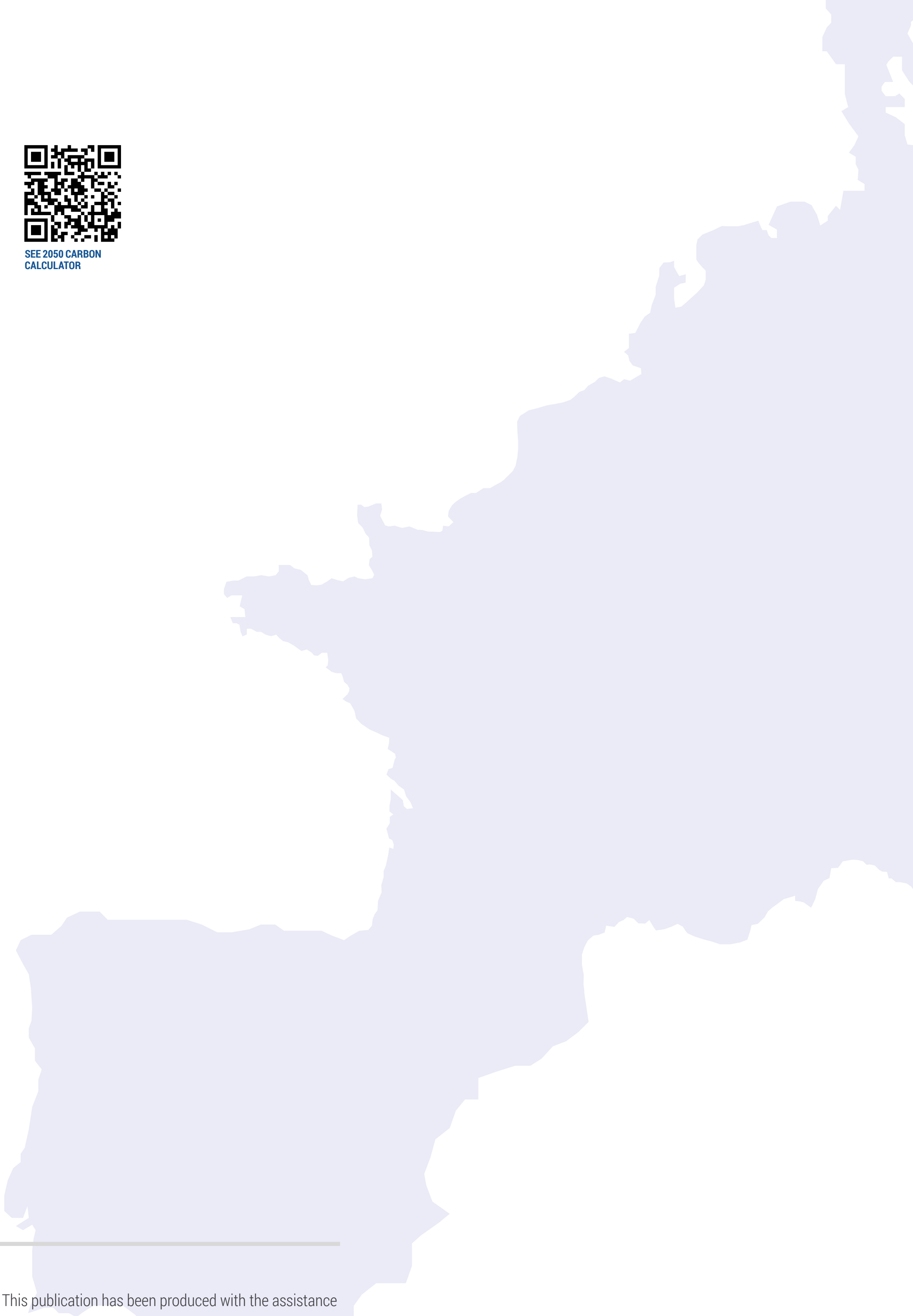
South East Europe
Sustainable Energy
Policy

SOUTH EAST EUROPE: THE EU ROAD OR THE ROAD TO NOWHERE?

An energy roadmap for 2050: Technical analysis

SEE 2050 ENERGY MODEL

SEE 2050 CARBON CALCULATOR



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According to the UN, Kosovo is "under the United Nations Interim Administration Mission in Kosovo (UNMIK) established pursuant to Security Council Resolution 1244." In this publication it is referred to as "Kosovo".

*** According to the UN, the official name for Macedonia is "The Former Yugoslav Republic of Macedonia"*

South East Europe Sustainable Energy Policy

With approximately 25 million potential new EU citizens in South East Europe, who are all energy consumers, energy is perhaps one of the most complex issues which is facing the region. It has inter-related and far reaching impacts on several areas, including society, the economy and the environment, particularly as South East Europe faces the imminent deregulation of the market in a less than ideal governance environment.

The South East Europe Sustainable Energy Policy (SEE SEP) programme is designed to tackle these challenges. This is a multi-country and multi-year programme which has 17 CSO partners from across the region (Albania, Bosnia and Herzegovina, Croatia, Kosovo*, Macedonia**, Montenegro and Serbia) and the EU, with SEE Change Net as lead partner. It is financially supported by the European Commission.

The contribution of the SEE SEP project is to empower CSOs and citizens to better influence policy and practice towards a fairer, cleaner and safer energy future in SEE.

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SANDER + PARTNER

RAEL Renewable & Appropriate Energy Laboratory

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FOREWORD

The future is low emissions prosperity

When I am asked what the most important joint policy for the European Union and the neighbourhood countries of South East Europe is today, I answer without hesitation – energy. Energy policy can be our springboard for secure and sustainable growth but also the bridge that connects the EU and its neighbours, literally and metaphorically.

To achieve greater resilience, independence and sustainability in energy we need to not only make full use of all energy sources, including sun and wind, but also change the way we use energy. This requires having a clear strategy as well as clear policies. I would like to share two points in this regard which I think are particularly relevant for the region of South East Europe.

The first is that we all know we need to reduce our greenhouse gases emissions, and we must do it in a way that will allow us to remain competitive. Balancing the two goals is a huge challenge but this is exactly what the future has to be – low emissions prosperity. Achieving it requires new technologies, some of which we are already developing, which will turn the “green revolution” into an opportunity for all.

This brings me to my second point: we need to invest more in energy research to inform policy. This is why I welcome the development of the South East Europe 2050 Energy Model and I congratulate the consortium who worked on it, including Renewable and Appropriate Energy Laboratory (RAEL) of University of California, Berkeley, Climact, Trove Research, SEE Change Net, their SEE SEP partners and independent experts. The open source model, also used by the International Energy Agency and 20 countries in other regions, forms the basis of this policy paper. It allows policymakers to clearly visualise the impact of their everyday decision-making on the energy systems out to 2050 and to better define concrete steps towards achieving full low emissions prosperity.

If we are to meet our energy needs, reduce our environmental footprint including greenhouse emissions and raise the competitiveness of our economies, using all the limited resources we have at our disposal, we need to choose the right policy options carefully. I am convinced that this EU Road Map policy document and the SEE 2050 Energy Model make an important contribution to making this choice.

Jerzy Buzek,

Member of the European Parliament, Chair of the Committee on Industry, Research and Energy of the European Parliament

EXECUTIVE SUMMARY

Policymakers and political leaders in South East Europe (SEE)[1] now stand at a pivotal crossroads. Each UN member state in the SEE region committed at the COP21 UN Climate Change Conference[2] in Paris to strive to keep global temperature increase below 1.5° C and those countries are also committed to membership of the EU[3]; which brings with it stringent conditionality in energy and environment amongst many other sectors[4]. Policymakers in South East Europe therefore need to choose between the current coal-based path of development or advance toward an EU accession pathway and a sustainable environment through integrated planning that utilizes diversified renewables, increased energy efficiency programs, and coordinated retirements of existing coal plants.

This paper provides the technical analysis that explains the critical pathway to achieve European integration and UN Climate commitments, described using the South East Europe 2050 Carbon Calculator; a policy decision-making tool that generates techno-economic scenarios for future decarbonization of the energy sector. The tool, which was developed by the Department of Energy and Climate Change (DECC) UK and now used by the International Energy Agency (IEA)[5] and several dozen countries[6] across the globe, is based on an open source design and emphasizes helping policymakers explore pathways and scenarios by changing levers and ambition levels in an online calculator tool.

Two key pathways are articulated and examined: a coal-dependent case called the “Road to Nowhere” based on planned coal investments and the “EU Road” case where South East European countries successfully comply with the current EU environmental and climate policies.

We identify four main conclusions:

1) moving toward renewables in the electricity supply along the EU Road is directly cost competitive with the coal-dependent case;

2) demand-side management yields opportunities for technological improvement, waste reduction, increased comfort/reduction of energy poverty, and job creation in the region;

3) the low-carbon transition offers the South East Europe countries to become leaders, not laggards, and;

4) all of these benefits accrue before considering the external costs of coal to public health and the environment.

Taken together, these findings highlight for a region once seen as both troubled and a ‘policy taker’, not a policy maker, a clear economic, environmental and policy benefit from the aggressive pursuit of a regional clean energy partnership.

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[1] For the purpose of this paper South East Europe is defined as the following countries: Albania, Bosnia and Herzegovina, Croatia, Kosovo, Macedonia, Montenegro, and Serbia. Kosovo is not a member of the UNFCCC and therefore did not sign the Paris Agreement. However, Kosovo is actively seeking EU membership.

[2] *http://www.cop21.gouv.fr/en/*

[3] *http://ec.europa.eu/enlargement/countries/check-current-status/index_en.htm*

[4] *http://ec.europa.eu/enlargement/policy/conditions-membership/index_en.htm*

[5] Global Calculator: *http://bit.ly/1TVd8BH*

[6] *http://seechangenetwork.org/2050-energy-model-for-south-east-europe/*

Glossary

SEE	*South East Europe*
UN	*United Nations*
COP	*Conference of Parties*
EU	*European Union*
DECC	*Department of Energy and Climate Change*
IEA	*International Energy Agency*
UNFCCC	*United Nations Framework Convention on Climate Change*
SCADA	*Supervisory Control and Data Acquisition*
AMI	*Advanced Metering Infrastructure*
PV	*Photovoltaic*
W	*Watt*
NDCs	*National determined contributions*
GHG	*Greenhouse gas*
CSO	*Civil society organization*
SEE SEP	*South East Europe Sustainable Energy Policy*
GW	*Gigawatt*
WACC	*Weighted Average Cost of Capital*
GDP	*Gross Domestic Product*
WB	*World Bank*
IMF	*International Monetary Fund*
TWh	*Terawatt-hour*
kWh	*Kilowatt-hour*
EPBD	*European Performance Building Directive*
CHP	*Combined heat and power*
LED	*Light emitting diode*
CFL	*Compact fluorescent lightbulb*
ICT	*Information and communication technology*
CNG	*Compressed Natural Gas*
Kt	*Kiloton*
Pkm	*Passenger-kilometer*
SO_2	*Sulfur dioxide*
NOx	*Nitrous oxides*
PM	*Particulate matter*
EUR	*Euro*
USD	*US Dollar*
LCOE	*Levelized cost of electricity*
CAPEX	*Capital expenditure*
O&M	*Operations and Maintenance*
TREES	*Training for Energy Efficient Social Housing*
Cm	*Centimeter*
EV	*Electric vehicle*
CSP	*Concentrating solar power*
DC	*Direct current*
AC	*Alternating current*
FIT	*Feed-in tariff*
DSM	*Demand-side management*
LTC	*Load tap changer*
FACTS	*Flexible AC transmission devices*
HVDC	*High Voltage DC*
NZEBs	*Near-zero energy buildings*
EECG	*Energy Efficiency Coordination Group*
NEEAP	*National Energy Efficiency Action Plan*
2DS	*2°C Scenario*
IPCC	*Intergovernmental Panel on Climate Change*
CAISO	*California Independent System Operator*
IED	*Industrial Emissions Directive*

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INTRODUCTION

With drastic reductions in the cost of solar and wind power and the aging of existing energy infrastructure in the region, South East Europe faces a choice to follow a pathway relying solely on new coal development, without any significant solar or wind, or advance toward EU accession by utilizing cleaner energy technologies and energy efficiency measures by planning from now until 2050. The price of solar PV alone is expected to drop from approximately €6.6/W in 2002 to €0.9/W by 2020[7]. Further advances in wind technology and other dispatchable renewable electricity options have altered the landscape for future investments in new generation capacity, where wind prices are expected to drop as well by 20–30% by 2030[8]. Here we provide the technical analysis that explains the critical pathways described by the 2050 South East Europe Carbon Calculator[9], a policy decision-making tool that develops techno-economic scenarios for future decarbonization of the energy sector in South East Europe. This document, using the 2050 Calculator, projects two scenarios and includes sliding levers to develop the changes across different economic sectors for outcomes using the online calculator tool. The pathways follow the case focused on future planned coal development and the "EU Road" case where South East European countries successfully comply with EU environmental and climate regulations.

The following sections outline the technical specifications of each pathway, including the methods, data, and results of the South East Europe 2050 Carbon Calculator. The scenarios explore different energy development pathways that follow along the coal trajectory and the EU Road. Developed alongside expert consultation across the region with engineers, policymakers, and academic institutions, we investigate supply and demand-side interventions in the energy sector to provide fairer, cleaner, and more efficient energy at a competitive cost with current coal-based proposals.

With a significant regional aim for individual states to accede into the European Union combined with Croatia's recent accession in 2013, countries including Montenegro and Serbia can set the stage for Macedonia, Albania, Bosnia & Herzegovina, and Kosovo's entry. Emerging EU policy, such as the Energy Union Strategy, shows that the EU considers South East Europe as an important region when resolving energy issues and that cooperation between the EU and the Energy Community countries is necessary to meet EU energy policy objectives. This Energy Community, a regional entity based on the Energy Community Treaty, represents an international organization dealing with energy policy in six South East Europe countries, Moldova, and Ukraine that work with the EU to bring EU energy policy into non-EU or prospective member states. The advantages of systems-thinking across the regional energy picture, set forth through the Energy Community, can set concrete examples to provide feasible pathways for nations to collaborate, join the EU, and create a fairer, cleaner, and more efficient energy sector. Therefore, it becomes a particularly important institution to facilitate transitions from centralized to distributed electricity generation paradigms and protect countries from going bankrupt on new energy assets. As many centralized investments are becoming less financially viable in Western Europe and the US, South East European countries run the risk of creating stranded assets when

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[7] Costs reflected in 2015 EUR. Zheng, C., & Kammen, D. M. (2014). An innovation-focused roadmap for a sustainable global photovoltaic industry. *Energy Policy, 67,* 159-169.

[8] Lantz, E., Wiser, R., & Hand, M. (2012). The past and future cost of wind energy. *National Renewable Energy Laboratory, Golden, CO, Report No. NREL/TP-6A20-53510.*

[9] For full calculator and web tool, visit: *http://www.see2050carboncalculator.net*

building large-scale coal-fired power plants with large generating capacity and high operating costs[10]. The centralized development paradigm increasingly faces direct competition from more resilient, decentralized power system designs. To get to the EU Road, the analysis presented demonstrates the cost and technical needs to meet energy demand in the region through energy efficiency and renewable electricity supply that simultaneously facilitates regional economic growth.

This report highlights four main findings: 1) moving toward renewables in the electricity supply along the EU Road is directly cost competitive with the coal-dependent case, 2) demand-side management yields opportunities for technological improvement, waste reduction, increased comfort/reduction of energy poverty, and job creation in the region, 3) the low-carbon transition offers the South East Europe countries an opportunity to become leaders, not laggards, and 4) all of these benefits accrue before considering the external costs of coal to public health and the environment.

Motivation/Rationale for 2050 Energy Model

Increased global concern for climate change culminating in the 2015 Paris Agreement spawned a heightened need to identify and detail technical pathways that achieve low-carbon and sustainable development across individual countries and across the world[11]. With six countries in South East Europe in agreement with the Paris Agreement and a view toward EU membership, detailing the path forward toward emission reductions and a healthier society remains critical. Countries provided flexibly designed national determined contributions (NDCs). Furthermore, the current EU goal is to reduce greenhouse gas emissions by 80–95% by 2050 based on 1990 levels with an interim target of at least 40% reductions by 2030[12]. Each country in South East Europe is now signatory to the Energy Community Treaty and is either on the path or plans to apply for EU membership before 2030[13].

Institutions like the Energy Community will only strengthen and support regional development aims while addressing problems at the intersection of the environment, energy sector, and society. Future planned coal-fired power plants—namely in Bosnia and Herzegovina, Croatia, Kosovo, Montenegro, and Serbia not only contribute to global climate change, but will incur irreversible regional costs to public health and the environment[14]. This model estimates the opportunity cost of these developments by using an accounting stock

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10 For further information on stranded assets and their relationship in South East Europe coal projects, see the Smith School report. *http://www.smithschool.ox.ac.uk/research-programmes/stranded-assets/publications.php* *http://bankwatch.org/sites/default/files/SEE-IFI-energy.pdf*

11 2015 Paris Agreement was signed on 22 April 2016 and six countries in South East Europe have signed, all except Kosovo as it is not part of the UN or UNFCCC. *http://www.un.org/sustainabledevelopment/blog/2016/04/parisagreementsingatures/*

12 *http://ec.europa.eu/clima/policies/strategies/2030/index_en.htm*

13 Croatia joined the EU in 2013. Montenegro and Serbia have started membership talks. Macedonia and Albania are candidate countries. Kosovo and Bosnia and Herzegovina are potential candidates for EU membership. Being in the Energy Community and being in the EU are mutually exclusive. Croatia is already an EU member state therefore it is no longer in the Energy Community.

14 A recent study put the cost of coal on public health in South East Europe at 8.5 billion euros in health costs (HEAL, 2016). *http://www.env-health.org/resources/press-releases/article/eur8-5-billion-in-health-costs*

framework and energy decision-making tool to analyze costs and emissions of the coal-based proposals on the table within South East Europe developed by the UK Department of Energy and Climate Change (DECC). With the technical calculator, we answer questions of technical resource availability, sectoral energy intensity, cost of scenario pathways, achieving emission reduction targets and air quality, which relate to energy security and public acceptance through the stakeholder consultations. There are two main aspects that drive change in the model – technological levers and policy drivers.

Technological levers for change: The technology available to achieve national and regional decarbonization is evolving rapidly. Particularly dramatic are the changes in global production volume and price of solar photovoltaic and solar thermal technologies, and wind power, but game-changing innovations are also ongoing in biomass energy, micro-hydro, and in conventional flow-battery, and other evolving storage technologies.

Policy drivers of change: Innovations in energy policy across the world have provided years of historical lessons for South East Europe countries. Facing the prospects of EU accession, countries in South East Europe can be proactive to shift the policy in favor of environmentally and health-friendly renewable energy policies that will address climate change and improve regional air quality. For instance, the EU has a regional target for at least a 40% reduction in GHG emissions by 2030 and following that a long-term target of 80–95% emission reductions by 2050. Achieving EU accession and simultaneously meeting environmental conservation goals requires significant action and coordination across the region.

In the Paris Agreement, all countries agreed to formulate and communicate long-term low greenhouse gas emission development strategies. The European Commission, in its post-Paris Communication, agreed to develop such a strategy before 2020. To facilitate the preparation of this strategy, the Commission will prepare an in-depth analysis of the economic and social transformations to feed the political debate in the European Parliament, Council, and with stakeholders. It is clear that both the global net-zero goal and the 1.5°C objective from the Paris Agreement change the whole landscape of Europe's long-term emission reduction objectives. It will be crucial to ensure the roadmap is developed based on the latest scientific evidence of the global carbon budget and the EU's fair share of targets and reductions. Setting a new long-term target should both help to identify policies, lifestyle changes and technology developments needed, and should as well identify new short – and mid-term targets for 2025, 2030 and even 2050. With this in mind, countries of South East Europe need to strive towards the full decarbonization in the second half of the century, to comply with the Paris Agreement and the requirements of the EU accession, but also to reap the benefits of decarbonization: including jobs, better health, and reduced dependency on fossil fuels.

The purpose of the model is to evaluate the costs and options, given the rapidly declining cost of solar PV, wind power, and sustainable biomass technologies for power generation. We investigate to what extent is the alternative EU Road cost-effective and economically empowering compared to the plans for new coal capacity. We analyze pathways through simultaneous action using technological levers and policy drivers.

