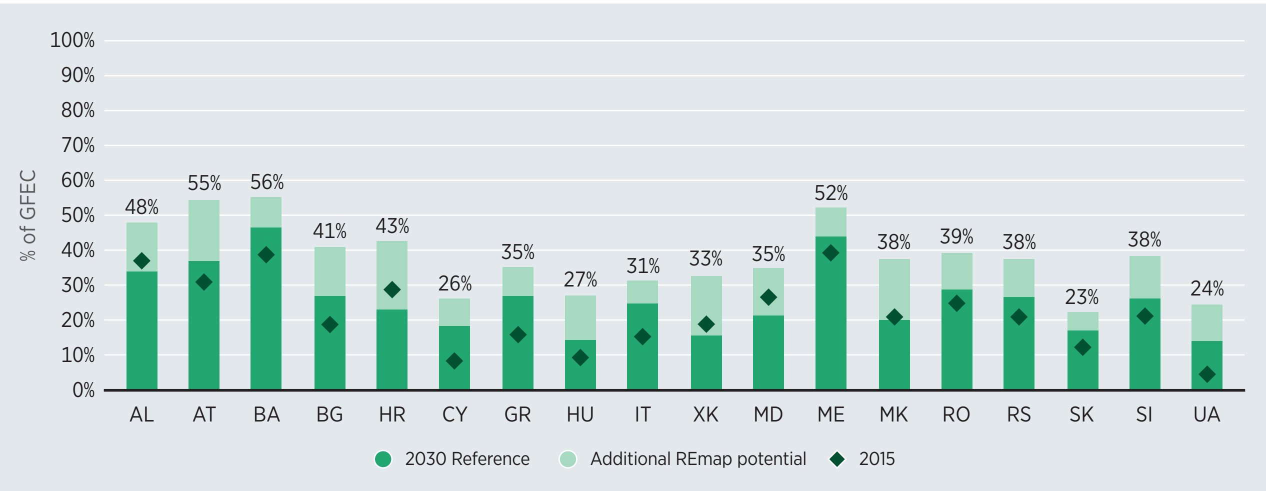
Renewable power generation

Renewable power technology has shown impressive progress over the last decade, resulting in large reductions in generation costs. As technologies become increasingly mature, they progressively take larger shares in the global markets for new installed capacity. In 2019, 176 gigawatts (GW) of renewable capacity was installed worldwide, compared to 68 GW for fossil and nuclear. For five years in a row, the world has installed more renewable capacity than fossil and nuclear capacity combined (IRENA, 2020c).

In most parts of the world today, renewables are the lowest-cost source of new power generation. Figure 4 shows the recent evolution of costs for utility-scale power generation technologies. Between 2010 and 2019, the global weighted-average LCOE of utility-scale solar PV and onshore wind has declined by 82% and 39%, respectively (IRENA, 2020e).

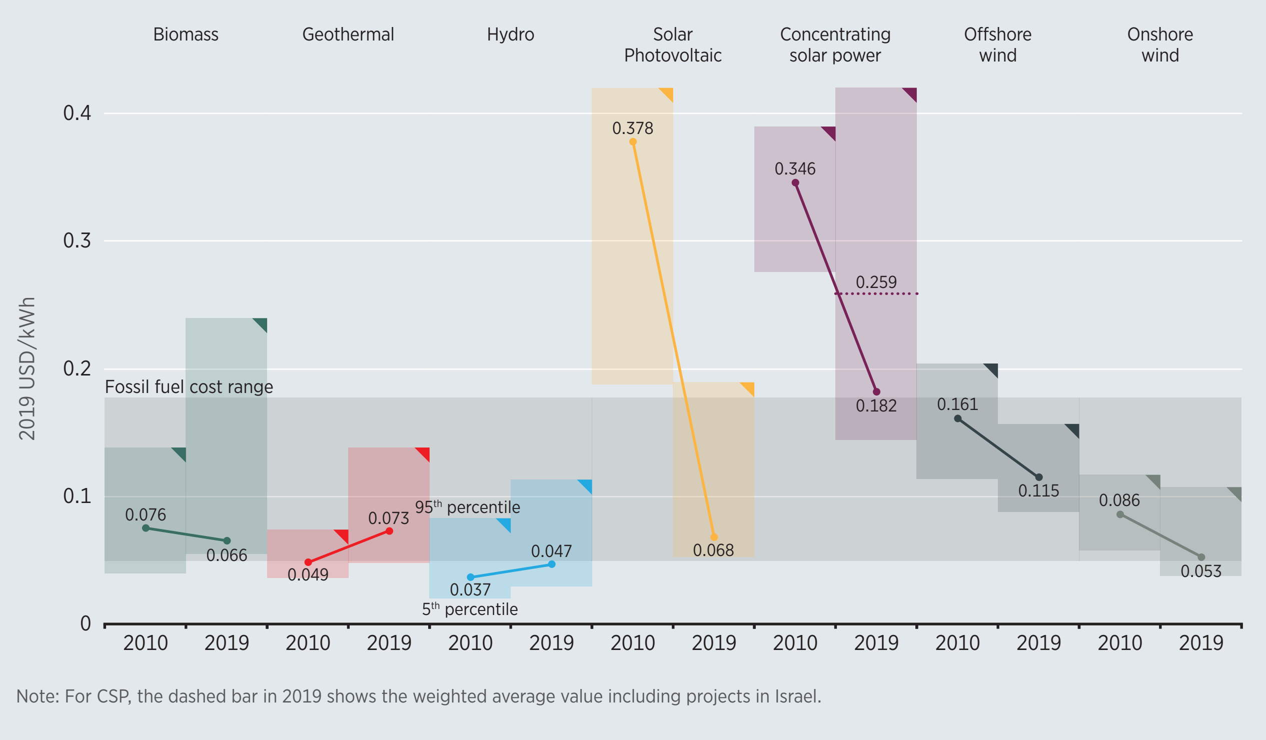
Over the next decade, onshore wind and solar PV are set to consistently offer a less expensive source of new electricity than the least-cost fossil fuel alternative, without financial assistance. New solar PV and onshore wind are expected to increasingly cost less than the marginal operating cost of existing coal-fired power plants. Furthermore, these cost reductions are expected to continue in the future, further extending the cost advantage

Figure 3 Share of renewables in gross final energy consumption by CESEC member (%)



Based on IRENA analysis

Figure 4 Global weighted average LCOE of utility-scale renewable power generation technologies, 2010-2019



Source: IRENA (2020e)

of renewable energy technology and making renewable power the competitive backbone of global energy systems (IRENA, 2019c).

The CESEC area has excellent resource conditions to scale up renewable power. The region has vast untapped potential for solar PV and onshore wind, two key technologies for the transformation of the power sector. Previous analysis for the region (IRENA, 2017d) has estimated the current cost-competitive potential for renewable power in South-East Europe[18] at about 130 GW. The cost-competitive potential for renewable generation will grow substantially towards 2030, driven by further reductions in technology costs. A conservative estimate of the technical potential in the broader CESEC region results in at least ~845 GW and ~402 GW for onshore wind and solar PV, respectively.[19] While only a fraction of the technical potential can be realistically deployed within the next decade, these figures illustrate that resource availability is not a limiting factor to accelerate the deployment of renewable technologies in the region. For comparison, the total installed capacity of all generation technologies in the CESEC region in 2015 was 274 GW.

Biomass and biogas power can also be substantially scaled up in the region. IRENA estimates the long-term sustainable potential at about 47 GW across the CESEC region. Bioenergy-based power generation is an important asset as it can improve energy diversity and security by reducing dependence on imported fuels linked to volatile international markets, while providing firm generation capacity in systems with high shares of variable renewables (IRENA, 2019b). Furthermore, bioenergy enables synergies between the power and the heat supply sectors. Biomass and biogas power can be deployed efficiently through combined heat and power (CHP) systems to feed district heating networks, which are abundant in the region.

18 Austria, Greece, Hungary, Italy and Slovakia were not covered in the scope of IRENA's 2017 study for South-East Europe.
19 IRENA estimation based on Joint Research Centre (2019) and IRENA (2017d).

Hydro power is a mature renewable technology, already accounting for about one-fifth of the CESEC region's power generation. Most of the existing capacity was installed decades ago. A substantial pipeline of additional hydro developments exists in several CESEC member countries (E3Consult, 2018; KPMG, 2010; Mott Macdonald, 2017; WBIF, 2019). Hydro plants can be a key asset to the electricity system by providing cost-competitive power and enabling cost-effective integration of variable renewables.

The untapped technical potential for the technology in the region remains large; however, the realistic potential for capacity expansion by 2030 is significantly smaller once environmental and social acceptance constraints are considered. Refurbishment or upgrading of existing plants are *no regrets* options. Additional capacity can be also be considered when meeting strict sustainability standards and complying with European environmental protection regulations in place.

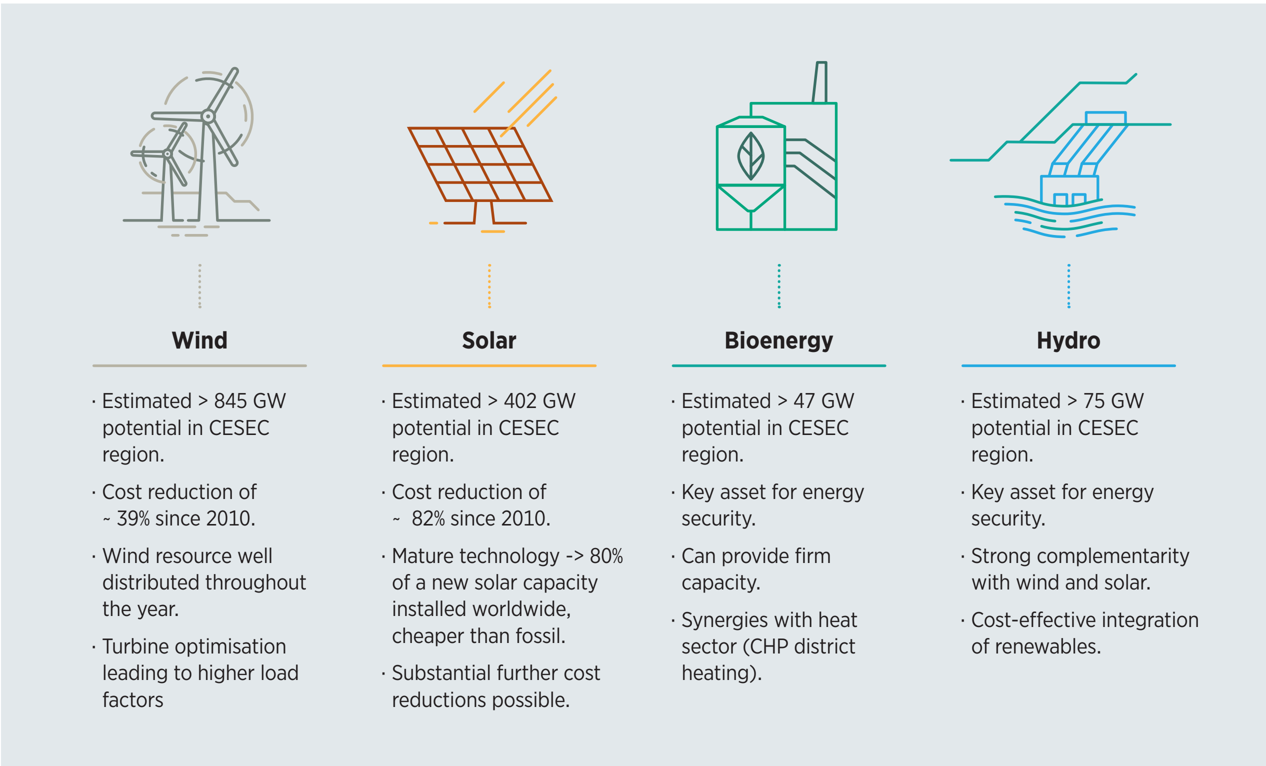
Electrification of heat and transport

Several heat and transport energy services currently supplied through direct use of fossil fuels can be converted to work with electricity. In the transport sector, increased electrification can be achieved with the deployment of electric or hybrid vehicles. In the building and industrial sectors, electric heat pumps can provide low- to medium-temperature heat for multiple applications.

Renewable electrification of heat and transport services is a core building block of a transition towards clean, efficient and modern energy systems. There are three key reasons for this:

1. Electrification can deliver large efficiency improvements. Electric heat pumps can deliver more than three times more useful heat than (renewable) electricity consumed, resulting in a much more efficient use of energy compared to even the most efficient boilers (IRENA, 2019d). Similarly, EVs can deliver the same transport service as internal combustion vehicles, while consuming a third to a quarter of the energy (EPRI, 2018).

Figure 5 Key power sector options for the CESEC region up to 2030



Based on IRENA analysis

2. The switch from a fuel to electricity as a carrier for heat and transport makes the penetration of renewables easier overall – as today there are already cost-effective renewable options for power generation. Furthermore, the elimination of the need for fuel mitigates the adverse effect of local air pollution related to direct combustion of the fuel and improves energy security, as natural gas and oil are mostly imported in the CESEC region.

3. Integrating the power sector with the heat and transport sectors creates potential synergies that can be tapped to accelerate an integrated, cost-effective transition in all sectors. Clean, cost-effective renewable power can supply the additional demand from electrified heat and transport services. Conversely, this additional demand – if managed flexibly – can facilitate the integration of larger amounts of variable renewable power on the grids.

Worldwide, electrification of heat and transport, in combination with the deployment of renewables in the power sector, can deliver more than 60% of the emissions reductions needed to meet the goals of the Paris Agreement (IRENA and State Grid Corporation of China, 2019).

IRENA's latest analysis of the world's pathway to a sustainable energy sector sees a fast increase in the share of electricity from less than a fifth of final energy demand today to nearly half by mid-century (IRENA, 2020a).

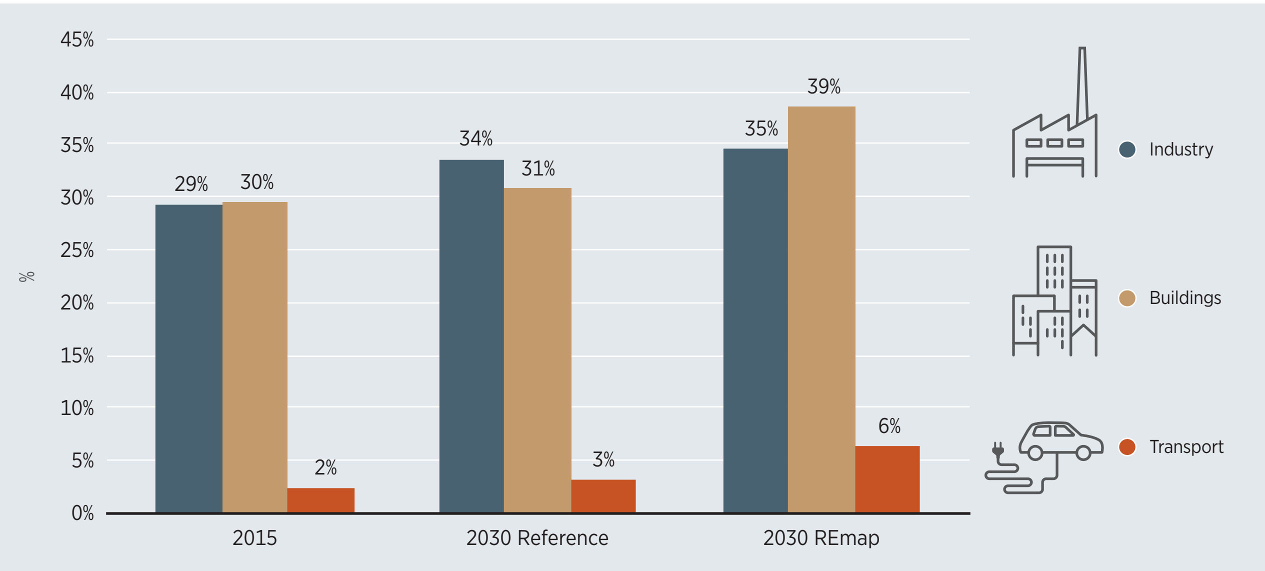
In 2015, the base year for this analysis, electricity accounted for 21% of the final energy consumption in the CESEC region. With accelerated adoption of heat pumps and electric mobility, electricity could have a more prominent role as a carrier for end uses by 2030. Under REmap, electricity would represent 28% of final energy consumption in 2030, up from 23% in the Reference Case.

In absolute terms, the additional electrification in REmap amounts to 96 terawatt-hours (TWh), an amount comparable to today's electricity consumption of Hungary and Greece combined. Figure 6 shows the share of electricity as a percentage of final energy consumption in industry, buildings and transport in the CESEC region.

Scale up of sustainable bioenergy use

Bioenergy is today the largest renewable source in the CESEC region, accounting for more than half of the primary renewable supply and for about 7% of the total primary energy supply (TPES). The relative importance of bioenergy as a source varies widely from as low as 2% of TPES in Cyprus to as high as 27% in the Republic of Moldova.

Figure 6 Degree of electrification of end-use sectors in CESEC (%)



Based on IRENA analysis

The bulk of current bioenergy use in the region is related to solid biomass – mostly for direct heat in buildings and industry but also as input to power and heat generation – followed by much smaller contributions of liquid biofuels and biogas.

The sustainability of bioenergy use also varies widely within the CESEC area. Most EU member states have realised widespread access to clean combustion technologies. However, the situation is different in Energy Community Contracting Parties – particularly in the Western Balkans – where a significant share of the use of biomass in households is in inefficient cooking or heating appliances. By 2016, in Bosnia and Herzegovina, Montenegro and North Macedonia, over 30% of the households had no access to clean cooking solutions. This compares to Ukraine, where only 4% of households did not have access to clean cooking solution (World Bank, 2017, 2019).

Several studies have analysed the long-term sustainable potential for bioenergy in all or parts of the CESEC region (Domac and Panoutsou, 2010; Geletuha and Martsenyuk, 1998; Ruiz *et al.*, 2015; S2Biom, 2017; World Bank, 2017). For this regional study, IRENA has conducted a bottom-up analysis of bioenergy potential in each CESEC member based on a methodology[20] originally established for global bioenergy assessments (IRENA, 2014) and subsequently applied to other regional bioenergy potential assessments, such as for Southeast Asia (IRENA, 2017b) and Sub-Saharan Africa (IRENA, 2017c).

Based on this analysis, IRENA estimates the potential for sustainable bioenergy supply in the CESEC region by 2030 at around 3 500 PJ. Additional sustainable supply could be unlocked in the longer term by realising further productivity improvements. In comparison, the primary energy demand for bioenergy carriers in the region in 2015 was 1 582 PJ.

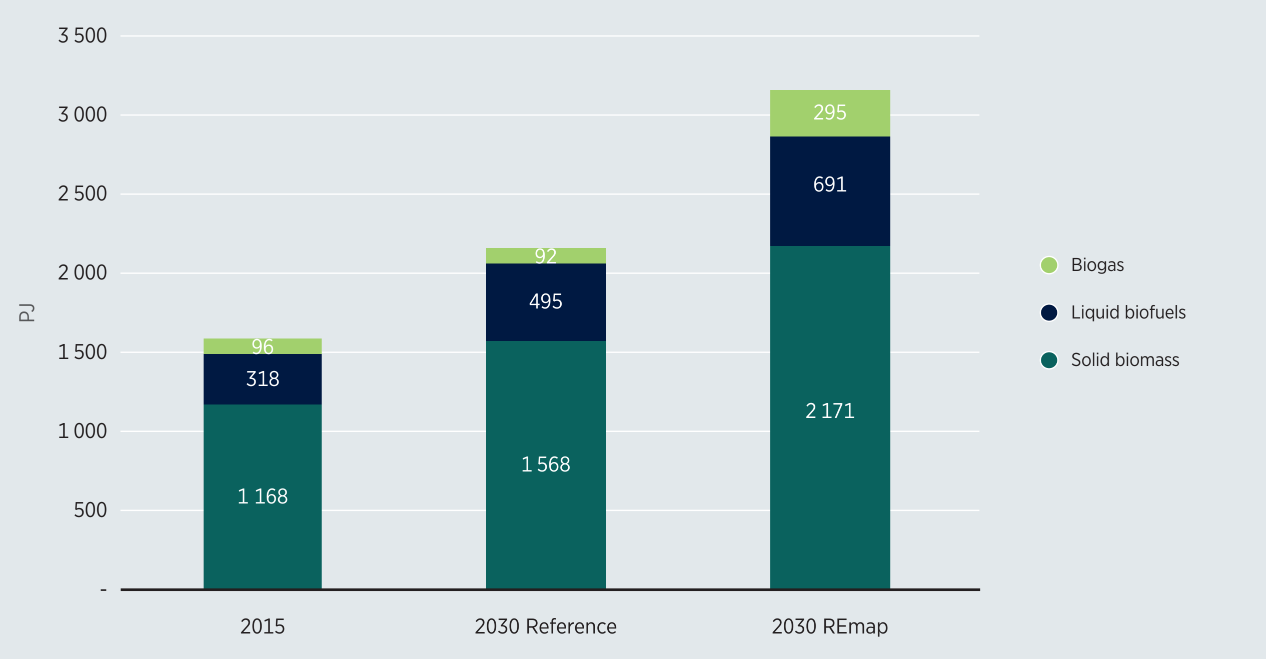
The supply of key bioenergy carriers in the Reference and REmap scenarios is compared in Figure 7. With the continuation of current trends, the overall bioenergy supply would grow by 36% compared to 2015 levels. In the REmap scenario, it would double from 2015 levels to reach 3 158 PJ.º Bioenergy production can be scaled up significantly without jeopardising food supplies or adversely affecting the environment. There is much room for making extensive use of residues and by-products generated along the supply chain of agriculture and forestry while maintaining soil fertility. Bioenergy feedstock production can be further boosted when land use planning is optimally designed to free up existing farmland for bioenergy crops through further improving crop yields, reducing losses and waste in the food chain, and to free up pastureland through improving livestock management (IRENA, 2016a). Several modern agricultural practices to improve yields have been adopted in many parts of the world, such as conservation agriculture, improved crops and varieties, improved nutrient supply and management, efficient water management, integrated pest management, and precision agriculture (FAO, 2019, 2016).

Scaling-up modern forms of bioenergy production and consumption will be key for CESEC members to progress on the decarbonisation of energy uses for which no other cost-effective solutions will be available. In the transport sector, bioenergy is a key renewable option for the stock of internal combustion vehicles that will remain on the road over the next decades, as well as for transport modes for which electrification is not yet an alternative, such as aviation and shipping. In the power sector, biomass and biogas power can provide firm and potentially flexible electricity generation. Biomass is also the most economic renewable option for high-temperature process heat in industry in the short- to medium-term.

There is a wide range of opportunities for bioenergy in the region based on technologies available now. Some of these solutions are: the modern use of bioenergy in district heating and directly in buildings; the use of waste bio-materials in CHP systems, along with biogas production; and the use of biofuels from sustainable feedstocks and processes (opening the way for more advanced technologies) (IRENA, 2019b).

20 See Annex D for more details on the approach taken for REmap CESEC.

Figure 7 Bioenergy supply in CESEC (PJ): 2015, Reference Case 2030, REmap 2030.



Based on IRENA analysis

IMPLICATIONS OF THE REMAP CASE FOR CESEC

Energy security

Ensuring security of the energy supply has been an issue of concern shared by all Central and South-East European countries. CESEC members are highly dependent on fossil fuel imports, and the region has been exposed to disruptions in gas imports in the past. Oil and natural gas accounted for about 58% of the primary energy supply in the region in 2017. About 90% of the oil and 75% of the natural gas used in the CESEC area are imported from outside the region.[21]

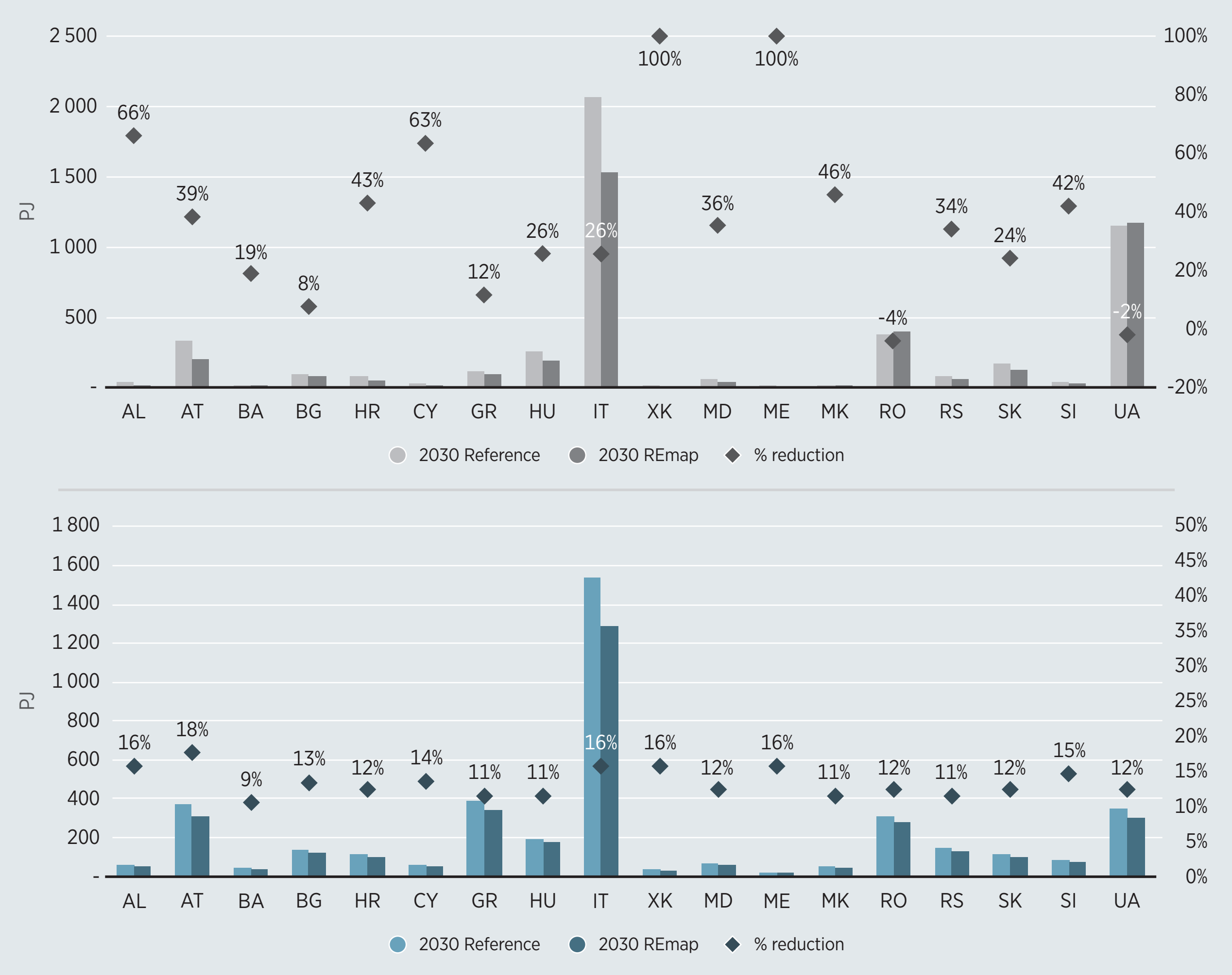
Accelerating the deployment of renewables in the power generation, buildings and industry sectors, together with improvements in energy efficiency, is a cost-effective option to reduce dependency on energy imports while avoiding investments in redundant natural gas infrastructure and mitigating the risk for stranded assets in the future. Figure 8 shows the natural gas and oil demand in 2030 for each CESEC member, comparing the REmap and Reference Case scenarios.

