ROMANIA

green growth

COUNTRY ASSESSMENT

Addressing a Changing Climate and Moving to Low Carbon

WORLD BANK GROUP

ROMANIA green growth COUNTRY ASSESSMENT

EUROPEAN UNION

GOVERNMENT OF ROMANIA

STRUCTURAL INSTRUMENTS 2007–2013

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June 2016

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acronyms and abbreviations

ANRE	National Energy Regulatory Authority (Autoritatea Naţionalţ de Reglementare în domeniul Energiei)
AquaCrop	agricultural yield model
BAU	business-as-usual
BCM	billion cubic meters
BIMR	Bucharest-Ilfov Metropolitan Region
CAP	Common Agricultural Policy of the European Union
CCS	carbon capture and storage
CGE model	computable general equilibrium model
CLIRUN	CLImate and water RUN-off model
CNP	National Commission for Prognosis (Comisia Nationala de Prognoza)
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
CSP	concentrated solar power
EC	European Commission
ECA	Eastern Europe and Central Asia region as designated by the World Bank which includes the following thirty countries: Albania, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Bulgaria, Croatia, Czech Republic, Estonia, Georgia, Hungary, Kazakhstan, Kosovo, Kyrgyz Republic, Latvia, Lithuania, FYR Macedonia, Moldova, Montenegro, Poland, Romania, Russian Federation, Serbia, Slovak Republic, Slovenia, Tajikistan, Turkey, Turkmenistan, Ukraine, and Uzbekistan
ESDA	Energy Service Demand Analysis model
ETS	Emissions Trading System of the European Union
EU	European Union
EU15	15 EU countries: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom
FDI	foreign direct investment
GCM	general circulation model
GDP	gross domestic product
GHG	greenhouse gas(es)
GIS	geographic information system
GTMP	General Transport Master Plan
GW	gigawatt(s)
ha	hectare(s)
ICAS	Romanian Forest Research and Management Institute (Institutul de Cercetări şi Amenajări Silvice)
IPCC	Intergovernmental Panel on Climate Change
IUS	Innovation Union Scoreboard of the European Commission
kgoe	kilogram(s) of oil equivalent
km	kilometer(s)
kt	kiloton(s)
$ktCO_2$	kiloton(s) of carbon dioxide
ktoe	kiloton(s) of oil equivalent
LC	Low Carbon Development

LNG	liquefied natural gas
LULUCF	land use, land use change, and forestry
MACC	marginal abatement cost curve
$MtCO_2e$	millions of metric tons of carbon dioxide equivalent
MW	megawatt(s)
NFA	National Forest Administration
NO_x	nitrous oxides
NPV	net present value
NRDP	National Rural Development Plan
OECD	Organization for Economic Cooperation and Development
OPCOM	Romanian gas and electricity market operator (Operatorul Pieţei de Energie Electrică şi de Gaze Natural din România)
PACE	Property Assessed Clean Energy
PM^{10}	particulate matter less than 10 microns in diameter
R&D	research and development
RACE model	Rapid Assessment of City Emissions model
ROM-E3 model	Romania Economy-Energy-Environment model
solar PV	solar photovoltaic
$tCO_2(e)$	metric tons of carbon dioxide (equivalent)
TFP	total factor productivity
TIMES	The Integrated MARKAL-EFOM System model, the successor to MARKAL (MARKet ALlocation model)
TRACE	Tool for the Rapid Assessment of City Energy
TRANSEPT	TRANsport Strategic Emission Prediction Tool
TWh	terawatt hour(s)
UMC	upper middle-income countries
WEAP	Water Evaluation And Planning model

acknowledgements

This report is a synthesis of extensive sector and topical analysis carried out under the Romania Climate Change and Low Carbon Green Growth Reimbursable Advisory Services (RAS) Program, at the request of the Government of Romania, through the Ministry of Environment, Water and Forests. The analytic component of the Program has been conducted by a World Bank team led by Erika Jorgensen. This synthesis report was authored by Erika Jorgensen and Maria Shkaratan, with support from Ka-Yee Ivy Lau, drawing on the analyses under the Program. The overall Program, co-financed by the European Regional Development Fund through Operational Program Technical Assistance 2007–2013 (OPTA), was managed by Jian Xie and Erika Jorgensen.

Sector and topic analysis was carried out by teams as follows:

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- Sanjay Pahuja, leading a **water** team of James Neumann, Kenneth Strzepek, Brent Boehlert, Alyssa McCluskey, Richard Swanson, Charles Fant, Jacqueline Willwerth, and Lisa Rennels (Industrial Economics), Thierry Davy, Adina Fagarasan, and local consultant, Catalin Simota (National Research and Development Institute for Soil Science, Agrochemistry, and Environment—ICPA Bucharest);
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- Carolina Monsalve, leading a **transport** team of Robin Kaenzig (Integrated Transport Planning), Cosmin Buteica, and local consultant, Otilia Nutu;
- Stephen Hammer, leading an **urban** team of Tatiana Peralta Quiros, Oliver Kerr and Silpa Kaza, and consultants Edward Leman (Chreod Ltd.), Gabriel Simion (University of Bucharest), and Octavia Stepan (Ion Mincu University of Architecture and Urban Planning). The team also benefited from the assistance of Cristiana Croituru (Technical University of Civil Engineering, Bucharest);
- Diji Chandrasekharan Behr, leading **forestry,** with inputs from local consultants, Bogdan Popa (Transylvania University of Brasov) and Marian Dragoi (Stefan cel Mare University, Suceava).

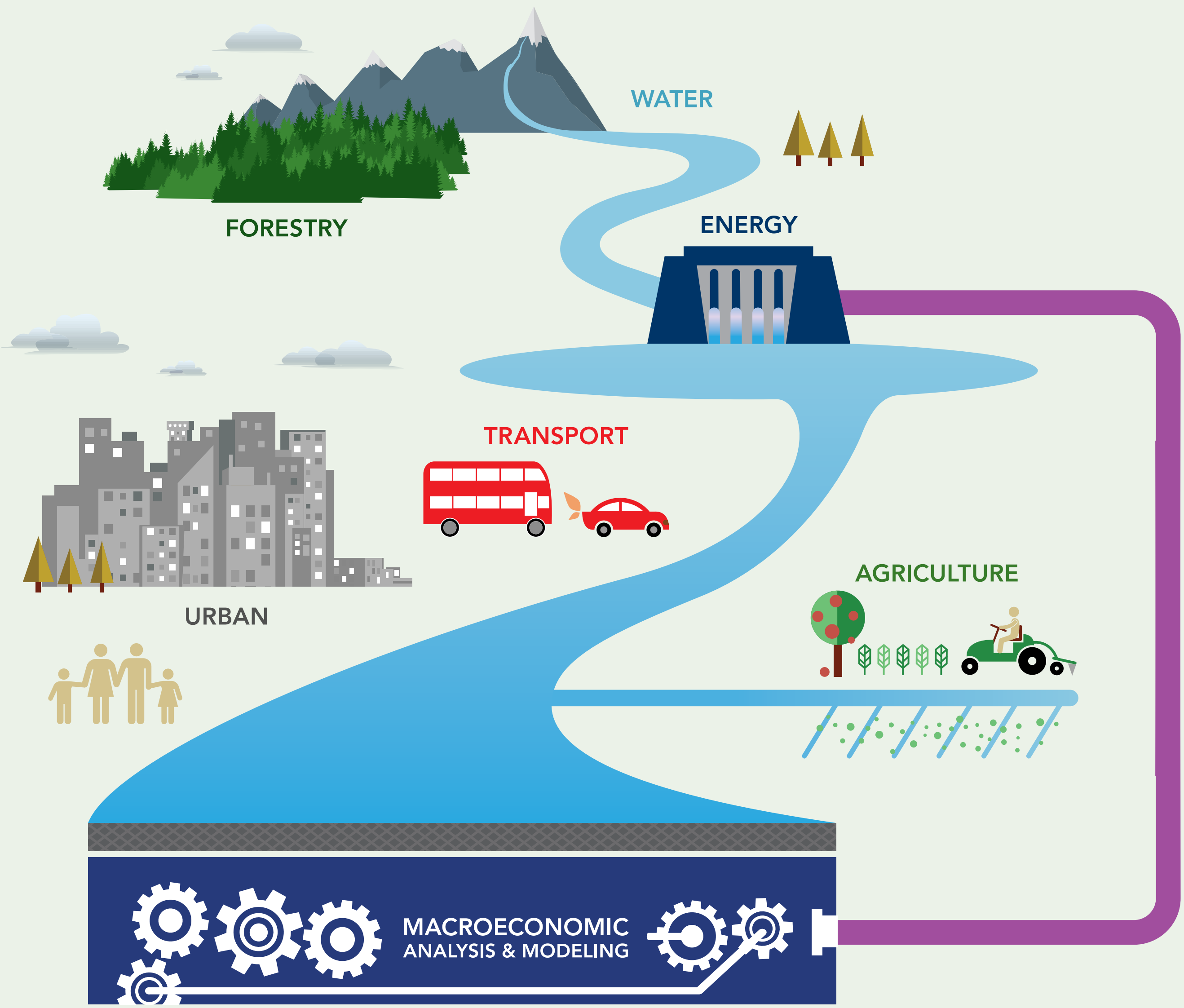
The work was carried out under the overall supervision of Kulsum Ahmed and the supervision of sector and topic analysis by Kulsum Ahmed, Juan Gaviria, Ivailo Izvorski, Ranjit Lamech, and Dina Umali-Deininger. Advice and support was provided by Mamta Murthi, Country Director, and Elisabetta Capannelli, Country Manager. Thierry Davy, Cosmin Buteica, and Adina Fagarasan have served energetically and effectively as the focal points for the Program in the Bucharest office and managed relations with the Romanian Ministry of Environment, Water and Forests.

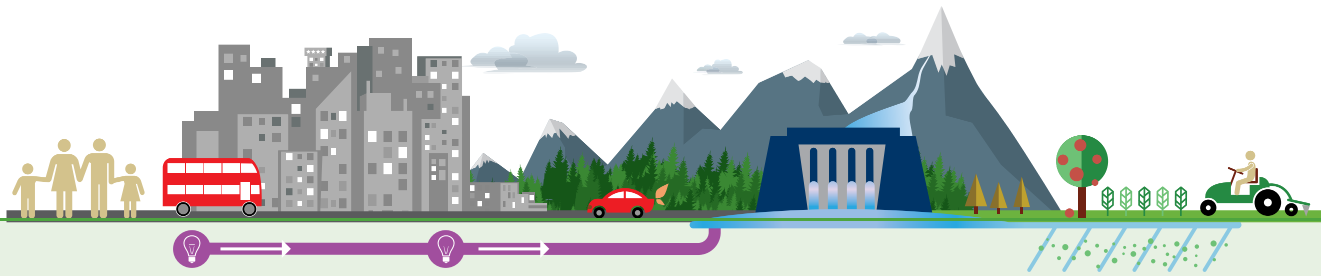
The work benefited from comments and suggestions from peer reviewers:

- For the overall report: Jane Ebinger, Claus Kondrup and Michael Toman;
- For macroeconomic modeling: Ulrich Bartsch;
- For water: Anju Gaur, Harshadeep Rao, Amal Talbi and Habab Taifour;
- For agriculture: Holger Kray and William Sutton;
- For energy: Morgan Bazilian Feng Liu, and Kari Nyman;
- For transport: Sameer Akbar and Andreas Kopp;
- For urban: Toshiaki Keicho, Josef Leitmann, and Victor Vergara;
- For forestry: Stig Johansson and Andrew Mitchell.

The country assessment benefited significantly from the ongoing interest, guidance, and support of Narcis Jeler, PIU Head of the World Bank Climate Change Program at the Romanian Ministry of Environment, Waters and Forests, and the extensive collaboration with local technical experts for each sector or topic report. We thank the numerous government officials for their collaboration throughout the Program, and we look forward to ongoing engagement on implementation of low carbon and green growth sustainable development recommendations.

executive summary





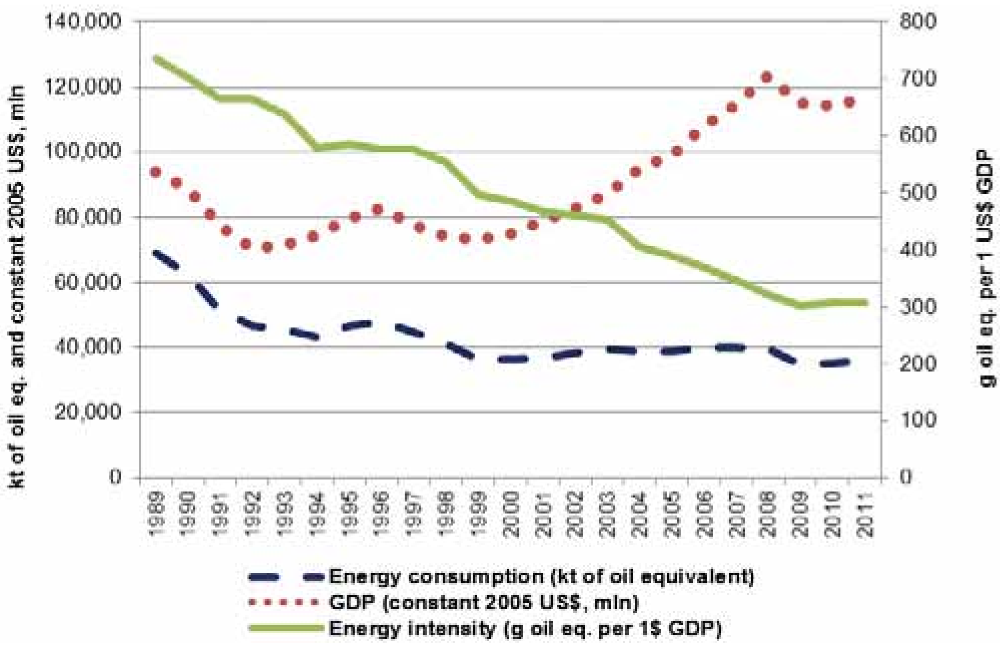
This assessment presents a synthesis of analysis to contribute to the definition of a lower carbon and greener growth path for Romania to 2050. The objective of Romania's green growth path is to implement mitigation actions and undertake needed adaptation while preserving growth and employment. Sectoral analysis of energy, transport, urban, water, agriculture, and forestry is complemented by economy-wide modeling. To bring together the findings, three multi-sector scenarios for Romania's economic development to 2050 are developed: the first without any additional greening actions but including current European Union (EU) climate policy—the **Baseline**; the second with modest effort at further action framed around implementation of the imminent EU 2030 low carbon targets and modest adaptation efforts—**Green**; and the third with ambitious action to align Romania with the EU's prospective Roadmap 2050 accompanied by ambitious adaptation—**Super Green**. Despite its technical depth, this report takes a practical approach to identifying specific challenges and opportunities Romania faces in building its green growth future and to present them in a form useful for decision makers. (See Table ES1 where the methodologies are presented by sector or approach.)

Romania has maintained a steady growth in output while containing the growth of its greenhouse gas (GHG) emissions. The country grew faster than the rest of Europe during 2000 to 2008 and recovered quickly from the international financial crisis. Meanwhile, Romania's greenhouse gas emissions continued on their long-term path of decline.[1] While emissions per capita are currently the lowest in the EU, Romania has among the highest levels of energy and emissions intensity (the energy or emissions per euro of GDP) in the European Union (EU) despite ongoing improvements, and the

1. In the period 1991–2013, the level of GHG emissions in Romania experienced a 46 percent decline, and in the period 1999–2013—an 18 percent decline. From 1991 to 2013, a year-on-year emission increase happened only in eight years.

FIGURE ES.1. Growth and energy consumption have been decoupling and energy intensity continuously declining since the early 1990s

Trends in growth, energy use, and energy intensity



Notes: Energy consumption is measured in thousand tons (metric) of oil equivalent. GDP is measured in millions of US$ at 2005 prices. Energy intensity is gallons of oil equivalent per dollar of GDP.
Source: Staff calculations based on World Bank data from 2015.

energy sector[2] in Romania is responsible for near 60 percent of emissions in the country.[3] Energy is, therefore, an obvious and necessary sector to lead on mitigation action (See Figure ES.1).

From now to 2050, real incomes in Romania are expected to continue to grow, and its carbon emissions are expected to continue declining. Romania's per capita income is converging towards EU averages albeit at a modest pace. Growth overall will be dampened by the ongoing decline in Romania's population and labor force, but continuing improvements in total factor productivity will keep growth positive. Expanding output and incomes will be sufficient to bring about higher energy demand, which in turn will support rising per capita and overall emissions. In the Baseline scenario, compliance with the current EU '2020 climate and energy package' and participation in the EU Emissions Trading Scheme (ETS) will offset this trend, with total emissions rising only slowly after 2020. Pressure to reduce energy intensity going forward will hasten the underlying momentum towards service sectors and away from heavy industry. At the same time, it is assumed that the country will tackle the many inefficiencies that keep it off its best possible growth path by pursuing reforms and investments to improve the overall performance of key sectors, apart from moving to greener growth paths. (See Figure ES.2).

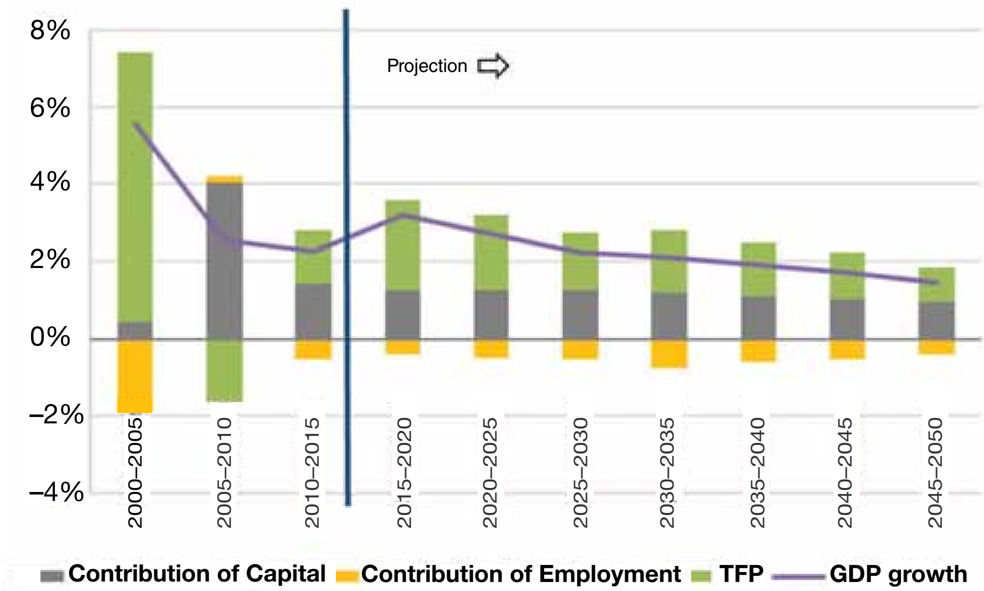
Romania can meet the targets of the Green scenario with only modest costs to growth and employment, EU emissions trading for energy-intensive sectors sets a uniform price for GHG allowances,

2. The energy sector is the standard IEA/IPCC definition and includes electricity and heat production and energy sector own-use.

3. Excluding LULUCF (land use, land use change, and forests).

FIGURE ES.2. Steady but modest total factor productivity improvements can keep growth positive

Solow decomposition of GDP growth in Romania, 1997–2050



Notes: The chart is based on the standard Solow analysis with a Cobb-Douglas production function ($Y = AK^{\alpha}L^{1-\alpha}$). Consequently, GDP growth can be decomposed as $\Delta\ln(Y_t) = \Delta\ln(A_t) + \alpha\Delta\ln(K_t) + (1 - \alpha)\Delta\ln(L_t)$. The first component is contribution of TFP, the second—capital and the third—labor. Capital is calculated on the basis of investment data, labor force comes from employment statistics. TFP was calculated implicitly, assuming that share of capital in GDP (α) is equal to 40 percent and depreciation rate (δ) is equal to 6 percent.
Source: World Bank staff estimates based on CNP forecast.

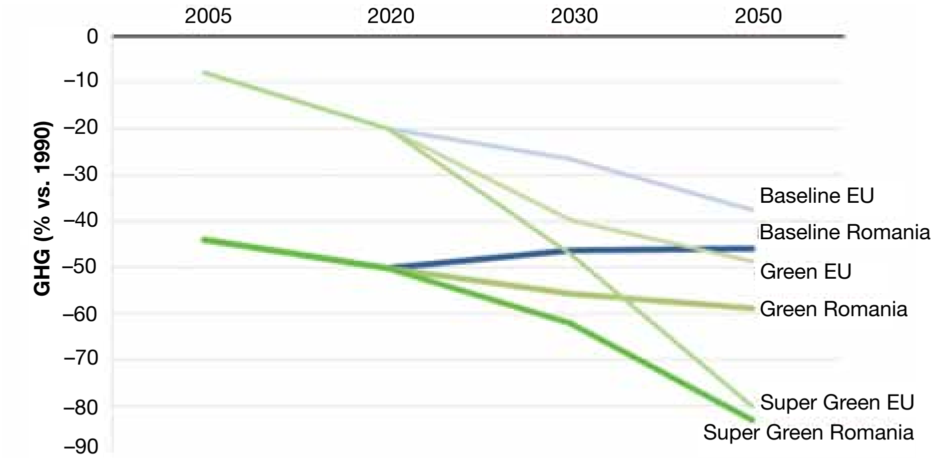
which generates an efficient allocation across countries of mitigation actions in those sectors. (See Figure ES.3). Even with no additional policy actions by the government, Romania is already on a declining carbon path because of the current EU climate and energy package. The tighter (imminent) targets of the Green scenario will reduce greenhouse gas (GHG) emissions in all sectors further, by more than one-fifth by 2030 compared to 2005 (an additional 17 percentage points beyond that achieved by current policies) at a cost of only 1.1 percent of output.

The Super Green scenario, in contrast, seems likely to prove expensive and demanding at the economy-wide level. By 2050, emissions could be more than two-thirds below 2005 levels, but at a likely cost of GDP four percent lower than otherwise. Employment impacts are similar. Importantly, the cost to Romania of either greener path is higher than the EU average.[4] This outcome reflects the fact that Romania is already on a downwards trend for carbon emissions, and modest additional mitigation is not overly burdensome despite Romania's starting point of relatively high energy intensity. However, mitigation as dramatic as that under the Super Green scenario is difficult and expensive. Moreover, since the shift to lower carbon will not be uniform across the economy, it will be important for the government to monitor sectoral, regional, and social impacts of the green transition, as labor and capital move across sectors, and stand ready with safety nets as warranted.

4. In 2050, the EU average GDP loss due to decarbonization in the Super Green scenario is 1.6 percent.

FIGURE ES.3. EU emissions trading allocates needed mitigation efficiently across countries

Total GHGs under each scenario for Romania and the rest of the EU, as % change from 1990



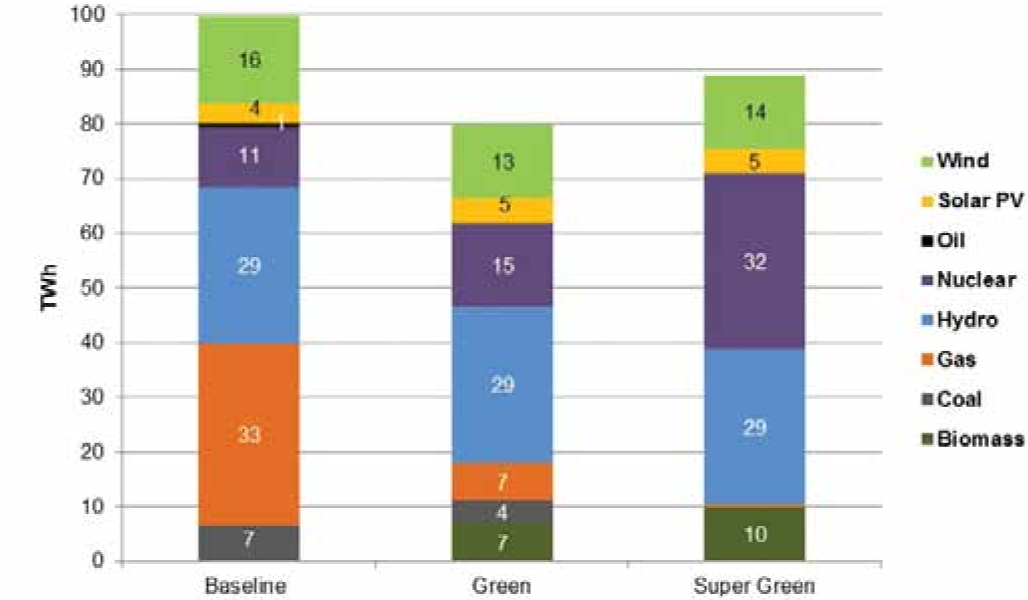
Notes: See Table 2.3 for description of baseline, green, and super green scenarios.
Sources: ROM-3 model outputs. See Macroeconomic Modeling Technical Report.

A greener energy sector needs to continue the transition towards low carbon fuels and away from coal. Achieving emission reduction targets beyond the EU 2020 targets—the Green (imminent EU 2030 targets) and the Super Green (prospective EU 2050 targets)—will require Romania to abandon plans for new coal-based power generation capacity and life-extension of existing plants. It will also require a significant additional renewable generation capacity. Replacement of obsolete fossil-fuel electricity plants poses a heavy investment burden irrespective of mitigation targets; and switching to renewable power to reduce energy sector emissions at the same time will augment those costs, especially because an increase in the variable wind and solar sources will require a corresponding additional peak load capacity. Ongoing participation in EU emissions trading will drive power emissions to 45 percent below 2005 levels by 2050, without any new policies (the Baseline scenario), as new generation focuses on renewables and nuclear power in the face of rising carbon prices. (See Figure ES.4 on how the structure of baseline power generation evolves.)

The difficulty of meeting the tighter targets for mitigation set out in the Green and Super Green scenarios will be eased significantly by improvements in energy efficiency. Improving energy efficiency across the board in all economic sectors, but especially in the residential sector and district heating, offers the most effective and also viable means for containing the growth of energy demand, limiting investment requirements to meet the growing demand, and reducing GHG emissions. Major measures include use of more efficient lighting and electric appliances, retrofitting buildings with wall, window and roof insulation, heating system improvement in residential, commercial and public buildings, and use of efficient electric motor and thermal energy equipment in the industry sector. These energy efficiency measures can reduce energy demand for space heating in buildings, promote energy efficiency in industry, and moderate household demand for electricity. Residential energy consumption can be reduced by more than one-quarter by 2050 (compared to Baseline levels); service sector energy use by almost one-third (because of the impact of efficiency measures in non-residential buildings); and more than one-sixth decline in industrial sector energy consumption.

FIGURE ES.4. Electricity generation is increasingly dominated by renewables with demand contained by energy efficiency

Total generation by fuel, 2050, in TWh



Source: Energy Sector Supply Technical Report.

The investment costs for these measures are substantial, totaling €19 billion through 2050;[5] however, they deliver significant abatement, are cost efficient, and require a modest implementation effort.

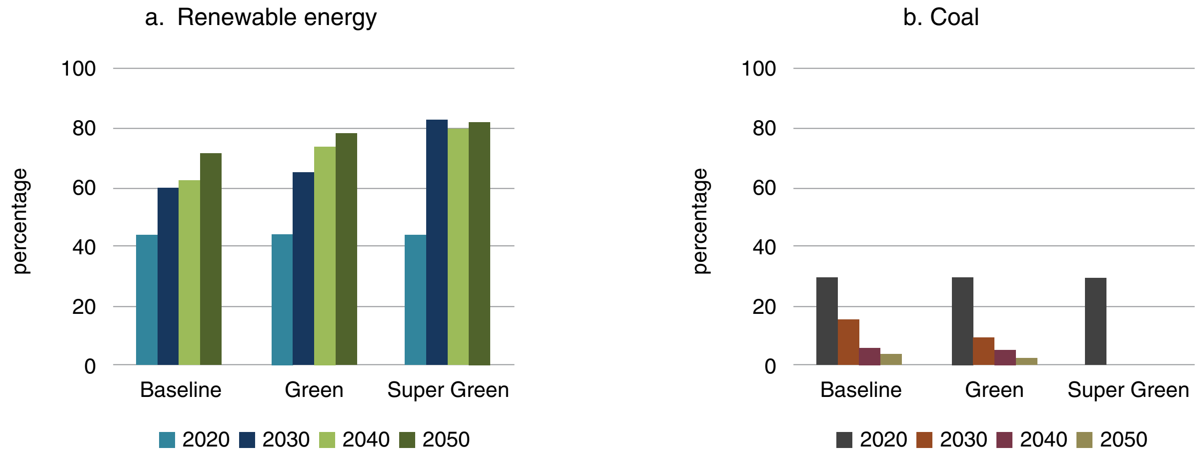
Investment in lower carbon power generation is the most expensive part of either green scenario. Under the Green scenario, in which power emissions are pushed to 45 percent of the 2005 level by 2030 (rather than by 2050 as in the Baseline), aggressive energy efficiency measures contain demand such that a nearly unchanged level of investment in power generation can add additional solar and nuclear, and electricity generation from fossil fuel-based sources decreases rapidly. Investment costs would rise from an average annual 0.8 percent of GDP of investment for the power sector in the Baseline scenario during 2015–50 to 1.1 percent for supply-side capital and demand-side energy efficiency measures under the Green scenario (or an increase from €28 billion of investment in the Baseline to €37 billion in the Green scenario[6]). Going to zero in the power sector in the Super Green scenario requires energy efficiency measures complemented by expensive new electricity generation from renewable sources and nuclear and eliminating electricity generation from coal-based sources by 2030. Romania's power sector emissions could be driven close to zero by 2050 by investing an average annual 1.7 percent of GDP in the power sector during 2015–50. (See Figure ES.5). Critically, for a successful shift towards low carbon energy, today's government must accelerate needed sector reforms in several areas: pricing, restructuring of lignite and coal power-generating companies, and support mechanisms for energy efficiency, renewable energy, and shale gas investment.

The challenges for mitigation in the fossil fuel-dependent transport sector are significant, especially as Romania's motorization rate converges with the EU average. Transport emissions are likely

5. Discounted at five percent.

6. In net present value terms using a five percent discount rate.

FIGURE ES.5. The share of renewables grows, mostly at the expense of coal, especially in the Super Green scenario



Notes: Percentages calculated based on installed capacity. There is no coal in the Super Green scenario after 2025.
Source: TIMES modeling outcomes.

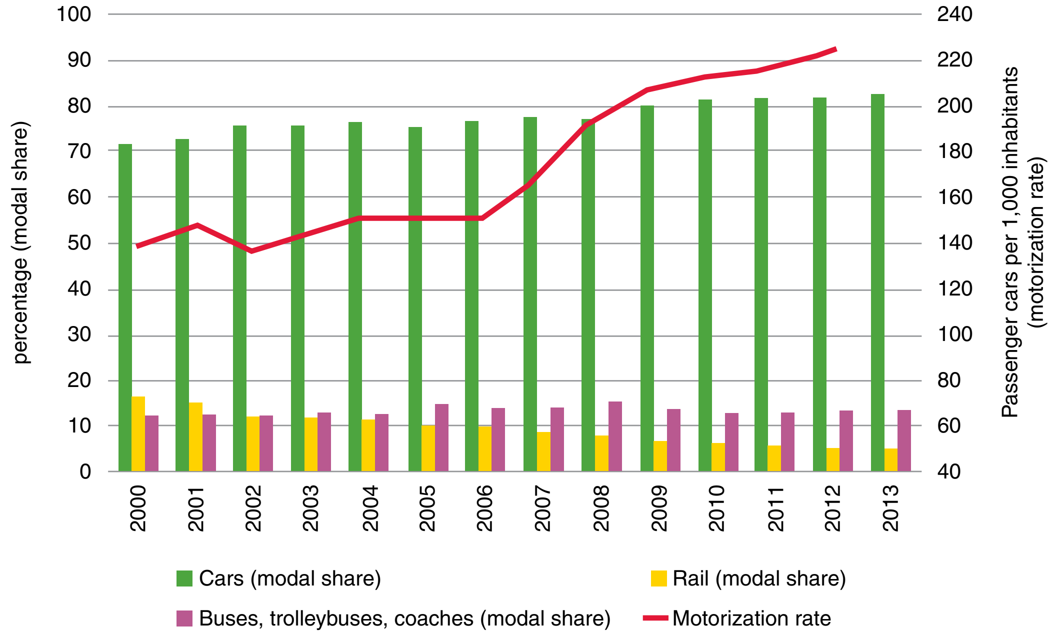
to grow under current policies by 15 percent by 2030 and 44 percent by 2050 as more people drive more cars more kilometers, and national policies have a leading role in pushing transport to contribute to the imminent 2030 EU target for such sectors of –20 percent (compared to 2005). Policies for the transport sector face the challenge of containing the pressure on emissions coming from continuing growth in vehicle ownership and road travel and the fossil fuel dependence of the sector. The ongoing shift towards road transport for both passenger and freight traffic derives from pricing that does not reflect the full costs of transport, technologies that are fuel inefficient, and the influences of spontaneous transition of the urban form (due to relaxation of land development controls, encouraging low-density development). Intertwined challenges are traffic congestion, poor parking management, declining public transport patronage, increasing private vehicle usage, an old taxi fleet, and lack of pedestrian and cycling infrastructure in urban areas. (See Figure ES.6).

A greener transport sector will require new and coordinated national policies and investments and will yield many additional benefits beyond GHG reduction. Since transport is not part of European emissions trading, mitigation policies are the responsibility of national governments. Romania already has a national transport plan which includes commitments to rail investment, as well as an existing set of taxes and incentives and traffic management measures. A greener transport sector can be fostered through new taxes on fuel and vehicles, and programs for eco-driving and 'smarter choices' in personal travel planning. The disincentive of high parking charges should be combined with an effective and efficient public transport system, and good walking and cycling facilities. Transport service provision needs to be addressed holistically to ensure that public transport is able to attract new users and realize the full climate and economic benefits. As shown in the marginal abatement cost analysis, transport options have very high calculated net costs in the absence of inclusion of important co-benefits such as reduced air pollution, diminished congestion, and fewer road accidents. Although challenging given the underlying trends, the growth in transport emissions can be slowed by implementing Green or Super Green packages. (See Figure ES.7 and ES.8.)

Urban areas, especially Romania's largest city of Bucharest, have the potential to lead on many green issues, starting with energy efficiency. Urban areas represent a concentration of population, economic activity, energy use, and GHG emissions, especially Bucharest. Low density development

FIGURE ES.6. Motorization is rising quickly, led by car use

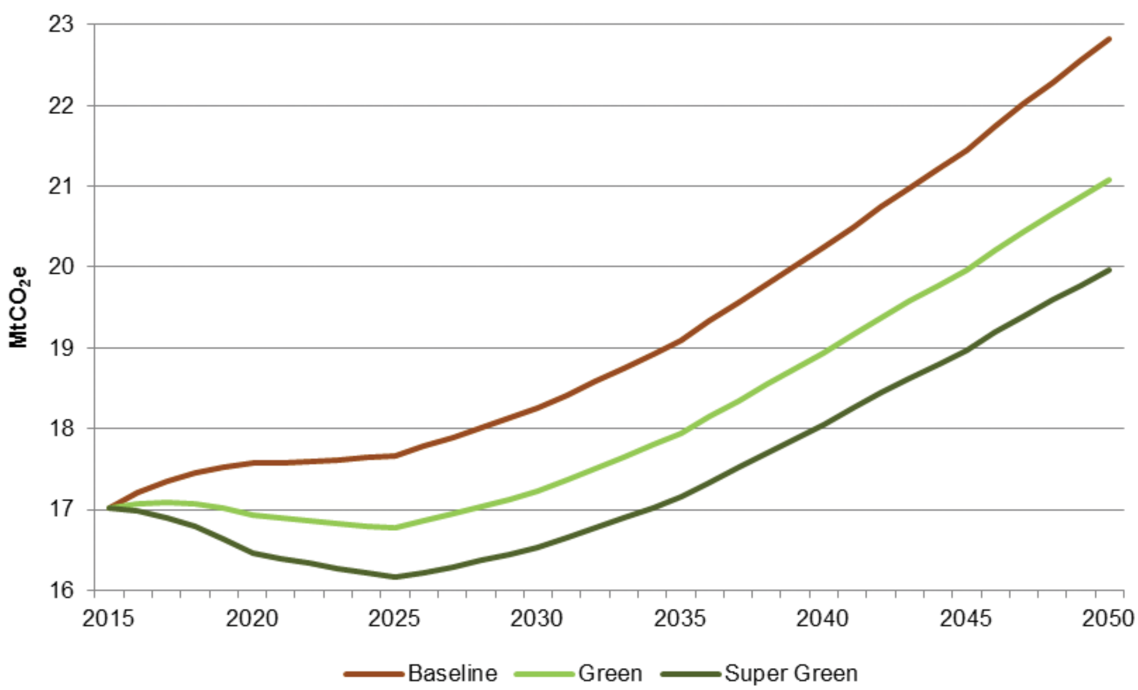
Motorization rate and passenger transport modal share (land-based modes)



Source: Eurostat.

FIGURE ES.7. Green scenerios for transport achieve significant abatement

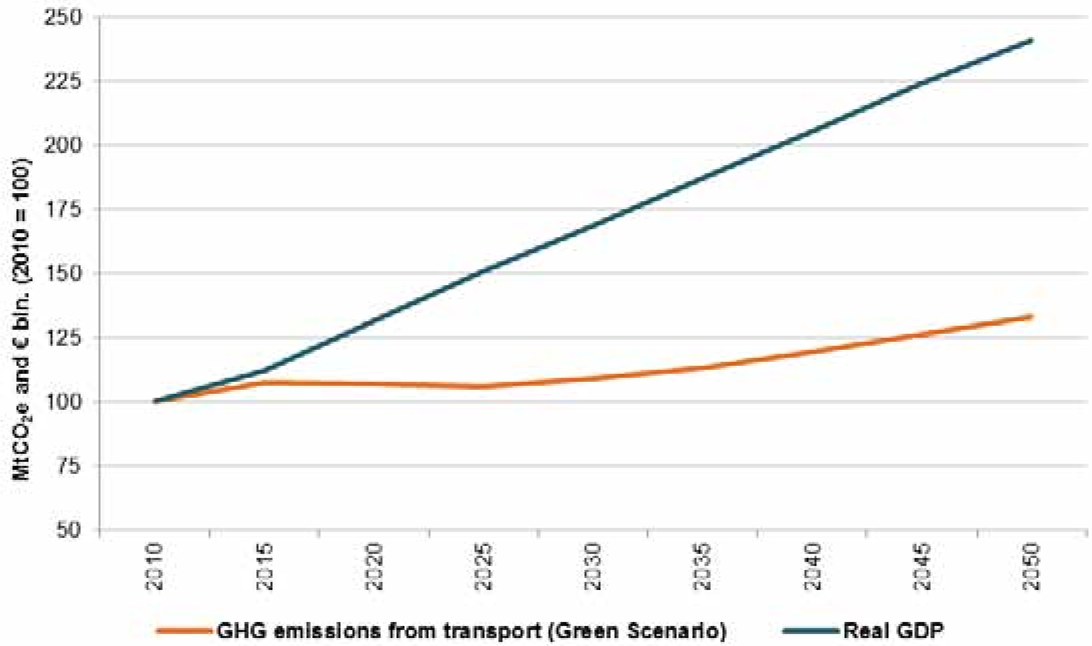
Romania's transport emissions under alternative carbon abatement scenarios



Source: TRANSEPT.

FIGURE ES.8. Green interventions lead to decoupling of transport emissions from economic growth

Transport GHG emissions and real GDP trends, Romania, 2010–2050 (2010 = 100)



Source: TRANSEPT.

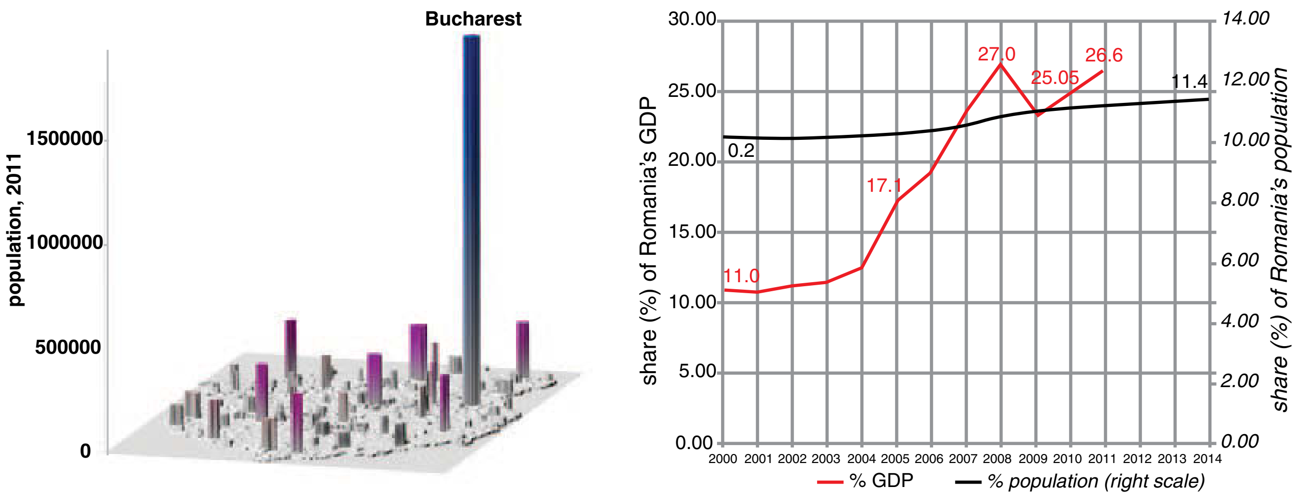
on the periphery of Bucharest with no integrated transport and land use planning has contributed to more inefficient urban form. Today, buildings account for the largest share of energy consumption, and residential buildings in particular use the majority of energy for heating. (See Figure ES.9).

Proactive measures to promote smart urban development in Bucharest and other urban areas, including more compact city design, improved vehicle stock and efficiency, and policies promoting building efficiency upgrades, can deliver sizable reductions in annual energy spending and emission levels. Such a package of urban low carbon measures would consist of a mixture of land-use planning and action to reduce emissions from buildings, transport and solid waste. Promotion of mixed land use, up-zoning and transit-oriented development are part of the recommended policy package, along with congestion pricing and district heating upgrades. Preferential land space for public transport, creation of pedestrian-only zones, parking policies and completion of ring roads are complementary transport actions. At the same time, energy efficiency can be fostered through various financing support and capacity-building programs. Such a policy shift can lead to less sprawl, higher densities, mixed-use, and a coordination of transit and spatial planning. In turn, better spatial development will generate significant improvement in energy use, energy spending and emissions. Overall, emissions from buildings in a Low Carbon scenario are projected at almost 40 percent below the BAU level in 2050, transport emission at 23 percent below BAU, PM_{10} emissions 39 percent lower, NO_x emissions will be reduced by 16 percent, and a total (real) savings in energy spending will amount to US$440 million per year by 2050, accrued to the municipal budget. The solid waste sector, currently mostly landfills, can achieve the highest proportional emissions reduction, with 80 percent below the baseline by 2050 if Bucharest-Ilfov meets all EU targets on recycling and biodegradable waste diversion. Finally, a successful shift to a low carbon pathway for Romania's capital city, and then for other municipalities as the lessons of Bucharest's experience emerges, demands strong local leadership to steward Bucharest to a low carbon future. (See Figure ES.10).

FIGURE ES.9. The Bucharest-Ilfov region dominates the landscape and the economy

a. Population Distribution in Romania, 2011

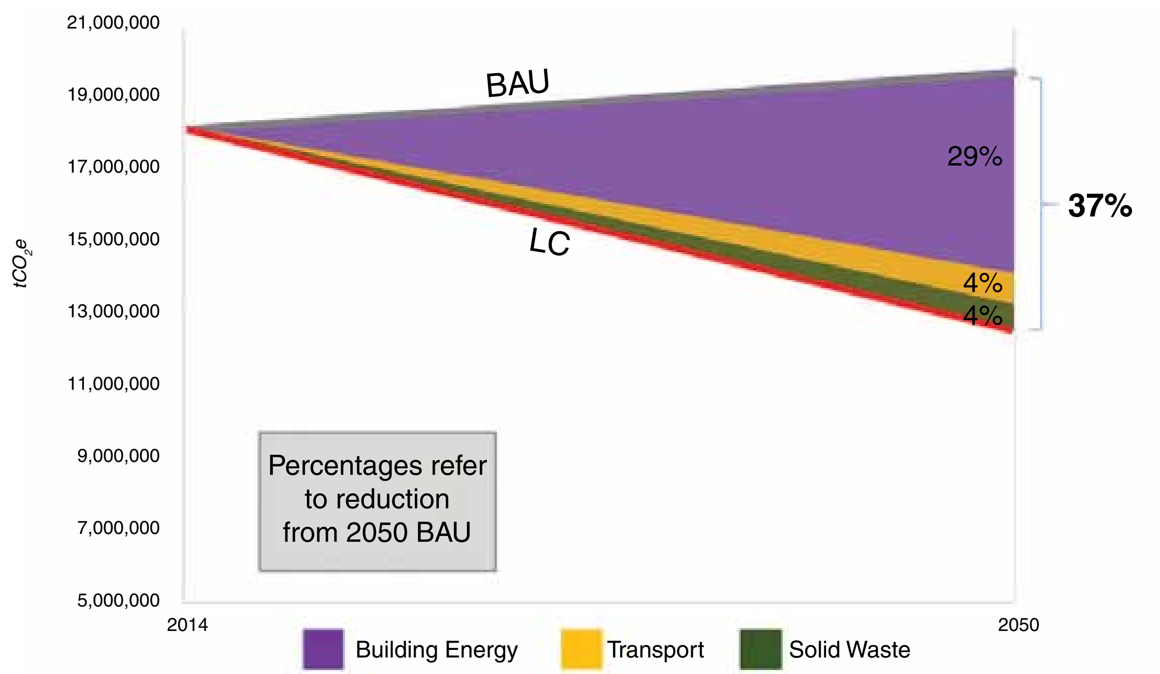
b. Bucharest-Ilfov Region's share of Romania's GDP and population



Source: World Bank staff calculations based on 2011 Population and Housing Census ad other data, from Urban Sector Technical Report.

FIGURE ES.10. Proactive spatial planning leads to significant emissions reduction

Carbon emissions reductions in tCO_2e under low carbon scenario relative to BAU, 2050



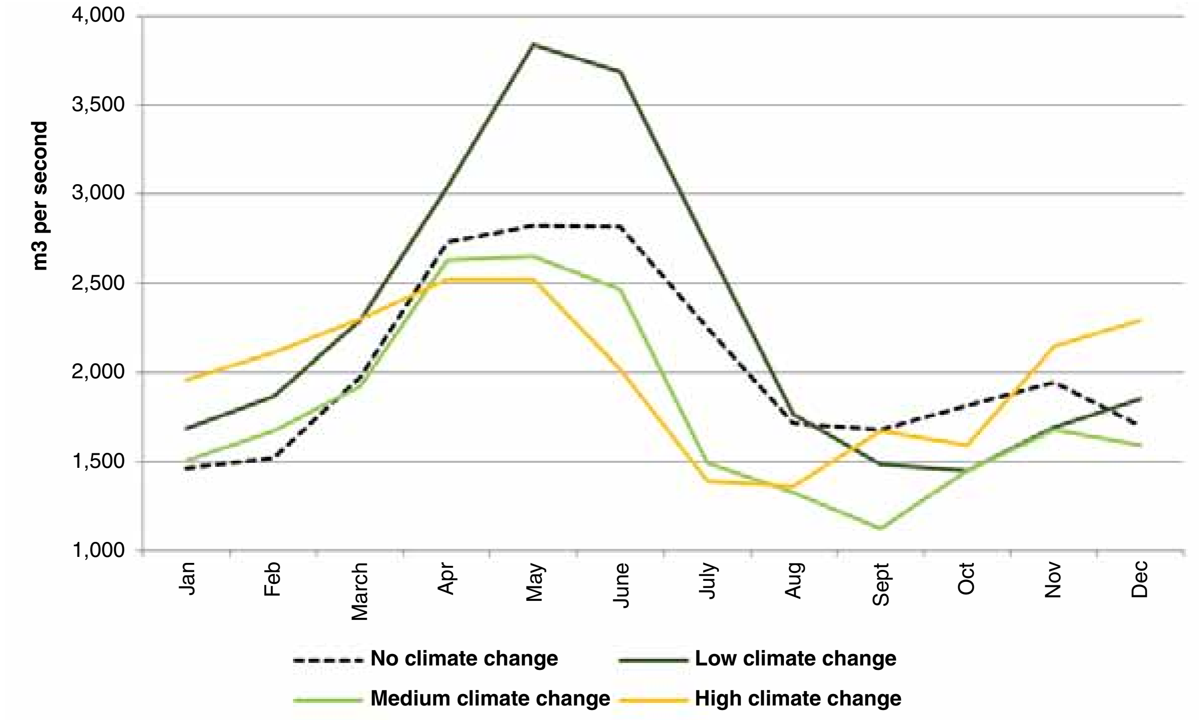
Source: World Bank staff calculations based on RACE model.

A changing climate will affect water and water-using activities and sectors in Romania, but there are numerous adaptation actions that make sense. Water demand for agriculture has decreased in correspondence to the long trend of reduction in irrigated areas, but water scarcity is serious in many basins during summer droughts, and climate change will threaten water availability during the primary growing months while raising irrigation water demand. At the same time, crop yields will be affected by climate-driven changes in soil moisture, direct temperature effects on crop growth, and changes in the evapotranspiration requirements of the crop, among other effects. Similarly, supply reliability for industrial and domestic use is most challenged for basins with lower endowment during summer months. A possible increase in hydropower generation as part of a lower carbon energy sector will both constrain and be constrained by changes in river runoff. (See Figure ES.11).

A greener water sector should pursue adaptation investments with the greatest potential. These investments include optimizing agronomic inputs, including fertilizer inputs, and rehabilitating irrigation infrastructure to restore irrigation production to currently rainfed areas. Expanded irrigation should be targeted to the Southeast and South-Muntenia regions. These measures would require complementary investment in high-quality extension services, as well as increased and/or subsidized availability of fertilizers, with the payoff being a significantly increased crop yield. To ensure consolidation of the smallest farms is encouraged while also avoiding an unnecessary subsidy to the largest farms which are already quite productive, fertilizer programs should be targeted for farms of medium

FIGURE ES.11. Climate change will threaten water availability during the primary growing months

Sum of mean monthly runoff across 91 sub-basins, baseline (1961–2000) versus three climate projections (2031–2050)



Source: Chapter 6 Water Sector Technical Report.

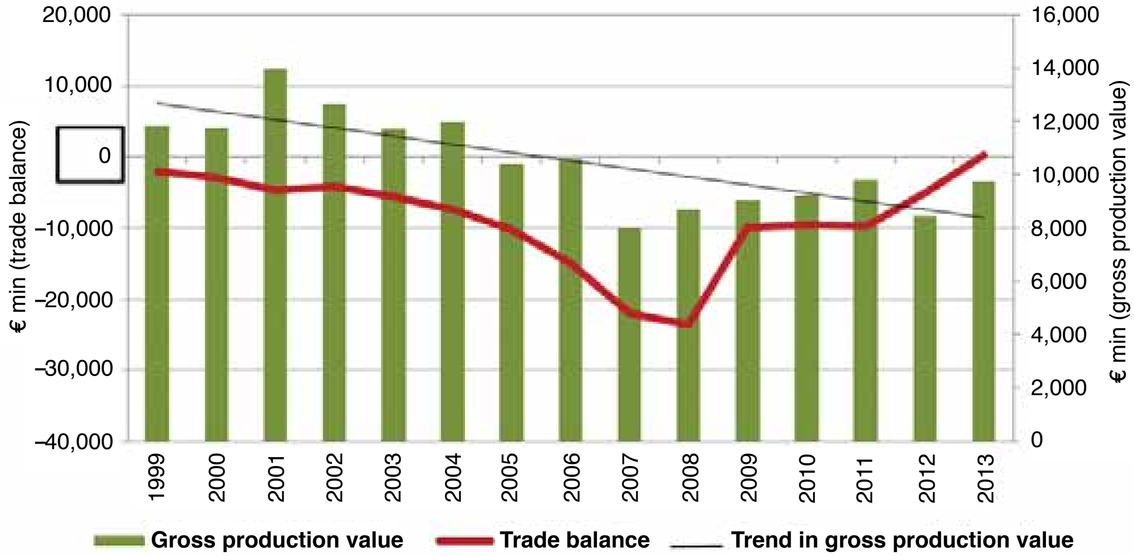
size (roughly 10 ha). Recommendations also include encouraging windbreaks and soil management to reduce soil erosion, promoting renewable energy sources, promoting organic farming, improving good farming practices, improving awareness of climate change and the need for adaptation, and strengthening policy, and institutional capacity is vital to support the recommended interventions. Modest adaptation actions in the water sector under the Green scenario, including investment in enhanced fertilizer application and in increased crop varieties, would cost about €1.8 billion over 2015–50 while more ambitious water sector investments in the Super Green scenario add investment in irrigation rehabilitation, pushing costs to over €11 billion for the period.[7]

Romanian agriculture requires adaptation actions, and the sector can also contribute to mitigation goals. Agriculture has average crop yields 30–50 percent below the EU average and labor productivity four times lower than the EU average, at least partly due to the large share of subsistence agricultural holdings. The ageing farm population and out-migration of the younger generation could trigger a significant change in the structure of the sector in the next 15 years. Effective policies will be essential to address the risk of land abandonment and address the issue of land fragmentation. As noted above, the main adaptation actions in Romanian agriculture include a reliable irrigation infrastructure, adjusted crop varieties, and improved fertilizer application, all of which will improve revenues more than sufficiently to cover costs. Emissions from the agriculture sector can be addressed

7. In net present value terms using a five percent discount rate.

FIGURE ES.12. Agricultural trade balance is recovering, but production is flat

Agricultural output and trade balance



Notes: Gross production value is at constant prices. Trade balance is exports minus imports.
Source: Staff calculations based on data from Eurostat and Food and Agriculture Organization, 2015.

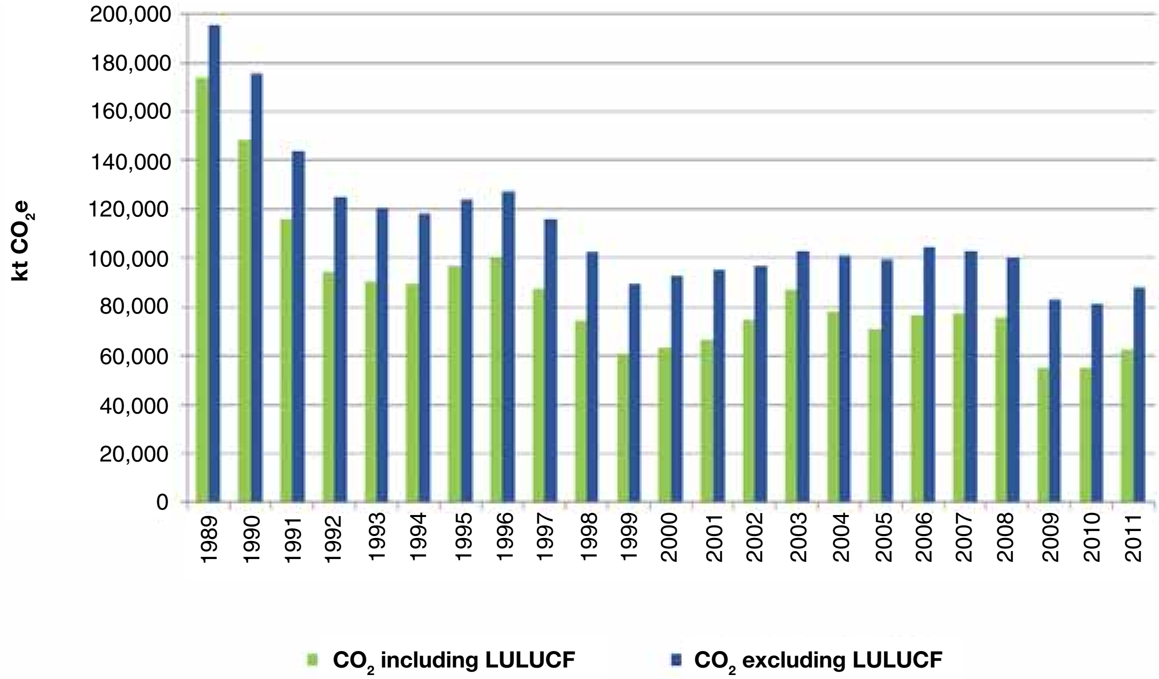
through a number of mitigation actions. Currently two major supported mitigation measures are minimum tillage and manure management. Financing needs for these measures are low, although small farms are ineligible for the related EU support. The measures are also highly beneficial from the point of view of sector efficiency. Moderating methane emissions from livestock through changes in feed may also prove important, especially if this part of the agricultural sector continues to expand into the future at recent rates of growth. (See Figure ES.12).

Romania's forests warrant a greater role in climate action. Romania has the largest intact tract of contiguous natural and naturally regenerated forests in Europe. LULUCF[8] activities (and mostly forestry activities) removed more than one-quarter of Romania's emissions during 2000–11. Climate change, however, is negatively affecting forest health and growth through drying and biological risks such as pest infestation and increased frequency of forest fires. This compromises forests' ability to sequester carbon, unless they are appropriately managed. Romania's forest holdings are a mix of private, public, small and large, and have uneven road accessibility, requiring concerted efforts to promote sustainable management of forests. With investments, forestry appears a very attractive option for Romania to reduce its emissions, and it would be important that the EU move rapidly toward defining the rules (including the country level targets and the flexibility rules) for LULUCF-based mitigation within its 2030 Framework. A greener path for the forestry sector would include better management of forest resources (both protection and production forests), afforestation, and policy measures to create incentives for sustainable forest management on both private and public forest lands. Intensive sustainable management of forests and increasing afforestation can increase the level of CO_2 sequestered. Romania's forests can provide significant mitigation contributions at low cost, but some public financing and good use of EU funds will be needed. (See Figure ES.13).