METHODS

Description of model

The SEE Change Net team along with CSO partners from the SEE SEP consortium conducted over 500 consultations[15] with regional stakeholders and energy experts in the region to develop plausible scenarios under the framework of the UK DECC (Department of Energy and Climate Change) 2050 Calculator. This open source energy modeling platform available online estimates energy supply, demand, emissions, and costs across different use sectors. The energy supply and demand disaggregates further into an electricity generation model that details system-level production on an annual basis. The energy modeling platform is hosted through a spreadsheet model that builds different scenarios based off of scenario parameters determined through stakeholder consultation and expert elicitation. The demand side of the analysis includes buildings, transport, cement, steel and aluminum sectors. The supply side includes analysis detailing oil and gas, hydropower, coal, and renewable potential capacity including solar, wind generation, and biomass energy for heating. The SEE 2050 Carbon Calculator incorporates 2010 and 1990 baselines and population growth rates to inform the demand and supply picture for emission reductions and costs.

We model energy supply and demand by sector until 2030 and 2050 to reflect the EU targets across short and long time horizons. The scenarios, developed in accordance with various stakeholders across the region[16], are detailed here. The model uses inputs of historical supply and demand on an annual basis to make projections for future capacity cost and incorporates operations and maintenance. The scenarios are developed in accordance with regional EU policies and directives set forth through the Energy Community Treaty and by using engineering approaches to estimate maximum technical resource potential. For a full description of all the costs, resource availability maps, and an open source version of the model: visit ***www.see2050carboncalculator.net***. There are multiple pathways to choose – however, for this report we focus on the costs and opportunities of the EU Road compared to the coal-dependent proposals. In this analysis, each pathway uses the same supply and demand side resource availability, but changes scenario design based on cost and ambition level.

The EU Road and Road to Nowhere

The EU Road describes the necessary path taken to meet EU climate and energy targets while decarbonizing South East Europe's power sector. The "Road to Nowhere" is the alternative, a pathway based on sustained and future planned investments in coal infrastructure across the region. We investigate the costs and benefits of both pathways. The current planned investments across South East Europe rely on low-quality and low-energy density lignite coal and minimal energy efficiency targets. This path will not bring any countries in South East Europe any closer to meeting EU energy and climate goals and targets. In contrast, the EU compliant pathway, known as the "EU Road," removes coal from future energy investments, while replacing it with solar, wind and a concerted effort to improve energy efficiency. Encouragingly, we find that over the period to 2050, South East Europe could reach the EU Road pathway for approximately the same cost as the following the Road to Nowhere path. The following section elaborates the details of these two pathways, while comparing and contrasting their policy implications.

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[15] *http://seechangenetwork.org/wp-content/uploads/2015/07/South-East-Europe-2050-Energy-Model-Call-for-Evidence-Report.pdf*

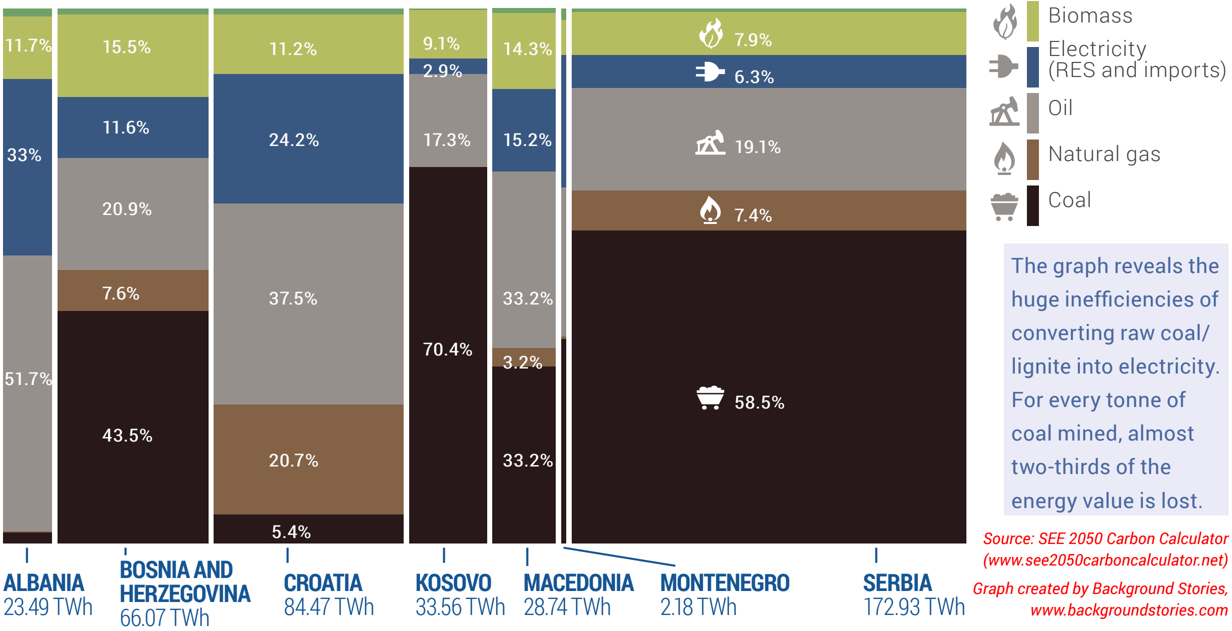
[16] Ibid

The EU Road

The EU Road represents the pathway that can bring countries within South East Europe to comply with the energy and environmental regulations that accompany EU accession. This pathway is depicted below, with emphasis on the levers of change including technological and sectoral choices to focus on decarbonization and build regional resilience. Furthermore, the co-benefits to moving beyond coal are high, including environmental protection, dealing with energy poverty issues, public health, and improving regional stability. These are all possible at comparable cost to a coal-based pathway, that precludes compliance with EU goals and targets and compromises the societal benefits associated with a clean energy transition.

In 2010, South East Europe's existing primary energy stock and electricity production is used as an inventoried historical baseline for both the EU Road and the Road to Nowhere case. Figure 1 highlights the strong dependence on large-scale coal and hydro power across the system.

FIGURE 1. Primary energy supply per country & technology



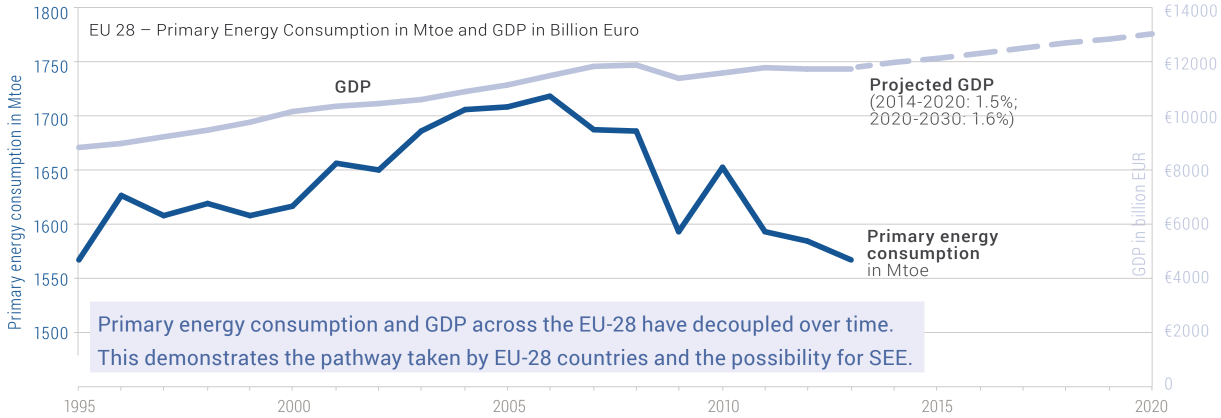
The graph reveals the huge inefficiencies of converting raw coal/ lignite into electricity. For every tonne of coal mined, almost two-thirds of the energy value is lost.

Source: SEE 2050 Carbon Calculator (www.see2050carboncalculator.net)

Graph created by Background Stories, www.backgroundstories.com

From a technical perspective, the EU Road envisions a dramatic shift from traditional centralized grid structures to a more distributed paradigm in the electricity sector. Transport and buildings will experience mode and use shifts. They may change from simple energy consumers to producers. Transportation and buildings may become electrified as a way to achieve decarbonization goals. Electric vehicles provide flexibility in transit and electrification of buildings for heating can alleviate stresses on fossil – or biomass-based heat in buildings.

FIGURE 2. Decoupling of growth from energy consumption in the EU



Primary energy consumption and GDP across the EU-28 have decoupled over time. This demonstrates the pathway taken by EU-28 countries and the possibility for SEE.

Source: Presentation by Paul Hodson, DG Energy, June 18 2015

The EU Road details the necessary investments to achieve an 80% reduction in greenhouse gas emissions from 1990 levels. This compares to the coal-dependent pathway, which achieves some incremental greenhouse gas emission reductions, but does not achieve the steep reductions necessary to meet EU climate targets. This model explores the extent to which the EU Road pathway is technically feasible and cost competitive with a coal-based path.

"Road to Nowhere" case

The "Road to Nowhere" case follows an unambitious pathway in terms of supporting diverse renewable energy projects and pursues minimal effort in energy efficiency targets. This path contains planned coal plants due to be built by 2025 and quantifies the direct financial and environmental costs. The projections and assumptions are outlined in the figures and table below for supply, demand and greenhouse gas emissions. Following this coal-dependent path hinders some countries from meeting increasingly ambitious EU climate commitments. Also, new coal plants incur additional stranded investment risk that will be difficult to recover due to technological path dependency. This pathway maintains heavy reliance on lignite coal across the region. The following figures display the supply, demand, and emissions picture of a coal-dependent path.

The EU Road presents a set of ambition levels for technology levers and policy drivers against the coal-dependent case summarized in Table 1. The assumptions are detailed in a side-by-side comparison to explain the differences between the EU Road pathway and the Road to Nowhere. These critical assumptions represent a wide divergence in both choice and environmental and climate impacts, yet interestingly enough, at a comparable overall system cost. This represents the feasibility of the clean energy transition and road to the EU, highlighting the point that it is more of a choice, than a necessity to build more coal and that even on a cost basis, there are multiple opportunities to meet future energy needs while enabling a better society—in terms of environment, health, job creation, and political stability.

Figures 3 and 4 detail the primary energy supply pathways for the coal-dependent "Road to Nowhere" and the "EU Road" respectively. Each path uses 2010 as a baseline year taking existing stocks and accounting for future investments in different primary energy supply sources.

Source: SEE 2050 Carbon Calculator (www.see2050carboncalculator.net)

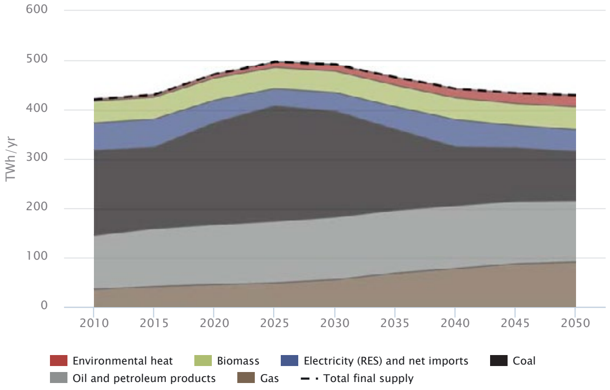


FIGURE 3. Coal-dependent pathway for primary energy supply from 2010–2050 in South East Europe.

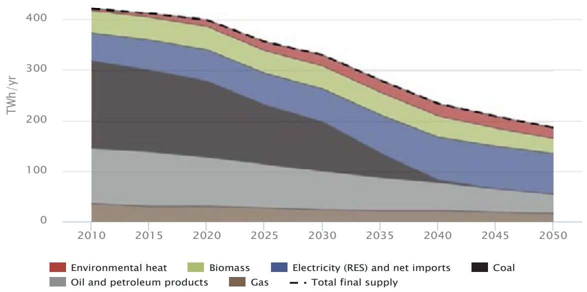


FIGURE 4. EU Road for primary energy supply from 2010–2050 in South East Europe

WHY?

The assumptions and description of the Road to Nowhere path and the EU Road remain clear. An EU Road contains no new coal, much more attention to renewable energy on the gigawatt scale, and incentives for energy efficiency to improve energy services and use less energy. This presents challenges in terms of changing from traditional baseload generators to more intermittent and variable renewable sources of electricity. There also remain significant technical and behavioral challenges related to shifting energy supply and demand.

TABLE 1. The supply, demand and global, assumptions comparing the EU Road and coal-based pathways.

Table 1	**EU ROAD**	**ROAD TO NOWHERE**
SUPPLY-SIDE ASSUMPTIONS		
Onshore wind	Best locations (resource-wise) and a few other locations that are less financially viable by 2050. (Ambition Level 3 – 13.1 GW installed)	Existing plants (no further extension of wind power in the future). (0.07865 GW installed)
Large-scale hydroelectric plants	Existing plants, plants that are under construction in baseline year 2010 and proposed plants that are neither in protected areas nor proposed or discussed on river stretches considered of outstanding importance, installed by 2050. (Ambition Level 2 – 10.966 GW installed)	No significant development, only existing plants and those under construction during 2010 year will remain by 2050. (10.426 GW installed)
Small hydro-electric plants	No significant development, only existing plants and those under construction during 2010 year will remain by 2050. (Ambition Level 1 – 0.3833 GW installed)	No significant development, only existing plants and those under construction during 2010 year will remain by 2050. (0.3833 installed)
Solar PV	50% of total roof space available for solar PV (taking into account solar thermal panels) on residential and public buildings is used. (Ambition Level 3 – 29.9 GW installed)	Existing capacity (no further extension in the future)
Solar Thermal	Area covered with solar thermal panels for the production of residential hot water requirements: gradual increase up to an average of 3m² per household in 2050. (Ambition Level 3)	Existing capacity (no further extension in the future)
Nuclear power	The only nuclear power plant in South East Europe region is Krško in Slovenia with net electrical power of 696 MW. It's connected to the grid supplying power to consumers in Slovenia and Croatia (350 MW). In this level of ambition it is assumed that Krško will operate until end of its originally planned lifetime in 2023.	Krško will operate until 2043.
Coal-fired power plants	Additional retrofits on existing plants to meet IE Directive are made and stations close when they are 50 years old. No new plants built by 2050. (Ambition Level 3 – 0.51GW installed)	Additional retrofits on existing plants to meet the requirements of the IE Directive are made and stations close when they are 50 years old. New capacities, those planned to be built until 2025, are assumed to be constructed. (6.66 GW installed)

continued –>

Table 1	**EU ROAD**	**ROAD TO NOWHERE**
Imports of electricity	Only if demand exceeds supply electricity consumed in 2050 is from imports.	
Biomass	Locally-sourced biomass use will increase by 20% compared to 2010 based on better management and afforestation. (Ambition level 2)	10% increase from 2010 levels by 2050 (linear growth rate)
Biofuels	3% of national liquid transport fuel consumption addressed with locally produced liquid biomass. (Ambition level 2) *Based on Renewable Energy Directive by 2020, the EU aims to have 10% of the transport fuel of every EU country come from renewable sources such as biofuels.*	
GLOBAL ASSUMPTIONS		
Demographic evolution	By 2050, the SEE population will decrease by ≈10%, from 22.6 million to 20.6 million people. This is due to the projected decline in most countries, especially Croatia and Serbia; Kosovo is the exception with the youngest population in Europe and expected population growth by 5% by 2050. Structure of households will be influenced by a variety of factors. Number of persons per household is assumed at 2.8 on average in the region.	Same demographic evolution assumed for the purpose of scenario exercise and comparison.
Economic growth	Average regional GDP growth of ≈2.5% per year. over the period by 2050. The team has opted for GDP growth assumptions which seem sensible over the long-term, even if they might be lower than pre-economic crisis levels or future growth projections[17].	Same GDP growth assumed for the purpose of scenario exercise and comparison.

continued –>

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[17] In case of SEE 2050 Energy Models, World Bank, IMF and PRIMES GDP projections have all been taken into consideration during the modelling process.

Table 1	**EU ROAD**	**ROAD TO NOWHERE**
DEMAND-SIDE ASSUMPTIONS		
Buildings	Energy consumption of buildings sector decreases by 34% (43 TWh) compared to today's level (2010).	Energy consumption of buildings sector increases by 44% (55 TWh) compared to today's level (2010).
New buildings and retrofit programs	Performance levels in building codes for new buildings and retrofits follow the EPBD[18] and EE policy framework; there is an early action with relatively small time lag compared to EU targets. • All new buildings are nearly zero-energy from 2025: they are well insulated and generate power from rooftop solar panels which is fed back into the grid. • Retrofitting of existing buildings ramps up – starting with significant improvements like wall and loft insulation and super-glazing, but reaching energy cuts of 90% or more from 2030. • Around ¾ of the existing buildings are renovated. This requires a sharp increase in renovation rates, from currently lower than 1% per year towards 2%–2.5% as of 2020. Floor space per person in the region grows moderately by 2050; at the same time, comfort levels improve (85% of space area heated in 2050). People lower their thermostats – to a lower but safe level of warmth. Service sector floor area grows, driven by the growth in Value added for services which is assumed to increase 2.3% annually.	Performance levels in building codes are characterized by slow and shallow improvements: • Heat demand of each new building will decrease to standard of "very low energy" of 30kWh/heated m² by 2030 • Shallow renovation, heat demand of renovated buildings will be reduced by 20%–40% • Less than half of the existing buildings are renovated by 2050, with ≤ 1.5% per year from 2020 Floor space per person in the region grows moderately by 2050; at the same time, comfort levels improve (85% of space area heated in 2050). People increase their thermostats – to a higher level of warmth compared to today. Service sector floor area grows, driven by the growth in Value added for services which is assumed to increase 2.7% annually.

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[18] "Nearly zero-energy" buildings are mandatory according to EPBD (European Performance Building Directive) for all new buildings as of 2021. EPBD Directive 2010/31/EU: "By December 31, 2018, new buildings occupied and owned by public authorities must be nearly zero-energy buildings. By December 31, 2020, all new buildings must be nearly zero-energy buildings".

Table 1	**EU ROAD**	**ROAD TO NOWHERE**
Performance of buildings	**Performance of renovated buildings**	**Performance of renovated buildings**
	Level 3 Deep renovation, heat demand of renovated buildings will decrease to level of 90% savings by 2030	Level 1 Shallow renovation effort, heat demand of renovated buildings will be reduced by 20%-40%
	Performance of new buildings	**Performance of new buildings**
	Level 3 Heat demand of each new building will decrease to standard of “passive house” by 2025	Level 1 Heat demand of each new building will decrease to standard of “very low energy” of 30kWh/heated m² by 2030
	Retrofit rates	**Retrofit rates**
	Level 3 ≥ 2% ≤ 2.5% p.a. from 2020	Level 1 ≤ 1.5 % p.a. from 2020
Heating /cooling technology	Heating based on heat pumps ramps up, with up to 75% of heating coming from heat pumps. Additional heating includes burning biomass, from community scale or CHP systems. There’s no gas, no oil, no coal. Solar thermal will cover almost all of the residential water heating requirements. Behavioral change also plays a role with more efficient use of hot water in dishwashing and hygiene, etc. The number of buildings that effectively use air conditioners will be the same or lower than in 2010 as a result of heat pumps penetration, which can also be used as cooling devices, as well as passive design measures.	Light electrification route, with around one quarter of the total heat demand coming from heat pumps. Major share of heating in all countries of the region is provided by gas and biomass in 2050, from community scale or CHP systems. There’s no oil, no coal in the mix. Air-con based cooling reaches much higher shares of buildings by 2050 compared to today.
Lighting and appliances	The lighting and appliances sector covers diverse areas such as consumer electronics and home computing, cold and wet appliances, and lighting. Most buildings replace their light bulbs with LED and only best performing appliances are adopted.[19] Even though the use of lighting and appliances grows, their energy consumption (incl. cooking) stays comparable to today’s level as a result of improved efficiency, motion-detecting lighting, better automation and control.	Light bulbs will be replaced with CFL and/or LED (higher % of CFL and lower % of LED) by 2030, and the number of light bulbs increases. The use of black and white appliances grows significantly while their efficiency standards improve only slowly and moderately. Energy consumption for lighting and appliances (incl. cooking) increases by 35% compared to today’s level.