Natural gas demand can be substantially reduced with a combination of renewable electrification of heat and deployment of solid biomass and solar thermal solutions in buildings and industry. The REmap scenario would result in natural gas demand reductions estimated at 18% (about 893 PJ) below levels in the Reference Case, comparable to today's primary demand for gas in Ukraine.

Oil demand can be significantly reduced with a combination of fast electrification of road transport and upscaling of liquid biofuels. The REmap Case reductions are also substantial, estimated at 14% (about 564 PJ) below the Reference Case, an amount comparable to today's combined oil consumption of Croatia and Greece.

21 Source: IRENA based on Eurostat energy balances

Figure 8 Demand for natural gas (above) and oil (below) by CESEC member: Reference 2030 and REmap 2030 (PJ)



Based on IRENA analysis

Climate change mitigation

In November 2018, the EC set out its vision for a climate-neutral EU by 2050. This objective is in line with the commitment to global climate action under the Paris Agreement.[22] The Contracting Parties of the Energy Community, as aspirants to EU accession, also face the challenge of energy system decarbonisation.

The evolution of the energy systems in the region covered by the CESEC initiative over the next decade is critical for Europe to realise its long-term decarbonisation goal. CESEC members host a large fraction of the remaining coal-based power generation in Europe and most of the new projects in development or permitting stages for new coal-based generation capacity. Similarly, existing plans to expand natural gas infrastructure could lock-in additional carbon emissions for the next couple of decades.

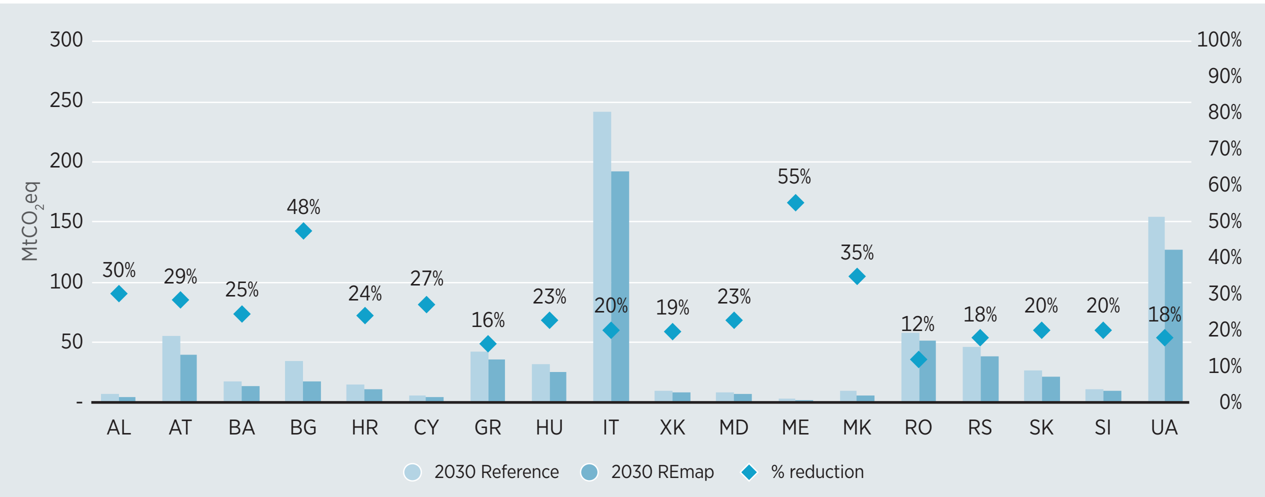
Accelerating the transition to a renewables-based energy system is one of the key cost-effective actions available for CESEC members to mitigate climate change and meet the goals of the Paris Agreement.

With the continuation of current trends, energy-related carbon dioxide (CO_2) emissions in CESEC are expected to decrease by 123 megatonnes (Mt) CO_2/year by 2030 (14% below 2015 levels). Most of this reduction is expected in EU member states, while the aggregate of emissions of Energy Community Contracting Parties would remain almost flat over the same period.[23]

The full deployment of REmap options identified in this study would deliver additional emission reductions estimated at 165 Mt CO_2/year, or 21% below the Reference Case in 2030. This amount is comparable to today's total emissions of Romania and Bulgaria combined. Of these additional emissions reductions, an estimated 51 Mt CO_2/year (20% below the Reference Case) could be realised in Contracting Parties of the Energy Community.

The identified potential for emission reductions compared to the Reference Case varies across the region. This is illustrated in Figure 9. Multiple factors play a role in this variability, including the composition and age of the remaining fleet of fossil-fuelled generation assets as well as the relative weight of fossil generation in the overall power supply of the country, among other factors.

Figure 9 Energy-related CO_2 emissions by country: Reference Case 2030 vs REmap 2030



Based on IRENA analysis

22 *The EU ratified the Paris Agreement in October 2016. The European Parliament endorsed the net-zero GHG emissions objective in its resolution on climate change in March 2019 and resolution on the European Green Deal in January 2020. The European Council endorsed in December 2019 the objective of making the EU climate-neutral by 2050, in line with the Paris Agreement.*

23 *The Reference Case for this study does not include GHG reduction targets by 2030 currently under discussion in the Energy Community.*

The additional emissions reductions that can be realised through the accelerated deployment of renewable energy in the REmap Case – together with additional energy efficiency efforts – will be key to set both the CESEC region and Europe in line with a long-term emissions pathway compatible with the objectives of the Paris Agreement.

Avoided costs of energy externalities

The case for accelerating renewables in the CESEC region is further strengthened when their potential to reduce the negative health and environmental impacts of energy consumption is considered.

The REmap analysis considers two types of energy externalities: 1) the cost of damages from air pollution emitted by the combustion of fuels on human health and agriculture crops; and 2) the environmental costs associated with CO_2 emissions.[24]

The potential for renewables to significantly reduce air pollution and improve the health of citizens is often overlooked in the energy debate. According to the European Environment Agency, air pollution is a major cause of premature death and disease and is the single largest environmental health risk in Europe,[25] causing around 400 000 premature deaths per year (European Environment Agency, 2019). Some countries in CESEC are among those with the highest levels of air pollution in Europe.

Renewables, in combination with energy efficiency and electrification of heat and transport, can reduce the need for combustion of polluting fossil fuels and contribute to a substantial improvement in air quality and the health of citizens in the region. The economic value of avoided air pollution with the deployment of the REmap scenario in the CESEC region is estimated at between EUR 5 billion and EUR 20 billion per year by 2030.

Similarly, the externality costs related to carbon emissions that can be avoided by transitioning to renewables in the CESEC region are also substantial, ranging between EUR 2 billion and EUR 12 billion per year by 2030.

Overall, IRENA estimates the economic value of avoided energy sector externalities with the deployment of the REmap scenario in the CESEC region at between EUR 8 billion and EUR 32 billion per year by 2030.

Required investments in the energy sector and associated benefits

CESEC members will need to scale up investments to modernise their energy systems over the next decade regardless of the choice of energy supply technologies. IRENA estimates the cumulative energy sector investments[26] required in the Reference Case in the CESEC region at EUR 303 billion over the period 2015-2030.

Most of the energy supply and transformation investments are required to build new power generation capacity or substitute for existing capacity that should come offline at the end of its useful operational life before 2030. Renewable capacity is expected to represent the largest share of power sector investments in the Reference Case. However, substantial amounts of capital would still be directed to build or upgrade the fossil generation capacity foreseen in some country plans.

In the REmap Case, CESEC members would invest about an additional EUR 78 billion cumulative up to 2030 compared to the Reference Case.

In the power sector, the required investments in REmap are just about 9% higher than those of the Reference Case; however, the structure changes drastically with renewables taking the bulk of the capital. Nuclear would account for most other power generation investments, directed to reactors already under construction or with firm investment decisions made.

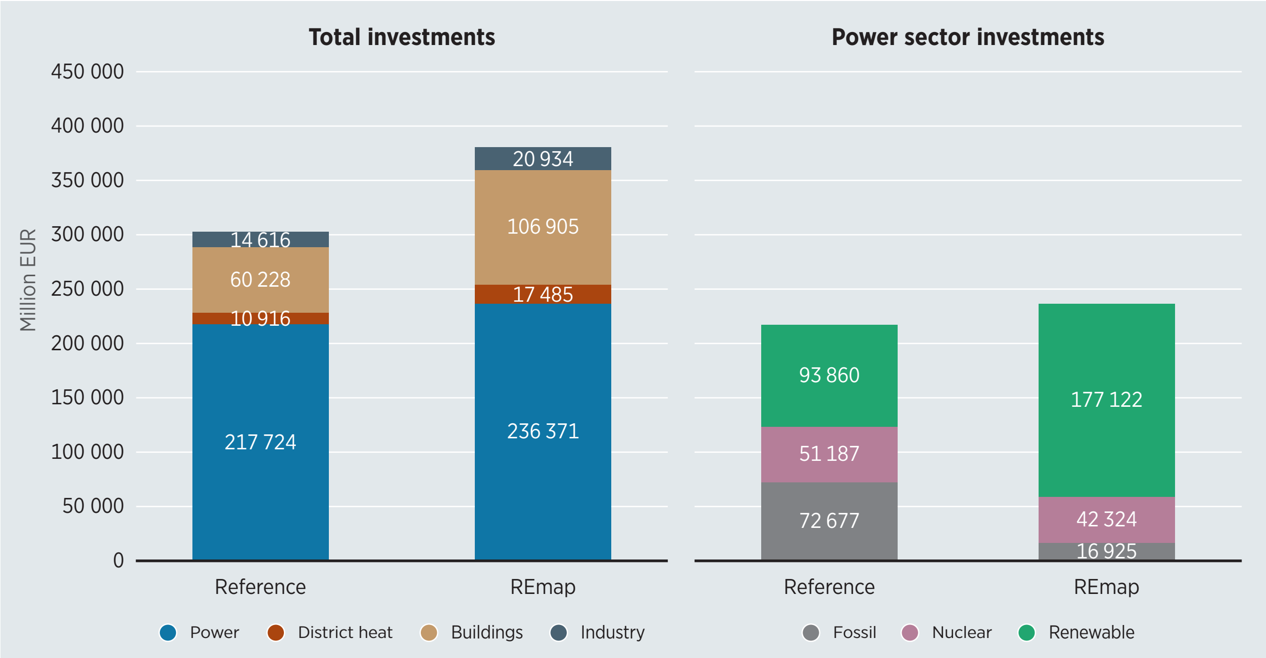
New nuclear projects still under discussion are not included in REmap, as renewable technologies are expected to deliver cheaper power over the next decade.

24 Methodology for externality cost calculations is based on IRENA (2016d).

25 Covers 39 European countries; excludes Turkey.

26 Including power and distributed heat generation assets as well as heat production equipment in buildings and industry. Excluding infrastructure investments.

Figure 10 Cumulative investments in energy systems in the CESEC region over the period 2015-2030: Reference Case vs REmap (EUR million)



Based on IRENA analysis

In annual terms, the REmap scenario requires additional investments beyond those in the Reference Case estimated at between EUR 5 billion and EUR 7 billion per year until 2030, equivalent to approximately 0.16-0.21% of the expected average annual gross domestic product (GDP) of the region over the next decade.

With these additional investments, CESEC members can build an energy system that is substantially less reliant on imported natural gas and oil, while still delivering energy at competitive costs. Such reduced reliance in (imported) fossil fuels brings multiple benefits, including not only a significantly reduced negative impact on the environment and the health of citizens, but also improved sector stability as countries are progressively less exposed to unforeseeable swings in the international prices of energy commodities.

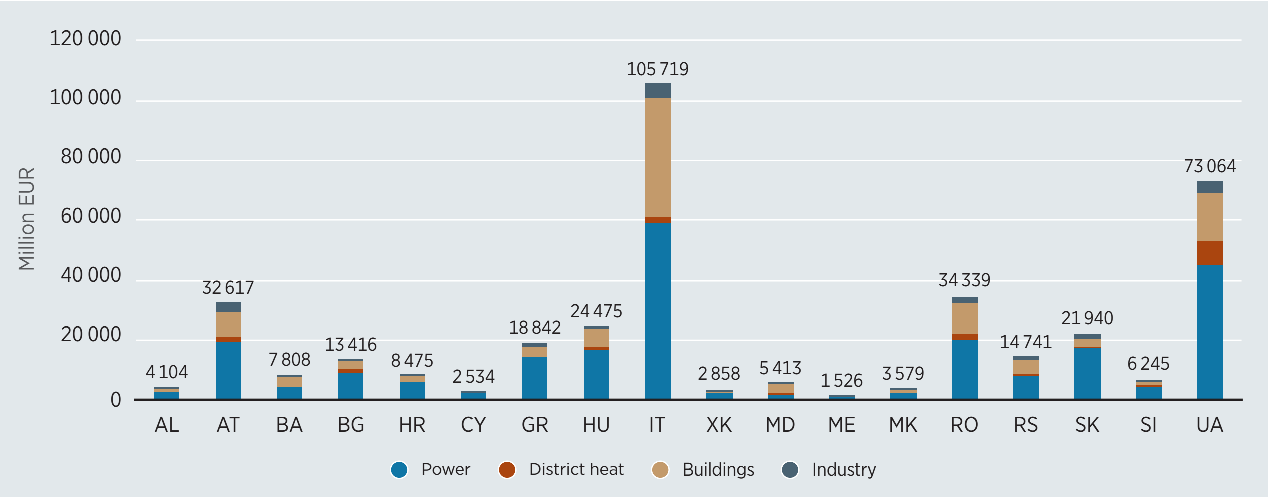
Outside the energy sector, the proliferation of renewable energy technologies and energy efficiency solutions in CESEC jurisdictions has the potential to stimulate economic activity and benefit society at large. Higher levels of investment in renewable energy and energy efficiency have the potential to produce a positive impact on GDP across the region.

Most of the renewable options considered in the REmap scenario deliver savings in terms of LCOE compared to the conventional technologies that are being substituted. These savings far outweigh the additional costs of the most expensive renewable technologies deployed. The full implementation of all REmap options is cost-effective in terms of LCOE, with associated savings estimated at EUR 3.4 billion per year by 2030.

Several factors could reduce these estimated savings,[27] including high costs of capital or persistently low international fossil fuel prices. Similarly, additional grid infrastructure investments not accounted for in this study – where needed in addition to the Reference Case – could reduce the estimated cost advantage of renewables (this is further discussed in Box 1). Conversely, faster than expected technology improvements could further improve the economics of renewables.

When the savings from a pure cost-benefit analysis of technologies are aggregated with the estimated economic value of avoided health and environmental damages, the REmap scenario could deliver benefits to society estimated at between EUR 11 billion and EUR 35 billion per year by 2030.

Figure 11 Cumulative investments 2015-2030 in REmap for each CESEC member (EUR million)



Based on IRENA analysis

27 A sensitivity analysis evaluating the impact of these factors in the estimated savings can be found in Annex B.

Table 1 Investment needs and economic benefits of the REmap scenario[28]

Accumulated, incremental investments until 2030 (Δ REmap vs Reference)	**EUR 78 billion**
Estimated LCOE savings	EUR 3.4 billion/year in 2030
Estimated avoided air pollution damages	EUR 5-20 billion/year in 2030
Estimated avoided environmental costs related to climate change	EUR 2-12 billion/year in 2030
Total savings and avoided externality costs REmap vs Reference Case	**EUR 11-35 billion/year in 2030**

Based on IRENA analysis

Box 1 Costs of variable renewable power integration

The REmap scenario relies on massive deployment of low-cost variable renewable energy (VRE) in the power systems of CESEC members. Integrating high shares of VRE may under some circumstances result in additional costs for firm backup capacity, increased interconnections or modernisation or reinforcements in transmission and distribution grids, among others.

The net savings to the energy system in 2030 reported in this study reflect the differences in the LCOEs between conventional technologies in the Reference Case versus renewable technologies in the REmap Case. The LCOE is a commonly accepted metric for the comparison of the costs of energy. However, it does not account for system effects that could be derived from the variability of renewable sources, for example the need for additional back-up generation capacity, storage, curtailment or grid expansions. Further detailed power sector modelling at the country level is required to establish these potential costs accurately and to develop smart integration strategies to minimise them.

Variable renewables pose new challenges to the operation of power systems, and these challenges increase as the VRE shares in the system increase. However, the overall costs of these challenges can be overestimated if the impacts on specific elements of the system – such as operation of conventional plants or interconnectors – are assessed in isolation.

Instead, a system-wide view is required to capture the whole range of possible cost-effective solutions. Investing in a diversified portfolio of power system flexibility options – including flexible generation, demand response, storage and interconnectors – results in important benefits in terms of system costs (Andrey *et al.*, 2017). Integration costs also can be greatly reduced with the adoption of best practices in system and market operation, adapted to the intrinsic nature of VRE technologies.

A recent review of studies suggests that the additional costs that VRE generation imposes upon electricity systems can remain relatively modest (Heptonstall *et al.*, 2017). This conclusion is applicable to CESEC members – most of which are in the early stages of VRE introduction – and is in line with an increasing body of practical experience demonstrating that markets with large shares of variable renewables incurred significantly lower integration costs than expected because of technology cost declines and the ability of markets to exploit low-cost flexibility options.

A large number of innovative projects and initiatives are being developed to facilitate the integration of high shares of VRE in terms of enabling technologies (such as battery storage, electric vehicle [EV] smart charging and power-to-x), business models (*e.g.*, aggregators, peer-to-peer trading and community ownership models) market design (*e.g.*, increased time and space granularity in markets, innovative ancillary services and time-of-use tariffs) and system operation (*e.g.*, deepened co-operation between distribution and transmission system operators, advanced forecasting of renewables and dynamic line rating). In an age of inexpensive VRE, the success of innovative integration strategies will be crucial for high shares of VRE to translate into low-cost electricity for consumers (IRENA, 2019a).

28 For more details on the definitions of the metrics for investments and savings, please consult the appendix in REmap methodology and data of REmap: Roadmap for a renewable energy future (IRENA, 2016c)

RENEWABLES IN ENERGY SUPPLY

POWER GENERATION

Recent trends in the region

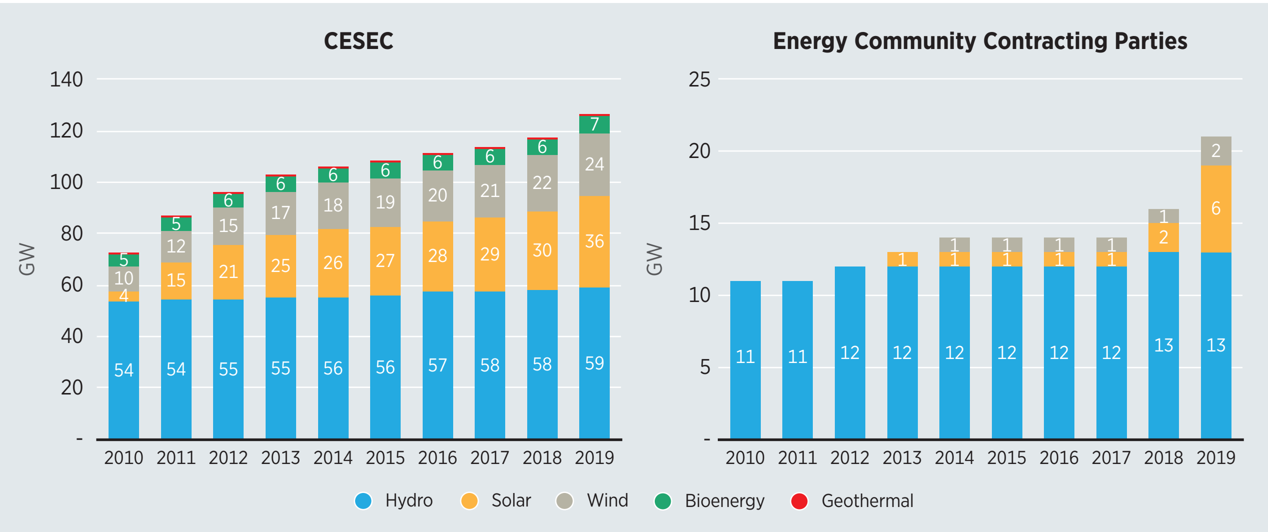
Over the last decade, the total installed renewable capacity in the CESEC region has grown from 73 GW in 2010 to 127 GW in 2019 (IRENA, 2020d). Figure 12 shows the historic evolution of renewable capacity in the region. Solar PV and onshore wind account for the bulk of the capacity additions over this period. One decade ago, hydro accounted for almost three-quarters of the total renewable capacity. Today, it accounts for less than half.

Some EU member states have realised sizeable deployment of solar PV and wind power. After the strong growth in the earlier part of the decade, deployment slowed down, following concerns about the costs of support.

More recently, investment in renewables has regained momentum. In the non-EU part of CESEC, the deployment of renewables – other than hydro – is still in the very early stages. However, there are significant developments or plans to scale up investment in most Contracting Parties of the Energy Community, and deployment is accelerating.

There are large differences across the CESEC region in terms of the power mix. For example, while Albania relies almost entirely on hydropower for its power generation, Kosovo* relies predominantly on lignite, and others have a mix of hydro and fossil fuel-based power generation. In 2015, the overall share of renewables in the power sector of the CESEC region was 29%. This share was substantially higher in EU member states, at 34%, while within the eight Contracting Parties of the Energy Community it lagged at 14%.

Figure 12 Historic evolution of renewable capacity (GW)



Based on IRENA analysis

* *This designation is without prejudice to positions on status and in line with the United Nations Security Council Resolution 1244 (1999).*

Prospects to 2030

Electricity demand is expected to increase substantially in the CESEC region over the coming decade (by about 15%, compared to 2015 levels). About three-quarters of this increase is expected in the eight Contracting Parties of the Energy Community.

Figure 13 shows the power generation capacity and power generation by technology in the base year, Reference Case 2030 and REmap 2030 in the CESEC region. With the continuation of existing plans and policies reflected in the Reference Case, the share of renewables in the power sector would grow from 29% in 2015 to 43% by 2030. Despite this expected growth in renewables, CESEC power systems would still rely heavily on fossil-fired generation, including carbon-intensive coal and lignite plants.

In the Reference Case, renewables are expected to represent most of the new capacity additions up to 2030. Overall renewable capacity is expected to grow from 109 GW in 2015 to 195 GW in 2030. Coal-fired capacity is expected to decrease substantially from 64 GW to 42 GW, while gas-fired capacity is expected to remain at levels similar to 2015. Nuclear generation capacity would increase by 4 GW if planned projects materialise.

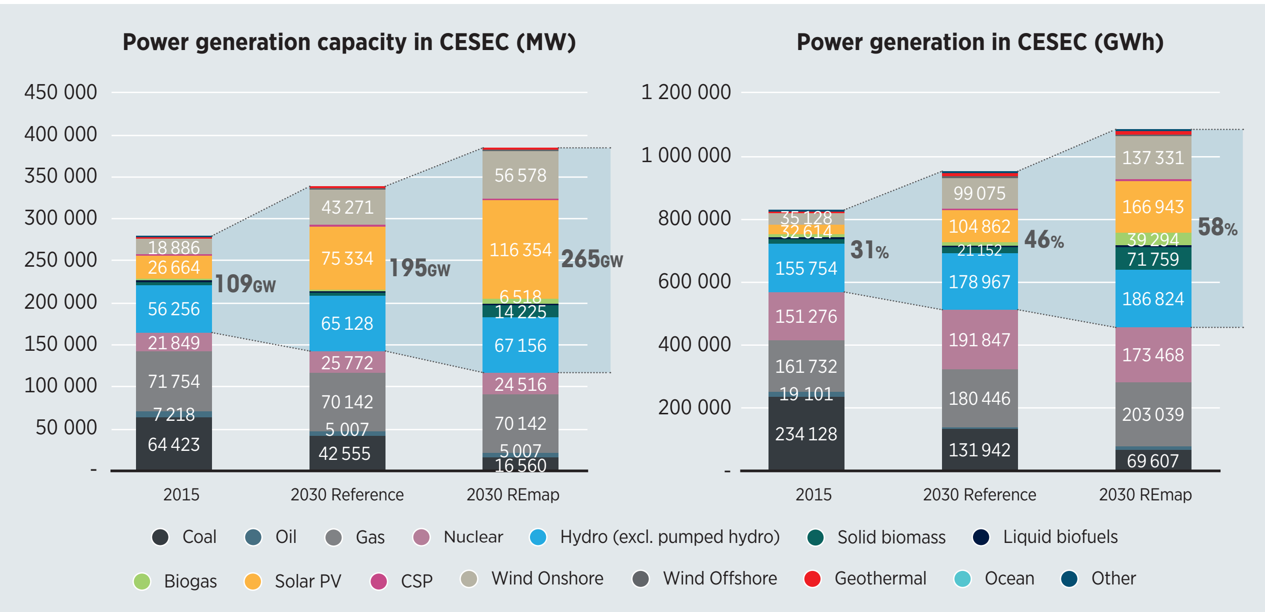
The REmap scenario presents an alternative to this Reference Case scenario, identifying cost-effective potential for substantially larger renewable capacity deployments to reach a total of 265 GW in 2030. Under this scenario, further reductions of coal-fired capacity would be possible – to just 17 GW, or about a quarter of 2015 levels.