8. Land use, land-use change and forestry sectors.

FIGURE ES.13. LULCF, especially forestry, is an important contributor to mitigation

Emissions removal by LULUCF



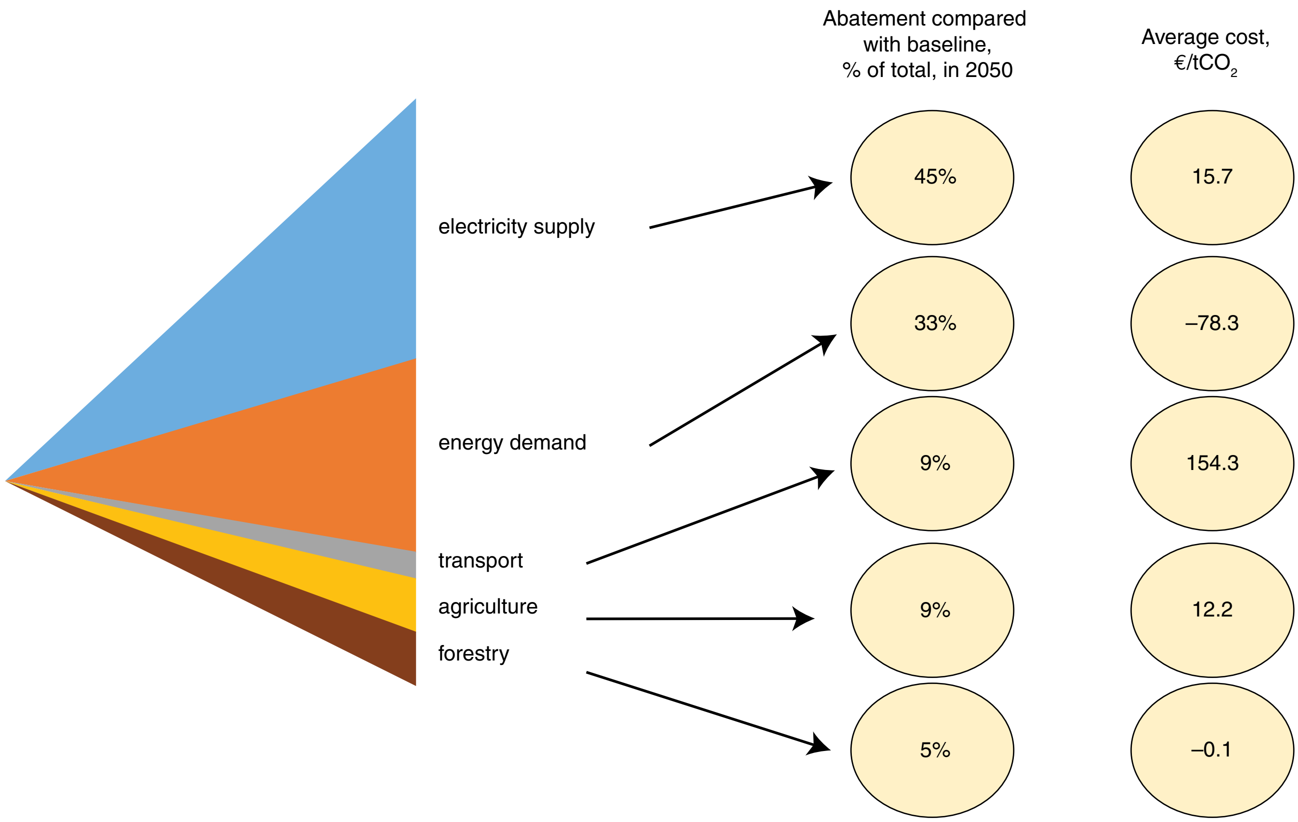
Source: Forestry Sector Technical Report.

An overview of the costs of this low carbon green growth path for Romania is informative for government planning. Drawing together the analysis of investment costs across four key sectors—electricity, energy efficiency, water, and transport—from 2015 to 2050, elicits an average annual 1.5 percent of GDP of additional investment needed for the Green scenario and 2.4 percent for the Super Green scenario. These numbers are equivalent to an annual investment of €3.5 billion in the Green scenario and €5.2 billion in the Super Green scenario in the period from 2015 to 2050.[9] Of the estimated costs from now until 2020 of €11 billion under the Green scenario, two-thirds belongs to electricity generation investments and more than one-quarter to energy efficiency; while under the Super Green scenario, with the total costs of €14 billion, electricity generation is responsible for one-half of the total and energy efficiency and water—for more than one-fifth each. The costs of building new power plants dominates investment needs under the Super Green scenario after 2030, when the urgent push for energy efficiency tapers off. Funding from the EU could prove key for financing some of these investments, in particular in energy efficiency and in forestry (the costs for which are additional to these aggregates). Importantly, the likely share of public investment is modest, at less than one-sixth of the total and less than one-quarter for the Green and Super Green scenarios respectively. Figure ES.14 provides an estimate of the sector contribution to the overall abatement and also of the cost each sector would have per unit of CO_2 abated. Marginal Abatement Curve for Romania (Figure ES.15) shows abatement potential and unit costs of each of the evaluated measures, across sectors. In year 2050, when all measures will be implemented in full, actions across the four

9. In net present value terms using a five percent discount rate.

FIGURE ES.14. Mitigation requires measures across many sectors

Emissions reduction by sector, 2050, Super Green scenario, and average cost of the green measures, 2015–2050

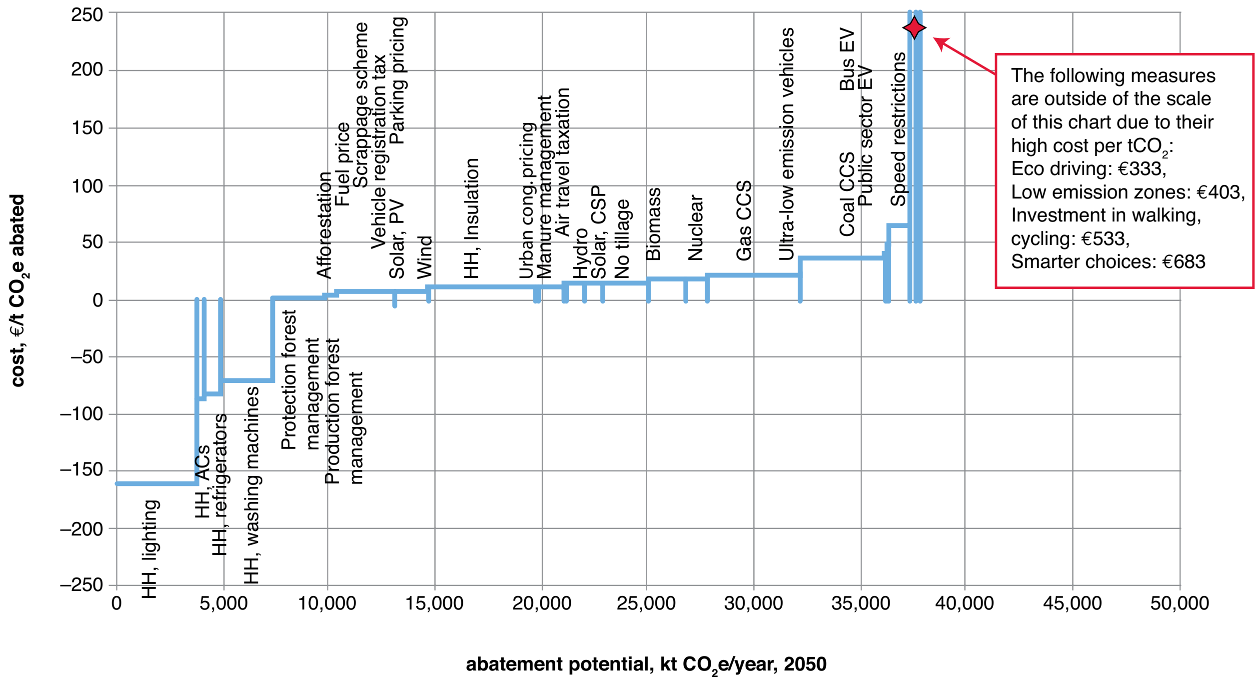


Source: Marginal Abatement Cost Curve Technical Report.

mitigation sectors in this assessment will reduce emissions in the country by 38 Mt CO_2 eq./year. It should be kept in mind that such costings are snapshots based on available data and the technology set that today is considered practical for such assessments. New technologies will certainly emerge over the coming decades that will change these costs and benefits, providing an important reason why governments need to update such analysis periodically.

FIGURE ES.15. Energy efficiency and forestry measures deliver net benefits while energy supply measures deliver substantial mitigation

Romania Marginal Abatement Curve, cross-sectoral, 2050, Super Green scenario



Note: How to read the MACC. The height of each column shows the average cost of abating one ton of CO_2e by 2050. The chart is ordered from left to right from the measures with the lowest cost to the ones with the highest cost. The width of each column shows the GHG emission reduction potential of the measures in year 2050, when all the measures have been fully implemented. See sector technical reports for discussion of technologies. Calculations use a tool developed at the World Bank.

Source: MACC technical report.

TABLE ES.1. Methodologies for the Green Growth Country Assessment

SECTOR OR ISSUE	OBJECTIVE	ANALYTIC FRAMEWORK	
		MODELS USED AND MODELING FRAMEWORK	MODELING OUTCOMES
Macroeconomic Modeling	To capture complex linkages between mitigation and adaptation policies and economic performance; and to set out a detailed economic baseline scenario.	The Romania Energy-Environment-Emissions (ROM-E3) **model**, a recursive stochastic general equilibrium model, was developed, drawing on the well-known GEM-E3 model, and applied to simulate green scenarios. Sector as well as macro outcomes, in particular, carbon prices from emissions trading, were then used in sector analysis to ensure consistency. As a global model, ROM-E3 can simulate the economic interactions of Romania with the rest of the EU and the rest of the world. EU climate and energy policies can be represented in detail and complexity in the model.	Growth, employment, fiscal, and investment impacts of mitigation actions, as well as impact on sectoral structure. Serves as the baseline scenario for other sector and macroeconomic analysis.
Energy	Mitigation options: To find optimal solutions for a power supply mix to cover demand at a minimum cost while reducing emissions of the power sector. Included potential reduction in power demand as a result of energy efficiency measures in industry, household, and non-residential sectors.	**Supply-side modeling (TIMES MARKAL), demand-side modeling (ESDA), coordinated with the macroeconomic model (ROM-E3).** The **ROM-E3 model** projected basic economic indicators which drive energy demand: GDP, energy sector value-added, and energy prices as well as emissions allowance prices needed to attain the green scenarios. **TIMES MARKAL** found a least-cost mix of power sources to meet power demand projections (using ESDA), while accounting for constraints such as resources, technology, user constraints and a cap on GHG emissions (the allowance prices). The **ESDA** modeling estimates energy sector end-user service demand and projected the penetration of a set of green technologies that could reduce energy demand.	Capacity and generation by fuel source in power generation under different scenarios. Emissions from the energy and power sectors. Required investment and other costs for each scenario.

SECTOR OR ISSUE	OBJECTIVE	ANALYTIC FRAMEWORK	
		MODELS USED AND MODELING FRAMEWORK	MODELING OUTCOMES
Transport	Mitigation options: To estimate the cost of proposed green investments and emissions reduction.	**TRANSEPT (Transport Strategic Emission Prediction Tool)** developed. Included Romanian General Transport Master Plan in the baseline scenario, as well as certain existing pricing instruments and regulations. **TRANSEPT** model evaluated the impact of various transport and environmental policies on the transport sector outcomes. Applied multi-criteria analysis to select transport measures for scenarios.	Road travel demand and road transport fleet composition and performance (fuel consumption and emissions) as a result of green policy implementation. Sectoral indicators (vehicle population and age, vehicle-kilometer traveled, ton-kilometer transported, volume of rail travel). Sectoral outcomes used to project the level of fuel consumption and emissions including CO_2, NO_X, and PM_{10}.[10]
Urban	To assess the impact of urban green policies and investments under two green growth scenarios.	**Rapid Assessment of City Emissions (RACE)** model is a geospatial model that compares population and development patterns for a region under different scenarios, in order to develop technical estimates of how they differ in terms of energy use, energy spending levels, air quality emissions, and GHG emissions. By changing assumptions about current and future land use patterns, the design and location of different public transport system options, the energy and emission factors assigned to different land use patterns in a city, and the solid waste management system design, it is possible to compare a "baseline" scenario with one or more alternative scenarios in terms of energy demand, energy spending, energy-related air quality emissions (PM_{10} and NO_x), and energy-related CO_2 emissions.	Population and development patterns and the implications for emissions under different scenarios. Energy demand, GHG emissions, PM_{10} and other emissions for each scenario. Fiscal savings for municipal government.

(continued)

10. NO_x is a generic term for mono-nitrogen oxides, in particular, NO_2. NO_2 forms quickly from emissions from cars, trucks and buses, power plants, and off-road equipment. In addition to contributing to the formation of ground-level ozone, and fine particle pollution, NO_2 is linked with a number of adverse effects on the respiratory system. NO_x are distinct from nitrous oxide (N_2O), a greenhouse gas emitted from agricultural lands. PM_{10} is atmospheric particulate matter smaller than 10 microns.

TABLE ES.1. Continued

SECTOR OR ISSUE	OBJECTIVE	ANALYTIC FRAMEWORK	
		MODELS USED AND MODELING FRAMEWORK	MODELING OUTCOMES
Water and Agriculture	Adaptation options: To assess the impact of a changing climate on competing uses of water, especially by the agriculture and power sectors.	**Global General Circulation Models (GCMs), Water Evaluation And Planning (WEAP) model, CLImate and water RUNoff model (CLIRUN) and a crop water productivity model (AquaCrop).** 1. **GCMs** produced climate projections, which were used as inputs in **CLIRUN** to estimate streamflow runoff and in **AquaCrop** to estimate crop yield and irrigation water demand. 2. Runoff and irrigation demand estimates from **CLIRUN** and **AquaCrop** were used as inputs in the **WEAP** tool, where water storage, hydropower potential, and water availability were modeled. 3. To refine the **AquaCrop** estimates of crop yield in irrigated areas, the unmet demand for irrigation water from **WEAP**, together with statistical data on irrigated crop sensitivity to water availability, was fed back into **Aquacrop**. 4. Finally, the **WEAP** hydropower generation and **AquaCrop** crop yield results are analyzed to produce estimates of their economic implications: projected revenue from crop production and hydropower and NPV of investments in these sectors.	**Intermediate outcomes:** • Climate projections • Water runoff • Irrigation water demand • Crop yield • Water availability • Hydropower potential • Water storage **Main outcomes:** • Projected revenues from crop production and hydropower generation • NPV of investments **Financial evaluation of infrastructure investment options for water and agriculture:** • Net present value of the cash flow of benefits and costs
Forestry	Mitigation: options for GHG removal	MAC curve analysis was undertaken for 3 mitigation measures: afforestation, sustainable management of production forests, and sustainable management of protection forests.	
Benchmarking	To provide an initial portrait of the country's status, prospects, and challenges with respect to green growth.	Using a broad set of indicators of green growth available for most countries to identify important elements of green growth for Romania. Key areas for indicators are: (i) Sustainable use of natural resources, including minerals, water and clean air, and biodiversity; (ii) mitigation of greenhouse gas emissions; (iii) adaptation to a changing climate, and (iv) innovation and green jobs. For any individual country, endowments and history matter for current 'greenness' and potential greening of growth paths. A framework of key questions with three aspects: (i) "how green?", (ii) "going green," and (iii) "riding a green wave," is used to guide a benchmarking exercise in which Romania is mapped against comparator countries and country groups using a dataset of more than 100 indicators for 69 countries for 1990 to 2009.	

SECTOR OR ISSUE	OBJECTIVE	ANALYTIC FRAMEWORK	
		MODELS USED AND MODELING FRAMEWORK	MODELING OUTCOMES
Marginal Abatement Cost Curve	Mitigation options: effectiveness of each proposed abatement measures by measuring its marginal net cost (present value of net cost per unit of CO_2e abatement) and the related abatement potential.	Marginal abatement cost (MAC) analysis is commonly used as a tool in evaluating emission reduction technologies in terms of their potential mitigation impact (emissions abated) and unit cost (cost per ton of CO_2e abated). They are also considered to be a most efficient communication instrument used in discussions of the abatement policies. MACC charts are designed to be a "brief": they compare technologies to be considered for implementation in a simple (easy to comprehend in a limited time) but informative way. The technologies can be presented one by one or at various levels of aggregation, including by blocks of technologies, by economic sector, or even by groups of sectors. In the MACC, each technology has two characteristics: the level of abatement, Mt CO_2e, which equals to the difference in emissions produced by the new technology as compared to the technology it replaces (abatement potential) and the cost of the technology per unit of abatement, €/t CO_2e. Electricity supply, energy efficiency, forestry, agriculture and water, and transport green measures were used in the MAC analysis.	

introduction

This assessment presents a synthesis of analysis to contribute to the definition of a lower carbon and greener growth path for Romania to 2050. The objective of Romania's green growth path is to implement mitigation actions and undertake needed adaptation while preserving growth and employment. Sectoral analysis of energy, transport, urban, water, agriculture, and forestry is complemented by economy-wide modeling and made consistent through the application of three common scenarios.

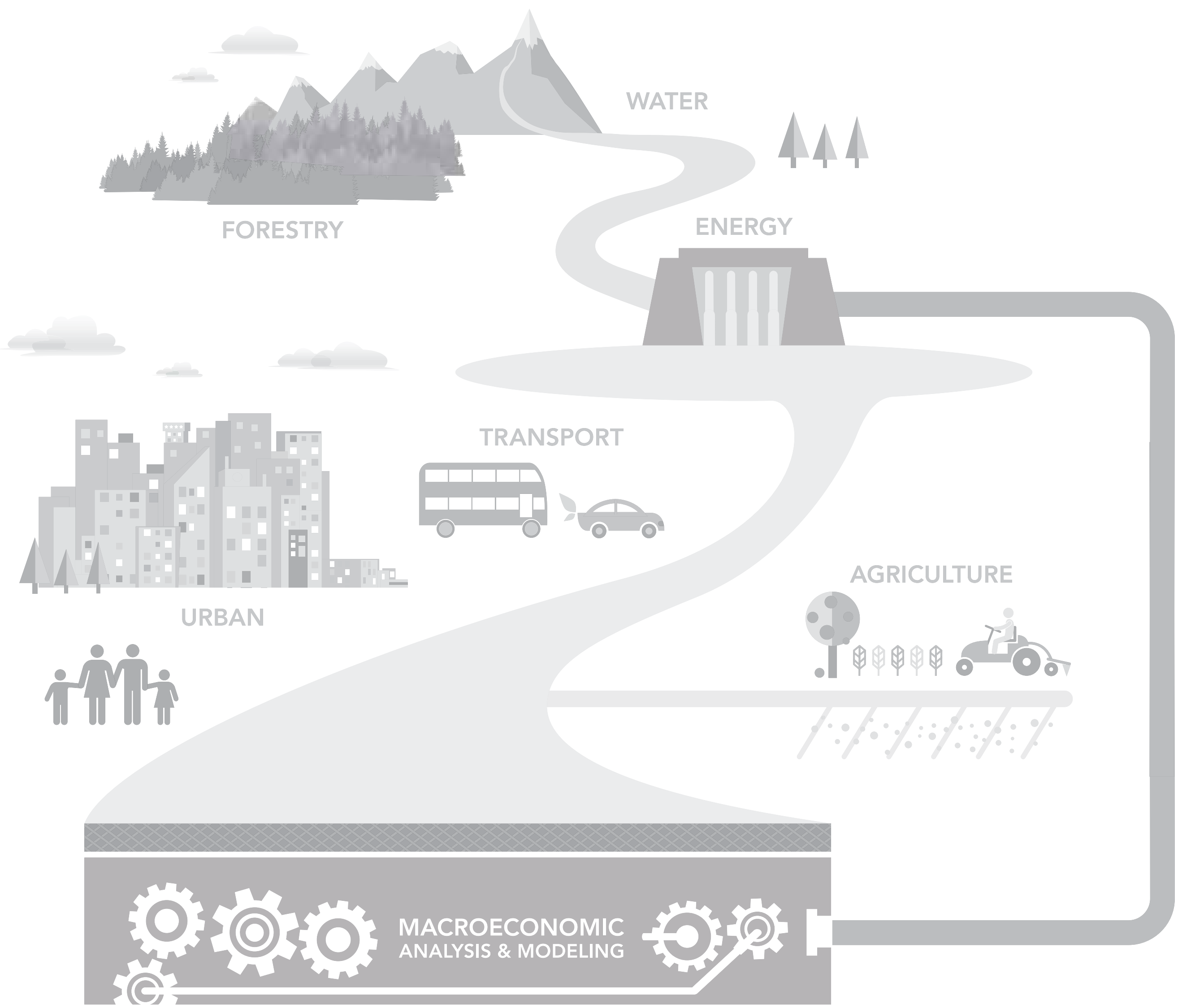
Chapters of the report have a standard structure, but the underlying analytic work varies. Each starts with a chapter summary, followed by a description of the relevant challenges to green growth. Then, the methodology is laid out, and the main findings summarized. Finally, conclusions and recommendations are introduced. Despite the identical structure of the chapters, analytic work undertaken for each sector differs depending on sector specifics, green growth objectives in particular sectors in Romania, and analytic tools available.[1] Therefore, the analysis has varying methodological frameworks, analytic tools including modeling, and types of findings and recommendations:

- **The Benchmarking analysis (Chapter 1)** aims to define, "What is green growth, and how green is Romania?" It provides an initial portrait of Romania's status, prospects, and challenges with respect to green growth using a framework for mapping the country against comparator countries and country groups on three aspects: "how green?," "going green," and "riding a green wave." The analysis makes use of a database of more than 100 indicators for 69 countries.
- **In the macroeconomic assessment chapter (Chapter 2),** forecasting Romania's economic path to 2050 and two alternative green paths is based on computable general equilibrium (CGE) modeling. A CGE model was developed for Romania, in collaboration with local experts, designed to address the complex and overlapping elements of the EU's climate and energy policy framework. It was applied to assess a Green and Super Green scenario against the baseline, which includes ongoing implementation of the EU's 2020 climate and energy package. The Green scenario imposes compliance with the main features of the EU 2030 Climate and Energy Policy Framework, while the Super Green assumes the Roadmap 2050 will be implemented.
- **Energy sector analysis (Chapter 3)** estimates the best solutions for Romania's energy supply mix given the country's current, imminent, and prospective mitigation obligations. A system optimization model is used for energy supply modeling while the potential for reduction of energy demand in end-use services through energy efficiency measures was estimated using a

1. Background technical reports are available for each of the chapters.

specially-developed demand analysis model. Marginal abatement cost analysis provided a cost comparison of the analyzed measures.

- **In transport analysis (Chapter 4),** a bottom-up, detailed engineering model was developed, utlizing Romania's General Transport Master Plan, as well as non-quantitative evaluation of barriers to implementation and externalities of green measures. Marginal abatement cost analysis assessed cost effectiveness and abatement potential of the measures.
- **Urban analysis (Chapter 5)** examines cross-sectoral urban (mitigation) issues using a geospatial model that compares population and development patterns under different scenarios for the Bucharest region. The cross-sectoral approach allows combined analysis of spatial issues, transportation, and building efficiency, among other issues. The findings propose focus areas for municipal policy decision making and recommend priority areas for interventions across municipal sectors.
- **Water sector analysis (Chapter 6)** examines adaptation solutions to address rising unmet water demand as the climate changes. A series of models were applied to project climate change, water availability for various users, and productivity of crop agriculture. Financial evaluation of adaptation measures was also conducted. The analysis was aimed at answering three questions: (i) how will climate change affect the water demand-supply gap? (ii) what impact will reduced water availability have on the sectoral outcomes in water-using sectors, such as agriculture, industry, municipalities, and hydropower? and (iii) which interventions and at what cost will contain or reverse those impacts?
- **In agriculture (Chapter 7),** the analysis addressed both mitigation and adaptation, applying outcomes from water sector modeling and marginal abatement cost curve calculations. The main adaptation measures in agriculture were assessed. Two key mitigation actions were costed using marginal abatement methods, based on country-specific cost estimates, a result of a detailed expert assessment.
- **Forestry analysis (Chapter 8)** is a combination of a review of existing sector analysis and marginal abatement cost estimates based on country-specific data and research conducted for this assessment. The analysis proposes priority measures for forestry that would support both mitigation (by improving the ability of forests to sequester carbon) and adaptation (by reducing the negative impact of climate change on the quality of the forests).
- **Marginal abatement cost curve analysis (Chapter 9)** provides estimates of mitigation potential and their cost for all emission reduction interventions that are recommended by the sectoral analyses conducted for this assessment. Such measures are recommended by the analyses in the energy, transport, agriculture, and forestry sectors. The chapter provides a summary comparison of key mitigation measures, a useful tool for policy makers' discussions and decision making.
- **A brief conclusion section** underlines the importance of green growth assessments for policy decision making and suggests ways in which this assessment can be useful for forming the mitigation and adaptation agenda in Romania.


WATER
FORESTRY
ENERGY
TRANSPORT
URBAN
AGRICULTURE
MACROECONOMIC
ANALYSIS & MODELING

CHAPTER 1

How Green Is Romania? A Benchmarking Exercise

CHAPTER SUMMARY

Using a broad set of indicators of green growth, Romania is compared to international and regional benchmarks to provide an initial portrait of the country's status, prospects, and challenges with respect to green growth. Green growth starts with a traditional concern about sustainable use of natural resources, including minerals, water and clean air, and biodiversity, and then adds consideration of mitigation of greenhouse gas emissions, attention to adaptation to a changing climate, and more focus on innovation and green jobs. For any individual country, the nature of a greener growth path will depend on endowments and history, which positions countries quite differently with respect to current 'greenness' and potential greening of their growth paths. A framework to define a list of questions key to understanding how Romania or any country compares in an international context is constructed with three aspects: "how green?," "going green," and "riding a green wave," and used to guide a benchmarking exercise in which Romania is mapped against comparator countries and country groups using a dataset of more than 100 indicators for 69 countries. This benchmarking exercise aims to define, "What is greener growth for Romania?"

Romania is well-endowed with various natural resources, which, if used productively, can support strong and sustained economic growth. The country possesses fuel and mineral deposits, hydropower resources, wind power resources, and agricultural and forest land. However, significant reforms in agriculture aimed at increased productivity are needed, and improved management of forests is critical for sustained quality of this resource. The country has been developing new sustainable energy sources such as wind energy, further bolstering its relatively high and increasing share of non-emitting and renewable generation. This approach to energy will, over time, assist Romania in improving its current high emissions and energy intensities and also contribute to (global) sustainability by mitigating greenhouse gas (GHG) emissions. Romania already faces obligations as a member of the EU to reduce its GHG emissions, with current, imminent, and prospective targets for reduction that will progressively tighten requirements for reducing carbon. Adaptation to protect tomorrow's output from climate

damage is also important for Romania. Although its projected exposure is only average, its large agriculture sector renders it more sensitive to climate shocks, and its rather weak adaptive capacity (or ability to address climate threats) means that, altogether, the country is vulnerable.[1]

A greener world will require economic transition, and successful transformation for a country will depend on the flexibility of its economy—its ability to absorb shocks—and its readiness to take advantage of new opportunities. A flexible economy has sufficient capital mobility to ease firms' entry and exit, a nimble sectoral structure with a high share of manufacturing and services, well-developed global links and openness to trade, a flexible labor market with human capital adequate for a modern economy, and a supportive business environment. Against these metrics, Romania's strengths are its high (although variable) level of investment in fixed assets, a large share of manufacturing in industry, and good energy security. Critical areas to improve economic flexibility are trade openness (strengthening competitiveness and exports) and better labor mobility. Policy reforms would include improving the regulatory environment (especially product market regulation) and liberalizing the labor market. The most pronounced green transition weakness of Romania is its lack of readiness for new green opportunities, reflected in innovation and knowledge economy indicators. Romania lags far behind the EU in research and development and a number of indices of innovation and connectedness. Altogether Romania's connections to global knowledge and readiness for an innovation revolution are insufficient to benefit from green technological change.

This benchmarking exercise identified a selected set of issues within the broad green growth agenda on which Romania should focus as it considers how to move onto a greener growth path. As the Romanian government considers implementation of green growth and low carbon measures, policymakers need to think when drawing down natural capital in the interest of economic growth is a wise tradeoff and when it is not. Certainly, more investment in maintaining and upgrading some natural assets seems warranted, in particular agricultural land and forests today and water going

1. See Chapter 2 for details on Romania's mitigation obligations and new climate projections.

forward. Substantial investments are needed, especially in the energy sector, to advance mitigation of greenhouse gases and contain growing energy demand; and government needs to manage actively the likely impacts of a changing climate on agriculture and water. To cope with a greening world, greater flexibility of the economy, strengthened connections to global knowledge, and more effective support of innovation should be fostered through policies and investments. Beyond the one-time exercise summarized in this chapter, a country pursuing green growth might find occasional benchmarking of value to identify emerging green issues. It would likely be most useful if supplemented with a locally-designed results framework, to monitor progress on current greening efforts and to support the implementation of its national strategies and plans related to climate action, resource use, and sustainability. With a growth path already shaped by the requirements of EU membership, this first glance at green growth for Romania seems to indicate much complementarity between the short term and the long term, with relatively little conflict between policies and structural reforms that will lead to more vibrant as well as more sustainable growth.

CHALLENGES FOR GREENER GROWTH

Overview

Green growth benchmarking is a diagnostic at the country level, which helps define a country's strengths and vulnerabilities in adopting a path to greener growth. Green growth can be considered simply as growth in economic output that preserves the ability of natural assets to provide the resources and services on which human welfare depends.[2] While most countries agree that such growth is a worthy goal, determining what a green growth path might mean for a particular country is a significant challenge. A starting point in the process of defining a country's green growth path should be analysis aimed at mapping the country's current position on a multi-dimensional chart of green growth, with each dimension defined by a green growth indicator. The purpose of such analysis is to understand what the country needs to do to pursue green growth and what policy decisions, investments and institution building need to be undertaken to support green growth. Green growth benchmarking is a methodology proposed for such analysis.

Green growth starts with a traditional concern about sustainable use of natural resources. The efficient exhaustion of nonrenewable resources such as energy and mineral deposits and the sustainable use of renewable resources such as forests and fisheries, water, and clean air have been considered part of a sustainable growth agenda for decades. Natural resources are necessary to economic activity, providing raw materials and environmental services essential for production to continue. Some components of natural resources have become of greater concern in recent years, among them freshwater resources affected by overexploitation, pollution, and climate change; and biodiversity under threat from habitat alteration and pollution.

Mitigation of greenhouse gas emissions is a critical additional component of environmental sustainability, with rising prominence and particularly difficult challenges for countries. The growing imbalance of greenhouse gases in the atmosphere is a clear example of the breeching of planetary boundaries and of a global public good. As such, individual countries can reap only local co-benefits such as reduced suspended particulates in the air if fossil fuel burning is reduced. Since the bulk

2. See, among other sources on green growth, World Bank. 2012. *Inclusive Green Growth: The Pathway to Sustainable Development.* Washington, DC: World Bank.

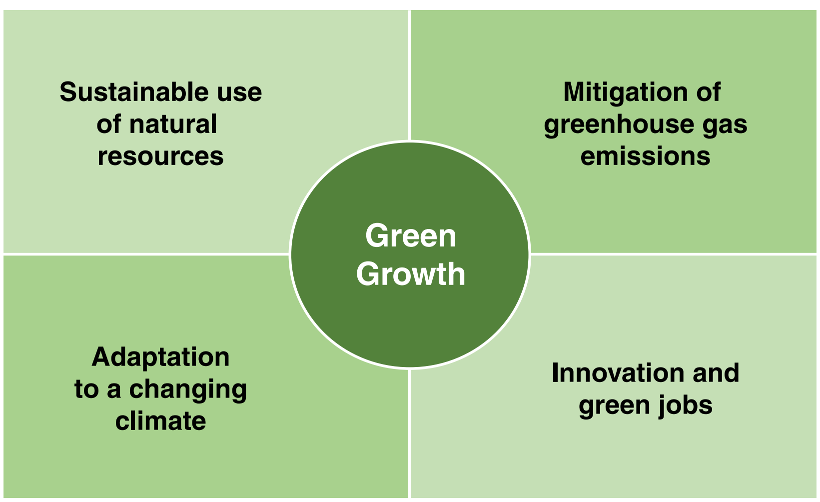
of the benefits do not accrue to an individual country, a decision to move to low 'carbon' (referring to emissions of greenhouse gases) generally must be motivated by other considerations, including access to carbon finance and other external funding, in response to regional standards and requirements such as those of the European Union, or driven by a decision to lead on global issues and prepare for an eventual global agreement.

Adaptation to a changing climate must also be part of a country's sustainable growth path. Regardless of future greenhouse gas emissions, climate is already changing, with more extreme weather events, rising sea levels, and overall warming. Some countries, sectors, and populations will be strongly affected, although with major impacts in most places not materializing for some decades. For many countries, it makes sense to consider how adaptation needs can be incorporated into decisions about long-lived infrastructure such as new hydropower plants. More generally, countries that will face significant impacts need to factor such shifts—in frequency of droughts, in crop yields, in coastal and riverbank flooding—into thinking about sustainable and greener development paths.

The newest element of the green growth agenda is the strong emphasis on innovation and green jobs. This dimension of green growth proposes that a shift towards greener growth will spur technological innovation, especially in the energy sector, and promote the emergence of new industries. Innovation can help decouple growth from natural resource depletion and greenhouse gas emissions by shifting out global production possibilities and allowing more production with fewer and more environmentally-friendly inputs. Environmental considerations do not necessarily constrain growth; but to the contrary, a dynamic technical change towards low carbon and low pollution technologies could drive growth and generate jobs at all skill levels (see Figure 1.1).[3]

FIGURE 1.1. Elements of environmental sustainability together constitute green growth

Diagram of green growth



Source: Green Growth Benchmarking Technical Report.

3. Such assessment is consistent with mainstream economic arguments that there is close substitutability between clean and dirty technologies. In that case, policies can push the economy towards a clean solution, causing the sector with clean technology to become large enough to be self-sustaining. In such a situation, the shift to greener technologies will support growth rather than limiting it. See Aghion, *et al.* 2011. "The Environment and Directed Technical Change." *Growth and Sustainability Policies for Europe (GRASP) Project of the European Commission.* Working Paper 21. Brussels: EC.

Challenges: Where Should Countries Start?

A greener growth path must address these four aspects and balance greening with growth of output and incomes, but the details of a country's path will depend on country-specific conditions and policy choices. Each country starts with a set of endowments, natural and man-made. While some aspects of any country's current condition are driven by recent policy choices, much derives from exogenous characteristics such as geography or endowments of fossil fuels, hydropower potential, or forests; and the myriad of distant policy decisions that drove national development to where it is today. These characteristics position countries quite differently with respect to their current 'greenness' and the potential greening of their growth paths. In considering the complex task of assessing green growth at the country level, the starting point is fundamental to the costs and tradeoffs the country faces in choosing a greener path forward.

One holistic approach to sustainability is national wealth accounting and the measurement of natural capital, which aims to capture a good part of the green challenges to orthodox growth measurement. Part of the determination of an optimal green growth path for a country involves proper valuation of environmental costs and benefits, an approach which has been part of the sustainability agenda for many years. Recent international agreement to support wealth accounting or green national accounts is moving this effort into the mainstream. A correct costing of depreciation of natural resources such as mineral deposits and of externalities such as air and water pollution will take countries who adopt such an approach a good distance toward maximizing a greener type of GDP.[4] However, some elements of greenness are not easily costed, among them greenhouse gas emissions, biodiversity, and the non-income benefits (or happiness) that comes from living in a country with a healthy and well-protected natural environment. A simpler starting point in such assessment is benchmarking against comparator countries—using indicators that measure various dimensions of green growth. This quick mapping can help identify challenging areas, as well as easy wins. It can create a balanced portrait of a country's green issues, and, as set out below, it can serve as primarily analytic rather than monitoring objectives.

METHODOLOGY AND FINDINGS

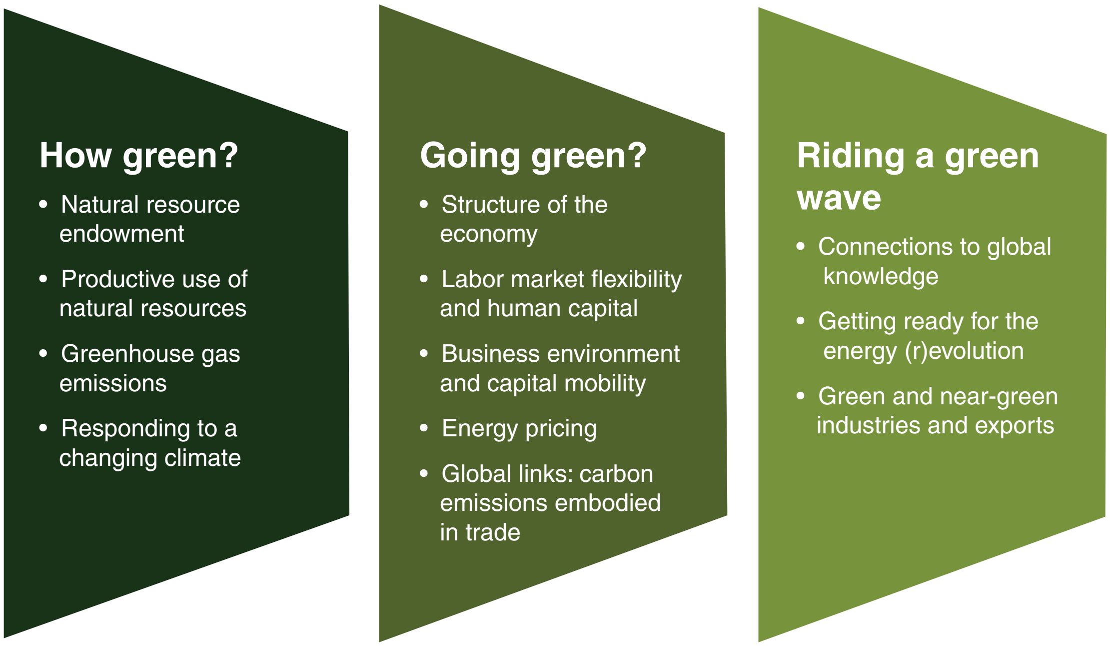
Methodology

A simple scheme helps to define a list of questions key to understanding how Romania or any country compares in an international context (see Figure 1.2). Firstly, how green is Romania? A country's natural resources support production and economic growth, but like other forms of capital, they require investment, maintenance and good management in order to be productive and contribute to rising output and welfare. How important are natural resources to current growth, and how productively has the country made use of them? Is pollution a major problem? Has Romania made any progress in decoupling economic growth and greenhouse gas emissions? Is the country preparing for the impacts of a changing climate? Secondly, what will be Romania's greatest challenges in going green? Transition to a green growth path is equivalent to an economic shock, and economies differ in their ability to weather such shocks. Is Romania's economy flexible enough to succeed in the transition towards green growth? Is Romania's economy well-diversified and ready to reap emerging opportunities? Is energy subsidized? Are Romania's imports emissions-intensive? Thirdly,

4. See World Bank, 2011. *The Changing Wealth of Nations: Measuring Sustainable Development in the New Millennium.* Washington, DC: World Bank.

FIGURE 1.2. Green growth benchmarking is aimed at analysis, not monitoring

An analytic framework for benchmarking



Source: Green Growth Benchmarking Technical Report.

can Romania 'ride the green wave' and reap substantial payoffs from 'going green'? More rapid green growth is inconceivable without innovation, which can help to decouple growth from natural capital depletion and environmental pollution, towards cleaner, more resource-efficient and resilient growth. How can Romania be ready for this surge of innovation, particularly in the energy sector, and be competitive in new and growing green industries? These three aspects of measuring 'green-ness' capture a country's status, prospects, and challenges with respect to the four elements in Figure 1.1.

Benchmarking can provide a practical starting point for a country green growth assessment, with an emphasis on analysis rather than monitoring. Attempting to measure green growth is not a new effort: this methodology builds on existing analysis and applications but with a new focus on how economies can cope with a greening world as the climate changes. The benchmarking method presented here differs from other green growth indicators in that it has a primarily analytic rather than monitoring objective and focuses on the economic factors of green growth and the economy's capacity to absorb the shock of a greening world and climate change using its natural resource endowment, flexibility of the economy and openness to technological transition. Using a specially-constructed database, Romania was benchmarked on more than 100 indicators across 69 countries.[5,6] Data is derived from a variety of sources, particularly the World Bank's various databases, with selec-

5. Romania was compared to three country groups: the European Union (EU), the Eastern Europe and Central Asia (ECA) region, and all upper middle income countries (UMC). For the list of 30 countries that constitute the ECA region as designated by the World Bank, see Acronyms. For comparisons to selected comparator countries as well as the three country groups, see the Green Growth Benchmarking Technical Report.

6. The design of the benchmarking database draws on lessons from recent OECD, UNEP, and Columbia-Yale Environmental Performance Index publications. See OECD. 2011. *Towards Green Growth: Monitoring Progress: OECD Indicators*. Paris: OECD. See UNEP. 2012, *Measuring Progress towards an Inclusive Green Economy.* Nairobi: UNEP. See Yale Center for Environmental Law and Policy, *et al.* 2012. *2012 Environmental Performance Index and Pilot Trend Environmental Performance Index.* Palisades, NY: NASA Socioeconomic Data and Applications Center (SEDAC).

tion of relevant indicators balancing data availability and reliability. This benchmarking intends to identify the most important components and issues to be addressed in a green growth assessment. It aims to provide an objective basis for understanding how 'green' countries are and to identify the key elements for each country that help define an optimal path to a green economy.

Findings

How Green?

Romania is well-endowed with various natural resources which, if used productively, can support strong and sustained economic growth. Figure 1.3 shows Romania's main strengths to be its significant endowment of agricultural land, low level of water withdrawals, middling level of air pollution (PM_{10}),[7] and moderate level of forest loss. Its main weaknesses as revealed by benchmarking are low productivity of agriculture as reflected in cereal yields, low water resources per capita, and impaired seafood resources (as indicated by fish stock damage). Partly countering these limitations is Romania's implementation of policies to protect its resources and its relatively high productivity of their usage. The country has substantial fuel and mineral deposits (including oil, gas, lignite, iron ore, copper, bauxite, manganese, lead, and zinc), which now include shale gas as well as hydropower and wind power resources. These local energy sources contribute to energy security and protect Romania's economy from global energy price shocks. The country also benefits from good quality agricultural land and substantial forest resources.

Agricultural land in Romania is a valuable resource, but agricultural productivity and incomes compare poorly with the EU. Agricultural land occupies near 60 percent of the country's area, and almost two-thirds of it is arable. However, Romania's agriculture sector today is highly inefficient: a sector with almost 30 percent of employment accounts for five percent of GDP, resulting in the lowest farm labor productivity and the lowest agricultural incomes in the EU.[8] Low productivity of agriculture in Romania is reflected in its cereal yields, which are significantly below those in other EU countries. While Romania produces 2.8 tons of cereal per hectare, the EU's average production is 5.0 tons per hectare, and top EU producers are at 7.2 tons per hectare (Germany) and 6.1 tons per hectare (Denmark). The direct reason for inefficiency is land fragmentation and the prevalence of subsistence farming. Reviving agriculture will require significant investment and policy measures to support rehabilitated irrigation and modern farming practices. Expanded irrigation will in turn create additional pressures on Romania's limited water resources. Romania's water withdrawals are relatively low, at three percent of available water used each year. However, Romania's water resources are far from being abundant: their level of 1,969 m^3 per capita is only slightly above the international benchmark for water stress of 1,700 m^3 per capita.[9]

Romania has significant forest land resources, and forest loss is low. Romania's forest covers more than one-quarter of its land area, creating a substantial natural asset (although that share stands below the EU average of 38 percent). Forest loss in Romania averaged a low four percent of forest stock over the period 2000–2010, significantly below the EU average of ten percent and below the comparator sample average of 5.4 percent. The annual allowable cut is 22 million hectares, but

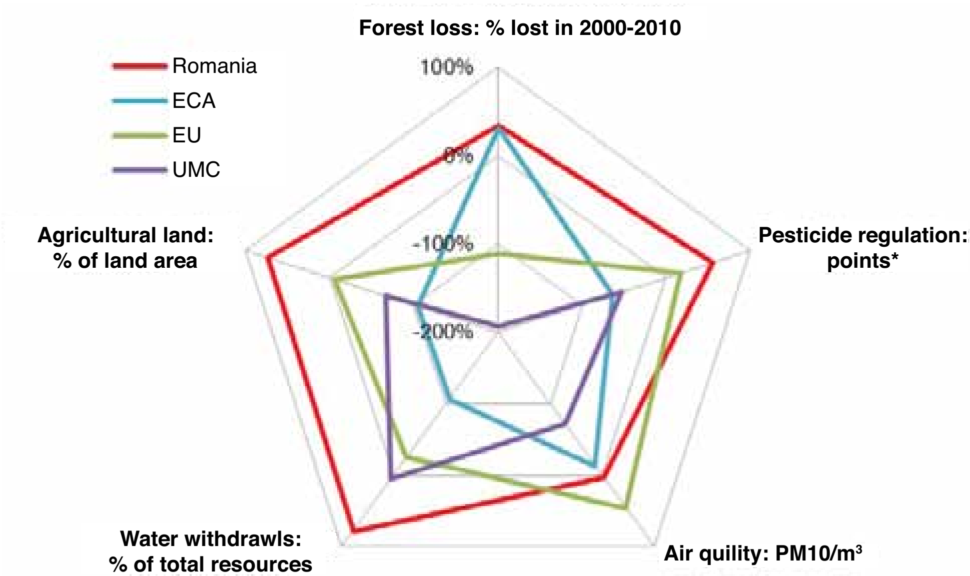
7. Romania's air pollution is better than ECA or UMC averages but worse than the EU average. PM_{10} is the concentration in urban air of suspended particulates less than 10 microns in diameter that are capable of penetrating deep into the respiratory tract and causing significant health damage.

8. In addition, Romania's performance is below the EU average in pesticide regulation, an indicator of damage to the rural environment.

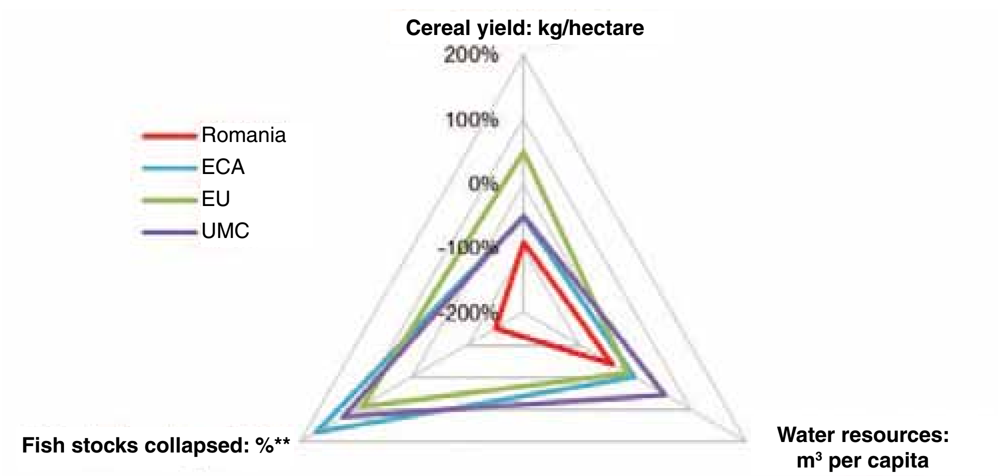
9. See Chapter 7 (Agriculture) and Agriculture Sector Technical Report. See Chapter 6 (Water) and Water Sector Technical Report.

FIGURE 1.3. Natural resource endowment and productive use of natural resources reveals contrasts within Romania's green performance

a. Romania's strengths in 'how green'



b. Romania's vulnerabilities in 'how green'



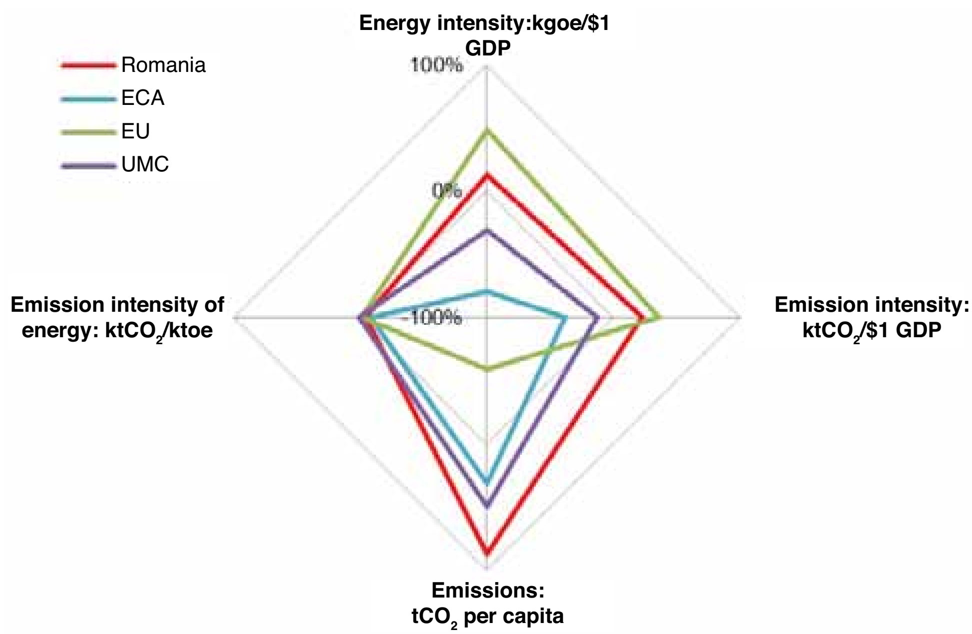
Notes: How to read the chart: the higher the indicator value, the better the outcome with respect to green growth. Data rescaling makes indicators measured in different units comparable, and adjustment of the data sign (+, –) is made to reflect the interpretation of the indicator. ECA is Eastern Europe and Central Asia, a World Bank regional country group (see Acronyms and Abbreviations for the full country list); UMC is upper middle-income countries, a World Bank global country group by income, which includes Romania. *Points for pesticide regulation reflect whether a country has signed and is implementing a main pesticide agreement, the Stockholm Convention. The country receives 2 points if a pesticide was banned and 1 point if its usage was limited. Pesticides increase production, but damage ecosystems and are a human health hazard. **% fish stocks collapsed is the percentage of species fished beyond sustainable levels.
Sources: World Bank databases; Columbia-Yale Environmental Performance Index. Green Growth Benchmarking Technical Report.

actual forest cuts are much lower: in 2013, they amounted to 19 million hectares, or 85 percent of the annual allowable cut, due to issues with accessibility.[10]

Romania's production has high GHG emissions-intensity and high energy-intensity, but the country already faces obligations as a member of the EU to reduce its greenhouse gas emissions. The emissions intensity of Romania's economy and its energy intensity remain high compared to EU averages despite drastic improvements since the early 1990s.[11] In 2010, the emissions intensity of the Romanian economy was still 2.8 times the EU average and 2.1 times the OECD average. The emissions intensity of energy in Romania is driven by the structure of power generation: while the country has a relatively large share of low-carbon generation, ranking fourteenth in the EU in its share of zero-carbon generation (including hydro, wind, solar and nuclear) and thirteenth according to the share of renewable generation, fossil sources still dominate its electricity production. Currently, the energy sector in the country is responsible for near 60 percent of emissions and is, therefore, a critical sector for mitigation.[12] With the EU's current, imminent, and prospective targets for emissions reduction that will progressively tighten requirements for reducing carbon, Romania needs to make substantial investments, especially in the energy sector to advance mitigation of greenhouse gases. (See Figure 1.4.)[13]

FIGURE 1.4. Romania's energy and emissions intensities need to improve further

Indicators of energy and emissions intensity



Note: How to read the chart: the higher the indicator value, the better the outcome with respect to green growth. Data rescaling makes indicators measured in different units comparable, and adjustment of the data sign (+, –) is made to reflect the interpretation of the indicator. ECA is Eastern Europe and Central Asia, a World Bank regional country group (see Acronyms and Abbreviations for the full country list); UMC is upper middle-income countries, a World Bank global country group by income, which includes Romania. kgoe is kilograms of oil equivalent. $ktCO_2$ is thousand metric tons of carbon dioxide. tCO_2 is metric tons of carbon dioxide. ktoe is thousand metric tons of oil equivalent.
Sources: World Bank databases. Green Growth Benchmarking Technical Report.

10. See Chapter 8 (Forestry) and Forestry Sector Technical Report.

11. The statistical definition of the energy sector used here is based on the standard International Energy Agency/Intergovernmental Panel on Climate Change definition and includes electricity and heat production and energy sector own-use.

12. The energy sector share of Romania's emissions excludes LULUCF (land use, land use change, and forests).

13. See Chapter 2 on Romania's mitigation obligations and Chapter 3 (Energy).

BOX 1.1. Measuring vulnerability to climate change

An aggregate index of vulnerability combining indicators of exposure, sensitivity, and adaptive capacity

The World Bank adaptation index is designed to support adaptation decision-making. The index is designed to focus on reducing vulnerability to the changing climate. Vulnerability is measured using three sub-indices: exposure, sensitivity and adaptive capacity. Exposure and sensitivity reflect potential impact of climate change (physical, economic, and societal), while the ability to react effectively depends on adaptive capacity.

Exposure to climate change is the extent of climate variability projected for 2070–2100 relative to the variability observed in the recent past (1961–1990). Climate variability is measured based on the number of hot, dry and wet years, summers, and winters.

Sensitivity to climate change is measured based on indicators likely to increase the impact of climate shocks. These include the level of water stress (renewable water resources per capita), the extent of air pollution (PM_{10}); the importance of agriculture in the economy (share of employment and value added); the exposure of the power sector to climatic risks (share of electricity generated by hydroelectric plants); the exposure of network infrastructure to climate change including extreme events (logistics index or index of overall quality of transport infrastructure); and the share of population under 5 (a measure of demographic/social flexibility of the society).

Adaptive capacity is a function of organizational skills, access to and ability to use information, and access to financing. It is measured by the Gini coefficient (income inequality), GDP per capita, and institutional adaptive capacity reflected in governance indicators.

Sources: Green Growth Benchmarking Technical Report. The definitions and many of the indicators used here replicate those proposed in Fay, et al., eds. 2009. *Adapting to Climate Change in Eastern Europe and Central Asia*. Washington, DC: World Bank. The exposure index is from Baettig, et al. 2007. "A Climate Change Index: Where Climate Change May Be Most Prominent in the 21st Century." *Geophysical Research Letters*, Vol. 34, Issue 1. Washington, DC: American Geophysical Union.

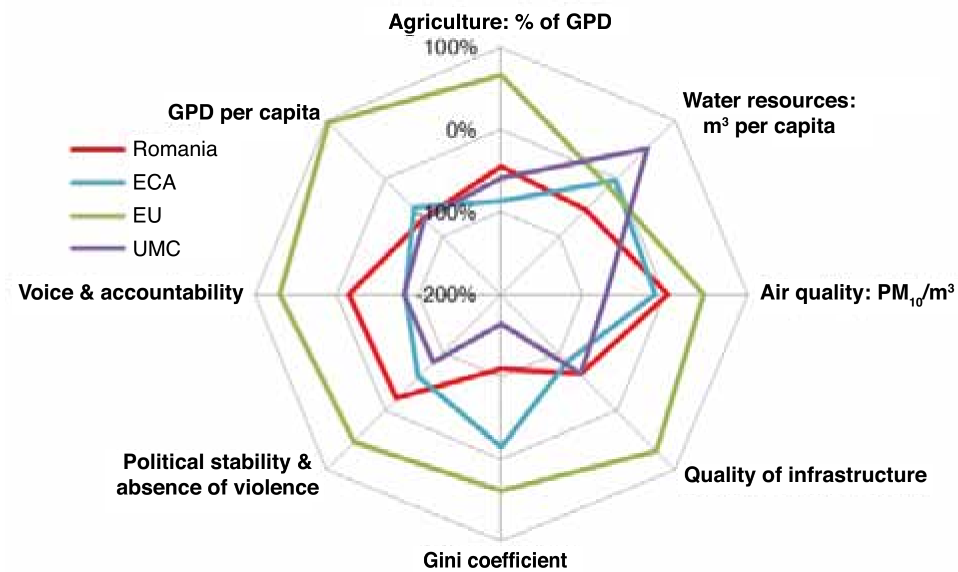
Adaptation to protect tomorrow's output from climate damage is also important for Romania, a country more vulnerable to climate change than other EU countries. According to the adaptation index (see Box 1.1), although its exposure (or projected climate variability for future decades) is average,[14] the country has higher sensitivity to climate shocks because of current characteristics such as limited water availability, the importance of agriculture, and the susceptibility of infrastructure and the power sector. Romania's weakest point on adaptation, though, is its adaptive capacity or ability to address climate threats, which requires organizational skills, access to and ability to use information, and access to financing. In particular, Romania's climate change sensitivity is reflected in the large share of agriculture in its economy. Romania has one of the highest shares of rural population and of agricultural employment within the EU: 45 percent of the total population is rural (compared to 26 percent EU-wide), and agricultural employment constitutes near 30 percent of total employment (compared to five percent across the EU). This dependence on a weather-sensitive economic sector raises the likely economic impact of a worsening climate. Romania's sensitivity to climate compared to the EU is also indicated by air pollution (with the 6th worst PM_{10} levels in the EU) which worsens the health impact of heat waves as well as relatively low water resources per capita (with a level 2.3 times below the EU average). Romania's water resources are already limited, leaving the country sensitive to the reduced water availability coming with higher temperatures and increased evaporation in future decades. In addition, Romania's index of the overall quality of transport infrastructure is significantly below that of the EU, and infrastructure in poor condition is more likely to break down as a result of extreme weather.[15] (See Figure 1.5.)

14. See Chapter 2 for new projections of future climate for Romania.

15. Overall quality of infrastructure measures the susceptibility of network infrastructure to climate change including extreme events. It includes quality of ports, roads, railroads, and information networks.

FIGURE 1.5. Romania needs to reduce its vulnerability to climate change

Indicators of vulnerability to climate change (sensitivity and adaptive capacity)



Notes: How to read the chart: the higher the indicator value, the better the outcome with respect to green growth. Data rescaling makes indicators measured in different units comparable, and adjustment of the data sign (+, –) is made to reflect the interpretation of the indicator. ECA is Eastern Europe and Central Asia, a World Bank regional country group (see Acronyms and Abbreviations for the full country list); UMC is upper middle-income countries, a World Bank global country group by income, which includes Romania. The Gini coefficient is a measure of statistical dispersion of income and is the most commonly used measure of inequality.

Sources: World Bank databases including Worldwide Governance Indicators. Green Growth Benchmarking Technical Report.