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[19] Assumptions on efficiency improvements in electric appliances have been taken from the report EU Energy, transport and GHG emissions trends to 2050. Estimates for 2050 consider best performing appliances currently available on the EU market, sourced from the Top Ten website, *http://www.topten.eu/*

<table>
<tr><th>Table 1</th><th>EU ROAD</th><th>ROAD TO NOWHERE</th></tr>
<tr><td>Transport</td><td>Energy consumption of transport sector decreases by 45% (37 TWh) and emissions decrease by 60% compared to today’s level. The use of diesel or petrol is reduced by 65%.</td><td>Energy consumption of transport sector increases by 47% (38 TWh) compared to today’s level.</td></tr>
<tr><td>Transport demand</td><td>With currently low mobility rates, far below the EU average, distance travelled by person will increase by 90% by 2050 (average, region).
There is an increase in goods movements per person by 65% by road and rail and water overall in the region. There’s a greater use of ICT (Information and Communications Technologies), more efficient routing and fewer kilometers travelled per delivery. Moderate growth in freight transport also implies that we buy less things from shops.
Future GDP growth has been taken to induce an increase in transport demand but there’s also a push and effort to decouple transport demand from GDP growth (role of ICT, urban planning, work patterns, etc.).[20]</td><td>Distance travelled by person will increase by 130% by 2050 (average, region), induced by the economic growth.
There is an increase in total freight transport volume by 100% by road and rail and water overall in the region.
Freight and passenger transport growth rates are induced by GDP growth while decoupling – actions and effort thought to influence future mobility patterns (urban planning, ICT, work patterns, etc.) – remains low.</td></tr>
<tr><td>Transport modal split</td><td>There’s a shift away from car travel, particularly in urban areas. The proportion of passenger kilometers travelled by car falls, but there’s an increase in cycling for short distance journeys and rail travel in medium-long distance journeys.
There’s an increase in car sharing, with 1 in 10 car journeys having an extra person(s) on board.
<table>
<tr><th></th><th>2010</th><th>Level 3</th></tr>
<tr><td>Non-motorized transport (cycling, walking)</td><td>0.5%</td><td>8%</td></tr>
<tr><td>Share of bus pkm in total</td><td>30%</td><td>37%</td></tr>
<tr><td>Share of rail pkm in total</td><td>2.5%</td><td>9%</td></tr>
<tr><td>Share of car pkm in total</td><td>67%</td><td>46%</td></tr>
</table>
There is a shift to rail in freight transport, with around 25% that’s currently going on road shifting to rail.</td><td>Car oriented mobility remains dominant in the region by 2050. The proportion of passenger kilometers travelled by car is 60%, and there’s a slight increase in cycling and rail travel.
Just as today – major share of freight transport will be going on road.</td></tr>
</table>

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[20] Some countries have already seen a trend of delinking suggesting the ways in which trends like urbanization (compact cities vs. sprawling cities), rising fuel costs, environmental consciousness, an aging society and digitalization influence mobility.

Table 1	**EU ROAD**	**ROAD TO NOWHERE**
Transport technology	Following the expected trends in the EU, where the vast majority of the region's cars originate, around 80% of cars will be electric or plug-in hybrids by 2050. Switching from petrol and diesel to electric cars will reduce pollution, especially in cities, but infrastructures must be ready. Electrification of transport will decrease dependence on imported oil. Freight transport poses a challenge; by 2050 it is predominantly fueled by oil and CNG, with a small share of electric trucks. Biofuel use stays on lower levels, until a number of sustainability concerns are overcome to enable biofuel consumption to increase in the future. Fully electric and plug-in hybrid trucks, as well as electric vans, are available already. Given that a large transition to electricity is a key theme following the Paris Agreement, energy used in transport could be diminished and emissions reduced to zero at a faster pace than anticipated in SEE 2050 Carbon Calculator.	The vast majority of the region's vehicles, 80% of cars, will run on oil.
Vehicle efficiency	Ambitious vehicle replacement rates bring the SEE region closer to the EU vehicle efficiency standards. Efficiency for new passenger cars (internal combustion engines – ICE) follow from the EU policy where a target value of 95 g/km of CO_2 for 2020 for the new car fleet is currently in place, with further improvements expected by 2050. Level 3 BUS ICE: 35% efficiency improvements by 2050 CAR ICE: 45% efficiency improvements by 2050	Efficiency of the vehicle fleet in the SEE region will improve but at a very slow pace. Level 1 BUS ICE: 15% efficiency improvements by 2050 CAR ICE: 15% efficiency improvements by 2050

continued –>

Table 1	EU ROAD	ROAD TO NOWHERE
Industry	Energy consumption of industry sector decreases by 37% (25 TWh) compared to today's level.	Energy consumption of industry sector decreases by 19% (13 TWh) compared to today's level.
Industrial output	Industry pathways include bottom-up modelling for energy and emissions intensive industries (steel, cement, aluminum), while other industrial activities (food, textile, etc.) are modelled high level. These industries use massive amounts of energy and need to achieve very high temperatures in their factories to produce their products. The production output (kt) of the heavy industry (steel, aluminum and cement) stabilizes at the current level or decreases moderately by 2050. There's a lot of effort to improve energy intensity. More efficient and less polluting industrial installations are adopted and there is a change in product characteristics (e.g. clinker substitution) and/or fuels used (e.g. shift to electricity).	Same production output (kt) of the heavy industry assumed for the purpose of scenario exercise and comparison. There's a very little or no effort at all to improve energy intensity of heavy industry. Fuel mix remains similar to that of today.

But the benefits are enormous…

The benefits of the EU Road are enormous. Electricity prices in South East Europe are currently less than half the price of the EU average. However, this “social pricing” of electricity generation and transmission is an illusion and comes at a high cost. South East Europe citizens already pay this full cost of an unsustainable electricity system—it just doesn’t show up on the electric bill. These costs include subsidies paid through taxation, loss of income, and opportunities due to corruption.

Social and environmental disasters are already unfolding across the region. Energy poverty remains a problem, where rural populations face low well-being from lacking adequate household heating services or face disproportionate costs for electricity. The latest Energy Community report on energy efficiency[21] highlights that “at least 50% of the population spends more than 10% of their net income on energy.” This falls under a standard definition of fuel poverty. Only ambitious building renovations and low-cost more sustainable renewable electricity supply can tackle real causes of increasing electricity prices and costs incurred through the transmission and distribution system.

There are increasing premature deaths from air pollution – a study by HEAL estimated over 7000 premature deaths per year caused by existing lignite based coal fired power plants in South East Europe[22]. Air pollution poses a significant threat to public health, but can be avoided by pursuing the EU Road. This would save on healthcare costs and improve air quality for breathing and exercise. The continued dependence on lignite coal for power will continue the combustion and release of particulate matter, sulfur dioxide, nitrous oxides, and mercury which reduce quality of life.

Climate change is causing extreme weather related events, affecting the supply and demand of electricity generation and consumption. Extreme floods in Serbia during 2014 caused an estimated €1.7–1.8 billion in damages[23]. Changing river flows and water levels cause problems not only for hydropower plants, but cooling requirements for large lignite thermal plants. Large-scale, centralized projects also pose risks for human resettlement and food shortages due to changing resource availability and climate activities.

Most important to the economy, unemployment rates have persisted throughout South East Europe due to a lack of economic productivity and growth. Foreign direct investment, creditor, and lending agencies have reduced credit ratings for countries across the region[24]. However, we find that there is significant jobs growth potential by promoting energy efficiency targets and distributed renewable energy supply technologies for the electricity sector. Often times, the decentralized nature of distributed energy resources facilitates quicker deployment schedules than large centralized projects and requires more human labor during the installation process. This promotes education and workforce skills training, which is important. The technology and jobs section later compares jobs creation potential for decentralized solar and wind projects with centralized baseload thermal plants. This clean energy transition toward distributed energy can promote jobs and skills training desperately needed in South East Europe and spur economic growth beyond the current paradigm.

The following sections describe each of these concepts and technologies and how existing technology and policies exist in practice for each ambition level advocated in the EU Road. The following section outlines the supply and demand-side technological levers and policy drivers to meet the EU Road or continue on the Road to Nowhere pathway.

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[21] Energy Community. 2015. Tapping On its Energy Efficiency Potential Energy Community Secretariat. *https://www.energy-community.org/portal/page/portal/ENC_HOME/DOCS/3750146/18B2AB6BA84663F2E053C92FA8C064DA.PDF*

[22] *http://env-health.org/IMG/pdf/factsheet_eu_and_western_balkan_en_web.pdf*

[23] Second Report on the Implementation of Social Inclusion and Poverty Reduction Strategy. 2015. *http://socijalnoukljucivanje.gov.rs/wp-content/uploads/2014/11/Second-National-Report-on-Social-Inclusion-and-Poverty-Reduction-final.pdf*

[24] See Appendix for credit ratings for different countries’ sovereign credit ratings.

Supply side information

On the supply side of the equation, our team gathered historical generation data by country for coal, oil, gas, hydro, wind, solar, and biomass. Presently, lignite coal accounts for more than 50% of all generation capacity and the region faces plans to increase the share in the coal-dependent pathway. Further information on the differences between ambition levels is included in the Appendix 1.

Hydro resource availability

The small – and large-hydro resource data were all formulated using figures developed by the SEE SEP Hydropower Working Group. For hydropower, capacity factors were calculated for each country in 2010 and then we assume constant future capacity factors until 2050. Though this may ignore future effects of climate change, this assumption keeps the accounting across countries standardized, as it remains uncertain the extent that water level changes will impact hydropower production.

Onshore wind resource availability

Figure 5 highlights the variation in onshore wind resource availability across the SEE region with stronger resources in the upper altitude areas of Montenegro, Bosnia and Herzegovina, and Croatia.

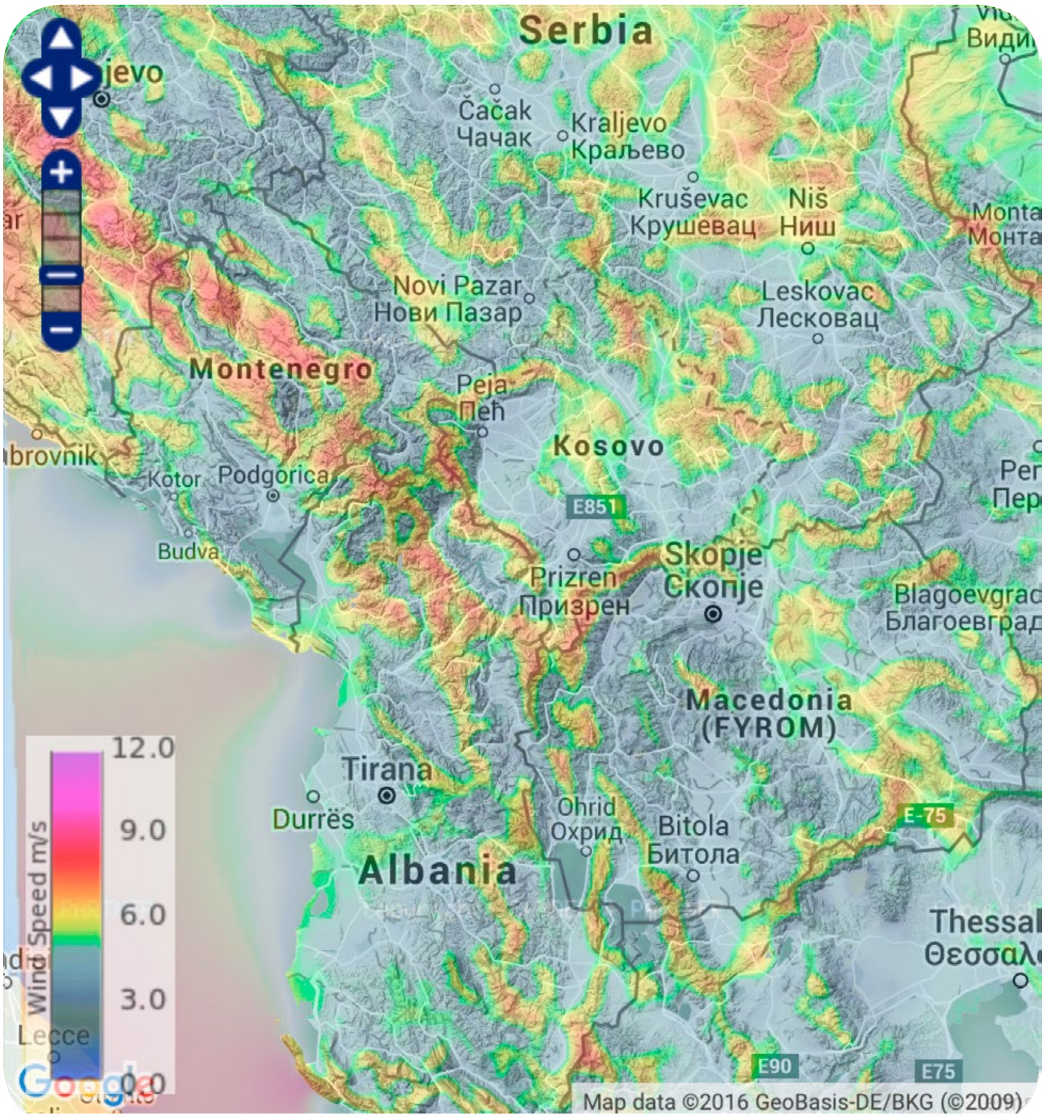

FIGURE 5. Balkan wind atlas from KfW.

Wind resource availability was obtained by the Balkan Wind Atlas commissioned by KfW and summarized in Table 2. The consultancy Sander and Partner also constructed lever settings for this model. It is likely that the wind technical potential used in this model is a lower-bound on regional wind potential because we have excluded production from sites in areas where topographic altitude is above 1800 meters, areas where the slope of the topography exceeds 20%, wooded lands, and areas within 900 meters of villages, all which could increase the available wind resource if included.

Country	Average capacity factor in 2010 (%)	Average capacity factor in 2050 (%)	Technical potential (GW)
Albania	25	35	2.55
Bosnia and Herzegovina	31	39	7.55
Croatia	31	33	4.97
Kosovo	25	33	1.55
Macedonia	28	33	1.25
Montenegro	32	37	0.72
Serbia	30	39	10.36

TABLE 2. Progress in capacity factors for wind by country to 2050.

Solar resource

FIGURE 6. Solar resource for South East Europe developed by the European Commission.
For further information on solar data—please see http://re.jrc.ec.europa.eu/pvgis/cmaps/eur.htm

Figure 6 details the solar resource across South East Europe. We observe a strong regional solar resource, notably as one moves further South. Compared to other regions in Germany and Western Europe where the solar resource is smaller and there is on average cloudier weather, the SEE resource is less variable throughout the year and more stable. There is seasonal discrepancy in solar resource between summer and winter months, and our model accounts for such variation. Inputs on solar potential are derived from the Belgium model developed by Climact[25]. The technical potential assessment used spatial information on total available roofspace for solar development (including potential sites that would support solar thermal) on residential and public buildings. Then, we used solar irradiation data developed by Suri et al. 2007 and Huld et al 2012 for South East Europe.[26] Therefore, the area of available land for solar is constrained by roofspace.

Biomass resource

Baseline biomass resource data came from Energy Community reports, notably the "Study on the Biomass Consumption for Energy Purposes in the Energy Community." All biomass resources available within the model must come from domestic production and we assume no imports of biomass resource.

Cost projections of electricity supply options

The levelized cost of electricity (LCOE) for intermittent renewables has rapidly declined alongside supply shortages for gas in the region. Therefore, new investments in solar, wind, and also biomass are now beginning to become cost competitive. Future investments in coal will require bulky sums of capital during construction and operation. The ability to rapidly purchase and deploy distributed renewable resources takes advantage of existing resource availability and the critical nature of addressing energy supply shortages due to the regional plague of energy poverty. Table 3 details the range of capital expenditure costs over time for the different technologies explored in the SEE 2050 Carbon Calculator. The costs change over time and are reported estimates from regional experts detailed in the Appendix.

Technology	CAPEX 2010	CAPEX 2015	CAPEX 2020	CAPEX 2025	CAPEX 2030	CAPEX 2035	CAPEX 2040	CAPEX 2045	CAPEX 2050
Coal (low-high)	1600–2300	1600–2300	1600–2300	1600–2300	1600–2300	1600–2300	1600–2300	1600–2300	1600–2300
Gas	700–800	688–738	674–723	664–712	654–701	640–686	626–672	612–657	599–642
Onshore wind	1300–1550	1200–1400	1140–1330	1313–1125	1110–1295	1107–1292	1104–1288	1092–1274	1080–1260
Large hydro	1270–3320	1270–3320	1270–3320	1270–3320	1270–3320	1270–3320	1270–3320	1270–3320	1270–3320
Small hydro	1270–5000	1270–5000	1270–5000	1270–5000	1270–5000	1270–5000	1270–5000	1270–5000	1270–5000
Solar PV	1000–1200	869–1127	669–868	474–614	278–361	261–338	243–316	222–287	200–259

TABLE 3. Range of capital expenditure cost for different technologies in South East Europe until 2050 in €/kW

The capital expenditure figures used in the model show a sensitivity across a range of potential future prices. The assumptions are summarized in the appendices based on critical analyses in South East Europe. Operations and Maintenance (O & M) costs used in the model are detailed online in the Call for Evidence report[27].

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[25] *http://climactv2.voxteneo.net/pathways/20111101111100111110110111101121212121212141412121013111110011011 10f1011111101001/emissions*

[26] Šúri M., Huld T.A., Dunlop E.D. Ossenbrink H.A., 2007. Potential of solar electricity generation in the European Union member states and candidate countries. Solar Energy, 81, 1295–1305, *http://re.jrc.ec.europa.eu/pvgis/*.
Huld T., Müller R., Gambardella A., 2012. A new solar radiation database for estimating PV performance in Europe and Africa. Solar Energy, 86, 1803–1815.

[27] *http://seechangenetwork.org/south-east-europe-2050-energy-model-conclusions-on-the-call-for-evidence-process/*

Table 4 reports the range of LCOE prices compared across the EU and further information on the assumptions for weighted average cost of capital (WACC) and credit sovereignty ratings are located in Appendix 2.

	LCOE Range (EUR/MWh) 2015 European Union	LCOE Range (EUR/MWh) 2015 South East Europe
Coal (lignite)	50 – 100	80–100
CCGT	70 – 90	80–100
Wind	50 – 100*	60–70
Hydro (large scale)	25 – 100	60–150
Solar	90 – 200	80–105

TABLE 4. Range of LCOE prices for EU and SEE used for validation and input in energy model.
** Highly dependent on local wind speeds*

Electricity prices are heavily regulated across South East Europe. With the liberalization of electricity markets within the region and unbundling of state-owned transmission and distribution enterprises, the price of electricity will increase. However, this may not alone incentivize demand for renewables or investments in energy efficiency in absence of good policy and appropriate incentives. The true costs of energy are not quantified in the current scheme. Short-sightedness in planning will result in extreme consequences for public health and the environment, without considering the implications of rate structures, market designs, and hidden subsidies for fossil-fuel based generation. In terms of capacity expansion, the switch to a lower marginal-cost, renewables based electricity sector changes the policy and financial environment, while inspiring new and innovative approaches. Overall, investments for new electricity supply will be essential to achieve EU Road targets of 80% greenhouse gas emission reductions from 1990 levels by 2050.

Demand-side information

The demand portion of the model aggregates public residential, commercial (service), industrial, and transport consumption information to project energy demand across sectors until 2050. The model also disaggregates demand into sectoral building stock and energy consumption to analyze priority technological and policy interventions. These interventions reflect different levels of ambition with regard to regional policy decisions and technology choices on the EU accession road.

Buildings demand

For example, the model uses a stock-turnover model to explain technological improvement over time until 2050 in energy demand from households. The model assumes different rates of the pre-2010 building stock renovation before 2050, and takes homes to different levels of energy consumption per square meter based on the ambition level, ranging from low energy performance levels for new and renovated buildings to passive-house designed buildings (<15 kWh/m^2) as highlighted by the case in Croatia detailed below in the text. The residential demand can be decreased in the model by several pathways – ranging from insulation, water heating, to passive-house and near-zero building design principles[28].

Insulating households could drastically reshape the demand picture for energy consumption in South East Europe as evidenced through the model. Increasing insulation reduces energy used to heat homes through traditional sources including biomass, but also inefficient resistive loads including electric space heaters that require functional electric distribution systems. Electrifying the household heating sector through the use of heat pumps, could help shift demand to alternative sectors. Secondly, electrifying the transportation sector

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[28] For further information see Conclusions on the Call for Evidence process:
http://seechangenetwork.org/south-east-europe-2050-energy-model-conclusions-on-the-call-for-evidence-process/

could also shift energy demand across sectors, providing a useful way to manage emissions from energy consumption and reduce loads.