Under such conditions, about 55% of the electricity consumed in the CESEC region could come from renewable sources. Meanwhile, coal generation could be reduced to below a third of 2015 levels.

Such a deep transformation of power systems is enabled by key renewable options: solar PV and wind power, which are expected to be deployable at lower costs than fossil and nuclear generation over the coming decade. Most of the additional renewable potential corresponds to these two technologies (41 GW and 13 GW additional compared to the Reference Case, respectively). Biomass power and hydro, both with substantial additional technical potential in the region, should also be considered by CESEC members as they can play a key role in ensuring system reliability and flexibility.

The power mix resulting from the REmap study can be realised with comparable levels of investment in generation assets as in the Reference Case.

Figure 13 Power generation capacity (MW) and power generation (GWh) by technology in the base year, Reference Case 2030 and REmap 2030



Based on IRENA analysis. MW = megawatt; GWh = gigawatt-hour

This is possible thanks not only to the impressive cost reductions in key renewable options, but also because some countries in the region face making significant investments to renovate their aging fossil generation fleet in any case.

The CESEC region was a net importer of electricity (about 8% of consumption, or 69 TWh) in 2015, the base year of this analysis. With the continuation of existing plans and policies, renewable production in the CESEC region is expected to grow by about 66% (or 172 TWh) by 2030 compared to 2015 levels. This projected growth in renewable generation is only enough to supply the expected increase in electricity demand and to slightly reduce the overall generation deficit of the region.

In the REmap Case, power demand grows further due to the proposed accelerated adoption of efficient heat pumps and EVs. The demand increase is estimated at ~96 TWh/year in 2030, an amount comparable to today's electricity consumption of Hungary and Greece combined. The increase in renewable capacity deployment proposed in the REmap Case could deliver almost twice that amount (~189 TWh/year) of additional renewable generation, further reducing the need for fossil generation and electricity imports, while supplying clean power for the efficient electrification of the heat and transport sectors.

The REmap Case results in deployment of large volumes of variable renewable generation capacity. Figure 14 shows the overall shares of renewables and the share coming from variable sources for each CESEC member.

The deployment of increasing shares of variable sources has implications for the operation of power systems in the CESEC region and in neighbouring European countries. These are further explored in the following section.

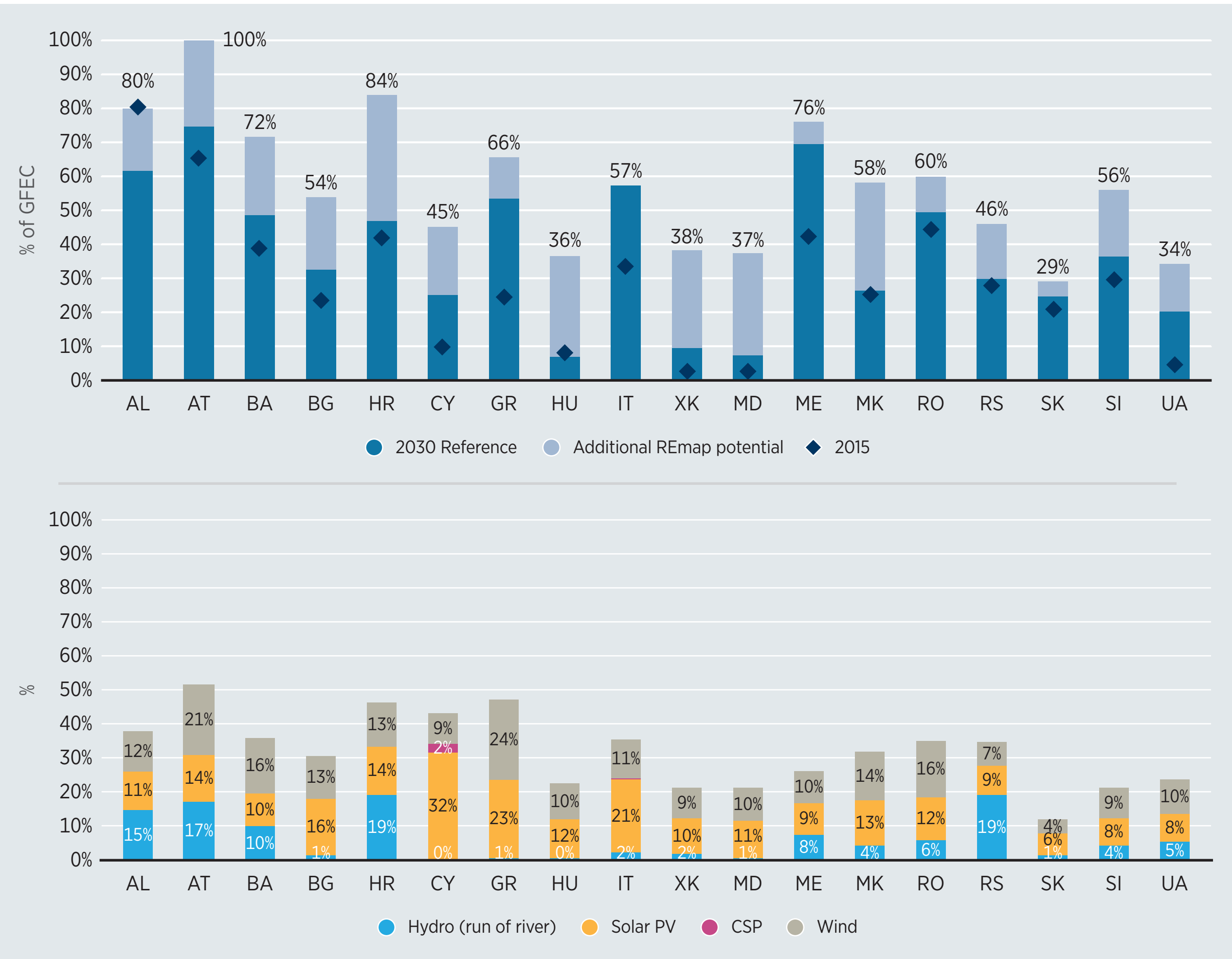
Regional co-operation, particularly when planning for security of supply and system adequacy, will be fundamental to realising the regional vision for the power sector laid out in the REmap scenario. This is particularly important for countries with limited experience and incipient domestic markets for modern renewable options.

POWER SECTOR OPERATION IN 2030

Several previous studies have explored the operation of power systems in the region under future scenarios of high renewable power penetration, *e.g.*, Szabo *et al.* (2017) and REKK Foundation (2019). As part of this REmap study for CESEC, a power sector modelling analysis was carried out to scrutinise the flexibility of the interconnected power systems of CESEC members in 2030 and their ability to absorb the levels of variable renewable sources resulting from the full implementation of the REmap Options.

For this purpose, both the Reference Case and REmap 2030 power generation mixes were analysed with a 39-country pan-European hourly electricity dispatch model based on Collins *et al.* (2018, 2017) originally developed by IRENA[29]

Figure 14 Share of renewables in the power sector in 2015, Reference Case 2030, REmap 2030 (%) (above) and share of variable renewables (%) in REmap 2030 (below)



Based on IRENA analysis

29 *The original version of the model as deployed in IRENA (2018c) covered all EU-28 member states, Switzerland and Norway. The model was expanded for this study to the eight Energy Community Contracting Parties which are members of CESEC to reach full CESEC coverage.*

in co-operation with University College Cork. Further detail about the model and assumptions can be found in Annex C. The analysis consists of detailed simulations of hourly unit commitment and economic dispatch using the tool PLEXOS® Integrated Energy Model.[30]

These simulations provide additional insights into REmap findings by allowing the power systems projected to be better understood in terms of how they would operate with increased amounts of VRE while still respecting constraints that govern reliable power system operation and assuming perfect competition. Power system flexibility will be key to maximising the utility of renewable energy resources (IRENA, 2018a). This analysis can help assess potential flexibility shortages at the regional level, assess the benefits of regional co-operation in renewable energy integration – as exemplified in Box 2 – and quantify expected levels of electricity trade, interconnector congestion, wholesale market price changes, effects on market clearing (*e.g.*, merit order, marginal unit) and other metrics.

This analysis should be interpreted as a first plausibility check of the REmap power generation mix proposed for the CESEC region. CESEC members are treated as a single network node with net transfer capacity considered between these country nodes.

Further analysis is needed to assess the full implications of the REmap Case in terms of short-term stability and localised power system flexibility requirements.

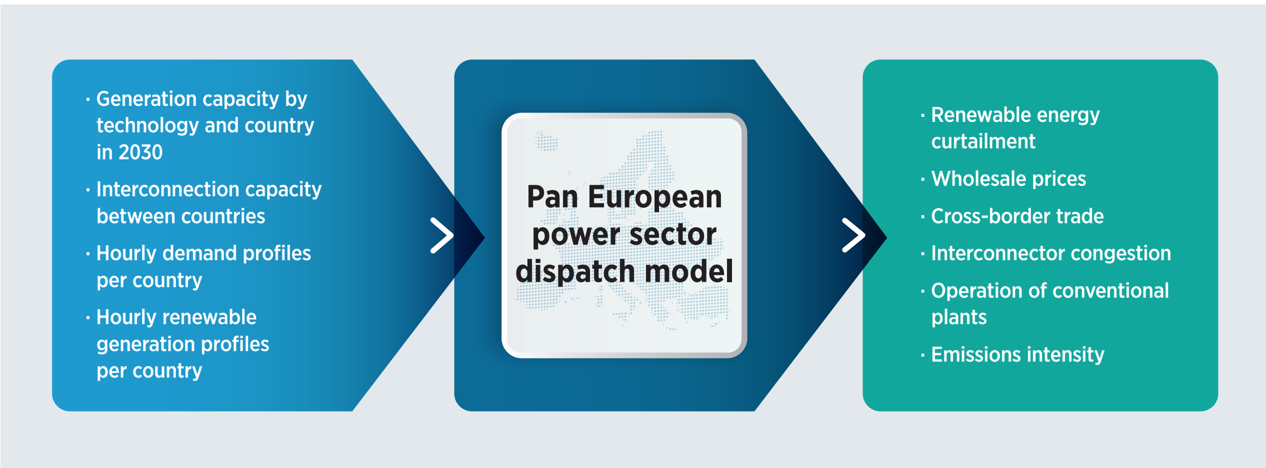
This analysis offers a glimpse into how the power system could function in the CESEC area in 2030. The operational insights gained in particular into the REmap scenario highlight the importance of regional co-operation in terms of both system operation and regulation to realise a power sector with high shares of renewables.

Enabling high shares of renewables through integration of regional power systems

The hourly simulations of the European power system indicate that the capacity mix in the REmap scenario could be operationally feasible at the regional level if CESEC members use interconnector lines (existing and planned) efficiently, *i.e.*, market coupling between countries must facilitate a well-functioning cross-border exchange of energy.

Examples of gains from improved market function and effective use of interconnectors can be found across Europe. For example, in the Central-Western Europe region, implementation of the flow based market coupling method has increased market integration and price convergence (Amprion, 2018; Kristiansen, 2020); in the Iberian Peninsula,

Figure 15 Power sector simulation approach



Source: IRENA

30 *The analyses were performed using the PLEXOS Integrated Energy Model software tool, copyrighted by Drayton Analytics Pty Ltd, Australia and Energy Exemplar Pty Ltd, Australia, pursuant to a Research End User License Agreement provided by Energy Exemplar.*

market integration enabled identical pricing between Spain and Portugal for most of the year in 2018 (OMIE, 2019); similarly, in the Nordic-Baltic electricity market, there was identical pricing in its 16 market zones for 20% of the year in 2018 (AleaSoft, 2019).

Past market fragmentation in South-East Europe hindered co-operation in joint energy projects and transmission infrastructure. Consequently, the level of cross-border exchange of electricity is still small compared to Central Europe (IRENA, 2019b).

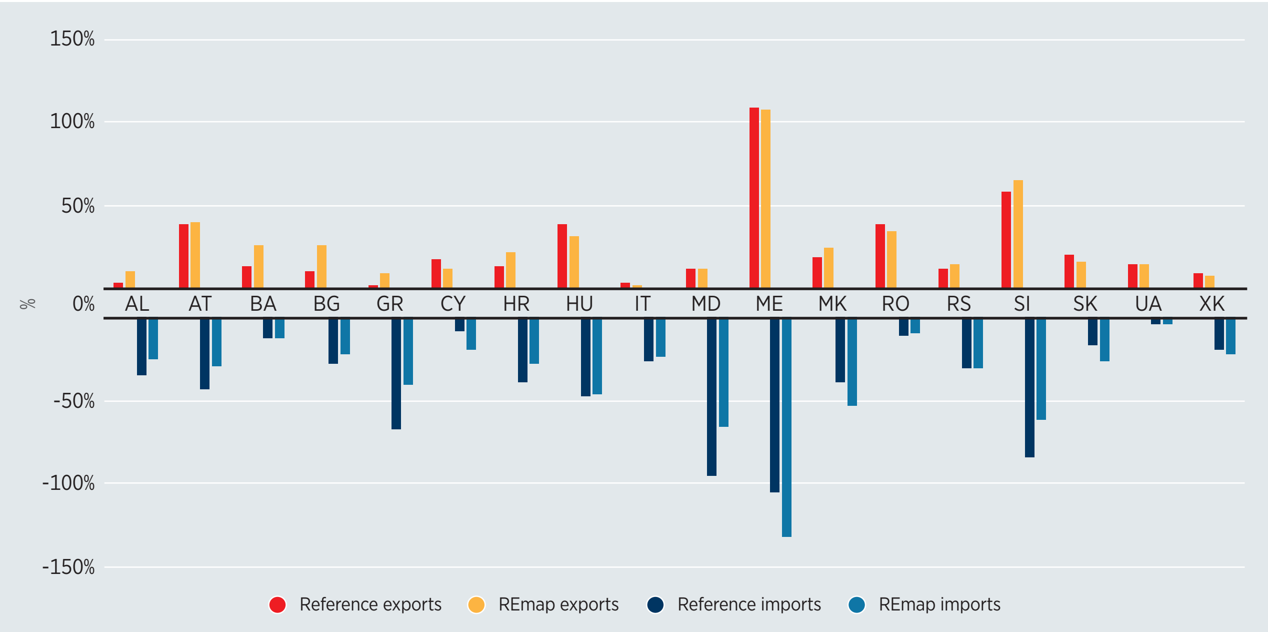
Progressing towards deeper regional market integration will be essential for cost-effective operation of the power systems in CESEC. It will minimise the need for investments in back-up capacity and the curtailment of variable renewables (which in turn will minimise the LCOE of these technologies) and – more broadly – allow for economies of scale by sharing of balancing resources.

Impact of REmap scenario in cross-border electricity exchange

The REmap scenario capacity mix reduces the electricity import dependency of the CESEC region from 7.3% to 5.6% (from 76 TWh to 58 TWh) when compared to the Reference Case despite a 12% increase in electricity demand driven by the electrification of heat and transport. This is achieved by investing in local renewable electricity generation to meet this demand growth. At the same time, this results in increased interdependency in power sector operation within the CESEC region with overall power flow between countries increasing by 4% in the REmap scenario compared to the Reference Case.

The analysis of overall imports and exports at an annual level, as shown in Figure 16, gives some initial insights into the level of mutual reliance of CESEC power systems required to effectively operate a system with high shares of variable renewables. This mutual reliance involves effective international transmission of variable renewable power to demand centres when it is available, as well as the sharing of dispatchable and flexible generation capacity across borders when it is not.

Figure 16 Power import and export activity in the CESEC region in the Reference Case and REmap scenarios as proportions of electricity consumption in each respective scenario for 2030



Based on IRENA analysis

Further insights into operational interdependency can be obtained from an analysis of sources and destinations of power flows. Figure 17 further unpacks this by showing the annual hours of congestion of individual interconnector lines.

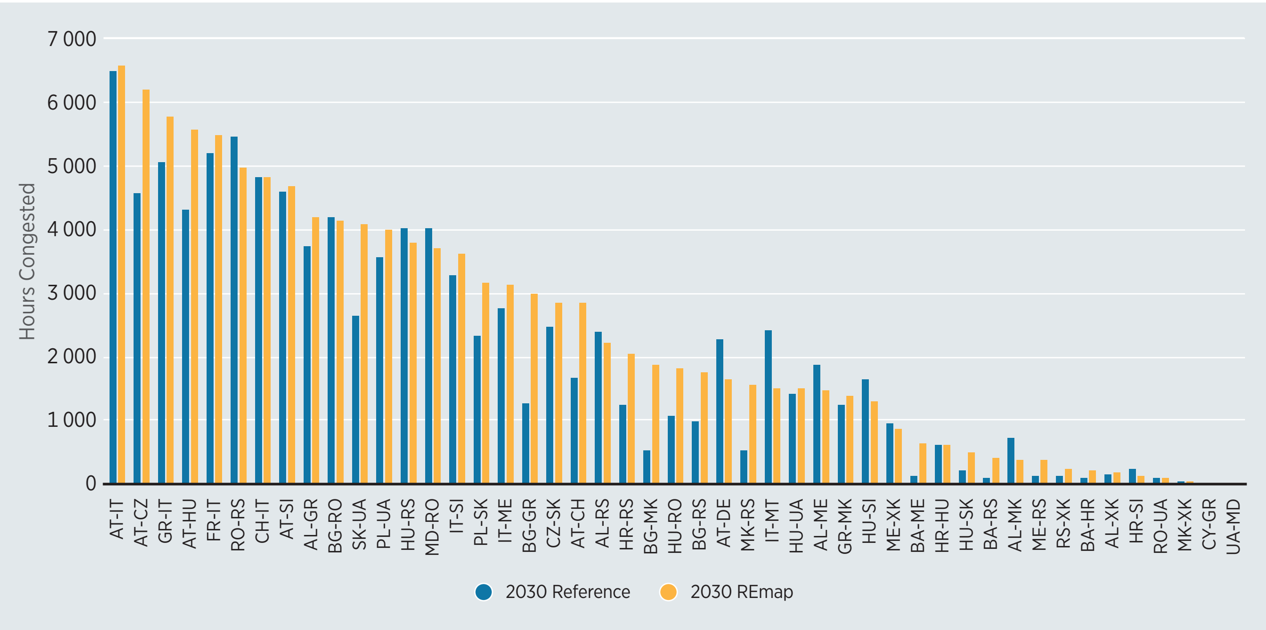
Most interconnector lines in the region show significant levels of congestion, with a weighted average congestion rate of 3 183 and 3 329 hours per year of operation at full capacity in the Reference Case and REmap scenarios, respectively. A few lines are expected to have high levels of congestion, such as those between Italy and the countries from which it imports significant amounts of power which include Austria, France and Greece. Expanding transmission capacity both nationally and internationally would have benefits, and this merits more detailed study; however, the simulations indicate that the interconnection infrastructure planned out to 2030 could in principle enable a power system with high shares of renewables as per the REmap scenario.

Impact of REmap scenario in wholesale electricity pricing

An increased share of VRE, with effectively zero short-run marginal costs, has an impact in wholesale electricity markets. VRE generators displace costlier fossil fuel-based generation in the merit order, leading to a reduction in prices at times of abundant renewable generation. At low VRE penetrations, this impact is negligible, but at high penetrations this market saturation of renewables can significantly reduce market prices (and sometimes even lead to negative market prices) and create the need for market redesign to appropriately value services provided by flexible generation resources (IRENA, 2019a).

Although positive from the point of view of the consumer, the downward pressure on prices created by low marginal cost renewables should not be overlooked, and appropriate market rules should be designed if additional VRE deployment is considered. On one hand, lower prices could undermine the business case for the deployment of renewables. On the other hand, if adequate rules are not in place, further systematic reductions in prices could endanger the viability of conventional dispatchable generation, which is required for security of supply and frequency regulation, among other essential services. Power market design needs to appropriately value and remunerate system services in short-term markets, balancing markets and long-term support mechanisms (Hogan, 2016; IRENA, 2020b, 2017a).

Figure 17 Hours of congestion on interconnector lines in 2030



Based on IRENA analysis

The downward pressure in wholesale prices driven by additional renewables in the REmap Case is partially mitigated by the additional power demand from the deeper electrification of end use sectors. Overall, in the CESEC region, the simulations show a modest weighted price reduction of 2% in the REmap Case compared to the Reference Case (pricing in different CESEC members ranged from EUR 64/megawatt-hour [MWh] to EUR 78/MWh in the REmap case).[31]

As the penetration of variable renewables increases, this can cause market saturation at times of high renewable production (*e.g.*, the midday peak for solar PV generation). This leads to VRE generators being affected more strongly by wholesale price reductions than other modes of generation.

In the REmap scenario, solar power receives an average price 12% below the weighted average wholesale price in the CESEC region. The price received by wind generators holds up better, with revenues 3% below the average wholesale market price over the course of the year thanks to a more stochastic generation profile.

The impact of externality pricing in the power systems of the region

The evolution of carbon pricing will be a key determinant of how power systems operate in 2030 in the region. Currently, CESEC members outside the EU have either no carbon price for power generation or carbon prices that are substantially below the European Union's Emissions Trading Scheme (ETS), neither of which allows for adequate internalisation of the negative externalities of such emissions. This can result in significant carbon leakage by the import of carbon intensive generation into areas governed by the ETS from generators that do not have to pay carbon costs. For this reason, the 2030 dispatch simulations in this study consider all countries in the scope of the model to have a carbon price in line with the EU ETS.[32]

An additional scenario without a carbon price in the Contracting Parties of the Energy Community was also simulated to gauge the impact of aligning all CESEC members with the EU ETS. The introduction of carbon price in line with the EU ETS across CESEC reduces coal generation by about a third compared to a scenario assuming the present-day geographical scope of the scheme. This results in significant carbon emissions reductions, estimated at 33 Mt CO_2 (about a fifth of the overall emissions reductions delivered by the REmap Case).

This illustrates the importance of a level playing field and a coherent regional approach to achieve emissions reductions cost-effectively in the overall CESEC area. This is not just applicable to emissions pricing but is also important in terms of energy subsidies and price regulation, which could also distort the market and have similar effects on system operation.

Box 2 Illustration of regional co-operation: 2030 hourly cross border exchange

The increased reliance on variable renewable power sources within CESEC in the REmap scenario raises the need for cross-border co-operation in power system operation to 2030. To best understand the implications, it is essential to consider what this means in terms of the extreme points of the year, such as how the system operates during the weeks in which demand is high but power supply from variable renewable sources is low and vice versa. The ability of a country to import and export power to neighbours during these periods is crucial to understanding how to operationalise a highly renewable low carbon power sector in the region.

To illustrate this, examples of two critical weeks (as simulated in the pan-European dispatch model) were selected for Hungary and are shown in Figure 18 in terms of national power generation and electricity demand as well as its imports and exports with neighbouring countries. Figure 18a shows a week in January 2030 when VRE supply is very low (serving 4% of overall demand) and Figure 18b shows a week in early May when VRE supply is very high (serving 38% of overall demand).

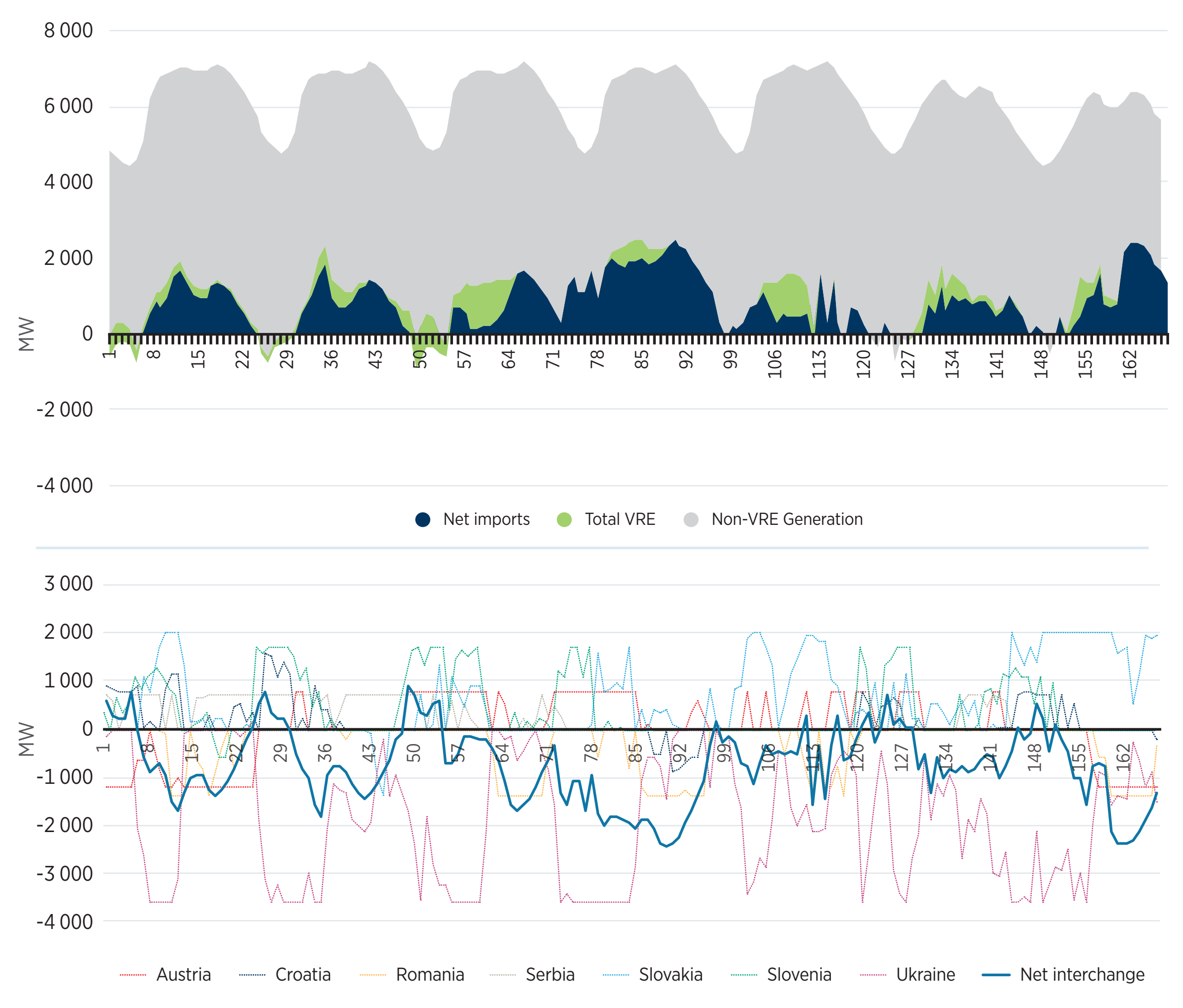
31 All EUR figures reported in this study reflect EUR values as of 2015.