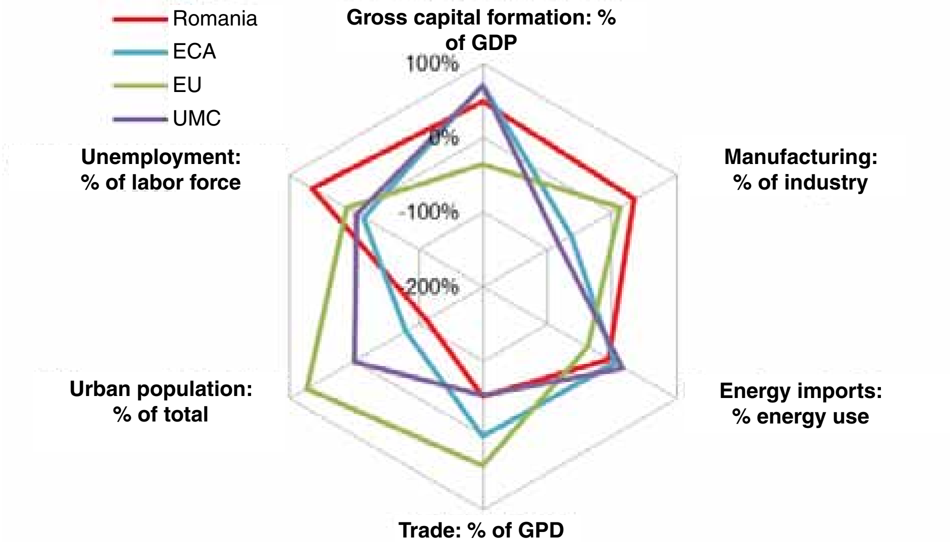
Romania's adaptive capacity—the ability to react effectively to climate change—is weaker than in other EU countries. Financing adaptation requires resources, and a country's overall wealth (GDP per capita) and its distribution (measured by the Gini coefficient) provides an indication of whether resources are available overall and accessible by households and firms across the country. With the second lowest GDP per capita in the EU and the highest inequality, Romania is not strong on either count compared to its European neighbors. In addition, Romania's institutional capacity is below that of the comparator countries: voice and accountability is estimated to be the lowest in the EU, political stability and absence of violence third from the bottom, and the measure of aggregate governance quality is second from the bottom. (See Figure 1.5.)

Going Green: Structure of the Economy and Labor Market

Romania's strengths in 'going green' include reasonably high although variable capital mobility. Romania has a high level of investment in fixed assets (gross capital formation), a high share of manufacturing in industry, and a moderate share of energy imports in energy use. On all three indicators, Romania significantly outperforms the EU average, although the significant fluctuations year to year in investment and manufacturing moderate the positive assessment of Romania. The current level of gross capital formation (reflecting capital mobility) is 23 percent of GDP, while the EU averages about 19 percent. During 1999–2013, gross capital formation fluctuated between 16 percent of GDP in 1999 and 31 percent in 2008, driven upwards by the construction boom of 2000–2008. Currently, investment is more diversified, flowing into construction, machinery, and transport equipment. A

FIGURE 1.6. Economic flexibility is backed by investments, low reliance on primary sectors, and low dependency on energy imports while weaknesses are in trade and rural issues

'Going green' key indicators: structure of the economy and labor market



Notes: How to read the chart: the higher the indicator value, the better the outcome with respect to green growth. Data rescaling makes indicators measured in different units comparable, and adjustment of the data sign (+, –) is made to reflect the interpretation of the indicator. ECA is Eastern Europe and Central Asia, a World Bank regional country group (see Acronyms and Abbreviations for the full country list); UMC is upper middle-income countries, a World Bank global country group by income, which includes Romania. Gross capital formation consists of outlays on additions to the fixed assets of the economy plus net changes in the level of inventories.
Sources: World Bank databases; Columbia-Yale Environmental Performance Index. Green Growth Benchmarking Technical Report.

less successful area is investment in infrastructure, which remains inefficient and has led to Romania's bottom rating within the EU on infrastructure quality.[16] (See Figure 1.6.)

Another strength is Romania's relatively high share of manufacturing in industry, indicating more flexibility. Manufacturing and services have greater flexibility than agriculture, because of their exposure to international competition and, thus, a higher potential for technological progress. Likewise, within industry, manufacturing firms have a stronger capacity to adjust to shocks by switching to new technologies than non-manufacturing (or primary) industrial firms such as mining and quarrying, construction, and energy. Such flexibility derives from manufacturing's greater sensitivity to global price competition due to easier product substitution. With a share of manufacturing in industry six percent above that of the EU average and exceeding that of ECA by one-third, Romania has a clear advantage in 'going green.'

A third area of strength in 'going green' is Romania's good energy security. The country has a moderate share of energy imports in energy use, supported by its indigenous energy resources. In particular, Romania is endowed with renewable resources, including wind, hydro, and biomass, as well as with fossil fuels—lignite, oil, and gas. In addition, one-fifth of its electricity generation comes from nuclear generation, further enhancing energy security. The level of energy imports is an important

16. An important aspect of this issue is the instability of priorities over time for public investment, which represents almost 20 percent of total investment (or five percent of GDP). Ensuring efficient investments in public infrastructure is a key challenge for the Romanian economy. See European Commission. 2015. "European Economy: Macroeconomic Imbalances. Country Report—Romania 2015," *Occasional Papers* 223. Brussels: EC.

indicator of economic flexibility because of the instability of world energy prices. An economy that is highly dependent on energy imports is continuously exposed to energy price shocks, which can be quite costly for both public and private sectors and disruptive overall for the economy.[17]

By contrast, Romania's weaknesses in 'going green' include limited openness of the economy. Openness of the economy to trade (as measured by the ratio of trade to GDP) promotes global competition and increases the likelihood of new technology transfer and absorption. Imports, and especially imports of investment goods, support modernization of capital assets and thereby increase the efficiency of production. However, according to 'going green' data, the share of trade in GDP for Romania is one-third lower than the EU average and one-fifth below the ECA average. However, strong export growth in recent years points to gradual improvement. Formerly unsustainable current-account deficits have been corrected and are expected to remain contained. The issues that still need to be resolved to support export growth are limited public administration capacity and an unstable tax policy.[18]

Another key weakness in 'going green' is insufficient labor mobility and other flaws in labor markets. While Romania's unemployment rate is reasonably low at five to seven percent, the official rate disguises a large informal sector (especially in rural areas), hidden unemployment and underemployment (in urban areas), generally low labor market participation, and labor market rigidity driven by guaranteed jobs in the public sector. Labor market participation in Romania is 59 percent, near the low end of the range in the EU. Rural population constitutes 45 percent of the total, but rural employment accounts only for 29 percent of total employment. Yet the official rural unemployment rate does not differ from the national rate, indicating very high informal rural employment and a very low participation rate in formal labor markets, which is consistent with the predominance of subsistence farming. The relatively low level of urbanization in Romania and the large share of employment in agriculture also indicate low labor mobility. However, labor mobility is likely to increase in future decades as agriculture is transformed by the aggregation of very small farms into larger commercial enterprises, driven by aging of the rural population and out-migration.[19]

Romania's business environment regulation remains too restrictive to support 'going green.' Romania ranks 25th of 27 EU countries in the restrictiveness of its regulatory environment, measured as the degree to which domestic policies restrict or promote competition in a recent OECD survey. Romania outperforms only Greece and Slovenia. The latest scores for Romania shows the country fares poorly in comparison with the EU in: state control (the extent to which the state owns, controls, or is involved in business), public ownership (state involvement in or control of business and preferential treatment of state enterprises), and administrative burdens on start-ups. Within those areas, Romania has weak governance of state-owned enterprises, high barriers to entrepreneurship, and high regulatory barriers in transport. On the other hand, Romania performs well in other regulatory areas: it has low barriers to trade and investment and low regulatory barriers in the energy and communications sectors.[20]

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17. See Chapter 3 (Energy).

18. European Commission. 2015. "European Economy: Macroeconomic Imbalances. Country Report—Romania 2015," *Occasional Papers* 223. Brussels: EC.

19. See Chapter 7 (Agriculture).

20. The OECD's Product Market Regulation (PMR) indicator study on regulatory structures and policies collects data through a questionnaire filled out by governments. The latest (2013) questionnaire had 1,400 questions on economy-wide or industry-specific regulations. The questions can either be answered with numeric values or by selecting an option from a menu. The survey does not include perception-based questions. From Koske, et al. 2015. "The 2013 Update of the OECD's Database on Product Market Regulation: Policy Insights for OECD and Non-OECD Countries." *OECD Economics Department Working Papers*, No. 1200. OECD Publishing, Brussels.

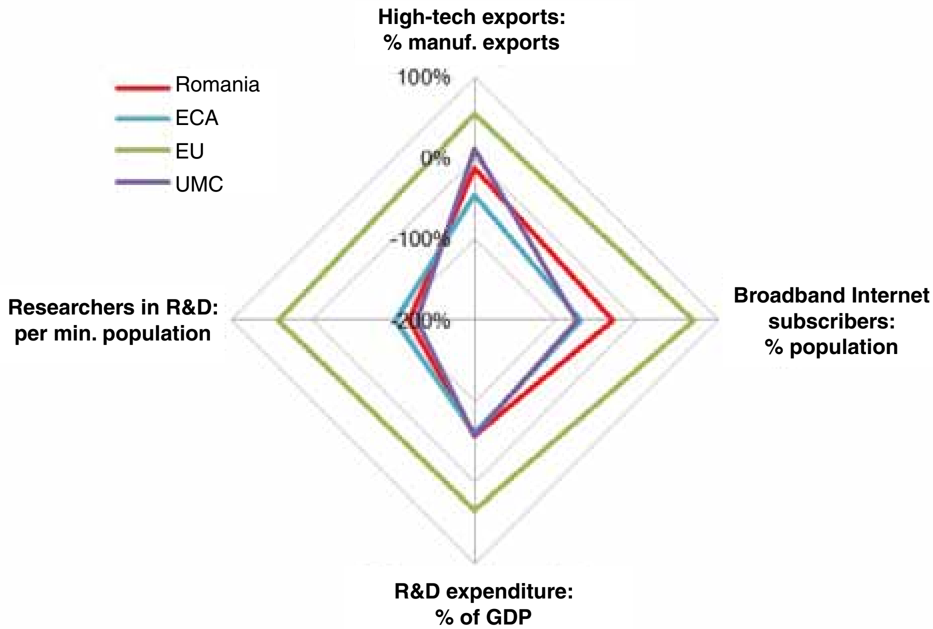
The low urbanization rate in Romania is another indicator of insufficient labor flexibility, reflecting inadequate growth of formal jobs in urban areas. The urban labor market also suffers from certain inefficiencies, a result of a large and rigid state-owned enterprise sector with guaranteed employment; a high level of emigration of the working age population over the past 20 years out of Romania, especially those with skills; an unsupportive business environment with one of the highest costs of opening, operating and closing a company in Europe; and a very limited supply of labor with adequate and modern skills. While the overall unemployment rate is low, the level of joblessness is much higher for the youngest working age group, those 15 to 24 years of age, and especially for young women. In 2009, about 20 percent of young women and 15 percent of young men were not in employment, education, or training; and these numbers increased in recent years. Higher unemployment and lower labor market participation is also a factor for women aged 25–49 and both men and women aged 55–64. A further challenge is inadequate skills of the workforce. Finding employees with appropriate skills is one of the three biggest concerns about doing business in Romania. The quality of education is low, and students often graduate without the skills required in a modern economy. The need to improve skills and education, especially those of children, to the levels typical for EU countries, is recognized by the Government: the National Education Law of 2011 strongly supports progress in educational outcomes.[21]

Inefficiency of the labor market is a remaining weakness of the Romanian economy in the context of 'going green.' Labor productivity started to improve only recently, including cost competitiveness. Non-cost competitiveness is still capped by low investment and innovation, as well as by the business environment. Labor demand and job creation remain subdued. The job vacancy rate remains

21. World Bank. 2013. *Romania Country Economic Memorandum: Reviving Romania's Growth and Convergence Challenges and Opportunities.* Washington DC: World Bank.

FIGURE 1.7. Romania significantly lags behind the EU in innovation and knowledge economy

'Riding the green wave' key indicators: innovation and knowledge economy



Notes: How to read the chart: the higher the indicator value, the better the outcome with respect to green growth. Data rescaling makes indicators measured in different units comparable, and adjustment of the data sign (+, –) is made to reflect the interpretation of the indicator. ECA is Eastern Europe and Central Asia, a World Bank regional country group (see Acronyms and Abbreviations for the full country list); UMC is upper middle-income countries, a World Bank global country group by income, which includes Romania. R&D is research and development.
Sources: World Bank databases. Green Growth Benchmarking Technical Report.

low, and the ratio of unemployed to hirings is the fifth highest in the EU. The lack of job opportunities forces people into inactivity or informality and contributes to migration of both qualified and unqualified labor.[22] Instead, Romania needs to aim at enhanced labor market flexibility and higher levels of human capital so that during the green growth transition, labor resources can easily move to new, more technologically-advanced jobs. Urban concentration facilitates the needed labor mobility, and, more importantly for Romania's situation, a large rural population with non-transferable skills remains a barrier to a green transition.

Riding the Green Wave: Innovation and the Knowledge Economy

Romania does not appear ready to take advantage of new green opportunities: various indicators of innovation and the knowledge economy reveal a need for improvement. Compared to the EU, Romania significantly underperforms on indicators such as broadband subscribers (as a share of the population), percentage of researchers in the population, research and development (R&D) expenditures (as a share of GDP), and high-tech goods in manufacturing exports. Romania's performance looks better when compared with all of ECA average, standing above average according to the same indicators (Figure 1.7). Against all the comparator countries, Romania is placed in the middle of the ranking by two indicators: patent applications (per million population) and share of green and 'close-to-green' exports in total exports. The polarization of performance of the EU countries and the non-EU ECA countries on innovation and the knowledge economy makes it difficult to analyze

22. European Commission. 2015. "European Economy: Macroeconomic Imbalances. Country Report—Romania 2015," *Occasional Papers* 223. Brussels: EC.

this particular area of benchmarking using the entire comparator list. Since Romania is part of the EU and convergence with the EU is expected on a wide range of performance indicators, including those reflecting innovation, it is reasonable to compare Romania in this area with the EU alone.

Romania is ranked last in the EU by the European Commission's Innovation Union Scoreboard (IUS). Research has been consistently underfunded for twenty years or more, which, together with the 'brain drain' caused by high rates of emigration of highly-skilled workers, has generated a crisis in Romania's research community. R&D expenditures currently constitute only 0.6 percent of GDP, compared with 1.5 percent in the EU on average and with top spending levels at 3.7 percent in Sweden, 3.0 percent in Switzerland and 2.9 percent in Denmark. As a result, Romania's gap with most EU countries in innovation has been increasing; and in 2014, Romania was the worst performer on the IUS innovation index in the EU. Most individual IUS innovation indicators (that together constitute the innovation index) place Romania either last or second to last in the EU. This result holds across indicators of research and innovation policy, both public and private R&D spending, and patent applications.[23,24]

23. From European Commission. 2014. *Innovation Union Scoreboard 2014*. Directorate-General for Enterprise and Industry. Brussels: EC.

24. Wagner, et al. 2014. "Romania Report." *SGI: Sustainable Governance Indicators*. Gutersloh, Germany: Bertelsmann Stiftung.

Even against a wider set of countries, Romania's innovation performance stands in need of improvement. According to the Global Innovation Index, Romania ranks 55th within 143 countries evaluated on their innovation capabilities and results. Romania scores particularly poorly on innovation outputs such as information and communications technology and on capabilities deemed critical to innovation such as intensity of local competition; net inflows of foreign direct investment; ease of paying taxes; market capitalization; government effectiveness; and ease of resolving insolvency. Romania scored well on other aspects that enable innovation: ease of getting credit; cultural and creative goods and services exports; and high and medium high-tech manufactures. Based on Romania's income level, a higher overall ranking would be expected, confirming that innovation and readiness for the knowledge economy are areas of particular weakness.[25]

CONCLUSIONS AND RECOMMENDATIONS

This benchmarking exercise identified a selected set of issues within the broad green growth agenda on which Romania should focus as it considers how to move onto a greener growth path. Mapping Romania against comparator countries and country groups allows policymakers to consider the country's relative standing on the three aspects of measuring 'green-ness': (i) How green?, (ii) Going green, and (iii) Riding a green wave. Benchmarking is, of course, only a starting point, making use of existing data to highlight in a quick fashion the key aspects for a particular country that merit more serious analysis and consideration. The subsequent chapters in this report take up the issues identified here as critical to a greener growth path, in particular those linked to mitigation and adaptation challenges which have not been elsewhere assessed. The issues identified for Romania's 'going green' and 'riding a green wave' are, in general, closely linked to structural reforms and investments that support growth overall and have been the focus of much other analysis.

Romania has significant natural resources, and the country needs to improve the efficiency of usage of its land resources, in particular in agriculture and forestry. As the Romanian government considers implementation of green growth and low carbon measures, policymakers need to think when drawing down natural capital in the interest of economic growth is a wise tradeoff and when it is not. Romania is developing new sustainable energy sources such as wind energy, further bolstering its relatively high and increasing share of non-emitting and renewable generation. Substantial investments will be needed in the energy supply and in energy efficiency. This approach to energy will, over time, assist Romania in improving its current high emissions and energy intensities and also contribute to (global) sustainability by mitigating GHG emissions. For water resources, Romania needs to prepare for a hotter, dryer future with higher water demand. A key part of improved management of water resources will be more sustainable and productive use of Romania's land resources. Agriculture has very low productivity, a high share of subsistence farms, and low living standards compared to urban areas. Increasing sector efficiency will require significant investment and policy reforms aimed at rehabilitation of irrigation and modernization of farming practices. These challenges will be heightened by climate change in coming decades. Lastly, in forestry, Romania's vast and high quality

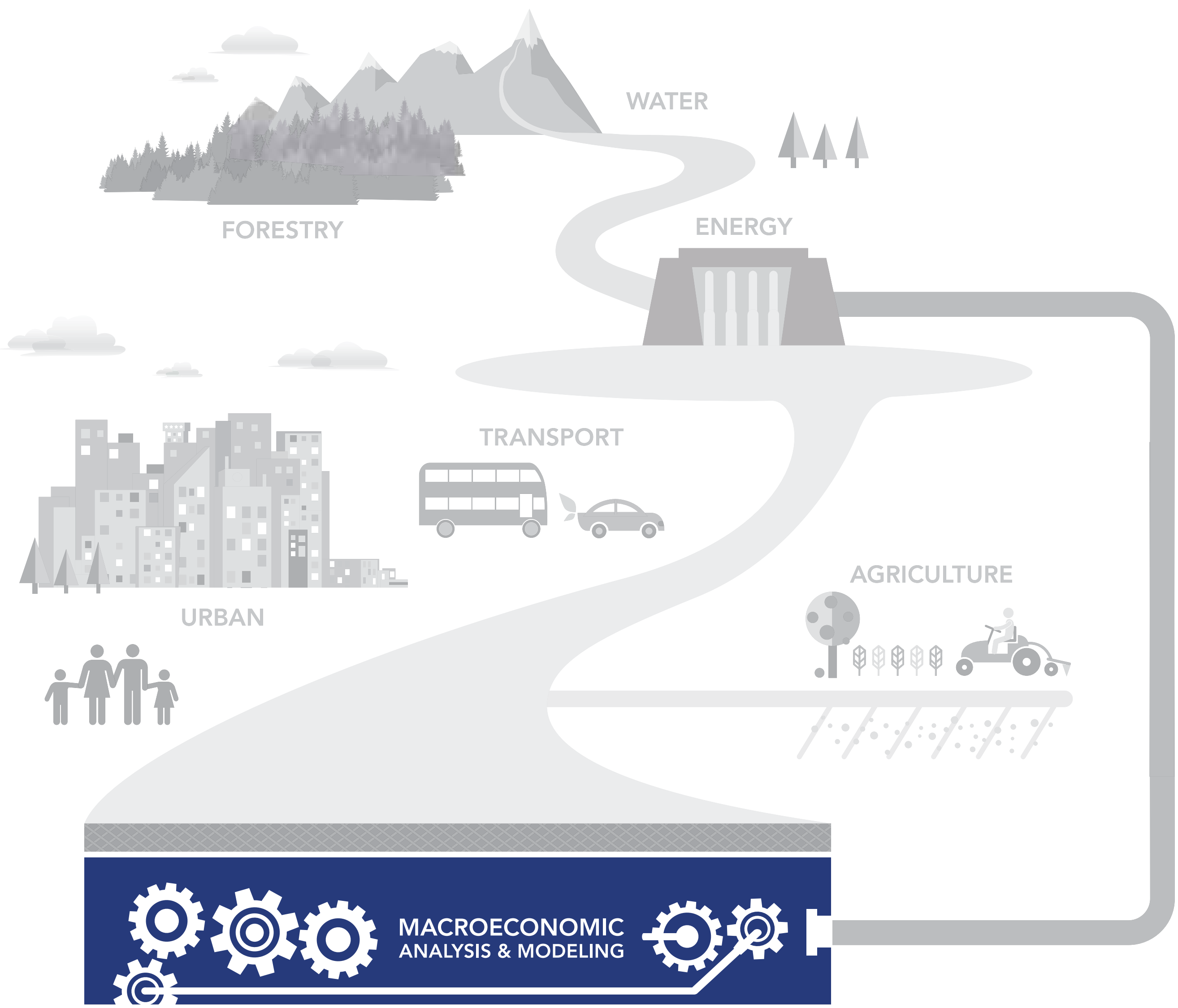
25. The Global Innovation Index (GII) 2014 is the 7th publication by Cornell University, INSEAD, and the World Intellectual Property Organization (WIPO, an agency of the United Nations). The Index ranks 143 world economies, accounting for 93 percent of the world's population and 98 percent of the world's GDP, in innovation capabilities and results. The GII is the average of two sub-indices: Input Sub-Index and Output Sub-Index. The Input Sub-Index evaluates five elements of the economy that enable innovative activities: Institutions; Human capital and research; Infrastructure; Market sophistication; and Business sophistication. The Output Sub-Index captures evidence of innovation: Knowledge and technology outputs; and Creative outputs. Indices are composed of 81 individual indicators. From www.globalinnovationindex.org.

forests are being negatively affected by inefficient forest management. Improvement in this area will require only modest expenditures but coherent institutional reforms in forestry. Together, these measures can allow forests to provide valuable mitigation and adaptation services to rural areas. Across all of Romania's natural resources, substantial investments are needed, with the heaviest financing needs in the energy sector to advance mitigation of greenhouse gases.[26]

A greener world heralds an economic transition, and successful transformation will depend on the flexibility of a country's economy and readiness for green opportunities. For Romania, the critical issues to achieve the level of economic flexibility needed for a green transition are trade openness via strengthened competitiveness and higher export growth along with improved labor mobility. Romania needs to address the issue of a restrictive regulatory environment by countering current high barriers for start-ups, excessive state control over businesses, and a large public sector with preferential treatment of state-owned enterprises. Although overall levels of capital formation have been strong, a weak area within investment in fixed assets is investment in infrastructure where improvement is still needed. The country would also benefit from addressing inefficiencies in its labor market, which are reflected in a high share of the informal sector (specifically in rural areas), hidden unemployment and underemployment (in urban areas), generally low labor market participation, labor market rigidity with guaranteed jobs in the public sector, and the inadequate level of skills and education of workers for a modern and green economy. A last challenge, and perhaps the most difficult, is in increasing connections to global knowledge and support of innovation, to bridge the gap with other European countries in access to modern communications and in support of scientific research. Research has been continuously underfunded and has suffered further from the long-term trend of emigration of highly-skilled workers. On the global level, Romania ranks well below what would be expected for development of its knowledge economy based on its income level.

As Romania moves towards implementation of green and low carbon actions, it should remain aware of the usefulness of ongoing reassessment of its green path while coordinating greening into its overall growth path. Beyond the one-time exercise summarized in this chapter, a country pursuing green growth might find occasional benchmarking of value to identify emerging green issues. It would likely be most useful if supplemented with a locally-designed results framework, populated with a combination of internationally-comparable and locally-developed indicators, to monitor progress on current greening efforts and to support the implementation of its national strategies and plans related to climate action, resource use, and sustainability. The newer dimensions of the green growth challenge—mitigation, adaptation, and innovation and green jobs—will require the most attention. Mitigation and adaptation are taken up in the subsequent chapters of this report. The issues identified for Romania's 'going green' and 'riding a green wave'—key to the innovation and green jobs aspect of green growth—are mostly linked to structural reforms and investments that support growth overall and have been the focus of much other analysis. Moreover, most of the shortcomings identified here are well-known and being addressed as part of the country's overall growth agenda. The country continues to implement policy and structural reforms that will lead to more vibrant as well as more sustainable growth, especially as its membership in the EU both limits its policy choices and aligns them with greener paths. With a growth path already shaped by the requirements of EU membership, this first glance at green growth for Romania seems to indicate much complementarity between the short term and the long term, with relatively little conflict between policies and structural reforms that will lead to more vibrant as well as more sustainable growth.

26. See Chapters 3 (Energy), 6 (Water), 7 (Agriculture), and 8 (Forestry).


WATER
FORESTRY
ENERGY
TRANSPORT
URBAN
AGRICULTURE
MACROECONOMIC
ANALYSIS & MODELING

CHAPTER 2

Where Is Romania Heading? Forecasting Economic Development and Green Growth

CHAPTER SUMMARY

The focus for Romania's low carbon green growth path is to implement mitigation actions and undertake needed adaptation while preserving growth and employment. Thinking through this path at the macroeconomic level can be simplified into three main scenarios for analyzing the impact of green interventions. The necessary horizon to assess the costs and impact of a new growth path is long, and 2050 is chosen as the endpoint for assessment. The backbone of the analysis is macroeconomic modeling, which provides both a consistent foundation for sector analysis and an overarching analysis of impacts economy-wide.

Romania's recent history of economic performance provides important clues about future directions but climate action will become more prominent, requiring both mitigation and adaptation measures. The country grew faster than the rest of Europe during 2000 to 2008 and recovered quickly from the international financial crisis. Meanwhile, Romania witnessed its greenhouse gas (GHG) emissions decline by almost one-third. Since Romania's economy does not yet match the typical pattern in the rest of the European Union (EU), the path to 2050 is likely to feature convergence towards Europe in income levels and economic structure. The path is also likely to include intensified climate action. Although the country's GHG emission levels are not large on a global scale, Romania faces current, imminent, and prospective limits on emissions of GHGs. Reducing these emissions will both require government action and affect Romania's growth path. At the same time, newly-developed climate scenarios show rising temperatures and falling precipitation in future decades, increasing the likelihood of water shortages which will harm agriculture and other water users.

The baseline scenario for Romania's economy through 2050, generated by a newly-built macroeconomic model, indeed finds real incomes in Romania likely to converge towards European Union averages albeit at a modest pace. Growth, although above the EU average, is dampened by the ongoing decline in Romania's population and labor force. The story the sector level is of divergence, rather than convergence. Part of those developments are driven by compliance with the current '2020 climate and energy package' and participation in the EU's Emissions Trading System (ETS), which generate pressure to reduce energy intensity going forward. This baseline scenario constitutes a critical first phase of the analysis, serving as a benchmark for comparisons of economic outcomes before and after policy actions or investments.

A computable general equilibrium model was developed for Romania, in collaboration with local experts, designed to address the complex and overlapping elements of the EU's climate and energy policy framework. Drawing on the well-known GEM-E3 model, the ROM-E3 model is capable of quantifying the first and second round effects of energy and climate change policies and regulations related to multiple economic sectors as well as the feedback and spillover effects within Romania and across countries through the trade channel. The model has been applied to assess a Green and Super Green scenario against the baseline, which includes ongoing implementation of the EU's 2020 climate and energy package. The Green scenario imposes compliance with the main features of the EU 2030 Climate and Energy Policy Framework, while the Super Green assumes the Roadmap 2050 will be implemented. (Table 2.3).

Implementing the imminent EU 2030 climate framework imposes only modest costs on Romania's economy, but fulfilling the prospective EU Roadmap 2050 will impose a heavy burden. EU emissions trading allocates mitigation efficiently across EU member states via a uniform carbon price (the emissions allowance price that clears the ETS market) for power generation and energy-intensive industry while a package of national policies will aim to achieve the mitigation targets set for each EU member state for other sectors. Likely 2030 obligations will require cutting GHGs by 36 percent by 2030 compared with 2005 at an estimated cost of 1.1 percent of GDP overall, but with high variability across sectors. By contrast, meeting the EU's proposed 80 percent mitigation goal in 2050 would leave Romania's output an estimated four percent lower.

Policymakers should find this analysis of interest. The analysis recommends that the government be prepared to monitor the cross-sectoral impacts of the green transition, as labor and capital move across sectors. Policymakers should consider, within the boundaries set by EU rules, applying the rising revenues from the auctions of emissions allowances to support renewable energy deployment, energy efficiency projects and to reduce labor taxes, thereby reaping a small 'double dividend'. Further, Romania can gain through the inclusion of stronger equity considerations into EU-wide climate policy discussions. Lastly, the macroeconomic model constructed for this analysis remains available for further development and application by the government for current and future policy questions related to low carbon and green growth.

CHALLENGES FOR GREENER GROWTH

Overview

Although green growth can be a broad concept, the main concern for Romania is moving onto a low carbon growth path while addressing key adaptation deficits. The benchmarking exercise in Chapter 1 found that mitigation of greenhouse gas emissions and adaptation to a changing climate are key elements in a greener growth path for Romania. The country's high emissions and energy intensity of output need to be reversed to make strong progress on mitigation. Moreover, the country already has obligations on mitigation of greenhouse gas emissions as a member of the European Union (EU), and proposed and tentative future obligations further render mitigation action an

inevitable part of Romania's future. At the same time, moderate vulnerability to climate damages is worsened by current weaknesses in Romania's productive use of its land resources. Romania needs to understand possible climate damages and what adaptation actions are advisable as part of a greener future. The impacts on Romania's economy for the years to come, some negative and some positive, merit investigation. This chapter summarizes analysis from the application of a macroeconomic model to provide important insights about the achievement of the EU's proposal for climate action for 2030 and also for 2050 and the selection of key adaptation measures, as well as a framework for the sector analysis presented in subsequent chapters. The energy, transport, forestry, and urban analysis in subsequent chapters provides sector-level conclusions on mitigation options while the chapters on water, agriculture, and forestry provide conclusions on adaptation options.

To assess the costs and impact of a lower carbon and green growth path for Romania, economic developments over a long horizon (to 2050) need to be considered despite the uncertainty inherent in such scenarios. For climate mitigation actions, such as building power plants with cleaner fuels or improving energy efficiency through new building standards, the benefits of action will materialize over decades. For climate adaptation actions, the horizon must be at least as long. Climate damages for most countries become more significant 30 and 40 years into the future although the appropriate adaptive response may require action today. The horizon for the scenarios and analysis for Romania extends to 2050—40 years is just about long enough to consider long-lived infrastructure needed for either mitigation or adaptation. Thinking so far into the future is inevitably associated with large uncertainty; but sensitivity analysis around key assumptions, transparency in methodology, and close collaboration with the client and local experts can all act as counterweights.

Macroeconomic modeling constitutes the backbone of the analysis, providing a consistent picture of economic impact, taking into account domestic sectoral inter-linkages and international trade

flows. General equilibrium models set up a coherent economy-wide framework and allow economic decision making to be the outcome of decentralized optimization by producers and consumers. They simulate the functioning of a market economy, including markets for commodities, for labor, and for capital. They provide a detailed look at how changes in economic conditions are mediated through prices and markets while assuring that all economy-wide constraints are respected. They also enable quantitative examination of how shocks or policies move through the economy and influence its performance and structure. Dynamic processes can be captured, which is important if the time horizon of the modeling is long (as is required for low carbon and green growth analysis). The modeling emphasizes the key economic relationships within Romania and with the EU and the rest of the world. As such, the CGE (computable general equilibrium) model constitutes a backbone for the harmonization of the sectoral work in a consistent and rigorous manner, providing key economic variables needed for sector analysis while assessing multi-sectoral impacts of low carbon and green actions on growth, sectoral output, employment, and fiscal revenues and expenditures.

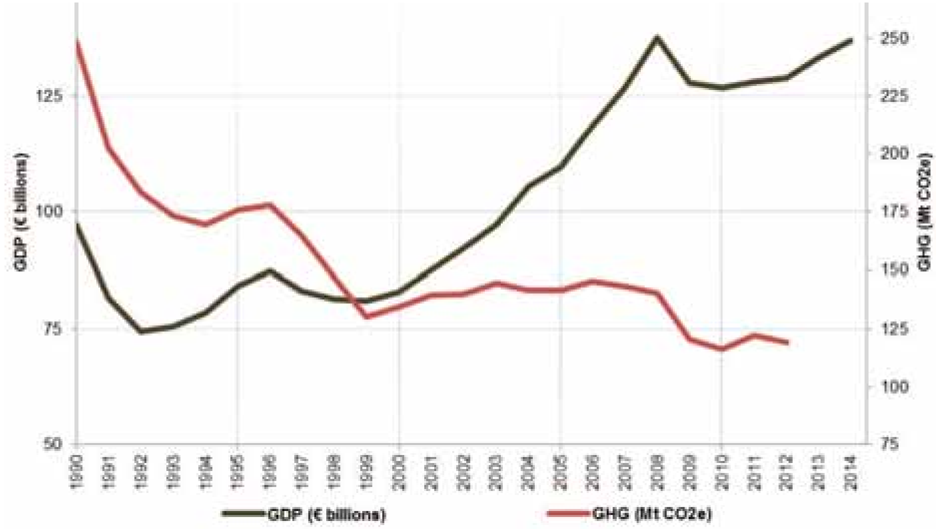
A baseline scenario serves as a benchmark for comparisons of economic outcomes before and after policy actions or investments—a hypothetical path that envisages what would happen under 'business-as-usual' or no policy change. Business-as-usual projections are often based on extrapolation of historical trends or adoption of steady-state GDP growth. The simplest of baselines would be a steady-state baseline, in which all physical quantities grow at an exogenous uniform rate while relative prices remain unchanged; this scenario would have the virtue of providing a transparent reference path for the evaluation of policy options. However, such a path is unrealistic, especially over a long time period, limiting the usefulness of the scenario results to policymakers, who need more realistic comparisons. For example, when a country decides on a target for mitigating greenhouse gases, the target is generally defined against a base year, as a certain percent reduction compared to that year. But such a definition provides little indication of the degree of challenge involved in meeting the target. What matters is the size of the reduction compared to the level of emissions in the target year, which lies in the future. This expected level is a matter for projections, determined by assumptions about the growth rate of emissions in the absence of additional policy—the business-as-usual emissions baseline. Faster expected growth translates to faster rising emissions, and the higher is the future emission level in the absence of climate policy, the more stringent are the effective reduction targets and, thus, the costs of abatement. (See Table 2.3 comparing the baseline scenario to the alternative low-carbon green scenarios used in this analysis).

Romania's Economy Today and Looking Ahead to 2050

Romania grew faster than the rest of Europe between 2000 and 2008, and from 2010 its economy bounced back following the international financial crisis. Per capita GDP (measured in purchasing power parity) rose from 26 to 47 percent of the EU average in the years preceding EU accession in 2007. Markets opened and institutions were reformed. Legal and institutional reforms were advanced through the process of adopting the *acquis communautaire*. Generous foreign direct investment and other financial inflows contributed to consumer demand, built up key industries, modernized wholesale trade, and spurred the movement of labor from low-productivity activities like agriculture towards high-productivity activities like manufacturing. Public and private investment in education pushed tertiary education enrollment from 12 to 23 percent. The income of the bottom 40 percent of the population grew by 5.5 percent on average during the 2000–2011 period, a pace slightly above the 4.8 percent growth in the income of all households and the 4.1 percent average growth. After plunging by near seven percent in 2009, growth had recovered by 2013, as robust industrial output

FIGURE 2.1. Romania's growth in the 2000s was strong while GHG emissions declined

GDP and GHG emissions, in billions of 2010 euros and Mt CO_2e, 1990–2014



Notes: GDP is in billions of euros at 2010 prices. GHG is in millions of metric tons of CO_2 equivalent.
Sources: GDP 1995–2014 from Eurostat: GDP 1990–1995 staff calculations from ESA 1995 data and ESA 2010 data. GHGs from European Environment Agency (via Eurostat).

and an abundant harvest led to double-digit export growth. GDP is expected to expand by more than three percent in 2015.[1,2] (See Figure 2.1).

Economic growth has been boosted since 2000 by the shift in output and employment toward more productive sectors. Romania has experienced a major change in allocation of workers—the proportion of the workforce in agriculture, which is comparatively unproductive, fell from 35 percent in 2002 to 26 percent by 2010. Workers tended to move to sectors that drove economic growth: between 2002 and 2010, the share of employment increased from four to nine percent of GDP in construction and from 16 to 21 percent of GDP in the wholesale/retail sector. These sectors continued to absorb labor through 2010 despite steep declines in output, and workers continued to leave agriculture. Between 2002 and 2010, labor reallocation contributed an average of about two percent a year to total growth; the rest was generated by increases in output per worker within sectors.[3]

Yet the structure of Romania's economy remains more concentrated in less productive and more energy-intensive sectors than the EU and the OECD[4] despite success in reducing greenhouse gas emissions. Comparing Romania's structure of value-added to other groups of countries, the

1. World Bank. 2013. A Country Economic Memorandum. Romania: Reviving Romania's Growth and Convergence Challenges and Opportunities. Available at: http://documents.worldbank.org/curated/en/2013/06/18028709/reviving-romanias-growth-convergence-challenges-opportunities-country-economic-memorandum

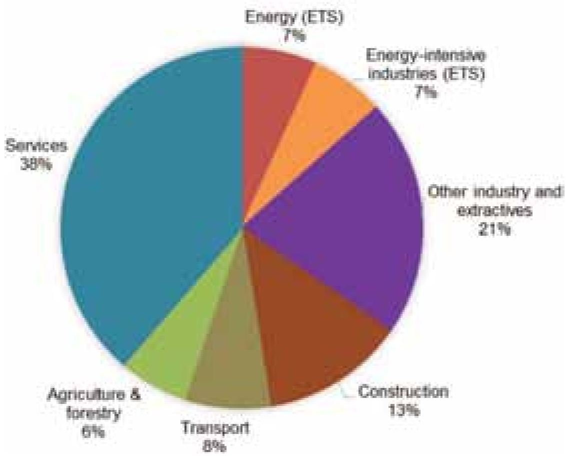
2. World Bank. 2015. Strengthening Recovery in Central and Eastern Europe—EU11 Regular Economic Report. July 2014.

3. World Bank. 2013. A Country Economic Memorandum. Romania: Reviving Romania's Growth and Convergence Challenges and Opportunities. Available at: http://documents.worldbank.org/curated/en/2013/06/18028709/reviving-romanias-growth-convergence-challenges-opportunities-country-economic-memorandum

4. The OECD is the Organization for Economic Cooperation and Development.

FIGURE 2.2. Services are not yet as important as is typical in the EU

Sector shares of production in Romania, 2010



Notes: Sectoral production includes value-added plus intermediate consumption. Energy (ETS) is oil refining and electricity supply, sectors included in the EU emission trading system (ETS). Energy-intensive industries (ETS) are ferrous metals, non-ferrous metals, chemical products, paper products, and non-metallic minerals, sectors included in the ETS. Other industry and extractives is coal, crude oil, gas extraction, gas, metal products, electrical goods, transport equipment, other equipment goods, and consumer goods industries. Transport: includes air, road, and rail for passenger and freight; note that air transport emissions are covered by the ETS.
Source: ROM-E3 model data.

biggest difference is the weight in total value-added of agriculture—almost double compared to other EU new member states and three times higher than the EU15.[5] The services sector (including both market and non-market services) is relatively small in Romania, below 40 percent of output while, for example, the EU15 has more than half of output from services. Production from energy-intensive sectors exceeds that of the OECD average by some 50 percent. (See Figure 2.2). Nevertheless, between the mid-1990s and the late 2000s, greenhouse gas emissions in Romania declined by almost one-third (see Figure 2.1). The country's success in mitigation was mainly driven by changes in the structure of output towards less polluting sectors as well as sectoral improvements in energy efficiency. Figure 2.3 decomposes the decline in emissions according to the well-known Kaya identity.[6] A decline in the carbon intensity of energy, from fuel switching away from fossil fuels, contributed to a lesser extent. These three factors fully offset the increase in emissions stemming from increased output. As a result, overall carbon dioxide emissions fell during 1995 to 2009 by almost over 40 million metric tons.

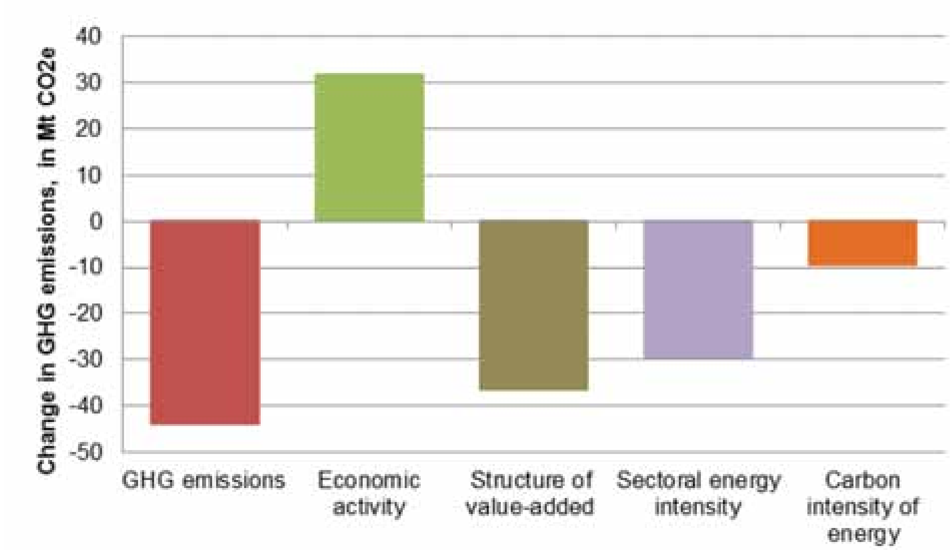
The path for Romania's economy to 2050 is likely to feature growing similarity in income levels and economic structure to the rest of Europe, i.e., convergence. Such a path continues the trends of the past two decades and the convergence processes observed across the EU. Since 1990, as noted above, Romania's economy has transformed its sectoral structure, moving strongly towards services, and it has become far less energy-intensive. Going forward, the shift away from agriculture

5. The EU15 are the 15 member states of the European Union before May 2004: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom.

6. CO_2 emissions = Population $\times \frac{GDP}{Population} \times \frac{Energy}{GDP} \times \frac{Co_2 \ Emissions}{Energy}$ Derived from Kaya, Yoichi, and Keiichi Yokobori (1997), *Environment, Energy, and Economy: Strategies for Sustainability.* Tokyo, Japan: United Nations University Press.

FIGURE 2.3. Romania's carbon emissions fell sharply in the past because of structural shifts

Decomposition of reduction in carbon dioxide emissions in Romania, 1995–2009



Notes: Decomposition uses the logarithmic mean Divisia index (LMDI) approach.
Source: Staff calculations based on World Input Output Database (WIOD) database, www.wiod.org.

and energy-intensive and polluting heavy industry towards lighter manufacturing and services should continue. Energy intensity should decrease in line with the shifting structure of the economy. Although there is no agreement over whether economic convergence of nations holds overall, the European Union has demonstrably fostered strong convergence among its members and also, to some extent, on candidate countries. The 'catch-up' hypothesis is driven by the assumption that productivity growth rates vary inversely with productivity levels. Then it follows that the convergence process stems from lower initial income levels, higher returns on capital, and substantial potential to improve labor participation and productivity, while the country benefits from a diffusion of global technological progress. Over a long forecasting period, such as the 40-year horizon used in this analysis, convergence is a convincing and practical approach to predicting what any individual economy might look like in the distant future.

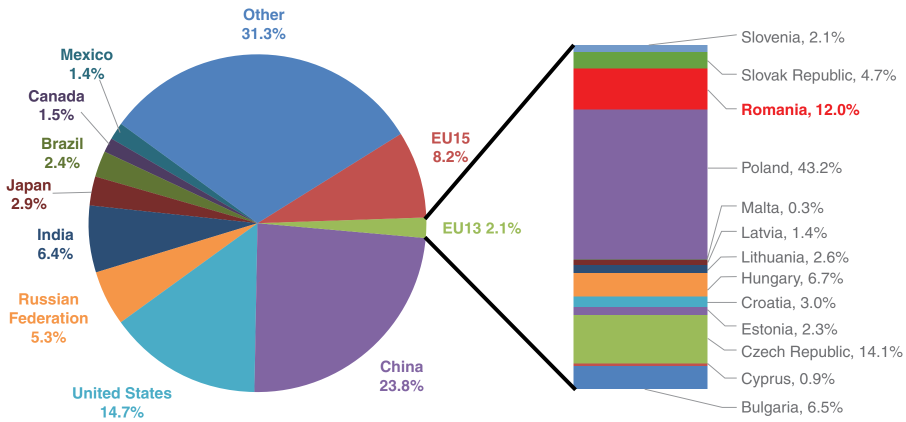
Romania's Mitigation Obligations

Romania contributes only marginally to the global carbon footprint with a share in global GHG emissions of less than one-half of one percent. (See Figure 2.4). The EU as a whole is responsible for about 13 percent of global emissions, while China and the US, the largest emitters, are responsible for almost 40 percent of global emissions between them. However, production in Romania is energy intensive, and energy used for each unit of output is the highest in Europe. The average energy intensity in the EU was 142 kilograms of oil equivalent (kgoe) per €1,000 in 2013, close to the world average, while Romania stands at 335.[7] However, irrespective of Romania's own carbon footprint, as a member of the European Union, it faces three sets of emissions mitigation obligations: one current; one imminent; and one prospective.

7. Energy intensity is measured as gross inland consumption of energy divided by GDP, or kgoe per €1000 of GDP at 2005 prices. Data is from Eurostat.

FIGURE 2.4. Romania provides a small contribution to world GHG emissions

Global GHG emissions by country, % of total



Notes: Total GHG emissions in 2010 (excluding land use, land use change, and forests) for carbon dioxide, methane, nitrous oxide, perfluorocarbons, hydrofluorocarbons, and sulphur hexafluoride, the six greenhouse gases named in the UN Framework Convention on Climate Change. EU13 are the 13 new EU member states: Bulgaria, Croatia, Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Romania, Slovakia, and Slovenia. EU15 are the 15 EU member states before May 2004: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, and the United Kingdom.
Source: World Development Indicators.

The '2020 climate and energy package' is under implementation until 2020. Approved in December 2008, the EU's current policies on GHG emissions require comprehensive action by EU members on overall emissions reduction across all sectors in the economy. The 2020 targets include a 20 percent reduction in emissions compared to 1990 levels (a 14 percent reduction compared to 2005); a 20 percent renewable energy target as a percent of gross final energy consumption, including a 10 percent share of biofuels in the transport fuel market; and a 20 percent indicative reduction in primary energy use compared to projected levels under a business-as-usual scenario, to be achieved through energy efficiency improvements. Large installations in energy-intensive sectors are covered by the EU-wide Emissions Trading System (ETS), a cap and trade arrangement. The overall target of –14 percent for emissions is further divided into a target of –21 percent for the ETS sectors and –10 percent for all other sectors (non-ETS). For the ETS sectors during 2013–2020, allowances are to decline by 1.74 percent each year. The non-ETS targets were translated into differential national targets varying by income level. Romania is under obligation for emissions from the non-ETS sectors to grow by no more than 19 percent relative to 2005. (See Box 2.1 for details of the ETS).[8]

The 2030 Climate and Energy Policy Framework was approved in October 2014. The new policy package proposes a binding target to reduce EU domestic greenhouse gas emissions by at least 40 percent below 1990 levels by 2030.[9] This target aims to ensure that the EU is on the cost-effective track towards meeting its objective of cutting emissions by at least 80 percent by 2050. In addition

8. As noted above, most of the comparisons for GHG reductions in this report are reported against 2005 levels because that is the year European emissions trading was established; thus, all practical rules and targets are formulated against 2005. 1990 is cited in the original broad policy statements because it is the EU's base year for the Kyoto Protocol and other international obligations.

9. The 2030 targets were reiterated in the EU's intended nationally determined contribution (INDC) submitted to the UNFCCC on March 6, 2015.

BOX 2.1. The centerpiece of EU climate policy is European emissions trading

The EU Emissions Trading System (EU ETS)

The ETS provides an EU-wide limit on greenhouse gas emissions. First launched in 2005,[10] the EU ETS is a regional (multi-country) system for trading GHG emission allowances. It is the first and largest greenhouse gas trading scheme in the world, now covering about 45 percent of the EU's GHG emissions. The system works on the "cap and trade" principle, in which a limit is set on the total amount of GHG emissions and the 11,000 or so heavy energy-using installations (in power generation and energy-intensive industry), who are required to participate, must secure emission allowances to cover their own emission and can trade with one another as needed. The ETS covers carbon dioxide emissions from power and heat generation; energy-intensive industry sectors including oil refineries, steel works and production of iron, aluminum, metals, cement, lime, glass, ceramics, pulp, paper, cardboard, acids and bulk organic chemicals; and from civil aviation. Also covered is nitrous oxide from production of nitric, adipic, glyoxal and glyoxlic acids; and perfluorocarbons from aluminum production.

The EU ETS is divided in three trading periods. The *first period* covered the period 2005–2007 and constituted 'learning by doing' by establishing national caps and mostly free allocation of allowances. In *phase two* (2008–2012) which coincided with the first commitment period of the Kyoto Protocol, three additional countries (Iceland, Liechtenstein and Norway) joined. Additional greenhouse gases were included so that all the main GHGs were covered. The system was extended to the aviation sector (in 2012). More auctioning of allowances occurred although some free allocation continued. The *third phase* of EU ETS runs from 2013 to 2020 and cuts allowances to reduce GHG emissions by 2020 by 21 percent compared to 2005. More harmonized rules have been put in place, in particular:

i) a single, EU-wide cap on emissions (replacing national caps);
ii) for each year after 2013, the overall cap decreases annually by 1.74 percent of the average total quantity of allowances issued annually during 2008–2012;
iii) auctioning (rather than free allocation) as the default method for allocating allowances (and up to half of allowances are expected to be auctioned during phase three); and
iv) about 90 percent of allowances will be distributed to EU member states (based on emissions shares in 2005), and at least half of auctioning revenues must be used by member states for climate and energy related purposes such as energy efficiency, renewables, research, and sustainable transport.

Sources: European Commission (2015), "The EU Emissions Trading System (EU ETS)," Climate Action, http://ec.europa.eu/clima/policies/ets/index_en.htm.

to the target for overall cuts, the Framework also sets out targets of at least a 27 percent share for renewable energy and at least a 27 percent improvement in energy efficiency. To achieve the overall 40 percent target, the Framework notes that sectors covered by the EU ETS would have to reduce their emissions by an estimated 43 percent compared to 2005. Emissions from sectors outside the EU ETS would need to be cut by about 30 percent below the 2005 level, and this EU-wide target will need to be translated into Member State targets. A 43 percent greenhouse gas reduction target in 2030 in the ETS translates into a cap declining by 2.2 percent annually from 2021 onwards, instead of the rate of 1.74 percent up to 2020 set by the 2020 package.

The European Union has laid out a vision for mitigation through 2050. A "Roadmap for moving to a competitive low carbon economy in 2050" was published in March 2011 by the European Commission.[11] Scenarios were created by combining the four main decarbonization options—energy efficiency, renewable energy, nuclear, and carbon capture and storage. The Roadmap sets out long-

10. The ETS was set out in *Directive 2003/87/EC of the European Parliament and of the Council of 13 October 2003 establishing a scheme for greenhouse gas emission allowance trading within the Community.*

11. European Commission (EC). 2011. A Roadmap for Moving to a Competitive Low Carbon Economy in 2050. COM/2011/0112 final. Brussels. Available at: http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52011DC0112

TABLE 2.1. The EU has set a long-term objective to cut emissions dramatically by 2050

Proposed emissions reduction for the EU under the 2050 Roadmap

GHG REDUCTIONS COMPARED TO 1990	2005 (ACTUAL)	2030	2050
Total	**–7%**	**–40 to –44%**	**–79 to –82%**
By sector:			
Power (CO_2)	–7%	–54 to –68%	–93 to –99%
Industry (CO_2)	–20%	–34 to –40%	–83 to –87%
Transport (incl. CO_2 aviation, excl. maritime)	+30%	+20 to –9%	–54 to –67%
Residential and services (CO_2)	–12%	–37 to –53%	–88 to –91%
Agriculture (non-CO_2)	–20%	–36 to –37%	–42 to –49%
Other non-CO_2 emissions	–30%	–72 to –73%	–70 to –78%

Source: http://ec.europa.eu/clima/policies/roadmap/perspective/index_en.htm

term objectives for EU mitigation: overall emissions for the EU are to drop by 79 to 82 percent, while emissions in the power sector are to disappear (–93 to –99 percent reductions). The Roadmap remains a long-term vision, not a policy proposal, but this objective has been reiterated by the EU in the context of its March 2015 offer to the UNFCCC, and the 2030 package is consistent with an emissions path that could get the EU to –80 percent by 2050. (See Table 2.1).

Projections of Climate Change in Romania to 2050

Future climate scenarios were developed, showing rising temperatures and falling precipitation. Historical temperature and precipitation data for each of Romania's river basins, derived from daily observations at 160 meteorological stations for 1961 to 2013,[12] were combined with projected changes obtained from global climate modeling to create scenarios of future climate for Romania for 2015 to 2050. Using 17 available combinations of global general circulation models (GCMs) and Reference Concentration Pathways (RCP) employed by the Intergovernmental Panel on Climate Change (IPCC), a crop model was run through 2050 to estimate the changes in irrigation water requirements for maize. Three climate scenarios were selected and further developed (low impact, medium impact, and high impact) based on the most positive, the median, and most negative changes.[13] The impact on precipitation and temperature is shown in Figure 2.5. All three scenarios show rising temperatures over coming decades. The pattern for precipitation is less clear. But it is important to remember that annual national averages are not what matter for water availability and agricultural production.[14]

12. Meteorological data were provided by the Romanian National Meteorological Administration (NMA, or Administratia Nationala de Meteorologie).

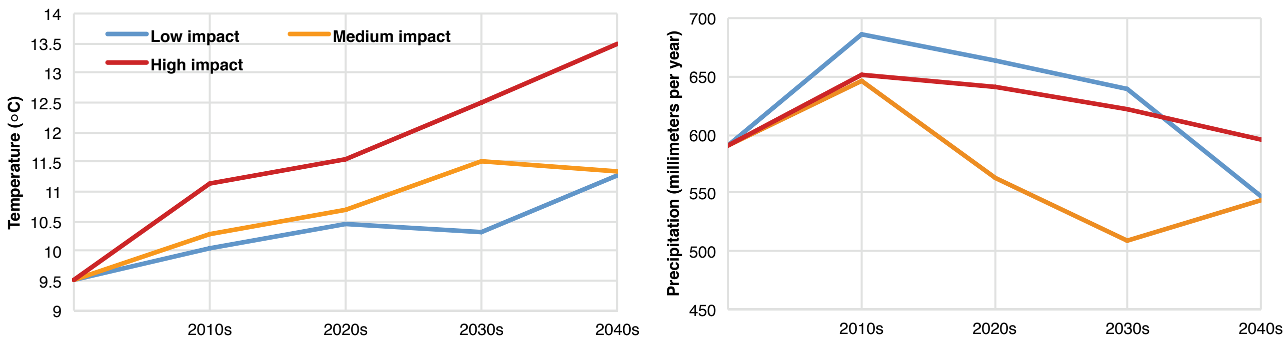
13. The high impact climate scenario was based on the GCM, Model for Interdisciplinary Research on Climate (MIROC) ESM using the IPCC emissions scenario, RCP 8.5. The medium impact scenario was based on the GCM, Geophysical Fluid Dynamics Laboratory (GFDL) ESM2M using the emissions scenario, RCP 4.5. The low impact scenario was based on the GCM, Geophysical Fluid Dynamics Laboratory (GFDL) ESM2G using RCP 8.5. RCP is a Representative Concentration Pathway as used in the fifth Assessment Report from the Intergovernmental Panel on Climate Change. AN RCP is gas concentration trajectory, and each is named after a possible range of radiative forcing values in the year 2100 relative to pre-industrial values. RCP 8.5 is a 'business-as-usual' pathway with no mitigation so emissions continue to rise throughout the 21st century. Emissions in RCP 4.5 peak around 2040, then decline.

14. See Chapter 6 (Water) and the Water Sector Technical Report for details on modeling.

FIGURE 2.5. Climate models find varying impacts on Romania's temperature and precipitation

a. Average temperatures under three climate scenarios through 2050

b. Average precipitation under three climate scenarios through 2050



Notes: For descriptions of climate scenarios, see text and footnote 13.
Source: Water Sector Technical Report.

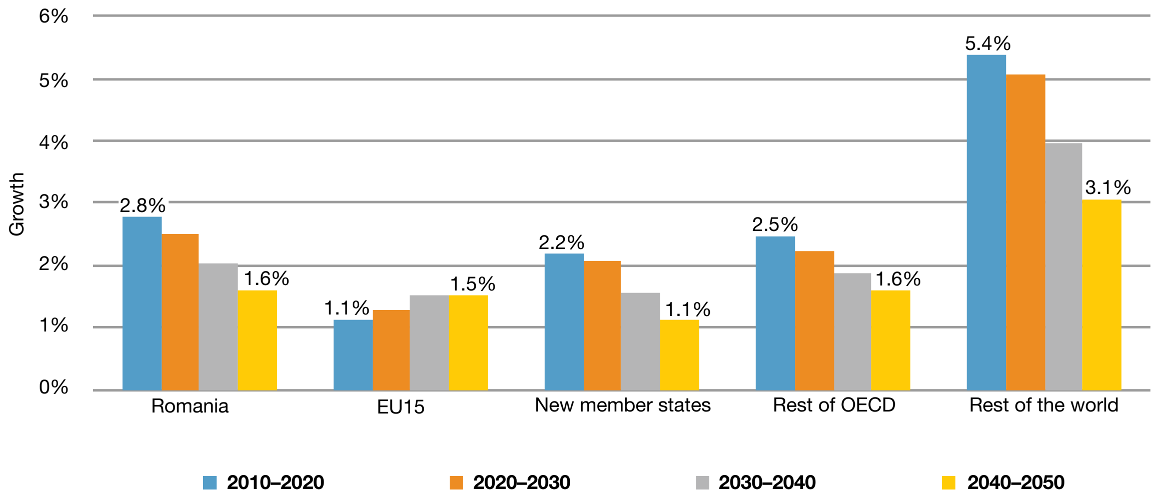
Baseline Scenario for Economic Development to 2050

The likely path for Romania's economy through 2050 before considering low carbon and green growth actions is generated by a macroeconomic model. Baseline scenarios can be created in different ways. Here the baseline relies mainly on the official long-term forecasts prepared by the government's National Commission for Prognosis (Comisia Nationala de Prognoza, CNP). The official CNP projection provides a consistent picture of economic and sectoral developments. The baseline also draws on economic convergence theory and utilizes information from empirical studies, reviews of sector strategies, and consultations with experts and stakeholders. A consistency framework is provided by the computable general equilibrium model, including consideration of Romania's links to the rest of the world. (The methodology section that follows provides details about the model.)