A clear example of energy in buildings retrofit occurred in Hungary[29]. These deep "efficiency" retrofits typically utilize prefabricated technology and modular building panels to reduce energy consumption on a square meter basis. A baseline study from Hungary documented average savings from 213 kWh/m^2 in building energy consumption to 39 kWh/m^2. More than just the energy savings from the building retrofit, the Hungary case highlights how seasonal summer and winter comfort can improve through more controllable loads. In the Hungary case, 16 cm polystyrene insulation was installed. A 21–34 cm layer of insulation installed at the roof yielded significant savings on the order of 80% of household energy consumption (TREES, Paris Mines Tech 2016). Critical factors that affected energy consumption in both winter and summer included opening windows, placement of ventilation units, ambient temperature, and use of venetian blinds in residential space. These factors play a large role in the summer as well. This is a trend across many European states, and could transfer easily across Serbia, Bosnia and Herzegovina, and the rest of South East Europe facing seasonal changes in weather for building energy management.

Domestic hot water heating accounts for significant shares of energy use and therefore building retrofits that address water heating through solar thermal technologies would also be able to reduce demand. These technologies remain cost competitive with alternative fossil-based water heating devices and/or electric water heaters.

Nearly zero-energy buildings already exist in most EU member states with notable pilot cases across Europe in Graz, Austria, Sofia, Bulgaria, and Šparna Hiža, Croatia. In Croatia, nearly zero-energy building movement already significantly reduced energy demand in several case studies[30]. In this country, nearly zero-energy buildings have achieved annual energy footprints of less than 15 kWh/m²/year for heating. Key characteristics include the use of 20 cm of stone wool, triple-glazed windows and solar thermal for domestic water heating. Furthermore, the cost-effective nature of this new building construction demonstrated[31] no additional costs compared to baseline residential buildings in Croatia and remained about 912 EUR/m². This cost compares to a baseline residential building and the return on investment is clear, as for the same investment, the owner saves on fuel costs in a low-energy house. For the same upfront investment, the buildings can use less energy. Combining building energy demand reductions with energy supply options — for instance – electrifying household heating through the use of heat pumps could provide significant savings that would drastically improve energy use across South East Europe.

Pulling together a suite of projects to address heightened energy demand in the region will help improve energy efficiency targets and efficiency, and reduce the pressure for electricity supply to provide energy services to South East Europe. In an electricity supply constrained system, demand-side management and improvements become supply-side resources and equally useful in addressing the transition to a low-carbon society and lowering household costs for energy.

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[29] For further information on case study see MINES Paris Tech analysis:
http://direns.mines-paristech.fr/Sites/TREES/Material/TREES_3.2_Dunaujvaros_text_261007.pdf

[30] Multi-family apartment building Šparna hiža, Koprvnica, Croatia
http://www.buildup.eu/en/practices/cases/multi-family-apartment-building-sparna-hiza-koprvnica-croatia

[31] *http://www.buildup.eu/en/news/overview-selected-international-examples-nearly-zero-energy-buildings*

Transportation demand

For regional transportation demand, we used the framework developed by the EU in its Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system[32]. The Roadmap includes concrete initiatives for the next decade to build a competitive transport system as well as dramatically reduce Europe's dependence on imported oil and cut carbon emissions in transport by 60% by 2050. Contributing to a 60% cut in transport emissions by the middle of the century, key goals, among others, include no more conventionally-fuelled cars in cities and a 50% shift of medium distance intercity passenger and freight journeys from road to rail and waterborne transport. We also account for electric vehicle (EV) adoption and the electrification of the transportation sector. Emerging EV manufacturers, including Tesla[33], pose as potential market entrants for electrifying transportation while experiencing significant decreasing costs on a wide scale with the goal of a 30,000 USD model by 2016 for consumers, directly competitive with upper-tier four-passenger automobiles. The model also explores how different levels of improvement in performance and increase of railway traffic, coupled with reduced share of cars, respond to a need to sooner or later meet the EU noise and outdoor air pollution standards and greenhouse gas emission reduction targets, as the region currently suffers from high rates of motorized pollution, congestion and noise.

The projections for demand use sustainable mobility planning outcomes developed through already implemented EU projects to test targets and projections estimated by the model. In the electrification of transportation, as prospective EU member states with an extremely large proportion of our current car stock coming from EU sources, the model assumes that the region will follow the EU electrification trends with perhaps some lag in the early years but steadily increasing as the region is absorbed into the EU.

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[32] Roadmap to a Single European Transport Area – Towards a more competitive and resource efficient transport system. *http://ec.europa.eu/transport/themes/strategies/2011_white_paper_en.htm*

[33] *www.teslamotors.com*

DEVELOPING A SMART GRID

Developing a smart grid remains a critical goal regionally and facilitates a wider transition to renewables as an integral part of the EU Road. New technologies, defined by the advent of the smart grid, improve the monitoring and control of the transmission and distribution systems by linking information networks and nodes. By merging routine grid upgrades with smart grid improvements, South East Europe could emerge as a leader in meeting EU environmental and climate goals. The Smart Grid is an information systems network that uses communication technology through the internet to assist with controls and operations of the electricity grid in real-time.

Supervisory Control and Data Acquisition

Supervisory control and data acquisition services (SCADA) have emerged as technological opportunities for change to improve the efficiency and distribution of electricity within South East Europe. Controllability of loads, data sharing, and advanced metering infrastructure (AMI) can help the transition toward a more efficient electric power system. More importantly, it will also cater to the integration of higher shares of intermittent renewable energy generation, primarily sourced from solar PV, wind, and existing hydropower plants.

Advanced Metering Infrastructure

Advanced Metering Infrastructure (AMI) deployed in Italy and Germany showcase the ability of new technologies to facilitate and integrate demand-response programs with monitoring of residential, commercial, and industrial energy consumption. Montenegro is already piloting a program to deploy smart meters. Albania also plans to follow suit with increased distribution-system level monitoring and smart meter deployment programs. This new technology allows for distribution-level systems planning and operations management previously unattainable. This reduces costs of distributed energy systems and improves ability for utility companies to collect on debts from commercial losses (i.e. Kosovo suffers from about 16% commercial losses due to theft on the system[34]). Better monitoring and management can improve efficiency in existing infrastructure and facilitate EU Road pathway. Given that new distribution equipment will require AMI regardless, due to technological changes, the grid improvements have the potential to leapfrog existing systems that do not provide the same level of services as across the EU.

Transmission interconnectivity

A lack of transmission system interconnectivity hinders regional development and electricity market integration in the Road to Nowhere case. First, expanding the market area for regional transmission trade provides opportunities to leverage excess hydropower supply and use it for grid stability and backup during blackouts. Using excess supply in different areas allows for load balancing and lower electricity prices through market competition.
Most countries in South East Europe, notably Kosovo, Serbia, Bosnia & Herzegovina, and Macedonia experience disproportionately high retail electricity rates for consumers, further pushing low-income groups into poverty due

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[34] ERO, Energy Regulatory Office. 2014 Tariff Rates for Kosovo. ERO Code: V_638_2014, 2014. *http://ero-ks.org/Vendimet/English/2014/V_638_2014_final_eng.pdf*

to high household heating and electric costs. This deters industry from investment. Furthermore, the expansion of the transmission interconnection system provides necessary upgrades while facilitating the global expansion of distributed energy resources as electricity generating options. This includes the potential for concentrating solar power (CSP) in Bosnia & Herzegovina to support existing steel factories which combines parabolic trough mirrors and molten salt-based thermal storage to provide dispatchable, baseload electricity. The modeling effort here highlights that regional cooperation is necessary to achieve a low-carbon transition for EU accession in the EU road. At the same time, a low-carbon transition could actually bring about regional cooperation by facilitating infrastructural upgrades and improvements in neighboring systems. To achieve lower electricity costs overall, transmission interconnectivity that utilizes smarter inverters, high voltage DC transmission cables, and further electronics within grid architecture will be necessary and sensible investments to avoid further costs down the road. The Road to Nowhere pathway does not enable this type of market exchange and system-level load balancing.

Transformer aging

Aging transformers in the region could pose problems. However, the new investments to replace them may be offset by the incorporation of new distributed energy resources on the grid. Including more distributed energy resources within the power supply mix could inject reactive power back into the grid in a positive way that could reduce the need to purchase future load tap changers, voltage regulators, and extra capacitors on the grid for voltage support and frequency regulation.

Smart buildings

Smart buildings have significant potential to aid the integration of renewable electricity into the South East European supply mix, while simultaneously providing enhanced monitoring on the demand side. The technological capacity for new buildings to include smart sensors and monitors provide better information for grid operators to forecast load. Also, smart buildings can self-generate electricity using distributed electricity resource generation including rooftop photovoltaics and/or backup on-site storage. Secondly, they can manage loads and electrify the heating sector with the use of heat pumps. Smart buildings already appear across Europe, and when government and public institutions take the initiative to invest in these technologies, it can spur adoption across the private sector and enable new partnerships. The advent of smart building infrastructure calls for enhanced demand management, better information for system-wide energy demands, and environmental data including building temperature, insulation, and required heating energy per unit area. Critical to South East Europe's deployment of sustainable energy options is the inclusion of smart buildings as a way to manage loads on the demand-side and transition the grid architecture to more distributed networks that improve system reliability and performance.

Feed-in tariffs as a policy option

Feed-in tariffs (FIT) share a history of success and failure across Europe, however key to their success remains design implementation. As a policy tool, feed-in tariffs will be critical to enable the EU Road and necessary for the 100% renewables case to deploy rapid decarbonization schemes. Taking the case of Italy, it becomes clear that through feed-in tariff type subsidies, the transition to lower-carbon electricity generators becomes much quicker and enables a smoother transition that can encourage technological learning across economies of scale, as demonstrated in the Figure 7. The rapid uptake of solar PV installations within Italy between 2010–2011 is illustrated by the feed-in tariff design policy. This could serve as an example for rapid rates of adoption and growth in the similar resource rich areas of South East Europe. Italy did exhibit a reduction in initial ambition from 23 GW of solar by 2012, due to oversubsidization, however this economic inefficiency is mostly explained by the rapid decline in cost of photovoltaics from a technological point-of-view. Therefore, policy design in South East Europe can learn from Italy to create more dynamic feed-in tariff rates, that benefit the consumer and place less pressure on government subsidies to promote renewable energy. Properly designed FIT schemes should ensure sustainable development and take into account environmental impacts of proposed projects through environmental impact assessments. For example, hydropower plants located in protected areas should not be eligible to receive public feed-in tariff subsidies, which has posed a problem in the past for South East Europe. On a direct cost basis, we find that solar PV has improved such that it could provide lower-cost and improved reliability in the electricity sector in South East Europe before needing to implement feed-in tariffs. However, due to large coal subsidies[35] in several countries including Kosovo, Bosnia and Herzegovina, and Serbia, it would be useful to take lessons from Italy's rapid solar development sector and apply them in a cautious way in South East Europe. This would broaden technological basis, improve job opportunities, and regional economic growth.

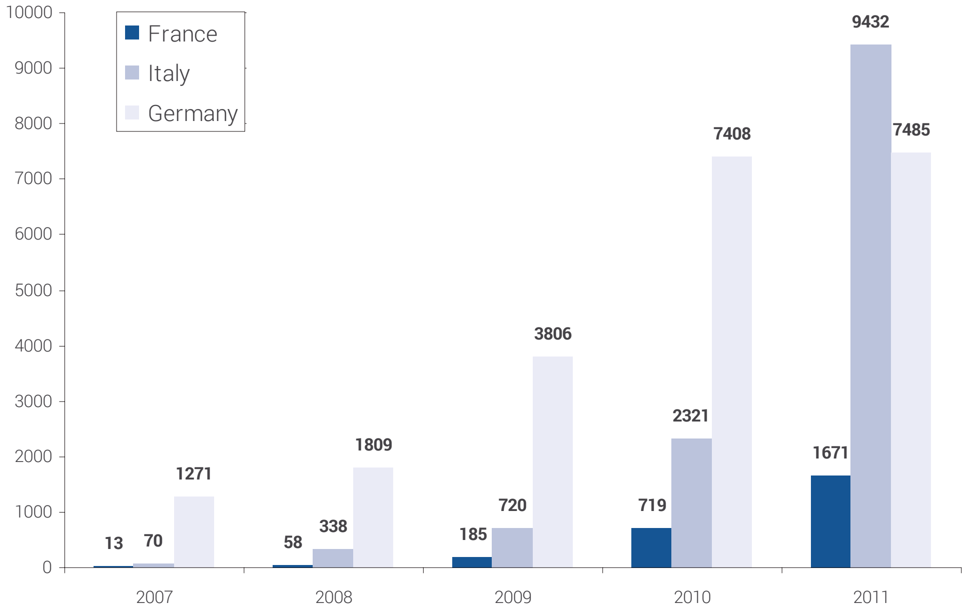

FIGURE 7. European solar PV installations (number) from 2007–2011[36]
Source:

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35 Risks for coal and electricity investments in the Western Balkans, Ukraine and Moldova due to state-aid rules. *http://bankwatch.org/publications/risks-coal-and-electricity-investments-western-balkans-ukraine-and-moldova-due-state-ai*

36 Ameli, N., Kammen, D.M. 2014. Innovations in financing that drive cost parity for long-term electricity sustainability: An assessment of Italy, Europe's fastest growing solar PV market. *Energy for Sustainable Development*, 19, 130–137.

Demand-side management as a supply resource

Enabling future grid infrastructural upgrades, including smart meters could allow for large scale demand response programs for industrial or commercial uses across the region. Currently, there are no reported demand-side management based programs and this could not only reduce peak loads from the overall grid, but could reduce the need for baseload power to deal with the intermittency of solar and wind-based generation. Energy efficiency or load reduction strategies could also reduce peak supply needs. The regional concern surrounding energy supply security would benefit greatly from coordinated system planning. Therefore, strategic investments in demand-side management going forward would greatly reduce the need for future supply-side investments. Given the current supply infrastructure, prioritizing and reducing demand first would ease the integration of variable and intermittent renewables. The increasing variability of supply combined with continued reliance on variable demand means that new technologies to control load or shift demand will greatly assist grid operators when working on infrastructure planning projects.

Building resilient, reliable smart grids

The transition to a smart grid requires investment in system monitoring equipment, infrastructure, and new architectures to deal with increasingly complex systems. Installing smart meters at households and commercial buildings offers greater flexibility in management and can significantly reduce the large reported losses across the region that can be as much as 30% by country, with Albania even at 40% in combined technical and commercial losses[37]. Furthermore, the lack of an integrated trading system for electricity reduces resiliency of the system in the case of emergency disasters. The July 2014 explosion of a generator in Kosovo A lignite plant required a surge in imports to make up for lost electricity that resulted in rolling blackouts across the country. Also, the Kolubara, Kostolac, and Šikulje mines in Serbia and Bosnia and Herzegovina experienced severe damage during the floods in the same year[38]. The flooded mines decreased coal electricity generation and increased the need to import electricity across the region. The weak regional transmission interconnection with Albania could be further improved to take advantage of excess supply and more resilience to avoid cascade effects from poor generation infrastructure. Secondly, since most losses within the electricity sector across South East Europe occur in the distribution system rather than the transmission system, then the upgrade to resilient systems requires advanced metering and improvements in voltage regulators, load tap changers, and capacitor banks all along the distribution system, all which are of considerable age and require new investment. There is no choice in upgrading existing infrastructure across South East Europe, as it has already started to fail, evidenced by frequent electricity outages including brownouts and blackouts. Therefore, if upgrades are inevitable, transition to a digital infrastructure and electronic grid will pay dividends forward as EU accession targets must be met. The inclusion of smart inverters, flexible AC transmission (FACTS) devices, and high voltage DC (HVDC) infrastructure can all enable a smart digital management system. The increased use of electronics within the electric grid improves system performance, reliability, and resiliency, and therefore comprises a key component for future power systems in South East Europe as it looks to comply with the EU environmentally, and in an integrated market context.

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[37] Losses for the transmission and distribution system are available by country in South East Europe from the Energy Community web portal: *https://www.energy-community.org/pls/portal/docs/3356393.PDF*

[38] For further information on the flooding, the following reports detail the damages from the Sikulje and Kostolac mines flooding: *http://tuzlalive.ba/aktuelna-tema-zasto-je-potopljen-rudnik-sikulje/* (in Bosnian), *http://www.balkanmagazin.net/struja/cid189–100744/izgradnja-bloka-b3-u-k…* (in Serbian)

Fix intermittency issues

The lack of grid preparedness remains a common critique of integrating variable wind and solar energy into the South East European grid. However, since substantial investment in the electricity sector will increase in the future due to necessary upgrades, proper investments and measures should ensure the integration of renewables and address issues of intermittency. Voltage excursions on the grid and reverse power flow may become issues due to distributed solar PV, however, in some cases, studies have shown the benefits of deferred investment in capacitor banks and load tap changers[39]. Furthermore, lignite coal-based electricity in several countries, notably Kosovo, Bosnia & Herzegovina and Serbia sometimes are variable despite the purported baseload label of coal fired power plants.

Complete necessary grid upgrades

The grid will need to fundamentally improve in South East Europe to meet any future energy demand. Transitioning to a renewable system will also necessitate or potentially contribute to the improvement of grid devices and performance. The purchase and installation of new transmission interconnections will expand balancing areas and provide opportunities for an open energy market. Market integration across the region remains an obligation under the Energy Community Treaty, and will promote regional coordination that could help countries accede to the EU.

PV as way to address feeder issues

Increased solar PV across the distribution system could also address issues in the feeder system. Distributed solar may necessitate further grid upgrades to accommodate new technologies, however, the grid will need upgrades for any new capacity. Secondly, with the improvement of distribution feeders (especially for countries like Kosovo), the distribution company can improve revenues and also monitor electricity. This would enable future demand response programs or other forms of energy efficiency interventions that could effectively reshape both electricity supply and demand across the region.

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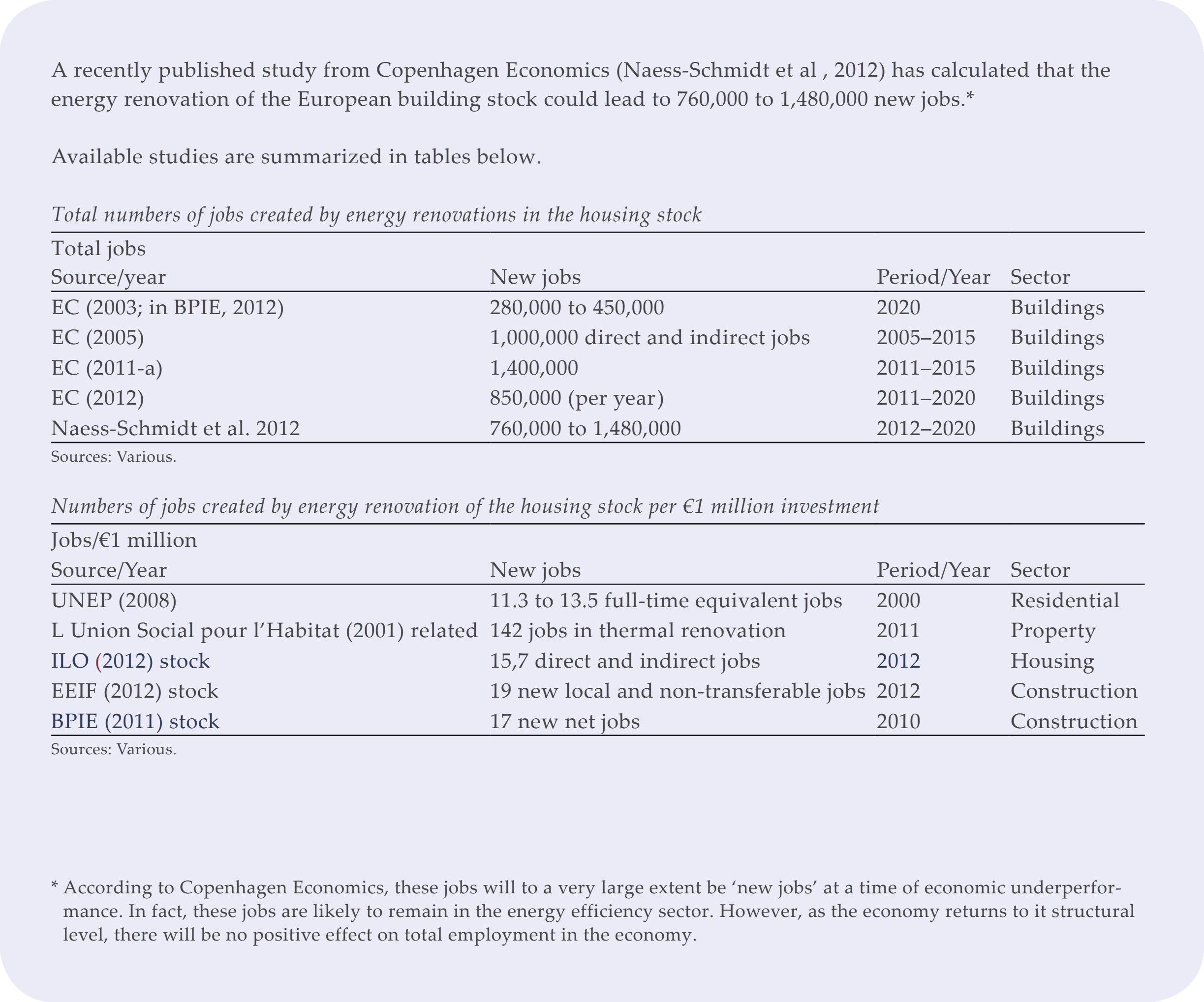
[39] Gil, H. A., & Joos, G. (2006). On the quantification of the network capacity deferral value of distributed generation. *Power Systems, IEEE Transactions on*, *21*(4), 1592–1599.