32 A price of EUR 25 per tonne of CO_2 in 2030 was used, as per the Impact Assessment of the European Commission for amending Directive 2003/87/EC to enhance cost-effective emissions reductions and low-carbon investments (European Commission, 2015).

During both periods, the country is a net importer of power with about 11% of demand served by imports in both the low and high VRE weeks. It remains a significant importer during the high VRE week because of simultaneous high amounts of VRE generation in the broader region which its substantial interconnection allows to be integrated cost-effectively. However, in both the low and high VRE weeks there are also a few periods in which the country is a net exporter, which shows the co-operation required to achieve high shares of VRE in the CESEC region for international balancing.

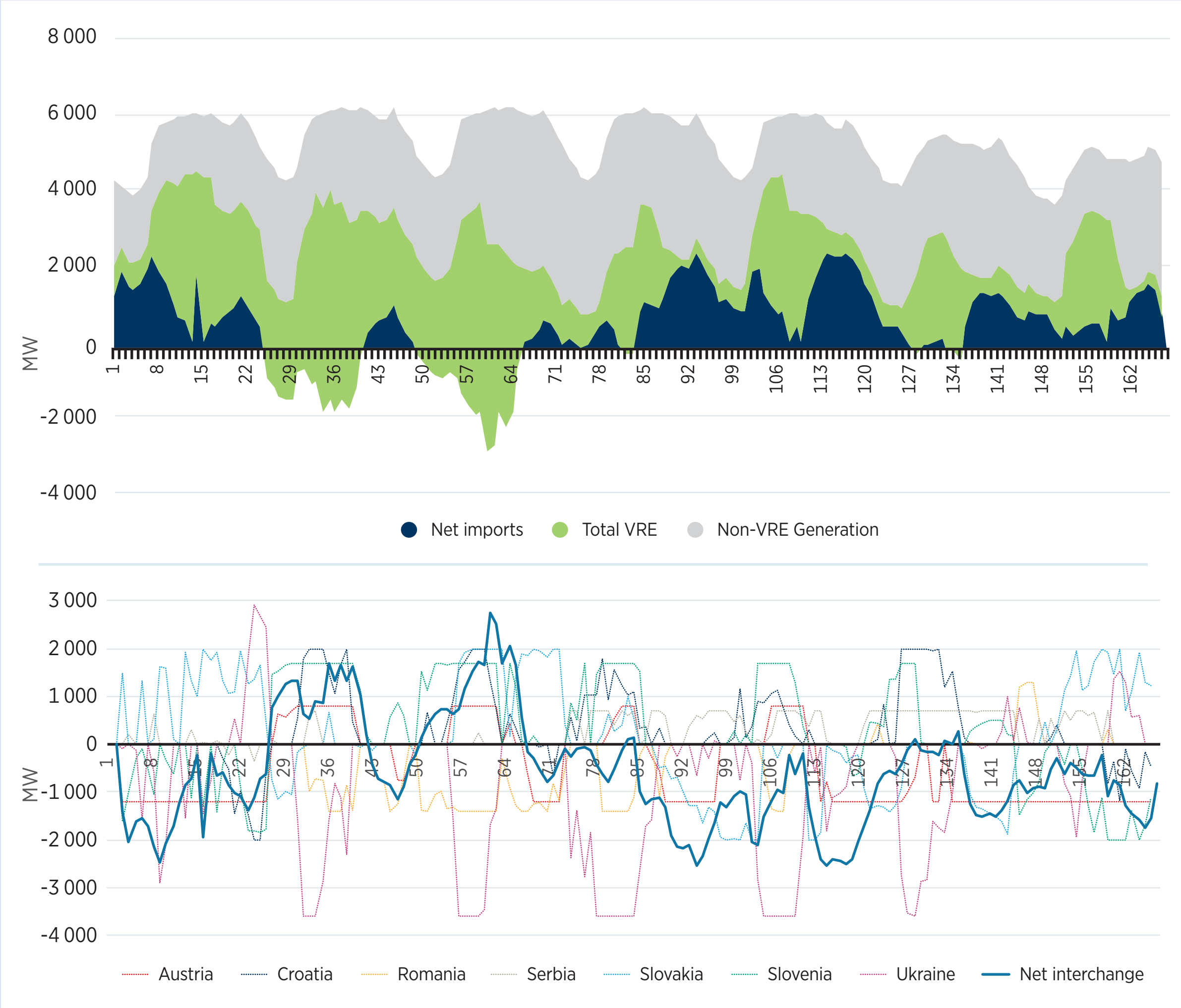
During both of these critical weeks, Hungary is often simultaneously importing and exporting power, which illustrates the regional interdependence in power system operation. When analysed at an hourly level across the year, 62% of the total power that Hungary imports is re-exported instantaneously. This is also true of other countries in the region, such as Montenegro (74%), Croatia (57%), Serbia (56%) and Slovakia (42%). These values were determined based on the assumption of minimal sub-national transmission and distribution constraints which, if significant, would reduce such wheeling of power through countries. Nonetheless, this demonstrates the important role of regional co-ordination for effective system operation to realise a system with high shares of renewable energy in the CESEC region.

Figure 18a A critical week with low VRE supply in the Hungarian power system in the 2030 REmap Case.



Note: The top section shows how demand was served during each hour which, if negative, indicates that Hungary was exporting. The lower section shows the flows on interconnectors (negative indicating imports and positive indicating exports) and overall net interchange in each hour.

Figure 18b A critical week with high VRE supply in the Hungarian power system in the 2030 REmap Case.



Note: The top section shows how demand was served during each hour which, if negative, indicates that Hungary was exporting. The lower section shows the flows on interconnectors (negative indicating imports and positive indicating exports) and overall net interchange in each hour.

DISTRICT HEAT GENERATION

District heating systems deliver about 13% of the overall heat demand in the CESEC region. This figure is comparable to the combined total energy demand of Hungary and Slovakia. The importance of distributed heat varies widely across CESEC members, from no role or a negligible role in some countries to a critical role in others. In terms of volume, Ukraine, Italy, Austria and Romania are the largest consumers, but distributed heat networks play an important role in multiple other CESEC members like Serbia, Bulgaria, Republic of Moldova, Slovakia or Hungary.

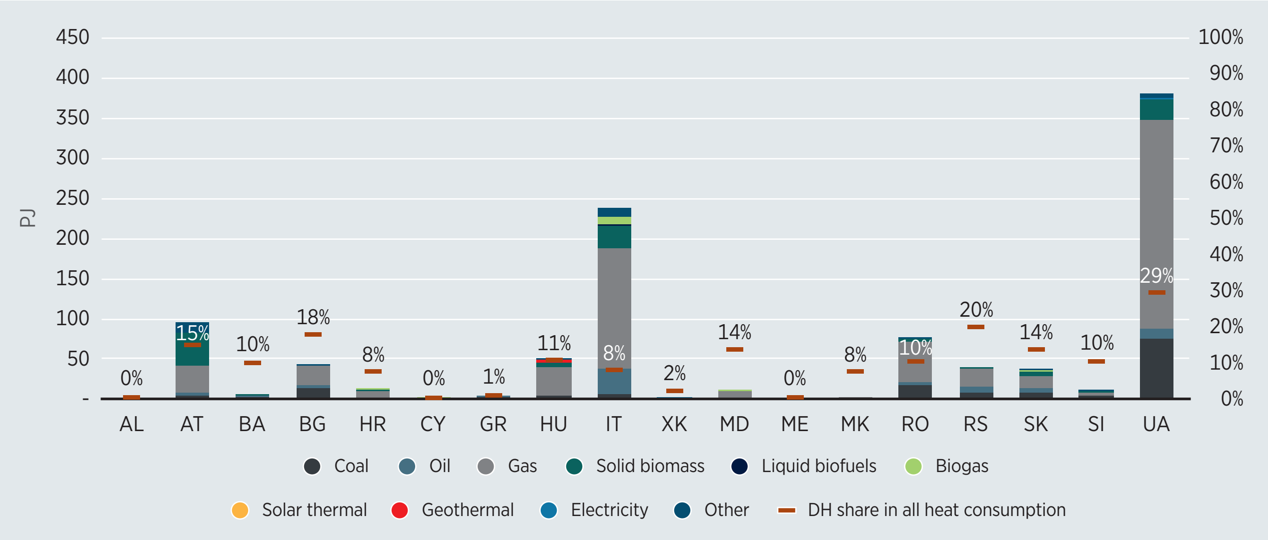
District heating systems in the region are mostly natural gas or coal fuelled. Natural gas accounted for almost two-thirds of the overall fuel input in 2017. The bulk of renewable supply was bioenergy (mostly solid biomass) with some degree of deployment in most CESEC members. Geothermal supply played a small role in Austria, Hungary, Italy, Romania, Slovakia and Slovenia. However, the overall penetration of renewables in the CESEC region remained low, at about 13%.

Figure 20 shows the breakdown of distributed heat generation in CESEC members by energy source in 2015 (base year), Reference 2030 and REmap 2030. By 2030, assuming the implementation of existing plans or continuation of recent trends, fossil fuels will still dominate the supply for distributed heat in the CESEC region. Natural gas consumption is expected to remain roughly flat, while coal consumption would decrease by about a third, compared to 2015.

Most CESEC members with significant district heating systems plan to scale up renewable adoption over the coming decade. Biomass accounts for the bulk of the projected growth, with much smaller contributions of geothermal and other renewable sources. Overall, in the Reference Case, the share of renewable energy in district heat generation is expected to grow from 12% in 2015 to 29% in 2030 across the CESEC region.

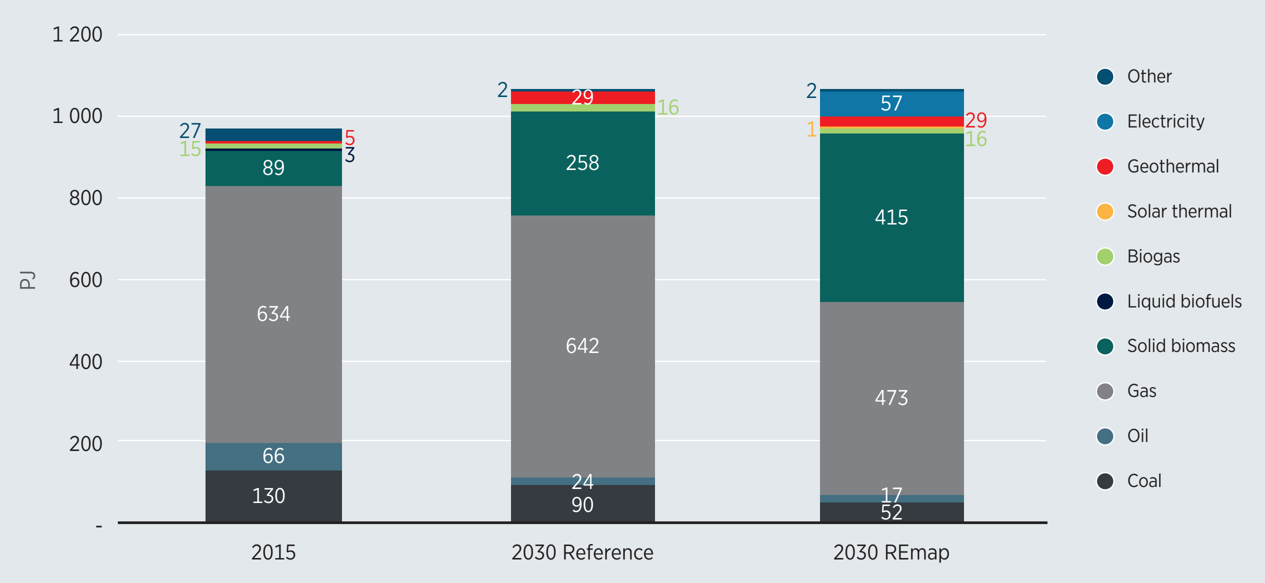
The REmap analysis for CESEC identifies significant additional potential in the region to upgrade existing distributed heat systems using renewable sources, both with direct heating and CHP-based

Figure 19 Distributed heat generation in 2017 by source (PJ) (left axis) and distributed heat share in total heat demand (%) (right axis)



Source: IRENA based on Eurostat energy balances

Figure 20 District heat generation by source in CESEC: Base year, Reference 2030, REmap 2030 (PJ)



Based on IRENA analysis

systems. Accumulated experience shows that with appropriate frameworks in place, solid biomass residues from forests and farms can be mobilised to serve district heating systems effectively (IRENA, 2019f). Several CESEC members with high shares of district heat in their supply mix also have large untapped solid biomass resource potential[33] that could be mobilised to accelerate the transformation of the sector.

Besides biomass, efficient electrification of district heating systems with heat pumps can further contribute to the improvement of efficiency and the introduction of renewables in the sector. Large-scale electric heat pumps have reached technological maturity (David *et al.*, 2017) and can be connected to a variety of possible sources, including geothermal heat, sewage water and industrial waste heat. Furthermore, a partial electrification of heat supply can contribute to the cost-effective integration of variable renewables in the power sector by providing an additional source of flexibility.

Geothermal heat can also be scaled up to increase the share of renewables in the sector. Several studies have documented the favourable geothermal resource conditions in the Pannonian Basin extending across much of the CESEC region, such as Dumas and Bartosik (2014) and DARLINGe (2018). The assessment of cost-effective potential for geothermal district heating requires a detailed mapping of high-resolution resource data with high-resolution locational data on heat supply networks, which is not available for all CESEC members. For this reason, the REmap scenario takes a conservative approach by including only projects planned or under development. Further analysis at the country level with higher geographical resolution would likely identify substantial untapped cost-effective potential.

In the REmap Case for the CESEC region, the overall share of renewable energy in district heating systems grows to almost half of total generation by 2030. This measure alone could reduce fossil fuel demand in the region by an estimated 251 PJ, an amount comparable to the total natural gas consumption of Austria.

33 More information about estimated CESEC bioenergy potential can be found in Annex D.

RENEWABLES IN END-USE SECTORS

TRANSPORT

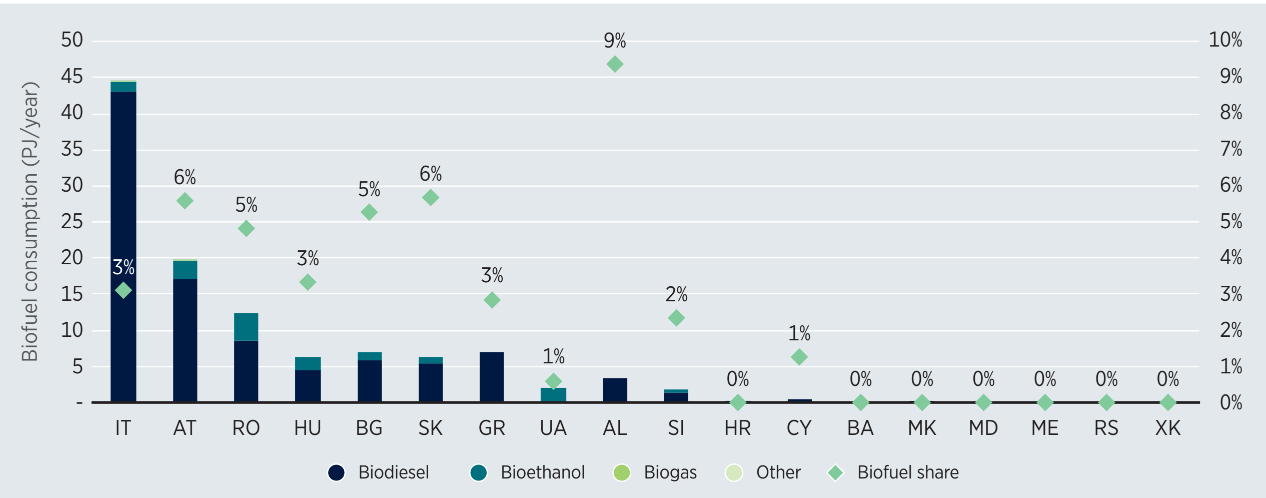
Recent trends in the region

Transport is the sector with the lowest renewable share in CESEC member countries. The contribution of renewables to deliver transport services across the region remains very low (at 3.8% of the final energy consumption of the sector in 2017 – the most recent year with available statistics for all CESEC members).

For comparison, the renewable share[34] in the EU in the same year was 5.3%. Most renewable consumption in the CESEC region corresponds to biodiesel in EU member states, driven by the EU's objective of 10% renewable share in the sector by 2020 established in Directive 2009/28/EC.[35] Renewable electricity in trains is significant in the region, accounting for about a fifth of all renewable consumption in the sector.

The contribution of renewables to overall transport consumption in the non-EU part of CESEC remains much lower, at about 1.4%, and it is limited to blended biodiesel in Albania, small fractions of bioethanol in Ukraine, and renewable electricity for rail in Bosnia and Herzegovina, Montenegro, North Macedonia, Serbia and Ukraine.

Figure 21 Biofuel consumption (PJ/year) and shares (%) by CESEC country in 2017



Source: IRENA based on Eurostat energy balances

34 Excluding multipliers for specific energy carriers established in EU Directives.

35 Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC.

Prospects to 2030

By 2030, demand for energy in the transport sector is expected to grow slightly in the CESEC region (about 4%) compared to 2015 levels. Growth is driven by the eight Energy Community Contracting Parties, while consumption in the EU part of CESEC is expected to decrease slightly.[36] In the Reference Case, the role of renewables in the sector is expected to remain very modest by 2030, representing only about 7% of final energy consumption.[36]

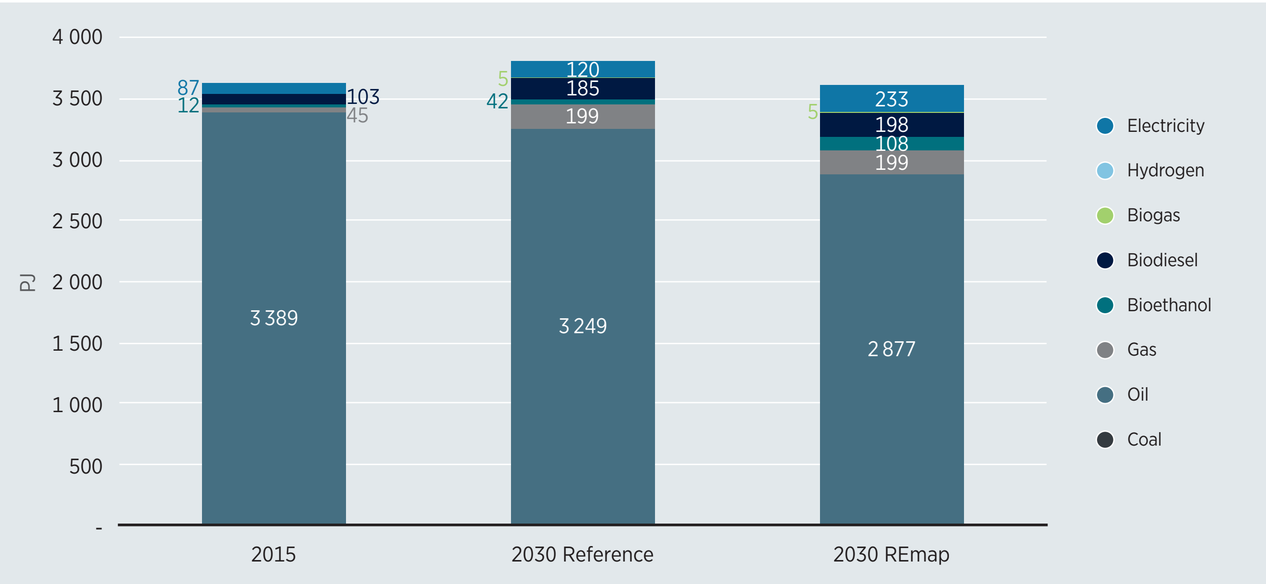
In the REmap Case for CESEC, the overall share of renewable energy grows further to about 12% of final energy consumption[37] by 2030, with additional deployment of EVs and liquid biofuels. Faster electrification of road vehicles is a key option for the modernisation of the transport sector. EVs typically consume three to four times less energy than internal combustion engine (ICE) vehicles, and the use of electricity enables an easier shift to renewables overall, as renewable power options are already cost-effective.

Today, deployment of EVs is negligible in CESEC members. However, the global automobile industry is changing at an accelerated pace, driven by technological progress – such as a steep reduction in the cost of batteries – and environmental regulations. While the upfront costs for EVs are still higher than for ICEs, the total cost of ownership is already favourable or comparable in an increasing number of use cases.

Furthermore, this cost reduction trend is expected to continue, possibly resulting in upfront cost parity for light duty vehicles within the first half the coming decade (Bullard, 2019; International Council on Clean Transportation, 2019).

The REmap analysis estimates that most new light duty vehicles sold could be electric by 2030 in CESEC. Overall, about 20% of the stock of light duty ICE vehicles could potentially be replaced across the region.[38] A fraction of heavy-duty vehicles like city buses and last-mile trucks could also be electrified by 2030.

Figure 22 Final energy consumption for transport by fuel in the CESEC region in the base year, Reference Case 2030 and REmap 2030 (PJ)



Based on IRENA analysis

36 For more detail on the sources to build the Reference Case for each CESEC member, see Annex A

37 Excluding multipliers for specific energy carriers established in EU directives.

38 The estimated potential vehicle stock replacement differs substantially per market, ranging from 12% to 28% depending on country conditions.

IRENA estimates that accelerating the electrification of road transport in line with the REmap scenario could reduce fossil fuel demand in the CESEC region by about 293 PJ below Reference Case levels in 2030, an amount comparable to the total energy consumption in the transport sector of Ukraine.

Liquid biofuels – both advanced and conventional – can also be significantly scaled up in the CESEC region.

Biofuels are a viable renewable solution for the large stock of road vehicles with ICEs that will remain in the roads for the next couple of decades, as well as for transport modes where electrification is not an option. IRENA estimates that the use of blended liquid biofuels could roughly triple by 2030 compared to today's levels, mobilising sustainable feedstocks available in the region.[39]

By 2030, biofuels could account for about 9% of energy consumption for transport in CESEC (or 306 PJ, an amount larger than twice the total energy consumption for transport in Bulgaria).

39 For more information on sustainable bioenergy potential assumptions, see Annex D

BUILDINGS AND INDUSTRY

Recent trends

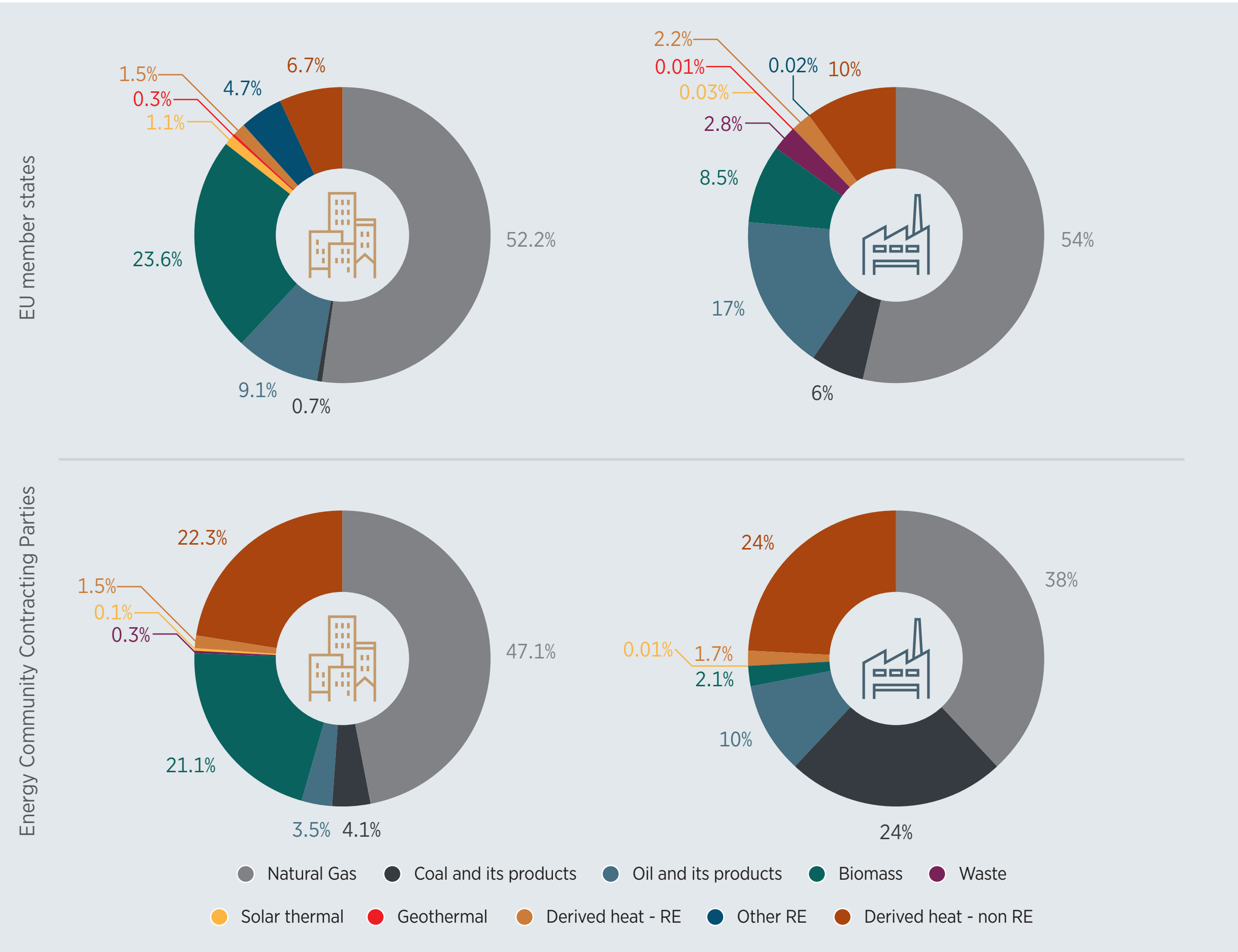
Heat accounts for about half of the total final energy demand in the CESEC region. The bulk of this heat (about 87%) is directly produced in equipment installed in residential and commercial buildings, and in industry.