Real incomes in Romania are expected to converge towards the European Union average but at a modest pace, averaging 2.2 percent annual growth through 2050 compared to 1.4 percent for the EU overall. These growth rates are higher in earlier years and then moderate, from just below three percent during 2010–20 to 1.6 percent during 2040–2050. But Romania's rate of expansion remains well above that of the EU as a whole and very slightly ahead of those of the OECD although below those in the rest of the world. (See Figure 2.6). Projected growth comes from the official long term forecasts of the National Commission for Prognosis (CNP, Romanian acronym). It reflects a broad consensus that income per capita in Romania is set to catch up gradually to EU levels. Total factor productivity gains and capital accumulation are expected to be the main growth drivers, consistent with the Solow model. Romania's total factor productivity (TFP) growth is projected to decline from 1.7 percent annually at the beginning of the period towards 1.5 percent at the end, higher rates than in the EU because Romania farther from the technological frontier, making it easier to adopt innovations from abroad and to benefit from foreign direct investment which will bring both organizational and technological innovations. (See Figure 2.7).

FIGURE 2.6. Romania's growth projected to outpace the EU and the OECD through 2050

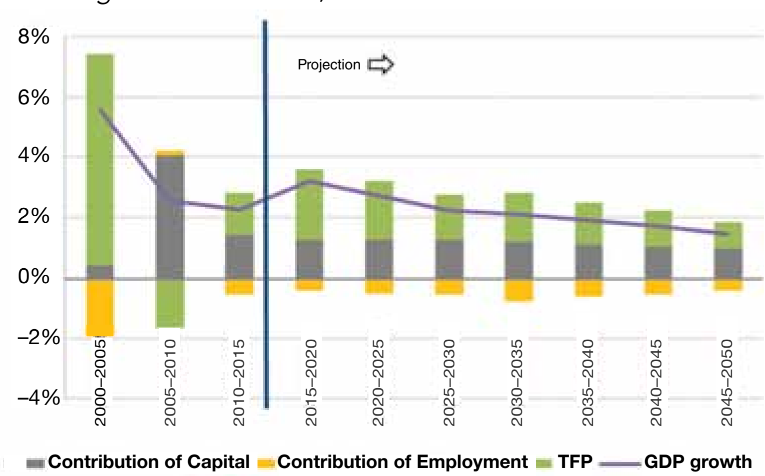
GDP growth rates in the baseline during 2010–2050



Source: ROM-E3 model.

FIGURE 2.7. Steady but modest total factor productivity improvements keep growth positive

Solow decomposition of GDP growth in Romania, 1997–2050



Notes: The chart is based on the standard Solow analysis with a Cobb-Douglas production function ($Y = AK^{\alpha}L^{1-\alpha}$). Consequently, GDP growth can be decomposed as $\Delta \ln(Y_t) = \Delta \ln(A_t) + \alpha \Delta \ln(K_t) + (1 - \alpha)\Delta \ln(L_t)$. The first component is contribution of TFP, the second—capital and the third—labor. Capital is calculated on the basis of investment data, labor force comes from employment statistics. TFP was calculated implicitly, assuming that share of capital in GDP (α) is equal to 40 percent and depreciation rate (δ) is equal to 6 percent.
Source: World Bank staff calculations based on CNP forecast.

Romania's population and labor force are continuing to shrink. Population, depleted by emigration, is projected to decline by 11.8 percent by 2050 (compared to 2010).[15] The labor force, affected by aging, will receive only a small boost from improving labor force participation from its current low levels but not enough to offset the shrinking number of workers. The unemployment rate is forecast

15. *2015 Ageing Report* prepared by DG ECFIN (DG ECFIN, 2014).

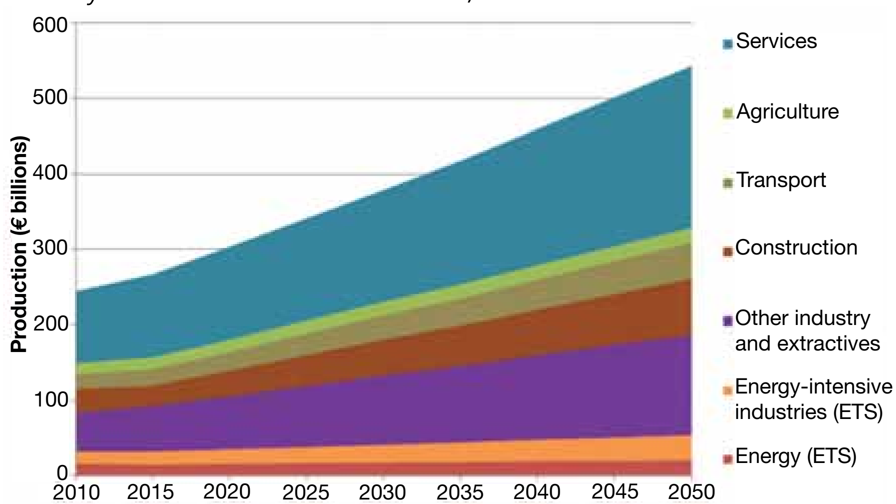
to remain close to 7 percent. Labor productivity is estimated to grow by more than 3 percent annually up to 2040 and more than 2 percent thereafter.

In the baseline, almost all economic sectors are projected to grow, but their growth rates will be quite diverse. These projections took into account the constraints imposed by possible developments in global markets (both in the EU and outside the EU). Overall, the trend away from energy-intensive sectors and towards higher productivity sectors will continue. Agriculture's share will fall due to reallocation of resources to low-end services such as trade and transport. According to CNP forecasts, services will gain about 3 percentage points during 2010–2050 period, remaining much below the EU average. Meanwhile, industry is to maintain its value-added share due to existing comparative advantages. The economy should follow the general historical growth pattern observed in more advanced EU countries alongside rising incomes. However, since sectoral transformation is a slow process, sectors such as agriculture and industry will continue to have a higher share in the Romanian economy than in the EU, and this will also be reflected in employment. Romania is to keep its specialization in selected primary sectors in comparison to the EU. (See Figure 2.8).

Under the baseline scenario, EU countries comply with the 2020 climate and energy package, which requires participation in the EU Emissions Trading System (ETS). The package sets a target of 20 percent reduction in GHG emissions for the EU as a whole from 1990 levels (equal to a 14 percent reduction compared to 2005 levels). Also, an increase to 20 percent in final energy consumption produced from renewable resources is required, and an indicative target was put in place for improvement of energy efficiency by 20 percent compared to the EU baseline level for 2020. Post-2020, the rules underlying the third phase of the EU ETS are assumed to continue (although they are only legally binding until 2020, the probability of the ETS disappearing completely after 2020 is

FIGURE 2.8. Output shifts from agriculture to services to 2050

Romania's production by sector in the baseline scenario, in billions of 2010 euros



Notes: Sectoral production includes value-added plus intermediate consumption. Energy (ETS) is oil refining and electricity supply, sectors included in the EU emission trading system (ETS). Energy-intensive industries (ETS) are ferrous metals, non-ferrous metals, chemical products, paper products, and non-metallic minerals, sectors included in the ETS. Other industry and extractives is coal, crude oil, gas extraction, gas, metal products, electrical goods, transport equipment, other equipment goods, and consumer goods industries. Transport: includes air, road, and rail for passenger and freight; note that air transport emissions are covered by the ETS.
Source: ROM-E3, using CNP projections on value-added at basic prices.

TABLE 2.2. The baseline scenario was constructed in collaboration with government

Overview of the main assumptions in the baseline scenario

REGION	TARGET	2020			2030	2040	2050
Romania	GHG target vs. 2005	14%	EU ETS	–21%	1.74% annual reduction in allowances		
			Non-ETS	–10%	Constant cost of 2020		
	Renewables*	24%	Minimum share of 24%				
EU	GHG target vs. 2005	14%	EU ETS	–21%	1.74% annual reduction in allowances		
			EU non-ETS	+19%	Constant cost of 2020		
	Renewables*	20%	Minimum share of 20%				
Romania and EU	Energy efficiency**	No requirement					
Romania and EU	Recycling carbon revenue	Reduction of general taxes***					
Non-EU	GHG target	Copenhagen COP-15 pledges			Constant carbon price (if any pledge)		
World	Fossil fuel prices	2014 International Energy Agency's World Energy Outlook: 'Current Policies' scenario					

Notes: *Renewables is share of renewable energy in gross final energy consumption. **The energy efficiency target under the '20-20-20' package was a 20 percent reduction in primary energy use compared to projected levels under a business-as-usual scenario, to be achieved through energy efficiency improvements; however, this target was not translated into a legally binding commitment but was left as indicative only. ***Revenues from sales of carbon allowances that accrue to governments are assumed to be used (recycled) to reduce general taxes. This is a simplifying assumption since current EU regulations require mixed use of these revenues to support energy efficiency. See Methodology and Findings sections of this chapter and Macroeconomic Technical Report for full details of baseline assumptions.
Sources: Various EU documents, International Energy Agency, World Bank staff, and Macroeconomic Technical Report.

low). These rules include: a harmonized single EU-wide cap instead of national caps, harmonization of monitoring and reporting, and full auctioning of allowances within the EU ETS. Post-2020, the emissions cap decreases annually by 1.74 percent of the average annual total quantity of allowances issued by the Member States in 2008–2012.[16] As a result, greenhouse gas emissions related to ETS entities decline to 21 percent below 2005 levels in 2020 to 34 percent lower in 2030 and 53 percent in 2050. (See Figure 2.10). The main policy assumptions on climate and energy in the baseline scenario are summarized in Table 2.2.[17]

16. For non-EU countries, in the baseline scenario, they commit to their 2020 emission pledges. There have been several actions at global level with the aim to commit countries to emission reductions. In 1992, countries joined the United Nations Framework Convention on Climate Change, to cooperatively consider what can be done to limit average global temperature increases and the resulting climate change, and to cope with whatever impacts were, by then, inevitable. In 1995, countries launched negotiations to strengthen the global response to climate change, and two years later, adopted the Kyoto Protocol. The Kyoto Protocol legally binds developed countries to emission reduction targets. In 2009 the Copenhagen Accord was drafted. Countries submitted emissions reductions pledges or mitigation action pledges.

17. For non-ETS sectors, the model assumes that each EU country imposes a domestic CO_2 tax which equalizes marginal abatement costs only across each country's domestic non-ETS emission sources. This assumption is a shorthand for the most efficient possible way for each EU member state to meet its individual non-ETS target. In reality, countries will likely use a mix of policy tools, including taxes, subsidies, standards and other regulation, and other measures.

Over the 40-year horizon, the energy intensity of the Romanian economy is projected to continue to decline, offsetting expanding output such that GHG emissions are close to stable. The energy intensity of production and the carbon intensity of energy are projected to decline. The reduction of energy intensity of GDP can be attributed to autonomous energy efficiency gains, structural changes of the economy away from energy-intensive activities and sectors (such as the ferrous and non-ferrous metals, chemicals, and cement industries), take-up of more efficient energy equipment by consumers, and the reaction of energy consumers to higher energy prices. The next most important factor is the ongoing shift in the structure of value-added towards less energy-intensive sectors—away from agriculture and industry to services—which was the main driver of emissions decline in the EU over the last two decades. Third is the reduction in energy-related CO_2 emissions compared to final energy demand, which corresponds to a higher penetration of carbon-free energy sources into the energy mix and substitutions within the fossil fuel mix towards less carbon-intensive fossil fuels, for example, natural gas substituting for coal or oil (that are more carbon-intensive and have lower energy efficiencies when used in final demand sectors and for electricity production).

METHODOLOGY AND MAIN FINDINGS

Methodology

The macroeconomic modeling was undertaken using a customized CGE model, built on the blueprints of the GEM-E3 model[18] and in collaboration with Romanian Government and other local experts. The "ROM-E3" model (Romania Economy-Energy-Environment model) is a recursive

18. For detailed documentation, see Capros P., Van Regemorter D., Paroussos L., Karkatsoulis P., Fragkiadakis C., Tsani S. and Charalampidis I. *The GEM-E3 Model Reference Manual*. Available at: http://www.e3mlab.ntua.gr/manuals/GEMref.PDF

dynamic computable general equilibrium model that covers the interactions between the economy, the energy system and the environment. The model is Romania-specific but also captures the interaction of the country with international markets—aggregated into five countries/regions (Romania, the EU-15 and other EU new member states, other industrialized countries, and developing countries). The international features allow it to analyze both the impact of EU policy choices on global markets and international spillovers triggered by emission abatement policies of other major industrialized regions.[19] The model contains 28 economic activities or sectors. While in standard global CGE models only CO_2 from combustion is modeled, in ROM-E3 all greenhouse gases are modeled, including process-based emissions from agriculture and industry. The model's horizon stretches to 2050, and institutional settings and policy instruments for climate policy implementation are included, including the complex rules for the EU Emissions Trading System (ETS) under which installations in power generation and energy-intensive industry must participate in ETS carbon trading (with the rest of the economy covered as part of the 'non-ETS sector' facing national emissions reduction targets).

Key sectors driving emissions are energy and transport, and a detailed bottom-up representation of each is included in the model.[20] Power supply is modelled by ten representative generation technologies whose market shares and cost structures are consistent with energy balances. The market shares and capital costs of power generation technologies have been harmonized with the results of energy modeling (see Chapter 3). For transport, major categories of transport[21] are represented, with two different categories distinguished by purpose: i) private, including households' expenditures for transport equipment (cars, motorcycles) and for public transportation (leisure trips, commuting trips), and ii) business, including firms' expenditures for transportation of goods (freight transport) and employees (passenger transportation paid by business).

Data sources and main assumptions are important to note, and the model includes some key market imperfections. The ROM-E3 model is calibrated to a base year (2010) dataset that includes full Social Accounting Matrices for each country/region represented in the model.[22] The key exogenous variables of the model are: total factor productivity, technical progress, fossil fuel prices, labor force, minimum consumption of households (adjusted based on population changes), public consumption, taxes and subsidies, shares of different technologies in power generation, and sectoral growth expectations. The labor market includes involuntary unemployment and fiscal instruments such as indirect taxes, subsidies, duties, and income taxes are modelled. Figure 2.9 explains how the baseline and policy scenarios are run.

The ROM-E3 model has been used to evaluate alternative GHG emission reduction scenarios—the Green and Super Green scenarios, in addition to the baseline. The baseline was presented above. The two green scenarios are defined below. (See Tables 2.1, 2.2, and 2.3). The Green package aims to quantify what is already agreed about EU commitments for mitigation in 2030, specifically the 40 percent emissions reduction by that year and the expected cuts from ETS and non-ETS sectors,

19. The non-EU regions do not participate in carbon trading or offsets but rather set a uniform domestic carbon tax.

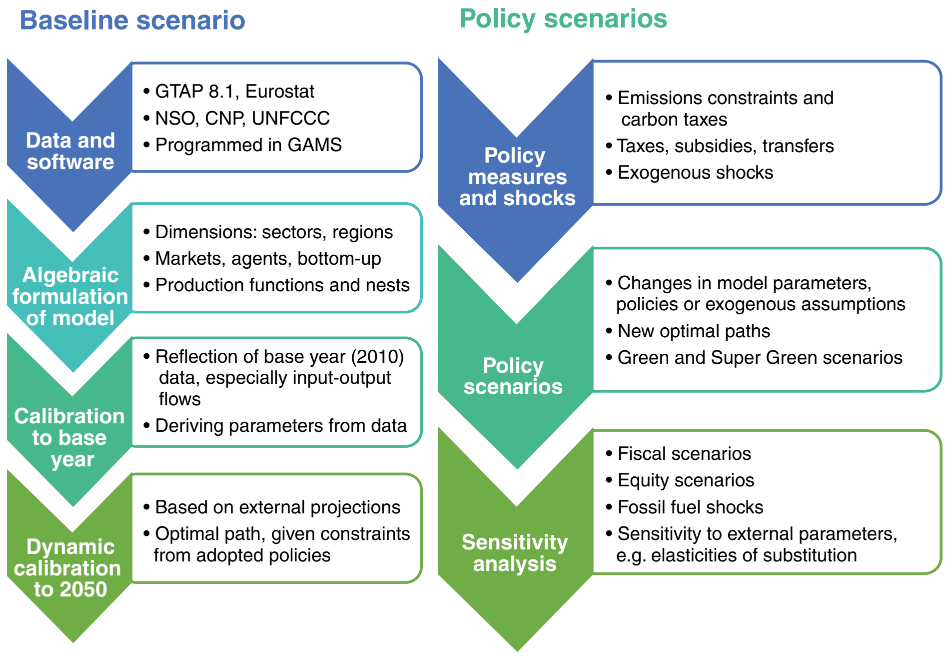
20. In the macroeconomic model, only electricity generation is modelled in detail, rather than the entire energy sector which also includes heat production and energy sector own-use (under the standard International Energy Agency/IPCC definition).

21. Public road transport (for passengers), road transport (for freight), rail transport (for passengers), rail transport (for freight), maritime transport (inland), and air transport.

22. The model is calibrated on the GTAP v8.1 database, with a base year of 2007. The Input-Output tables for Romania were updated to 2010 using national statistical data, and 2010 was the base year used in ROM-E3. GTAP is Purdue University's Global Trade Analysis Project database.

FIGURE 2.9. Modelling scenarios follow a careful and detailed procedure

The modeling steps for the baseline and policy scenarios in ROM-E3 model



Notes: GTAP 8.1 is a version of the Global Trade Analysis Project database, a global database of bilateral trade patterns, production, consumption and intermediate use of commodities and services, and CO_2 emissions for 2007 covering 129 regions/countries for 57 sectors. NSO is Romania's National Statistical Office. CNP is Comisia Nationala de Prognoza, Romania's National Commission for Prognosis. GAMS is General Algebraic Modeling System, a high-level modeling system for mathematical programming and optimization.
Source: Macroeconomic Modeling Technical Report.

but numerous details remain to be decided, in particular the national targets that will aggregate to the overall non-ETS abatement effort. The Super Green package aims to quantify implementation of the Roadmap 2050, which is a broad strategy document with no legally binding power although it has been reiterated as the EU's long-term objective on mitigation (see the anticipated sectoral contributions in Table 2.1).

The Green scenario imposes compliance with the main features of the 2030 Climate and Energy Policy Framework. As determined in the October 2014 decision of the European Council, the 2030 Framework sets an all-EU target for emissions reduction of 40 percent compared to 1990. For ETS sectors, EU-wide carbon trading ensures equal prices of emissions abatement across the EU in all scenarios. The sectors covered by the EU emissions trading system (EU ETS) would have to reduce their emissions by 43 percent compared to 2005.[23] Emissions from sectors outside the EU ETS would need to be cut by 30 percent below the 2005 level on average. While the EU ETS operates as a single market, differential emission reduction targets are to be imposed for the non-ETS segments of the respective EU economies. For non-ETS sectors, as in the baseline, the model assumes that each EU country imposes a domestic CO_2 tax as a shorthand for the most efficient possible way for each EU member state to meet its individual non-ETS target. In reality, countries will likely use a mix of pol-

23. 2005 was the first year of ETS trading and so is the year against which emissions reductions are measured.

TABLE 2.3. The baseline and two green scenarios provide a wide spectrum of green options

Main features of green scenarios quantified by the ROM-E3 model

SCENARIO FEATURES	BASELINE	GREEN	SUPER GREEN
EU mitigation package	2020 Package	2030 Framework	Roadmap 2050
Target year	2020	2030	2050
Overall mitigation target (vs. 1990)	–20%	–40%	–80%
Overall mitigation target (vs. 2005)	–14%	–36%	–79%
ETS target	–21%	–43%	An integrated EU-wide market for all emissions is assumed.
Non-ETS target (EU / Romania)	–30% / +19%	–30% / 0%*	
Extensions beyond target year to 2050	–1.74% annual decline in ETS allowances post-2020; constant cost of non-ETS emissions	–2.2% annual decline in ETS allowances post-2030; constant cost of non-ETS emissions	n.a.
Adaptation action	None	Modest	Ambitious

Notes: This modeling aims to capture the key features of each mitigation package. Sensitivity scenarios were run to confirm that these simplifications accurately captured actual EU policies as known or indicated in EU documents. *National non-ETS targets for 2030 are not yet set. An efficient allocation of non-ETS reductions results in Romania's target of 0%, similar to an equity-driven allocation. Also see Table 2.2 on baseline assumptions. See Chapters 6 and 7 on adaptation actions.
Source: World Bank staff based on various EU documents. For full details on scenarios, see Macroeconomic Technical Report.

icy tools, including taxes, subsidies, standards and other regulation, and other measures. As in the baseline scenario, marginal abatement costs are equalized across each country's domestic non-ETS emission sources; in addition, in the Green scenario, the national non-ETS targets were selected as the most efficient allocation, but an allocation based on equity generates similar targets: Romania has a target of 0 percent change in non-ETS emissions by 2030 compared to 2005. In the Green scenario, as in the baseline, the revenues from auctioned ETS allowances and domestic taxation of non-ETS emissions are recycled through general taxes (because no restrictions on use of auction revenues have yet been set; however, it is likely that the EU will restrict use of revenues as it does under the 2020 climate package.)[24]

A more ambitious mitigation scenario—Super Green—reflects the reduction of emissions by almost 80 percent compared to 1990 levels for developed economies. In order to stabilize GHG concentrations at safe levels (i.e., 450 ppm according to the UNFCCC), there is a need for global action. The Super Green scenario imposes an emissions constraint on richer countries (the EU and OECD) for 2050 while emissions are allowed to increase in line with the baseline path for developing countries. According to the milestones set in the March 2011 "2050 Roadmap for the EU," the EU

24. Under the current 2020 package, at least 50 percent of auctioning revenues are to be used by Member States for climate and energy related purposes.

should prepare for reductions in its domestic emissions by 80 percent by 2050 compared to 1990. Further, all reductions of EU emissions should come from within the EU itself and not result from carbon offsets. (See Table 2.1 and surrounding text).

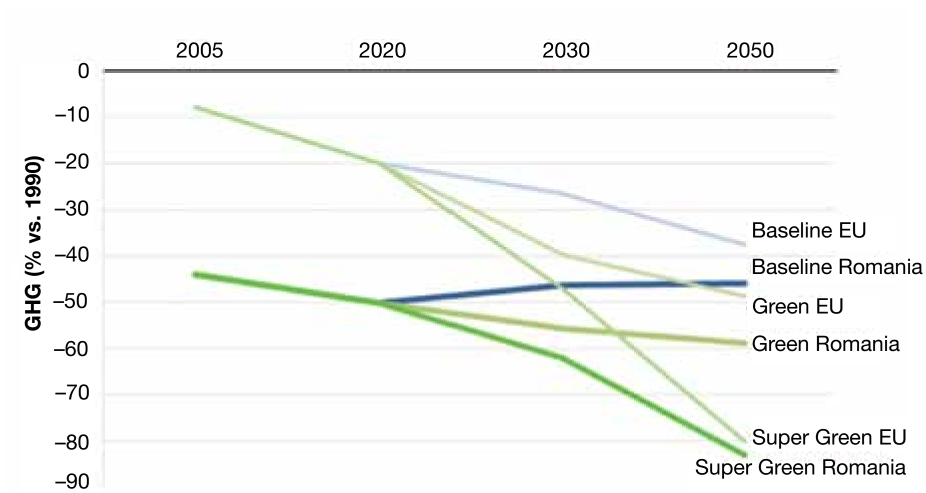
Main Findings

The Green scenario imposes only modest net costs on Romania's economy. EU-wide emissions trading in the model determines how the overall EU ETS reduction of 43 percent compared to 2005 will be most efficiently allocated across countries, while each country meets their individual non-ETS target to aggregate to –30 percent for the EU overall. Total emissions for Romania will decline by 21 percent by 2030 vs. 2005, compared to a 36 percent decline for the EU overall. For Romania, energy-intensive sectors (or ETS sectors) must reduce emissions by 23 percent by 2030 or about 12 percentage points more in 2030 compared to the baseline pattern of ETS emissions. The EU will cut ET emissions by 43 percent or nine percentage points additional to the baseline scenario. Together, this additional mitigation compared to the baseline will reduce Romania's GDP by 1.1 percent in 2030 compared to baseline. (See Figure 2.11 and Table 2.4). Employment is harmed more, with a reduction of 1.7 percent. (See Figure 2.10 for emissions reductions under all scenarios compared to 1990). If carried on through 2050, the 2030 Framework would generate 2.0 percent lower GDP in 2050 compared to the baseline. Nevertheless, although not as high as baseline GDP, GDP in 2050 under the Green scenario would stand 111 percent higher than in 2015.

Moderate effects at the economy-wide level mask significant output, employment, and trade effects at the sectoral level, but energy-intensive and trade-exposed industries are not devastated by emissions abatement. Capital is substituted for energy as an input factor. Energy, extractive and energy-intensive sectors lose in output terms, while services and light industry win. Declines in output of over 10 percent are recorded for fossil fuel extraction, agriculture, oil products, and power supply subsectors. The higher costs of production for those sectors in which (fossil fuel) energy inputs represent a significant share of direct and indirect costs leads to a loss in competitiveness,

FIGURE 2.10. EU emissions trading allocates needed mitigation efficiently across countries

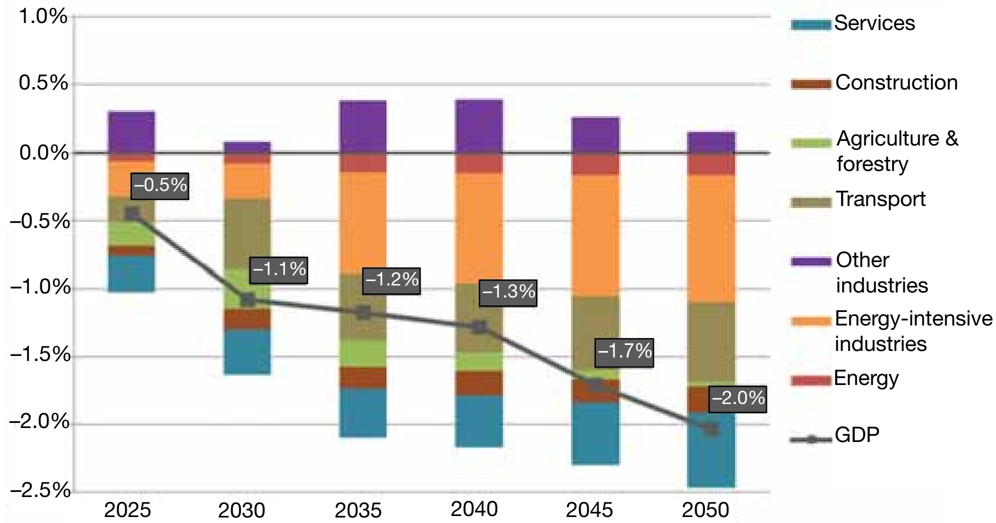
Total GHGs under each scenario for Romania and the rest of the EU, as % change from 1990



Notes: See Table 2.3 for description of baseline, green, and super green scenarios.
Sources: ROM-3 model outputs. See Macroeconomic Modeling Technical Report.

FIGURE 2.11. Modestly lower output in the Green scenario is driven by slower growth of energy-intensive industries

Contributions to changes in production compared to baseline by sector in the Green scenario



Notes: Sector contributions to overall value-added include intermediate consumption while GDP does not. In 2020, all scenarios are aligned, i.e., the Green scenario is identical to the baseline.
Sources: ROM-3 model outputs. See Macroeconomic Modeling Technical Report.

depressing production. The strongest boost comes to production of electrical goods, other equipment, transport equipment, and non-ferrous metals subsectors. In the new equilibrium, real wages are lower, and unemployment rises. Since many of the new technological options come from abroad, in the form of imported goods, the current account deteriorates. In the first 15 years or so, the greatest adjustment comes in the transport sector, but then energy-intensive industry comes to dominate the losses in production compared to baseline. (See Figure 2.11). Despite these costs, all sectors would experience positive growth in all future decades to 2050 (except for a half percent decline in energy during the next ten years).

If the revenues from auctioning ETS allowances in Romania were recycled to aim to reap a 'double dividend', the output and employment impacts would be somewhat smaller. Two alternatives within the Green scenario generate positive differences in GDP and employment impact. The standard tax recycling option used in the Green scenario is that public revenues are used to reduce general taxation. A variant has been explored—a Mixed Double Dividend scenario—in which tax revenues are used to reduce labor costs, finance renewable energy, and boost energy efficiency. More specifically, half of the revenues are used to reduce social security contribution rates for employers, one-quarter is used to finance deployment of renewables, and the last quarter is used to finance energy efficiency projects. This mixed use of revenues achieves better results than a simple 'double dividend' policy of devoting all of revenues to reducing labor taxes. It is also better aligned with the likely rules on use of revenue under the 2030 Framework (based on discussions and decisions to date). The marginal benefits accrued from all the alternative recycling options that were tested peak at a relatively early stage. All recycling options exhibit decreasing returns but have different multiplier effects on the economy. The mixed double dividend approach simultaneously achieves three targets: (i) offsetting somewhat the loss of competitiveness of the economy, (ii) reducing the crowding-out effect in

TABLE 2.4. Macroeconomic impacts of the green scenarios

Change in GDP and employment compared to the baseline, in % of GDP

IMPACT BY SENSITIVITY SCENARIO	GREEN		SUPER GREEN	
	IN 2030	IN 2050	IN 2030	IN 2050
Impact on GDP:	**–1.1**	**–2.0**	**–1.4**	**–4.0**
w/Mixed Double Dividend	–0.7	–1.8		
w/Low Fuel Price	–1.0	–1.8	–1.3	–4.0
Impact on Employment:	**–1.7**	**–1.4**	**–2.2**	**–5.3**
w/Mixed Double Dividend	–1.4	–1.4		
w/Low Fuel Price	–1.2	–1.0	–1.7	–5.3

Notes: See text for explanation of sensitivity scenarios.
Sources: ROM-3 model outputs. See Macroeconomic Modeling Technical Report.

the capital market induced by the deployment of capital-intensive renewable energy technologies, and (iii) reducing the cost of additional energy efficiency projects. These effects partly offset the impact of restricting emissions on production costs and reduce upward pressure on prices overall. Thus, domestic demand is less depressed than in the main Green scenario. The decrease in the cost of labor sustains demand for labor and, as a consequence, the reduction in wage income is less. Together, the impact of the Green emissions targets on private consumption is lower than in the alternative taxation case. This option also slightly benefits employment, by 0.3 percentage points in 2030 when compared to the main Green scenario. Importantly, while this option aims to mimic likely EU rules, any such recycling option would have to follow actual EU guidelines and rules, which are not yet determined for the 2030 Framework. (See Table 2.4).

Romania benefits only slightly from halving of oil prices through 2030 as compared to the baseline scenario. The gains of the Low Fuel Price alternative relative to the Green scenario are much bigger outside Romania—for the other new member states or for the EU15. This is because terms-of-trade effects are more pronounced for larger net energy importers. If Romania were to perform the same emissions reduction effort in 2030 under lower fossil fuel price, the country would benefit from access to low cost energy resources. However, product prices in other countries would decrease and so Romania will increase its imports, hence reducing the positive effect of low fossil prices on its GDP. The positive effects for private consumption are much more significant (a difference of 1.5 percentage points).

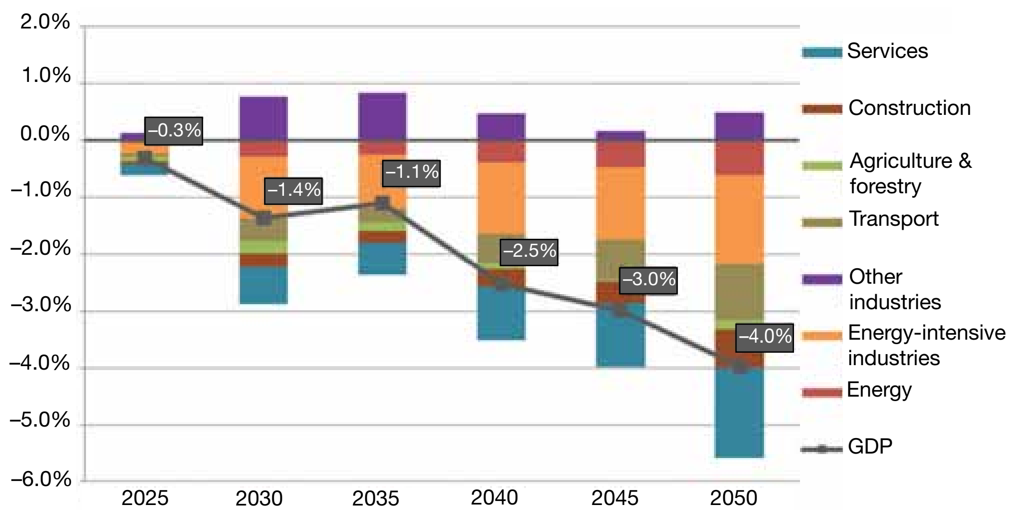
Maintaining the 2030 Framework through 2050 allows assessment of the continuing impact of unchanged 2030 policies. Overall emissions for Romania will continue to decline, reaching 26 percent below 2005 levels by 2050 while the EU as a whole would reduce emissions by 46 percent. Romania's emissions from ETS sectors would shrink by 54 percent by 2050 with no additional actions but only the maintenance of the 2030 Framework (and the ongoing reduction of ETS allowances by 2.4 percent each year). As noted above, the cost to Romania in GDP in 2050 is estimated at 2.0 percent while employment will be lower by 1.7 percent. (See Figure 2.11 and Table 2.4).

The Super Green scenario imposes distinctly larger costs on Romania's economy as the need for deep decarbonization, including complete elimination of emissions from the power sector, drives significant economic restructuring. For the EU overall to cut emissions by near 80 percent by 2050, Romania's contribution will be similar: –70 percent compared to 2005 levels. By 2030, Romania's GHGs will need to be 37 percent below 2005, and its energy-intensive sectors must reduce emissions by more than 50 percent below 2005 or 26 percentage points below the baseline pattern of ETS emissions in 2030. In 2050, GDP losses for decarbonizing the EU economy are around 1.6 percent and 4.0 percent for Romania. Employment losses for Romania come to above five percent. Romania suffers a much larger adjustment cost than the EU average mainly because: i) it provides larger potential for cost-effective abatement options, and ii) in the baseline scenario, Romania's energy sector is still dominated by fossil fuels; hence, it must be restructured more thoroughly than the EU average. At the same time, a large part of the equipment required to decarbonize the Romanian economy is to be imported. (See Table 2.4 and Figure 2.12). (Note that some part of these relatively higher costs for Romania are driven by the modeling assumption that an integrated EU-wide market for all emissions is used to achieve the 2050 target.) By comparison with the Green scenario, here energy-intensive industry suffers the biggest losses in output compared to baseline from the start. Even in the Super Green scenario, however, except for energy and energy-intensive industry (which suffer very modest output declines of one percent or less), sectors continue to expand output throughout the period to 2050. GDP in 2050 in the Super Green scenario is projected at 107 percent greater than GDP today.

In the Super Green scenario, lower fossil fuel prices could marginally mitigate the adverse impacts of rising carbon prices. Compared to the Super Green scenario with higher fuel prices, lower energy costs do not affect GDP, while private consumption could gain around one percent as consumers would benefit from lower energy bills for imported fuels. In the Super Green scenario, it has been assumed that developed countries globally undertake intense GHG mitigation action consistent

FIGURE 2.12. Lower output in the Super Green scenario is driven by slower growth of energy-intensive industries as well as services

Contributions to changes in production compared to baseline by sector in the Super Green scenario



Notes: Sector contributions to overall value-added include intermediate consumption while GDP does not.
Sources: ROM-3 model outputs. See Macroeconomic Modeling Technical Report.

with a 450 ppm target. It can be expected that this action will have an impact on fossil fuel prices. The reduction of fossil fuel prices due to global climate action decreases overall prices and costs, allowing consumers to maintain demand and compensate for the additional investment costs needed for energy restructuring purposes. Thus, lower fossil fuel prices mitigate the adverse impacts of carbon prices and can even offset the depressive demand effect due to decarbonization. This holds mainly in developed countries which have high fossil fuel prices and less so in developing countries where fossil fuel prices are subsidized and taxation is low. (See Table 2.4).

CONCLUSIONS AND RECOMMENDATIONS

After accounting for economy-wide impacts and feedback as well as interactions globally, the costs of implementing the imminent EU 2030 climate framework are modest for Romania's economy. EU emissions trading allocates mitigation efficiently across EU member states via a uniform carbon price (the emissions allowance price that clears the ETS market). Romania can meet the 2030 obligations by cutting GHGs by 34 percent by 2030 compared with 2005 or by 10 percentage points compared to baseline emissions at a cost of 1.1 percent of GDP and 1.7 percent of employment. Simply maintaining likely 2030 policies until 2050 will reduce emissions to about one-third below 2005 levels by 2050 for Romania and to near 45 percent lower for the EU. Importantly, the relatively modest overall cost masks highly variable impacts across sectors, with more energy-intensive sectors suffering much higher dislocation.

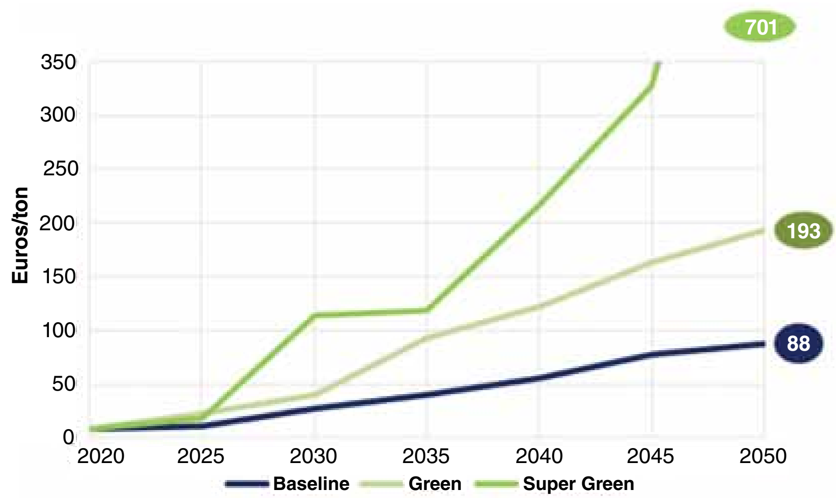
The same approach to assessing the prospective EU Roadmap 2050 finds a heavy burden in costs for Romania's economy. Reducing overall emissions by more than 70 percent and ETS emissions by near 80 percent by 2050 will leave Romania's output an estimated four percent lower and employment almost five percent lower. This path represents a radical shift compared to the current EU 2020 policies or even the upcoming 2030 Framework. However, it is important to note that the modeling simplification under this scenario of a single EU-wide emissions market for all sectors, without consideration of equity, likely imposes higher costs on Romania than actual future EU policies (since even by 2050, Romania's per capita income is projected to rise to just 40 percent of the EU average).

Since modeling requires simplifying assumptions, model outputs must be interpreted with care. Not every output of a CGE model is meant to be a precise reflection of the real world or how an economy works in practice. A good example of this is the use of a carbon price to drive the adjustments necessary to achieve a GHG mitigation target. Because the model used here is driven by the price of emissions (a carbon price), those prices must rise to extreme levels to achieve the Super Green targets, but reality will likely differ greatly from this part of the forecast. (See Figure 2.13). It should be kept in mind that the costings and coefficients used in the ROM-E3 model (which drive the required carbon price needed to achieve emissions reductions) are snapshots based on available data and the technology set that today is considered practical for such assessments. Despite the quite detailed and sophisticated treatment of technological progress in the ROM-E3 macroeconomic model, new technologies will certainly emerge over coming decades that will change these costs and benefits, providing an important reason why governments need to update such analysis periodically.

The government needs to be prepared to monitor the cross-sectoral effects of the green transition and consider measures aimed at facilitating the reallocation of labor and capital from one sector

FIGURE 2.13. A very high carbon price is required to meet ambitious mitigation targets

ETS allowance price, 2020–2050 under baseline and green scenarios



Notes: Price are in constant 2010 euros per (metric) ton.
Sources: ROM-3 model outputs. See Macroeconomic Modeling Technical Report.

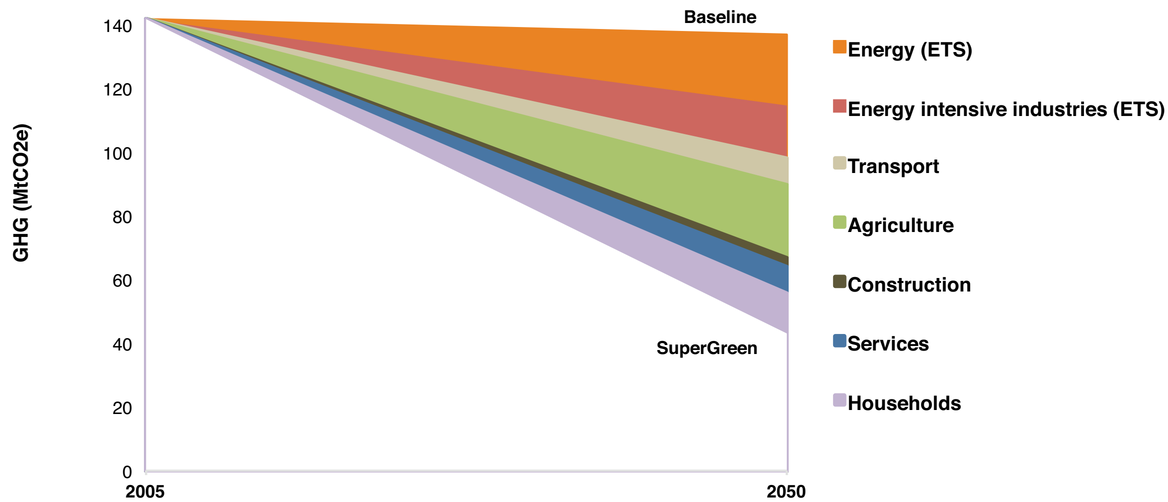
to another. Mitigation measures induce differing economic repercussions across sectors, and the costs of adjustment are borne mainly by energy-intensive and trade-exposed sectors. The estimated value-added patterns in energy-intensive sectors, such as power and heavy industry, reveal higher declines in output and employment than in the rest of the economy through 2030/2050. These sectors play an important role in a small and open economy such as Romania, and the government may wish to consider appropriate measures to assure targeted assistance for displaced workers.

A mixed use of rising revenues from auctioning of ETS allowances, including reduction of labor taxes but also financing of renewables and energy efficiency measures seems to be a smart option, given its positive impact on GDP, sectoral output, and employment, if such a policy falls within EU rules. While economy-wide models are designed to focus on real sector developments over long horizons, they also offer insights on fiscal issues. The ROM-E3 model assumes fiscal neutrality so that the impact of mitigation options on fiscal expenditures or revenues must be financed by offsetting changes in spending or taxes. However, a choice can be made of which taxes or costs to reduce. The mixed use of revenues—the Mixed Double Dividend scenario—is the recycling option most supportive of output, job creation, and a reduction of the unemployment rate. This phenomenon is referred to as the 'double dividend', i.e., that a tax on a 'bad' (GHG emissions) allows the reduction of a tax on a 'good' (employment, renewables, or energy efficiency). However, the government's ability to recycle revenues is likely to be constrained by upcoming EU guidelines and rules under the 2030 Framework. Such rules, if similar to those under the EU 2020 climate policy, will require revenues to be invested in low-carbon urban mobility, energy efficiency measures and renewables support, similar to the design of the mixed scenario assessed here.

From the viewpoint of cost efficiency and economic performance, Romania has much to gain through addressing some of the following challenges. Firstly, the inclusion of strong equity considerations into EU-wide climate policy discussions serves Romania well. Because the Romanian economy is projected to expand faster than the EU and because Romania remains one of the poorest EU countries (reaching just 40 percent of EU average income levels by 2050), it could be argued that

FIGURE 2.14. ETS sectors, agriculture, and forestry provide the greatest mitigation

Emissions reduction contributions by sector in the Super Green scenario

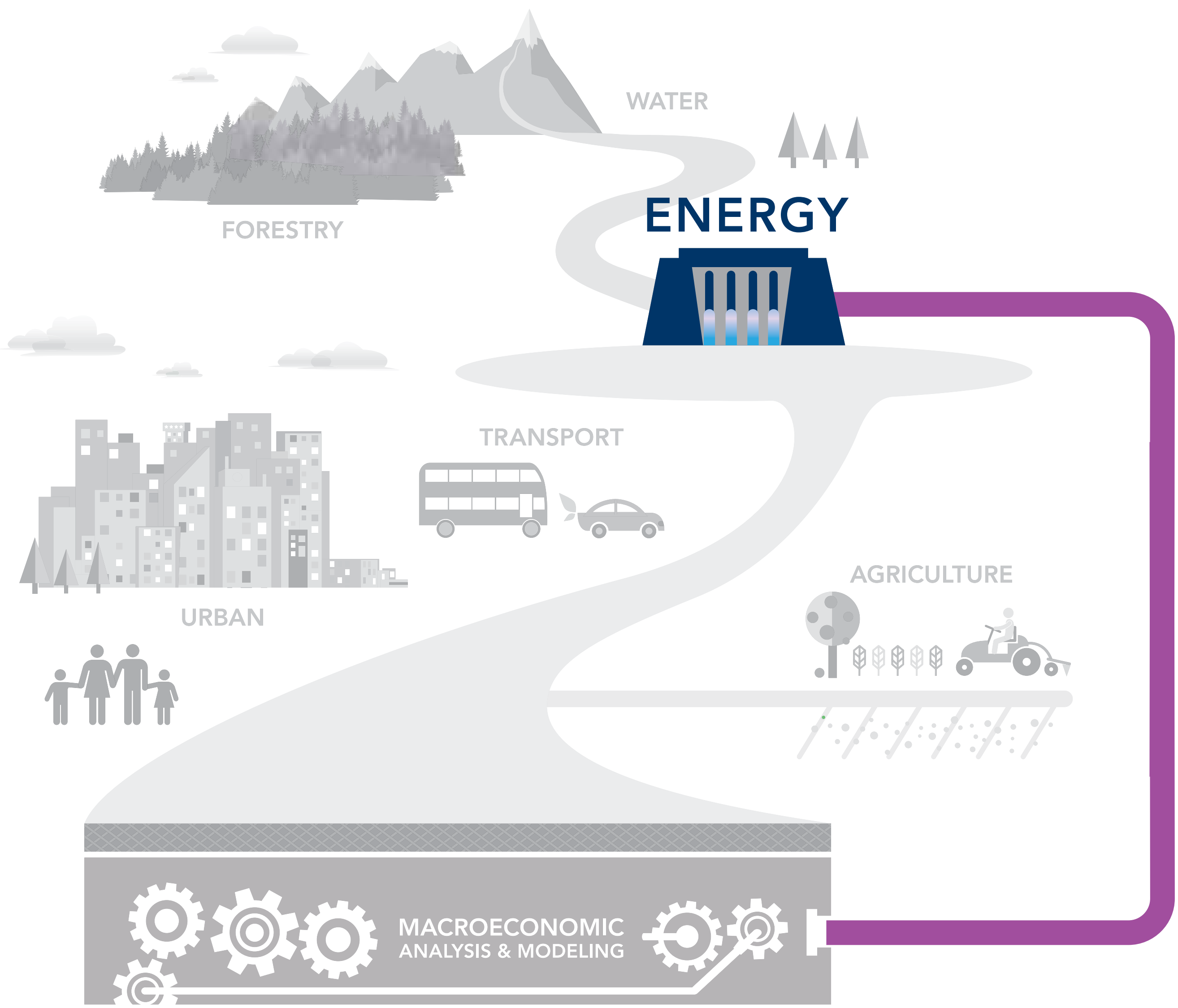


Notes: See notes to Figure 2.8 for description of sectors. Excludes carbon sequestration from agriculture and forestry.
Sources: ROM-E3 model outputs, staff calculations, and Macroeconomic Technical Report.

the constraints on emissions in its non-ETS sectors for 2030 (and perhaps for 2050) should be looser on equity grounds. Secondly, recycling allowance revenues in a mixed fashion, as set out above, improves outcomes. Thirdly, enhancing the flexibility of Romania's economy so that resources and production factors can be reallocated more easily (or increasing the 'elasticities' in the economy) will allow for higher growth with reduced emissions. Fourthly, aggressive exploitation of the sizable potential for energy efficiency improvements in most economic sectors meets multiple goals at efficient cost. Lastly, funding from external non-debt creating sources (such as EU structural funds) for emissions-mitigation investments greatly lowers overall costs to the Romanian economy.

This economy-wide modeling provides a framework and an integrated approach to considering low carbon and green actions, but further sector analysis provides valuable confirmation about greening potential and tangible details about how to achieve that potential. Figure 2.14 illustrates the contributions to mitigation by sector under the Super Green scenario of the ROM-E3 model. Of the total mitigation in 2050 compared to baseline of 43 $MtCO_2e$, energy provides near one-quarter of total mitigation while energy-intensive industries and agriculture and forestry contribute about 17 percent each (not considering carbon sequestration). In the chapters that follow, detailed sector analysis and modeling will supplement this first assessment of mitigation potential. Adaptation actions are also of importance, and the sector analysis in subsequent chapters will address these green actions as well.

Last, the macroeconomic model constructed for this analysis remains available for further development and application by the government for current and future policy questions related to low carbon and green growth. The ROM-E3 model was built in collaboration with Romanian government experts, and it is being transferred to the Commission for Prognosis. The government has the opportunity to apply this model to numerous questions about EU, global, and national policies related to emissions mitigation and other green growth issues and to provide the needed regular updates of this assessment (as noted above). The model also can be applied to a large set of policy questions not related to green growth. There is also the possibility of developing this model further to strengthen its ability to answer questions of interest to the government.


WATER
FORESTRY
ENERGY
TRANSPORT
URBAN
AGRICULTURE
MACROECONOMIC
ANALYSIS & MODELING

CHAPTER 3

How Can Energy Supply and Demand Be Transformed?

CHAPTER SUMMARY

Romania's emissions have dropped significantly from their peak in the late 1980s as a co-benefit of structural transformation and due to the growth in the share of low-carbon energy sources. The energy sector in Romania[1] is characterized by a relatively high share of zero-carbon sources, which constitute one-quarter of primary energy supply[2] and 45 percent of electricity generation and include hydropower, nuclear, wind, biomass, and solar photovoltaic (solar PV). Romania participates in EU emissions trading (the Emissions Trading System, ETS) for energy-intensive sectors which is designed to secure mitigation across the EU of 21 percent compared to 2005 for those sectors, as the centerpiece of the European Union's current climate rules. Those rules are expected to tighten for 2030 and further for 2050. In addition, while the energy intensity of Romania's economy has been decreasing, it is still one of the highest in the EU. However, continuing de-carbonization of Romania's energy sector is a challenging process and will require further transformation of power generation: 46 percent of primary energy and 40 percent of generation still depend on coal[3] and oil. As a result, the energy sector remains responsible for almost 60 percent of Romania's total emissions (excluding LULUCF[4]), and climate change mitigation targets beyond the current set for 2020 cannot be achieved without significant action in the energy sector. Moreover, the country faces substantial investment needs irrespective of mitigation obligations, to replace obsolete fossil-fueled electricity plants; and switching to renewable power to reduce energy sector emissions at the

1. The energy sector is defined here based on the standard IEA/IPCC definition and includes electricity and heat production and energy sector own-use. Note that the energy sector model applied to Romania includes both energy supply and energy demand (or end-users).
2. Total primary energy supply is the sum of production and imports subtracting exports and storage changes.
3. Note that coal includes lignite (or brown coal), sub-bituminous, bituminous, and anthracite (hard coal).
4. Land use, land-use change and forestry.

same time augments those costs. Nonetheless, with good policies and appropriate investments, the energy sector in Romania has the potential to become an engine of economic growth.

Analysis and modeling aimed to find the best solutions for Romania's energy supply mix given the country's current, imminent, and prospective mitigation obligations. Such solutions were modeled as satisfying future energy demand at a minimum cost while meeting emissions mitigation requirements. A TIMES model[5] was used for energy supply modeling while the potential for reduction of energy demand in end-use services through energy efficiency measures was estimated using a tool—Energy Service Demand Analysis (ESDA)—developed for this purpose. Green policy measures were evaluated under three scenarios: Baseline (current EU policy with 2020 targets), Green (likely EU 2030 targets), and Super Green (possible EU 2050 targets). The findings identify optimal power generation and energy efficiency measures to meet the emissions mitigation requirements of the Green and Super Green scenarios. Under the Baseline scenario, energy sector emissions are found to fall to two percent below 2005 levels by 2050, while this reduction is 26 percent in the Green scenario, and 43 percent in the Super Green. Within the energy sector, electricity emissions will drop by 36, 72, and 97 percent respectively. Inclusion of a set of selected energy efficiency measures is critical for the implementation of both the Green and Super Green scenarios, as these measures deliver significant abatement, are cost efficient, and require a modest implementation effort.

Romania can meet the mitigation obligations likely under the EU's 2030 Climate and Energy Policy Framework at moderate costs; but the prospective requirements of the EU 2050 Roadmap, which necessitate at least 80 percent reduction in emissions and the virtual elimination of emissions from the power sector, are likely to be both expensive and challenging to implement. The investment effort in the power sector (including demand management) required for the implementation of the

5. The Integrated MARKAL-EFOM System (TIMES) model, the successor to the Market Allocation Model (MARKAL), both developed by the International Energy Agency.

Green scenario (to meet 2030 requirements) is estimated at €37 billion (present value)[6] or an average annual 1.1 percent of GDP through 2050, while the investment costs of the Super Green scenario (to meet 2050 requirements) are projected to amount to €54 billion (present value) or an average annual 1.7 percent of GDP. The required investments shift upwards after 2030 in both green scenarios, as remaining fossil-based plants are replaced with renewable and nuclear capacity. A lower carbon path for Romania's energy sector will impose significant costs and complex planning challenges on the sector, in particular on power generation. Achieving emissions reduction targets beyond the EU 2020 targets will require Romania to abandon plans for new coal-based power generation capacity and life-extension of existing plants. It will also require significant additional renewable generation capacity and, therefore, a regulatory environment that would promote it. Nevertheless, the government cannot be distracted from critical near-term sector reforms, many of which lay essential conditions for the success of the long-term green transition. Although the costs of greening are projected to rise significantly over time and as requirements for emissions reduction tighten, a lower carbon energy sector needs to be part of Romania's long-term planning. In support of that enduring objective, the TIMES supply model and the Energy Service Demand Analysis tool constructed for this analysis remain available for further development and application by the government.

CHALLENGES FOR GREENER GROWTH

Overview

Romania's economic growth and energy consumption have been decoupling since the early 1990s, and the energy intensity of the economy has been continuously decreasing.[7] However, a significant increase in energy demand is expected to accompany future growth. After the large contractions of the economy and energy consumption in the 1990s, Romania's GDP recovered, expanding by 53 percent during 2000 to 2011, while energy demand remained flat. This slow growth of energy demand was in large part due to structural shifts of the economy toward higher-value-added manufacturing and services and away from energy-intensive industries, as well as significant improvements of energy efficiency within industries. As a result of these two factors, the energy intensity of the economy has been continuously decreasing for more than two decades and is now less than half its 1989 level (see Figure 3.1). In the medium- to long-term, energy consumption patterns are expected to converge toward those of high-income EU countries, and energy demand will increase, in particular, due to growth in demand for transportation and services. These changes are already underway: from 2000 to 2011, energy used in transport grew by 25 percent and in the services sector by 260 percent (although from a relatively small base), while residential and industrial demand declined by 6 and 21 percent, respectively.[8]

At present, primary energy consumption is characterized by a relatively high and growing share of zero-carbon energy sources, leading to a shrinking carbon footprint of the energy sector. This trend has been supported by Romania's high renewable energy potential and production, as well as by nuclear power production. From 1990 to 2012, the share of primary energy supply from zero-carbon

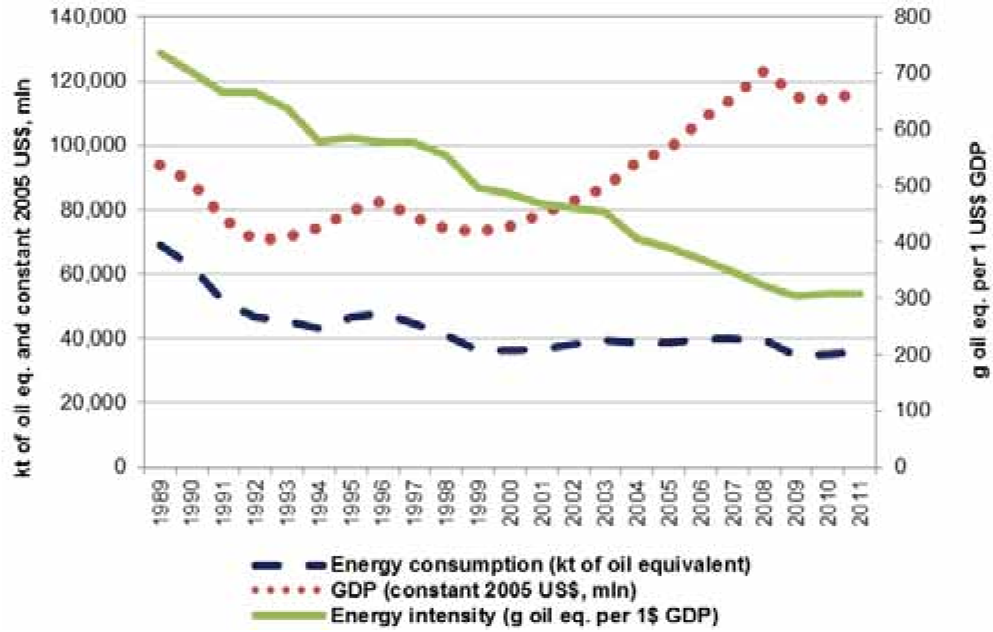
6. At a five percent discount rate. The discount rate was selected as a mid-range social discount rate (the typically used social discount rates range from four to six percent).

7. Energy intensity is measured as primary energy consumption (g of oil eq.) per $1 GDP (constant 2005 US$).

8. Total energy supply needs to satisfy total energy demand in the economy including the transport sector; however, transport GHG mitigation measures are not addressed as part of the energy sector since separate transport sector modeling was undertaken (see Chapter 4).