TECHNOLOGY AND JOBS

Several case studies are already emerging throughout the region taking advantage of new technologies and lessons from around Europe to support an advanced economy and job creation as a pathway to EU accession. For instance, heat pumps installed in public buildings could contribute to a growing trend toward electrifying the household heating sector, one of the largest contributors to primary energy consumption in the region. Expanding the utilization of heat pumps within the region could inspire cross-regional learning and development. This technology significantly reduces costs in the household and commercial heating sectors. Renovating buildings presents a huge potential to create direct new jobs in the construction sector. A study developed by Copenhagen Economics estimated the renovation of the European building stock to promote almost 1,000,000 new jobs summarized in Figure 7. The study suggested due to increased human labor requirement for the insulation and promotion of energy efficiency technologies within buildings, then this could promote skills training and job creation. For South East Europe especially, this remains a critical piece of the economic puzzle and the Road to Nowhere path would maintain little-to-no additional job creation because of the reliance on centralized and highly mechanized lignite plants. Without building renovations and retrofits, the building stock will continue to decay and infrastructural value will decline in economic value.



A recently published study from Copenhagen Economics (Naess-Schmidt et al , 2012) has calculated that the energy renovation of the European building stock could lead to 760,000 to 1,480,000 new jobs.*

Available studies are summarized in tables below.

Total numbers of jobs created by energy renovations in the housing stock

Total jobs Source/year	New jobs	Period/Year	Sector
EC (2003; in BPIE, 2012)	280,000 to 450,000	2020	Buildings
EC (2005)	1,000,000 direct and indirect jobs	2005–2015	Buildings
EC (2011-a)	1,400,000	2011–2015	Buildings
EC (2012)	850,000 (per year)	2011–2020	Buildings
Naess-Schmidt et al. 2012	760,000 to 1,480,000	2012–2020	Buildings

Sources: Various.

Numbers of jobs created by energy renovation of the housing stock per €1 million investment

Jobs/€1 million Source/Year	New jobs	Period/Year	Sector
UNEP (2008)	11.3 to 13.5 full-time equivalent jobs	2000	Residential
L Union Social pour l'Habitat (2001) related	142 jobs in thermal renovation	2011	Property
ILO (2012) stock	15,7 direct and indirect jobs	2012	Housing
EEIF (2012) stock	19 new local and non-transferable jobs	2012	Construction
BPIE (2011) stock	17 new net jobs	2010	Construction

Sources: Various.

* According to Copenhagen Economics, these jobs will to a very large extent be 'new jobs' at a time of economic underperformance. In fact, these jobs are likely to remain in the energy efficiency sector. However, as the economy returns to it structural level, there will be no positive effect on total employment in the economy.

FIGURE 8. Job creation through energy renovation of the building stock.

For further information see Meijer, F., Visscher, H., Nieboer, N., & Kroese, R. (2012) Jobs creation through energy renovation of the housing stock. NEUJOBS Working Document. http://www.iza.org/conference_files/neujobs_2014/4.pdf

Another option to consider for the low-carbon transition in South East Europe includes the utilization of existing sites for concentrating solar power (CSP) development even though not considered in the model. For instance, in Bosnia and Herzegovina, abandoned aluminum facilities already could demarcate the land area necessary for specific CSP projects. By integrating CSP and other large-scale photovoltaic or wind developments with existing or previous industry, and combining with molten salt thermal storage, systems can run on clean energy and use biomass stocks to support seasons when solar or hydropower outputs decline. However, only solar photovoltaic technologies appear in the SEE 2050 Carbon Calculator at this time.

Improving regional grid transmission intra-connections for better load balancing and renewable integration support remains a key feature of expanded investment in grid infrastructure. Geographically, resource sharing makes sense due to inequitable distribution of renewable energy resources across countries. Wei et al. investigated job creation potential from renewable energy and energy efficiency initiatives to calculate average lifetime employment per unit of energy and found that in the US the renewable energy and low carbon sectors generate more jobs per unit energy delivered than fossil fuel-based sectors and solar PV creates the most job growth potential compared to wind, biomass, and geothermal technologies (Wei et al., 2010)[40]. These results would apply in the European context as well because most plants employ a comparative number of people across locations (for instance a typical 300 MW coal unit employs 200–300 people). Solar PV and energy efficiency operations including building retrofits specifically require more distributed labor during installation and transportation of materials. Building energy cooperatives alongside international development projects, joint municipal and state ventures, and private sector initiatives across the region all contribute to job creation and technological development. These cooperative ventures need not only occur across supply side trading, but also in the demand sector, specifically with regard to buildings. The current plans documenting Kosovo, Macedonia, Montenegro and Serbia progress related to nearly zero-energy buildings (NZEBs) is described in the countries' reports on implementation of EPBD from 2013/2014[41]. So far there is however limited use of the possibility to develop targets and plans for increasing the number of NZEBs. The Work Programme of their Energy Efficiency Coordination Group (EECG) for 2015–2016 foresees activities on harmonized development of the NZEB concept and action plans and the promotion of existing EU applications and concepts[42]. The report on NZEB targets, available NZEBs and plans in the next round of the National Energy Efficiency Action Plans (NEEAPs) should be available as of June 2016.

The benefits of integrating energy efficiency opportunities as a critical role in decarbonization of the grid are clear. Figure 9 highlights the potential for efficiency to decrease greenhouse gas emissions while synergizing with electrification efforts and low-carbon fuel substitution. In California's case, energy efficiency programs facilitate significant reductions in energy demand and can simultaneously reduce greenhouse gas emissions intensity of key industries. For instance, in Kosovo, it is estimated that nearly 2000 GWh of energy savings potential could be leveraged toward reducing the need for new coal capacity.

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[40] Wei, M., Patadia, S., & Kammen, D. M. (2010). Putting renewables and energy efficiency to work: How many jobs can the clean energy industry generate in the US?. *Energy Policy*, *38*(2), 919–931.

[41] Energy Efficiency Action Plans. (2015). Energy Community. Available online at: *https://www.energy-community.org/portal/page/portal/ENC_HOME/AREAS_OF_WORK/Instruments/Energy_Efficiency/EEAPs*

[42] For further information see the Task Force Coordination Group Work Programmes at *https://www.energy-community.org/portal/page/portal/ENC_HOME/AREAS_OF_WORK/Instruments/Energy_Efficiency/Task_Force_Coordination_Group/Work_Programmes*

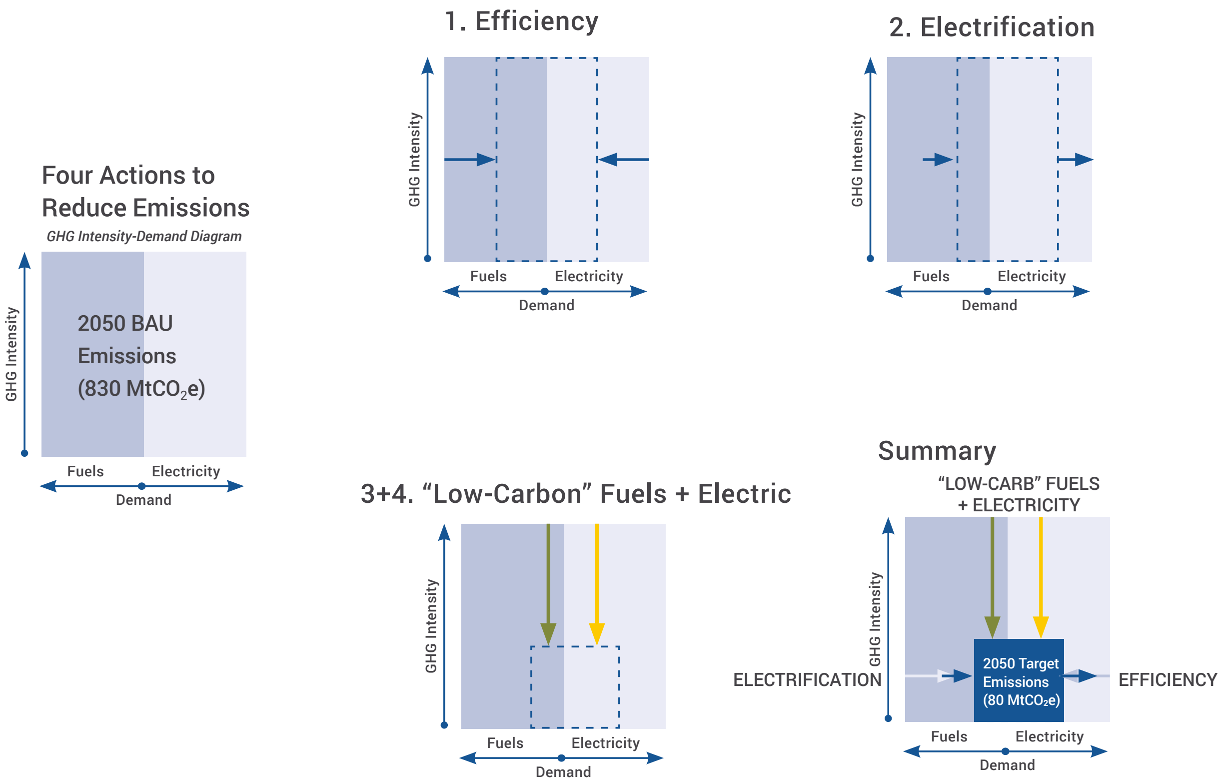


FIGURE 9. Actions to reduce emissions integrating end-use efficiency with electrification efforts in California.

Source: http://ccst.us/publications/2011/2011energy.pdf

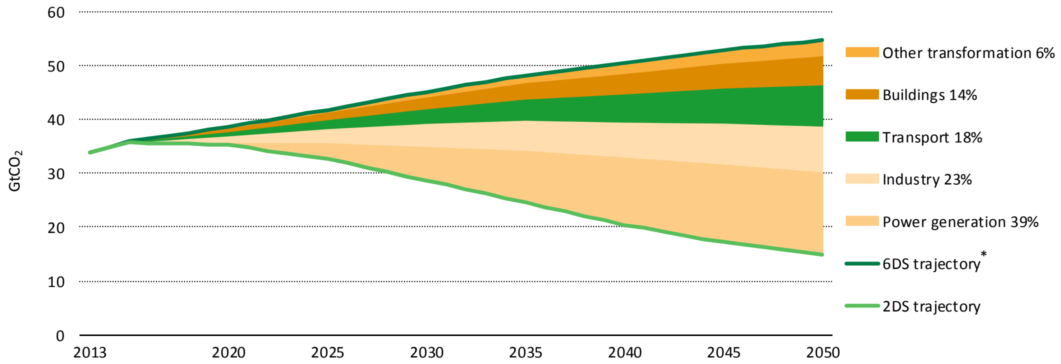
South East Europe can also benefit from significant infrastructural upgrades that will facilitate transitioning toward efficiency and electrification in the transportation sector.

Electrification of the transport sector

Electrification within the transport sector remains a critical piece of the path toward deep decarbonization. Different initiatives underway in Scandinavia already highlight the potential for plug-in hybrid electric vehicles with Oslo a leading city in EV adoption and charging stations. Furthermore, vehicle-to-grid interactions can spur innovation in the distribution system to improve reliability and provide ancillary services. In the European Union, roadmaps are already enabling the electrification of vehicles as regional tools. The expansion of regional power grid networks through the electrification of vehicles has initiated discussion. In South East Europe, electrification of transportation will facilitate emission reductions on the EU road, as the burden of gasoline powered vehicles can switch to utilizing domestic electricity resources. These transitions are being led by countries like Norway, where 50,000 electric vehicles were registered by April 2015. This has been achieved through policy and financial mechanisms that include tax exemptions, prioritized parking allotments, free parking, and the ability to drive in bus or carpool lanes which can be replicated in South East European context. Looking toward 2050, electrification of vehicles will be necessary and a critical step toward meeting the EU Road, and avoiding the Road to Nowhere.

Globally, electric vehicles remain critical to decarbonization goals. Figure 10 illustrates the key role of transport CO_2 reductions in the International Energy Agency's (IEA) "2DS" scenario (2°C Scenario), which describes a future energy system that would limit average global temperature increases to 2°C by 2050. The IEA 2DS indicates that the global transport sector must contribute about one-fifth of the total reduction of GHG emissions from energy use in 2050. Meeting the 2030 target of the IEA 2DS implies that the global stock of electric cars should maintain annual growth rates above 25% by 2025 and in the range of 7% to 10% between 2030 and 2050. Even still, leading scientists suggest that limiting global warming to 2°C could still result in catastrophic events, and 1.5°C remains a stronger target (IPCC, 2014). The Paris Agreement struck in 2015 underscores this notion that countries have agreed globally to contribute to greenhouse gas emission reductions and South East Europe could present the case as a leader, not a laggard, for other transition economies facing the choice of centralized large-scale coal and hydro development versus the more distributed, decentralized path that includes electrification of the transport sector in accordance with decarbonization of the electricity sector. A large transition to electricity is a key theme, and the EU Road demonstrates this ability for South East Europe to lead, following the Paris Agreement.

GHG emissions reductions by sector to 2050 on a 2DS trajectory versus a 6DS trajectory



* The IEA 6°C Scenario (6DS) is largely an extension of current trends and excludes the adoption of transformative policies of the energy system. By 2050, energy use almost doubles (compared with 2010) and total GHG emissions rise even more, leading to an average global temperature rise projected to be at least 6°C in the long term.

Note: $GtCO_2$ = gigatonnes of carbon dioxide.

FIGURE 10. The role of transport in achieving CO_2 reduction goals from the IEA, 2DS scenario.

Source: IEA, Global EV outlook 2016, Beyond one million electric cars. http://www.iea.org/publications/freepublications/publication/Global_EV_Outlook_2016.pdf

Heat pumps

Heat pumps are important to electrify space heating in residences and commercial buildings across South East Europe. Existing projects in Sweden exhibit the transformative properties of heating electrification, as they lead Europe with hundreds of thousands of installed heat pump units[43]. On a per capita basis, Sweden leads European nations for electrification of household heating and has jumpstarted the economy with an annual turnover of 700–800 million euros[44]. Transferring the learning and experience from developing over 30 TWh of installed heat pump generation in Sweden to South East Europe would address many of the issues during wintertime and displace the heavy reliance on biomass fuels in households. This could offer health and environmental benefits within households in addition to cost savings. Therefore, electric heat pumps could serve as an example technological approach to electrification of household heating, which is established globally as a transition necessary to achieve decarbonization goals.

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43 Ground source heat pumps in Greece and Turkey have also been exploited on a pilot and demonstration scales for district heating, for instance at the National Technical University of Athens. Sanner, B., Karytsas, C., Mendrinos, D., & Rybach, L. (2003). Current status of ground source heat pumps and underground thermal energy storage in Europe. *Geothermics*, *32*(4), 579–588.

44 Swedish Heat Pump Industry. *http://cleantechfunding.org/2014/03/26/the-evolution-of-the-swedish-heat-pump-industry-an-efficient-use-of-development-resources/*

Flexibility as a response to intermittence

One key feature of the EU Road is the flexibility provided by renewable electricity compared to the Road to Nowhere. The expansion of electricity markets through regional integration facilitates a greater deal of intermittency from variable renewable generators like solar and wind. Intermittency is often considered a problem by grid operators. In reality, intermittency brings upon a new opportunity to promote technological innovation. The technological advancements by dealing with an intermittent grid actually provide smaller-scale, rapidly deployable systems that can be more resilient in the face of natural disaster or during supply shortages. Building solar based systems combined with integrated demand management and a variety of technological options within the electricity portfolio offers greater flexibility to meet power demand at any given time. Diversifying the electricity sector provides needed flexibility for times of over – and under-generation. Linking of markets for instance between Albania and Kosovo could yield the opportunity to balance loads with surplus sustainable hydropower and reduce reliance on lignite generation from the strained Kosovar grid. As in the case of Germany, the regionalization of the grid, especially looking toward the EU, helps expand opportunities for power trading which can improve system reliability and directly lowers cost. This intermittency in South East Europe could promote regional integration and power trade. Smaller-scale, distributed minigrid type systems coupled with solar, wind, biomass, and small-scale sustainable hydropower generators would provide more diversified and flexible systems adapted to a variety of situations faced by the South East Europe power sector, including supply shortage and climate change.

Additionally, intermittent solar and wind have the flexibility to respond to demand more easily than the ramping constraints of a thermal generator. Therefore, demand response programs and increased automation and power electronics within the physical grid that will occur as a result of smart meter upgrades regardless of the pathway are more easily integrated into the entire system. This flexibility changes the dispatch order of traditional plants and reduces the need for conventional "baseload" generators. Therefore, the solar and wind can combine with sustainable small-hydro and biomass to provide cleaner, more dispatchable electricity without concern. The addition of pumped hydro storage to the system would also allow for fast ramping backup plants rather than the must-run lignite thermal plants common in Kosovo, Montenegro, and Serbia for example. The pumped hydro storage could be converted from existing hydropower facilities and accommodate the need for fast-ramping backup support to stopgap intermittent solar and wind on a seconds-to-minutes timescale. The model does not include any additionally built pumped hydro storage, but assumes that as technologies mature there will be some of cost-effective storage technology to address solar and wind integration and improve system flexibility.

The Case of California—Experiencing Renewable Integration

California is an important global leader for integrating intermittent renewable energy on the grid and transitioning from a highly centralized system to a system inclusive of smaller, distributed power producers. Within California specifically, concerns were initially raised with the prospect of achieving greater than 20% penetration of solar and wind during the day. The "duck" chart in Figure 11 represents the changing conditions of the net load due to intermittent solar generators requiring a ramping risk for thermal power plants. Because demand for electricity does not always coincide directly with solar availability during the middle of the afternoon, there is a risk that too much solar disappearing in the evening could strain the system. However, this need for solar and ramping systems has elucidated a series of innovative technical and policy solutions to address the problem in advance.