Natural gas dominates the energy supply for heating in residential and commercial buildings, accounting for more than half of the consumption. Solid biomass is the largest renewable source for heating overall, both in EU and non-EU CESEC members. It accounts for about 23% of heat consumption in buildings across the whole region. The consumption of solid biomass in traditional cookstoves still plays a vital role in all of South-East Europe as a direct source of heat for residential buildings (IRENA, 2019b).

In terms of industrial heat, direct use of renewables is limited to small shares of biomass and waste (less than 9% of industrial consumption in CESEC), with negligible contribution of other renewable sources. Natural gas, oil and coal still supply the bulk of energy for heat applications in industry in the region. In the eight Contracting Parties of the Energy Community, coal still plays an important role, accounting for about a quarter of the industrial heat demand.

Besides the use of biomass and renewable waste, the current adoption of other renewable heating options in both the building and industrial sectors is almost negligible. Despite the very good solar resource in the region, the current deployment of solar thermal technology is minimal except in Albania, Austria, Cyprus, Greece (the only countries with a solar thermal share above 1% of energy consumption in buildings).

Figure 23 Breakdown of final energy consumption of energy carriers (excluding electricity) in 2017 for heat in buildings (left) and industry (right)



Source: IRENA based on Eurostat energy balances

The market adoption of efficient heat pump systems is either negligible or in the early stages in most countries in the region.

Prospects to 2030

An analysis of the Reference Case indicates that the energy demand in buildings and industry is expected to grow slightly in the region over the next decade.

In residential and commercial buildings, the share of renewables is expected to increase from 27% in 2015 to 33% in 2030. This growth is almost exclusively driven by the higher share of renewable electricity – and to a lesser extent, renewable district heat – expected in the mix. Besides the use of higher shares of renewable power and district heat, the mix of energy carriers directly consumed in buildings is expected to remain almost unaltered.

In industry, renewables are expected to grow from 6% in 2015 to 15% in 2030, driven by higher shares of renewable power and district heat as well as a substantial increase in the use of solid biomass for heat production.

The REmap analysis identified significant additional potential to accelerate renewables in both sectors beyond the Reference Case.

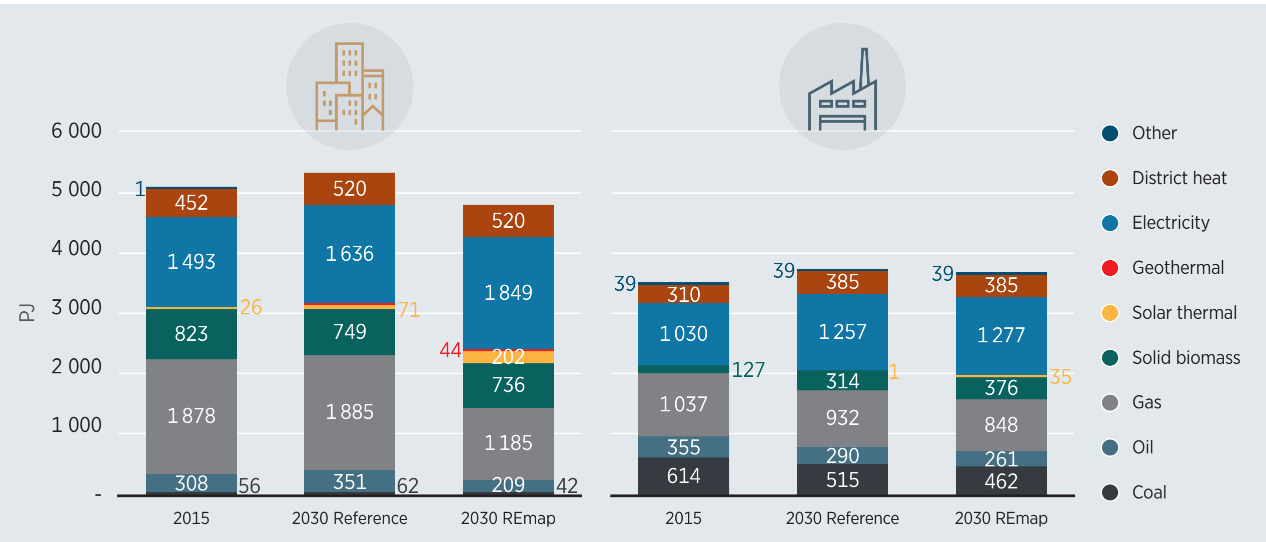
Solid biomass is already extensively used in buildings across the region.

In some CESEC members there is room for scaling up use, while in others – where traditional cookstoves are still pervasive – the adoption of new, more efficient appliances can unlock additional potential, delivering more energy services with substantially less biomass consumption and reduced indoor air pollution. In industry, there is potential to scale up the use of solid biomass for high temperature processes.

Accelerating the efficient electrification of low temperature heat with heat pumps could reduce fossil fuel use in buildings and industry in CESEC members by about 11% (or 583 PJ) in 2030, below the Reference Case. This amount is larger than the total energy consumption in these two sectors in all the Western Balkans. Electrification of heat in buildings needs to be considered in conjunction with improvements in the overall energy performance of the buildings to tap the full potential for fuel demand reductions.

In addition to increased electrification, solar thermal can provide affordable hot water in residential and commercial buildings as well as competitive low temperature heat for certain industry sub-sectors. Most countries in the region can scale up deployment of this technology substantially. Solar thermal systems could reduce demand for fossil fuels in the CESEC region's heat sector by about 3% in 2030 compared to the Reference Case.

Figure 24 Final energy consumption by carrier in CESEC members in 2015, Reference Case 2030 and REmap 2030 (PJ). Buildings (left); Industry (right).



Based on IRENA analysis.

MOVING FORWARD

A REGIONAL ENERGY TRANSITION TO ADDRESS COMMON CHALLENGES IN THE CESEC REGION

Over the next decade, CESEC members face a multifaceted challenge. They will need to modernise aging energy systems while maintaining a secure, healthy and affordable energy supply and complying with international environmental commitments.

A shift towards renewables can help CESEC members to realise all these objectives effectively.

CESEC members will have to scale up energy investments significantly in the coming years, regardless of the choice of technology mix. Renewables provide a cost-effective opportunity to modernise the CESEC region's energy systems while improving energy security, reducing pollution and aligning the region with long-term international decarbonisation goals.

The CESEC region is endowed with vast amounts of high-quality renewable energy resources which can be tapped cost-effectively over the coming decade.

The long-term economic potential for key technologies like solar PV and wind power in the region is many times larger than the deployment by 2030 in IRENA's REmap scenario.

Other key renewable sources – such as bioenergy – can also be scaled up significantly and sustainably from today's consumption levels.

Furthermore, the economies of the CESEC region – in several cases with significantly lower GDP per capita than the EU average – could be a very attractive target for international investors in the energy sector, provided that transparent and reliable regulatory frameworks are in place. Renewables provide a clear opportunity for CESEC members to attract large volumes of foreign clean energy investment into the region, create jobs and further drive growth.

The COVID-19 pandemic has devastated people's lives around the world and thrown economies into severe crises – including those of CESEC members. The energy sector is at the centre of the economy and will be a crucial element of the recovery post-COVID-19.

An energy system fuelled primarily by renewable sources in the CESEC region is technically feasible and economically desirable. By placing energy transition investments, regulations and policies at the centre of recovery plans, policy makers can simultaneously alleviate the economic impacts of the COVID-19 crisis, stimulate economic growth and create jobs, while accelerating the transformation of the energy sector.

CESEC MEMBERS WILL BENEFIT FROM EMBRACING THE ONGOING GLOBAL ENERGY TRANSFORMATION

Driven by disruptive innovation and deep cost reductions in key technologies such as solar, wind power and electricity storage, the global energy sector is undergoing a profound transformation. The world's energy sector is transitioning at an accelerated pace towards more decentralised, more digitalised and more integrated energy systems, with increasingly cheap renewable electricity at the core.

Onshore wind and solar PV are set to consistently offer a less expensive source of new electricity than the least-cost fossil fuel alternative, without financial assistance.

New solar PV and onshore wind increasingly cost less than the marginal operating cost of existing coal-fired power plants. Furthermore, cost reductions for solar and wind power technologies are set to continue. Data from IRENA's Auction and Power Purchase Agreement (PPA) Database show that all existing available renewable power generation options will soon compete head-to-head with incumbents (IRENA, 2019c).

Recognising in a timely manner the strong and irreversible momentum of these macro technology trends will be critical for CESEC members to successfully steer their energy systems towards future economic competitiveness and energy affordability for their citizens, and away from long-term carbon liabilities and stranded assets.

Renewables and energy efficiency can deliver more than 90% of the emissions reductions needed to meet the goals of the Paris Agreement by 2050, according to IRENA's global energy transformation roadmap. However, the case for renewables and efficiency extends far beyond environmental arguments.

Investing into the renewables-based energy system makes strong economic sense. IRENA's analysis shows that a global shift to renewables and energy efficiency in line with the long-term decarbonisation objectives of the Paris Agreement can create more energy jobs than those lost in fossil fuel industries, while boosting economic growth and significantly improving overall welfare (IRENA, 2020a).

Making the transition to a renewables-based energy supply driven by domestic resources can enable CESEC members to capture increasing shares of the energy value added chain within the region (IRENA, 2018b, 2017e), progressively build domestic technological capacity and turn the energy system into a driver of clean economic growth, rather than a burden on public budgets.

Furthermore, accelerating the deployment of renewables in the CESEC region is a cost-effective strategy to reduce dependency on energy imports and improve the security of supply. At the same time, a shift to electrification of heat with renewables can avoid further investments in redundant gas infrastructure, which would be at high risk of becoming stranded if the region is to meet the goals of the Paris Agreement.

Finally, accelerating renewables will deliver significant benefits to society by reducing air pollution and improving the health of citizens in CESEC member countries.

KEY ACTIONS TO ENABLE THE TRANSFORMATION

Achieving the shift to modern, clean, competitive and regionally integrated energy systems in the CESEC region will require decisive policy action at the national and regional levels. Developing a long-term vision in national plans is a key and important first step. But the necessary investments will also depend on adopting appropriate regulatory and market frameworks. Neighbours can work closely with each other to reduce costs and tap the synergies of a regional approach.

At the national level, CESEC members should focus on improving the conditions for investment in their respective renewable markets.

- Although renewables are ready to compete, they need a level playing field, with open, stable and transparent regulatory frameworks to enable fair competition with fossil technologies. Key elements of such a level playing field are a progressive elimination of remaining subsidies to fossil fuels – including through indirect mechanisms, such as below-market regulated energy prices – and a fair set of market and operation rules, adapted to the intrinsic variable nature of renewable technologies.

- The energy supply sector provides an immediate opportunity for scaling up renewable investments in the region, as technologies are cost-competitive and there is a need to replace obsolete fossil generation assets. However, policy makers need to foster the transition towards renewables in end-use sectors as well. Planning for an acceleration of renewable electrification of heat and transport is fundamental to developing the markets and the infrastructure as quickly as possible and tapping the large potential benefits.
- The high cost of capital has been an important barrier for renewable investment in several CESEC members. Even under challenging macroeconomic conditions, national energy policy can go a long way in reducing risks for investors, for example by adopting best practices in auctions[40] and administrative procedures. Additionally, CESEC members can work together with the EU, the Energy Community Secretariat, as well as with multilateral financial institutions to develop risk-mitigation mechanisms tailored to the specific conditions and needs of the region.
- Cities in the region will benefit from a cleaner energy system and can also play an important role in driving the transformation. Co-ordination of national energy planning with subnational entities can accelerate the transition in areas such as electromobility or the adoption of distributed renewables. Additionally, decentralised structures such as renewable energy communities have a role to play in mobilising private investment and securing public acceptance.

At the regional level, CESEC members should work closely with neighbours to tap the synergies of regional co-operation.

Co-operation can happen at multiple levels involving both the *software* and the *hardware* of energy systems. This can accelerate the transition by mutual experience-sharing in developing and implementing policies and regulations and by reducing the costs of balancing energy systems and security of supply. Open co-operation at the regional level can also increase the attractiveness of renewable energy in individual countries – particularly for smaller CESEC members – by reducing the risk perception for investors and increasing addressable market size for developers.

- One key area for regional co-operation is the transition towards integrated electricity markets, which will be instrumental for cost-effective decarbonisation of national power systems. Co-operation towards building functional regional markets is also applicable to other renewable carriers with large potential for trade in the CESEC region, such as biomass.
- Integrated markets require integrated infrastructure. In this area there is also significant potential for co-operation. CESEC members could work towards regional or subregional co-ordinated investment plans to share the costs and benefits of key infrastructure for the transition to renewables such as equipment manufacturing facilities, transboundary hydro projects, biofuel conversion plants and EV charging infrastructure.
- Some CESEC members will need external help to develop their national plans, address socio-economic challenges and mobilise the required investments. European institutions, international organisations, development agencies and multilateral banks can and should play important roles in supporting these countries moving forward.

40 In 2018, the European Bank for Reconstruction and Development and the Energy Community Secretariat, in collaboration with IRENA, issued joint policy guidelines to help countries design and implement competitive selection processes for supporting renewable energy. The guidelines are available from: www.ebrd.com.

ANNEX A
METHODOLOGY

THE REMAP APPROACH

REmap is IRENA's renewable energy roadmap that focuses on identifying the realistic potential of renewable energy to the year 2030 and beyond, in all sectors of the energy system. It assesses renewable energy in terms of its costs and investments, as well as its contribution to climate and environmental objectives.

The REmap analysis generates renewable energy alternatives for decision makers to consider. It is an analysis of technology options that quantifies the renewable energy potential by sector and by country. REmap follows a bottom-up approach, where each country contributes to achieve higher renewable energy uptake at the regional or global level.

REmap analyses two forward-looking scenarios. The first one, called the "Reference Case", is a baseline featuring continuation of current trends and implementation of planned policies; the second, called "REmap", is an accelerated renewable energy scenario to 2030 (IRENA, 2016c).

Based on the energy mix projected by a country in the Reference Case, the REmap analysis focuses on identifying cost-effective alternatives to provide energy services with renewables. These alternatives are named "REmap Options", based on the realistic renewable energy potential realisable by 2030 at the sector and technology levels.

REmap Options are assessed for the energy supply (*i.e.*, electricity and distributed heat production) and for end-use sectors, including heating and cooling in industry and buildings (*i.e.,* residential, commercial and public buildings) as well as electrification and biofuels in the transport sector.

REmap Options aim to close an important knowledge gap for many countries by helping policy makers better understand the renewable energy opportunities before them. Several factors are considered in identifying and analysing REmap Options,[41] including resource availability, access to finance, human resource needs and supply, manufacturing capacity, policy environment, available infrastructure, annual capacity additions, and the age of existing capital stock as well as the costs of technologies by 2030.

The process of the REmap analysis for a country can be summarised in the following steps:

- **Building the Reference Case:** The energy balance of the country is determined for the base year (2015) and for 2030, derived from detailed datasets in national energy plans whenever available or other relevant studies.
- **Assessment of REmap Options:** Once the Reference Case is determined, the additional realistic potential of renewables is identified by sector and by technology and source.

41 IFor further details on the REmap methodology and metrics, please consult the appendix of REmap: Roadmap for a renewable energy future (IRENA, 2016c), available at www.irena.org/remap.

Table 2 Key REmap options, approach and sources for analysis

Sector	REmap Option	Adoption in base year	Potential applicable market	Renewable supply potential
Buildings	**Electric heat pumps**	Eurostat (2019c) WBIF (forthcoming) EHPA (2017)	Space heating consumption	Unconstrained
Buildings	**Solid biomass boilers**	IRENA based on Eurostat (2019a)	All thermal loads in buildings	IRENA analysis (see Annex D)
Buildings	**Solar thermal**	IRENA based on Eurostat (2019a)	Hot water consumption	Medium-term penetration of 1 m² (square metre) solar thermal panel/capita
Industry	**Electric heat pumps**	Eurostat (2019c) WBIF (forthcoming) EHPA (2017)	Country-specific % of low temperature industrial heat Penetration potential of heat pumps informed by Wolf and Blesl (2016)	Unconstrained
Industry	**Solid biomass boilers**	IRENA based on Eurostat (2019a)	Country-specific % of industrial heat	IRENA analysis (see Annex D)
Industry	**Solar thermal**	IRENA based on Eurostat (2019a)	Country-specific % of low temperature industrial heat	Country-specific % of low temperature industrial heat
Transport	**EVs**	IRENA based on Eurostat (2019a)	Stock of ICE vehicles (full stock of light duty vehicles plus fraction of heavy duty vehicles)	Unconstrained
Transport	**Liquid biofuels**	Eurostat (2019a)	Stock of ICE vehicles in road transport	IRENA analysis (see Annex D)
Power	**Solar PV utility scale**	Eurostat (2019b, 2019d) IRENA (2020d)	Power generation gap in 2030 resulting from planned decommissioning of existing conventional capacity at end of lifetime and expected power demand increase	IRENA (2017d) Joint Research Centre (2019)
Power	**Solar PV distributed**			Joint Research Centre (2019)
Power	**Wind onshore**			IRENA (2017d) Joint Research Centre (2019)
Power	**Hydro power**			WBIF (2019) Mott Macdonald (2017) Althesys (2019) IRENA (2015a) KPMG (2010) E3MLab *et al.* (2016)
Power	**Biomass**			IRENA analysis (see Annex D)
Power	**Biogas**			IRENA analysis (see Annex D)
Distributed heat	**Biomass**	IRENA based on Eurostat (2019a)	Heat generation gap in 2030 resulting from decommissioning of existing capacity at end of lifetime and expected demand increase	IRENA analysis (see Annex D)
Distributed heat	**Electrification**		Low temperature district heating networks	Unconstrained
Distributed heat	**Other renewable**		-	Subject to project-specific information

Each REmap Option is characterised by its renewable energy contribution and its costs and is used to substitute an equivalent amount of energy (and related capacity) provided by the non-renewable technology.

- **Building the REmap Case:** The scenario resulting from the substitution of conventional technologies – from the Reference Case – with the identified REmap Options is called the REmap Case. This is reflected in an alternative energy balance for the country in 2030.
- **Compilation of cost-supply curve:** Both the renewable energy potential and the cost of each REmap Option compared to the conventional technology are compiled into a cost-supply curve, allowing evaluation of the available cost-effective potential and the level of renewable energy penetration that can be achieved with different options.[42]
- **Estimation of costs and benefits of the REmap Case:** Once the REmap analysis is completed, the overall costs and benefits of the REmap Case compared to the Reference Case are calculated. These include the impact of the energy system costs, investments, environmental, climate and human health externalities.

The objective of a REmap analysis is to identify a portfolio of options to accelerate renewables deployment. The political feasibility of, and challenges to, implementing each option in different sectors and countries vary depending on the countries' national circumstances as well as on the level of commercialisation that technologies have reached.

Each REmap Option is characterised by its renewable energy potential in terms of final energy and its "**substitution cost**", which is expressed in EUR[43] per energy unit (typically in gigajoules [GJ]) of final renewable energy. The substitution cost is the difference between the annualised costs of the REmap Option and a non-renewable energy technology used to deliver the same energy service (*e.g.*, electricity, heat). It is based on the capital, operation and maintenance and fuel costs in 2030 and considers technological learning as well as energy price changes between now and 2030.

When the substitution costs of all REmap Options are multiplied by their energy potential (in petajoules [PJ] per year), the resulting figure reflects the impact of additional renewable deployment on "**energy costs**". The resulting costs and savings are estimated for the whole energy system and at the sector level. No further assumptions are made with regard to infrastructure needs (*e.g.*, transmission grids and charging infrastructure for electric mobility) beyond what countries plan, and the assessment of any related costs is also excluded from the study.

The calculation of benefits of renewable energy in REmap includes the estimation of avoided externalities from CO_2 emissions and emissions of air pollutants, including their impact on human health and agricultural crops. A range of USD (US dollars) 17 to USD 80 per tonne (t) of CO_2 is assumed for carbon costs, and a wide range of unit external costs is assumed for air pollutants (IRENA, 2016d).

Lastly, in this REmap study, costs are estimated from a government perspective. For this reason, energy prices exclude taxes and subsidies. To account for broad societal goals, a discount rate of 4% is used in the energy cost calculations.

42 *The costs represented in the cost-supply curve do not consider the savings due to externalities. These are estimated separately to calculate the net costs/savings of the energy transformation.*

43 *The base year for the REmap analysis is 2015. All EUR figures reported in this study reflect EUR values as of 2015 , unless otherwise stated.*

Reference Case to 2030

This section presents the approach and key sources of information used to build the Reference Case to 2030 for the countries in the scope of the analysis.

Over the course of the REmap study for the CESEC region, EU member states submitted their draft integrated NECPs to the EC. These draft plans varied widely in terms of the level of detail provided. To the extent possible, the Reference Case considers the information available from draft country plans.

However, for most countries, the level of detail available was insufficient to obtain a full picture of the energy balance of the country representative of the expected situation in 2030. In these cases, the Reference Case was developed by IRENA based on the EU Reference Scenario 2016 (E3MLab *et al.*, 2016). For CESEC members outside the EU, information was compiled from the most recent official planning documents – where these were available – and/or from other publicly available reputable scenarios.

Table 3 Key sources for Reference Case 2030

Country	Sources for Reference Case
AL	IRENA based on WBIF (forthcoming)
AT	IRENA analysis based on E3MLab *et al.* (2016)
BA	IRENA based on WBIF (forthcoming)
BG	IRENA analysis based on E3MLab *et al.* (2016)
HR	IRENA analysis based on E3MLab *et al.* (2016)
GR	IRENA analysis based on E3MLab *et al.* (2016)
HU	IRENA analysis based on E3MLab *et al.* (2016)
IT	Draft Integrated National Energy and Climate Plan (Government of Italy, 2018)
MK	IRENA based on WBIF (forthcoming)
MD	IRENA analysis based on Renewable readiness assessment for Republic of Moldova (IRENA, 2019e) and *Energy strategy of the Republic of Moldova to the year 2030* (Government of the Republic of Moldova, 2012)
ME	IRENA based on WBIF (forthcoming)
RO	IRENA analysis based on E3MLab *et al.* (2016)
RS	IRENA based on WBIF (forthcoming)
SK	IRENA analysis based on E3MLab *et al.* (2016) and Slovak proposal for an Integrated National Energy and Climate Plan (Slovak Ministry of the Economy, 2018)
SI	IRENA analysis based on E3MLab *et al.* (2016)
UA	IRENA analysis based on *Energy strategy of Ukraine for the period up to 2035* (Government of Ukraine, 2017), Diachuk *et al.* (2017) and consultations with State Agency for Energy Efficiency of Ukraine
XK	IRENA based on WBIF (forthcoming)
CY	IRENA (2015b)

Energy carrier prices

Table 4 Energy carrier prices in 2030 (EUR/GJ)

	Country / Carrier	AL	AT	BA	BG	HR	GR	HU	IT	MK	MD	ME	RO	RS	SK	SI	UA	XK	CY
Power	Coal	4.4	1.9	2.6	1.9	1.9	1.9	1.9	1.9	2.8	1.9	2.3	1.9	2.1	1.9	1.9	1.9	2.2	1.9
	Gas	9.3	8.1	13.9	8.2	10.9	10.0	9.3	8.8	10.1	9.2	9.3	5.1	13.2	9.8	9.7	6.7	9.3	9.3
	Oil	17.2	9.5	10.6	12.3	18.0	11.1	14.8	10.6	12.6	12.3	9.1	14.4	8.8	9.5	11.4	12.3	9.1	17.3
	Nuclear fuel	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9	1.9
	Biomass	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4	3.4
	Biomethane	2.9	5.7	3.0	3.2	3.6	5.2	3.7	4.9	3.9	3.2	4.3	3.1	4.3	3.9	4.4	2.8	3.1	4.2
Industry	Coal	4.4	1.9	2.6	1.9	1.9	1.9	1.9	1.9	2.8	1.9	2.3	1.9	2.1	1.9	1.9	1.9	2.2	1.9
	Gas	10.5	10.3	13.9	9.7	12.5	11.3	11.4	10.7	10.2	9.5	10.5	6.9	14.0	11.4	11.1	8.6	10.5	10.5
	Biomass	5.5	4.1	5.3	5.4	4.9	5.9	5.6	5.8	6.4	6.4	6.0	4.5	5.9	4.6	5.0	5.9	6.2	6.2
	Electricity	15.9	20.3	17.2	20.2	24.2	28.6	21.7	25.9	22.9	20.5	21.3	19.3	16.9	30.0	19.8	16.5	20.2	36.6
Building	Gas	12.5	18.2	13.9	12.4	12.7	19.6	9.5	18.6	14.0	10.1	12.5	5.7	13.4	14.1	15.2	5.9	12.5	12.5
	Diesel	20.1	19.5	19.1	20.2	18.7	19.4	22.2	23.0	19.1	19.1	16.5	14.8	14.9	19.1	18.0	19.1	19.1	22.2
	Biomass	9.6	9.1	8.6	9.5	9.6	16.4	10.4	12.8	8.6	7.5	9.4	9.2	9.0	8.6	15.8	6.1	14.8	12.9
	Electricity	18.8	34.7	19.5	22.0	27.9	33.9	24.9	41.4	19.5	23.6	24.2	25.9	13.5	34.1	31.3	6.6	13.4	42.2
Transport	Gas	10.5	10.3	13.9	9.7	12.5	11.3	11.4	10.7	10.2	9.5	10.5	6.9	14.0	11.4	11.1	8.6	10.5	10.5
	Diesel	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
	Gasoline	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
	Kerosene	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7	17.7
	Biodiesel 1st gen.	28.5	36.1	28.6	25.1	25.0	42.0	24.8	34.5	19.4	21.4	31.7	24.0	26.7	26.5	22.5	20.7	29.2	41.9
	Biodiesel 2nd gen.	33.8	30.5	30.6	28.8	28.7	32.7	28.9	32.1	30.4	29.3	30.5	30.1	28.4	30.9	32.0	27.1	32.4	37.8
	Bioethanol 1st gen.	25.9	27.4	23.5	24.1	24.0	30.3	23.6	27.3	23.5	22.2	34.8	22.6	29.3	23.8	22.5	21.4	36.5	53.0
	Bioethanol 2nd gen.	35.2	28.9	31.7	27.1	26.1	30.8	26.3	30.7	30.7	29.4	31.4	29.7	26.0	31.1	33.6	26.3	35.1	43.7

Technology cost assumptions

Table 5 Investment costs (USD/kW)

		CESEC (EU)	CESEC (Non-EU)
Power	Coal	3 000	2 150
	Oil	1 200	1 200
	Gas	1 000	1 000
	Nuclear	7 500	5 500
	Hydro	2 000	2 000
	Biomass	2 500	2 500
	Biogas	3 500	3 500
	Wind onshore	1 300	1 300
	Wind offshore	2 900	2 900
	Solar PV utility	800	800
	Solar PV distributed	1 200	1 200
	CSP	2 720	2 720
Industry	Heat pumps	700	700
	Solar thermal	300	300
	Biomass boiler	500	500
	Oil boiler	200	200
	Natural gas boiler	100	100
Building	Heat pumps	800	800
	Solar thermal	150	150
	Biomass boiler	600	600
	Oil boiler	175	175
	Natural gas boiler	175	175

ANNEX B
SENSITIVITY OF REMAP SCENARIO COSTS TO KEY ASSUMPTIONS

The cost difference between REmap and Reference Case scenarios in terms of levelised cost of energy services in 2030 is sensitive to multiple factors, markedly the evolution of fossil fuel prices and the discount rate applied. The results of a sensitivity analysis against these two variables are shown in Table 6.