FIGURE 3.1. Growth and energy consumption have been decoupling and energy intensity continuously declining since the early 1990s

Trends in growth, energy use, and energy intensity



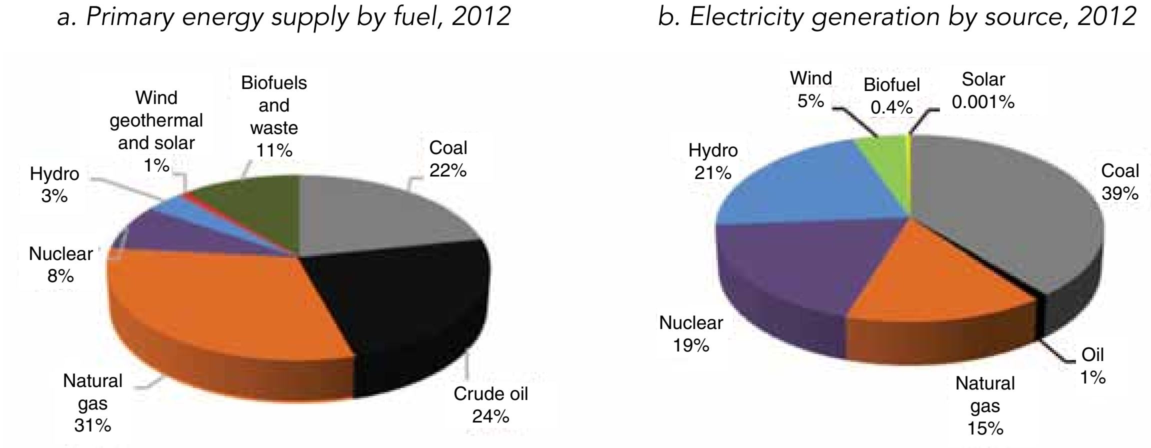
Notes: Energy consumption is measured in thousand metric tons of oil equivalent. GDP is measured in millions of US$ at 2005 prices. Energy intensity is gallons of oil equivalent per dollar of GDP.
Source: Staff calculations based on World Bank data from 2015.

sources (nuclear, hydropower, wind, solar PV, and geothermal) increased from under two percent to 12 percent, and the share of renewable sources grew from 2.5 to 15 percent of the total. At the same time, natural gas declined slightly, from 46 to 31 percent of the total (see Figure 3.2.a). This trend continues to be supported by the country's rich renewable energy potential: hydropower technical potential of 36 terawatt-hours (TWh) per year, wind generation potential of 23 TWh per year (the highest in Southern Europe), high solar potential with an average solar radiation level of 1,400, and rich forestry resources promising to cover 19 percent of total demand.[9]

Electricity production also uses substantial zero-carbon sources and a growing share of renewables, although fossil fuels still dominate. Total installed capacity at the end of 2013 was 22,947 megawatts (MW), and total production was 59,045 gigawatt hours, consisting of 55 percent fossil fuel-based generation, 19 percent nuclear, and 26 percent renewables (see Figure 3.2.b). It ranks 14th among the EU's 29 countries according to the share of zero-carbon generation and 13th according to the share of renewable generation (and fifth in Europe in terms of the amount of wind capacity installed). However, fossil-based generation still dominates electricity production, and about one-third of the fossil fuel-fired capacity is co-generation. The fossil fuel-fired plants consist of predominantly obsolete, high-emissions coal and gas-fired generation units, most of which need to be decommissioned or modernized. Over the period 2005–2011, Romania decommissioned 3,000 MW of thermal generation capacity. Further decommissioning is expected because many plants do not

9. World Energy Council, available at http://www.worldenergy.org/data/resources/country/romania/.

FIGURE 3.2. The share of non-fossil sources of energy is large, but there is room to increase it



Notes: Primary energy supply is the sum of production and imports subtracting exports and storage changes.
Source: IEA.

meet EU requirements. Overall, many generation assets are beyond their useful life: 30 percent are 40 or more years old.[10]

Romania is a net exporter of electricity, with a fast growing volume of power exports. In 2013, it exported 4.7 TWh of electricity, about 8.5 percent of its electricity production, transporting it to Bulgaria, Serbia, and Hungary. Electricity exports, after dropping in the first years of transition and reaching a low point in 1995, surged almost eleven-fold between 1995 and 2011, when the power sold abroad amounted to 5.3 TWh, while imports increased 3.3 times over the same period. However, the trend is characterized by variability, reflecting economic and weather conditions. Going forward, the country plans to further increase its power exports, responding to the growing demand in neighboring countries.

Romania is a significant producer of oil and natural gas, and most of gas consumption is covered by domestic sources; it uses domestic coal entirely for heat and power generation. It has the fifth-largest proven natural gas reserves in Europe, of 3.9 trillion cubic feet, and the fourth-largest proven crude oil reserves in Europe, of 600 million barrels.[11] A significant proportion of gas demand is met from domestic supplies. However, production of these fuels has been declining.[12] Romania also holds 51 trillion cubic feet of technically-recoverable shale gas resources, and there are plans to develop the domestic shale gas industry.[13] However, these plans remain uncertain because of public concerns regarding related environmental issues and perceived potentially high costs of production.

10. Morales Pedraza, Jorge. 2015. *Electrical Energy Generation in Europe*. Switzerland: Springer International Publishing.

11. As of the end of 2012. See BP Statistical Review of World Energy. June 2013. Available at http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy.html.

12. From 1990 to 2012, crude oil production in Romania declined from 169.1 thousand to 83.1 thousand barrels per day and natural gas production decreased from 2.74 billion to 1.06 billion cubic feet per day. The reserve to production ratio is estimated at six years. See World Energy Council, "Gas in Romania," available at http://www.worldenergy.org/data/resources/country/romania/gas/.

13. See US Energy Information Association, "Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States," June 2013, available at http://www.eia.gov/analysis/studies/worldshalegas/.

Currently, all imported natural gas comes from Russia and is delivered via Ukraine. Romania is exploring the possibility of diversifying and importing natural gas from other producers (mainly, Azerbaijan) and is discussing various transport options. Importing LNG (liquefied natural gas) is also a possibility, depending on how global LNG prices evolve over time. Romania's total hard coal (anthracite) resources are estimated at near 2,500 million tons, of which about 11 million tons are commercially exploitable reserves. Lignite resources amount to 9,640 million tons, including reserves of 280 million tons.[14]

Romania has achieved significant progress in reforming energy sector pricing in recent years. One achievement is completing regulatory reform related to non-residential electricity and gas prices in January 2014 and January 2015, respectively. Resulting gas price increases for industry have contributed to a significant reduction in gas consumption. While regulatory reform for residential electricity prices has made progress, the process stalled in mid-2014. Pricing of district heat is the second remaining pricing issue in the energy sector. Heat prices are defined by the regulator, and municipalities can either charge these prices to the consumers or reduce them through subsidies from local budgets. However, non-payment of subsidies by municipalities is common. (A law allowing the Ministry of Public Finance to deduct non-payments from the municipalities' allocation of central transfers was enacted in 2011 but proved politically unfeasible to implement.)

Romania has also undertaken important reforms that promote good governance, managerial and operational efficiency, and financial improvements in the power and gas sectors. Following restructuring and privatization measures taken during the previous decade, several measures were implemented in recent years: the Government Emergency Ordinance on State-Owned Enterprise Governance in 2011, a new Electricity and Gas Law and new regulator (Autoritatea Naţională de Reglementare în domeniul Energiei, the National Energy Regulatory Authority, ANRE) in 2012, initial public offerings of shares of Nuclearelectrica, Romgaz and Electrica and secondary public offerings of the shares of Transelectrica and Transgaz during 2012–14, as well as mandatory competitive electricity trade by the generators through OPCOM (Operatorul Pieţei de Energie Electrică şi de Gaze Natural din România, the Romanian gas and electricity market operator).

Romania's support mechanism for renewable energy was implemented, but later scaled back because it pushed up end-user tariffs. The support mechanism for renewable energy sources established in 2008, a Green Certificate System with centralized trading organized by OPCOM, attracted substantial investment (estimated at €7–8 billion), resulting in construction of approximately 5,200 MW of renewable energy capacity over the next four years and including 3,221 MW of wind, 1,293 MW of solar PV, 586 MW of mini-hydropower, and 102 MW of biomass. Originally-envisioned support levels were doubled when the support system was approved by the Parliament, making the system highly attractive to investors but very expensive to electricity consumers, triggering protests. The energy regulator, ANRE, concluded that the system over-compensated producers and scaled it back for 2014 and onward.

These measures have put Romania's coal power-generating companies under operational and financial stress, depressing their share in total power generation and bringing Romania closer to its emissions and renewable energy targets. Electricity price liberalization, mandatory use of OPCOM for trading, and the renewables support scheme, against a backdrop of subdued demand for electricity following the 2008–2009 crisis, led to a drop in the market share of coal power-generating

14. EURACOAL, "Romania Country Profile," available at http://www.euracoal.com/pages/layout1sp.php?idpage=77.

companies. In some European electricity markets, most notably in Germany, the increase in renewable energy at a time of flat electricity demand has led to a decrease in gas-fired power generation and the shutdown of gas-fired generating units. In Romania, this impact was softened by the country's rising electricity exports, and coal power plants have largely absorbed it, losing competitiveness against existing hydropower and nuclear power plants,[15] but receiving financial support from the government. As a result of decreased coal power production, Romania now expects to exceed its EU-mandated renewable energy target of 20 percent renewable energy in gross final energy consumption by 2020.

Challenges

The energy supply sector is the largest contributor to the country's carbon footprint, responsible for 58 percent of total greenhouse gas emissions (GHGs); and the emissions intensity of the economy significantly exceeds the EU average.[16] Romania's total and per capita emissions have dropped significantly from their peak in the late 1980s as a co-benefit of structural transformation, a pattern typical for transition economies, and the growth in the share of non-emitting energy sources.[17] Total

15. Use of gas in power is concentrated in municipal power and heating plants.

16. Excluding LULUCF. Energy supply sector emissions are from electricity and heat production, which are the sum of three IEA categories: (i) emissions from electricity generation, combined heat and power generation, and heat plants supplying the public (including emissions from own use of fuel in power plants); (ii) emissions from generation of electricity and/or heat by auto-producers (in whole or partly for their own use as an activity which supports their primary activity) (note that these emissions would more typically be distributed between industry, transport, and "other" sectors and counted as part of those sectors' emissions); and (iii) other (including emissions from fuel combusted in petroleum refineries, for the manufacture of solid fuels, coal mining, oil and gas extraction and other energy-producing industries). Data is from IEA, available at http://www.iea.org/stats/index.asp.

17. Total emissions follows the IEA/IPCC definition and includes emissions from the following sectors: energy (electricity and heat production and energy sector own use), transport (all transport activity regardless of the economic sector), residential (fuel combustion in households), and other (commercial/institutional activities, fishing, and emissions not specified elsewhere).

GHG emissions in Romania amounted to 115 million metric tons of CO_2 equivalent in 2010, accounting for a modest 2.5 percent of total European Union emissions and 0.25 percent of global emissions. Per capita emissions are also low; however, the emissions intensity of the economy, while dropping 3.3 times from its 1989 level, was still much higher in 2010 than in many other countries: 2.8 times above the EU level, 2.1 times above the OECD average, and seven percent higher than the world average.[18]

The expense of reducing energy sector emissions comes on top of already high investment needs to address obsolete fossil-based plants and is further augmented by the intermittency of the renewable plants that are replacing them. Eighty percent of existing fossil fuel-fired generation plants and 60 percent of the power distribution networks in the country are already old; and retrofitting of fossil fuel-fired power plants in the last 20 years has yielded scant returns. Replacing such massive existing capacity with new capacity is financially challenging. This capacity will be partially replaced by renewable energy, which creates additional challenges. Expansion of wind and solar is expensive but also technically difficult. Moreover, since wind and solar are variable resources and do not provide capacity commitments against peak load, increase in their penetration will require complementary peak load capacity.

The continued deterioration and decline of district heating systems is particularly wasteful of existing assets and undermines the quality of life in Romanian cities. Many of the remaining operators are no longer economically viable because a substantial number of dissatisfied customers have disconnected from the systems and chosen alternative heating options. Inefficiency and high losses in district heating systems also make them among the most costly to operate in the EU. A multi-year comprehensive program is needed to modernize those district heating systems that are economically viable: to improve efficiency and service quality on the one hand and to implement sector reforms to restore district heating company financial sustainability on the other, while ensuring that subsidies are well targeted to poor households.

Despite substantial progress, Romania still lags significantly behind most EU countries in the broadest measure of energy efficiency in key end-user sectors. Its energy intensity was 40 percent higher than the EU average in 2011, by some measures.[19] The efficiency gap is most pronounced for residential space heating where specific heat consumption is one-third higher than EU best practice. For the two largest industrial energy users, chemicals manufacturing has a value-added energy intensity over four times higher than the EU average (indicating structural issues), and steel-making has an energy intensity per ton of steel that is 70 percent higher than the EU average. These three areas of end-use together account for roughly 40 percent of Romania's final energy consumption.

Thermal retrofit of residential buildings is both a financial and an implementation challenge. Only about one percent of the 150 million square meters of apartment buildings which were determined to be in need of thermal retrofit had been retrofitted as of 2012. Despite very high capital subsidies (of up to 80 percent) provided by the national and local governments, many low-income households are still reluctant to participate. Subsidized energy prices create disincentives. In addition, a lack of positive incentives, insufficient information, inadequate skills, and lagging administrative improvements

18. Emissions intensity here is measured as kilograms of CO_2 equivalent per US dollar of GDP at constant 2005 prices.

19. Measured in GDP in US$. When energy intensity of the economy is measured using GDP in purchasing power parity terms, Romanian energy intensity exceeds that of the EU by just over five percent.

such as strategic planning, prioritization, systematic evaluations and coordination between different levels of government are to blame.

METHODOLOGY AND FINDINGS

Methodology

The analysis summarized in this chapter aims at understanding how energy supply and demand can contribute to Romania's current, imminent, and prospective obligations under the EU to reduce GHG emissions. How would meeting EU and global obligations alter Romania's overall energy[20] and electricity supply mix over the next 35 years? What would be the costs of meeting these obligations? The main objective of the analysis is to find best solutions for Romania's energy supply mix that would satisfy future energy demand at a minimum cost under the different scenarios that represent EU mitigation obligations. Complementary to the supply analysis, the possibility of reducing energy demand in end-use services (such as space heating, lighting, and electrical machines) through energy efficiency measures in the household, non-residential, and industry sectors is also investigated.

The analysis was undertaken in three steps: demand-side modeling, supply-side modeling, and marginal abatement cost curve (MACC) analysis.[21] Green policy measures were evaluated using three scenarios: the Baseline scenario, the Green scenario, and the Super Green scenario. The outcomes of the Green and Super Green scenarios were compared with the outcomes of the Baseline scenario to assess the cost of green measures and their emissions-reducing impact. For each of the three scenarios, demand-side modeling projected the level of overall demand through 2050 and calculated related emissions. Detailed demand modeling was completed for three end-use sectors—residential, services, and industrial—and the level of investment needed to implement proposed green demand-side measures was estimated. Supply-side modeling provided the best solution for the electricity supply mix at minimum cost for all three scenarios, ensuring that the volume of power supplied should be sufficient to meet the level of overall demand projected in the demand-side analysis and that the GHG emissions reduction target should be met.

The supply and demand modeling was linked to macroeconomic modeling and to the marginal abatement cost analysis. The analysis was implemented in the following sequence (see Figure 3.3):

- **Step 1.** The macroeconomic model produced projections for basic macroeconomic indicators, which are considered the key factors of energy demand: GDP, energy sector value-added, and energy prices.[22] These projections were used as inputs in the Excel-based model which projected energy demand.
- **Step 2.** The end-use energy demand model used the macroeconomic projections, together with other input data, to project Baseline energy demand for four end-use sectors—residential, services, industrial, and transport—for 2015 to 2050. The demand model also estimated potential energy efficiency reductions for various end-uses.

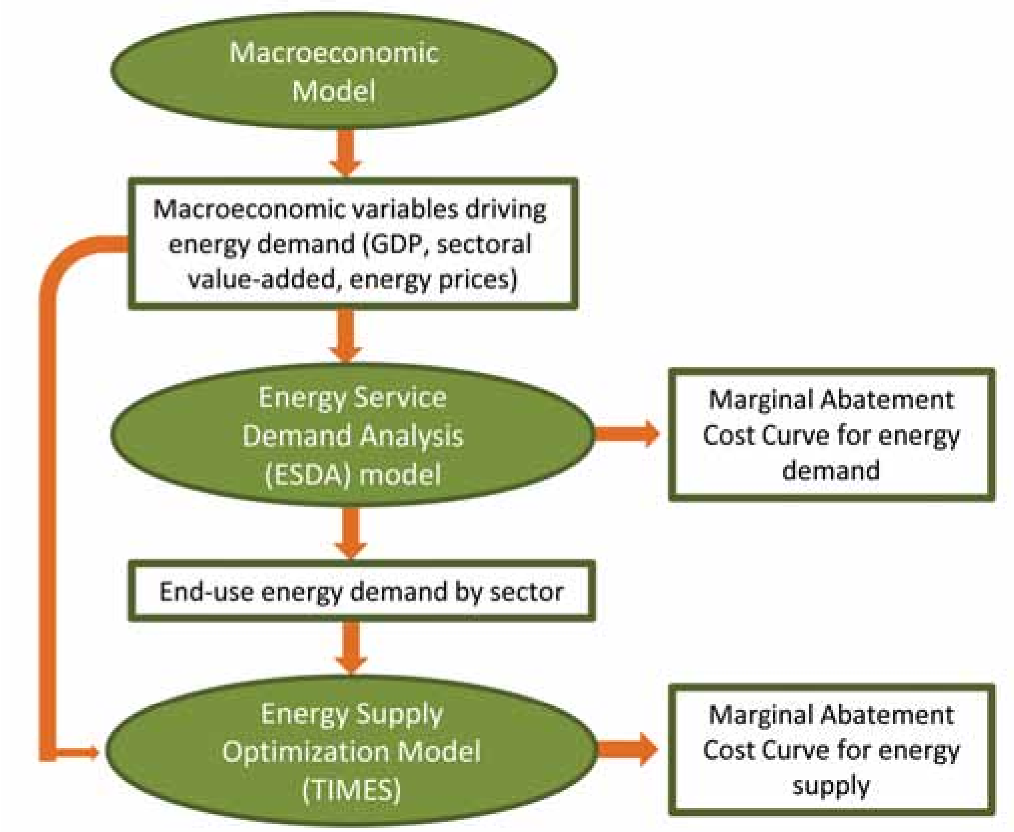
20. In this analysis, energy sector includes electricity supply, non-electric energy supply, and end-use sectors (residential, industry, services/non-residential, and transport). Detailed transport modeling was undertaken separately (see Chapter 4).

21. The MACC analysis is summarized in Chapter 9.

22. See Chapter 2 for details on the ROM-E3 computable equilibrium model constructed to undertake macroeconomic analysis.

FIGURE 3.3. Energy modeling of supply and demand was linked to macroeconomic analysis

Overall analytic framework for energy analysis



Source: Energy Sector Supply Technical Report.

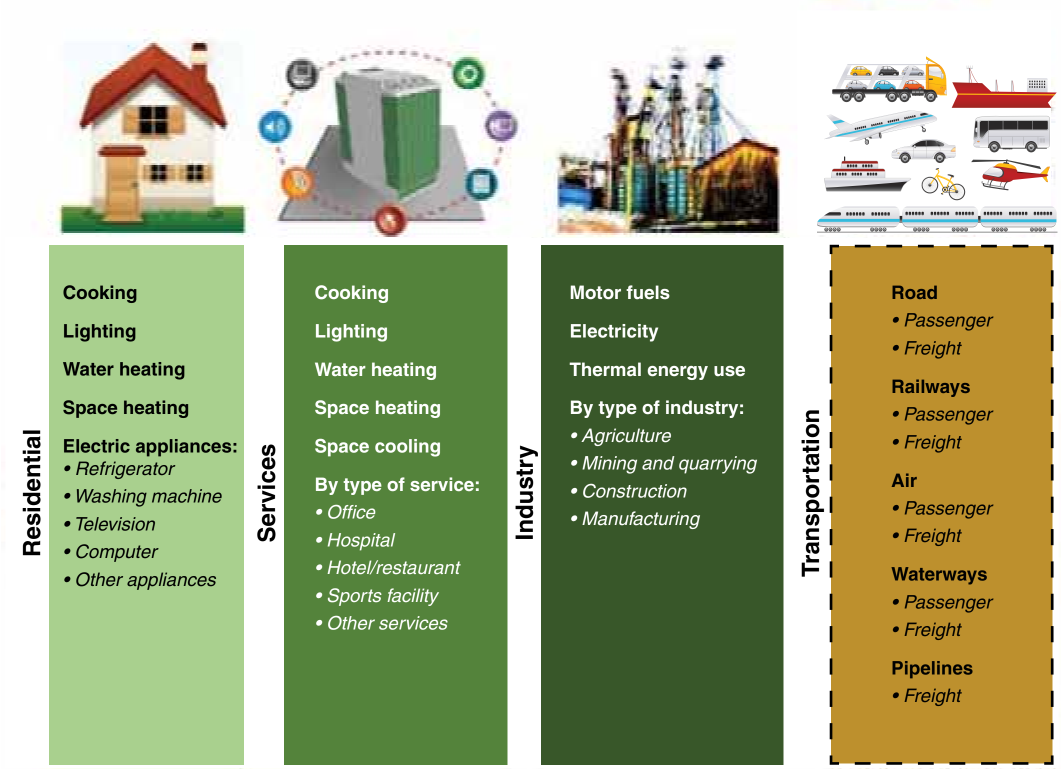
- **Step 3.** To meet power demand projected in Step 2 and the mitigation targets, the energy supply model, TIMES, developed energy supply plans for the Baseline scenario and the Green and Super Green scenarios, with consideration of relevant green measures on both the energy demand and supply sides. The incremental costs under the green energy supply plans additional to Baseline plans were calculated. Also, reductions of GHG emissions under the green scenarios were derived.
- **Step 4.** A marginal abatement cost curve was developed for all generation sources included in the Green and Super Green scenarios and for selected energy efficiency measures.

Demand Side Modeling

A tool, Energy Service Demand Analysis (ESDA), was developed for demand projections. This easy-to-implement Excel-based bottom-up framework serves the purpose of estimating long-term energy sector end-user service demand (see Figure 3.4). It makes use of key demand variables such as sectoral outputs, household income, and GDP, the projections of which are provided by the macroeconomic model (see Chapter 2). These variables are linked with energy consumption through parameters such as specific end-use energy consumption, intensity of energy services (e.g., liters of hot water per person; joules of heat needed per square meter of living area for space heating), and

FIGURE 3.4. The demand analysis tool addressed key elements of all end-users and energy efficiency options

Demand model: simplified sector and end-use service classification



Notes: For residential, services/nonresidential, and industry, demand and emissions were modeled. Transportation demand for energy is modelled separately (see Chapter 4). Manufacturing includes iron & steel, non-ferrous metals, chemicals & petrochemical, non-metallic minerals, food & tobacco, textile & leather, paper, pulp & print, transport equipment, machinery, wood & wood products, and other manufacturing.
Source: Energy Sector Demand Technical Report.

utilization factors of energy service appliances.[23] The demand modeling exercise assessed energy efficiency options in different end-uses. The energy efficiency analysis was designed to reflect the EU's energy and climate strategies, including the 2030 Climate and Energy Policy Framework and the Roadmap for Moving to a Competitive Low Carbon Economy in 2050 (see Chapter 2 for more details). Major energy efficiency improvement measures include use of more efficient lighting and electric appliances, retrofitting buildings with wall, window and roof insulation, and heating and air conditioning system improvements.

Supply Side Modeling

Starting from the end-use energy demand forecasts, the TIMES energy supply model[24] determined the optimum mix of final energy to meet the end-use energy service demand. To meet projected final energy demand, TIMES optimizes the energy supply system, accounting for all potential

23. See the Energy Sector Demand Technical Report for details.

24. The Integrated MARKAL-EFOM System (TIMES) model, the successor to the Market Allocation Model (MARKAL), both developed by the International Energy Agency.

resources (such as coal, crude oil, natural gas, and hydropower), production/transformation facilities (such as electricity generation and district heating) and transportation/transmission/distribution networks, satisfying various resource, technical, economic, environmental and other constraints (including the size of the plants, their capacity factor, and the need for back-up capacity).

The following characteristics of TIMES are of essence to understanding its functioning:

- **It is an optimization model.** It computes the least cost (optimized) path of an energy system for the specified time frame. It aims to supply energy services at minimum global cost (more accurately, at minimum 'loss of surplus') by simultaneously making equipment investment, operating primary energy supply, and making energy trade decisions.
- **It is an equilibrium model.** It is important to note that the TIMES energy economy is made up of producers and consumers of commodities such as energy carriers, materials, energy services, and emissions, and, like most equilibrium models, it assumes competitive markets for all commodities. Thereby, it ensures that there is a supply-demand equilibrium that maximizes net total surplus: based on prices, suppliers produce exactly the quantities demanded by consumers in each time period.
- **It uses a scenario approach** that consists of a set of assumptions about future demand trajectories and their determinants, leading to a coherent organization of an energy system. A scenario typically consists of four types of inputs: energy service demands, primary resource potentials, a policy setting, and a description of the set of technologies.

The structure of TIMES is defined by the data input provided by the user. Qualitative data include lists of energy carriers, the technologies that are deemed applicable over a specified time horizon, as well as the environmental emissions that are to be tracked. Quantitative data contains the technological and economic parameter assumptions specific to each technology, region, and time period (see Figure 3.5).

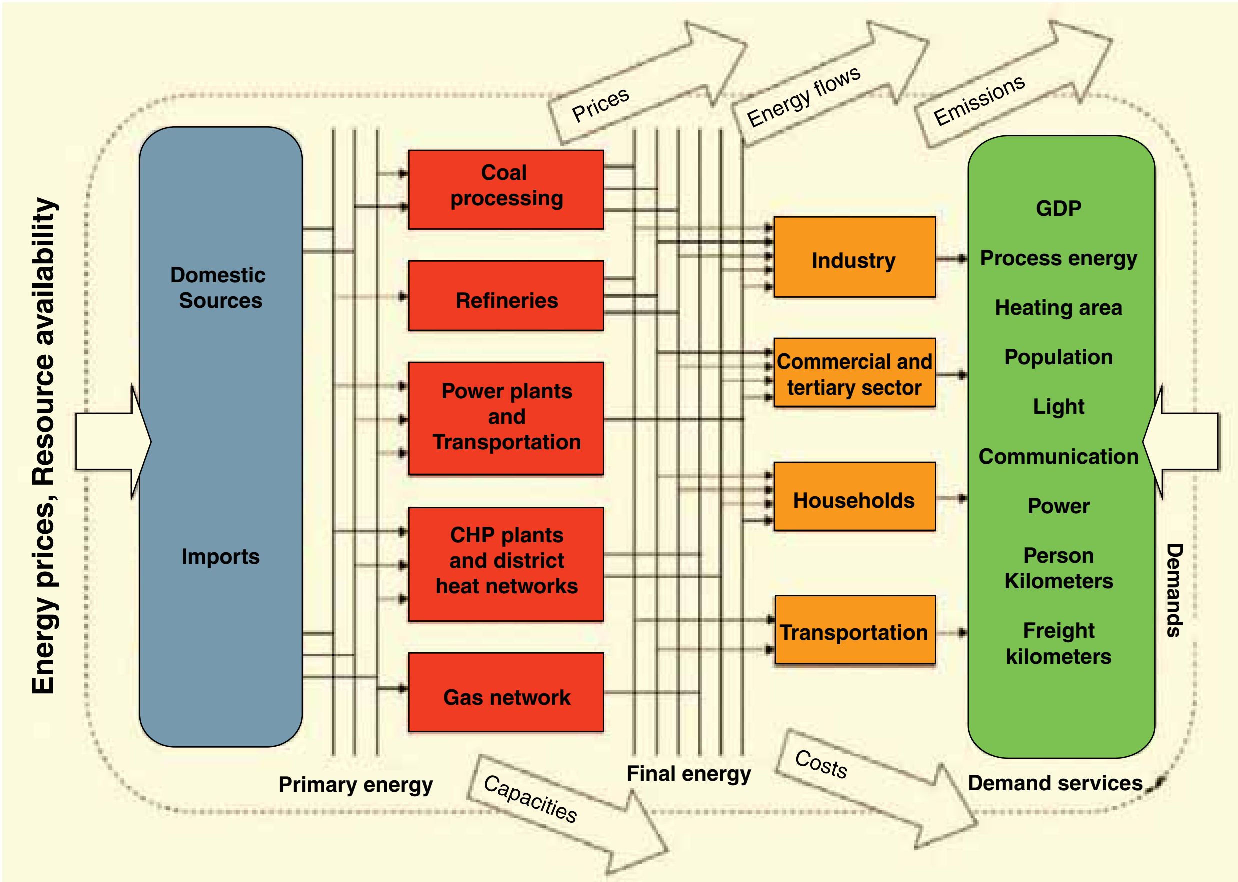
Three scenarios for energy system optimization were considered: a Baseline, a Green scenario, and a Super Green scenario. The scenarios, consistent with those used for macroeconomic analysis (see Chapter 2), were defined in the following way:

- The **Baseline scenario** is an extrapolation of the current state of the energy sector including already planned or implemented mitigation measures, in particular ongoing implementation of the current EU 2020 Climate and Energy Package, which sets an EU-wide target to reduce GHG emissions by 21 percent compared to 2005 in energy-intensive sectors, which participate in EU emissions trading. However, it does not include broader reforms that the energy supply system needs to implement in line with the EU's long-term plan to reduce carbon emissions.[25]
- The **Green scenario** models implementation of the proposed EU 2030 Climate and Energy Policy Framework, which sets overall GHG mitigation at 40 percent compared to 1990 levels. For the power sector and other ETS participants, the proposed EU 2030 target corresponds to the reduction of GHG emissions of 43 percent for the EU as a whole compared to 2005.

25. Emissions reduction here are generally cited against 2005 because that is the year EU emissions trading was established; thus, all practical rules and targets are formulated against 2005. 1990 is cited in the original broad policy statements because it is the EU's base year for the Kyoto Protocol and other international obligations.

FIGURE 3.5. Supply modeling selects optimum mix of final energy and power generation

The structure of the supply side model, TIMES/MARKAL



Source: IEA-ETSAP (Energy Technology Systems Analysis Program of the International Energy Agency) and Energy Sector Supply Technical Report.

- The **Super Green scenario** is driven by the EU's prospective Roadmap for Moving to a Competitive Low Carbon Economy in 2050 which aims for the EU to reduce GHG emissions by at least 80 percent below 1990 levels by 2050, to a large extent by almost total decarbonisation of the power sector.

Marginal Abatement Cost Analysis

A marginal abatement cost curve (MACC) for electricity supply and energy efficiency is estimated in addition to the demand and supply modeling. The measures examined are presented according to two parameters of the MACC: potential mitigation impact (kilotons of CO_2, carbon dioxide equivalent, abated) and the unit cost of abatement (cost per metric ton of CO_2e abated). The MACC calculations for energy demand measures applied the ESDA model and include only end-use energy efficiency measures for the household sector, as these measures bring the most immediate and effective results. The MACC calculations for electricity supply used the TIMES model but included all green power technologies available for development in Romania: solar, hydropower, wind, biomass, natural gas plants with installed carbon capture and storage (CCS, nuclear). The TIMES model constructed the best (minimum cost) mix of generation sources to achieve a desired abatement level in eight different cases, corresponding to the eight green generation technologies. The abatement level was set as a constraint, and each scenario maximized generation from one out of the eight generation sources, within the constraints of the model. For example, in one case, solar PV was set to be maximized in the electricity supply system, and the rest of the generation technologies were selected by the model. The model also calculated the cost of such a system and the cost of the baseline system. The difference between these two costs constituted the marginal cost, which was then converted into net present value.

Findings

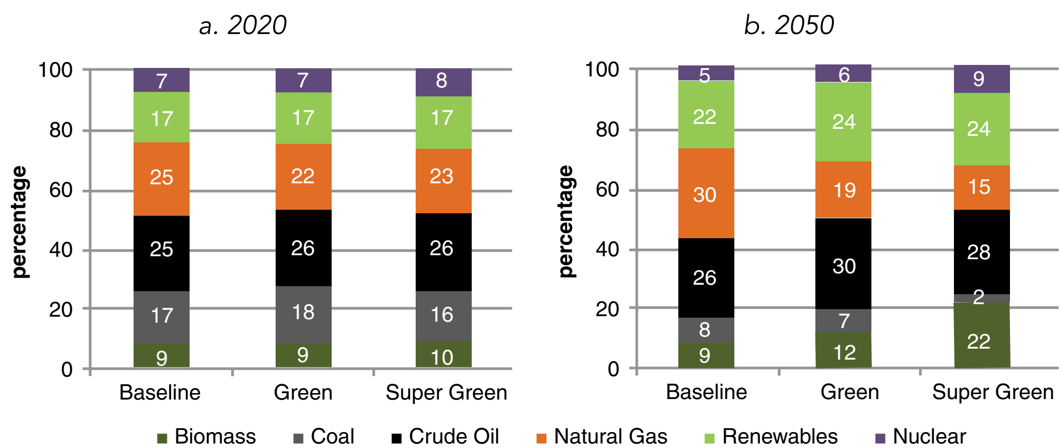
This section presents the main finding of modeling. It aims to demonstrate the impact of green measures on sector outcomes by comparing the trends in sector development under the three scenarios: Baseline, Green, and Super Green. The sector outcomes include projections of primary energy supply, the structure of electricity generation capacity, and electricity generation mixes, required investment and total costs (investment and operations and maintenance), and the level of emissions.

Primary Energy Supply

Under the Baseline scenario, Romania's total primary energy supply in 2050 is projected to increase by almost half from 2015 levels, from about 38,000 ktoe (kilotons of oil equivalent) to about 57,000 ktoe. The structure of primary energy supply reflects only a moderate increase in the share of cleaner energy sources. The share of renewable energy (hydropower, wind and solar PV) increases from 17 percent in 2015 to 22 percent in 2050. While oil and natural gas continue to be the most important sources of primary energy, the contribution of gas to the mix increases and the share of oil decreases over time: oil's share in the Baseline scenario drops slightly from 29 percent in 2015 to 26 percent in 2050, while the share of gas increases by eight percentage point, from 22 percent in 2015 to 30 percent in 2050. The share of coal drops from 16 percent in 2015 to eight percent in 2050 in the Baseline. The share of biomass remains at nine percent. (See Figure 3.6).

FIGURE 3.6. Low carbon sources replace fossil fuels in energy supply in all scenarios

Primary energy supply by source, 2020 and 2050



Note: Renewable sources include hydropower, wind and solar PV. Biomass is presented separately from other renewable sources because it is not free of emissions.
Source: Energy Sector Supply Technical Report.

Moving further towards a greener energy system, the Green scenario contains further expansion of renewable and non-fossil energy supply and contraction of fossil energy supply. In the Green scenario, the share of renewables (hydropower, wind and solar PV) in 2050 is higher than in the Baseline: in 2050, it equals 24 percent or two percentage points higher than in the Baseline. The share of biomass is three percentage points higher in the Green scenario than in the Baseline in 2050. The reverse happens with natural gas: its share in 2050 in the Green scenario is 19 percent or five percentage points lower than in the Baseline. (See Figure 3.6).

The Super Green scenario assumes that GHG emissions from power generation are eliminated along with a significant reduction of non-power sector energy emissions—requiring much more aggressive measures than in the Green scenario. While the share of renewables stays at the same level as in the Green scenario, the share of biomass is higher (22 percent) and the share of gas is lower (15 percent). Coal almost disappears from the mix, falling to two percent. Also, nuclear energy increases to nine percent of the total (from six percent in the Green and five percent in the Baseline scenarios). (See Figure 3.6).

Electricity Capacity

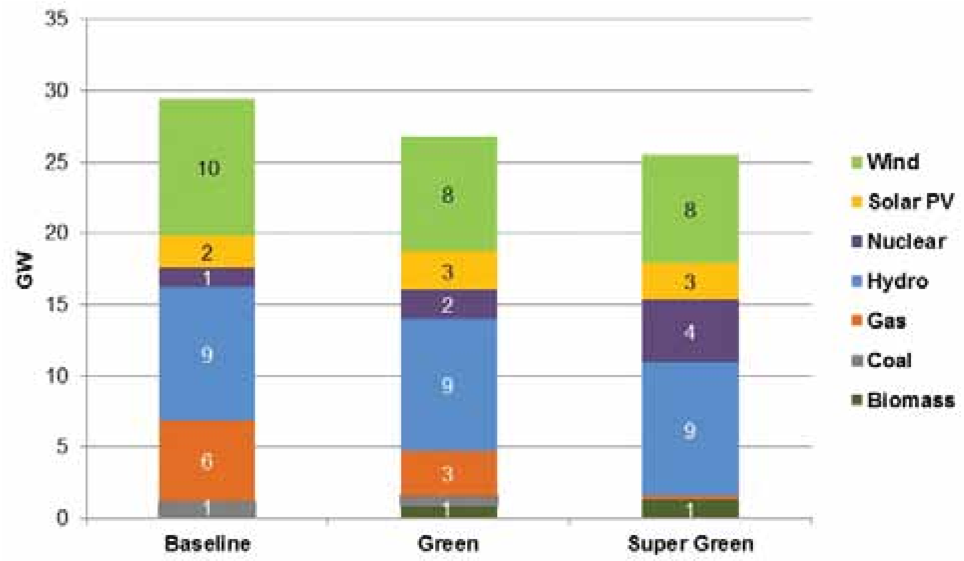
To meet increasing demand in the face of predicted rising prices for emissions allowances under the ETS in the Baseline scenario, total installed capacity for power generation is projected to increase from 23 gigawatts (GW) in 2015 to 30 GW by 2050—an expansion of 29 percent. This increase will be largely covered by new wind, hydropower, solar PV, and also gas capacities, which replace coal and oil sources in the mix. From 2015 to 2050, oil declines from two GW to 0.2 GW (from seven percent to one percent of total capacity), and coal from seven GW to one GW (from 30 percent to four percent of total capacity). The share of wind and solar PV will increase tremendously: together they constitute four GW in 2015 and 12 GW in 2050. Nuclear capacity is unchanged: Romania's two nuclear power plants, Cernavado Plants 1 and 2, currently account for about six percent of the country's total installed capacity, and there will be no installation of new nuclear capacity under the Baseline through 2050.

The higher share of intermittent or variable generation resources (wind and solar) creates a challenge for load balancing. The Baseline scenario would have ten GW of new wind and solar capacities over the next 35 years. This high penetration of variable generating sources creates a challenge in balancing generation and load. To meet peak load, installed capacity should also have sources that provide constant, non-variable, generation (e.g. coal, gas, and nuclear). At present, Romania has a ratio of 23 GW of installed capacity versus 10 GW of peak load. Adding more variable sources would require a higher ratio of total installed capacity to peak load, because the risk of insufficient generation for peak load increases faster than the growth in the share of intermittent sources. However, because non-variable generation involves economies of scale, electricity generation from all non-variable sources will not be fully utilized domestically. Exporting the excess generation could be a solution.

The need for zero-emission sources for power generation is higher in the Green and much higher in the Super Green scenario than in the Baseline. Fossil fuel-based generation resources (i.e., coal, gas) decrease in the Green scenario and are almost completely eliminated by 2050 under the Super Green scenario. On the other hand, nuclear power capacity increases by one GW in the Green and three GW in the Super Green scenario, as compared with the Baseline, providing base load capacity needed to back up the increase in variable generation. As a result, the share of nuclear in the 2050 capacity mix increases from five percent in the Baseline to 13 percent in the Green and 15 percent

FIGURE 3.7. Generation capacity in 2050 is cleaner in the green scenarios with demand contained by energy efficiency measures

Total Installed capacity by fuel, 2050, in GW



Source: Energy Sector Supply Technical Report.

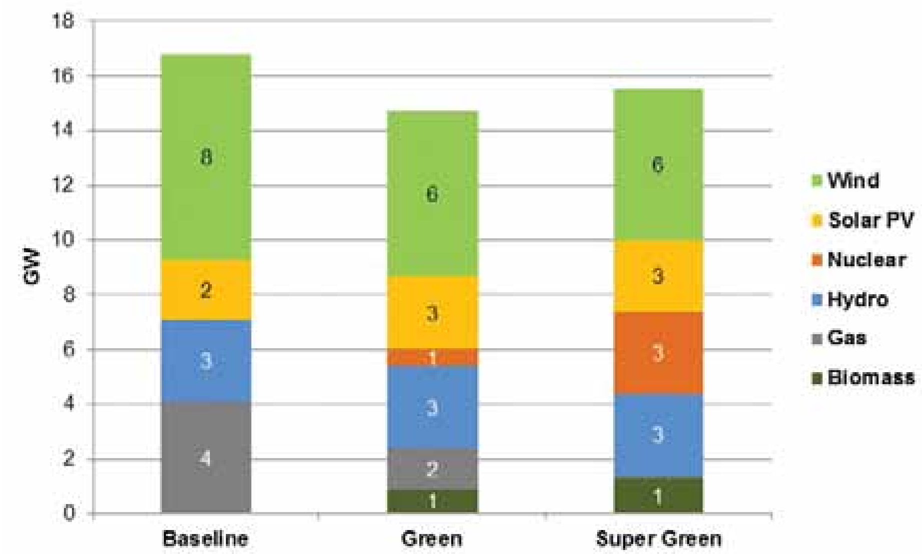
in the Super Green scenario. Wind, solar PV, and hydropower have approximately the same capacity level across scenarios in 2050. Biomass is not part of the capacity mix in the Baseline but is present in both the Green and Super Green scenarios at a level of one GW. (See Figure 3.7).

Energy efficiency measures on the demand side can significantly contribute to lowering the capacity needed for electricity generation. Large-scale energy efficiency improvements on the demand side (in energy end-use sectors such as the residential and commercial sectors) are considered in the Green and Super Green scenarios. Major energy efficiency improvement measures include use of more efficient lighting and electric appliances; retrofitting buildings with wall, window and roof insulation; heating system improvements in residential, commercial and public buildings; and use of efficient electric motors and thermal energy equipment in industry. The implementation of such measures leads to a projected 26 percent reduction of residential sector energy consumption by 2050 from that in the absence of these measures. The energy efficiency measures in non-residential buildings (e.g., more energy efficient space heating and space cooling) result in a 30 percent reduction in service sector energy demand. In the case of the industrial sector, the introduction of more energy-efficient technologies, especially electric motors and boilers, leads to a 16 percent reduction in industrial sector energy consumption. If the energy efficiency measures considered in the analysis are implemented successfully, it would save three GW and four GW of installed capacity under the Green and Super Green scenarios respectively (see Figure 3.7). The impact of the energy efficiency measures is also clearly visible in the demand for new generation capacity; addition of new capacities under the Green and Super Green scenarios would be two and one GW lower as compared to that under the Baseline scenario (see Figure 3.8).

The new installed capacity (constructed during 2015–2050) consists of wind, solar PV, hydropower, natural gas, biomass, and nuclear. The structure of new capacity differs by scenario. Only wind and hydropower play the same role (in terms of capacity level) in all three scenarios: wind capacity exceeds

FIGURE 3.8. New capacity is dominated by renewables and nuclear in green scenarios, with demand contained by energy efficiency

New installed capacity, 2015–2050, GW



Source: Energy Sector Supply Technical Report.

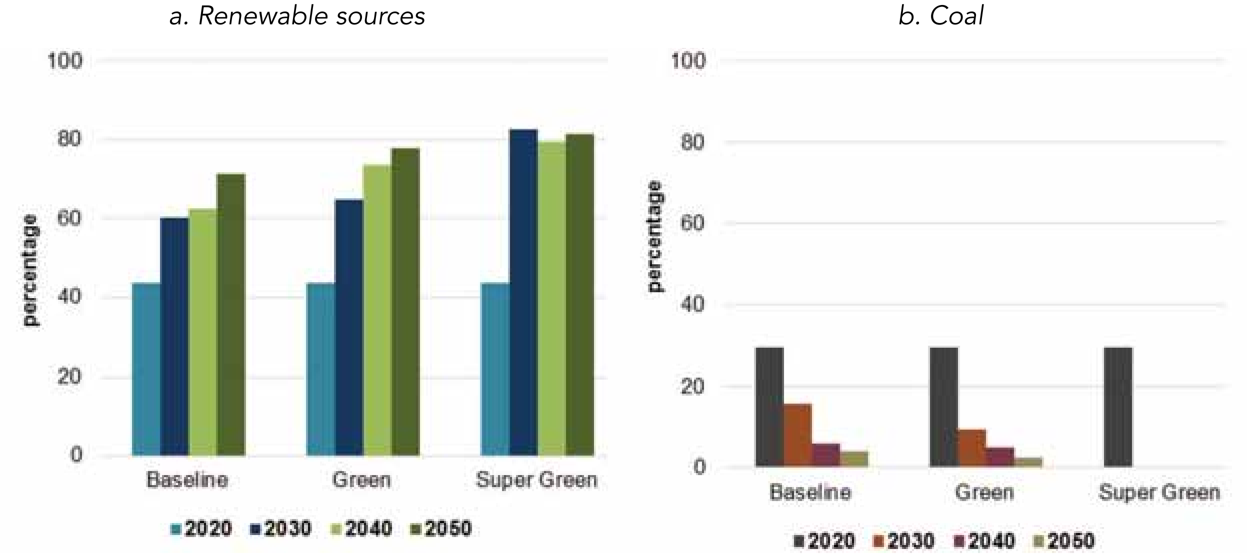
six GW[26] and hydropower capacity amounts to three GW. The new hydropower capacity is assumed to operate at a very low capacity factor of 34 percent, thereby incorporating any adverse potential climate change impacts on catchment areas and run-off.[27] Solar PV has importance in all scenarios but to a differing extent: capacity is higher in the Green and Super Green scenarios (with three GW in each) but just two GW in the Baseline. Nuclear capacity of three GW would be added in the Super Green scenario while natural gas capacity is built under the Baseline (four GW) and Green scenarios (two GW). Under the Super Green scenario, no fossil fuel plants, old or new, will exist by 2040; and in this scenario, the power sector in Romania would be emissions-free by 2050. (See Figures 3.8 and 3.9).

Electricity Generation

The electricity generation mix changes significantly across scenarios. While the share of non-fossil fuel based electricity generation equals near 60 percent under the Baseline in 2050, it exceeds 85 percent under the Green scenario and reaches 100 percent under the Super Green scenario. Under the Green and Super Green scenarios, electricity generation from fossil fuel-based sources decreases rapidly. For example, there would be no electricity generation from coal, gas, or oil by 2040 under the Super Green scenario. Electricity generation from nuclear power generation facilities under the Green and Super Green scenarios would be almost three times as high as that of the Baseline scenario. The impact of demand side energy efficiency measures on saving electricity generation is significant. If the demand-side energy efficiency measures are implemented successfully, the need for electricity generation would be reduced by 20 and 11 percent in the Green and Super Green scenarios respectively. The lower reduction in generation under the Super Green scenario as compared to the Green scenario is explained by the Super Green scenario's mitigation target (almost complete

26. Note that Romania has 12–14 GW of economically exploitable wind potential, and the current capacity is three GW.
27. See Chapter 6 (Water) for analysis of the impact of climate change on water availability.

FIGURE 3.9. The share of renewables grows, mostly at the expense of coal, especially in the Super Green scenario



Notes: Percentages calculated based on installed capacity. There is no coal in the Super Green scenario after 2025.
Source: TIMES modeling outcomes.

elimination of power sector emissions) and the consequent high level of renewable (variable) power sources in this scenario. The higher share of variable sources of generation requires a higher ratio of total installed capacity to peak load to avoid the risk of insufficient generation for peak hours. This pushes up baseload capacity, which is almost fully limited to nuclear, and, as a result, nuclear generation has a much bigger presence in the Super Green scenario. (See Figure 3.10).

Despite the focus on the electricity portion of the energy sector, because of its critical role in energy sector mitigation, other parts of the energy sector were also considered. Heating, oil refineries, and households as providers of energy services for own use were reviewed. This analysis found that demand for space heating is likely to grow in the future despite energy efficiency improvements, due to increasing residential and office space. Currently, heat is produced mainly by combined heat and power plants that use natural gas or biomass. Modelling demonstrated that final demand for heat increases by 20–23 percent in 2050 compared to 2015 if energy efficiency measures are not implemented. However, with the implementation of energy efficiency measures, the situation reverses: heat demand decreases by 10–14 percent in 2050 from the 2015 level. While natural gas remains the main fuel source in heat production during 2015–50 in all scenarios (because there is no obvious alternative source), mitigation is achieved by improved (cleaner) technologies used for heat production and the decentralization of the heating sector.

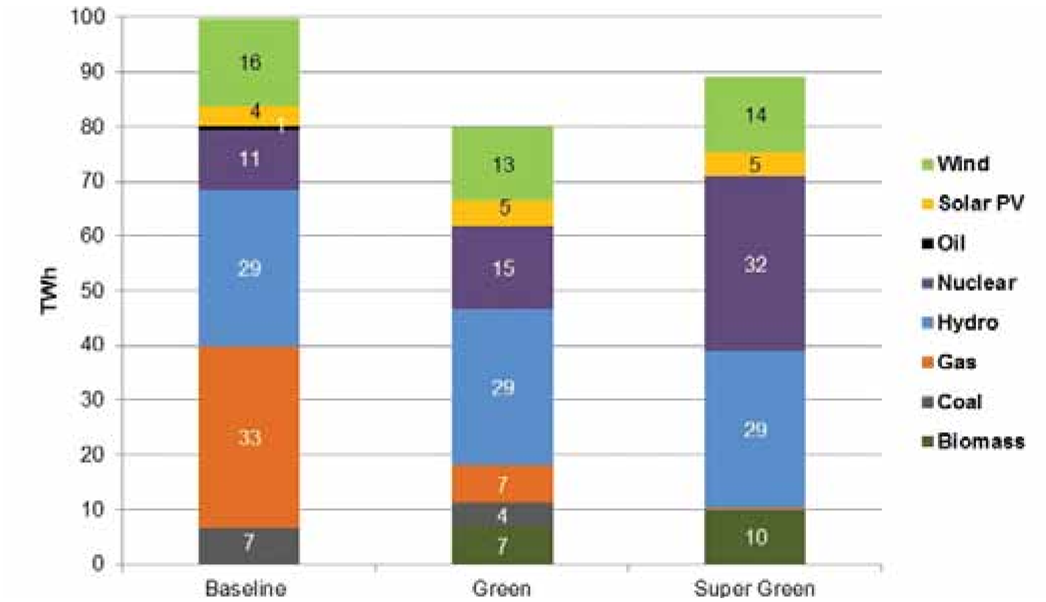
Total Supply Costs: Energy Sector and Electricity Sector[28]

Total energy supply costs decrease from Baseline to Green scenario and grow more significantly in the Super Green scenario. In the Baseline scenario, energy supply costs (including capital, fuel and

28. As noted above, the energy sector model applied to Romania includes both energy supply and energy demand (or end-users).

FIGURE 3.10. Generation in 2050 is dominated by renewables with demand contained by energy efficiency

Total generation by fuel, 2050, in TWh



Source: Energy Sector Supply Technical Report.

operational costs) over 2015–2050 will total an estimated €336 billion (in present value),[29] but would decrease to €326 billion in the Green scenario due to implementation of energy efficiency measures on the demand side. Total energy supply costs under the Super Green scenario are projected to increase further, to €356 billion, as the reduced operational costs from energy efficiency implementation is offset by expensive new nuclear power and CCS-equipped gas plants for power generation. Energy efficiency measures that reduce energy demand and thereby lower required energy supply require additional investment of €19 billion over the 2015–2050 period (or about 0.6 average annual percent of GDP) but save €29 billion in fuel and operational costs on the supply side.

Energy sector investment costs are the biggest contributor to total costs, and the Super Green scenario has especially heavy additional investment needs. Romania is facing a substantial replacement of existing coal-based power plants by gas and renewable energy-based power generation: existing fossil-based plants are quickly becoming obsolete, and the switch to lower emissions supply is present even in the Baseline. In the Baseline, the retirement of coal and lignite plants happens mostly early on: 1.5 GW of coal capacity retires by 2025, an additional 3.7 GW by 2035, and another 0.3 GW by 2040. Since the costs of replacing these plants arrive relatively soon, their discounted value is higher. In addition, other plants retire over the years: overall, the Baseline involves newly-built capacity of 17 GW, while Green includes 15 GW of new plant capacity (with demand contained by energy efficiency measures). Therefore, the incremental (to Baseline) cost under the Green scenario is not significant, because the heaviest financial burden is already imposed in the Baseline. The incremental cost of the Super Green scenario as compared to the Green scenario is high because less-expensive generation sources are replaced by more expensive ones (in particular,

29. At a five percent discount rate. The discount rate was selected as a mid-range social discount rate (the typically used social discount rates range from 4 to 6 percent).

three GW of nuclear are built in the Super Green while only one GW is built in the Green scenario), and this happens earlier, increasing the discounted costs. Also, the Super Green scenario requires more generation than the Green, pushing up capital, fuel, and operations and maintenance costs.

The electricity system will require €28 billion in investment costs in the Baseline during 2015–2050 to meet demand or about 0.8 percent of GDP on average. Required investment increases to €37 billion (present value) in the Green and to €54 billion in the Super Green scenario, or 1.1 and 1.7 percent of GDP through 2050 respectively. The additional costs of the green scenarios above baseline costs come partly from investment in energy efficiency measures that contain the growth of demand for electricity (costing eight billion euros). In addition, the Super Green scenario almost eliminates power sector emissions by 2050, and this is costly: almost all fossil plants are replaced by 2050 by more capital-intensive renewable energy-based generation. As a result, investment needs in the power sector double from the level needed in the Baseline.

Investment needs for the electricity sector are substantial in all cases but rise significantly as requirements for emissions reduction tighten. Until 2020, investment needs in electricity supply and demand total about seven billion euros (present value) in the Baseline to over nine billion euros in the green scenarios. In all three scenarios, the burden of investment rises over time, with 40–45 percent of the total falling due in the last decade of 2040–2050, partly because most of the fossil-based plants retire at that time. In the Green scenario, new wind, solar PV, nuclear, hydropower, and gas is added, and coal and oil-based generation almost disappears by 2050. In the Super Green scenario, new electricity generation from renewable sources and nuclear sufficient to eliminate electricity generation from coal-based sources by 2030 is constructed. Nuclear plant investment after 2030 further contributes to high investment costs in the Green and Super Green scenarios. Energy efficiency measures require significant and rising investments of their own. For both these categories, financing will come from the private sector, although the public sector may need to establish programs of support for energy efficiency, with some financing available from the European Union (See Table 3.1).

Emissions: Energy Sector and Electricity Sector[30]

Romania's energy sector GHG emissions return to near the 2005 level by 2050 under the Baseline scenario, but the green scenarios secure dramatically lower levels. In the Baseline scenario, 2030 emissions stand nine percent lower than 2005 emissions while 2050 emissions are just two percent below 2005. Emissions in the Green scenario are about 25 percent below 2005 by 2030 and hold steady through 2050, while the Super Green scenario pushes energy sector emissions to almost half of 2005 by 2030, and they rise only slightly by 2050. While the absolute level of emissions in all three scenarios decreases throughout 2015–2050, the pace of emissions reduction exhibits different trends across scenarios. It decreases steadily in the Baseline scenario because growing demand is not restrained in the Baseline and because of only moderate action toward the replacement of fossil fuels with renewable energy. When more aggressive actions on energy efficiency and lowering carbon are taken in the Green scenario and when more aggressive replacement of fossil fuels is implemented in the Super Green scenario, the pattern of emissions reduction changes. In these two scenarios, during 2015 to 2020/2025, the pace of emissions reduction slows because many of the measures that have been taken require time for implementation (e.g., electricity plant construction).

30. As noted above, the energy sector model applied to Romania includes both energy supply and energy demand (or end-users).

TABLE 3.1. Electricity investment requirements jump after 2030

Schedule of electricity investments and energy efficiency by scenario, billions of 2010 Euros

	2015–2020	2020–2030	2030–2040	2040–2050	2010–2050 (DISCOUNTED)[1]
Electricity supply:					
Baseline	7.4	14.2	17.5	27.6	27.6
Green	7.4	12.5	19.5	31.6	28.2
Super Green	7.3	22.5	38.3	51.9	45.3
Energy efficiency:	3.1	11.1	15.2	19.0	**19.1**
Electricity[2]	1.6	5.3	5.9	6.8	8.3
Other[3]	1.4	5.8	9.3	12.2	10.8
Total electricity investment:[4]					
Baseline	7.4	14.2	17.5	27.6	27.6
Green	9.0	17.8	25.5	38.4	36.5
Super Green	9.0	27.8	44.2	58.7	53.6
Total energy investment:[5]					
Baseline	7.4	14.2	17.5	27.6	27.6
Green	10.4	23.6	34.8	50.6	47.3
Super Green	10.4	33.6	53.6	70.9	64.5

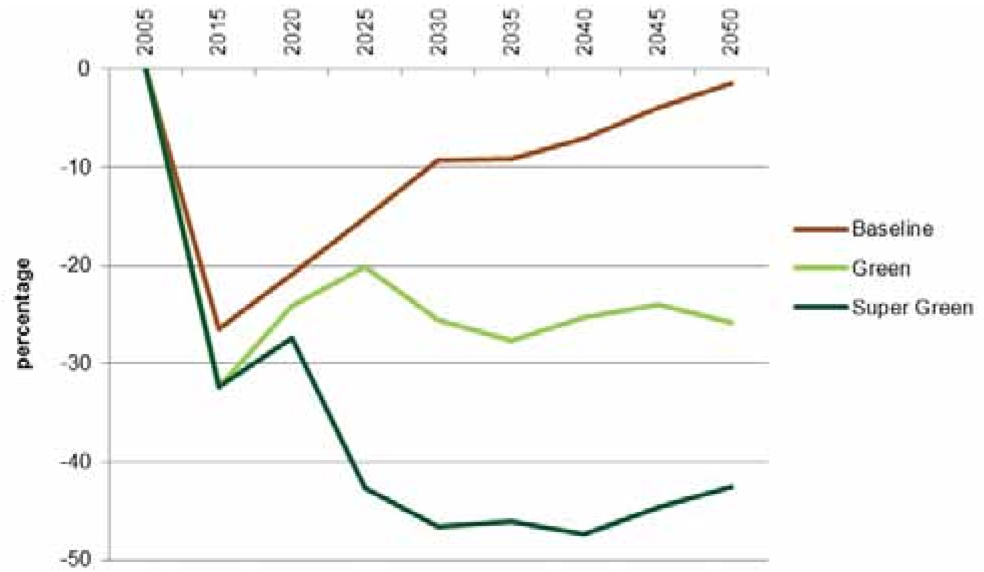
Notes: [1]using a five percent discount rate. All other columns are in constant prices but not discounted. [2]electricity energy efficiency is more efficient electrical appliances in residential and nonresidential buildings. [3]other energy efficiency is residential and nonresidential space heating and cooking measures. [4]electricity supply investment and investments in electricity-saving efficiency measures. [5]electricity supply investment and investments in all energy efficiency measures.
Sources: Energy Sector Supply Technical Report and Energy Sector Demand Technical Report.

After this phase, the pace of emissions reduction increases through 2030 or so and then holds steady. (See Figure 3.11).

The electricity sector experiences a large reduction of emissions in all scenarios over time, and the pace of reduction increases in all three scenarios in later years. This pattern emerges in the green scenarios due to a combination of aggressively implemented energy efficiency measures that significantly constrain demand growth and as a result of aggressive actions on the supply side—an increase in the share of non-fossil sources of electricity. In the Baseline scenario, emissions in 2030 are 20 percent below 2005 and 36 percent below 2005 in 2050, while the respective outcomes in the Green scenario are 45 percent in 2030 and 72 percent in 2050. The biggest reduction is in the Super Green scenario: 92 percent emissions reduction in 2030 and 97 percent in 2050. In this scenario, the electricity sector almost completely eliminates emissions. Both the absolute level of emissions and the pace of its drop increase in all three scenarios throughout 2015–2050, although the pace of emissions reduction initially slows while the measures are in the process of implementation during 2015–2020/2025, a typical delay in outcomes when measures require time for implementation. (See Figure 3.12).