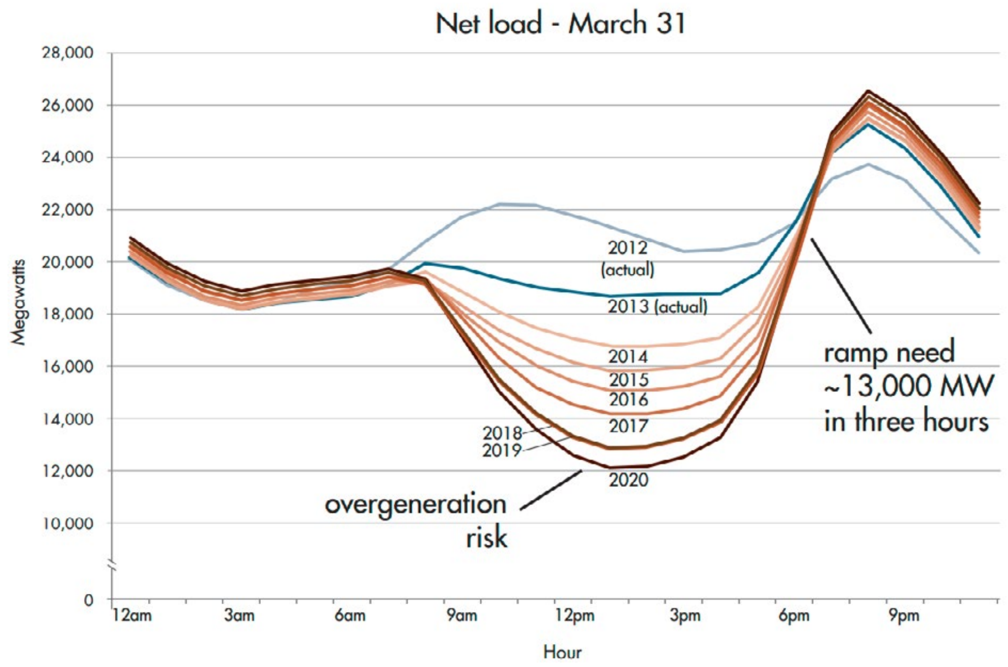

FIGURE 11. Potential ramp requirements from overgeneration of solar PV in California due to changing times of generation and peak load in evening times when sun does not shine

Source: http://content.caiso.com/green/renewrpt/20150722_DailyRenewablesWatch.pdf

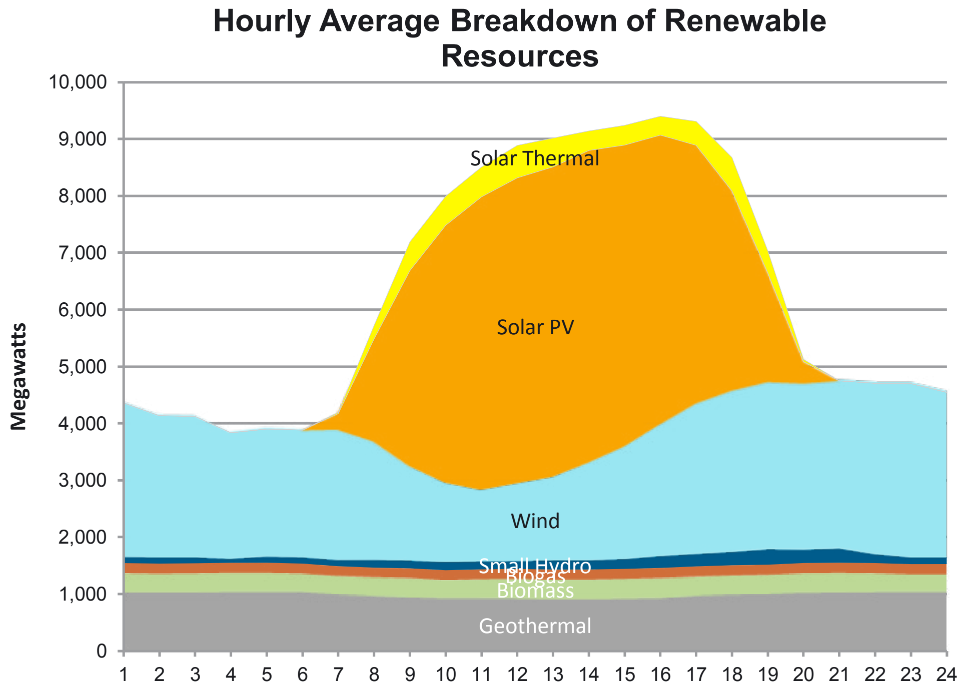

FIGURE 12. The experience of California dealing with significant mid-day expansion of solar PV generation from California Independent System Operator

Source: von Meier, Alexandra (2006) Electric Power Systems: A Conceptual Introduction (Wiley-IEEE, New York)

Figure 12 highlights California's experience with intermittent renewables, where policy targets of 33% renewable generation by 2020 and 50% by 2030 are rapidly being met. The figure above details hourly averages of renewable resources on July 22, 2015 exposing the significant expansion of solar PV generation during mid-day. Traditional grid operators balk at the notion of not being able to turn on and off solar PV electricity. However, in California's case, as evidenced through the duck curve, much of the solar PV reduces need for gas generation during the day, and innovations in demand response and energy storage alleviate ramping constraints. The result is a more resilient system that does not rely heavily on one single centralized source of generation, but a growing network of diversified, distributed options.

Germany and Denmark

Germany and Denmark have also dealt with increased penetrations of solar and wind based generation in the European context, respectively. In 2013, Germany actually hit a 59% peak load met through intermittent renewables. In total, the incoming solar radiation within South East Europe greatly exceeds that of Germany, making solar an attractive option especially in southern states like Albania, Macedonia, and Kosovo. The case of wind generation in Denmark speaks volumes for South East Europe as the country transitions into a more integrated energy market. In September 2015, when wind generation exceeded 100% of Denmark's demand for one day and generation peaked at 140%, the transmission interconnections set up between neighboring countries facilitated a great export of excess wind electricity across Western Europe and prices went negative[45]. The strong wind fields in Croatia and Serbia would be poised to build excess wind generating capacity for power export to supply constrained countries for instance, Kosovo and Albania. In other parts of Croatia and Serbia, they could benefit from imports and two-way exchange. This would facilitate lowered costs across the entire system. In addition, regional interconnections provide greater flexibility to manage loads and conduct load following exercises. Supply risk becomes lessened with the expansion of interconnections to balance renewables. Feasibly, stronger interconnections across with Austria could feed into the rest of the European Union and enable high penetrations of renewables, and certainly meet the targets laid forth by the EU Road pathway. However, as is the case elsewhere, a business-as-usual approach will not be able to meet the flexibility needs of a 21st century power grid.

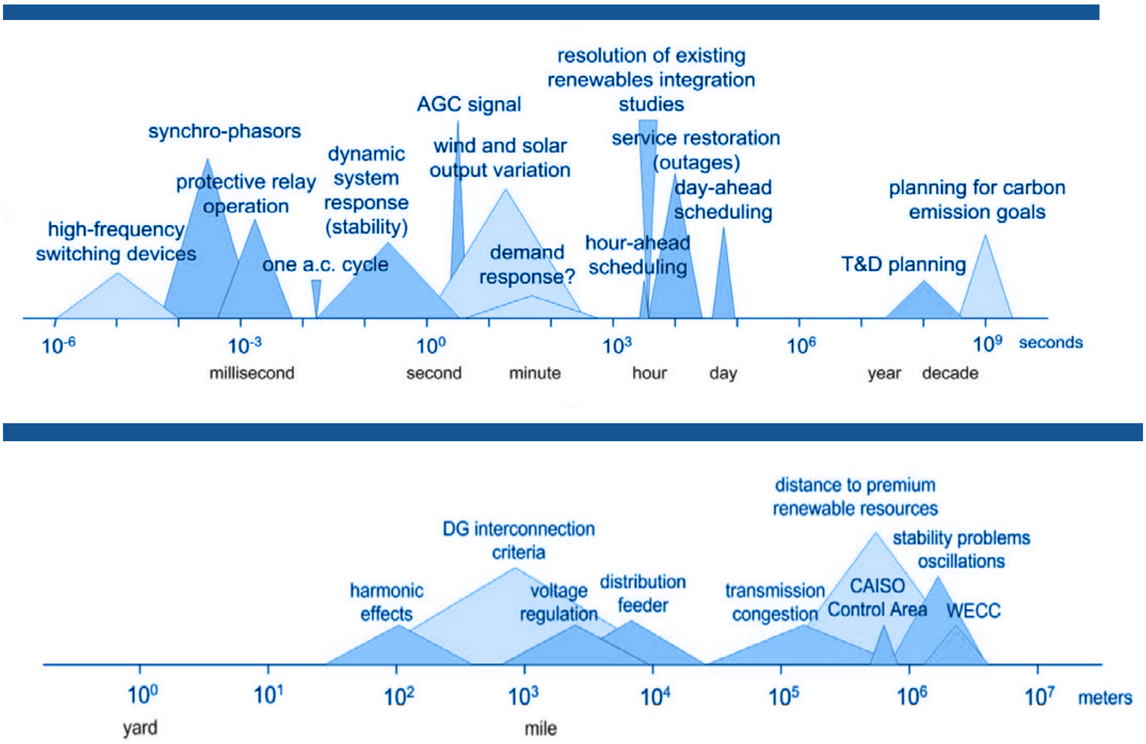

FIGURE 13. Timing and scale of different planning systems necessary to plan for flexibility and a changing grid.
Source:

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[45] Europe's storms send power prices plummeting to negative. 9 January 2014. Reuters *http://www.reuters.com/article/us-europe-power-prices-idUSBREA080S120140109*

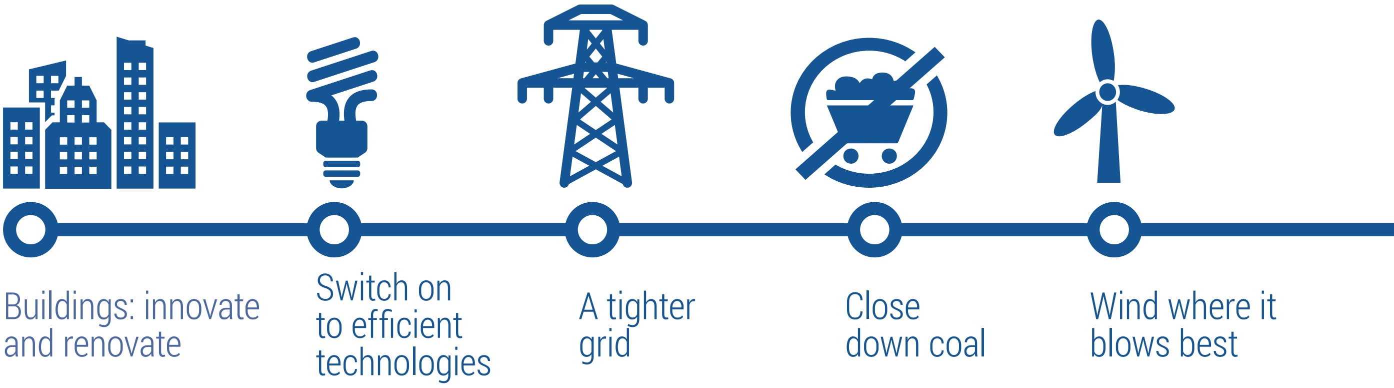
Furthermore, the transition to a modern grid, that remains flexible and resilient requires coordination along multiple time scales. Figure 13 explains the technologies and coordination efforts necessary to facilitate distributed renewables. The planning for new types of energy systems occurs across jurisdictional levels, time scales, and technologies. The policies developed in California and elsewhere help inform the technical aspects of integrating renewables to encourage a low-carbon transition. In South East Europe, for instance, investment in distribution system upgrades will significantly augment efforts in replacing decommissioned coal capacity with solar and wind. The experience in California, highlights the possibilities, not only technically, but as an economic center where renewables simultaneously stimulate job creation and technical training. Within South East Europe, an opportunity emerges to enhance cross-cultural exchange of scientific and engineering information and implement technologies that increase grid efficiency while mitigating the problems of intermittency from solar PV and wind.

Regional Examples

Across South East Europe, we are already observing a grand choice between the Road to Nowhere and EU Road pathways. The results of the model can be illustrated with several highlights from countries within the region to meet decarbonization and reliability targets. For instance, Albania's energy sector is remarkably low-carbon, however the system relies on hydropower for electricity generation. There are significant opportunities in the future to expand solar photovoltaic generation through an abundant resource. Additionally, Albania would serve the region well as an electricity trading hub to countries including Bosnia and Herzegovina and Kosovo. The potential for regionally transmitted pumped hydropower storage, to provide reservoir and dispatchable services, akin to Switzerland's role in the EU power mix, albeit on a much smaller scale, would greatly benefit regional cooperation and lower overall cost of electricity. Serbia and Bosnia and Herzegovina are second to Kosovo in terms of electricity generation from lignite coal. There are more efficient and more cost-effective energy pathways, however, and future investments in lignite coal for Serbia and Bosnia and Herzegovina are not necessary. The Road to Nowhere pathway would support the extension of large-scale coal projects. Moving along the EU Road pathway would require a significant shift in thinking by utilizing effective policies to promote distributed energy resources and a transition from locking in to large centralized projects. Future proposed lignite-based coal fired power plants in Bosnia and Herzegovina and Serbia would not comply with EU climate targets, and furthermore would detract from the solar PV, wind, sustainable hydropower, and biomass opportunities in the region. The energy sector in Macedonia faces grand challenges to comply with EU policies or goals. The EU Road case requires at least 72% reduction in greenhouse gas emissions from 1990 levels by 2050. However, through our model, the EU Road shows that Macedonia's energy consumption could greatly improve through efficiency improvements in the heating and cooling sectors. Trading regionally would also benefit neighboring states to complement networks in Kosovo, Serbia, and Albania and build a fully decarbonized electricity system. The vast solar resource in Macedonia complements supply shortages in neighboring countries like Albania and Kosovo, while could generate up to 50% of supply needs from solar PV by 2050 at similar cost of other options as estimated by the 2050 SEE SEP energy model. The different pathways exist and may not seem easy at first, however, the regional examples highlight paths to decarbonization and the ability to implement EU requirements, bringing countries further along the path toward accession.

There are ten priority steps found in the model to meet the EU Road and avoid the Road to Nowhere pathway that remain critical for success. They include the following steps:

THE EU ROAD



1. BUILDINGS: INNOVATE AND RENOVATE

All new buildings are near-zero energy from 2025: they are well insulated, use highly efficient heating, cooling and lighting, and generate power from rooftop solar panels which is fed back into the grid. Retrofitting of existing buildings ramps up – starting with significant improvements like wall and loft insulation and super-glazing, but reaching energy cuts of 90% or more after 2030.

2. SWITCH ON TO EFFICIENT TECHNOLOGIES

Everyone switches to efficient fluorescent bulbs and, increasingly, LED lighting by 2030 – part of a general shift to energy-efficient technology. Improvements in efficiency of household appliances means higher standards of living don't increase electricity consumption.

3. A TIGHTER GRID

Improvements to infrastructure, management and law enforcement mean less electricity is lost in the transmission and distribution network. By 2030, transmission and distribution losses are cut from the regional average of 22%[46] to 10% – the standard currently set by Croatia, which has the lowest distribution losses in the region[47].

4. CLOSE DOWN COAL

Most of the region's coal power plants are reaching the end of their life. Retrofits are made on existing plants so they meet the EU Industrial Emissions Directive, and all plants close once they are 50 years old[48]. A total of 39 units are closed by 2050, and no new plants built[49].

5. WIND WHERE IT BLOWS BEST

There's a large but managed expansion of wind power, focused only on the best locations – outside protected areas – where the largest proportion of power can be generated. More than 5,000 wind turbines of 2.5 MW each are installed by 2050.

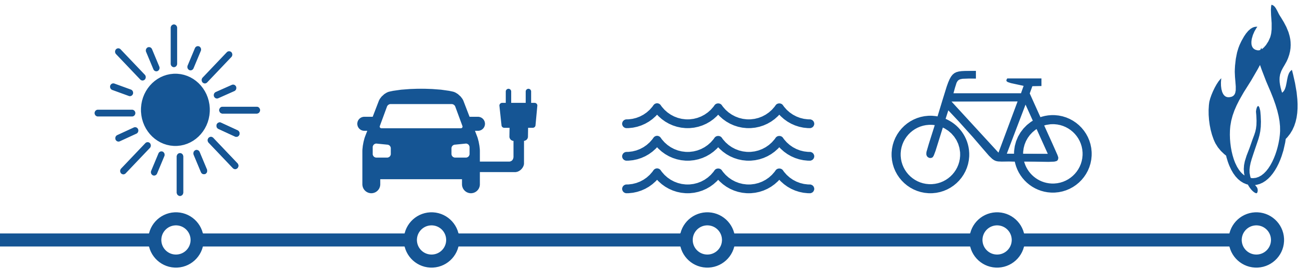
[46] Regional average (excluding Croatia) for year 2014, according to Energy Community Annual Implementation Report, 2015; *www.energy-community.org/portal/page/portal/ENC_HOME/DOCS/3872267/23B450386A075E64E053C92FA8C0F69F.PDF*

[47] Distribution and transmission losses in Croatia in 2014, Croatian energy regulatory agency (HERA), 2014 annual report: *www.hera.hr/hr/docs/HERA_izvjesce_2014.pdf* p.35-36

[48] This is 10 more years than usual plant lifetimes; with the increasingly poor economics of coal, they may not all be kept in operation this long. However, the reality in the region is that many plants are already more than 40 years old: closing coal plants at 40 would mean that 90% of units would need to be closed between 2018 and 2023.

[49] Stanari in Bosnia and Herzegovina, which is currently under test operation, runs for its full foreseen lifetime.

10 milestones on the road to a fairer, cleaner, sustainable and more efficient energy system in South East Europe



Sunny roofs

A drive toward electric vehicles

Hydro: a steady flow

Different modes of transport

Grow biomass responsibly

6. SUNNY ROOFS

Solar panels are installed on half of all suitable rooftops. Total output in 2050: 50 TWh, a little more than the 47 TWh generated by coal in the region in 2010. Total cost: between €5.97 billion and €7.75 billion. Added to this, 3m^2 of solar thermal installations per household help to meet hot-water demand.

7. A DRIVE TOWARD ELECTRIC VEHICLES

Electric cars become the norm, reducing emissions and dependence on predominantly imported oil. Following expected trends in the EU, where the vast majority of the region's cars originate, 80% of cars will be electric or plug-in hybrids by 2050. Cars in the region also catch up with continually improving EU efficiency standards.

8. HYDRO: A STEADY FLOW

Existing plants and those that were under construction in 2010 remain in operation. Proposed plants go ahead provided they are not in protected areas or river stretches of outstanding quality, and are built following sustainable hydropower development guidelines.

9. DIFFERENT MODES OF TRANSPORT

There's a shift away from car travel, particularly in urban areas. The proportion of passenger kilometres travelled by car falls by at least 30% compared to a 2010 baseline, but there's an increase in cycling, and rail travel returns to the level it enjoyed before 1990. While investment is needed into public transport, cycle networks and urban planning, by 2050 capital costs and fuel costs are lower than if car travel continues to increase.

10. GROW BIOMASS RESPONSIBLY

The use of solid biomass – mainly for domestic heating – increases by 20%, and wood stoves are made cleaner and more efficient. Biomass use is based on efficient, sustainable forest management and reforestation, and none of the wood is imported.

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DATA

Historical trends

Historically, the Balkan region has relied primarily on lignite and hard coal for electricity generation. This is supplemented with some gas reserves in Serbia and Croatia, however, on the whole the coal resource stocks have supplied electric generators for decades. The problem, however, remains the reliance on coal-fired power plants — from an emissions perspective and fly ash waste. Secondly, the centralized-paradigm grid desperately needs upgrades to accommodate any new generation. Advances in smart grid technology – including SCADA systems (Supervisory Control and Data Acquisition), FACTS (flexible AC transmission system) devices, smart inverters, and basic supplies in the electric distribution system could transform the ability to manage and operate the unmonitored grids in SE Europe and facilitate a clean transition to renewables. Thus far, we have not seen governments or electric utilities sufficiently investing in the necessary power electronics for a modern electricity grid. Yet these investments would propel South East Europe toward economic recovery and a sustainable and reliable electric grid.

Data collection process

For each country we collected baseline data (year 2010) through expert elicitation within the region by convening a stakeholder network of 17 expert civil society, and public interest organizations. They all remained input providers to the project and scenarios to ensure robustness.

Limitations

This model only addresses supply and demand-side investments in electricity generation, transmission, distribution, household heating, cooking, and energy use, and does not model power flow simulations on an hourly basis. It is an annual generation model. Costs have their own pre-defined trajectories by 2050. They can be used only to compare overall energy system costs across pathways. However, the model provides significant insight into investment and variable costs over time as well as a quantitative framework for comparing the different pathways across the region and in different countries.

RESULTS

Here are the pathways pictured for South East Europe until 2050. Scenarios included are the coal-dependent and the EU Road (which complies with EU climate and energy targets) for direct generation, emissions, and cost comparison.