The central value reported (EUR 3.4 billion/year savings in 2030) considers flat oil and gas prices (in real terms) per 2018 levels and a social discount rate of 4% to evaluate benefits to society from a governmental perspective.

In a pessimistic scenario in which very high discount rates occur across CESEC (14%) and there are sustained cheap fossil fuel prices (30% below 2018 levels), the REmap Case would potentially result in additional costs estimated at EUR 1.5 billion/year in 2030.

Conversely, a scenario of higher fossil fuel prices would result in much larger savings, estimated at EUR 6.9 billion/year in 2030. A very high discount rate scenario (14%) with flat fossil fuel prices would still deliver savings in the cost of energy services estimated at EUR 1.6 billion/year in 2030.

All calculations exclude the additional economic benefits of avoided fossil fuel externalities.

Table 6 LCOE savings of REmap scenario vs cost of capital and international fossil fuel price assumptions (EUR million/year)

		Low discount rate	High discount rate	Very high discount rate
		4%	9%	14%
Low fossil fuel prices	0.7	218	(530)	(1 478)
Moderate fossil fuel prices	1.0	3 386	2 586	1 646
High fossil fuel prices	1.3	6 952	6 108	5 021

Based on IRENA analysis

ANNEX C
POWER SYSTEM SIMULATIONS – METHODOLOGY AND ASSUMPTIONS

The modelling approach applied is based on a soft-linked methodology as initially described in Deane *et al.* (2012) and Giannakidis *et al.* (2015). This approach takes a scenario that includes the power generation capacity mix defined through the application of an energy system model and subsequently simulates the optimal dispatch for that mix via another dispatch model. Such methodology has been applied in an assessment of European power system policy development in Brower *et al.* (2015) and Collins *et al.* (2018, 2017). Each country was represented as a node, and only interconnection transmission capacity with other countries was considered.

The model developed for this study is based on the model developed for IRENA's REmap analysis for the European Union (IRENA, 2018c). It was expanded to 39 nodes to include any CESEC members not previously present in the model; a detailed methodological description of this modelling approach is available in Collins *et al.* (2018). The model ran at hourly resolution for the target year of 2030 using country-specific electricity demand and wind and solar generation profiles. It simulated the cost-optimal operational dispatch of both scenarios for that year. A few aspects of power system operation are excluded from the analysis, namely trading strategies, risk management, reserves and ancillary services.

Version 7.4 of PLEXOS® was used on a Microsoft® Windows Server® 2012 R2 Standard with four Intel® Xeon® E5-4669V4 processers and a total of 88 cores. The FICO® Xpress-MP solver was used with rounded relaxation unit commitment and a six-hour look ahead. An hourly dispatch over the course of 365 days of the year in 2030 took approximately two hours to complete.

Generation portfolio

Installed capacities for the generator portfolios in the Reference and REmap cases up to 2030 for CESEC members were determined as described in Annex A.

For all non-CESEC countries considered, the installed capacities of the generator portfolios are the same as in IRENA (2018c) in both the Reference and REmap cases. Switzerland and Norway were also considered in the model but were based on the conservative "Slowest Progress" Vision 1 scenario of the European Transmission system operator's (ENTSOE) scenario development report used to inform their 2016 Ten-Year Network development Plan and left unchanged between Reference and REmap cases (ENTSO-E, 2015). Installed pump, generation and storage capacities of pumped hydroelectricity storage plants were derived from Geth *et al.* (2015) for all counties in the EU as well as the United Kingdom, Switzerland and Norway.

For Albania, Bosnia and Herzegovina, Kosovo*, Montenegro, North Macedonia and Serbia, these facilities were based on information gathered from multiple publicly available sources by a group of consultants on behalf of IRENA (WBIF, forthcoming).

Generator plant characteristics

Due to the scale of the European power system, which has thousands of power stations, the generation portfolio for each country is represented by generators with standard characteristics (maximum capacity, minimum stable levels, ramp rates, maintenance rates, forced outage rates, start costs, etc.). A selection of these characteristics can be seen in Table 7. Each disaggregated generation capacity was built up by many identical generators that sum to the total installed capacity as split by technology in the aggregate generation mixes. To determine exact unit size and total number of units for each country, the total sum of capacity by mode in each country was first divided by the corresponding maximum capacity shown in Table 7, which was then rounded up to the nearest integer to determine the total number of units. The unit size by mode of generation for each country was subsequently calculated by dividing the total installed capacity by this number of units.

Due to a lack of availability of a consistent dataset across the whole region and a need to represent the flexibility of natural gas-fired generation, 10% of installed capacity was assigned as open-cycle gas turbine (OCGT) to reflect the impact of the flexibility of these less efficient plants on the power system with the remainder of natural gas-fired plants being modelled as combined-cycle gas turbine (CCGT) units.

Generation by CHP units is constrained to a minimum generation level annually based on the electricity production by CHP units in the EU Reference Scenario 2016 for 2030 (E3MLab *et al.*, 2016) with division by fuel in proportions based on Eurostat values from the year 2015 (Eurostat, 2019a). If not considered in the EU Reference Scenario 2016 (as is the case for all non-EU countries except the United Kingdom), 2015 CHP-based electricity generation was left constant in absolute terms by mode of generation up to 2030 based on Eurostat values for 2015.

Heat rates for the various types of power plant in the model are defined at the country level and are as they appear in the EU Reference Scenario 2016 results for EU countries and the United Kingdom. For non-EU countries, heat rates are based on indicative values derived from the EU Reference Scenario results.

Table 7 Standard generator characteristics

Plant type	Max. capacity (MW)	Start cost (EUR)	Min. stable factor (%)
Solid biomass fired	300	10 000	30
Biogas fired	150	12 000	40
Geothermal	70	3 000	40
Hydropower, lakes	150	0	0
Hydropower, run of river	200	0	0
Natural gas CCGT	450	80 000	40
Natural gas OCGT	100	10 000	20
Nuclear energy	1 200	120 000	60
Oil fired	400	75 000	40
Coal fired	300	80 000	30

* *This designation is without prejudice to positions on status and in line with the United Nations Security Council Resolution 1244 (1999).*

Interconnections

Net power transfer capacities (NTCs) are limited here to the interconnection between countries, *i.e.*, no interregional transmission is considered. The electricity network expansion is aligned with reference NTCs presented in the two latest Ten Year Network Development Plans from ENTSO-E released in 2016 and 2018 (ENTSO-E, 2018, 2015). Given the more stringent criteria applied in the 2018 Ten Year Network Development Plan for projects to be represented in the reference NTC capacities for 2030 (which meant that any project had to be further progressed in the planning stage to qualify), the higher NTC value was used between the two studies when determining NTC between countries. All interconnection for Ukraine reflects present-day capacities, which were based on levels indicated by the expert group on electricity interconnection targets established by the EC (European Commission, 2019). For Albania, Bosnia and Herzegovina, Kosovo*, Montenegro, North Macedonia and Serbia, data were gathered from multiple publicly available sources by a group of consultants on behalf of IRENA (WBIF, forthcoming). Interconnection capacity with the Russian Federation is not considered in the model.

While greater resolution in terms of transmission capacity within national borders would be desirable, this would require greater nodal disaggregation in the model which would lead to substantial increases in data requirements (*i.e.*, require disaggregation of demand, renewables profiles, generation capacity, etc., by node). These pan-European transmission capacities provided by the European transmission system operator at a country level provide a reasonable assessment of how the system may develop up to 2030 and allow for a high-level assessment of power system operation in a pan-European context.

Hourly demand profiles

The REmap and Reference Case scenarios were simulated at hourly resolution for each model node for the year 2030 and thus required an hourly electricity demand profile.

In the absence of a technology-rich bottom-up demand study, historic demand profiles were scaled to 2030 levels with most being based on profiles from ENTSO-E for 2015 (ENTSO-E, 2016) except for those used for Republic of Moldova and Ukraine.

The demand profiles used for the Republic of Moldova were provided by the transmission system operator of the Republic of Moldova. For Ukraine, power demand profiles were sourced from the publicly available PLEXOS world model developed by University College Cork (University College Cork, 2019). The peak load value for all nodes was scaled proportionally with overall demand growth. This demand scaling was done using the tool in PLEXOS® software for this purpose and ensured that representative variations in demand patterns by country were maintained.

Hourly generation profiles of renewables

To assess the flexibility of the European power system in 2030 and its ability to absorb high levels of intermittent renewables, the modelling process must sufficiently capture the effects of the intermittent nature of these modes of generation with localised profiles for each country.

■ Onshore and offshore wind power

Hourly wind generation profiles for each country (except Malta, Republic of Moldova and Ukraine) were derived from the EMHIRES dataset developed by the Joint Research Centre of the European Commission, which uses US National Aeronautics and Space Administration (NASA) atmospheric reanalysis data to model hourly electricity production from the installed wind farms in Europe for every hour over the course of the 30 historic weather years (Gonzalez Aparicio *et al.*, 2016).

The profiles of the EMHIRES dataset are at a national scale and were developed based on historic installed capacities, which means they do not capture future technological development. To represent technological improvements that are anticipated to come online by 2030, these were scaled to the capacity factors anticipated on the potentials outlined in the ENSPRESO database (Joint Research Centre, 2019) for the top 30% of wind locations in each country for the year 2030.

For the Republic of Moldova and Ukraine, wind generation profiles were based on Staffell and Pfenninger (2016) and scaled to the capacity factors anticipated by 2030 based on the potential outlined in the ENSPRESO database (Joint Research Centre, 2019) for the top 30% of wind locations in each of these countries.

Table 8 Interconnection capacity in 2030 used in pan-European dispatch model

	Export limit (MW)	Import limit (MW)		Export limit (MW)	Import limit (MW)
AL-GR	250	-250	EE-LV	1 600	-1 600
AL-ME	400	-400	ES-FR	8 000	-8 000
AL-MK	500	-600	ES-PT	4 200	-3 500
AL-RS	500	-500	FI-SE	3 200	-3 200
AL-XK	630	-630	FR-IE	700	-700
AT-CH	1 700	-1 700	FR-IT	4 500	-2 360
AT-CZ	1 000	-1 200	FR-LU	380	0
AT-DE	7 500	-7 500	FR-UK	6 900	-6 900
AT-HU	1 200	-800	GR-IT	500	-500
AT-IT	1 655	-1 385	GR-MK	1 200	-1 200
AT-SI	1 200	-1 200	HR-HU	2 000	-2 000
BA-HR	1 844	-1 812	HR-RS	600	-600
BA-ME	1 275	-1 575	HR-SI	2 000	-2 000
BA-RS	1 350	-1 525	HU-RO	1 300	-1 400
BE-DE	1 000	-1 000	HU-RS	700	-800
BE-FR	2 800	-4 300	HU-SI	1 700	-2 000
BE-LU	1 080	-700	HU-SK	2 000	-2 000
BE-NL	3 400	-3 400	HU-UA	3 590	-3 590
BE-UK	1 000	-1 000	IT-ME	1 200	-1 200
BG-GR	1 728	-1 032	IT-MT	200	-200
BG-MK	600	-500	IT-SI	1 640	-1 895
BG-RO	1 400	-1 500	LT-LV	2 100	-1 800
BG-RS	825	-725	LT-PL	1 000	-1 000
CH-DE	5 600	-3 300	LT-SE	700	-700
CH-FR	1 300	-3 700	MD-RO	600	-600
CH-IT	6 240	-3 860	ME-RS	1 325	-1 275
CY-GR	2 000	-2 000	ME-XK	450	-450
CZ-DE	2 600	-2 000	MK-RS	1 050	-950
CZ-PL	600	-600	MK-XK	900	-1 100
CZ-SK	2 100	-1 100	NL-NO	700	-700
DE-DK	4 000	-4 000	NO-SE	3 695	-3 995
DE-FR	4 800	-4 800	PL-SE	600	-600
DE-LU	2 300	-2 300	PL-SK	990	-990
DE-NL	5 000	-5 000	PL-UA	2 094	-2 094
DE-NO	1 400	-1 400	RO-RS	1 350	-1 300
DE-PL	2 000	-3 000	RO-UA	5 040	-5 040
DE-SE	1 315	-1 315	RS-XK	700	-700
DE-UK	1 400	-1 400	SK-UA	789	-789
DK-NL	700	-700	MD-UA	1 300	-1 300
DK-NO	1 700	-1 640	UK-IE	500	-500
DK-SE	2 440	-1 980	UK-NL	1 000	-1 000
DK-UK	1 400	-1 400	UK-NO	2 800	-2 800
EE-FI	1 016	-1 016			

Note: Directionality of the flow limit on each line is the export limit from the first country code to the second country code (from left to right) and the import limit for the alternate direction.

All profiles created were then normalised with the respective generation capacity for each country.

Solar power

Country-specific hourly solar profiles for each country were also derived from the EMHIRES dataset developed by the Joint Research Centre of the European Commission (except Cyprus, Malta, Republic of Moldova and Ukraine), which models hourly electricity production from installed solar PV facilities in Europe for every hour of 30 historic weather years (Gonzalez Aparicio *et al.*, 2017). The profiles of the EMHIRES dataset are at a national scale and were developed based on historic installed capacities, which means that they do not capture future technological development. To account for technological improvements anticipated to come online, these were scaled to the capacity factors anticipated on the potentials outlined in the global solar atlas (Global Solar Atlas, 2020).

For Cyprus, Malta, Republic of Moldova and Ukraine, solar PV generation profiles were derived based on Pfenninger and Staffell (2016) and similarly scaled to the capacity factors anticipated in the potentials outlined in the online global solar atlas (Global Solar Atlas, 2020). All profiles created were then normalised with the respective generation capacity for each country.

Hydro power

The hydro generation profiles used in the analysis have monthly resolution and were derived from average historic generation profiles from ENTSO-E (2020) for each model node except Albania, Kosovo* and Republic of Moldova. Due to lack of data for Albania and Kosovo*, synthetic monthly profiles were developed based on neighbouring countries and then scaled to their own long-term annual average capacity factor. Each profile was scaled to the long-term average capacity factor derived from historic generation data available in Eurostat (2019d). Each country considered has both run-of-river and lake generation facilities, and these were modelled differently. For lake facilities, the capacity factor was bound to the monthly level with flexibility in operation as long as that monthly value was not exceeded. For run-of-river facilities, operation was bound to the monthly average value at an hourly level to capture their inflexibility.

Fuel and carbon prices

Fuel prices are available in Annex A. Biomass and biomethane fuels were priority-dispatched in model simulation, which meant that their actual cost did not feature in the dispatch. The carbon price used in this analysis was derived from the impact assessment of the EC for amending Directive 2003/87/EC[44] to enhance cost-effective emissions reductions and low-carbon investments (European Commission, 2015) equivalent to 25 EUR per tonne of CO_2 and was assumed to apply to all countries considered in the model unless otherwise stated.

* *This designation is without prejudice to positions on status and in line with the United Nations Security Council Resolution 1244 (1999).*

44 *Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for GHG emission allowance trading within the Community and amending Council Directive 96/61/EC.*

ANNEX D
SUSTAINABLE BIOENERGY POTENTIAL ASSESSMENT

For this study, IRENA has conducted a bottom-up analysis of bioenergy potential in CESEC members based on the methodology originally established in IRENA for global bioenergy assessments (IRENA, 2014) and subsequently improved and applied to regional bioenergy potential assessments, *e.g.*, Southeast Asia (IRENA, 2017b) and Sub-Saharan Africa (IRENA, 2017c).

The bioenergy potential for CESEC members is evaluated into three final bioenergy carriers: solid biomass, liquid biofuels and biogas. Table 9 shows the estimated potential for each CESEC member in each of these categories.

Liquid biofuel is the aggregate of all types of liquid biofuel converted from agricultural crops and residues exclusively. The potential of agricultural crops for biofuel production is evaluated based on the food-first approach. It allows agricultural crops for bioenergy use to be planted only on farmland that is freed up by intensification of farming practices after meeting the food demand; thus, no land use change – direct or indirect – associated with the cultivation of energy crops is foreseen. The amount of freed-up land that could be used for bioenergy production in each country is calculated as the difference between land required in the Food and Agriculture Organization (FAO) base case scenario, which fully provides for anticipated food needs, and reduced amounts of land required in the more ambitious yield growth scenarios. The yield gap between current and potential lands, as calculated by FAO, is limited to the best practice level observed in benchmark countries in Europe such as Italy, France, Spain and Netherlands.

Freed-up land is then multiplied by improved yield of one of the four bioenergy crop groups: starch crop and sugar crop for first generation bioethanol, oil-bearing crop for first generation biodiesel, and grass and woody crop for second generation biofuel, depending on the final use. Each of these crop potentials is converted into liquid biofuel potential for corresponding conversion route (Gerssen-Gondelach *et al.*, 2014; IRENA, 2016b).

For every tonne of food crop produced, an amount of residue is available in the field after harvest, of which a fraction can be practically and sustainably collected. This fraction is typically assumed to be between a quarter and a half, so enough residue is left behind to maintain the soil's organic carbon. In addition, a share of residues is attached to crops when they enter processing plants, most of which can also be collected.

Total residue is the sum of harvest residue and process residue. Harvest and process residue factors, in tonnes of residue per tonne of crop, RPR (residue to production ratio) with projected growth in food supply (Alexandratos and Bruinsma, 2012) can be multiplied by the amounts of each crop produced (Smeets and Lewandowski, 2004) and the share of residues collected (assumed here to be 25% for harvest residues and 90% for process residues) to calculate amounts of harvest and process residues collected. The methodologies for energy crop potential and agricultural residues estimation were based on previous studies (IRENA, 2017b, 2017c, 2016a).

Solid biofuel is mainly from forestry biomass. It is composed of supply from “surplus forest growth” and “logging and processing residues”. Surplus forest growth is estimated by subtracting the projected demand for industrial roundwood production from forest productivity growth. Logging residues are estimated by multiplying industrial roundwood production with logging residue generation and collection rate. Wood processing residues are estimated based on the projected demand for each type of wood product, such as sawn wood and wood-based panels, using corresponding residue generation ratios, respectively. Technically, forestry biomass (lignocellulosic biomass) can be also used as a feedstock for liquid biofuel production. However, the allocation of forestry biomass to solid biofuel shows better relevance considering its important presence as a solid biofuel feedstock in the region. The applied methodology was developed based on previous studies (IRENA, 2017c; Smeets and Faaij, 2007).

Biogas potential is estimated based on methane (CH_4) generation from municipal solid wastes (MSW) and animal manure. Among different types of MSW and waste management practices, wastes from food, paper, textile and wood classified in open dump/landfill and incineration are considered in the estimation. Also, generation of methane (CH_4) from animal manure is dependent on animal type and manure management practice. The methodology for both types of biogas potential is based on methane accounting methodology described in Intergovernmental Panel on Climate Change guidelines (IPCC, 2006) and previously applied in IRENA (2014). Biogas to biomethane upgrade is also considered in the final stage for use in the transport sector (IRENA, 2016b).

Table 9 Estimated sustainable bioenergy supply potential in CESEC members (PJ)

	Liquid biofuels	Solid biomass	Biogas
AL	12	1	12
AT	6	216	19
BA	20	44	8
BG	56	86	17
HR	22	48	8
GR	104	37	25
HU	87	70	23
IT	158	329	106
MK	16	10	4
MD	38	14	6
ME	2	18	2
RO	186	258	54
RS	74	68	19
SK	34	70	8
SI	2	36	4
UA	603	361	108
XK	9	7	7
CY	2	0	3

ANNEX E: COUNTRY FACTSHEETS

AL Albania

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**1 897**	**2 947**	**4 476**
		Renewable capacity	**MW**	**1 799**	**2 397**	**3 926**
		Hydropower	MW	1 798	2 150	2 150
		Wind - onshore	MW	-	-	536
		Wind - offshore	MW	-	80	80
		Biofuels (solid, liquid, gaseous)	MW	-	47	86
		Solar PV	MW	1	120	1 074
		CSP	MW	-	-	-
		Geothermal	MW	-	-	-
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**98**	**550**	**550**
		Coal	MW	-	-	-
		Oil	MW	-	-	-
		Gas	MW	98	550	550
		Nuclear	MW	-	-	-
		Total electricity generation	**GWh**	**5 895**	**12 744**	**13 217**
		Renewable generation	GWh	5 895	8 894	12 200
		Hydropower	GWh	5 895	8 235	8 214
		Wind	GWh	-	168	1 794
		Biofuels (solid, liquid, gaseous)	GWh	-	299	495
		Solar PV	GWh	-	192	1 697
		CSP	GWh	-	-	-
		Geothermal	GWh	-	-	-
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	-	3 850	1 017
		Coal	GWh	-	-	-
		Oil	GWh	-	-	-
		Gas	GWh	-	3 850	1 017
		Nuclear	GWh	-	-	-
	DH	**Total district heat generation**	**PJ**	**-**	**1**	**1**
		Biofuels (solid, liquid, gaseous)	PJ	-	-	0
		Geothermal	PJ	-	0	0
		Solar thermal	PJ	-	-	-
		Renewable electricity	PJ	-	-	0
		Non-renewable DH	PJ	-	1	1
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	22	39	34
		Direct uses of renewable energy	**PJ**	**9**	**12**	**16**
		Solar thermal - Buildings	PJ	0	1	3
		Solar thermal - Industry	PJ	0	0	0
		Geothermal - Buildings	PJ	-	-	-
		Geothermal - Industry	PJ	-	-	-
		Bioenergy - Buildings	PJ	8	11	11
		Bioenergy - Industry	PJ	0	1	2
		Non-renewable - Buildings	**PJ**	**6**	**15**	**8**
		Non-renewable - Industry	**PJ**	**8**	**12**	**10**
	Transport	**Total fuel consumption**	PJ	35	46	43
		Liquid biofuels	**PJ**	**1**	**3**	**4**
		Bioethanol	PJ	-	-	1
		Biodiesel	PJ	1	3	3
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**-**	**-**
		Non-renewable fuels	**PJ**	**34**	**43**	**39**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**78**	**130**	**125**
RE shares		RE share in power sector		81%	62%	80%
		RE share in district heat generation		0%	9%	29%
		RE share in Buildings - direct uses		58%	43%	63%
		RE share in Buildings - incl. RE electricity and DH		70%	52%	72%
		RE share in Industry - final energy use, direct uses		5%	6%	20%
		RE share in Industry - incl. RE electricity and DH		32%	33%	49%
		RE share in Transport fuels		4%	7%	8%
		RE share in Transport fuels incl. RE electricity		4%	7%	11%
		Share of RE in GFEC		**37%**	**34%**	**48%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-60
		Energy-related CO_2 emissions [Mt CO_2/yr]			7.0	4.9

AT Austria

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**24 090**	**25 722**	**38 814**
		Renewable capacity	**MW**	**18 251**	**21 633**	**35 500**
		Hydropower	MW	13 351	13 741	13 741
		Wind - onshore	MW	2 489	4 235	7 313
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	1 473	901	3 789
		Solar PV	MW	937	2 754	10 655
		CSP	MW	-	-	-
		Geothermal	MW	1	2	2
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**5 839**	**4 089**	**3 314**
		Coal	MW	1 213	774	-
		Oil	MW	290	423	423
		Gas	MW	4 336	2 892	2 892
		Nuclear	MW	-	-	-
		Total electricity generation	**GWh**	**60 970**	**77 465**	**104 160**
		Renewable generation	GWh	47 245	59 729	94 298
		Hydropower	GWh	37 057	43 201	42 638
		Wind	GWh	4 840	9 549	19 301
		Biofuels (solid, liquid, gaseous)	GWh	4 410	3 722	19 637
		Solar PV	GWh	937	3 245	12 711
		CSP	GWh	-	-	-
		Geothermal	GWh	-	11	11
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	13 726	17 736	9 862
		Coal	GWh	5 081	3 378	-
		Oil	GWh	773	65	870
		Gas	GWh	7 871	14 293	8 992
		Nuclear	GWh	-	-	-
	DH	**Total district heat generation**	**PJ**	**84**	**94**	**94**
		Biofuels (solid, liquid, gaseous)	PJ	40	32	65
		Geothermal	PJ	1	12	12
		Solar thermal	PJ	0	1	1
		Renewable electricity	PJ	-	-	4
		Non-renewable DH	PJ	43	49	12
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	465	471	399
		Direct uses of renewable energy	**PJ**	**123**	**158**	**168**
		Solar thermal - Buildings	PJ	8	8	13
		Solar thermal - Industry	PJ	-	-	4
		Geothermal - Buildings	PJ	0	0	0
		Geothermal - Industry	PJ	-	-	-
		Bioenergy - Buildings	PJ	69	76	76
		Bioenergy - Industry	PJ	47	74	74
		Non-renewable - Buildings	**PJ**	**118**	**111**	**43**
		Non-renewable - Industry	**PJ**	**224**	**202**	**188**
	Transport	**Total fuel consumption**	PJ	355	329	290
		Liquid biofuels	**PJ**	**27**	**18**	**23**
		Bioethanol	PJ	3	2	7
		Biodiesel	PJ	24	16	16
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**0**	**0**	**0**
		Non-renewable fuels	**PJ**	**328**	**310**	**266**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**1 110**	**1 127**	**1 052**
RE shares		RE share in power sector		66%	75%	100%
		RE share in district heat generation		48%	48%	87%
		RE share in Buildings - direct uses		39%	43%	68%
		RE share in Buildings - incl. RE electricity and DH		49%	54%	85%
		RE share in Industry - final energy use, direct uses		17%	27%	29%
		RE share in Industry - incl. RE electricity and DH		31%	41%	53%
		RE share in Transport fuels		8%	6%	8%
		RE share in Transport fuels incl. RE electricity		9%	8%	16%
		Share of RE in GFEC		**31%**	**37%**	**55%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-418
		Energy-related CO_2 emissions [Mt CO_2/yr]			55.1	39.4