FIGURE 3.11. Energy sector emissions drop in green scenarios, but at different paces

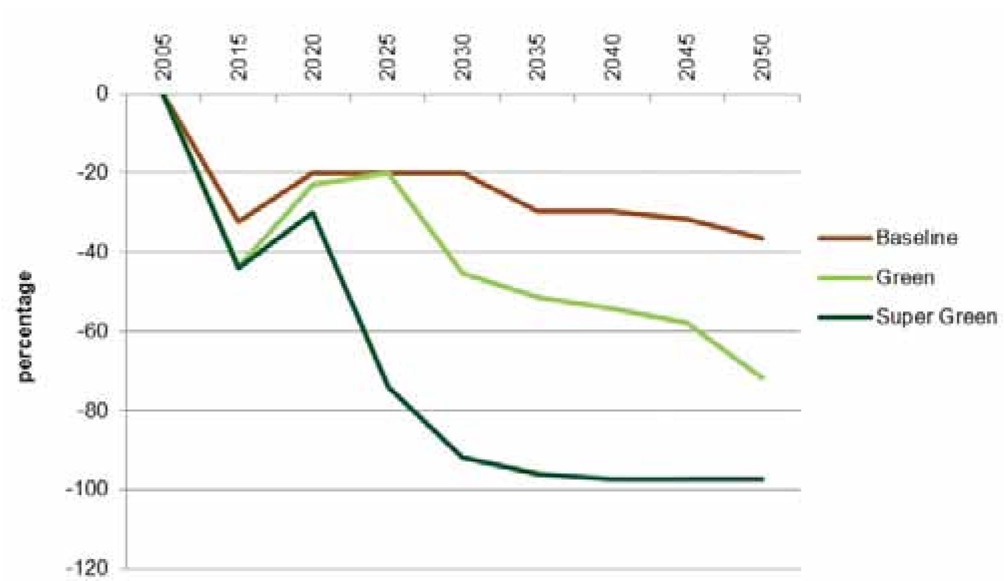
GHG emissions reduction in energy sector, compared to 2005, in %



Source: Energy Sector Supply Technical Report.

FIGURE 3.12. Electricity sector demonstrates a significant and increasing emissions reduction

GHG emissions reduction in electricity sector, compared to 2005, in %



Source: Energy Sector Supply Technical Report.

Marginal Abatement Cost Curve

The marginal abatement cost curve shows that the proposed measures provide significant potential abatement, totaling near 30 million metric tons of carbon dioxide equivalent per year in 2050 under the Super Green scenario. The demand side measures mostly have negative net costs (positive benefits), and when applied on a large scale, they will deliver a significant level of mitigation. Therefore, they are the first candidates for implementation. Then, the most cost-efficient electricity supply options are solar PV and wind, followed by hydropower, biomass and nuclear. Gas with CCS would require higher expenses reaching €20 per tCO_2e abated. Of the almost 12.5 million tons in abatement deliverable by energy demand measures, the highest abatement potential is residential building insulation, followed by efficient lighting by households. In electricity supply, delivering a total of about 17 million tons, the highest abatement can be achieved from the development of electricity generation using natural gas plants with installed carbon capture and storage (gas with CCS). Among renewable energy options, the highest abatement potential is in wind, followed by biomass, and then solar PV. (See Figure 3.13).

CONCLUSIONS AND RECOMMENDATIONS

Romania can meet the mitigation obligations likely under the EU 2030 Climate and Energy Policy Framework at moderate costs. With an energy sector responsible for almost 60 percent of total GHG emissions, Romania clearly cannot achieve climate change mitigation targets beyond those of the current EU 2020 policy without significant action in the energy sector. The Green scenario compels substantial emissions reduction in the power sector which requires moderate incremental investment as compared with the Baseline. The Green scenario will achieve 45 percent emissions reduction by 2030 (and 72 percent reduction by 2050) as compared with 2005. The investment cost of the Green power sector scenario through 2050 is €37 billion (present value),[31] equal to an annual average 1.1 percent of GDP through 2050.

The prospective requirements of the EU 2050 Roadmap, which entail at least 80 percent reduction in emissions and the virtual elimination of emissions from the power sector, are both expensive and challenging to implement. The Super Green power sector scenario will provide 92 percent emissions reduction between 2005 and 2030 and 97 percent reduction by 2050, achieving an almost complete elimination of emissions from power. This scenario also delivers abatement on a faster schedule than the Green scenario. The investment cost of the Super Green scenario to 2050 is €54 billion (present value) or an average annual of 1.7 percent of GDP.

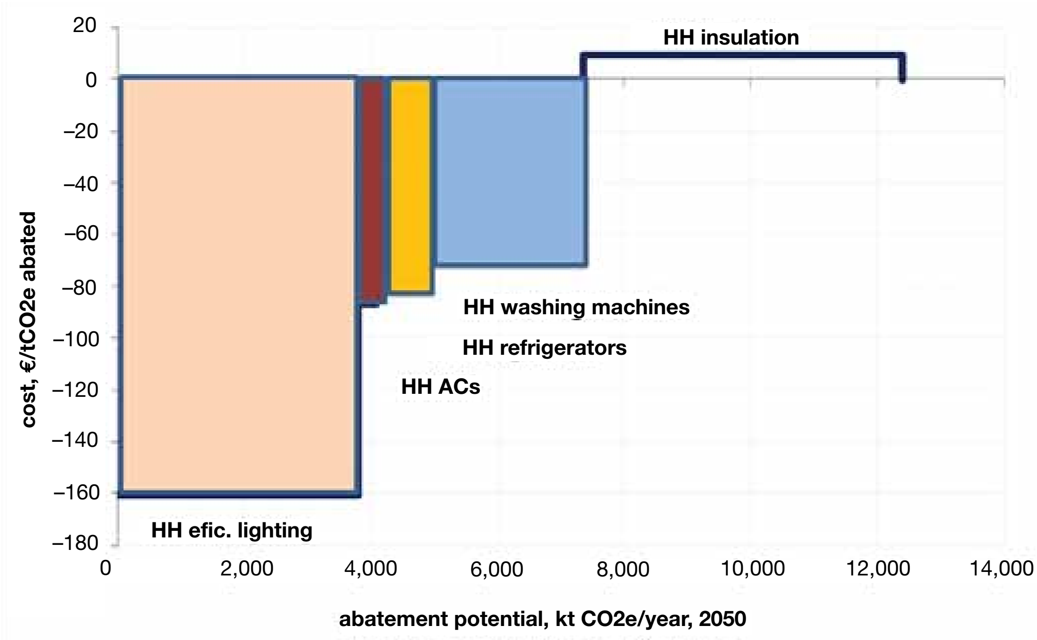
Implementation of the same set of aggressive energy efficiency measures is a key part of the Green and the Super Green scenarios, as these measures deliver low cost abatement in the short term, require moderate upfront investment, and have modest implementation barriers. Improving energy efficiency across the board in all economic sectors, but especially in residential and non-residential sectors, offers the most effective and also viable means for containing the growth of

31. At a five percent discount rate. The discount rate was selected as a mid-range social discount rate (the typically used social discount rates range from 4 to 6 percent).

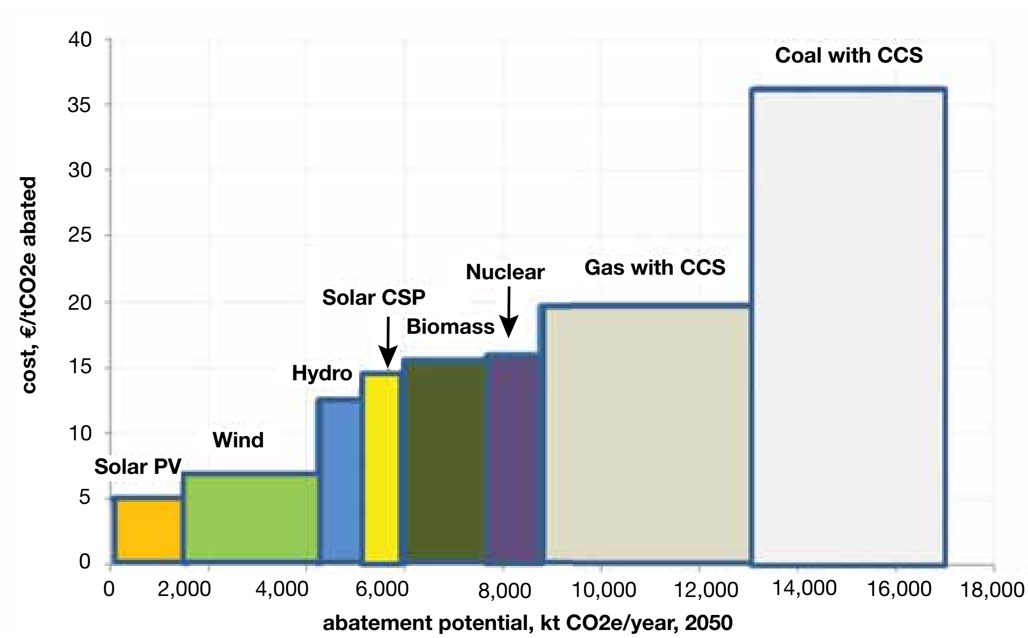
FIGURE 3.13. Significant abatement is possible from energy sector measures

Marginal abatement cost curves for the energy sector, Super Green scenario

a. Demand measures



b. Supply measures



Notes: Demand measures are for households only and include efficient lighting, air conditioning (ACs), and more efficient household appliances (refrigerators and washing machines). Supply measures include concentrated solar power (Solar CSP).
Source: MACC Technical Report.

energy demand, limiting investment requirements to meet the growing demand, and reducing GHG emissions. Beyond the climate agenda, improving energy efficiency is also critical for Romania's competitiveness in the European Union. While the energy intensity of Romania's economy has been decreasing for the past two decades, it is still one of the highest in the EU, and greater efficiency will go hand in hand with modernized and more competitive companies and sectors.

A lower carbon path for Romania's energy sector imposes significant costs and complex planning challenges on the sector, in particular on power generation. Achieving emissions reduction targets beyond the EU 2020 targets—the Green (likely EU 2030 targets) and the Super Green (possible EU 2050 targets)—will require Romania to abandon plans for new coal-based power generation capacity and life-extension of existing plants. It will also require significant additional renewable generation capacity and, therefore, a regulatory environment that would promote it.

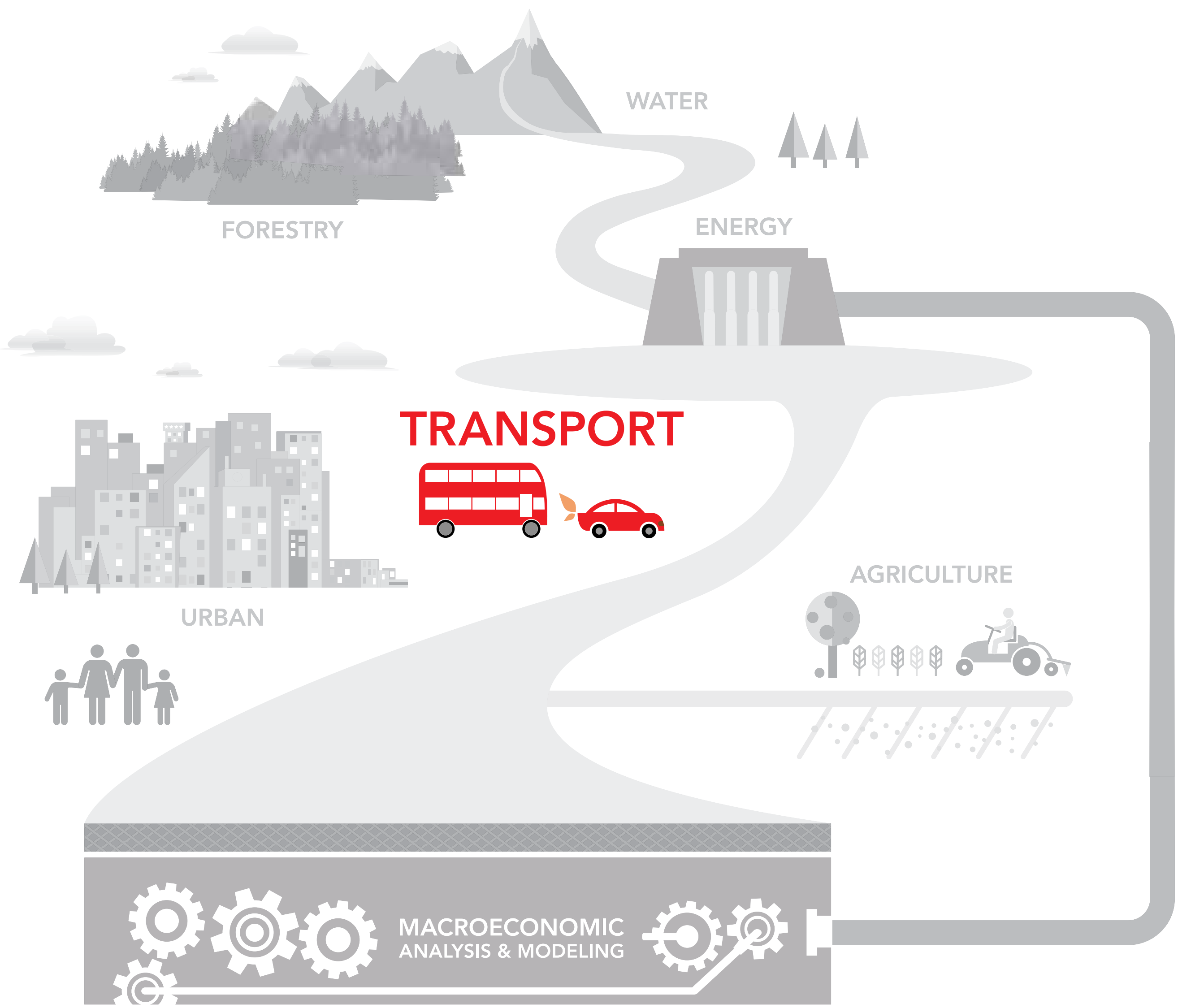
While this assessment included a set of generally-agreed technologies at costs based on today's best analysis, both technologies and costs will surely evolve, and updated analysis will be needed. The TIMES supply model and the Energy Service Demand Analysis tool constructed for this analysis remain available for further development and application by the government for current and future policy questions related to the energy sector, in particular questions related to low carbon. The Ministry of Energy has already taken on these models to apply to critical questions in support of the country's new energy strategy. The usefulness of such tools and models will only increase into the future as Romania begins to take a more active role in contributing to EU climate and energy policy, as well as implementing it.

At the same time, it should be noted that the energy sector in Romania has the potential to become an engine of economic growth. Romania's endowment of energy resources is significant and diversified well beyond coal, including hydropower and other renewable resources, natural gas, and even uranium to fuel its nuclear power industry. Romania has the potential to satisfy its own needs and export electricity and gas into the regional and European energy markets (even without the use of coal), to energize the economy and create jobs and prosperity.

While long-term sector development to 2030 and 2050—the subject of this assessment—is important, the government cannot be distracted from critical near-term sector reforms. Implementation of the energy reform program jointly supported by the European Commission, the International Monetary Fund, and the World Bank should continue. The measures recommended here under the Green and the Super Green scenarios to allow Romania to meet various GHG mitigation obligations require long-term implementation. In the short-term, it is critical that the sector continues with current reform efforts, many of which lay down essential conditions for the success of the long-term green transition. These reforms include completion of the ongoing liberalization of residential electricity and gas prices; adoption and implementation of the Minimum Social Insertion Program (a social safety net which *inter alia* will help secure access of low income households to basic energy services); restructuring of the Hunedoara and Oltenia energy complexes; and adoption and implementation of the Law on Corporate Governance for further improvements in the corporate governance of state-owned energy enterprises. Along with energy security, competitiveness and fiscal benefits, these measures are key for Romania's achievement of emissions reduction targets.

Greening of the energy sector implies substantial costs, which rise significantly over time and as requirements for emissions reduction tighten, but a lower-carbon energy sector needs to be part of Romania's long-term planning. Careful modeling of the power sector provides a detailed assessment of low carbon possibilities. A need for 30 percent more installed power capacity between now and 2050, along with existing mitigation obligations, push even Baseline investment costs to a very high level of €28 billion through 2050 or an average annual 0.8 percent of GDP. Lower carbon scenarios economize on supply costs by pushing energy efficiency to contain demand and achieve significant mitigation: in 2030, emissions are 31 percentage points and 94 percentage points below Baseline in the Green and the Super Green scenarios respectively; while by 2050, emissions are 56 percent below the Baseline in the Green scenario and almost completely eliminated in the Super Green. This is achieved with additional costs during 2015–2050 in the Green scenario (costs above Baseline) of about nine billion euros and in the Super Green scenario of about €26 billion. Until 2020, investment needs in electricity supply and demand total about seven billion euros in the Baseline and just over nine billion euros in the green scenarios. These costs jump after 2030, as remaining fossil-based plants are replaced with renewable and nuclear capacity and aggressive energy efficiency actions continue. Financing for these investments, whether power generation or energy efficiency, will be the responsibility of the private sector, although the public sector may need to establish programs of support for energy efficiency, with some financing available from the European Union.

Source: Myrabella/Wikimedia Commons.


WATER
FORESTRY
ENERGY
TRANSPORT
URBAN
AGRICULTURE
MACROECONOMIC
ANALYSIS & MODELING

CHAPTER 4

How Can the Pace of Emissions Growth in Transport Be Contained?

CHAPTER SUMMARY

In Eastern Europe including Romania, the transport sector is characterized by fast-increasing emissions, and controlling the pace of this growth, much less reversing it, is challenging. Transport is the second biggest greenhouse gas (GHG) emitting sector in the European Union (EU), following the energy sector, and is responsible for 29 percent of total EU emissions. However, EU transport emissions have been falling since 2007. By contrast, in Eastern Europe including Romania, transport emissions continue growing at a fast pace, driven by increasing car ownership and usage and a high-emission old vehicle fleet. In Romania, road transport (mainly cars) is the source of over 90 percent of transport emissions (while the EU average is about 70 percent); increasing car transportation is pushing out other modes of road transport; and the usage of non-road transport has decreased. Vehicle usage and emissions-intensity of vehicles have been subject to mitigation policies; however, more efforts are needed. Decoupling transport sector emissions from economic growth is a key challenge. Promoting local co-benefits, such as the improvement of local air quality, and reduction of congestion, noise, and traffic accidents, is a critical element to secure significant progress in transport sector mitigation.

The objective of the analysis was to assess the impact of green policies and investments on transport emissions. For this purpose, a strategic mitigation model—the Transport Strategic Emission Prediction Tool (TRANSEPT)—was developed for Romania. TRANSEPT is a bottom-up, detailed engineering model. The baseline scenario in modeling was based on Romania's General Transport Master Plan and is consistent with the baseline in the European Commission (EC) "Trends to 2050" model. Apart from modeling, the assessment involved a non-quantitative evaluation of the barriers to implementation and the externalities of each green measure. The costs of the green measures have been estimated using international case study evidence and adjusted to the Romanian context. Marginal abatement cost (MAC) analysis was conducted to assess cost effectiveness and abatement potential of the measures and to illustrate their benefits relative to each other in a form useful for policy discussions.

Source: Radu Bercan/Shutterstock.

The findings show that selected green interventions in Romania lead to a significant reduction of GHG emissions as compared with the baseline scenario and to a decoupling of transport sector emissions growth from economic growth, thus achieving a highly challenging goal of transport sector mitigation. The proposed mitigation action plan recommends fuel pricing policies, taxation of new vehicles based on emission standards, parking pricing measures and tightened parking regulation and enforcement, an efficient public transport system and walking and cycling facilities, and eco-driving campaigns. Investment in infrastructure is key for a shift from cars to public transport. Institutional arrangements are critical. Financing needs for the recommended measures increase from the Green to the Super Green scenarios. Additional investments total €135 million over 2015–50 in the Green scenario, but almost €1.7 billion in the Super Green scenario. Most of the costs are incurred in the first fifteen years, during 2015–30. In the first five years, 2015–2020, the recommended transport measures will cost just above €60 million in the Green scenario but approximately €608 under the Super Green scenario.

CHALLENGES FOR GREEN GROWTH

Overview

Transport is the second biggest GHG-emitting sector in the European Union, following the energy sector, and responsible for 29 percent of total EU emissions; however, emissions from transport have been falling since 2007. While GHG emissions from other sectors have been on a generally downward trend since 1990, transport in the EU experienced rising emissions through 2007. Despite the subsequent downward trend, EU transport emissions are still above their 1990 level. EU transport emissions are dominated by road transport which is responsible for 72 percent of transport's total. The next largest transport contributors—aviation and maritime transport—produce 13 percent and 14 percent respectively. The EU has policies in place to reduce emissions from transport: aviation is required to acquire emissions allowances through the EU Emissions Trading System (EU ETS), and the rest of transport is included in the EU's national targets for emissions reduction for sectors outside the ETS.[1]

In Eastern Europe including Romania, transport emissions continue growing at a fast rate, driven by increasing car ownership and usage and a high-emissions, aged vehicle fleet. East European countries are moving toward the EU's motorization level for passenger transport. Increasing incomes have made it possible for more households to own cars and also to move to the suburbs, the latter leading to falling land-use densities in many urban areas. Urban sprawl has pushed up the costs of public transportation and, in many cases, made it financially non-viable. In turn, reduced availability of public transport has exacerbated car usage: significantly more cars are on the roads, and the number and lengths of car trips have been increasing. Also, East European countries have a large share of older vehicles, with higher emissions per kilometer driven. In freight transport, while a number of East European countries had relatively high rail use before 1990, rail's modal share has been declining, pushing up motorization rates for freight.

Policies aimed at mitigation will be needed to control the growth in transport emissions in Romania. All these continuing processes mean that transport sector emissions in East European countries including Romania have been growing fast and will still grow in the near future. However, with transport sector policies aimed at mitigation[2], such growth can be reduced. Currently, the transport sector accounts for 13 percent of Romania's total GHG emissions, still significantly below the EU average of 25 percent.[3] However, from 1990 to 2012, the transport sector's share in total emissions increased by 78 percent in Romania and only by 10 percent in the EU. Considering this trend, which is expected to continue with rising incomes and Romania's overall convergence with the EU, EU levels of transport emissions will be reached soon (see Figure 4.1).

Road transport, mainly by car, is the source of 91 percent of transport emissions in Romania today, while the respective EU average is 72 percent. While Romania has been experiencing rapid growth in motorization, from 152 passenger cars per 1,000 inhabitants in 2006 to 224 in 2012, its current rate is still the lowest in the EU and significantly below other EU new member states. Lithuania's rate is 130 percent higher, and Romania's closest neighbor, Bulgaria, exceeds Romania's rate by 72 percent (see Figure 4.2). Car ownership is projected to continue its growth, with the motorization rate exceeding 350 cars per 1,000 inhabitants by 2030, an increase of over 50 percent during 2012 to 2030. At the same time, Romania's share of cars in total transport already equals the EU average. Together, these trends mean that when car ownership in Romania reaches EU levels, car usage (and related emissions) will exceed that of the EU, unless other modes of transportation develop.

Increased car use has been crowding out other modes of road transport for passengers, and the shift from rail to road is also evident for freight. During the last two decades, Romania experienced a marked increase in the share of road passenger transport and a significant decrease in the share of rail. Within road transport, the share of buses, trolley buses, and coaches has been dropping since

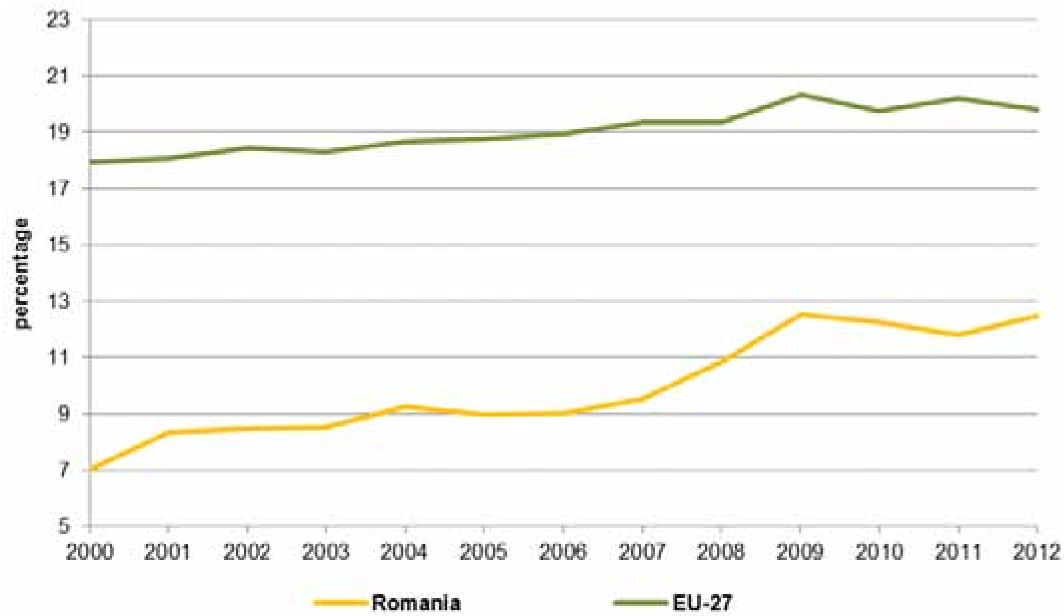
1. See Box 1 in Chapter 2 for details about EU mitigation policies. Aviation transport is partly included in the ETS for 2013–16: flights within Europe must secure emissions allowances. The International Civil Aviation Organization has agreed to develop a global market-based mechanism to address international aviation emissions by 2016 and to apply it by 2020.

2. Also, see Chapter 5 (Urban) on related urban policies.

3. This covers emissions from transport (road, rail, inland navigation and domestic aviation) and includes the GHG emissions regulated by the Kyoto Protocol and relevant for transport (carbon dioxide, methane, and nitrous oxide).

FIGURE 4.1. The share of transport emissions in Romania has been rising faster than in the EU

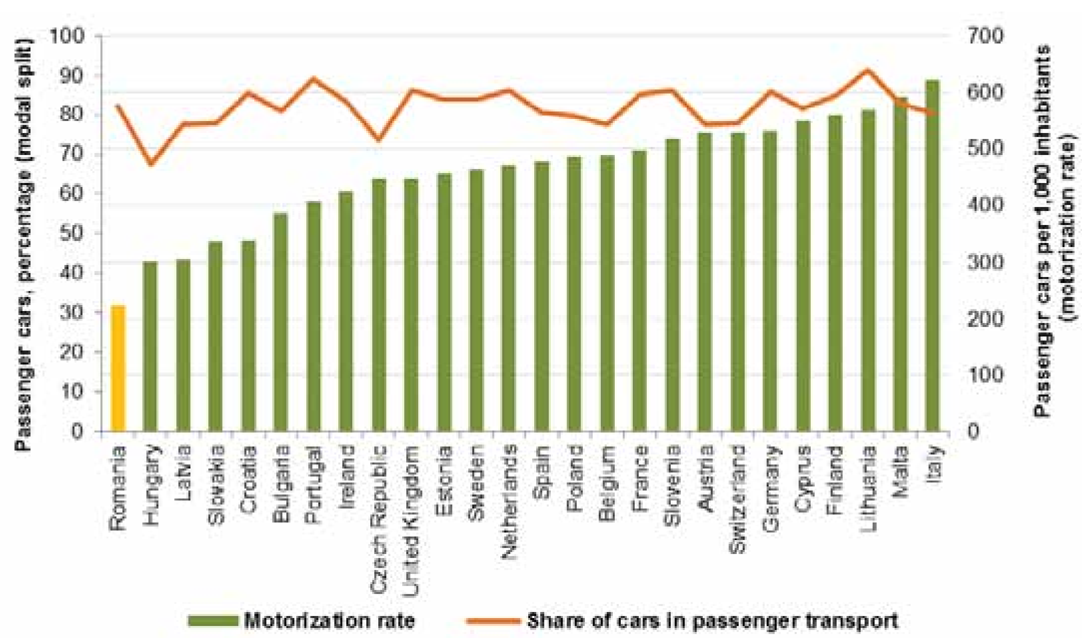
Transport GHG emissions as percentage of total, Romania and EU



Source: European Environment Agency.

FIGURE 4.2. Romania's motorization rate is the lowest in the EU, while its modal split matches the EU average

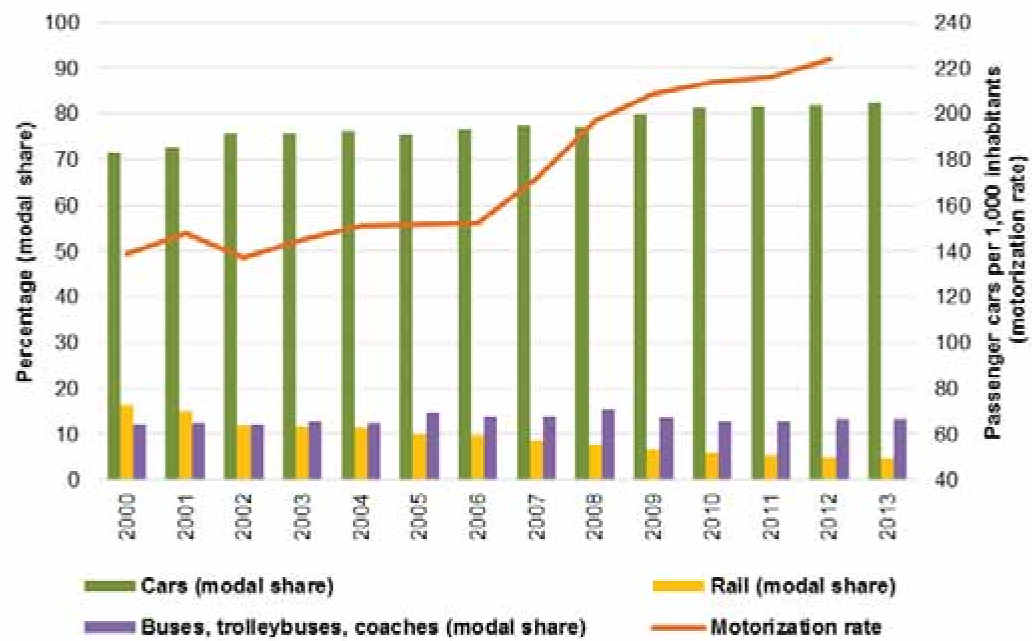
Motorization rates and modal split in EU countries, 2012



Source: Eurostat.

FIGURE 4.3. Motorization is rising quickly, led by car use

Motorization rate and passenger transport modal share (land-based modes)



Source: Eurostat.

2008. Figure 4.3 shows the modal split for passenger transport between the three main land-based modes of domestic travel—private car, rail, and bus/trolleybus/coach. Between 2000 and 2013, the mode share of passenger cars has increased by 15 percent, reaching 82 percent of the total, equal to the EU average. In the same period, the mode share of passenger rail shrunk by almost three-quarters from 16 percent to five percent, below the EU's eight percent average. The share of buses/trolleybuses/coaches fluctuated during the period but was at approximately the same level in 2000 (12 percent) as in 2013 (13 percent), exceeding the EU average of 9 percent (2013). Furthermore, the modal split for freight movements has experienced similar trends (although to a lesser extent).[4] The mode share of rail freight has declined in terms of percentage of ton-km travelled, although it is still higher than the EU average; while road freight has increased its share. The decline in rail and the shift to road in both the passenger and freight segments can be attributed not only to increased demand for road transportation but also to underinvestment and poor maintenance of the Romanian railway system, resulting in slow and unreliable train services.[5]

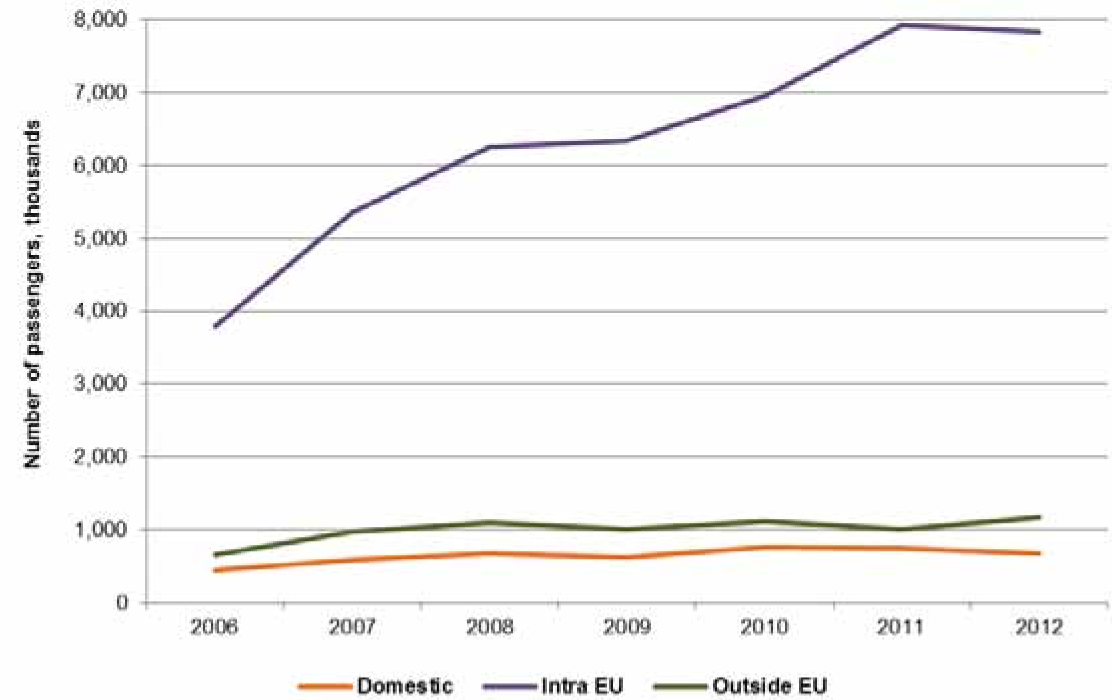
Non-land transportation—maritime and civil aviation—currently contribute little to overall emissions in Romania's transport sector. Emissions from maritime transport constitute just over one percent of overall transport emissions in Romania, compared to 14 percent in the EU; and emissions from civil aviation produce less than four percent of Romania's transport total, compared to

4. Eurostat data at http://epp.eurostat.ec.europa.eu. The amount of freight moved by air (which is excluded from the modal split figures shown above) is very small—28,523 tons in 2011, up from 19,229 tons in Romania's first year of EU membership in 2007. By comparison, some 65 million tons of freight were transported on Romania's railways in 2007.

5. European Commission (EC). 2012. *Position of the Commission Services on the Development of Partnership Agreement and Programs in Romania for the Period 2014–2020*. Ref. Ares (2012)1240252—19/10/2012.

FIGURE 4.4. Air traffic in Romania is low, but intra-EU traffic has been increasing

Air passengers using Romanian airports (excluding transit passengers), by destination



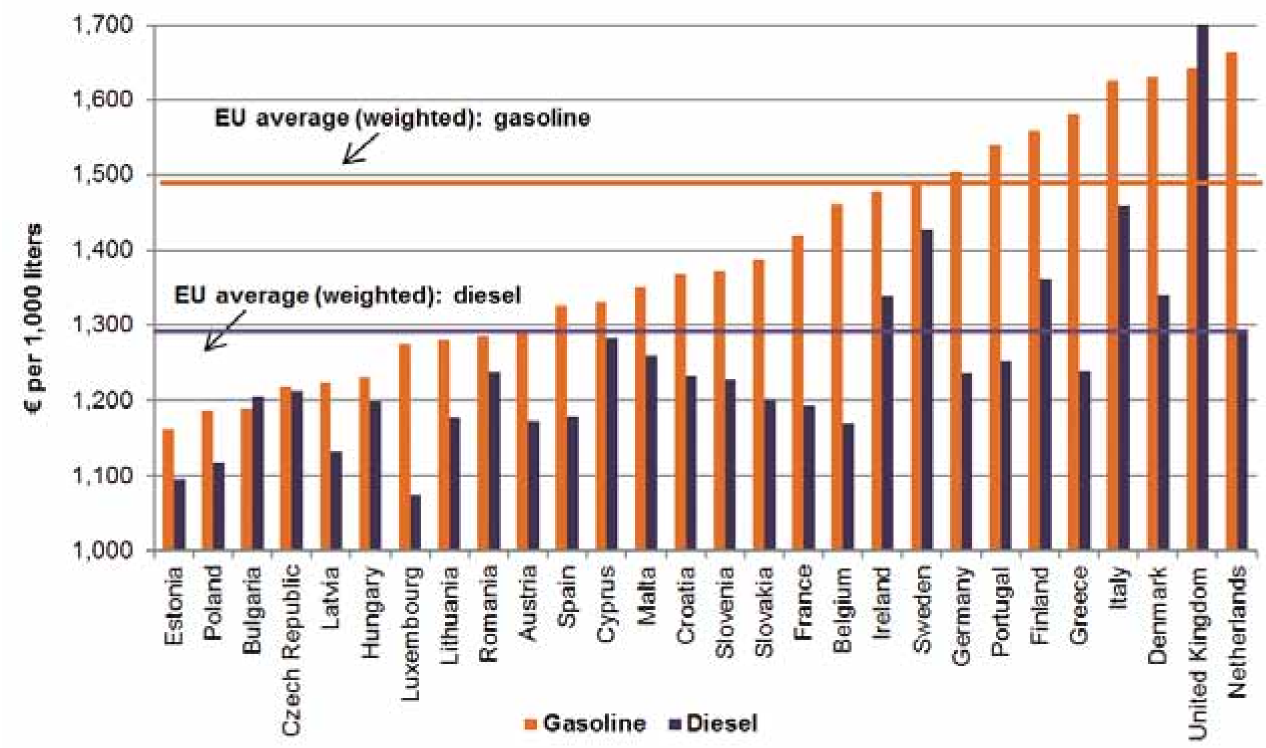
Source: National Institute of Statistics, Romania.

13 percent in the EU. Domestic air passenger transport activity (within Romania) forms a small share (seven percent) of total passenger movements through Romanian airports, which is relatively low compared to other EU countries: the EU-27 average is 18 percent. It has slightly increased in recent years (see Figure 4.4). Passengers flying to and from other EU countries form the great majority of all passengers using Romanian airports, equaling 81 percent, while those flying to and from destinations outside of the EU form the remaining 12 percent of the total. Civil aviation activity is projected to increase in the future.

Vehicle usage and the emissions intensity of vehicles—the major emission drivers in Romania—have been subject to mitigation policies; however, there is more to be done. Policy instruments used include fuel taxation, vehicle scrappage schemes, parking pricing, and new vehicle registration taxes. While fuel taxes have been increasing, gasoline and diesel prices remain significantly below the EU average (see Figure 4.5). Parking fees in Bucharest are low compared to other East European capitals (see Figure 4.6). A policy of higher prices for parking—especially when mass transit public transport is available—can be an efficient mechanism to discourage the use of private vehicles. A vehicle scrappage scheme, known as the '*Rabla*' (clunkers), has been in place in Romania since 2005. Approximately 500,000 ageing and high-polluting vehicles have been scrapped, and the purchase of around 250,000 more efficient vehicles has been subsidized. Uptake of the scrappage scheme peaked in 2010, with almost 190,000 cars scrapped, and has since fallen to much lower levels. Romania has introduced another pricing mechanism to change the age and emissions intensity of the vehicle fleet—an "Environment Stamp" tax on new vehicle registrations. The broad regulatory framework has been in place since 2013, with flexibility to adjust rates to encourage uptake of greener vehicle technology.

FIGURE 4.5. Fuel prices in Romania are significantly below the EU average

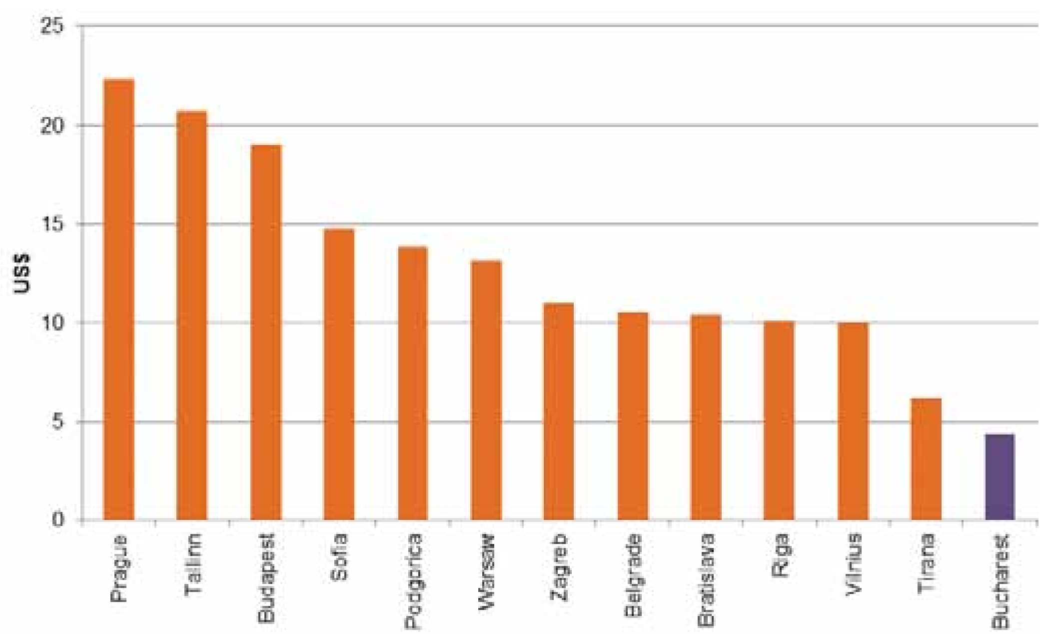
Gasoline and diesel prices as of June 2015, EU countries



Source: European Commission (EC). 2015. Consumer Prices of Petroleum Products Including Duties and Taxes. Available at: https://ec.europa.eu/energy/sites/ener/files/documents/2015_04_13_with_taxes_1747.pdf

FIGURE 4.6. Parking rates in Bucharest are the lowest among capital cities nearby

Daily parking prices in new member states' capitals



Source: Colliers International. 2011. Global Central Business District Parking Rate Survey. Available at: http://downtown houston.org/site_media/uploads/attachments/2011-07-19/Colliers_International_Global_Parking_Rate_Survey_2011.pdf

In addition to pricing measures, Romania has also implemented regulations to control emissions from urban road transport, including traffic management and restrictions on urban access and speed. The Bucharest Urban Traffic Control Center introduced an adaptive urban traffic control and public transport management system, which is estimated to have reduced travel times (and, therefore, congestion and resulting emissions) by 20 percent and achieved a 10 percent reduction in CO_2 in the area.[6] Bucharest has access restrictions that ban vehicles over five metric tons from the central area of Bucharest at certain times and require them to have a permit to enter at other times. Romania's speed limits for cars and motorcycles are currently set at 130 km per hour on motorways, 110 km per hour on expressways, and 90 km per hour on other non-urban roads; trucks and buses are limited to 110 km per hour, 90 km per hour and 80 km per hour respectively.[7]

Source: Alexandru Nika/Shutterstock.com

Challenges

Given the growth in vehicle ownership and road transport, decoupling transport sector GHG emissions from economic growth represents a key challenge and will require departure from business-as-usual policies in the transport sector. The main challenge the transport sector faces is how to reduce the system's dependence on oil, limit GHG emissions, and minimize externalities, without compromising efficiency, mobility and economic growth. Economic growth and GHG emissions from the transport sector in Romania have moved in parallel to date (see Figure 4.7). During 2000–2012, GHG emissions rose by 54 percent while real GDP rose by 55 percent. The challenge is to decouple transport sector emissions from growth by channeling transport demand into low-emissions transportation modes and increasing the share of low emission vehicles.[8,9]

Maximizing local co-benefits is key to transport sector mitigation since such benefits are frequently needed to offset the relatively high costs of transport mitigation policies or investments. Local co-benefits—such as reduced traffic congestion and noise, improved air quality and road safety, or enhanced energy security—are important objectives of transport policies that can complement mitigation action. The World Bank's recent transport climate change strategy advocates for the important role of the local social costs of transport in designing GHG emissions reduction for the sector.

6. SWARCO MIZAR. Urban Traffic Management, Romania, Bucharest 2007–2014. Available at: http://www.swarco.com/mizar-en/Projects/ITS-References/URBAN-TRAFFIC-MANAGEMENT,-Romania,-Bucharest-City-of-Bucharest

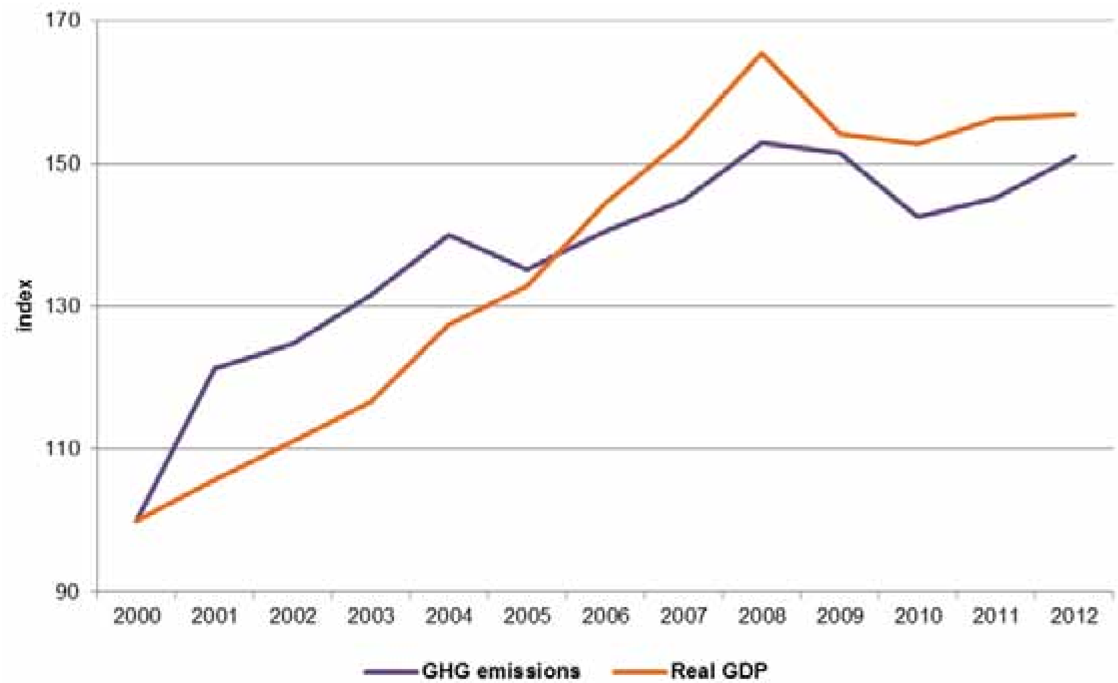
7. Vehicle fuel consumption accelerates at speeds above 90 km per hour.

8. International Transport Forum (ITF) and Organization for Economic Co-operation and Development (OECD). 2008. *Greenhouse Gas Reduction Strategies in the Transport Sector: Preliminary Report*. Available at: http://www.internationaltransportforum.org/pub/pdf/08ghg.pdf/

9. Andreas Kopp, Rachel I. Block, and Atsushi Iimi. 2011. *Turning the Right Corner: Ensuring Development through a Low-Carbon Transport Sector*. World Bank: Washington D.C. Available at: http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/05/31/000445729_20130531125005/Rendered/PDF/780860PUB0EPI0050240130right0corner.pdf

FIGURE 4.7. Decoupling transport GHG emissions from economic growth represents a key challenge

Real GDP growth and transport sector GHG emissions (2000=100)



Source: World Bank and European Environment Agency.

Not only do such combined concerns render climate-friendly transport actions more attractive to policy makers and the public, but aiming at multiple objectives with a single set of policies, in this case, can reduce significantly the net costs to Romania. For example, congestion levels in a city such as Bucharest and the city's trends toward increased motorization constitute as much a classic problem of transport and urban planning as a GHG emissions challenge. Attacking congestion and emissions together generates significant co-benefits that are also powerful in motivating support for improved transport policies, which simultaneously can be GHG-friendly policies.

Road transport mitigation is most challenging as it produces over 90 percent of transport sector emissions in Romania and, with rising motorization, will grow in the future unless policies change. Inefficiencies of the road transport sector can be grouped into the following three types: pricing inefficiencies, fuel-inefficient technology, and those that follow spontaneous transition of urban form. At present, pricing does not reflect the full costs of transport, failing to include costs of negative externalities and the costs of investing beyond roads. Adequate pricing policies are critical to support transport investments, change demand and existing behaviors, allocate resources more efficiently, and raise funds to invest in more sustainable forms of transport. Both fuel tax and parking fees in Romania are low compared with other EU countries. Other pricing instruments can be used more widely, including the new vehicle registration fees and urban congestion fees. Increasing the use of renewable energy and the uptake of low-carbon vehicle technology can lower the energy intensity of the transport sector, but the lack of infrastructure for alternative fuels is an issue that needs to be addressed. At present,

there are only 20 electric vehicle charging stations, constraining the use of alternative fuel vehicles.[10] In 2014, only seven electric or hybrid electric vehicles were registered in Romania. By comparison, a total of over 75,000 were registered across the EU. Moreover, relaxation of land development controls across Eastern Europe has led to inefficiencies associated with low-density development. In Romania, there has been a decrease of residential use in urban core areas (with residential use replaced by commercial), an increased rate of residential suburbanization and subsequent increase in personal vehicle ownership, travel time, and congestion. Integrating land use and transport planning in urban areas in Romania is key to managing road travel and minimizing GHG emissions in the future.

Specific urban transport problems include high vehicle concentration, traffic congestion, and pedestrian areas filled with parked cars, resulting in high emissions and undermining of urban well-being. Urban traffic congestion has significantly worsened as a result of increased private vehicle ownership and usage. Insufficient parking spaces in Romanian cities has led to "informal" parking arrangements, with vehicles parked on footways, cycle tracks, and public spaces. Urban public transport, which includes metro systems and tram, trolley bus, and bus networks, requires costly modernization and maintenance to be able to provide services at the level needed to compete with private cars, and, as a result of insufficient financing, has suffered from a decline in public patronage. Cycling infrastructure needs to be developed and pedestrian areas modernized, although there are examples of improvement of pedestrian areas across the country.[11] All these issues are more

10. Association for Promoting Electric Vehicles in Romania (AVER). Available at: www.aver.ro.

11. In particular, in Brasov in 2008, the Municipality developed a pedestrian area in the historical center with ten streets closed to car traffic and streets repaved with cobblestones, using funding from the 2007–2013 Regional Operational Program. In Ploiesti, an EU-supported CIVITAS project promoted walking, and a pedestrian zone was created in the city center, backed by a campaign to encourage behavioral change. As a consequence, there has been a 20 percent reported improvement in public transport speed, in addition to a 15 percent reduction in pollution in the central zone of the city.

pronounced in Bucharest and, as a result, carbon dioxide emissions from road transport in the capital (833 kt per year) are higher than the total of the 19 next largest cities combined (596 kt per year).[12]

Transport service provision needs to be addressed holistically to ensure that public transport, as well as non-road modes of transportation, are able to attract users and thereby realize full climate and economic benefits. A modal shift from road to low-emissions rail transportation could help contain road transportation demand and emissions, while also resulting in a co-benefit of reduced road congestion. Such a shift requires reasonably high occupancy or ridership rates or else rail and road public transport can be more emissions-intensive per passenger-km or ton-km than private cars and trucks. Romania's General Transport Master Plan argues that Romanian railways "are in a crisis situation." To increase demand for rail service, it is necessary to combine investment in rail assets with improved maintenance, operational efficiency, quality service and pricing that reflects costs and is competitive with other modes of transportation.

METHODOLOGY AND FINDINGS

Methodology

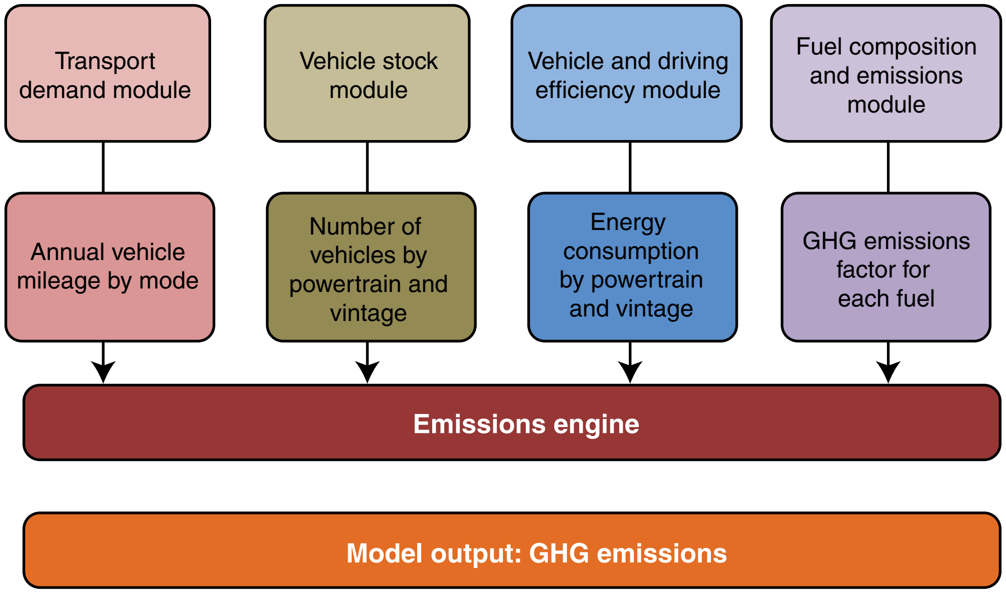
The objective of the analysis was to assess the impact of green policies and investments on transport emissions. For this purpose, the Romania strategic mitigation model—the Transport Strategic Emission Prediction Tool (TRANSEPT)—was developed. TRANSEPT is a bottom-up engineering model and models the measures individually (as opposed to using a systems approach). It includes four modules for calculation of GHG emissions: (i) transport demand, (ii) vehicle stock, (iii) vehicle and driving efficiency, and (iv) fuel consumption. Each module takes a number of baseline datasets as input and applies policy interventions under three scenarios—Baseline, Green and Super Green. The adjusted datasets are then used as input matrices to the final module of TRANSEPT, which calculates the resulting GHG emissions for all three scenarios. The process is outlined in Figure 4.8**.** The impact of green policies is assessed by comparing the outcomes of the Green and Super Green scenarios to the Baseline scenario. The costs of the green interventions are assessed outside of TRANSEPT using case studies. Interventions are selected for both the Green and Super Green scenarios using multi-criteria analysis. The outcome of the analysis is a proposed list of potential interventions, their cost (investment and operational), and their abatement potential.

The Baseline scenario in this assessment is consistent with the Baseline in the EC's "Trends to 2050" model: transport activities, related energy demand, and resulting emissions are expected to grow (with continuation of current polices but no new policies on climate). Table 4.1 and Figure 4.9 show consistency between the transport projections (in terms of demand for fuel and resulting emissions) by the European Commission's "Trends to 2050" model and by the modeling developed under this assessment. In both projections, passenger and freight activities are on an upward trajectory, the energy demand for transport is estimated to grow, and GHG emissions are

12. To date, there are only four countries in the EU that have spatially-disaggregated emissions inventories at a national level: the UK, the Netherlands, Denmark and Sweden. This data has been analyzed to understand better the distribution of emissions between urban and non-urban areas. The largest 20 cities (with populations over 100,000) were identified and their respective emissions levels analyzed. *E-PRTR: The European Pollutant Release and Transfer Register: Welcome to E-PRTR*. EEA; Copenhagen. Available at: http://prtr.ec.europa.eu

FIGURE 4.8. Overview of the TRANSEPT model

Datasets and green interventions are used to estimate impact on emissions



Source: Transport Sector Technical Report.

TABLE 4.1. Transport fuel demand projections in this assessment are consistent with the EC's

Transport fuel demand projections for Romania in the EC's "Trends to 2050" and in TRANSEPT (ktoe)

	EC'S "TRENDS TO 2050"					TRANSEPT (THIS ASSESSMENT)				
Year	2010	2020	2030	2040	2050	2011	2020	2030	2040	2050
Cars and motorcycles	2,018	1,992	1,952	2,096	2,161	2,080	2,007	1,928	2,017	2,117
Buses	137	152	161	171	183	122	121	118	114	109
Trucks	2,245	3,060	3,221	3,338	3,336	2,098	2,864	3,458	4,274	5,171
Rail passenger and freight	221	282	325	346	334	120	148	163	176	194
Aviation	272	418	524	619	733	324	348	376	401	417
Inland navigation	59	76	89	97	99	88	90	112	137	169
Total	4,953	5,980	6,272	6,668	6,846	4,832	5,578	6,154	7,120	8,177

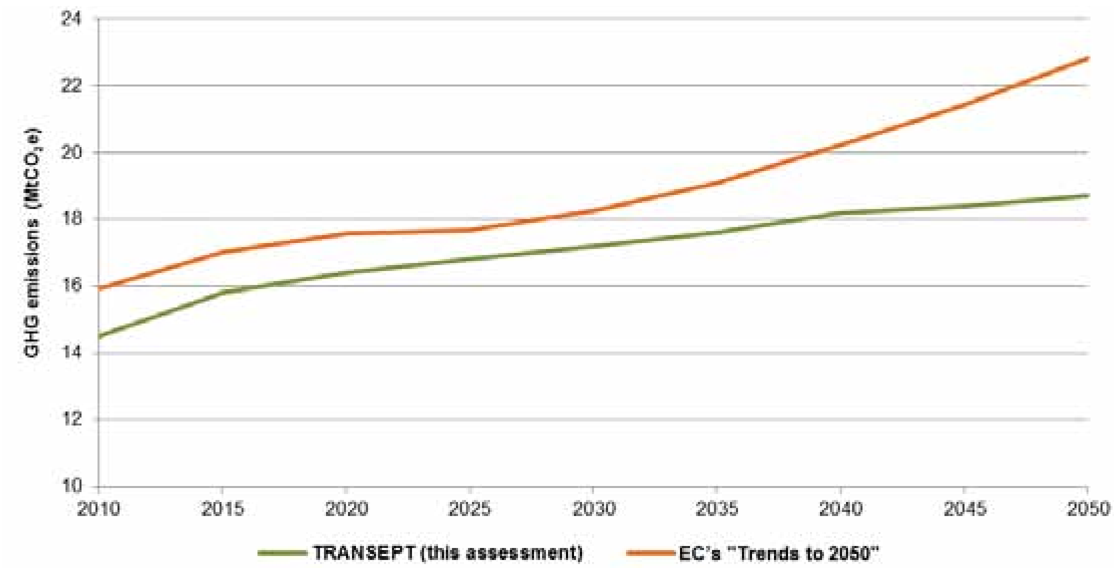
Source: Transport Sector Technical Report.

projected to increase.[13] The differences in projections between the two models result from the variations in the assumptions regarding the trends for different modes of transport, with the model in this assessment forecasting a greater growth in vehicle usage, fuel demand, and growth in GHG emissions.