Figures 14–25 detail the results of the SEE 2050 Carbon Calculator for the coal-dependent and EU Road pathways. Figures 14–19 represent the coal-dependent pathway and Figures 20–25 represent the EU Road. These set of figures output the results of the model from 2010 to 2050 including energy demand by sector, primary energy supply by source, greenhouse gas emissions by source, electricity demand by sector, electricity production by source, emissions from electricity, and energy system costs by sector. These figures provide the basis for comparison of each pathway, and when used in the online calculator tool provide an open source way to explore different energy transition pathways and their effects on greenhouse gas emissions and energy system costs.

Source: SEE 2050 Carbon Calculator (www.see2050carboncalculator)

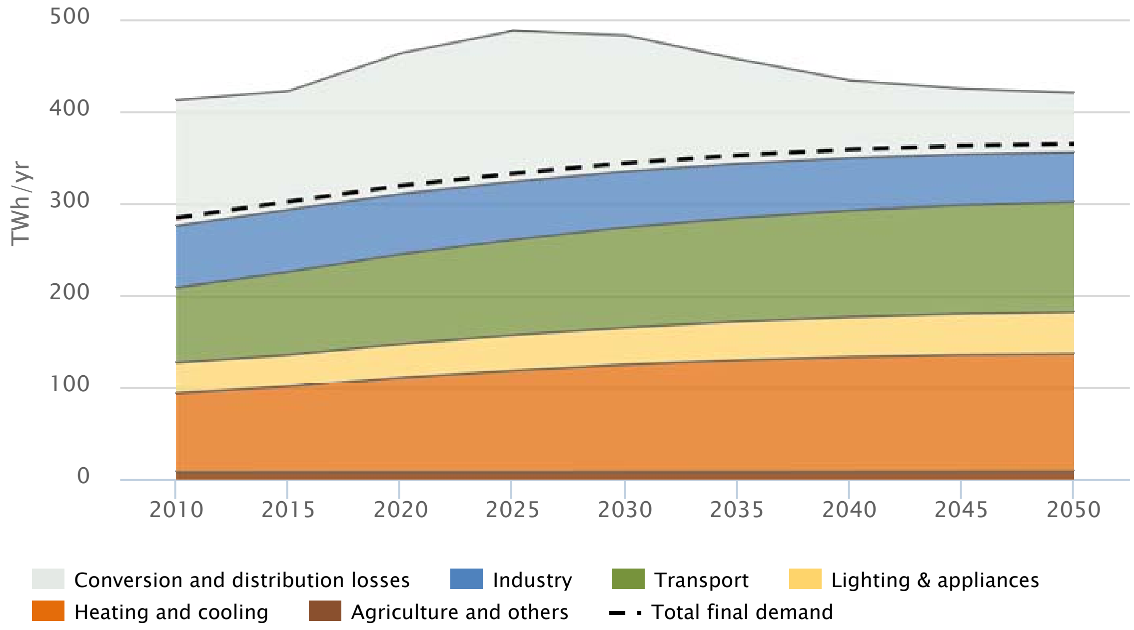

FIGURE 14. Final energy demand by sector for coal-dependent pathway from 2010 to 2050.

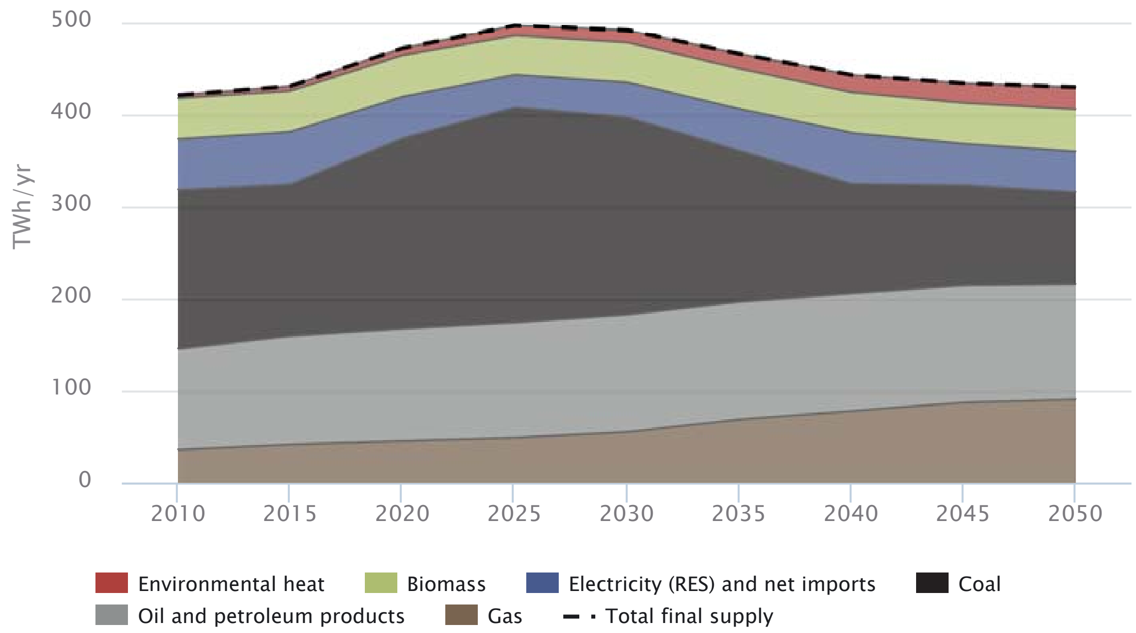

FIGURE 15. Primary energy supply by source for coal-dependent pathway from 2010 to 2050.

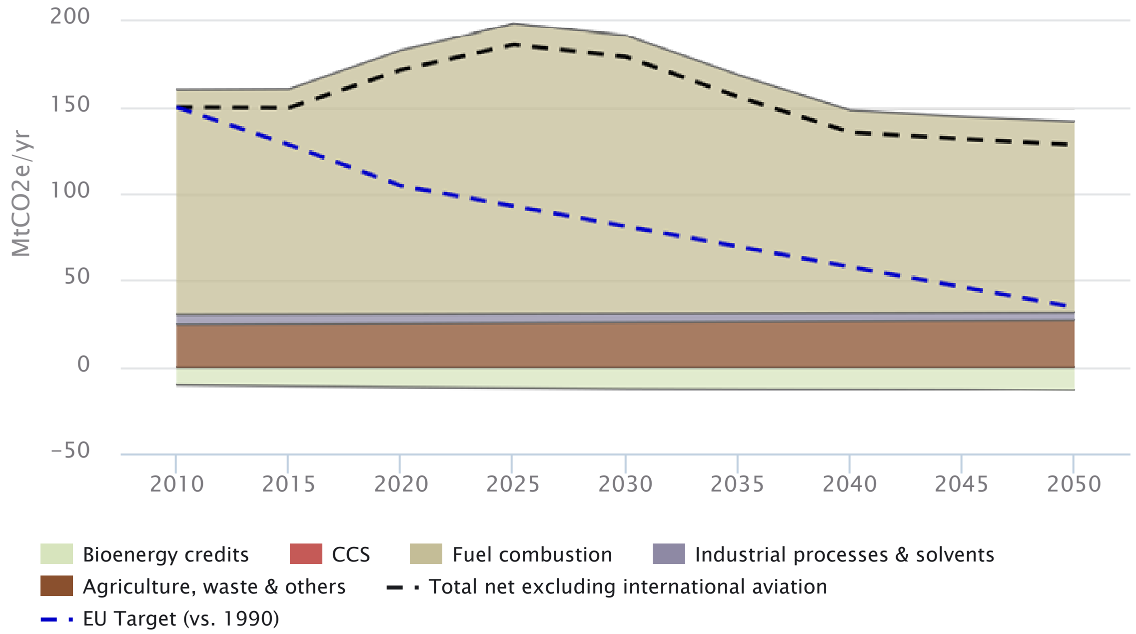

FIGURE 16. Greenhouse gas emissions by source for coal-dependent pathway from 2010 to 2050.

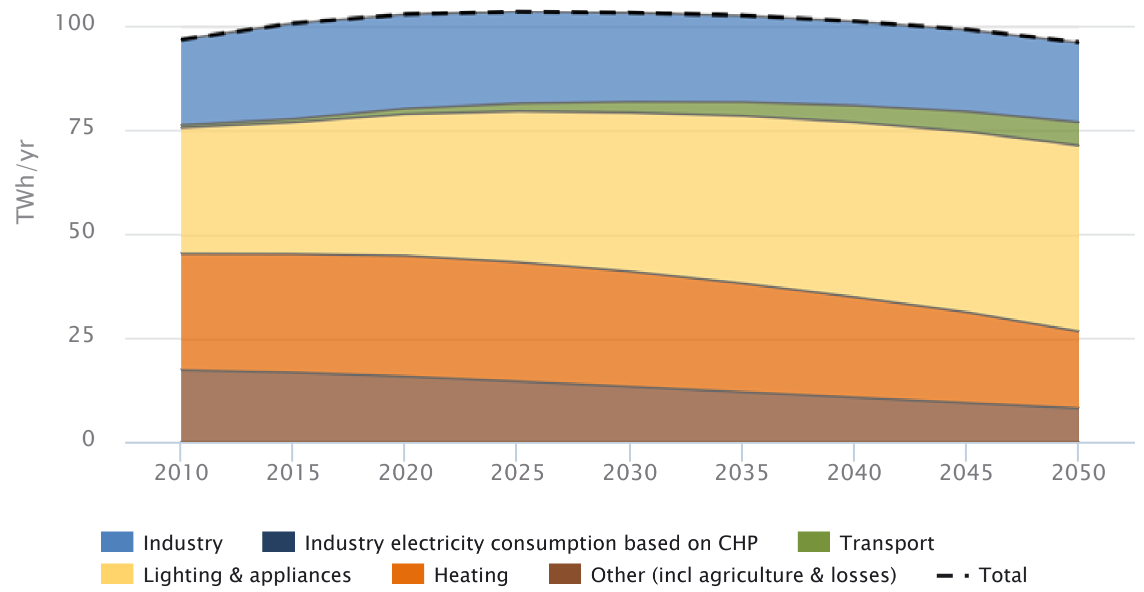

FIGURE 17. Electricity demand by sector for coal-dependent pathway from 2010 to 2050.

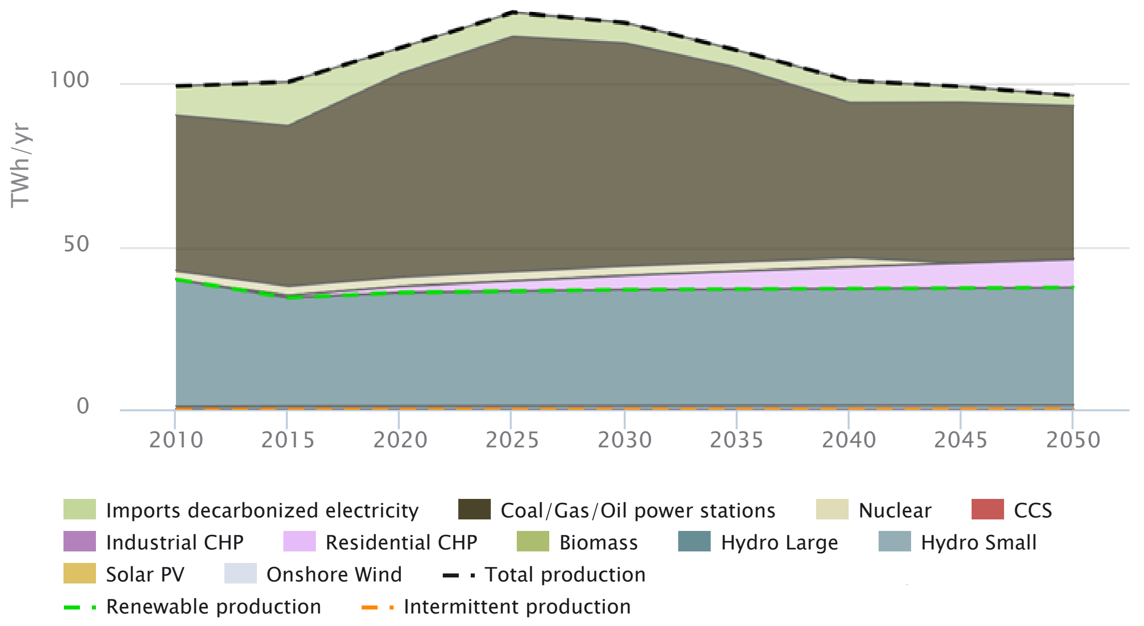

FIGURE 18. Electricity supply by source for coal-dependent pathway from 2010 to 2050.

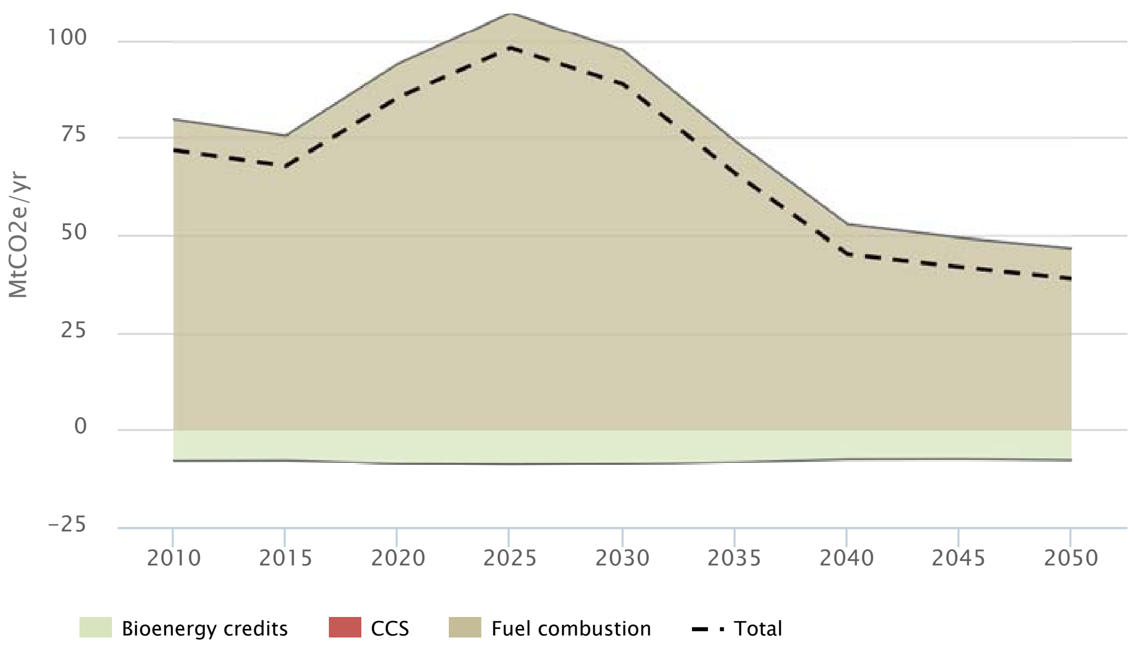

FIGURE 19. Emissions from electricity for coal-dependent pathway from 2010 to 2050.

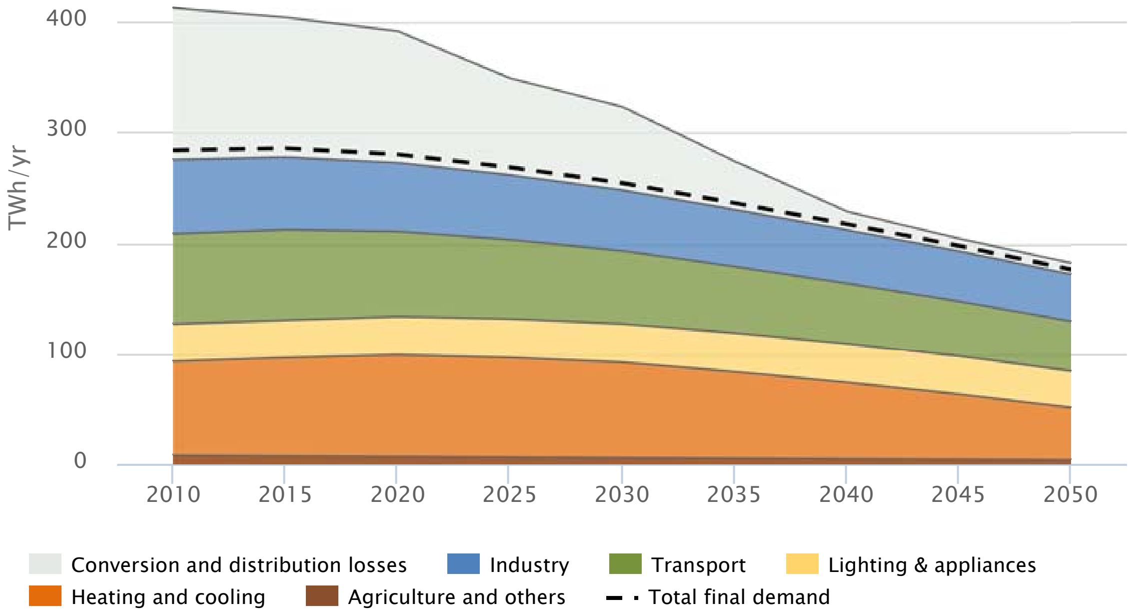

FIGURE 20. Final energy demand by sector for EU Road pathway from 2010 to 2050.

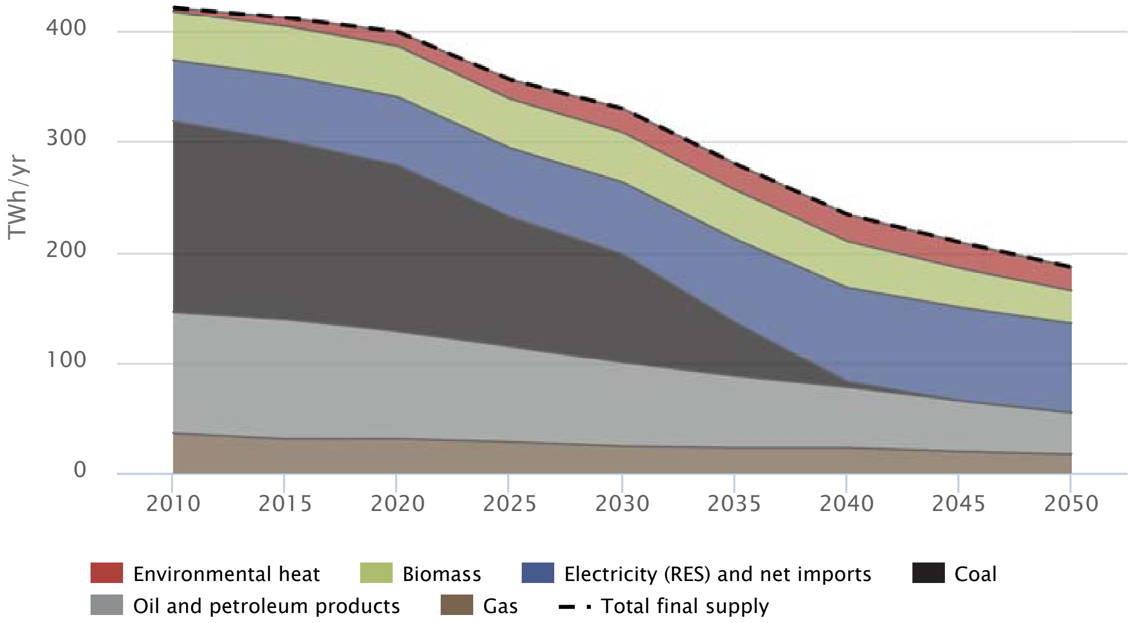

FIGURE 21. Primary energy supply by source EU Road pathway from 2010 to 2050.