BA Bosnia and Herzegovina

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**3 839**	**5 102**	**6 335**
		Renewable capacity	**MW**	**2 074**	**3 068**	**5 213**
		Hydropower	MW	2 055	2 454	2 454
		Wind - onshore	MW	0	548	1 033
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	8	42	362
		Solar PV	MW	10	25	1 363
		CSP	MW	-	-	-
		Geothermal	MW	-	-	-
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**1 765**	**2 034**	**1 122**
		Coal	MW	1 765	2 034	1 122
		Oil	MW	-	-	-
		Gas	MW	-	-	-
		Nuclear	MW	-	-	-
		Total electricity generation	**GWh**	**16 437**	**19 227**	**20 996**
		Renewable generation	GWh	5 551	8 040	13 055
		Hydropower	GWh	5 551	6 397	6 382
		Wind	GWh	-	1 392	2 952
		Biofuels (solid, liquid, gaseous)	GWh	-	230	1 910
		Solar PV	GWh	-	20	1 811
		CSP	GWh	-	-	-
		Geothermal	GWh	-	-	-
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	10 886	11 187	7 941
		Coal	GWh	10 802	11 187	7 941
		Oil	GWh	51	-	-
		Gas	GWh	33	-	-
		Nuclear	GWh	-	-	-
	DH	**Total district heat generation**	**PJ**	**5**	**7**	**7**
		Biofuels (solid, liquid, gaseous)	PJ	0	1	4
		Geothermal	PJ	-	-	-
		Solar thermal	PJ	-	-	-
		Renewable electricity	PJ	-	-	0
		Non-renewable DH	PJ	5	6	3
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	77	100	85
		Direct uses of renewable energy	**PJ**	**48**	**62**	**52**
		Solar thermal - Buildings	PJ	-	-	2
		Solar thermal - Industry	PJ	-	-	0
		Geothermal - Buildings	PJ	-	-	-
		Geothermal - Industry	PJ	-	-	-
		Bioenergy - Buildings	PJ	47	57	44
		Bioenergy - Industry	PJ	1	5	5
		Non-renewable - Buildings	**PJ**	**13**	**20**	**15**
		Non-renewable - Industry	**PJ**	**16**	**18**	**17**
	Transport	**Total fuel consumption**	PJ	43	32	30
		Liquid biofuels	**PJ**	**-**	**-**	**1**
		Bioethanol	PJ	-	-	1
		Biodiesel	PJ	-	-	0
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**-**	**-**
		Non-renewable fuels	**PJ**	**43**	**32**	**29**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**164**	**190**	**178**
RE shares		RE share in power sector		39%	49%	72%
		RE share in district heat generation		9%	15%	64%
		RE share in Buildings - direct uses		79%	74%	75%
		RE share in Buildings - incl. RE electricity and DH		64%	65%	73%
		RE share in Industry - final energy use, direct uses		5%	23%	24%
		RE share in Industry - incl. RE electricity and DH		20%	33%	47%
		RE share in Transport fuels		0%	0%	3%
		RE share in Transport fuels incl. RE electricity		0%	3%	9%
		Share of RE in GFEC		**39%**	**47%**	**56%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-72
		Energy-related CO_2 emissions [Mt CO_2/yr]			17.4	13.1

BG Bulgaria

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**12 010**	**13 015**	**15 819**
		Renewable capacity	**MW**	**3 988**	**6 788**	**11 631**
		Hydropower	MW	2 206	2 338	2 754
		Wind - onshore	MW	699	2 134	2 725
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	54	101	1 066
		Solar PV	MW	1 029	2 215	5 085
		CSP	MW	-	-	-
		Geothermal	MW	-	-	-
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**8 022**	**6 227**	**4 188**
		Coal	MW	5 311	3 263	1 169
		Oil	MW	110	2	2
		Gas	MW	626	1 043	1 043
		Nuclear	MW	1 975	1 920	1 975
		Total electricity generation	**GWh**	**48 612**	**47 323**	**45 642**
		Renewable generation	GWh	8 768	12 961	23 214
		Hydropower	GWh	5 660	4 201	5 055
		Wind	GWh	1 451	5 455	5 435
		Biofuels (solid, liquid, gaseous)	GWh	273	503	5 614
		Solar PV	GWh	1 383	2 802	7 110
		CSP	GWh	-	-	-
		Geothermal	GWh	-	-	-
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	39 844	34 362	22 428
		Coal	GWh	22 529	15 490	1 839
		Oil	GWh	79	-	-
		Gas	GWh	1 857	4 235	6 920
		Nuclear	GWh	15 379	14 637	13 669
	DH	**Total district heat generation**	**PJ**	**51**	**48**	**48**
		Biofuels (solid, liquid, gaseous)	PJ	1	5	19
		Geothermal	PJ	-	-	-
		Solar thermal	PJ	-	-	-
		Renewable electricity	PJ	-	-	2
		Non-renewable DH	PJ	50	43	28
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	113	121	104
		Direct uses of renewable energy	**PJ**	**44**	**61**	**62**
		Solar thermal - Buildings	PJ	1	3	3
		Solar thermal - Industry	PJ	-	-	1
		Geothermal - Buildings	PJ	1	6	6
		Geothermal - Industry	PJ	-	-	-
		Bioenergy - Buildings	PJ	31	34	34
		Bioenergy - Industry	PJ	11	18	18
		Non-renewable - Buildings	**PJ**	**14**	**14**	**-**
		Non-renewable - Industry	**PJ**	**55**	**46**	**42**
	Transport	**Total fuel consumption**	PJ	135	131	123
		Liquid biofuels	**PJ**	**6**	**8**	**12**
		Bioethanol	PJ	1	1	4
		Biodiesel	PJ	5	7	7
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**0**	**0**
		Non-renewable fuels	**PJ**	**129**	**123**	**111**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**383**	**398**	**380**
RE shares		RE share in power sector		23%	33%	54%
		RE share in district heat generation		3%	11%	42%
		RE share in Buildings - direct uses		70%	75%	100%
		RE share in Buildings - incl. RE electricity and DH		37%	46%	66%
		RE share in Industry - final energy use, direct uses		17%	28%	31%
		RE share in Industry - incl. RE electricity and DH		16%	27%	40%
		RE share in Transport fuels		5%	6%	9%
		RE share in Transport fuels incl. RE electricity		5%	7%	11%
		Share of RE in GFEC		**19%**	**27%**	**41%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-111
		Energy-related CO_2 emissions [Mt CO_2/yr]			34.0	17.8

CY Cyprus

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**1 696**	**1 987**	**2 627**
		Renewable capacity	**MW**	**244**	**887**	**1 682**
		Hydropower	MW	-	-	-
		Wind - onshore	MW	158	250	336
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	10	28	28
		Solar PV	MW	76	559	1 268
		CSP	MW	-	50	50
		Geothermal	MW	-	-	-
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**1 452**	**1 100**	**945**
		Coal	MW	-	-	-
		Oil	MW	1 452	-	-
		Gas	MW	-	1 100	945
		Nuclear	MW	-	-	-
		Total electricity generation	**GWh**	**4 535**	**6 103**	**4 838**
		Renewable generation	GWh	399	1 603	3 185
		Hydropower	GWh	-	-	-
		Wind	GWh	221	384	629
		Biofuels (solid, liquid, gaseous)	GWh	51	120	141
		Solar PV	GWh	127	927	2 243
		CSP	GWh	-	172	172
		Geothermal	GWh	-	-	-
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	4 136	4 500	1 653
		Coal	GWh	-	-	-
		Oil	GWh	4 136	-	-
		Gas	GWh	-	4 500	1 653
		Nuclear	GWh	-	-	-
	DH	**Total district heat generation**	**PJ**	**0**	**0**	**0**
		Biofuels (solid, liquid, gaseous)	PJ	0	0	0
		Geothermal	PJ	-	-	-
		Solar thermal	PJ	-	-	-
		Renewable electricity	PJ	-	-	-
		Non-renewable DH	PJ	-	-	-
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	17	17	15
		Direct uses of renewable energy	**PJ**	**4**	**6**	**6**
		Solar thermal - Buildings	PJ	3	4	4
		Solar thermal - Industry	PJ	-	0	0
		Geothermal - Buildings	PJ	0	0	0
		Geothermal - Industry	PJ	-	-	-
		Bioenergy - Buildings	PJ	1	1	1
		Bioenergy - Industry	PJ	0	1	1
		Non-renewable - Buildings	**PJ**	**7**	**7**	**4**
		Non-renewable - Industry	**PJ**	**6**	**5**	**4**
	Transport	**Total fuel consumption**	PJ	36	51	46
		Liquid biofuels	**PJ**	**0**	**5**	**5**
		Bioethanol	PJ	-	2	2
		Biodiesel	PJ	0	3	3
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**-**	**-**
		Non-renewable fuels	**PJ**	**36**	**46**	**41**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**67**	**89**	**84**
RE shares		RE share in power sector		9%	25%	45%
		RE share in district heat generation		100%	100%	100%
		RE share in Buildings - direct uses		35%	42%	52%
		RE share in Buildings - incl. RE electricity and DH		20%	32%	47%
		RE share in Industry - final energy use, direct uses		7%	20%	20%
		RE share in Industry - incl. RE electricity and DH		7%	22%	29%
		RE share in Transport fuels		1%	10%	11%
		RE share in Transport fuels incl. RE electricity		1%	10%	13%
		Share of RE in GFEC		**8%**	**18%**	**26%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-91
		Energy-related CO_2 emissions [Mt CO_2/yr]			6.0	4.4

GR Greece

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**17 614**	**23 457**	**24 517**
		Renewable capacity	**MW**	**7 439**	**15 165**	**18 364**
		Hydropower	MW	2 693	3 579	3 579
		Wind - onshore	MW	2 091	5 636	5 636
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	51	232	931
		Solar PV	MW	2 604	5 718	8 218
		CSP	MW	-	-	-
		Geothermal	MW	-	-	-
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**10 175**	**8 292**	**6 153**
		Coal	MW	4 925	2 799	660
		Oil	MW	930	755	755
		Gas	MW	4 320	4 738	4 738
		Nuclear	MW	-	-	-
		Total electricity generation	**GWh**	**51 709**	**52 994**	**57 876**
		Renewable generation	GWh	14 848	30 870	40 768
		Hydropower	GWh	6 098	5 559	6 911
		Wind	GWh	4 621	15 262	14 581
		Biofuels (solid, liquid, gaseous)	GWh	230	652	5 088
		Solar PV	GWh	3 900	9 396	14 188
		CSP	GWh	-	-	-
		Geothermal	GWh	-	-	-
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	36 861	22 124	17 108
		Coal	GWh	22 107	8 815	4 847
		Oil	GWh	4 885	2 335	2 395
		Gas	GWh	9 869	10 974	9 866
		Nuclear	GWh	-	-	-
	DH	**Total district heat generation**	**PJ**	**2**	**4**	**4**
		Biofuels (solid, liquid, gaseous)	PJ	0	0	1
		Geothermal	PJ	-	-	-
		Solar thermal	PJ	-	-	-
		Renewable electricity	PJ	-	-	0
		Non-renewable DH	PJ	2	4	3
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	214	186	168
		Direct uses of renewable energy	**PJ**	**52**	**64**	**65**
		Solar thermal - Buildings	PJ	8	22	22
		Solar thermal - Industry	PJ	0	0	1
		Geothermal - Buildings	PJ	0	1	1
		Geothermal - Industry	PJ	-	0	-
		Bioenergy - Buildings	PJ	36	22	22
		Bioenergy - Industry	PJ	8	19	19
		Non-renewable - Buildings	**PJ**	**88**	**65**	**50**
		Non-renewable - Industry	**PJ**	**74**	**57**	**53**
	Transport	**Total fuel consumption**	PJ	274	291	272
		Liquid biofuels	**PJ**	**6**	**12**	**22**
		Bioethanol	PJ	-	2	11
		Biodiesel	PJ	6	9	11
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**0**	**0**
		Non-renewable fuels	**PJ**	**268**	**279**	**249**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**665**	**652**	**627**
RE shares		RE share in power sector		24%	53%	66%
		RE share in district heat generation		3%	10%	26%
		RE share in Buildings - direct uses		33%	41%	47%
		RE share in Buildings - incl. RE electricity and DH		29%	47%	58%
		RE share in Industry - final energy use, direct uses		9%	25%	28%
		RE share in Industry - incl. RE electricity and DH		15%	35%	42%
		RE share in Transport fuels		2%	4%	8%
		RE share in Transport fuels incl. RE electricity		2%	5%	10%
		Share of RE in GFEC		**16%**	**27%**	**35%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-147
		Energy-related CO_2 emissions [Mt CO_2/yr]			42.7	35.8

HR Croatia

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**3 522**	**5 243**	**7 674**
		Renewable capacity	**MW**	**2 434**	**3 311**	**6 188**
		Hydropower	MW	1 915	2 190	2 495
		Wind - onshore	MW	418	727	1 066
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	53	28	406
		Solar PV	MW	48	365	2 222
		CSP	MW	-	-	-
		Geothermal	MW	-	-	-
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**1 088**	**1 933**	**1 485**
		Coal	MW	335	658	210
		Oil	MW	28	107	107
		Gas	MW	725	1 169	1 169
		Nuclear	MW	-	-	-
		Total electricity generation	**GWh**	**11 238**	**13 885**	**19 785**
		Renewable generation	GWh	7 509	8 356	16 694
		Hydropower	GWh	6 391	6 339	9 087
		Wind	GWh	795	1 366	2 556
		Biofuels (solid, liquid, gaseous)	GWh	266	134	2 200
		Solar PV	GWh	57	517	2 851
		CSP	GWh	-	-	-
		Geothermal	GWh	-	-	-
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	3 729	5 529	3 091
		Coal	GWh	2 310	853	458
		Oil	GWh	208	184	352
		Gas	GWh	1 211	4 492	2 281
		Nuclear	GWh	-	-	-
	DH	**Total district heat generation**	**PJ**	**11**	**14**	**14**
		Biofuels (solid, liquid, gaseous)	PJ	2	2	9
		Geothermal	PJ	-	-	-
		Solar thermal	PJ	-	-	-
		Renewable electricity	PJ	-	-	1
		Non-renewable DH	PJ	9	12	4
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	115	95	81
		Direct uses of renewable energy	**PJ**	**51**	**22**	**32**
		Solar thermal - Buildings	PJ	0	2	4
		Solar thermal - Industry	PJ	-	-	1
		Geothermal - Buildings	PJ	0	2	2
		Geothermal - Industry	PJ	-	-	-
		Bioenergy - Buildings	PJ	49	12	19
		Bioenergy - Industry	PJ	1	6	6
		Non-renewable - Buildings	**PJ**	**35**	**44**	**23**
		Non-renewable - Industry	**PJ**	**30**	**28**	**26**
	Transport	**Total fuel consumption**	PJ	87	95	88
		Liquid biofuels	**PJ**	**1**	**8**	**9**
		Bioethanol	PJ	-	2	2
		Biodiesel	PJ	1	6	6
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**0**	**0**
		Non-renewable fuels	**PJ**	**86**	**87**	**80**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**266**	**255**	**241**
RE shares		RE share in power sector		42%	47%	84%
		RE share in district heat generation		15%	15%	69%
		RE share in Buildings - direct uses		59%	27%	51%
		RE share in Buildings - incl. RE electricity and DH		51%	33%	67%
		RE share in Industry - final energy use, direct uses		4%	18%	22%
		RE share in Industry - incl. RE electricity and DH		15%	25%	41%
		RE share in Transport fuels		1%	8%	10%
		RE share in Transport fuels incl. RE electricity		2%	9%	13%
		Share of RE in GFEC		**29%**	**23%**	**43%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-213
		Energy-related CO_2 emissions [Mt CO_2/yr]			14.4	10.9

HU Hungary

Section	Sector	Item	Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**7 303**	**8 442**	**14 439**
		Renewable capacity	**MW**	**1 073**	**1 036**	**8 701**
		Hydropower	MW	57	57	60
		Wind - onshore	MW	329	468	2 566
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	519	357	1 311
		Solar PV	MW	168	101	4 712
		CSP	MW	-	-	-
		Geothermal	MW	-	52	52
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**6 230**	**7 407**	**5 738**
		Coal	MW	1 134	347	-
		Oil	MW	91	5	5
		Gas	MW	3 005	2 533	2 533
		Nuclear	MW	2 000	4 522	3 200
		Total electricity generation	**GWh**	**30 138**	**39 616**	**43 322**
		Renewable generation	GWh	3 210	2 921	18 428
		Hydropower	GWh	234	227	240
		Wind	GWh	693	872	5 248
		Biofuels (solid, liquid, gaseous)	GWh	2 161	1 665	6 943
		Solar PV	GWh	122	92	5 932
		CSP	GWh	-	-	-
		Geothermal	GWh	-	65	65
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	26 928	36 695	24 894
		Coal	GWh	5 908	1 725	-
		Oil	GWh	57	-	4
		Gas	GWh	5 129	2 092	2 459
		Nuclear	GWh	15 834	32 879	22 431
	DH	**Total district heat generation**	**PJ**	**52**	**49**	**49**
		Biofuels (solid, liquid, gaseous)	PJ	7	14	22
		Geothermal	PJ	2	11	11
		Solar thermal	PJ	-	0	0
		Renewable electricity	PJ	-	-	1
		Non-renewable DH	PJ	43	23	14
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	312	299	247
		Direct uses of renewable energy	**PJ**	**39**	**51**	**60**
		Solar thermal - Buildings	PJ	0	2	8
		Solar thermal - Industry	PJ	-	-	2
		Geothermal - Buildings	PJ	1	13	13
		Geothermal - Industry	PJ	0	0	-
		Bioenergy - Buildings	PJ	32	20	20
		Bioenergy - Industry	PJ	5	16	17
		Non-renewable - Buildings	**PJ**	**171**	**183**	**129**
		Non-renewable - Industry	**PJ**	**102**	**64**	**58**
	Transport	**Total fuel consumption**	PJ	177	191	177
		Liquid biofuels	**PJ**	**7**	**15**	**18**
		Bioethanol	PJ	2	4	7
		Biodiesel	PJ	6	11	11
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**0**	**0**
		Non-renewable fuels	**PJ**	**170**	**176**	**159**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**656**	**664**	**619**
RE shares		RE share in power sector		7%	7%	36%
		RE share in district heat generation		18%	52%	71%
		RE share in Buildings - direct uses		16%	16%	25%
		RE share in Buildings - incl. RE electricity and DH		14%	17%	33%
		RE share in Industry - final energy use, direct uses		5%	20%	24%
		RE share in Industry - incl. RE electricity and DH		7%	19%	33%
		RE share in Transport fuels		4%	8%	10%
		RE share in Transport fuels incl. RE electricity		4%	8%	12%
		Share of RE in GFEC		**10%**	**15%**	**27%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-328
		Energy-related CO_2 emissions [Mt CO_2/yr]			32.2	24.9

IT Italy

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**104 565**	**137 345**	**139 836**
		Renewable capacity	**MW**	**46 807**	**93 194**	**95 685**
		Hydropower	MW	14 628	19 200	19 200
		Wind - onshore	MW	9 137	17 500	17 500
		Wind - offshore	MW	-	900	900
		Biofuels (solid, liquid, gaseous)	MW	3 367	3 764	6 255
		Solar PV	MW	18 901	50 000	50 000
		CSP	MW	6	880	880
		Geothermal	MW	768	950	950
		Other (Ocean / Tide / Wave / Other)	MW	0	-	-
		Non-renewable capacity	**MW**	**57 758**	**44 151**	**44 151**
		Coal	MW	9 582	-	-
		Oil	MW	4 157	2 290	2 290
		Gas	MW	44 019	41 861	41 861
		Nuclear	MW	-	-	-
		Total electricity generation	**GWh**	**278 539**	**306 282**	**295 499**
		Renewable generation	GWh	108 909	186 700	212 256
		Hydropower	GWh	45 538	49 300	48 028
		Wind	GWh	14 845	40 100	42 576
		Biofuels (solid, liquid, gaseous)	GWh	19 399	15 700	33 497
		Solar PV	GWh	22 943	71 948	79 665
		CSP	GWh	-	2 552	1 390
		Geothermal	GWh	6 185	7 100	7 100
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	169 629	119 582	83 243
		Coal	GWh	45 388	-	-
		Oil	GWh	11 518	5 564	3 080
		Gas	GWh	112 723	114 018	80 163
		Nuclear	GWh	-	-	-
	DH	**Total district heat generation**	**PJ**	**217**	**208**	**208**
		Biofuels (solid, liquid, gaseous)	PJ	31	31	44
		Geothermal	PJ	1	1	1
		Solar thermal	PJ	0	-	-
		Renewable electricity	PJ	-	-	6
		Non-renewable DH	PJ	185	176	157
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	1 958	1 713	1 397
		Direct uses of renewable energy	**PJ**	**297**	**340**	**411**
		Solar thermal - Buildings	PJ	7	32	93
		Solar thermal - Industry	PJ	0	1	11
		Geothermal - Buildings	PJ	3	7	7
		Geothermal - Industry	PJ	0	-	-
		Bioenergy - Buildings	PJ	270	220	220
		Bioenergy - Industry	PJ	16	80	80
		Non-renewable - Buildings	**PJ**	**1 106**	**964**	**607**
		Non-renewable - Industry	**PJ**	**554**	**409**	**379**
	Transport	**Total fuel consumption**	PJ	1 609	1 500	1 369
		Liquid biofuels	**PJ**	**49**	**94**	**126**
		Bioethanol	PJ	1	6	37
		Biodiesel	PJ	48	89	89
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**0**	**4**	**4**
		Non-renewable fuels	**PJ**	**1 560**	**1 402**	**1 239**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**4 739**	**4 397**	**4 095**
RE shares		RE share in power sector		33%	57%	57%
		RE share in district heat generation		15%	15%	25%
		RE share in Buildings - direct uses		20%	21%	35%
		RE share in Buildings - incl. RE electricity and DH		24%	33%	44%
		RE share in Industry - final energy use, direct uses		3%	17%	19%
		RE share in Industry - incl. RE electricity and DH		15%	32%	35%
		RE share in Transport fuels		3%	6%	9%
		RE share in Transport fuels incl. RE electricity		4%	8%	13%
		Share of RE in GFEC		**16%**	**25%**	**31%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-1392
		Energy-related CO_2 emissions [Mt CO_2/yr]			242.2	192.6

MD Moldova

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**494**	**689**	**2 072**
		Renewable capacity	**MW**	**21**	**216**	**1 599**
		Hydropower	MW	16	19	19
		Wind - onshore	MW	1	127	422
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	3	26	315
		Solar PV	MW	1	44	843
		CSP	MW	-	-	-
		Geothermal	MW	-	-	-
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**473**	**473**	**473**
		Coal	MW	-	-	-
		Oil	MW	69	69	69
		Gas	MW	404	404	404
		Nuclear	MW	-	-	-
		Total electricity generation	**GWh**	**939**	**1 477**	**4 698**
		Renewable generation	GWh	69	607	3 822
		Hydropower	GWh	50	66	65
		Wind	GWh	2	356	1 003
		Biofuels (solid, liquid, gaseous)	GWh	15	129	1 656
		Solar PV	GWh	1	57	1 098
		CSP	GWh	-	-	-
		Geothermal	GWh	-	-	-
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	870	870	876
		Coal	GWh	-	-	-
		Oil	GWh	8	8	-
		Gas	GWh	862	862	876
		Nuclear	GWh	-	-	-
	DH	**Total district heat generation**	**PJ**	**10**	**10**	**10**
		Biofuels (solid, liquid, gaseous)	PJ	1	1	4
		Geothermal	PJ	-	-	-
		Solar thermal	PJ	-	-	-
		Renewable electricity	PJ	-	-	0
		Non-renewable DH	PJ	9	9	5
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	47	93	76
		Direct uses of renewable energy	**PJ**	**26**	**38**	**42**
		Solar thermal - Buildings	PJ	-	-	2
		Solar thermal - Industry	PJ	-	-	0
		Geothermal - Buildings	PJ	-	-	-
		Geothermal - Industry	PJ	-	-	-
		Bioenergy - Buildings	PJ	26	38	38
		Bioenergy - Industry	PJ	0	0	1
		Non-renewable - Buildings	**PJ**	**17**	**46**	**28**
		Non-renewable - Industry	**PJ**	**4**	**9**	**7**
	Transport	**Total fuel consumption**	PJ	28	57	54
		Liquid biofuels	**PJ**	**-**	**-**	**2**
		Bioethanol	PJ	-	-	1
		Biodiesel	PJ	-	-	1
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**-**	**-**
		Non-renewable fuels	**PJ**	**28**	**57**	**52**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**97**	**185**	**171**
RE shares		RE share in power sector		2%	7%	37%
		RE share in district heat generation		6%	6%	48%
		RE share in Buildings - direct uses		61%	45%	59%
		RE share in Buildings - incl. RE electricity and DH		44%	36%	53%
		RE share in Industry - final energy use, direct uses		1%	1%	22%
		RE share in Industry - incl. RE electricity and DH		2%	4%	31%
		RE share in Transport fuels		0%	0%	4%
		RE share in Transport fuels incl. RE electricity		0%	0%	5%
		Share of RE in GFEC		**27%**	**22%**	**35%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-99
		Energy-related CO_2 emissions [Mt CO_2/yr]			8.8	6.8