13. For more details about the models and comparison of the projections, see the Appendix of the Transport Sector Technical Report.

FIGURE 4.9. GHG emissions projections of this assessment are consistent with the EC's ($MtCO_2e$)

GHG emissions projections for Romania in the EC's "Trends to 2050" and in TRANSEPT ($MtCO_2e$)



Source: Transport Sector Technical Report.

Romania's General Transport Master Plan (GTMP) is used as the basis of the Baseline scenario of this assessment, and the relevant investments in urban planning and transport sector operational efficiency are considered in the Baseline, as well as regulatory impacts. In order to ensure complementarity, the country-specific strategy should be consistent with the EU-level transport strategy, which focuses on assuring sustainable mobility for people and goods and contributing to ambitious GHG emissions reduction targets. The Romanian GTMP was developed under the guidance of the European Commission as a condition for its approval of the Strategic Operational Program for Transport (SOPT). The GTMP includes significant investment in public transport infrastructure (including the national rail system). Also, the Sustainable Urban Mobility Plans that are under development for a number of cities, involving integrated land use and transport planning in the capital city (Bucharest and Ilfov County) and seven larger cities that are considered growth poles, were used to develop the Baseline. Existing measures to improve operational efficiency include well-established eco-driving programs in the freight sector to reduce fuel consumption and emissions and freight and logistics hubs (as part of the GTMP).

At the last step of the analysis, a marginal abatement cost curve (MACC) provides a framework to present the outcomes of the transport sector analysis in a form useful for policy discussions. Cost and abatement potential of the proposed interventions estimated in this assessment are used as input into a tool developed at the World Bank to calculate MACC parameters.[14] The MAC curve also allows for comparisons of measures across sectors, with the caution that only certain aspects of measures can be simplified into the MACC presentation, which is of particular interest to policymakers designing an overall mitigation strategy that reaches across multiple sectors.

14. See Chapter 9 in this report, which describes the MACC approach used in this assessment across sectors in detail.

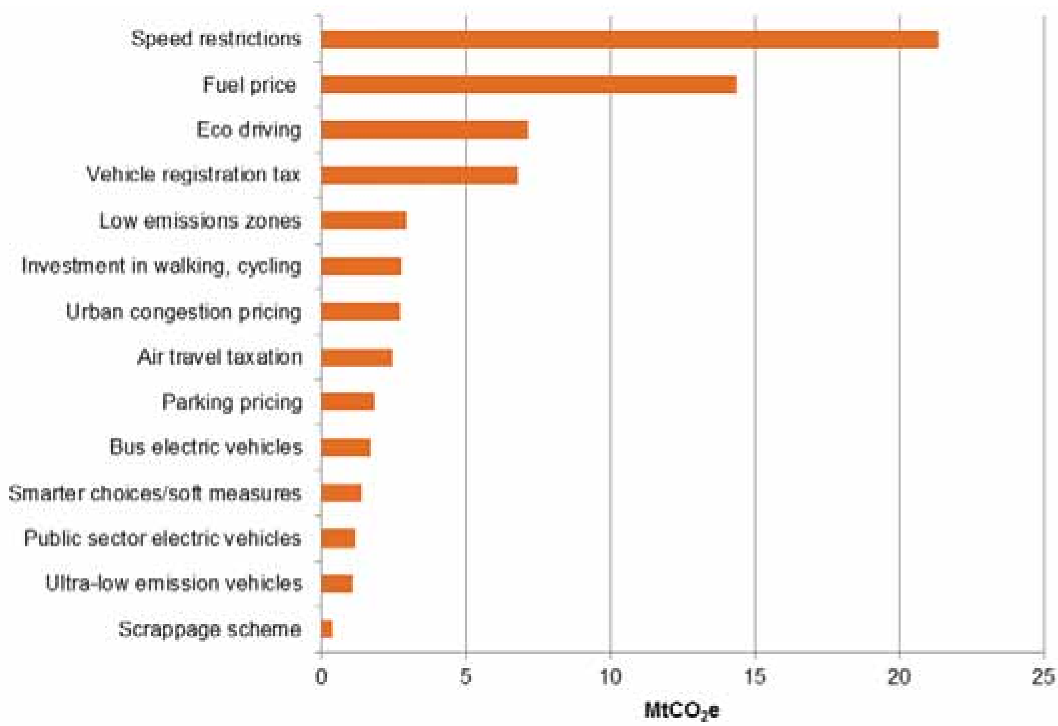
Main Findings

The main modeling outcomes include abatement and cost. The TRANSEPT modeling methodology described above generates outcomes on abatement potential, cost, and the cost effectiveness (cost per unit of abatement) of the selected green interventions for the period 2015–2050. The assessment also involved a non-quantitative evaluation of the barriers to implementation and the externalities of each measure. Marginal abatement cost analysis was conducted to assess cost effectiveness and abatement potential of the measures and to illustrate their benefits relative to each other.

Four measures have potential to deliver high abatement over the course of the modelled period of 2015 to 2050. The four highest potential measures were found to be: (i) lowering of speed limits (speed restrictions); (ii) increasing the fuel tax; (iii) eco-driving programs which encourage more efficient driving patterns, with advertising campaigns targeted at private car users and training programs focused on the freight transport and public transport sector; and (iv) implementing a more progressive new vehicle registration tax (Environmental Stamp) promoting the adoption of low emission vehicles. Figure 4.10 summarizes the cumulative abatement results for each intervention over 2015–2050. Then, Table 4.2 provides a comparison of the abatement potential of the proposed interventions in three different time periods: the period 2015–2022 corresponds to the timeframe of the Government Action Plan, the period 2015–2030 parallels the time horizon of the Government Transport Strategy, and the period 2015–2050 is the timeframe of the analysis presented in this assessment.

FIGURE 4.10. Ranking of the assessed interventions by their abatement potential

Cumulative abatement potential per intervention, Romania, 2015–2020 ($MtCO_2e$)



Source: TRANSEPT.

TABLE 4.2. Cumulative abatement from interventions in three time periods

Cumulative abatement potential per intervention, Romania, by time period ($MtCO_2e$)

INTERVENTION	2015–2022	2015–2030	2015–2050	% OF TOTAL EMISSIONS, 2015–2050
Speed restrictions	2.17	6.29	21.36	3.09
Fuel price tax	1.03	4.14	14.37	2.08
Eco-driving	1.06	2.69	7.14	1.03
Vehicle registration tax	0.07	0.57	6.79	0.98
Low emissions zones	0.23	0.72	2.92	0.42
Investment in walking, cycling	0.46	1.20	2.77	0.40
Urban congestion pricing	0.05	0.60	2.73	0.39
Air travel taxation	0.27	0.76	2.44	0.35
Parking pricing	0.19	0.64	1.85	0.27
Bus electric vehicles	0.04	0.23	1.68	0.24
Smarter choices/soft measures	0.22	0.58	1.37	0.20
Public sector electric vehicles	0.02	0.13	1.15	0.17
Ultra-low emission vehicles	0.02	0.12	1.08	0.16
Scrappage scheme	0.24	0.33	0.35	0.05

Note: The periods in this table are selected to represent three timeframes: 2015–2022 is the time horizon of the Government's Action Plan, 2015–2030 is that of the Government's Strategy, and 2015–2050 is that of the analysis presented in this assessment.

Source: TRANSEPT.

Interventions were selected for the assessment in the Green and the Super Green scenarios based on a multi-criteria analysis. This approach considered: (i) investment cost to the government, (ii) cumulative emission savings, (iii) cost effectiveness of abatement (unit abatement cost), (iv) barriers to implementation, and (v) local co-benefits. The co-benefits included better local air quality, reduced congestion, reduced noise, improved safety, reduced inequity, and positive health impact.[15] Table 4.3 summarizes the outcomes of the multi-criteria analysis. The costs of delivering the identified interventions have been estimated using international case study evidence and adjusted to the Romanian context. Importantly, the costs are limited to those borne directly by government (public costs) and include both investment and operational and maintenance costs.

The Green scenario comprised a selective list of measures that have high performance according to the multi-criteria analysis while the Super Green scenario included all interventions analyzed. Based on the multi-criteria analysis, the following measures were selected for inclusion in the Green scenario based on lower costs, both total and per unit of CO_2 abated: (i) fuel price taxation increase,

15. These benefits were considered at a qualitative level but not included in costs.

TABLE 4.3. Multi-criteria analysis supported selection of green interventions for the assessment

Outcomes of the multi-criteria analysis, color-coded (green=most favorable, blue=moderate; orange = least favorable)

INTERVENTION	TOTAL COST, € MLN, 2015–2050, DISCOUNTED*	CUMULATIVE ABATEMENT, 2015–2050, $MTCO_2E$	UNIT ABATEMENT COST, 2015–2050, €/TCO_2E**	IMPLEMENTATION	REDUCED EXTERNALITIES***
Fuel price taxation	0.9	14.4	0.06	Challenging	High
Vehicle registration tax	0.9	6.8	0.13	Moderate	Moderate
Speed restrictions	22.6	21.4	1.1	Challenging	High
Air travel taxation	3.5	2.4	1.4	Moderate	Moderate
Eco-driving	34.4	7.1	4.8	Good	High
Parking pricing	10.7	1.9	5.8	Moderate	Moderate
Smarter choices/ soft measures	18.8	1.4	13.7	Good	High
Investment in walking, cycling	56.3	2.8	20.3	Good	High
Low emissions zones	60.4	2.9	20.7	Moderate	Moderate
Public sector electric vehicles	28.2	1.2	24.6	Good	Moderate
Bus electric vehicles	222	1.7	133	Moderate	Moderate
Ultra-low emission vehicles	163	1.1	152	Moderate	Moderate
Urban congestion pricing	793	2.7	291	Politically Challenging	Moderate
Scrappage scheme	146	0.4	413	Good	Very High

Notes: *Total cost 2015–2050 includes capital and operational and maintenance costs and is discounted at a rate of four percent to provide the present value. **Cost effectiveness is total cost in 2015–2050 (discounted) divided by cumulative carbon reduction over 2015–2050 (undiscounted). ***Externalities include local air quality, decongestion, noise, reduced safety, inequity, and health impact.
Sources: World Bank and TRANSEPT.

(ii) new vehicle registration tax, (iii) eco-driving program, (iv) smarter choices/personal travel planning programs, (v) investment in walking and cycling infrastructure, (vi) parking pricing, and (vii) air travel taxation. The Super Green scenario included, in addition to the seven Green measures, (viii) speed restrictions, (ix) low emissions zones, (x) public sector electric vehicles, (xi) bus electric vehicles, (xii) ultra-low emissions vehicles, (xiii) urban congestion pricing, and (xiv) scrappage schemes. No specific pre-defined GHG saving targets were used to constrain the choice of interventions, since the approach adopted for the assessment was bottom-up. This assessment estimated that total

TABLE 4.4. Costs of the Green and the Super Green scenarios differ significantly

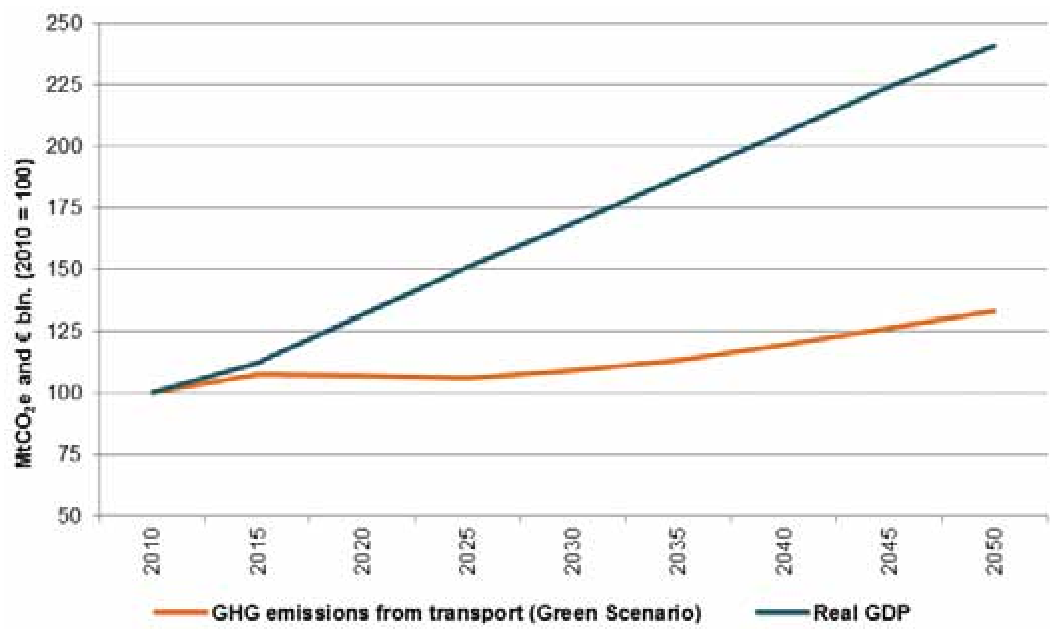
Total cost of the scenarios, Euro millions

	UNDISCOUNTED INVESTMENT COST			DISCOUNTED INVESTMENT COST		
	2015–2022	2015–2030	2015–2050	(2015–2022)	(2015–2030)	(2015–2050)
Green	101	147	194	86	117	135
Super Green	956	1,595	2,811	808	1,227	1,687

Note: *A four percent discount rate was used. The periods in this table are selected to represent three timeframes: 2015–2022 is the time horizon of the Government's Action Plan, 2015–2030 is that of the Government's Strategy, and 2015–2050 is that of the analysis presented in this assessment.*
Source: TRANSEPT.

FIGURE 4.11. Green interventions lead to decoupling of transport emissions from economic growth

Transport GHG emissions and real GDP trends, 2010–2050 (2010 = 100)



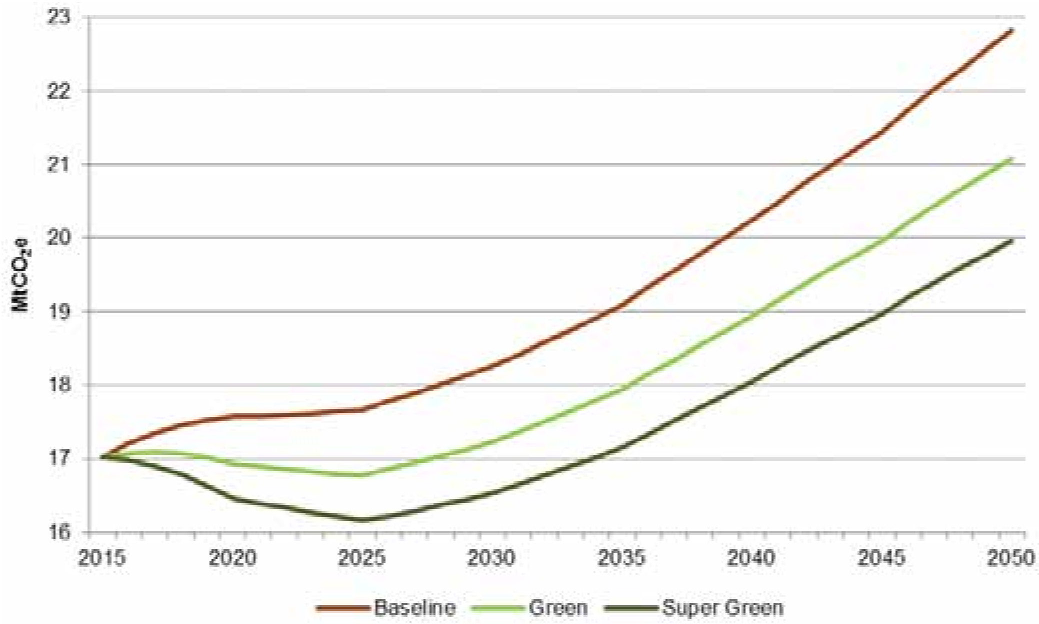
Source: TRANSEPT.

discounted capital investment costs equal €135 million over the period 2015–2050 under the Green scenario but rise sharply to €1,687 million for the Super Green scenario (Table 4.4).

Green interventions in this assessment lead to decoupling of transport sector emissions growth from economic growth in Romania, achieving a transport sector objective that is challenging for most countries. As shown in Figure 4.11, GHG emissions from transport are projected to decouple from economic growth even in the Green scenario: they grow more slowly than the real economy. Both Green and Super Green scenarios achieve significant reduction of GHG emissions as compared

FIGURE 4.12. Green scenarios achieve significant abatement as compared with the Baseline

Romania's transport emissions under alternative carbon abatement scenarios



Source: TRANSEPT.

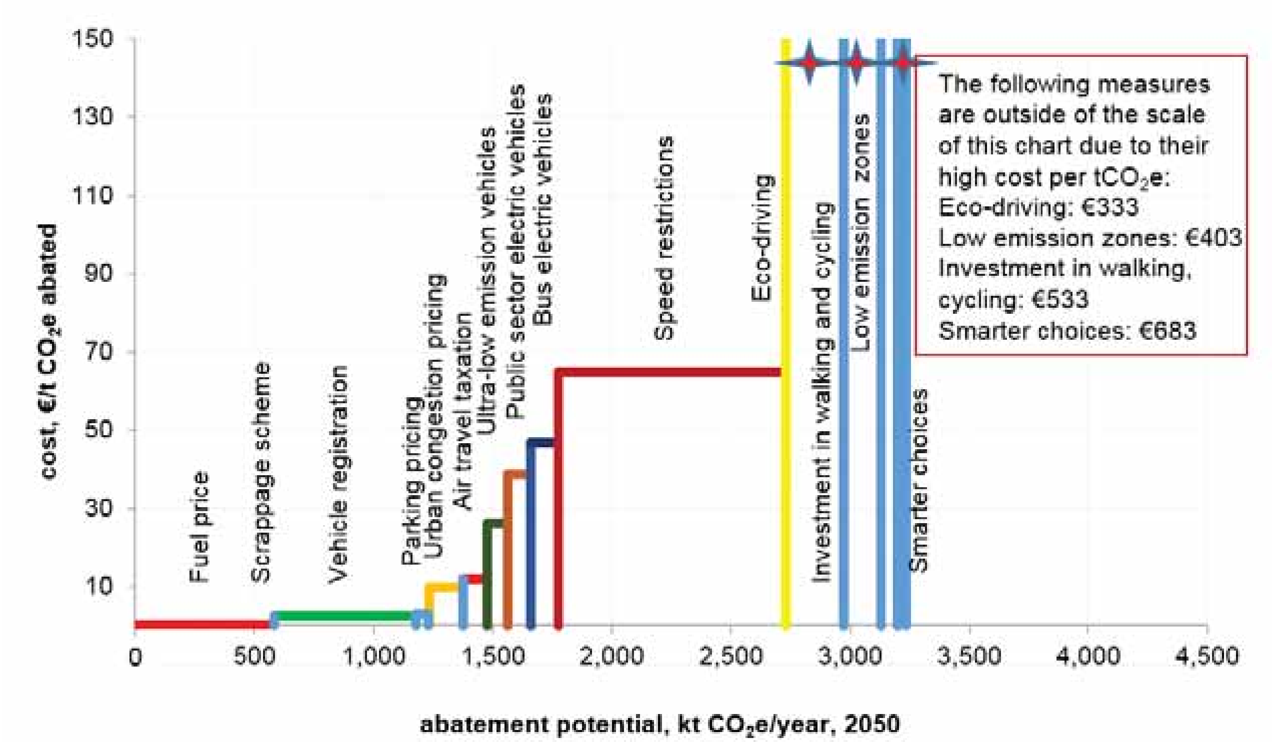
with the Baseline scenario (Figure 4.12). Under the Baseline scenario, emissions grow by 34 percent during 2015–2050, while under the Green scenario, emissions growth slows to 24 percent. Emissions growth slows further to 17 percent under the Super Green scenario. Note that the impact of the bundle of measures is not identical to the sum of the individual measures due to the inter-relationship between them. In all cases, GHG emissions from the transport sector will rise, with different rates of growth. These results are in line with many studies which suggest that reducing GHG emissions in the transport sector is hard to achieve. This is more so in the countries of Eastern Europe where motorization rates are still rising. Policies should aim at achieving reduced growth of transport emissions instead.

Marginal abatement cost curve analysis then provided a method of comparison and presentation to policymakers. The outcomes, presented in Figure 4.13, show that the most cost-efficient measures are a fuel price tax, scrappage schemes, vehicle registration taxes, parking pricing, and urban congestion pricing, while the measures delivering maximum abatement are speed restrictions, vehicle registration, and fuel price taxation. When compared with other sectors, transport measures have very high costs and, at the same time, limited abatement potential.[16] This finding is consistent with the experience of transport MACCs in other countries and is explained by the nature of transport mitigation: transport abatement has significant co-benefits which are difficult to include in the estimates of net costs. The examples include the cost of a life lost in a traffic accident, the costs of a traffic injury, potential municipal budget revenue from developing urban business-friendly infrastructure, improved well-being from reduced noise and pollution, and gains from reduced commuting time. If such benefits were to be taken into account, the net cost of transport sector mitigation is significantly reduced.

16. See Chapter 9 and the Marginal Abatement Cost Curve Technical Report.

FIGURE 4.13. Transport measures vary in their abatement potential and their unit cost

Romania's marginal abatement cost curve for transport in 2050, Super Green scenario



Source: World Bank calculations using cost and emissions estimates from TRANSEPT assessment.

CONCLUSIONS AND RECOMMENDATIONS

As Romania's motorization rate converges with that of the European Union, transport emissions are expected to grow even if green measures in the sector are implemented. Unlike other sectors, where the objective is to reduce emissions, the goal of green growth development in transport is to decouple growth of emissions from sector growth or, in other words, to lower the GHG intensity of the transport sector going forward.

The proposed mitigation action plan recommends a set of actions on the basis of the estimates made in this assessment. The main areas of concern coincide with the top drivers of emissions, and many of them—such as the old vehicle fleet and the rising private ownership of vehicles—should be addressed using policy or behavioral incentives such as taxes, regulations, fees and pricing aimed at encouraging replacement of old vehicles and discouraging driving. Particular policy instruments recommended include the following:

- **Fuel pricing** is a particularly effective policy instrument that discourages vehicle usage and encourages the purchase of more fuel-efficient vehicles, thereby reducing vehicle-fuel intensity. Fuel taxes are relatively inexpensive to collect, easy to administer and reasonably equitable.
- The **New Vehicle Registration Tax (Environment Stamp)** is levied according to a vehicle's European emissions standard, CO_2 emissions, and engine displacement, with a discount rate applied depending on the age of vehicle. A gradual pre-announced increase of the tax on the most polluting cars has been a means of influencing purchasing decisions. The cost of changing the rates

under the existing regulatory framework would be negligible. It is assumed that the change in tax rates is fiscally neutral as higher taxes for high-polluting vehicles are offset by lower taxes for more efficient vehicles.

- **Parking pricing, in conjunction with tightened parking regulation and enforcement,** may be considered to be a more cost-effective, more readily implementable solution to in-town congestion, instead of urban congestion charging. Parking pricing is a market-based measure which offers the potential for emissions savings with a high level of cost effectiveness. Indeed, the measure would be expected to offer a stream of revenue which could facilitate some of the investment measures in the transport sector.
- **Air travel taxation** presents a mechanism for exerting some control over the growing demand for air travel and also offers a revenue stream which may be put to useful purpose. The implications for the economy need to be considered, but there are potentially positive equity impacts from what is expected to be a strongly progressive form of taxation.
- Best practice examples typically combine the disincentive of high parking charges with an effective and efficient **public transport system, and good walking and cycling facilities.** Smarter choices programs, combined with investment in walking and cycling infrastructure, have been demonstrated to lead to modal shift, achieving not only a reduction in emissions levels but also significant wider benefits including health and well-being, and decongestion. Smart choices programs are "soft" behavioral change programs that provide better information to travelers on available choices and highlight the potential benefits of sustainable transport modes. Smart choices schemes and policies include workplace and school travel plans, personalized travel planning, awareness campaigns, public transport information and marketing, car-sharing schemes, teleworking and teleconferencing. In cost-benefit analysis, these schemes typically perform strongly, with cost-benefit ratios in excess of 20 by comparison with highway and public transport schemes with ratios calculated to be in the low single figures. Concerted and sustained investment can realize emissions savings at a reasonable level of cost effectiveness.

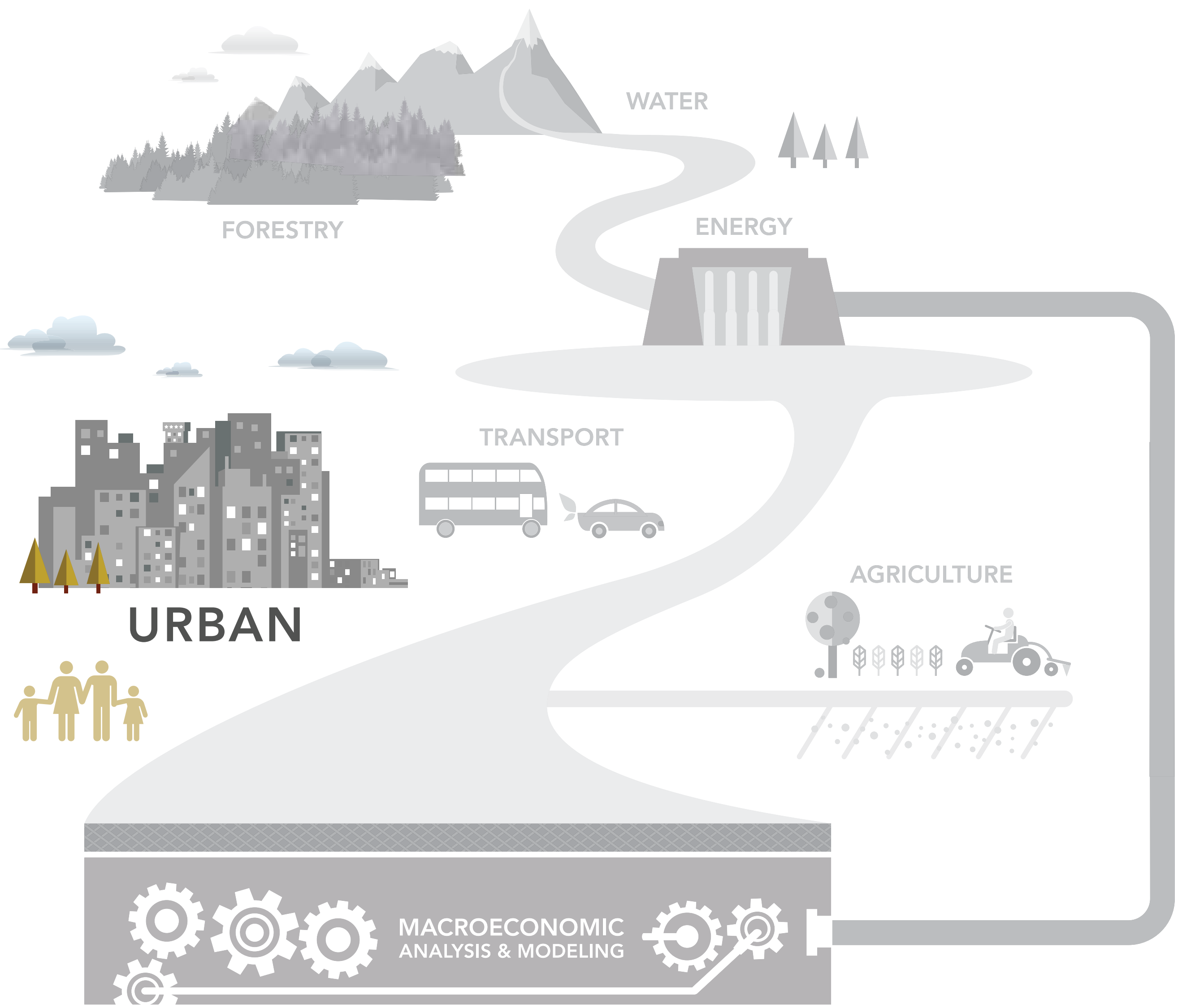
The investment in infrastructure required to achieve modal shift from private cars towards public transport depends on local circumstances and the extent of the targeted shift. It is important to address needs for transport services holistically to ensure that public transport is able to attract new users and realize its full climate and economic benefits. Rail transport or public transport can end up being more emissions-intensive per passenger-km or ton-km than the use of private cars and trucks if ridership remains low or declines further. A modal shift from road to much less emission-intensive rail transportation, or to public transport more broadly (national rail system, and local bus, tram, or trolleybus systems) could help contain road transportation demand and emissions, while also resulting in a co-benefit of reduced road congestion.

Institutional arrangement and coordination are also critical. Actions should start with collaboration between transport stakeholders, such as government ministries, the rail sector, the City of Bucharest and other municipalities, bus operators, and parking management organizations. More complicated but also necessary actions in this area should aim at creating clear governance structures and contractual arrangements, as well as increasing administrative and technical capacity to support strategy development and project implementation.

Financing needs for the recommended measures in transport rise sharply between the Green and Super Green scenarios but still remain modest, as incremental investments within a large sector. Under the Green scenario, additional investments total about €135 million over 2015–50[17] but almost €1.7 billion in the more ambitious Super Green scenario. Most of the costs are incurred in the first fifteen years, during 2015–2030. In the first five years, 2015–2020, the implementation of the recommended transport measures will require just above €60 million in the Green scenario but approximately €608 under the Super Green scenario.

17. Discounted at four percent rate.

Source: Gaspar Janos/Shutterstock.


WATER
FORESTRY
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AGRICULTURE
MACROECONOMIC
ANALYSIS & MODELING

CHAPTER 5

Can Urban Areas Lead on Greening?

CHAPTER SUMMARY

Urban areas are critical to lower greenhouse gas (GHG) emissions, and despite some interest from Romanian cities, challenges are many. Rising suburbanization is leading to less efficient urban forms but is not captured in Romanian urban statistics. The motorization or car ownership rate in Romania is currently low compared to the rest of the European Union (EU), but it has been rising, exacerbating existing traffic congestion problems in most cities. Buildings, and residential buildings in particular, account for the largest share of energy consumption in Romania. Although Romania has the lowest per-capita energy consumption in the EU, significant growth in electricity demand is already occurring, partly due to the decline of highly-polluting and inefficient district heating. Lastly, Romania's overwhelming reliance on landfilling as its primary strategy for municipal solid waste disposal boosts the greenhouse gas emissions generated by the country's waste management sector.

Since the Bucharest-Ilfov Metropolitan Region (BIMR) dominates Romania's population, economic landscape and land-use development patterns, analysis of BIMR can provide a leading example of lower-emissions urban development for Romanian cities. Suburban development pressures are strong, as a richer population seeks bigger homes which are available only in service-poor outer areas of BIMR. As in most cities, the distribution of total building stock in BIMR shows a radial pattern driven by proximity to major roads. The ongoing shift towards private cars produces traffic congestion that is increasingly a part of daily life in the Bucharest-Ilfov region, despite the fact that the City of Bucharest is well-served by one of the most comprehensive public transport networks in all of Europe. Since buildings, and residential buildings in particular, account for the largest share of energy consumption in Romania, and since heating, especially in residential buildings, drives much of the energy use in BIMR's buildings, the sharp decline of Bucharest's vast but already inefficient district heating system contributes to rising GHG emissions. In addition, Bucharest-Ilfov recycles little of its solid waste and captures none of the methane related to landfills. The situation in the Bucharest-Ilfov

region is critical to Romania's overall GHG emissions path into the future, both because of its current and future domination of the economy but also because it can provide a replicable example of lower-emissions growth.

There have been multiple obstacles to a greener urban path to date. The financial resources available to upgrade major infrastructure systems have been limited by the regional economic slowdown and Romania's difficulty in absorbing EU funds. Low-carbon urban actions have been impeded by institutional challenges, including the lack of formal roles in planning and implementing, policy-planning disconnects between different government entities, and a lack of transparency. Also, subsidized energy prices for households and selected energy-intensive state-owned enterprises have led to low energy prices and an immature market for energy efficiency-focused firms.

The Rapid Assessment of City Emissions (RACE) model is a geospatial model that compares population and development patterns for a region under different scenarios, in order to develop technical estimates of how they differ in terms of energy use, energy spending levels, air quality emissions, and GHG emissions. First, a baseline inventory of metropolitan elements was constructed from a wide variety of available data to develop baseline estimates of current energy demand, energy spending, and GHG and air quality emission levels for each location in BIMR. Then a general development scenario for 2050 was prepared, applying assumptions about future demographic and economic conditions and the relative accessibility of each cell to the city center that drive estimates of future demand for industrial and residential building stock, which RACE then uses to calculate emissions. Next, a Business-as-Usual (BAU) scenario was modeled to reflect recent spatial patterns of development while a Low Carbon (LC) Development scenario is modeled based on higher densities. These scenarios estimate the technical potential for change in energy demand, emissions, and other variables, but not the cost-effectiveness of different interventions. By comparing the energy and emission impacts of different development options, local and regional authorities can identify the types of policies that affect the long-term economic and environmental sustainability of their city. Action plans can then be prepared to comprehensively review and, where appropriate, adjust these policies to minimize emissions.

A comparison of the two modeled scenarios provides useful insights on policies that can cut GHG emissions in the Bucharest-Ilfov region. The Business-as-Usual scenario contains continued low-density growth of residential, office and industrial development and lacks integration between new development and public transit (trams, buses and metro). Overall energy use and associated emissions continue to increase through 2050 although there are some efficiency gains in buildings. Rising vehicle-kilometers travelled are somewhat offset by efficiency gains and a cleaner fuel mix, while rates of recycling and biodegradable waste diversion in Bucharest would reach half the levels mandated by EU targets. In contrast to the BAU scenario, spatial development in BIMR under the Low Carbon (LC) Development scenario exhibits less sprawl, higher densities, mixed-use, and a coordination of transit and spatial planning. Efficiency gains from urban land use and reduction in travel distances are achieved in this scenario through spatial planning. Unsurprisingly, proactive spatial planning leads to significant improvement in energy use, energy spending, and emissions, even though the gross building area remains unchanged relative to the BAU scenario. Reduced energy use cuts total energy spending by US$1.4 billion per year in real terms, and emissions from buildings, transport, and solid waste in BIMR will see reductions by 2050 under the LC scenario.

The modeling of a greener path for BIMR summarized in this chapter provides local authorities with insights into how policies affect the speed, location, and density of urban growth and the resulting

GHG emissions. Several cross-sectoral measures are recommended, including data-collection improvements and strengthening of metropolitan governance and management. Recommended land-use policies include promotion of mixed land-use, up-zoning, and transit-oriented development. Overlapping land-use and transportation proposals include preferential space for public transport, creation of pedestrian-only zones, parking policies, and completion of ring roads. Also important will be congestion pricing for traffic management and district heating upgrades. Building efficiency-related recommendations include Property Assessed Clean Energy (PACE) finance; green mortgages; point-of-sale efficiency upgrades/audits; and energy efficiency capacity-building programs. Other Romanian cities interested in this type of assessment are encouraged to evaluate the quality of data available for their city and consider application of the RACE model, keeping the fundamental limitations of the model in mind.

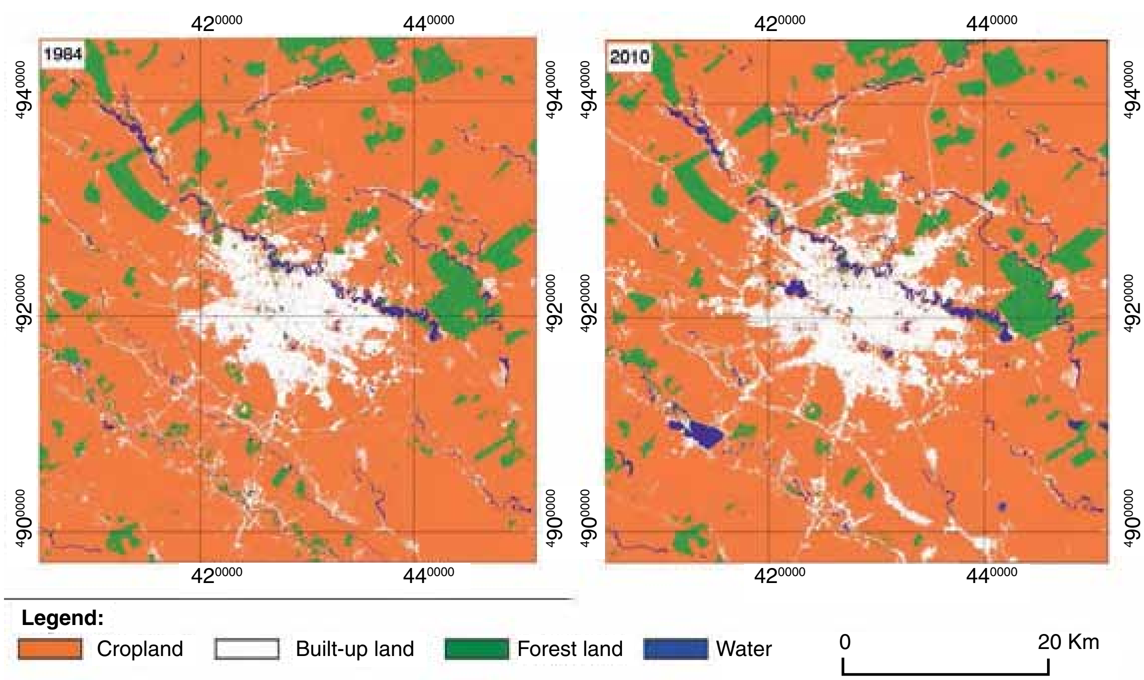
CHALLENGES FOR GREENER GROWTH

Overview

Rising suburbanization is leading to less efficient urban forms but is not captured in Romanian urban statistics. The official urbanization rate in Romania is roughly 55 percent, which is low compared to other parts of Europe and has been fairly constant for the past two decades. Migration out of rural areas has been to the outskirts of major cities, which are still categorized as rural. For example, population in Ilfov County (on the periphery of Bucharest) has increased 69 percent between 1977 and 2011, jumping from 230,000 to 389,000 people. (See Figure 5.1). Other Romanian cities are experiencing a similar phenomenon of expansion as built-up areas increase (See Table 5.1).

FIGURE 5.1. Suburbanization has been rising around Bucharest

Expansion in built-up areas around Bucharest, 1984–2010



Source: B Mihai, C Nistor, & G Simion, "Post-socialist urban growth of Bucharest, Romania—a change detection analysis on Landsat imagery (1984–2010)," *Acta Geographica Slovenica (forthcoming).*

TABLE 5.1. Romanian cities are seeing expansion and suburbanization

Changes in built-up areas of Romanian growth pole cities, 1992–2012

	BUILT-UP AREA OF SELECTED CITIES (in hectares)			CHANGE IN BUILT-UP AREA
	1992	2002	2012	1992–2012
Brasov	3,511	3,928	4,360	24.2%
Bucharest	20,251	21,497	23,955	18.3%
Cluj-Napoca	4,295	4,410	5,346	24.5%
Constanta	4,258	4,382	4,566	7.2%
Craiova	4,045	4,628	5,152	27.4%
Iasi	3,596	3,966	4,224	17.5%
Ploiesti	3,039	3,120	3,238	6.5%
Timisoara	4,920	5,130	5,568	13.2%

Source: World Bank, *Enhanced Spatial Planning as a Precondition for Sustainable Urban Development.* 2013. p. 18.

Romanian cities have shown some interest in reducing greenhouse gas emissions, and some have undertaken assessments to identify low carbon options. Sixty communities, together representing 25 percent of Romania's population, have signed on to the European Commission's Covenant of Mayors program, which requires development and implementation of an energy action plan. The World Bank's Tool for the Rapid Assessment of City Energy (TRACE) has been deployed in seven Romanian cities to support local energy efficiency planning efforts, by assessing energy use in six key sectors, benchmarking against peer cities, and evaluating which interventions might be most appropriate. TRACE is most useful in addressing sectors over which a local authority has the greatest control—the public bus system, for example, rather than private automobiles—but it does not address other options important to lower carbon emissions, such as renewable energy or other fuel switching.

The motorization or car ownership rate in Romania is low compared to the rest of the European Union (EU), but it has been rising, exacerbating existing traffic congestion problems in most cities. Many cities have public transport systems (including buses, trams and trolleys), but declining ridership has made it difficult for system operators to finance those upgrades which might bring riders back to the system. Taxis are plentiful in most cities, but many of the vehicles are old and fuel-inefficient, mirroring the make-up of the nation's vehicle fleet. Some cities have an age limit for taxi vehicles, but this varies significantly from city to city. Finally, pedestrian and cycling infrastructure varies greatly in quality and quantity between different towns and cities, and within city areas. Responsibility for urban transport investment generally sits with the municipalities in Romania. Sustainable urban mobility plans are currently under development in Romania's seven growth pole cities and Bucharest/Ilfov.[1]

1. A detailed discussion of the transport sector can be found in Chapter 4 of this report.

Buildings, and residential buildings in particular, account for the largest share of energy consumption in Romania. Buildings account for 44 percent of total demand, followed by industry (30 percent) and transport (23 percent). Energy use in buildings is influenced primarily by the thermal efficiency of the building, its size, its age, and its level of use. Approximately 80 percent of buildings-related energy demand occurs in residential buildings. Heating constitutes 57 percent of all energy use in buildings, though the ratio is even higher in residential buildings. Romania's building stock is fairly old, with nearly 90 percent of residential buildings constructed before 1989. In other words, they were constructed at a time when there were no specific thermal performance standards. Such buildings are unlikely to have much insulation and are very likely to have mechanical systems that would be considered unacceptable under today's modern energy or building codes.

Although Romania has the lowest per-capita energy consumption in the EU, significant growth in electricity demand is already occurring, partly due to the decline of highly-polluting and inefficient district heating.[2] Demand growth is coming from the residential and commercial sectors, some of which is driven by households' moving away from reliance on district heating. District heating systems were once a prominent feature of many Romanian cities, and in other countries, such systems have become an energy-efficient and low-carbon heating option. Romania's 300 systems operating in 1995/96 had declined to 83 by 2011. In 16 of the 31 district heating systems with more than 10,000 customers, the number of customers had dropped by more than 50 percent. In many cities, district heating has become a serious drain on public finances because tariffs for residential consumers are highly subsidized, on average by 50 percent. Service quality, cost, and concern over high pollution

2. A detailed discussion of the energy sector can be found in Chapter 3 of this report.

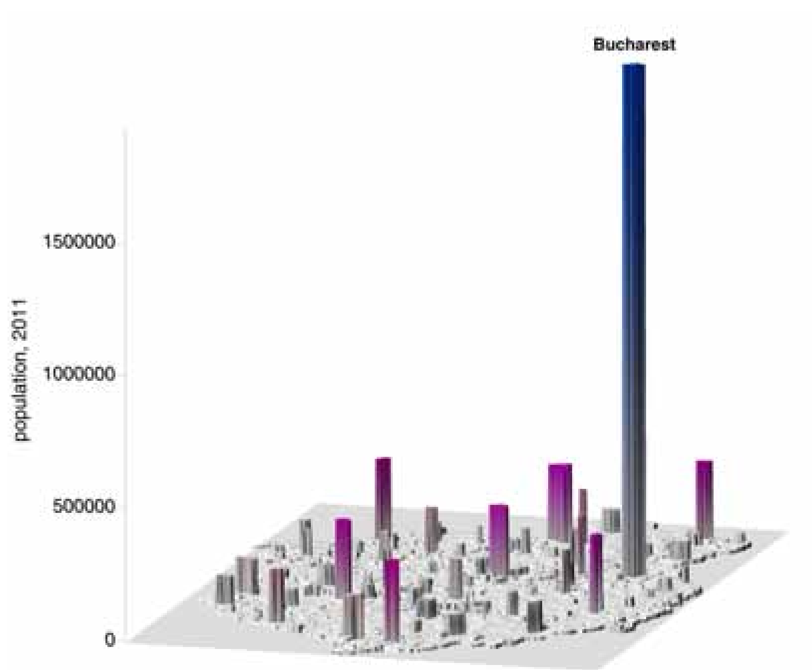
levels are among the primary reasons for declining demand. Most of the old, inefficient cogeneration units and heat-only boilers have not been upgraded or replaced with modern generation equipment, nor are they equipped with adequate burning equipment, resulting in SO_2 and NO_X emissions that exceed EU norms. With an average of 275 tons of CO_2 per gigacalorie,[3] Romania's district heating producers rank among the most polluting service suppliers in the EU. Heat distribution networks suffer an average of 30 percent heat and water losses, compared to five to ten percent for newer networks. As a result of those inefficiencies, the cost of district heating is about 18–20 percent higher than in some other EU countries.

Romania's overwhelming reliance on landfilling as its primary strategy for municipal solid waste disposal boosts the greenhouse gas (GHG) emissions generated by the country's waste management sector. The GHG emissions associated with municipal solid waste disposal in Romania total approximately two percent of the country's overall emissions, with the majority resulting from landfilling. Organic waste entombed in a landfill decays anaerobically, producing methane, a GHG with 25 times the heat-trapping potential of carbon dioxide.

Since the Bucharest-Ilfov Metropolitan Region (BIMR) dominates Romania's population, economic landscape and land-use development patterns, analysis of BIMR can provide a leading example of lower-emissions urban development for Romanian cities. With a population of 2.3 million, the region ranks 37th in size among all metropolitan regions in wider Europe. The region's share of Romania's population increased from 10.2 percent in 2000 to nearly 11.4 percent in 2011, a pattern that will likely continue over the next few decades (Figure 5.2). This increase is in stark contrast to

FIGURE 5.2. Bucharest Region dominates the country

Population distribution in Romania, 2011



Source: World Bank team calculation based on 2011 Population and Housing Census.

3. One gigacalorie is a unit of energy equal to 1163 kilowatt hours at 15° C.

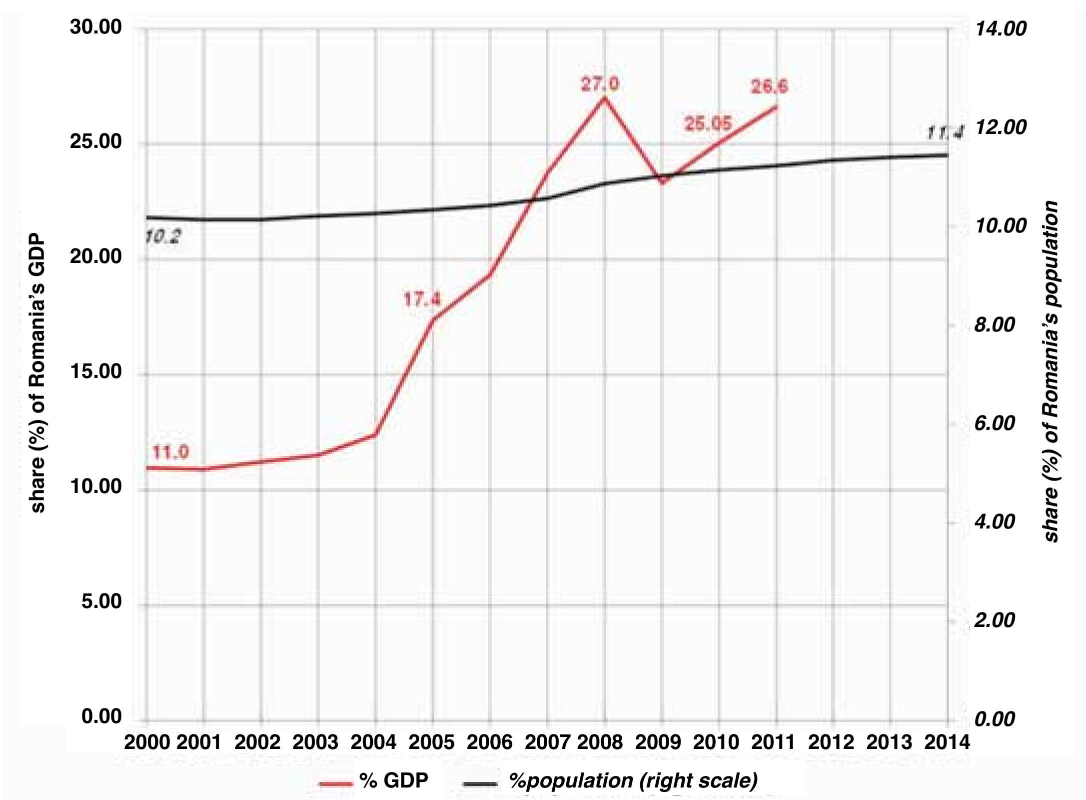
other cities around the country, where the population has declined significantly. Moreover, BIMR accounted for over 27 percent of the country's GDP in 2011, up from 11 percent in 2000 (Figure 5.3). Bucharest is the capital of Romania, its financial center, the leading industrial and cultural hub, and home to many of Romania's top universities. Located in the southeastern part of Romania, the region is approximately 100 kilometers (km) south of the Carpathian Mountains, 200 km west of the Black Sea, and 60 km north of the Danube River. The region's climate is temperate, with hot summers and cold winters. BIMR is composed of the city of Bucharest and Ilfov County.

Bucharest has administrative and political powers shared between the Municipality and local sector councils, with little overlap in authority. The city government is headed by a mayor (Primar General) and city council (Consiliu General). The city is further subdivided into six administrative districts (Sectoare), each with their own mayor and city council. In general, the Municipality is responsible for major city infrastructure systems such as the public transport network, major roadways, and the water and sewage system. Sectoare town halls manage secondary roads, parks, schools, and street cleaning.

Ilfov County is managed by a County Council that is responsible for basic public services and the road and transport network outside of the administrative limits of each of the 32 communes located within the County. As is the case with Sectoare governments above, Communes are responsible for local infrastructure and other government service issues within their boundaries. While Bucharest's population has declined over the past two decades, Ilfov County—the nearly 1600-square-kilometer

FIGURE 5.3. The capital region has grown even more dominant

Bucharest-Ilfov Region's share of Romania's GDP and population, in %



Source: World Bank staff calculations.

Source: Radu Bercan/Shutterstock.

administrative district that surrounds Bucharest—grew by 35 percent from 1992 to 2011. Ilfov County now accounts for more than 17 percent of the metropolitan area's population, up from 12 percent in 1992. This population shift has largely resulted from Bucharest residents moving from urban areas into new, single-family residences in suburban areas in Ilfov.

Suburban development pressures are strong, as a richer population seeks bigger homes. Population distribution within the Bucharest-Ilfov Metropolitan Region reflects three historical conditions typical of many eastern European cities: (i) lower population densities in the historical core area; (ii) high densities in outer clusters of high-rise apartment complexes adjacent to industries, built during the Communist era following the Soviet model; and (iii) scattered, low-density suburban sprawl that has evolved since transition in 1989 and the subsequent privatization of land. Many of the high-rise, prefabricated panel apartment blocks in Bucharest have small units. Public spaces have deteriorated over the years due to poor maintenance. With the privatization of land, suburban farmers are now able to sell individual plots for the development of single-family homes. Growing incomes have enabled many Bucharest residents to move to the suburbs, even though they continue to have weak public services in terms of schools and commercial facilities.

Overall, the distribution of total building stock in BIMR shows a radial pattern driven by proximity to major roads. The distribution of residential building stock clearly shows these spatial patterns. Suburban low-rise development is occurring at very low densities, generally about six dwellings per hectare. The medium-rise residential stock is largely comprised of three- to five-story walkup apartments in central areas. High-rise residential stock is principally panel blocks built during the Communist era. Other salient characteristics of Bucharest's building stock are the low quantity of commercial offices and their central location, the high number of large-scale retail (big-box) in suburban areas, and the distribution of industrial buildings, clustered around older industries in the inner urban area and, more recently, scattered in the suburbs.[4]

The Bucharest-Ilfov region's economy is still in transition, with an ongoing shift from manufacturing to services. Only eight percent of employees worked for state-owned enterprises in 2012, in contrast to 25 percent in 2000. Approximately 13 percent worked for foreign-owned firms in 2011, in contrast to only five percent in 2005. Services currently account for more than 76 percent of employment, with higher value-added producer services accounting for 31 percent of total employment. Manufacturing is still the largest employer (159,800 employees in 2011), but numbers have decreased by almost 23,000 from 2008 to 2011. BIMR's manufacturing sector is gradually innovating, but traditional industries (food, apparel, metal fabrication, printing machinery, furniture, tanning/dyeing) still provide the largest share of employment. Exports grew by 69 percent from 2005 to 2011.[5]

Per capita GDP in BIMR is 2.5 times the national average; and the region has several major comparative advantages that will continue to drive its economic growth over the coming decades. The GDP of BIMR grew by 12.3 percent between 2010 and 2011,[6] and growth has been high for most of the past 15 years. BIMR's economic hinterland is large: within a one-day drive by truck from the center of Bucharest is a population of 11 million; within a two-day drive, the hinterland reaches Budapest, Vienna, Athens, Istanbul and Kiev, a market of 83 million. BIMR has the most educated human capital in Romania: 33 percent of its working age population has vocational and tertiary educational attainment, compared to less than 15 percent in other regions. Supplementing these advantages are labor costs, which are the third lowest in wider Europe.

Traffic congestion caused by private cars is increasingly a part of daily life in the Bucharest-Ilfov region, despite the fact that the City of Bucharest is well-served by one of the most comprehensive public transport networks in all of Europe. Approximately 38 percent of trips in the region are made via automobile. Traffic congestion is becoming a serious problem, particularly in the urban core, at intersections along the main ring roads, and on the main thoroughfares traveling through the city along a north-south axis. A primary contributor to the congestion problem is rapid growth in vehicle ownership rates, which have risen from 152 vehicles per 1000 inhabitants (2006) to 224 vehicles per 1000 inhabitants (2012). Also, insufficient off-street parking facilities in the central area led many drivers to use illegal "parasite" spaces on the roadway, narrowing lane space and further inhibiting the flow of vehicles. Non-motorized transport is the second most utilized means of transport for daily trips: 31 percent of trips are made by walking, while two percent of trips are made on a bicycle. The growing dependence on the automobile has occurred despite Bucharest's dense public transport network, consisting of the 51-station metro system, and the RATB's (Regia Autonoma de Transport Bucuresti) network of 120 bus lines, 24 tram and light rail lines, and 15 trolleybus lines. The bus is the most-utilized form of public transport, followed closely by the metro. Metro stations are located approximately every 1.4 km. A fifth metro line is expected to open in 2017. The majority of the bus and tram fleet has been overhauled in recent years to improve passenger comfort and vehicle efficiency.

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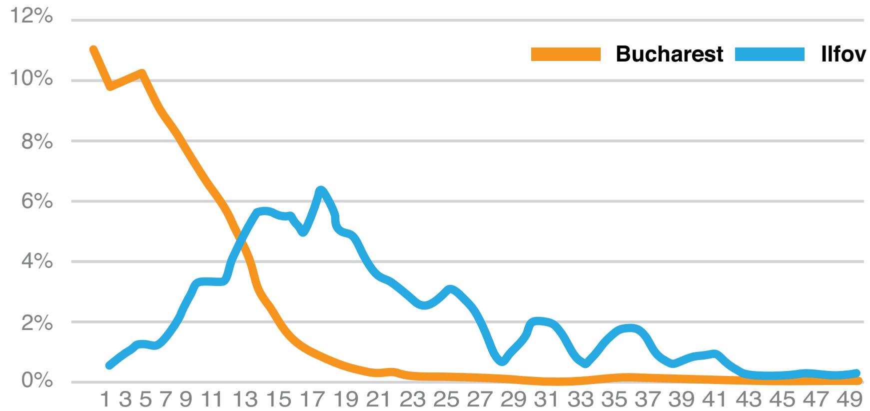
4. Using the RACE model, building areas have been calculated in all 500 meter cells in BIMR.
5. Bucharest Statistical Yearbook, 2012.
6. European Commission. *Regional Innovation Monitor Plus.* https://ec.europa.eu/growth/tools-databases/regional-innovation-monitor/base-profile/bucharest-ilfov.

FIGURE 5.4. Suburban residents of BIMR take longer trips than in Bucharest center

Distribution of travel distance for trips over 1 km for Bucharest and Ilfov



Source: AVENSA, Travel Habits Survey 2014.

Circumstances in Ilfov County are quite different, with little public transport and longer trips. Nearly one-quarter of roadways in Ilfov County consist of high-speed motorways. Access to a bus system is virtually non-existent, as there are just a few lines serving Ilfov County residents commuting into Bucharest. There are 2.6 trips per capita per day in the BIMR, with Bucharest residents traveling approximately 6.3 km on average and Ilfov residents traveling longer distances. The average trip distance for the entire Bucharest-Ilfov region is approximately 6.8 km (Figure 5.4).

Heating, especially in residential buildings, drives much of the energy use in BIMR's buildings, and Bucharest's vast district heating system is increasingly inefficient. Despite the importance of thermal efficiency in buildings, the level of compliance in Bucharest with thermal performance standard (under the EU's Building Performance Directive) is unclear. Heating systems in buildings around Bucharest typically involve freestanding boiler units inside the building or, in larger buildings, a connection to a large district heating system. Bucharest's district heating system is vast—the second largest urban system in the world—involving more than 4,000 km of distribution pipes and satisfying 72 percent of the city's thermal energy needs. The number of customers linked to the system has declined over the years, as has often been the case elsewhere in Romania. Service quality, cost, and concern over high pollution levels have been the primary reasons for declining demand. Bucharest's district heating system is fired by natural gas (54 percent), fuel oil (26 percent), and coal (20 percent). The electricity consumed in buildings in Bucharest and Ilfov is assumed to have the same characteristics as across the national grid, meaning it is heavily dominated by coal and hydropower. Coal use in Romania is considerably higher than in many other European countries. Energy prices for selected industrial customers and all residential customers are subsidized.

Bucharest-Ilfov recycles little of its solid waste and captures none of the methane related to landfills. Nationally, Romania is reported to recycle only five percent of its total waste stream, with virtually all of the remaining material ending up in landfills. Data from the National Institute of Statistics in 2011 disclosed that Bucharest-Ilfov generated a total of 881,000 tons of municipal solid waste, with Bucharest responsible for approximately 86 percent of that total. Approximately 45 percent of the region's waste is considered biodegradable (meaning it could be composted and converted into a useful soil amendment), while another 30 percent of the waste stream is made up of commonly

recycled materials. No regional landfill facilities currently have any methane gas recovery system in place, which is problematic because organic waste entombed in a landfill decays anaerobically and produces methane gas. Unless the landfill is properly designed, capturing or flaring the methane via a series of pipes embedded in the landfill, the gas will slowly leak out of the landfill for many years, including long after it is formally closed. Proposals have been floated to develop a large waste-to-energy facility that would convert waste heat into electricity. The status of this project is unknown.