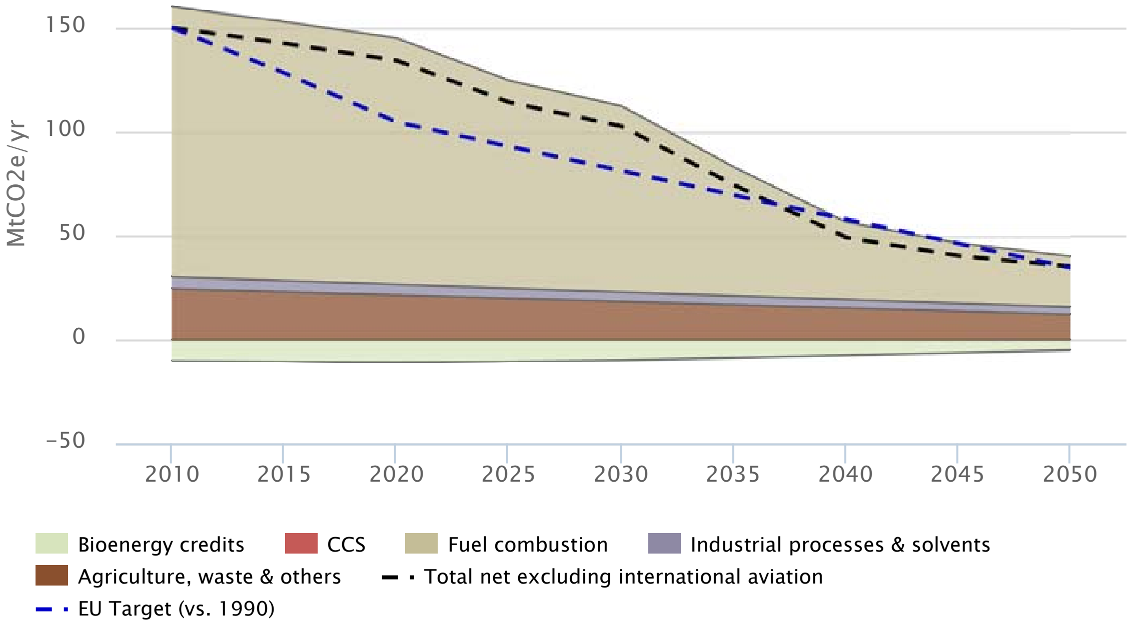

FIGURE 22. Greenhouse gas emissions by source for EU Road pathway from 2010 to 2050.

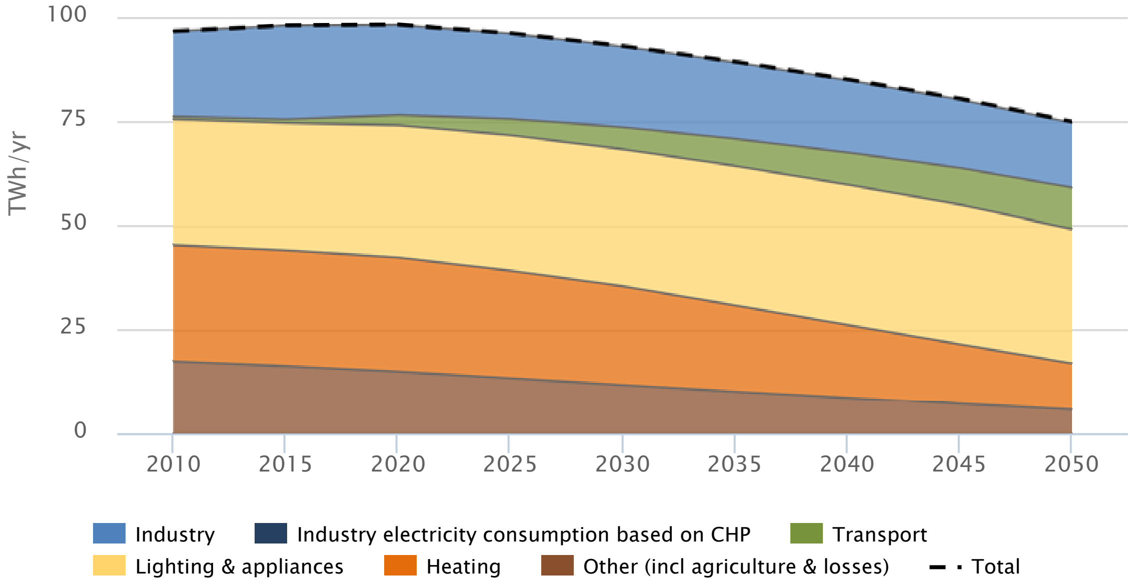

FIGURE 23. Electricity demand by sector for EU Road pathway from 2010 to 2050.

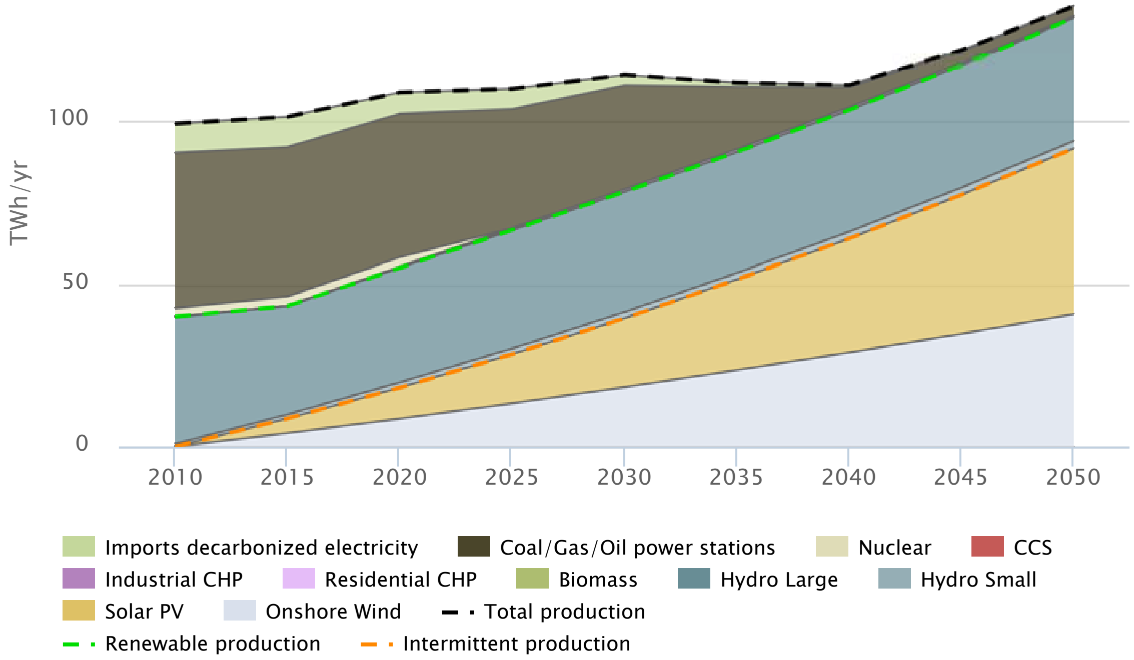

FIGURE 24. Electricity supply by source for EU Road pathway from 2010 to 2050.

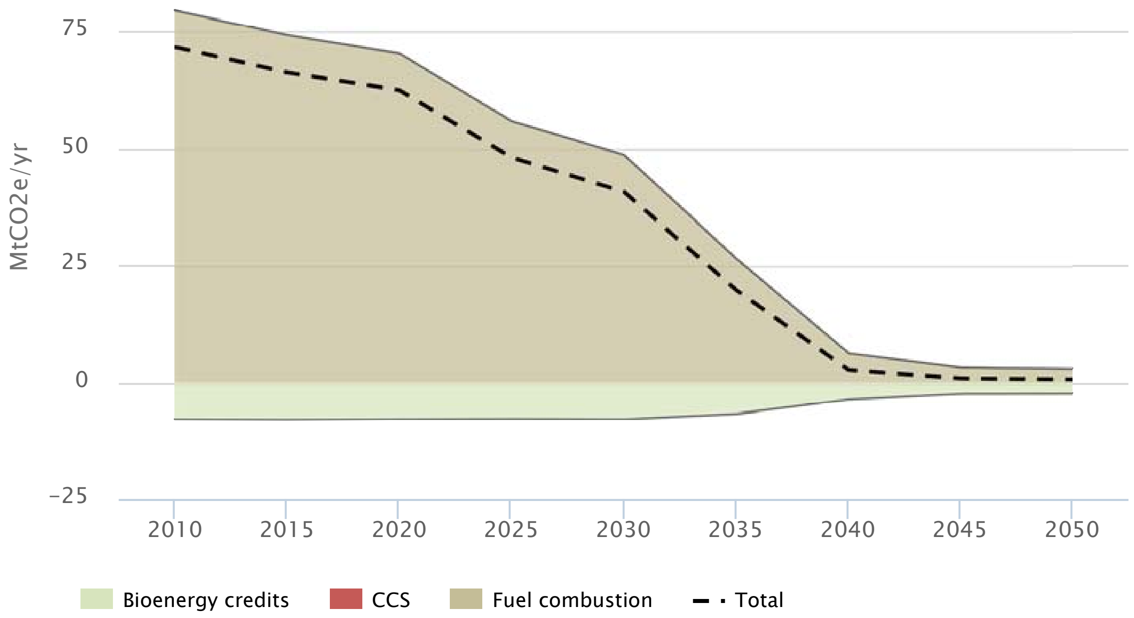

FIGURE 25. Emissions from electricity for EU Road pathway from 2010 to 2050.

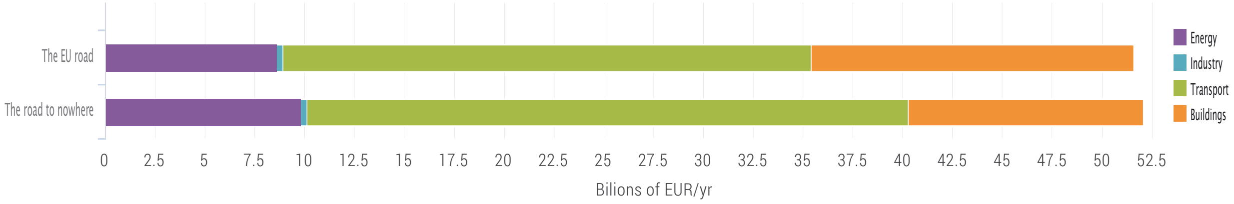

FIGURE 26. Energy system costs by sector for the EU Road and coal-dependent pathway from 2010 to 2050.

Figure 26 depicts the costs necessary to follow the EU Road compared to the Road to Nowhere. We find directly competitive costs with the coal-dependent path. The EU Road is approximately 49.9 billion EUR/year on average over a 35 year period or approximately 2300 EUR/person/year. This compares to the coal-dependent "Road to Nowhere" scenario that costs approximately 51.4 billion EUR/year on average or 2380 EUR/person/year. Cost estimates are expressed as undiscounted real Billion EUR/year between 2010–2050 for energy system costs including capital expenditures, operating expenditures, and fuel costs. This is not a view of the energy bill or societal costs and it is not a full cost-benefit analysis. Externalities such as avoided environmental impacts are not included. We do note that there is a stark reduction in greenhouse gas emissions in the EU Road. For instance, the coal-dependent pathway reduces GHG emissions to 75% of 1990 levels, representing a 25% reduction. However, the EU Road meets the EU goal of 80% reduction in GHG emissions from 1990 levels. It remains clear that the EU Road could be directly competitive or about 1.5 billion EUR less per year compared to the Road to Nowhere in infrastructural capital, operating, maintenance, and fuel costs. This is before considering public health or the environment. Also, primary energy supply and demand are easily met in both scenarios without compromising safety or security in system functioning.

DISCUSSION

The pathways presented across the region can be contextualized within global and European trends highlighting the declining cost of renewable energy, the ability for energy efficiency and renewable measures to bring jobs to scale at a rapid pace, and the feasibility of integration by using new network architectures that can make South East Europe become leaders, not laggards in the production of energy and deployment of technological infrastructure. Policies and global-scale technological innovation will pave the way forward across the EU Road and coal-dependent pathways. However, the choice will remain which levers for change to prioritize, including feed-in tariff policies, technological flexibility and improvement through the introduction of new resources.

The main finding from the different pathways within the South East Europe energy sector is that renewables can compete directly with fossil fuel based options for electricity and energy supply on a pure cost basis before considering environmental or health externalities through the EU Road. This is true across a number of cases, notably Serbia, Kosovo, Montenegro, Bosnia and Herzegovina, Macedonia, Croatia, and Albania where the Road to Nowhere leads to increased coal production along with political, health, and environmental problems. Furthermore, renewable energy expands the diversity of electricity supply and removes previous constraints on fossil fuel reserves in the region. The future adoption of more advanced digital technologies including the transition to a smart grid would greatly facilitate the adoption of wind and solar by grid operators within the region. A coordinated regional transmission network and market integration could also provide the necessary interconnections to improve transmission system wide efficiency and lower levelized cost of renewable electricity. The environmental and health costs of the options are not considered in this study, though should not be ignored, as lignite coal constitutes a majority of coal consumed within South East Europe and has negative health effects on air quality, including the presence of mercury and sulfur in particulate emissions, and presents challenges for fly ash removal. The renewable options presented here would facilitate necessary grid upgrades that require investment regardless, as much of the infrastructure in South East Europe dates beyond 1970 for electric generation, transmission, and distribution. Distributed PV could even defer certain upgrades to voltage regulators, load tap changers, and capacitor banks by providing voltage support and some frequency regulation on the grid in combination with energy storage. The cost of complying with EU climate and energy targets is comparable to the Road to Nowhere, but the stakes remain high. The EU Road provides the opportunity for EU accession, tackling energy poverty through lowered service costs, decreased levels of hazardous air pollution, increased comfort through household heating and increased electric services, including critical political and economic stability. This would improve overall energy system reliability and resiliency at a comparable cost to new centralized coal and large hydropower plants.

This analysis highlights the multiple pathways that remain feasible and range of options that could provide more reliable and resilient energy in both the supply and demand sectors compared to the Road to Nowhere case. The implications of the findings will impact plans for EU accession and form a regionally-collaborative integrated energy market that will leverages excess supply and demand volumes. This expands the load balancing area within the region and lowers total electric grid system costs. Secondly, it shows that dealing with emissions from the energy sector will not accrue much cost, especially when considering the cost of business-as-usual investments. Therefore, South East Europe could become a future trendsetting region when joining the EU and could provide an influx of jobs and economic growth in a region facing dismal employment prospects and current stagnancy in the economy and society. In terms of total costs, the EU Road is around €53 billion less costly than the coal-dependent case over the course of 35 years. This is roughly equivalent to annual costs and it furthermore provides necessary social and environmental safeguards and protection. The EU Road clearly provides a path toward accession and meeting the EU GHG emission targets of an 80% reduction of 1990 levels by 2050, which enables South East Europe to become a climate leader, not laggard across the world.

CONCLUSION

The options detailed here evaluate the emissions, energy supply and demand, electricity generation, and cost of implementation for South East Europe as a region across the main pathways. The development of clean energy infrastructure therefore is a political choice, not a technical obstacle. This remains clear throughout the EU Road path. Decarbonizing energy and addressing global climate change in South East Europe would bring the region global attention as a leader and primary example for other economies in transition. The outdated infrastructure and the need to invest regionally may actually provide opportunities for the individual countries to leapfrog the coal-rich past and establish stronger economies based on renewable energy including solar and wind electricity. The regional approach allows for greater storage opportunities and market efficiency that would enable a resilient network. South East Europe has the chance to highlight one example of a region where distributed energy resources could replace large-scale centralized projects at a comparable cost.

First, we find a large potential savings by moving toward renewables in the electricity supply on a direct cost basis in the EU Road scenario compared to the coal-based path. Second, we find that energy efficiency or demand-side management measures offer significant opportunities for reducing unnecessary energy demand in the region given the vast resource lost through transmission and distribution systems. Third, by following this path, South East Europe could become energy leaders as individual states accede to the EU, rather than laggards, putting them at a climate advantage rather than disadvantage following the 2015 Paris Agreement. Lastly, these benefits all accrue before considering the external costs of air pollution or public health of developing future coal-investments in the electricity and industrial sectors. The coal-dependent path is a road to nowhere, and the EU Road presents a feasible opportunity to enable a cleaner, fairer, and more efficient power system through emphasized regional coordination and technological innovation within South East Europe by 2050.

APPENDICES

Appendix 1.

Summary of Ambition Level Description

Scenario	Coal Assumptions	Large Hydro assumptions	Small hydro	Wind	Solar PV	Biomass
Level 1 – All coal, business-as-usual	Additional retrofits on existing plants to meet the requirements of the IE Directive are made and stations close when they are 50 years old. New capacities, those planned to be built until 2025, are assumed to be constructed	No significant development, only existing plants and those under construction during 2010 year will remain by 2050	No significant development, only existing and under construction plants in baseline 2010 year will remain in 2050	Existing plants (no further extension of wind power in the future)	Existing plants (no further extension in the future)	10% increase from 2010 levels by 2050 (linear growth rate)
Level 2 – No retrofits	No additional retrofits made on existing plants and they close by the end of their lifetime. But new capacities, those planned to be built until 2020, are assumed to be constructed	Existing plants, plants that are under construction during the baseline year 2010 and proposed plants that are not in protected areas as well as proposed or discussed plants on river stretches considered of outstanding importance installed by 2050	33% of technically feasible potential installed by 2050	The “monetary” view: only best locations, with highest capacity factors	20% of maximum technical potential	20% increase from 2010 levels by 2050 (linear growth rate)

Scenario	Coal Assumptions	Large Hydro assumptions	Small hydro	Wind	Solar PV	Biomass
Level 3 – Stations close at 50 years of life	Additional retrofits on existing plants to meet the requirements of the IE Directive are made and stations close when they are 50 years old. No new plants built by 2050.	Existing plants, plants that are under construction during the baseline year 2010 and proposed or discussed plants that are not in protected areas installed by 2050	66% of technically feasible potential installed by 2050	The "save the climate" view: best locations and a few other locations that are less financially viable	50% of maximum technical potential	25% increase from 2010 levels by 2050 (linear growth rate)
Level 4 – Stations close at 40 years of life	Additional retrofits on existing plants to meet the requirements of the IE Directive are made and stations close when they are 40 years old. No new plants built by 2050.	Technical potential that can really be implemented installed by 2050	100% of technically feasible potential installed by 2050	100% of technically feasible potential installed by 2050 Productive areas exclude areas where topographic altitude is above 1800 m, areas where slope of topography is >20%, wooded areas, inhabited areas with a 900m buffer	70% of technical feasible potential	30% increase from 2010 levels by 2050 (linear growth rate)

Appendix 2.

Sovereign credit ratings for selected EU and SEE countries

Country	Sovereign Credit rating	Corporate spread from AAA
Germany	AAA	–
UK	AAA–AA+	0.5–1.0%
Slovakia	A–A2	1.5%
Croatia	BB	4.0%
Bulgaria	BB+	4.0%
Bosnia & Herzegovina	B–B3	4.0–8.0%

TABLE 5. Sovereign credit ratings for selected EU and SEE countries

Appendix 3.

Costs for EU Road and "Road to Nowhere" scenarios

EU Road Cost (bn EUR/yr)									
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**AVERAGE** bn EUR/yr
Buildings	12,309	14,440	15,948	16,472	16,791	17,376	17,744	18,428	16,189
Transport	19,591	24,152	26,225	28,240	29,077	29,402	29,052	26,235	26,497
Industry	0,024	0,065	0,108	0,151	0,185	0,208	0,251	0,285	0,160
Energy	8,219	8,319	7,525	6,670	7,603	7,603	6,153	4,137	7,029
TOTAL	**40,143**	**46,976**	**49,806**	**51,533**	**53,656**	**54,589**	**53,200**	**49,085**	**49,874**
Population (milions)	22,48	22,38	22,15	21,92	21,62	21,33	20,98	20,63	
EUR/person/year	**1785,7**	**2099,0**	**2248,6**	**2351,0**	**2481,8**	**2559,3**	**2535,7**	**2379,3**	**2305,045**

TABLE 6. Costs for EU Road scenario.

Road to Nowhere Cost (bn EUR/yr)									
	2015	**2020**	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**	**AVERAGE** bn EUR/yr
Buildings	10,182	11,115	11,375	11,778	11,956	12,364	12,540	13,086	11,800
Transport	22,152	25,219	27,663	30,105	32,047	33,753	35,059	35,523	30,190
Industry	0,013	0,014	0,026	0,059	0,071	0,073	0,096	0,118	0,059
Energy	8,062	9,337	8,411	8,458	9,577	10,417	10,158	10,332	9,344
TOTAL	**40,409**	**45,685**	**47,475**	**50,400**	**53,651**	**56,607**	**57,853**	**59,059**	**51,392**
Population (milions)	22,48	22,38	22,15	21,92	21,62	21,33	20,98	20,63	
EUR/person/year	**1797,6**	**2041,3**	**2143,3**	**2299,3**	**2481,5**	**2653,9**	**2757,5**	**2862,8**	**2379,652**

TABLE 7. Costs for coal-based "Road to Nowhere" scenario.

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