ME Montenegro

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**873**	**1 299**	**1 385**
		Renewable capacity	**MW**	**654**	**1 074**	**1 385**
		Hydropower	MW	651	781	823
		Wind - onshore	MW	-	190	190
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	-	71	79
		Solar PV	MW	3	32	293
		CSP	MW	-	-	-
		Geothermal	MW	-	-	-
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**219**	**225**	**-**
		Coal	MW	219	225	-
		Oil	MW	-	-	-
		Gas	MW	-	-	-
		Nuclear	MW	-	-	-
		Total electricity generation	**GWh**	**3 003**	**4 565**	**3 776**
		Renewable generation	GWh	1 491	3 205	3 776
		Hydropower	GWh	1 491	2 217	2 314
		Wind	GWh	-	436	473
		Biofuels (solid, liquid, gaseous)	GWh	-	500	542
		Solar PV	GWh	-	52	447
		CSP	GWh	-	-	-
		Geothermal	GWh	-	-	-
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	1 512	1 360	-
		Coal	GWh	1 512	1 360	-
		Oil	GWh	-	-	-
		Gas	GWh	-	-	-
		Nuclear	GWh	-	-	-
	DH	**Total district heat generation**	**PJ**	**-**	**0**	**0**
		Biofuels (solid, liquid, gaseous)	PJ	-	0	0
		Geothermal	PJ	-	0	0
		Solar thermal	PJ	-	-	-
		Renewable electricity	PJ	-	-	0
		Non-renewable DH	PJ	-	-	0
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	10	19	16
		Direct uses of renewable energy	**PJ**	**7**	**9**	**10**
		Solar thermal - Buildings	PJ	0	0	0
		Solar thermal - Industry	PJ	-	-	0
		Geothermal - Buildings	PJ	-	-	-
		Geothermal - Industry	PJ	-	-	-
		Bioenergy - Buildings	PJ	7	8	8
		Bioenergy - Industry	PJ	0	2	2
		Non-renewable - Buildings	**PJ**	**1**	**2**	**-**
		Non-renewable - Industry	**PJ**	**2**	**8**	**6**
	Transport	**Total fuel consumption**	PJ	9	13	12
		Liquid biofuels	**PJ**	**-**	**-**	**0**
		Bioethanol	PJ	-	-	0
		Biodiesel	PJ	-	-	0
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**-**	**-**
		Non-renewable fuels	**PJ**	**9**	**13**	**12**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**28**	**45**	**43**
RE shares		RE share in power sector		42%	69%	76%
		RE share in district heat generation		0%	100%	100%
		RE share in Buildings - direct uses		92%	81%	100%
		RE share in Buildings - incl. RE electricity and DH		68%	76%	87%
		RE share in Industry - final energy use, direct uses		14%	19%	29%
		RE share in Industry - incl. RE electricity and DH		28%	35%	45%
		RE share in Transport fuels		0%	0%	2%
		RE share in Transport fuels incl. RE electricity		0%	2%	5%
		Share of RE in GFEC		**40%**	**44%**	**52%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-8
		Energy-related CO_2 emissions [Mt CO_2/yr]			3.1	1.4

MK North Macedonia

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**2 004**	**2 226**	**3 311**
		Renewable capacity	**MW**	**716**	**1 139**	**2 791**
		Hydropower	MW	658	824	824
		Wind - onshore	MW	37	200	589
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	4	30	247
		Solar PV	MW	17	75	1 121
		CSP	MW	-	-	-
		Geothermal	MW	-	10	10
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**1 288**	**1 087**	**520**
		Coal	MW	828	800	233
		Oil	MW	210	-	-
		Gas	MW	250	287	287
		Nuclear	MW	-	-	-
		Total electricity generation	**GWh**	**5 645**	**7 279**	**8 898**
		Renewable generation	GWh	2 028	3 100	7 206
		Hydropower	GWh	1 865	2 500	2 473
		Wind	GWh	121	380	1 756
		Biofuels (solid, liquid, gaseous)	GWh	20	57	1 312
		Solar PV	GWh	22	144	1 646
		CSP	GWh	-	-	-
		Geothermal	GWh	-	19	19
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	3 617	4 179	1 692
		Coal	GWh	3 295	4 000	1 661
		Oil	GWh	140	-	-
		Gas	GWh	183	179	31
		Nuclear	GWh	-	-	-
	DH	**Total district heat generation**	**PJ**	**2**	**3**	**3**
		Biofuels (solid, liquid, gaseous)	PJ	-	-	1
		Geothermal	PJ	-	-	-
		Solar thermal	PJ	-	-	-
		Renewable electricity	PJ	-	-	0
		Non-renewable DH	PJ	2	3	2
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	25	44	39
		Direct uses of renewable energy	**PJ**	**10**	**11**	**15**
		Solar thermal - Buildings	PJ	-	-	2
		Solar thermal - Industry	PJ	-	-	0
		Geothermal - Buildings	PJ	0	0	0
		Geothermal - Industry	PJ	-	-	-
		Bioenergy - Buildings	PJ	9	11	11
		Bioenergy - Industry	PJ	0	1	2
		Non-renewable - Buildings	**PJ**	**3**	**11**	**5**
		Non-renewable - Industry	**PJ**	**12**	**22**	**19**
	Transport	**Total fuel consumption**	PJ	26	33	32
		Liquid biofuels	**PJ**	**-**	**2**	**3**
		Bioethanol	PJ	-	-	1
		Biodiesel	PJ	-	2	2
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**-**	**-**
		Non-renewable fuels	**PJ**	**26**	**31**	**30**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**77**	**114**	**110**
RE shares		RE share in power sector		25%	26%	58%
		RE share in district heat generation		0%	0%	35%
		RE share in Buildings - direct uses		73%	49%	73%
		RE share in Buildings - incl. RE electricity and DH		43%	37%	64%
		RE share in Industry - final energy use, direct uses		2%	3%	11%
		RE share in Industry - incl. RE electricity and DH		10%	12%	29%
		RE share in Transport fuels		0%	7%	9%
		RE share in Transport fuels incl. RE electricity		0%	8%	12%
		Share of RE in GFEC		**20%**	**20%**	**38%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-32
		Energy-related CO_2 emissions [Mt CO_2/yr]			9.2	6.0

RO Romania

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**24 206**	**23 700**	**29 354**
		Renewable capacity	**MW**	**10 933**	**14 316**	**20 466**
		Hydropower	MW	6 359	6 645	6 907
		Wind - onshore	MW	3 130	5 293	5 358
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	118	157	1 160
		Solar PV	MW	1 326	2 221	7 041
		CSP	MW	-	-	-
		Geothermal	MW	0	-	-
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**13 273**	**9 384**	**8 888**
		Coal	MW	6 669	1 909	1 390
		Oil	MW	1 020	676	676
		Gas	MW	4 173	3 971	3 971
		Nuclear	MW	1 411	2 828	2 851
		Total electricity generation	**GWh**	**65 920**	**71 990**	**96 135**
		Renewable generation	GWh	26 202	32 900	46 277
		Hydropower	GWh	16 632	16 545	17 822
		Wind	GWh	7 064	12 571	12 689
		Biofuels (solid, liquid, gaseous)	GWh	525	1 017	6 164
		Solar PV	GWh	1 982	2 767	9 602
		CSP	GWh	-	-	-
		Geothermal	GWh	-	-	-
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	39 718	39 090	49 858
		Coal	GWh	18 218	7 316	3 421
		Oil	GWh	216	212	158
		Gas	GWh	9 642	9 291	26 983
		Nuclear	GWh	11 640	22 271	19 296
	DH	**Total district heat generation**	**PJ**	**77**	**92**	**92**
		Biofuels (solid, liquid, gaseous)	PJ	4	17	38
		Geothermal	PJ	0	2	2
		Solar thermal	PJ	-	-	-
		Renewable electricity	PJ	-	-	3
		Non-renewable DH	PJ	73	74	49
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	453	511	443
		Direct uses of renewable energy	**PJ**	**135**	**166**	**184**
		Solar thermal - Buildings	PJ	0	0	16
		Solar thermal - Industry	PJ	0	0	3
		Geothermal - Buildings	PJ	1	9	9
		Geothermal - Industry	PJ	0	0	-
		Bioenergy - Buildings	PJ	124	113	113
		Bioenergy - Industry	PJ	10	43	43
		Non-renewable - Buildings	**PJ**	**143**	**165**	**89**
		Non-renewable - Industry	**PJ**	**175**	**180**	**170**
	Transport	**Total fuel consumption**	PJ	230	279	260
		Liquid biofuels	**PJ**	**8**	**23**	**29**
		Bioethanol	PJ	3	3	9
		Biodiesel	PJ	6	20	20
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**0**	**0**
		Non-renewable fuels	**PJ**	**221**	**256**	**232**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**887**	**1 037**	**976**
RE shares		RE share in power sector		44%	49%	60%
		RE share in district heat generation		5%	20%	46%
		RE share in Buildings - direct uses		47%	43%	61%
		RE share in Buildings - incl. RE electricity and DH		42%	41%	59%
		RE share in Industry - final energy use, direct uses		6%	19%	21%
		RE share in Industry - incl. RE electricity and DH		16%	27%	34%
		RE share in Transport fuels		4%	8%	11%
		RE share in Transport fuels incl. RE electricity		4%	9%	14%
		Share of RE in GFEC		**25%**	**29%**	**39%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-87
		Energy-related CO_2 emissions [Mt CO_2/yr]			58.0	51.1

RS Serbia

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**6 687**	**8 472**	**12 588**
		Renewable capacity	**MW**	**2 432**	**4 195**	**9 222**
		Hydropower	MW	2 408	2 941	2 941
		Wind - onshore	MW	10	1 026	1 796
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	5	54	898
		Solar PV	MW	9	170	3 582
		CSP	MW	-	-	-
		Geothermal	MW	-	5	5
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**4 255**	**4 277**	**3 366**
		Coal	MW	4 038	4 079	3 168
		Oil	MW	5	-	-
		Gas	MW	212	198	198
		Nuclear	MW	-	-	-
		Total electricity generation	**GWh**	**37 593**	**42 474**	**47 564**
		Renewable generation	GWh	10 116	15 403	25 586
		Hydropower	GWh	10 081	12 337	12 326
		Wind	GWh	-	2 409	3 727
		Biofuels (solid, liquid, gaseous)	GWh	24	366	4 720
		Solar PV	GWh	10	256	4 778
		CSP	GWh	-	-	-
		Geothermal	GWh	-	35	35
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	27 477	27 070	21 978
		Coal	GWh	27 231	25 800	21 800
		Oil	GWh	28	-	-
		Gas	GWh	218	1 270	178
		Nuclear	GWh	-	-	-
	DH	**Total district heat generation**	**PJ**	**35**	**29**	**29**
		Biofuels (solid, liquid, gaseous)	PJ	0	0	18
		Geothermal	PJ	-	-	-
		Solar thermal	PJ	-	-	-
		Renewable electricity	PJ	-	-	1
		Non-renewable DH	PJ	35	29	11
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	125	234	207
		Direct uses of renewable energy	**PJ**	**43**	**84**	**85**
		Solar thermal - Buildings	PJ	-	-	6
		Solar thermal - Industry	PJ	-	-	3
		Geothermal - Buildings	PJ	0	0	0
		Geothermal - Industry	PJ	-	-	-
		Bioenergy - Buildings	PJ	38	73	55
		Bioenergy - Industry	PJ	6	11	21
		Non-renewable - Buildings	**PJ**	**27**	**42**	**32**
		Non-renewable - Industry	**PJ**	**54**	**108**	**90**
	Transport	**Total fuel consumption**	PJ	85	117	111
		Liquid biofuels	**PJ**	**-**	**11**	**11**
		Bioethanol	PJ	-	2	2
		Biodiesel	PJ	-	8	8
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**-**	**-**
		Non-renewable fuels	**PJ**	**85**	**107**	**100**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**335**	**517**	**493**
RE shares		RE share in power sector		28%	30%	46%
		RE share in district heat generation		0%	1%	63%
		RE share in Buildings - direct uses		58%	63%	66%
		RE share in Buildings - incl. RE electricity and DH		37%	47%	56%
		RE share in Industry - final energy use, direct uses		9%	9%	21%
		RE share in Industry - incl. RE electricity and DH		13%	14%	33%
		RE share in Transport fuels		0%	9%	10%
		RE share in Transport fuels incl. RE electricity		0%	10%	11%
		Share of RE in GFEC		**21%**	**27%**	**38%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-178
		Energy-related CO_2 emissions [Mt CO_2/yr]			46.7	38.2

SI Slovenia

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**3 385**	**3 972**	**5 339**
		Renewable capacity	**MW**	**1 420**	**2 224**	**3 635**
		Hydropower	MW	1 115	1 220	1 220
		Wind - onshore	MW	5	187	807
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	62	118	463
		Solar PV	MW	238	698	1 146
		CSP	MW	-	-	-
		Geothermal	MW	-	-	-
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**1 965**	**1 748**	**1 704**
		Coal	MW	869	632	600
		Oil	MW	100	16	16
		Gas	MW	308	400	400
		Nuclear	MW	688	700	688
		Total electricity generation	**GWh**	**14 808**	**17 950**	**19 332**
		Renewable generation	GWh	4 354	6 121	10 457
		Hydropower	GWh	3 808	4 690	4 848
		Wind	GWh	6	266	1 688
		Biofuels (solid, liquid, gaseous)	GWh	266	403	2 462
		Solar PV	GWh	274	762	1 459
		CSP	GWh	-	-	-
		Geothermal	GWh	-	-	-
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	10 454	11 828	8 875
		Coal	GWh	4 387	4 030	4 313
		Oil	GWh	16	-	3
		Gas	GWh	404	1 796	80
		Nuclear	GWh	5 648	6 002	4 479
	DH	**Total district heat generation**	**PJ**	**9**	**10**	**10**
		Biofuels (solid, liquid, gaseous)	PJ	1	2	7
		Geothermal	PJ	0	0	0
		Solar thermal	PJ	-	-	-
		Renewable electricity	PJ	-	-	0
		Non-renewable DH	PJ	8	8	3
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	64	64	56
		Direct uses of renewable energy	**PJ**	**25**	**27**	**28**
		Solar thermal - Buildings	PJ	0	2	2
		Solar thermal - Industry	PJ	-	-	1
		Geothermal - Buildings	PJ	2	5	5
		Geothermal - Industry	PJ	-	-	-
		Bioenergy - Buildings	PJ	19	12	12
		Bioenergy - Industry	PJ	3	8	8
		Non-renewable - Buildings	**PJ**	**16**	**16**	**9**
		Non-renewable - Industry	**PJ**	**24**	**21**	**19**
	Transport	**Total fuel consumption**	PJ	75	81	74
		Liquid biofuels	**PJ**	**1**	**6**	**6**
		Bioethanol	PJ	0	1	2
		Biodiesel	PJ	1	5	5
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**0**	**0**
		Non-renewable fuels	**PJ**	**74**	**75**	**67**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**192**	**206**	**196**
RE shares		RE share in power sector		29%	36%	56%
		RE share in district heat generation		10%	19%	72%
		RE share in Buildings - direct uses		57%	54%	69%
		RE share in Buildings - incl. RE electricity and DH		44%	45%	64%
		RE share in Industry - final energy use, direct uses		12%	26%	30%
		RE share in Industry - incl. RE electricity and DH		19%	30%	44%
		RE share in Transport fuels		2%	7%	9%
		RE share in Transport fuels incl. RE electricity		2%	8%	12%
		Share of RE in GFEC		**21%**	**26%**	**38%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-27
		Energy-related CO_2 emissions [Mt CO_2/yr]			11.5	9.2

SK Slovakia

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**6 332**	**7 946**	**9 681**
		Renewable capacity	**MW**	**2 385**	**3 259**	**5 480**
		Hydropower	MW	1 606	1 755	1 755
		Wind - onshore	MW	4	350	736
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	242	400	400
		Solar PV	MW	533	750	2 585
		CSP	MW	-	-	-
		Geothermal	MW	-	4	4
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**3 947**	**4 687**	**4 201**
		Coal	MW	913	486	-
		Oil	MW	208	84	84
		Gas	MW	886	1 097	1 097
		Nuclear	MW	1 940	3 020	3 020
		Total electricity generation	**GWh**	**26 509**	**37 203**	**35 910**
		Renewable generation	GWh	6 041	8 822	11 600
		Hydropower	GWh	3 866	4 822	4 736
		Wind	GWh	6	560	1 587
		Biofuels (solid, liquid, gaseous)	GWh	1 663	2 660	2 659
		Solar PV	GWh	506	750	2 588
		CSP	GWh	-	-	-
		Geothermal	GWh	-	30	30
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	20 469	28 381	24 310
		Coal	GWh	3 332	1 838	-
		Oil	GWh	361	88	173
		Gas	GWh	1 629	3 095	1 810
		Nuclear	GWh	15 147	23 360	22 327
	DH	**Total district heat generation**	**PJ**	**35**	**41**	**41**
		Biofuels (solid, liquid, gaseous)	PJ	7	11	15
		Geothermal	PJ	0	2	2
		Solar thermal	PJ	0	0	0
		Renewable electricity	PJ	0	0	1
		Non-renewable DH	PJ	27	28	23
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	211	230	202
		Direct uses of renewable energy	**PJ**	**18**	**34**	**40**
		Solar thermal - Buildings	PJ	0	0	5
		Solar thermal - Industry	PJ	-	-	1
		Geothermal - Buildings	PJ	0	0	0
		Geothermal - Industry	PJ	-	-	-
		Bioenergy - Buildings	PJ	1	4	4
		Bioenergy - Industry	PJ	17	30	30
		Non-renewable - Buildings	**PJ**	**73**	**87**	**57**
		Non-renewable - Industry	**PJ**	**120**	**109**	**105**
	Transport	**Total fuel consumption**	PJ	87	111	101
		Liquid biofuels	**PJ**	**6**	**8**	**11**
		Bioethanol	PJ	1	1	4
		Biodiesel	PJ	5	7	7
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**0**	**0**
		Non-renewable fuels	**PJ**	**81**	**103**	**91**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**421**	**483**	**457**
RE shares		RE share in power sector		21%	25%	29%
		RE share in district heat generation		22%	33%	44%
		RE share in Buildings - direct uses		2%	4%	14%
		RE share in Buildings - incl. RE electricity and DH		11%	15%	25%
		RE share in Industry - final energy use, direct uses		12%	21%	23%
		RE share in Industry - incl. RE electricity and DH		15%	23%	25%
		RE share in Transport fuels		7%	7%	10%
		RE share in Transport fuels incl. RE electricity		7%	7%	12%
		Share of RE in GFEC		**12%**	**17%**	**23%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-109
		Energy-related CO_2 emissions [Mt CO_2/yr]			26.0	20.8

UA Ukraine

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**53 663**	**67 062**	**63 713**
		Renewable capacity	**MW**	**6 102**	**21 200**	**34 021**
		Hydropower	MW	4 697	5 000	6 000
		Wind - onshore	MW	514	4 500	7 918
		Wind - offshore	MW	-	500	500
		Biofuels (solid, liquid, gaseous)	MW	52	1 000	3 754
		Solar PV	MW	839	10 000	15 648
		CSP	MW	-	-	-
		Geothermal	MW	-	200	200
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**47 561**	**45 862**	**29 692**
		Coal	MW	25 334	23 500	7 330
		Oil	MW	-	580	580
		Gas	MW	8 392	9 000	9 000
		Nuclear	MW	13 835	12 782	12 782
		Total electricity generation	**GWh**	**161 642**	**185 300**	**247 845**
		Renewable generation	GWh	7 104	41 900	76 620
		Hydropower	GWh	5 397	11 500	15 028
		Wind	GWh	1 084	13 400	22 910
		Biofuels (solid, liquid, gaseous)	GWh	145	4 500	19 724
		Solar PV	GWh	477	11 800	18 258
		CSP	GWh	-	-	-
		Geothermal	GWh	-	700	700
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	154 538	143 400	171 225
		Coal	GWh	56 064	40 000	18 313
		Oil	GWh	745	700	263
		Gas	GWh	10 102	10 000	61 383
		Nuclear	GWh	87 627	92 700	91 266
	DH	**Total district heat generation**	**PJ**	**377**	**448**	**448**
		Biofuels (solid, liquid, gaseous)	PJ	13	157	183
		Geothermal	PJ	-	-	-
		Solar thermal	PJ	-	-	-
		Renewable electricity	PJ	-	-	8
		Non-renewable DH	PJ	364	291	257
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	1 041	1 009	859
		Direct uses of renewable energy	**PJ**	**51**	**35**	**109**
		Solar thermal - Buildings	PJ	-	-	20
		Solar thermal - Industry	PJ	-	-	4
		Geothermal - Buildings	PJ	-	-	-
		Geothermal - Industry	PJ	-	-	-
		Bioenergy - Buildings	PJ	48	30	36
		Bioenergy - Industry	PJ	4	5	49
		Non-renewable - Buildings	**PJ**	**409**	**506**	**341**
		Non-renewable - Industry	**PJ**	**581**	**468**	**409**
	Transport	**Total fuel consumption**	PJ	281	352	330
		Liquid biofuels	**PJ**	**1**	**19**	**29**
		Bioethanol	PJ	1	19	19
		Biodiesel	PJ	-	-	10
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**-**	**-**
		Non-renewable fuels	**PJ**	**279**	**333**	**301**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**2 043**	**2 369**	**2 246**
RE shares		RE share in power sector		4%	20%	34%
		RE share in district heat generation		3%	35%	43%
		RE share in Buildings - direct uses		10%	6%	14%
		RE share in Buildings - incl. RE electricity and DH		7%	16%	28%
		RE share in Industry - final energy use, direct uses		1%	1%	11%
		RE share in Industry - incl. RE electricity and DH		2%	13%	25%
		RE share in Transport fuels		1%	5%	9%
		RE share in Transport fuels incl. RE electricity		1%	7%	11%
		Share of RE in GFEC		**4%**	**14%**	**24%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-354
		Energy-related CO_2 emissions [Mt CO_2/yr]			154.2	126.8

XK Kosovo

			Unit	2015	Reference Case 2030	REmap 2030
Energy production and capacity	Power sector	**Total installed power generation capacity**	**MW**	**1 333**	**1 494**	**2 317**
		Renewable capacity	**MW**	**45**	**444**	**1 639**
		Hydropower	MW	43	234	234
		Wind - onshore	MW	1	150	385
		Wind - offshore	MW	-	-	-
		Biofuels (solid, liquid, gaseous)	MW	-	15	253
		Solar PV	MW	0	45	767
		CSP	MW	-	-	-
		Geothermal	MW	-	-	-
		Other (Ocean / Tide / Wave / Other)	MW	-	-	-
		Non-renewable capacity	**MW**	**1 288**	**1 050**	**678**
		Coal	MW	1 288	1 050	678
		Oil	MW	-	-	-
		Gas	MW	-	-	-
		Nuclear	MW	-	-	-
		Total electricity generation	**GWh**	**6 119**	**7 087**	**9 049**
		Renewable generation	GWh	140	937	4 035
		Hydropower	GWh	140	830	657
		Wind	GWh	-	-	948
		Biofuels (solid, liquid, gaseous)	GWh	-	45	1 328
		Solar PV	GWh	-	62	1 102
		CSP	GWh	-	-	-
		Geothermal	GWh	-	-	-
		Other (Ocean / Tide / Wave / Other)	GWh	-	-	-
		Non-renewable generation	GWh	5 979	6 150	5 014
		Coal	GWh	5 964	6 150	5 014
		Oil	GWh	15	-	-
		Gas	GWh	-	-	-
		Nuclear	GWh	-	-	-
	DH	**Total district heat generation**	**PJ**	**1**	**2**	**2**
		Biofuels (solid, liquid, gaseous)	PJ	-	-	-
		Geothermal	PJ	-	-	-
		Solar thermal	PJ	-	-	-
		Renewable electricity	PJ	-	-	0
		Non-renewable DH	PJ	1	2	2
Final energy use - direct uses	Buildings and Industry	**Total direct uses of energy**	PJ	22	32	28
		Direct uses of renewable energy	**PJ**	**11**	**10**	**14**
		Solar thermal - Buildings	PJ	0	0	1
		Solar thermal - Industry	PJ	-	-	0
		Geothermal - Buildings	PJ	-	-	-
		Geothermal - Industry	PJ	-	-	-
		Bioenergy - Buildings	PJ	10	10	10
		Bioenergy - Industry	PJ	1	0	3
		Non-renewable - Buildings	**PJ**	**4**	**8**	**4**
		Non-renewable - Industry	**PJ**	**7**	**14**	**11**
	Transport	**Total fuel consumption**	PJ	16	24	22
		Liquid biofuels	**PJ**	**-**	**1**	**1**
		Bioethanol	PJ	-	0	0
		Biodiesel	PJ	-	1	1
		Biokerosene	PJ	-	-	-
		Other (biogas, methanol, hydrogen)	**PJ**	**-**	**-**	**-**
		Non-renewable fuels	**PJ**	**16**	**22**	**20**
Total final energy consumption (electricity, DH, direct uses)			**PJ**	**55**	**88**	**84**
RE shares		RE share in power sector		2%	9%	38%
		RE share in district heat generation		0%	0%	3%
		RE share in Buildings - direct uses		72%	54%	76%
		RE share in Buildings - incl. RE electricity and DH		41%	27%	50%
		RE share in Industry - final energy use, direct uses		6%	3%	21%
		RE share in Industry - incl. RE electricity and DH		5%	4%	25%
		RE share in Transport fuels		0%	5%	6%
		RE share in Transport fuels incl. RE electricity		0%	5%	8%
		Share of RE in GFEC		**19%**	**16%**	**33%**
Other		Incremental energy costs REmap vs Reference [M USD/yr in 2030]				-30
		Energy-related CO_2 emissions [Mt CO_2/yr]			9.9	8.0

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