Challenges

The financial resources available to upgrade major infrastructure systems have been limited by the regional economic slowdown and Romania's difficulty in absorbing EU funds. Foreign direct investment (FDI) has generally been good for the BIMR: 60 percent of the country's total FDI went to the region ten years ago. However, by 2010, FDI levels had dropped by nearly 80 percent, a situation from which Bucharest is still recovering.[7] The slowdown in the real estate market also has obvious implications in terms of the tax resources available to the Municipality for major infrastructure projects. Another critical factor has been Romania's difficulty in absorbing European Union Regional Operating Program funds. As of the end of March 2015, the absorption rate for the period 2007–2013 was 49 percent. Between 2007 and 2009, however, the absorption rate was zero percent, as there was considerable ramp-up time to train staff, prepare portfolios of projects, develop the necessary legal framework and regulations, and focus on strategies and the analytic foundation.

7. CJ Pen and M Hoogerbrugge, *Economic Vitality of Bucharest*. European Metropolitan Network Institute (EMI). 2012.

Low-carbon urban actions have been impeded by institutional challenges, including the lack of formal roles in planning and implementing, policy and planning disconnects between different government entities, and a lack of transparency. Compelled by the problems of traffic congestion, diminished air quality, and excessive energy spending, 60 Romanian communities have voluntarily opted to create Sustainable Energy Action Plans under the auspices of the city-focused Covenant of Mayors program. However, Romania lacks a formal urban climate strategy and action plan, and clarity regarding the formal role of local authorities in crafting and implementing changes that are necessary to reduce urban GHG emissions. High-level climate policy statements typically speak only in terms of sectoral or infrastructure changes but do not specify who is responsible for planning or implementing these changes. The ambiguity around the role of local authorities is an obstacle to their engagement in ways that are more reflective of local considerations rather than national or global imperatives. Moreover, policy and planning disconnects between different tiers of government or ministries with overlapping functions have proven to be a major impediment to the resolution of several major infrastructure challenges. Examples can be found in all sectors. Two different regulatory agencies are responsible for policies relevant to district heating systems. The metro system in Bucharest is operated by METROREX under Ministry of Transport control, while the surface transport system (trams, bus and trolley) is managed by RATB (Regia Autonoma de Transport Bucuresti), which is under city control.

Lack of transparency by different government agencies has made it hard to plan and set priorities. For example, public access to information about the building stock in Romanian cities is limited, and there are no reports published to date comparing the Energy Performance Certificate scores across cities, despite the fact that the law has been fully implemented as of 2011.[8] Were such information available, local authorities could more easily compare building upgrade strategies or set priorities among different types of buildings.

Subsidized energy prices for households and selected energy-intensive state-owned enterprises encourage over-consumption and repress the market for energy efficiency-focused firms. As part of its accession into the European Union, Romania agreed to move away from tightly regulated and heavily subsidized energy prices to a market-based system. As of early 2015, businesses must now pay market rates for electricity and gas, but energy prices for selected industrial customers and all residential customers remain subsidized. Energy-intensive state-owned enterprises continue to receive preferential electricity and gas prices. State and local subsidies for residential district heating cover roughly 50 percent of residential customer costs. Household energy prices will not be fully liberalized until January 2018 (electricity) and January 2019 (gas) respectively, reducing the incentive to adopt energy saving measures. No timeline has been given for removing district subsidies. In addition to influencing energy demand, low prices have meant the market for energy efficiency-focused firms and expertise has been slow to develop. That should change in the coming years, either through firms in other European countries targeting the Romanian market, or through more home-grown endeavors. Trade groups such as the Romania Green Building Council are becoming more active, although membership rates remain quite low.[9]

8. Required by the EU Energy Performance of Buildings Directive (2002/91/EC) and its Recast (2010/31/EU).

9. Interview with Steven Borncamp, Romania Green Building Council. July 2014.

METHODOLOGY AND FINDINGS

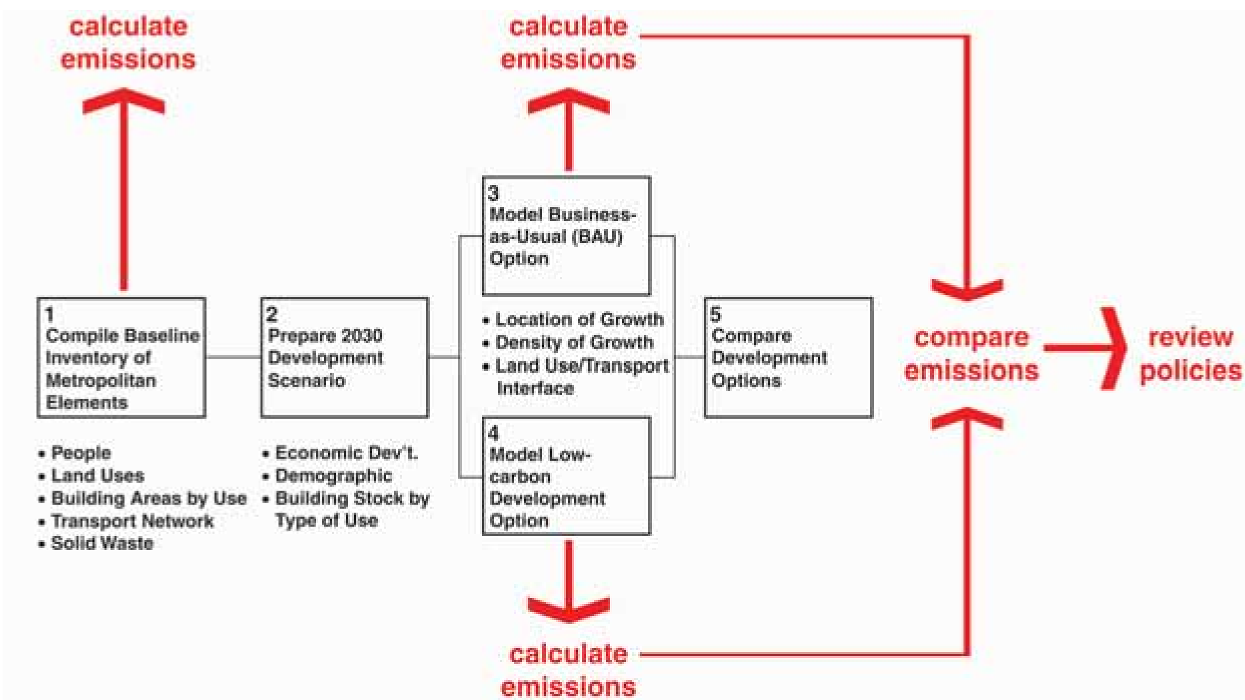
Methodology

The Rapid Assessment of City Emissions (RACE) model is a geospatial model that compares population and development patterns for a region under different scenarios, in order to develop technical estimates of how they differ in terms of energy use, energy spending levels, air quality emissions, and GHG emissions. By changing assumptions about current and future land use patterns, the design and location of different public transport system options, the energy and emission factors assigned to different land use patterns in a city, and the solid waste management system design, it is possible to compare a baseline scenario with one or more alternative scenarios in terms of: (i) total energy demand; (ii) total energy spending (in real terms); (iii) total energy-related air quality emissions (PM_{10} and NO_x); and (iv) total energy-related CO_2 emissions (Figure 5.5).

Step 1: Compile a baseline inventory of metropolitan elements. Without the legacy of GIS-analytics or data tracking in the Bucharest-Ilfov region, digitized information on local land use patterns, the location of roads or highways, population data, and building stock data was obtained from a variety of sources and, in many cases, manually generated based on high-resolution satellite imagery. A comprehensive land-use map with information on shape, dimensions and uses of individual buildings was developed by leveraging data through OpenStreetMap, satellite imagery, field studies and geo-referenced photographs. Population data was obtained from the 2011 census. The digital representation of road, local rail, and public transport networks was obtained from the work on the

FIGURE 5.5. A model of urban development is constructed

Overview of the RACE model



Source: Chreod Ltd.

Bucharest Sustainable Urban Mobility Plan (SUMP) and OpenStreetMap and manually created using GIS and digital images. The 2012 Bucharest Statistical Yearbook provided the enterprise address and employment data, which was used to develop maps of different types and locations of business activity around the Bucharest-Ilfov region.

Step 1 was completed, once the spatial model was fully developed, by assigning population, land use, and business activity across the region. This information was reallocated by superimposing a 500m × 500m grid scale over the entire Bucharest-Ilfov region.[10] Data attached to an individual cell or to an aggregation of cells is more easily extractable for analysis in a relational database or a spreadsheet, as is the case with the RACE model. Once the data is transferred into the RACE spreadsheet model, energy and emission factors are applied to develop baseline estimates of current energy demand, energy spending, and GHG and air quality emission levels for BIMR. Solid waste management system parameters are also entered into the analysis at this point, as the various disposal options are not necessarily spatially linked. This information serves as the starting point for the scenario analysis.

10. This technique is commonly employed in GIS (Geographic Information System) analyses to help remedy the fact that data is often available at wildly disparate scales (e.g., building scale vs. census tract vs. specific addresses).

Step 2: Prepare a development scenario for 2050. The future development scenarios modeled in RACE posit assumptions about future demographic and economic conditions likely to exist in the city/region. In making these calculations, the scenario must explicitly address the pace of expected growth and shifts in the city's reliance on manufacturing value chains (i.e., the expected shift from low to high value-added manufacturing) and in consumer and product services. Collectively, these assumptions drive estimates of future demand for industrial, commercial, and residential building stock, which RACE then uses to calculate emissions. Moreover, transport infrastructure assumptions are necessary to construct "accessibility indices" for each 500m grid cell, which measure the relative accessibility of each cell to the city center or other areas of anticipated economic growth, thereby defining areas most likely to attract development activity. At least two different spatial growth options can be constructed to accommodate the projected population and building stock requirements: a Business-as-Usual option and a Low Carbon option. These options articulate different visions for the location of growth, the density of growth, the land use mix of growth, and the extent to which these land uses are integrated with the city's transport infrastructure.

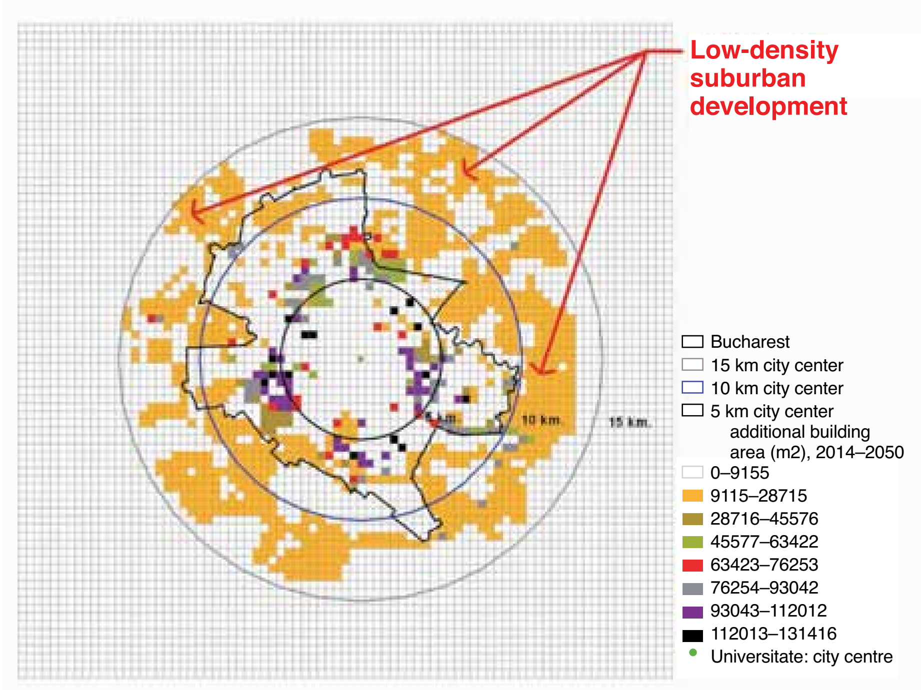
Step 3: Model a Business-as-Usual (BAU) scenario. The BAU scenario reflects recent spatial patterns of development: the land-use mix is assumed to remain relatively segregated. In other words, large residential areas with little or no formal employment spaces; growth driven by changes in population levels and/or economic expansion continues to focus on suburban and peri urban areas (with little, if any growth distributed to the core and inner city areas), based on the assumption that land values and resettlement costs are lower in the suburbs. Grid cells with building densities higher than the city average are also excluded as growth areas. Finally, the BAU scenario assumes little attempt is made to link development growth to public transport systems in the region. With these assumptions in mind, growth is then distributed around the city using GIS, factoring in accessibility indices that prioritize available marketable land and recent growth trends. Once this is done, it is possible to recalculate energy demand, energy spending, and emissions for the region. Any changes in the solid waste management system structure (compared to the baseline period) are also accounted for at this time.

Step 4: Model a Low Carbon (LC) Development scenario. The Low Carbon scenario presumes very different growth parameters than the BAU scenario. High-density clusters of mixed use development are proposed, minimizing the need for travel to places of work, education, commerce, and recreation. Because growth is concentrated in areas with the best accessibility, there is tight integration of land uses with transport infrastructure. The LC scenario can propose changes to transport routes or the creation of new transit nodes to improve land use–transport integration and facilitate even higher density development. Solid waste management system options known to increase a city's carbon performance are also changed in the model. Energy demand, energy spending (in real terms), and emission levels are then calculated for the new configuration.

Step 5: Compare development options. The models employed in this analysis have been used to estimate the technical potential for change in energy demand, emissions, and other variables, but not the cost-effectiveness of different interventions. It highlights indicative changes that can be attributed to different policy decisions or estimates of how and where growth will manifest itself around a city. By comparing the energy and emission impacts of different development options, local and regional authorities can identify the types of policies that affect the long-term economic and environmental sustainability of their city. Action plans can then be prepared to comprehensively review and, where appropriate, adjust these policies to minimize emissions.

FIGURE 5.6. Building density remains low in the BAU scenario

Distribution of new building stock density in BIMR, BAU scenario, 2050



Source: World Bank.

Findings

The first option is business-as-usual (BAU), which assumes the continuation of low-density growth of residential, office and industrial development. For residential development, which accounts for the majority of both floor space and energy use, residents in high-rise Communist-era apartment blocks are assumed to continue the recent market trend of moving to single-family homes in the suburbs around Bucharest. Consequently, low-rise's share of total residential building stock grows from 42 percent in 2014 to 60 percent in 2050. The BAU scenario involves extensive suburbanization in the ring 10–15 kms from the center of the city, since there is insufficient land to accommodate low density residential growth within Bucharest (Figure 5.6). Given the absence of public transport in this outer ring, residents would need to rely on private vehicles for journeys to work, education, shopping, and recreation. Indeed, the BAU scenario is notable for its lack of integration between new development and public transit (trams, buses and metro).

In the BAU scenario, overall energy use and associated emissions continue to increase through 2050. While this is to be expected given the low density development and lack of coordination with transport planning, what is most surprising is the slow rate of growth in GHG emissions. Even as demand for energy continues to increase between 2014 and 2050 as a result of the demographic and spatial trends—including a 30 percent increase in population and building area—carbon emissions grow much less rapidly (at nine percent) over the same period. This is explained by a number of positive trends in building (including anticipated improvements in building efficiency; changes in carbon intensity of the electricity grid; and reduction in technical losses in the district heating system), transport (fuel efficiency gains and cleaner fuel mix), and solid waste management (rates of recycling and biodegradable waste diversion).

Under the BAU scenario, there are efficiency gains in buildings, which can be attributed to several current trends. Key trends even in the BAU scenario include renovation of the existing building stock at the current pace of one percent per year, energy savings from retrofits at a conservative 15 percent, new buildings with moderate energy savings of 45 percent (due to various EU policies) compared with existing building stock.[11] Total GHG emissions from buildings are also affected by changes in the carbon intensity of the electricity grid, as coal-fired plants are largely replaced by natural gas facilities. The thermal efficiency of buildings in the Bucharest-Ilfov region is also expected to increase thanks to anticipated reductions in technical losses from the district heating system (from 15 percent to 13 percent).

Rising vehicle-kilometers travelled are somewhat offset by efficiency gains and a cleaner fuel mix. As people move to the suburbs, the number and average length of trips increase while speeds decrease as a result of increased congestion (and speed is an important determinant of emissions). Under the BAU scenario, the number of trips is projected to increase by 30 percent and average trip length by eight percent during 2014 to 2050. However, all vehicle classes will also experience efficiency gains (of 40 percent in private vehicles and almost 20 percent in buses) as a result of current EU directives on fuel efficiency and natural replacement of vehicles (an increase in Euro III/3 and later vehicles and a decrease in less-efficient older models). In the absence of coordinated land-use and transit policy, it is assumed in the BAU scenario that modal split will stay the same, but there is a trend towards a cleaner fuel mix, with particularly notable growth in LPG (liquefied petroleum gas) consumption in private cars.

Lastly, under the BAU scenario, it is anticipated that rates of recycling and biodegradable waste diversion in Bucharest would reach half the levels mandated by EU targets. In the solid waste sector, emissions are projected to increase along with population and income growth. While waste composition is assumed to remain constant over the time period, management of waste is expected to change in line with the current trend of improvement.

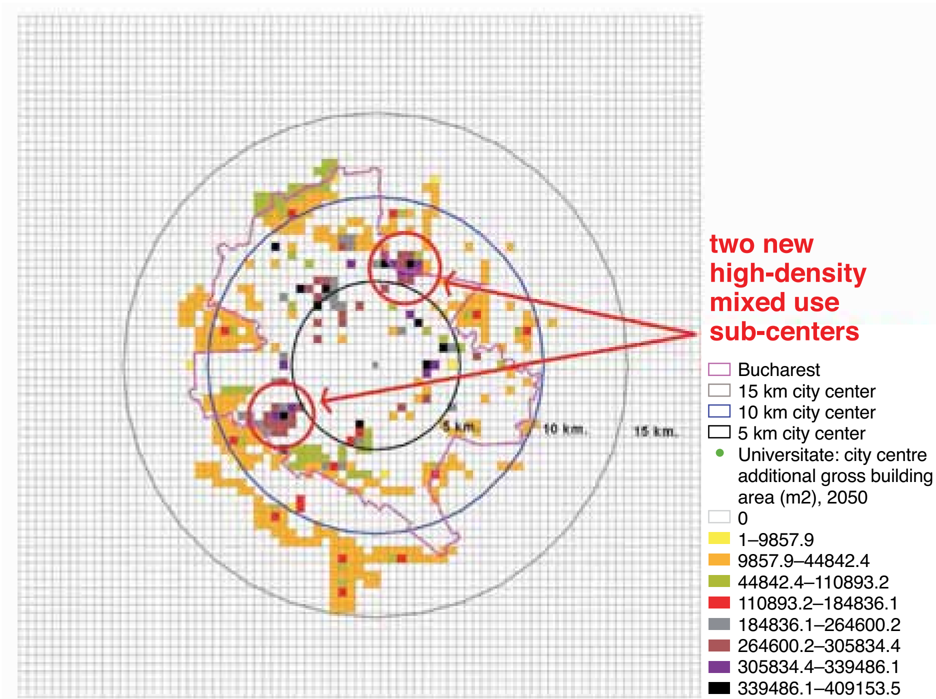
The second option modeled is a Low Carbon Development scenario under which spatial development in BIMR exhibits less sprawl, higher densities, mixed-use, and a coordination of transit and spatial planning when compared to the BAU scenario. The LC scenario assumes proactive local action to reduce energy consumption in buildings and transport and to change local solid waste practices, and ambitious national initiatives to promote clean power and cleaner vehicles. Spatially, growth is concentrated in a number of strategic areas (Figure 5.7). The LC scenario creates two major new sub-centers with high densities and a mix of residential, office, and retail uses. Very high-density residential is distributed in the immediate vicinity of metro stations, reflecting a strong coordination of transport and land use planning.

Efficiency gains from urban land use and reduction in travel distances can be achieved in the LC scenario through spatial planning. In terms of residential development, the LC scenario halves the share of low-rise development, doubles the share of high-rise development, and more than doubles

11. These assumptions on the rate and depth of change are informed by Building Performance Institute Europe (BPIE). 2014. Renovating Romania: A Strategy for the Energy Renovation of Romania's Building Stock. Available at: http://bpie.eu/renovating_romania.html#.VWxEQzLGVyU.

FIGURE 5.7. Building growth is concentrated in strategic areas in the Low Carbon scenario

Distribution of new building stock density in BIMR, Low Carbon scenario, 2050



Source: World Bank.

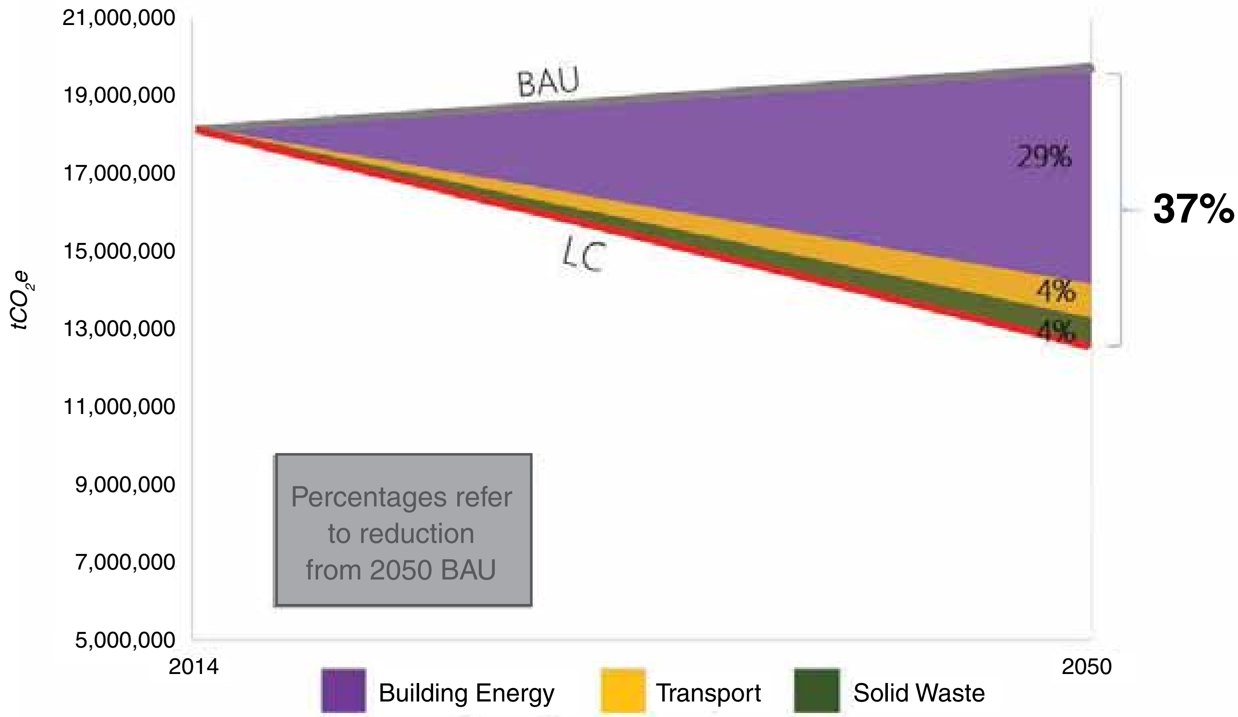
the share of very high-density development in 2050, compared to the BAU scenario. Retail becomes more dispersed in high-density communities, reducing the need to travel to shops. Similar to the BAU scenario, the Low Carbon scenario assumes that 100 percent of industrial development is in industrial estates; spatially, these are concentrated in two large industrial parks strategically located close to rail and expressways. For space of institutional buildings, the LC scenario assumes a drop in government buildings' share, accounting for e-government reforms that reduce the need for building space. Education's share increases, reflecting a qualitative improvement in space per student. The amount of land allocated to healthcare facilities increases, reflecting a growing demand from an aging population. Transportation's share grows only slightly, reflecting an increase in the number of metro stations and hubs by 2050.

Unsurprisingly, proactive spatial planning leads to significant improvement in energy use, energy spending and emissions, even though the gross building area remains the same as in the BAU scenario. The scenario leads to carbon emissions reductions of 37 percent relative to a BAU pathway, with buildings-related energy use delivering three-quarters of savings. (Figure 5.8) The biggest difference between the LC and BAU scenarios is the attention to land use planning. In particular, development of high density buildings and mixed uses around transit nodes is reflected in a changed modal split, with a nine percent increase in public transportation and a three percent increase in non-motorized transit.

Reduced energy use cuts total energy spending by US$1.4 billion per year in real terms. In the buildings sector alone, energy savings amount to US$956 million per year by 2050. Thermal energy savings, relative to the BAU scenario, amount to as much as US$632 million. Given that retail prices

FIGURE 5.8. Proactive spatial planning leads to significant emissions reduction

Carbon emissions reduction under Low Carbon Development scenario relative to BAU, 2050, tCO_2e



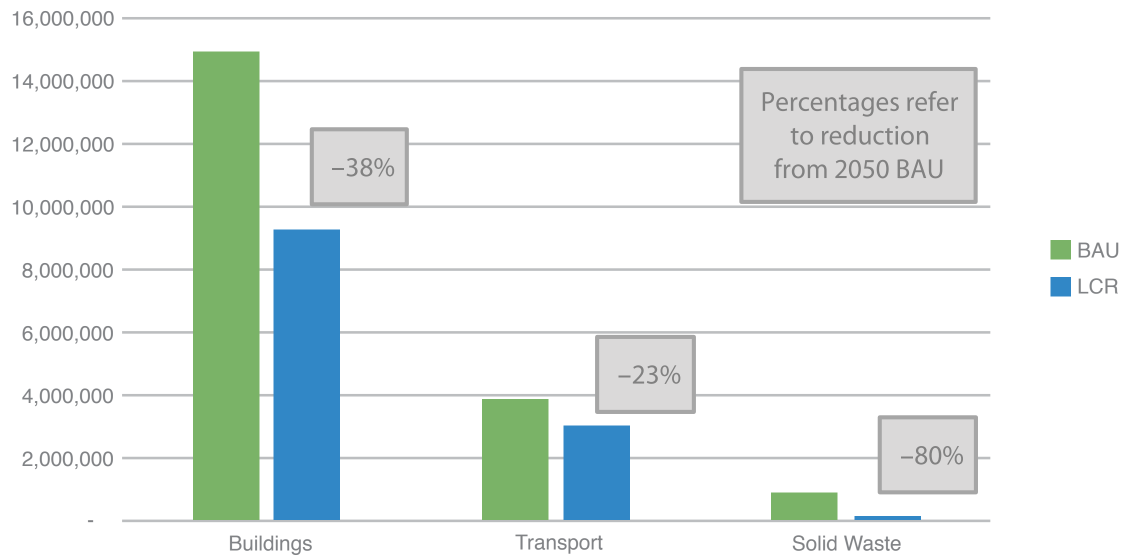
Source: World Bank staff calculations based on RACE model.

for heating are set by the government, it is likely that most of these savings will accrue to the municipal budget—an important savings given the large burden of subsidizing thermal energy use in Bucharest.

Emissions from buildings, transport, and solid waste in BIMR will see reductions by 2050 under the LC scenario, but with different key drivers. Under the Low Carbon scenario, reductions in building-related emissions will come from reductions in fossil fuels for electricity generation and improvement in transmission and distribution efficiency, in addition to the increase in the proportion of higher-density buildings. Also important will be actions by both local and national governments to increase the rate and depth of building energy efficiency above and beyond the BAU path. Together, these factors push building-related emissions 38 percent lower relative to the BAU scenario. In transport, new spatial patterns will lead to reductions in the number and length of trips and in traffic congestion. Combined with measures to improve vehicle stock and efficiency, transport emissions in 2050 are 23 percent lower in the LC scenario than the BAU scenario, with a total (real) savings in energy spending amounting to US$440 million per year by 2050. Moreover, particulate matter (PM_{10}) emissions will decline by 39 percent and nitrous oxide (NOx) emissions by 16 percent, relative to the BAU scenario. These improvements in local air quality, along with improvements in urban mobility, can make Bucharest a much more attractive and healthier place for people to live and work. While its relative contribution to region-wide emissions is low, the solid waste sector under the LC option shows a greater reduction proportionate to its BAU development trajectory than any other sector. An 80 percent reduction in emissions relative to BAU is achieved if Bucharest-Ilfov meets all EU targets with regards to recycling and biodegradable waste diversion. Emissions reductions are driven primarily by a reduction in methane, via a combination of composting and the capture of 100 percent of the methane emissions from local landfills (Figure 5.9).

FIGURE 5.9. Sectors contribute differentially to emissions reduction

Emissions from buildings, transport and solid waste, BAU and Low Carbon scenarios, 2050, tCO_2e



Source: World Bank.

CONCLUSIONS AND RECOMMENDATIONS

The modeling of a greener path for BIMR summarized in this chapter provides local authorities with insights into how policies affect the speed, location, and density of urban growth and the resulting GHG emissions. Government must consider the type, mix, and location of transport infrastructure, the local waste infrastructure, and the degree of integration between different land uses and transport services, which together can strongly influence the long-term economic and environmental sustainability of a city. Delivering changes that lead Romania to a low-carbon future will take considerable financial resources and strong political leadership on the part of a range of stakeholders. The following table presents different categories of recommendations that focus more directly on initiatives the Bucharest Municipal Government, District governments in Bucharest, and Ilfov County, and Commune officials should consider.

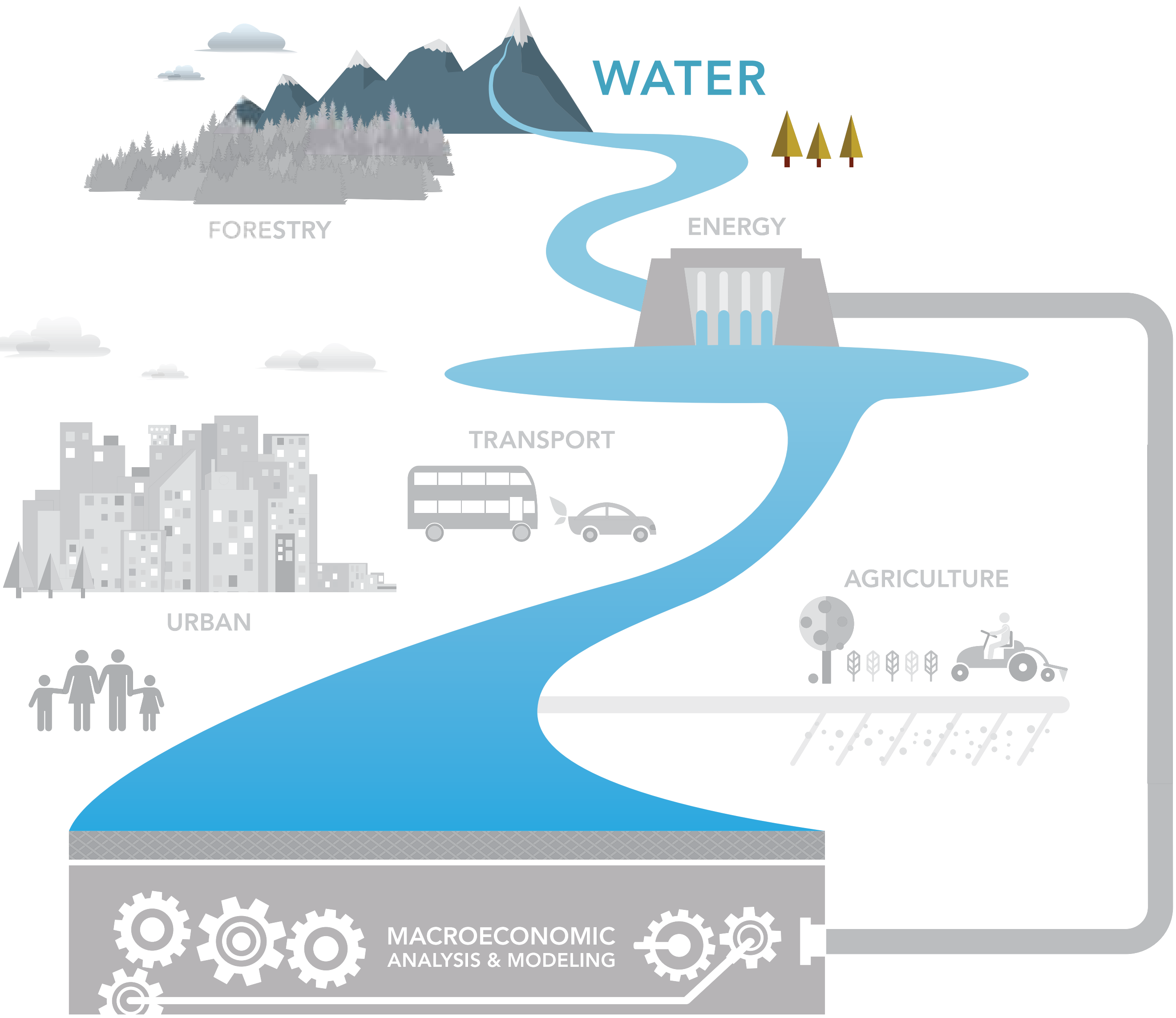
Other Romanian cities interested in this type of assessment are encouraged to evaluate the quality of data available for their city and consider application of the RACE model, keeping the fundamental limitations of the model in mind. RACE should be used to obtain knowledge into indicative changes in energy demand, energy spending, and emissions levels that can be attributed to different policy decisions or strategic changes in how and where growth should be directed around a city. The RACE model highlights the value of strategic planning in promoting more compact city design, transport-oriented development (and other policies resulting in changes in modal-split), upgrades to more efficient vehicle stock, and policies promoting building efficiency upgrades. Such changes in a city's development path can deliver sizable reductions in annual energy spending and emissions levels.

TABLE 5.2. Policy recommendations

SECTOR FOCUS	POLICY RECOMMENDATIONS	TYPE OF POLICY INITIATIVE
Cross-sectoral	*Data collection training, dissemination, and use:* Expand the amount of land use, building stock, and building and transport-related energy use data systematically collected and made available for public use. Local authority staff should be trained on data collection strategies and methods of analysis (including GIS).	Administrative and policy reform
	Guidance: Convene multi-stakeholder coordinating group to ensure policy coordination on land use and transport policies and investments	Administrative and policy reform
	Improve metropolitan governance and management: Evaluate, with all affected stakeholders, mechanisms to improve coordinated and integrated strategic planning, development monitoring and control, and delivery of metropolitan public services at the scale of the metropolitan region (including land use planning, public transport, and environmental management).	Administrative and policy reform
	Improve management of suburban growth: Design, enact as a statutory instrument, and enforce a growth management strategy for the metropolitan region that limits uncontrolled suburban sprawl, and subsequent consumption of agricultural land and forests.	Administrative and policy reform
Land use	*Promote mixed land use:* Adopt mixed land use policies, where different types of land use (housing, shops, offices, other urban amenities) are interspersed rather than segregated, thus providing more convenient access to goods/services and employment opportunities. Mixed land use policies are recognized for their ability to reduce the use of motorized transport.	Land use policy reform
	Up-zoning: Change the floor-to-area (FAR) ratio allowed on certain land parcels or in certain neighborhoods, thus increasing the level of population or economic activity that can be accommodated. Note that these changes must be made to take into account the carrying capacity of local streets, sidewalks, and parking areas to ensure they do not become overloaded.	Land use policy reform
	Transit-oriented development: A variation on upzoning by specifically targeting these changes in the vicinity of high-capacity transit nodes, thereby increasing the size of the population likely to make use of the mass transport system. Note that these changes must be made in close coordination with relevant transport agencies to ensure that transit system capacity (overall, or at specific nodes) does not become overwhelmed by higher rates of usage.	Land use policy reform
Land use and transportation	*Preferential lane space for public transport/high occupancy vehicles:* Dedicated lane can ensure that high occupancy vehicles are not adversely affected by slow-moving vehicles. Interest in public transport use typically increases if it is seen as a time-saving option compared to private vehicles.	Roads policy reform
	Creation of pedestrian-only zones: Designating core city areas as pedestrian-only zones can reduce demand for motorized vehicles.	Land use and roads policy reform
	Parking policies: On-street parking takes up scarce lane space that could be used to facilitate vehicle movement around the city. Different parking policies (e.g., variable rate pricing with higher rates during peak travel periods, on-street parking bans, or time-based restrictions) should be considered for important thoroughfares. Land-use policies can also be amended to promote the creation of more off-street parking. On the periphery of the city, 'Park and Ride' facilities should be established at the end of high-capacity transit lines to encourage the use of public transportation when entering Bucharest. (Such systems are critically needed if congestion pricing programs are established in the urban core. See below.)	Roads policy

TABLE 5.2. Continued

SECTOR FOCUS	POLICY RECOMMENDATIONS	TYPE OF POLICY INITIATIVE
Land use and transportation	*Completion of ring road(s):* The incomplete nature of the ring roads around Bucharest leads through-traffic to drive through the city center, competing with local traffic and increasing congestion levels.	Roads policy
Traffic management	*Congestion pricing:* Congestion pricing charges a fee to use the scarce road space in the center of a large city. Typically, congestion pricing in cities is limited to heavily trafficked areas; drivers entering must pay a toll to enter that area. Congestion pricing programs presume that effective alternatives (such as public transit) exist to allow individuals to enter that area at no or low charge.	Roads policy
District heating systems	*District heating system upgrades:* Conduct or require strategic reviews of local district heating systems to identify cost-effective efficiency upgrade opportunities. Systems can also be analyzed for the possible use or integration of low(er) carbon energy sources.	Engineering analysis
Building efficiency	*Property Assessed Clean Energy (PACE) finance:* PACE systems create a revolving loan fund that can be tapped to support energy efficiency upgrades. Property owners can apply for these funds, which are then paid off via a surcharge on their energy bill (typically at a rate equivalent to the energy savings the upgrades deliver to the building). Because the loan is attached to an individual property rather than the owner of the property, when the property is sold/transferred, the loan obligation is immediately transferred as well. PACE programs can be capitalized by private investors or other municipal finance strategies.	Public finance
	Green mortgages: Green mortgages typically enable borrowers to obtain larger mortgages (or preferred rates) because their properties have been certified as meeting minimum efficiency standards. The monthly savings on energy spending can thus be transferred to allow the borrower to afford higher monthly mortgage payments. Local authorities can partner with and promote the Romania Green Building Association's new green mortgage program that provides preferential rates to property owners buying or investing in more efficient buildings.	Public finance
	Point of sale efficiency upgrades/audits: To bring older buildings closer to the energy performance of new buildings, these requirements must be satisfied before a property can be sold, transferred from one occupant to another, or renovated beyond a certain limit. To ensure that the retrofit burden does not become excessive, such policies typically cap the total cost of required improvements at some fraction of the sale or rental price. These requirements mesh well with EU-imposed building performance disclosure requirements, because underperforming properties can easily be identified.	Energy policy
	Energy efficiency capacity-building programs: Local authorities can create programs to improve local knowledge of building efficiency upgrade opportunities. These programs can be run centrally out of City Hall, or support can be given to relevant community-based organizations in a strong position to influence/inform the public.	Energy policy/education


WATER
FORESTRY
ENERGY
TRANSPORT
URBAN
AGRICULTURE
MACROECONOMIC
ANALYSIS & MODELING

CHAPTER 6

Which Measures Would Best Support Adaptation to Reduced Water Availability?

CHAPTER SUMMARY

Romania's water sector is vulnerable to climate change, and adaptation efforts are essential for its continued ability to meet demand for water from end-use sectors—households, industry, agriculture, and hydropower. The water sector in Romania is facing a dual challenge: water availability is dropping and demand for water increasing, both due to climate change. Irrigation supply is constrained by inadequate irrigation infrastructure, while irrigation availability is becoming critical for agriculture due to climate change. Similarly, supply reliability for industrial and domestic use is most challenged for basins with lower water endowment during the summer months. Hydropower generation will both constrain and be constrained by water demand in other sectors in Romania. It is also sensitive to water scarcity in basins during the dry season. Adaptation efforts are, therefore, important.

A series of models were used to analyze the impact of climate change on water availability and demand and the offsetting impact of adaptation measures: climate models, water and agriculture models, and adaptation scenario models for financial evaluation of proposed green investments. Two green (adaptation) scenarios—Green and Super Green—were compared to the outcomes in the Baseline scenario. The analysis found that climate change will lead to decreased river runoff, which in turn will negatively affect the water demand-supply balance. In agriculture, water availability will be threatened during the primary growing months, while demand for irrigation will increase due to rising temperatures and decreasing and more variable precipitation. Unmet municipal demand will be modest, but industrial activities may be more seriously affected if no adaptation efforts are undertaken.

Climate change presents a substantial risk to agricultural production, irrigation, municipal and industrial water uses, and hydropower generation in Romania. However, these risks can be addressed by green growth investments, which would significantly counteract the negative impact of climate change on crop agriculture in most regions and even increase crop yields beyond current levels. The

most promising green growth investments—(i) rehabilitating irrigation infrastructure, (ii) optimizing agronomic inputs, including fertilizer inputs, and (iii) adopting improved, drought tolerant, crop varieties—were assessed for their impact on crop yields (productivity) and their financial impact. While the first two measures have clearly positive productivity and financial outcomes across regions and crops and should be implemented at the country level, the third one (crop varieties) is estimated to provide benefits in particular regions and crops, to which it should be targeted.

Required investment in the Green scenario, with modest adaptation actions, amounts to €1.8 billion or 0.05 percent of GDP, while the Super Green scenario, with very ambitious and more expensive adaptation actions, requires €11.0 billion in investment costs or 0.32 percent of GDP.[1] The schedule of investments generates a higher burden for 2015–2030 when approximately 65 percent of the total required investment occurs.

CHALLENGES FOR GREENER GROWTH

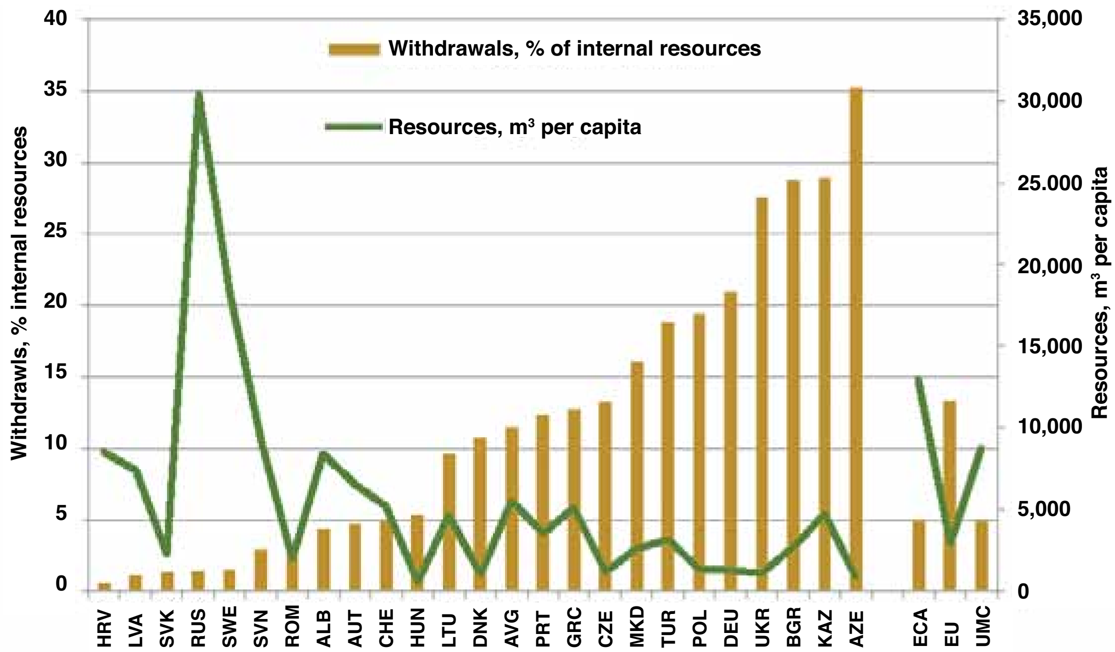
Overview

Romania's water resources are moderate but sufficient with prudent resource management that would ensure conservation and sustainability; regional and interannual variation is, however, significant. The utilizable level of water resources (surface and ground) in Romania, as defined by the existing capacity to extract and use water, is 40 billion cubic meters (BCM) per year, while total water demand stands at eight BCM per year. With a current population of 20.2 million, per capita water availability in Romania amounts to approximately 2,000 cubic meters per capita per year. This value is lower than the European average of 4,500 cubic meters and only slightly above the international

1. Euro amounts are present values using a five percent discount rate.

FIGURE 6.1. Water availability in Romania is relatively low, but withdrawal levels are modest

Water resources per capita and withdrawals as percentage of internal resources, Romania and comparator countries in Europe and Central Asia



Source: World Bank.

threshold for water stress of 1,700. Water withdrawals, however, remain at a modest level, substantially below the international benchmark for pressure on available water resources—water stress is defined at 10 percent of water withdrawal as a share of water resources, and Romania's level is 3.2 percent. (Figure 6.1) However, various uses and locations of water are interlinked, and Romania faces a challenge from the significant interbasin and interannual variation in water availability. In the driest years, water availability has fallen to 20 BCM. Water availability also varied across basins, and the basins of Jiu, Arges-Vedea, Buzua-Ialomita, Siret, Prut-Barlad, and Dobrogea-Littoral are facing water scarcity. (Figure 6.2)

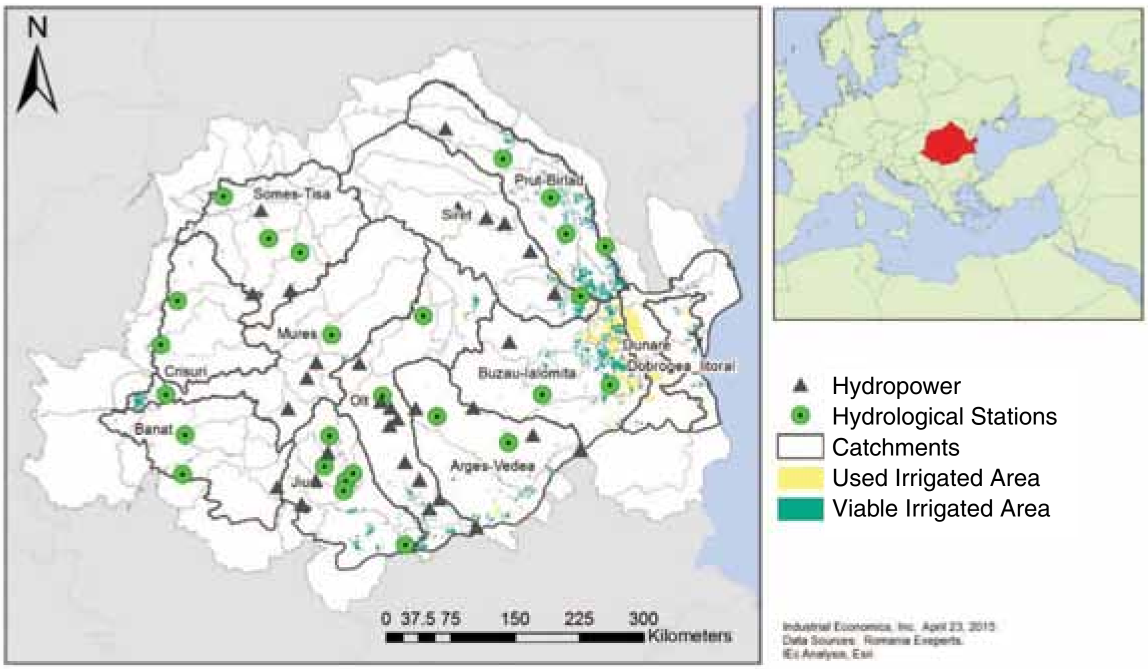
There is a degree of overcapacity in the water supply system, due to the steady decrease in water demand caused by structural changes in the economy starting in the 1990s. Current water demand comprises industry (67 percent), agriculture (18 percent), and municipalities or households (15 percent). Water demand has steadily decreased since the 1990s because of the reduction in industrial activity and shutdown of economically unviable irrigation schemes, as well as due to the introduction of water metering and tariffs and reduction of system losses in domestic water supply. Total demand, in terms of volume of water made available to users, decreased from approximately 20 BCM per year in the early 1990s to 8 BCM in 2012, while water consumption in the latter year equaled 6.5 BCM.

Challenges

Romania's water sector is vulnerable to climate change, and adaptation efforts are essential for its continued ability to satisfy demand for water from end-use sectors—households, industry, agriculture, and hydropower. The water sector in Romania is facing a dual challenge: water availability

FIGURE 6.2. Various uses of water are interlinked in Romania

Twelve river basins and 91 sub-basins, 26 hydrological stations, used and viable irrigated areas, and major hydropower facilities in Romania



Source: Water Sector Technical Report.

is dropping, and demand for water increasing, both due to climate change. Water availability is decreasing due to the warmer and shorter winters, with less snow volume and earlier and faster snow melting, lowering of the groundwater table in summer months, and less precipitation. Water demand is increasing due to higher summer temperatures and higher evapotranspiration, pushing up demand for water not only from agriculture, but also from industry and municipalities. Further, water quality will tend to degrade due to higher summer temperatures, through decreases in dissolved oxygen, eutrophication and algae growth. The wastewater sector will suffer from more frequent floods, storm water infiltration in sewer systems, and direct inundation of treatment facilities. The hydropower capacity factor, and therefore hydro generation output, will be adversely affected by decreased water availability. Hydropower facilities and storage reservoirs will be also affected by increased flooding.

Irrigation supply is constrained by the inadequate irrigation infrastructure, while irrigation availability is becoming critical for agriculture due to climate change. Irrigated area in Romania has decreased from two million hectares (ha) in the early 1990s to approximately 0.8 million ha that is currently considered irrigable with functional infrastructure, as economically unviable schemes were closed down. Moreover, land under irrigation has remained below 300,000 ha for the past five years. Irrigation volume fell from eight BCM per year in the early 1990s to one BCM per year in 2012. There are areas of water scarcity in many basins, where summer droughts are a significant concern. This situation is becoming more serious with the increasing impact of climate change, including rising temperatures and reduced rainfall across Romania. Addressing this challenge will require adopting climate-resilient agriculture and updating river basin plans—while taking

climate change impacts into account—to reassess the sustainable levels and modes of irrigation in water-scarce basins.

Similarly, supply reliability for industrial and domestic use is most challenged for basins with lower water endowment during summer months. The majority of the basins in Romania have no serious problems in ensuring sufficient volume of water to meet municipal and industrial demands. However, the basins with lower endowment of water (Jiu, Arges-Vedea, Buzau-Ialomita, Siret, Prut-Barlad, and Dobrogea-Litoral) face supply reliability challenges during the summer months, especially in dry years. The Dobrogea-Litoral basin is the most severely affected in this regard: as a result, almost 95 percent of the supply for the city of Constanta is being sourced from groundwater, which is being pumped from significant depths of 300–700 meters. A number of cities in the Banat and Moldova basins also face water scarcity in summer months. These cases, however, stand apart from the situation in most of the urban areas in Romania, especially Bucharest, which have multiple sources of water and offer significant buffer supplies and a high degree of reliability.

Hydropower generation will both constrain and be constrained by water demand in other sectors in Romania. It is also sensitive to water scarcity in basins during the dry season. Romania's hydropower potential is estimated at 36 terawatt hours per year, and the generation in 2012 was 19 terawatt hours (using six gigawatts of generation capacity). Hydropower generation accounts for 33 percent of Romania's total electricity generation. While coal and other fossil fuels remain the primary source of energy and electricity generation for Romania, the share of renewable sources of energy is large and increasing. The government intends to decommission and modernize some of the high-emission and obsolete thermal power plants and is considering options for promoting growth of renewable capacity, including support of small- and micro-scale hydropower generation.[2]

While hydropower is not a consumptive user of water, operation of hydropower facilities reduces the amount of water available for other uses. Therefore, the proposed new hydropower facilities would need to be planned while taking into account existing and anticipated future water uses in all sectors, as well as projected water availability in each basin under climate change. In the basins with the highest climate change impact, where scarcity already arises in summers of dry years, new hydropower plants will not be viable and the existing hydropower production will be adversely affected for a short duration. These constraints can be alleviated to a large extent by careful systems planning and operations optimization accounting for climate change impacts. Furthermore, the development of new hydro infrastructure will need to ensure that the environmental and hydro-morphological impacts are managed in compliance with the requirements of the European Union's Water Framework Directive.

METHODOLOGY AND FINDINGS

Methodology

The water analysis aimed to assess how climate change affects water availability and how green (adaptation) policies and investments can offset the impact of changing water availability on sectoral outcomes in water-consuming sectors, especially agriculture. Financial evaluation of the proposed green measures was also conducted. The analysis was based on scenario modelling. First, climate scenarios were generated and used for water availability projections and crop yield and hydropower impact estimates. Second, three scenarios were used to assess the impact of green policies and investments: the Baseline scenario and two adaptation scenarios, Green and Super Green. The Green scenario required a moderate adaptation effort, while the Super Green involved ambitious interventions necessitating significant investment. All three scenarios account for the impact of climate change on water availability and water demand. Table 6.1 provides details of the green measures (policies and investments included in each scenario) being evaluated. The emphasis is on measures in agriculture, making the modeling findings important for both the water and agriculture sectors.[3] Water sector outcomes were measured using indicators of annual water availability and the water demand-supply gap in agriculture (irrigation), in the municipal and industrial sectors, and in the energy sector (hydropower demand). Agriculture sector outcomes were measured by crop yields in irrigated and rainfed areas, before and after the implementation of green measures, and related revenues and costs. Hydropower production outcomes were estimated by the indicators of annual generation of hydropower and related revenues and costs.

The following models were used for the analysis: global General Circulation Models (GCMs), a water run-off model (CLIRUN), an agricultural yield model (AquaCrop), and the Water Evaluation And Planning (WEAP) model. The models were implemented in the following sequence (Figure 6.3):

- Step 1. The global GCMs produced climate projections for Romania as a function of initial conditions and projected quantities of greenhouse gases emitted.

2. Energy sector modeling in this assessment projects adding three gigawatts of new hydropower capacity by 2050 (see Chapter 3 (Energy)).

3. Relevant findings are discussed in Chapter 7 (Agriculture).

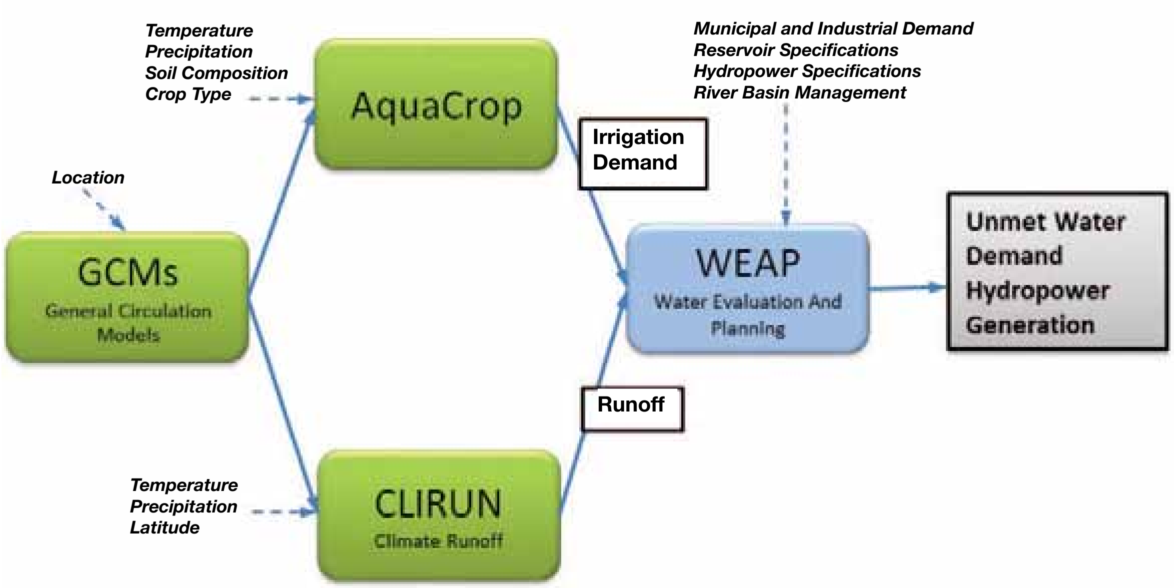
TABLE 6.1. Differences in adaptation characterize the various green scenarios for the water sector

Summary of water and agriculture sector green growth policy scenarios

SCENARIOS	SCENARIO CHARACTERISTICS INCLUDING POLICIES AND INVESTMENTS
Baseline (no adaptation)	• All current and planned thermal and nuclear plant deployment or retirement. • All current and funded or in construction future hydropower plants and associated storage. • Current but no additional reservoir construction. • Irrigation capacity, use, and efficiency at current levels.
Green Scenario (modest adaptation effort)	• Improved fertilizer application in the agriculture sector. • Improved varieties of crops in agriculture and extension to support farmer training in their use. • Measures are applied over approximately 530,000 ha, identified as areas of current medium agricultural production with potential for high production.
Super Green Scenario (ambitious adaptation effort)	• Application of fertilizer and improved-varieties measures as in the Green scenario, but applied over a larger area of 2.1 million ha identified as total areas of current medium agricultural production with potential for high production. • Expansion of the currently irrigated area by approximately 430,000 ha, a five-fold increase, in areas identified as viable for irrigation expansion.

FIGURE 6.3. Four models interacted to analyze the impact of climate on water

Overall analytic framework



Source: Water Sector Technical Report.

- **Step 2.** Climate projections from GCMs were used as inputs in the CLIRUN model to estimate streamflow runoff and also in the AquaCrop model to estimate crop yield and irrigation demand.
- **Step 3.** The runoff and irrigation water demand estimates from CLIRUN and AquaCrop, along with other hydrologic system inputs and nonirrigation water demand estimates, were incorporated into the WEAP tool, where water storage, hydropower potential, and water availability were modelled.
- **Step 4.** To refine the AquaCrop estimates of crop yield in irrigated areas by adjusting it to water availability modeled in WEAP, the unmet demand for irrigation water from WEAP, together with statistical data on irrigated crop sensitivity to water availability, was fed back into Aquacrop.

In addition to modelling, analysis involved financial evaluation of the measures used in the Green and the Super Green scenarios: the WEAP and AquaCrop output—hydropower generation and crop yield results—were analyzed to produce projections of the cost and revenue flows from crop production and hydropower and to calculate on that basis the net present value of the proposed green investment in these sectors. Also, the benefit-cost ratio was calculated, where benefits were estimated as direct financial flows that result from the investment. Evaluated investment options included construction and rehabilitation of irrigation infrastructure and optimization of its usage, fertilizer enhancement, and improvement of crop varieties. The irrigation improvement measure was only included in the Super Green scenario, while the other two measures were applied in both Green and Super Green scenarios. A discount rate of five percent and a base year of 2014 were used for the present value calculations.

The water and agriculture sector analyses address four policy-relevant issues: (1) the possible adaptive responses by farmers to climate change and the resulting marginal impact on agricultural production and incomes; (2) projected impacts on energy (hydropower) production under the modelled development and climate scenarios; (3) trade-offs between alternative water uses (for irrigation, hydropower, and municipal and industrial use); and (4) financial implications of climate change and green growth investments.

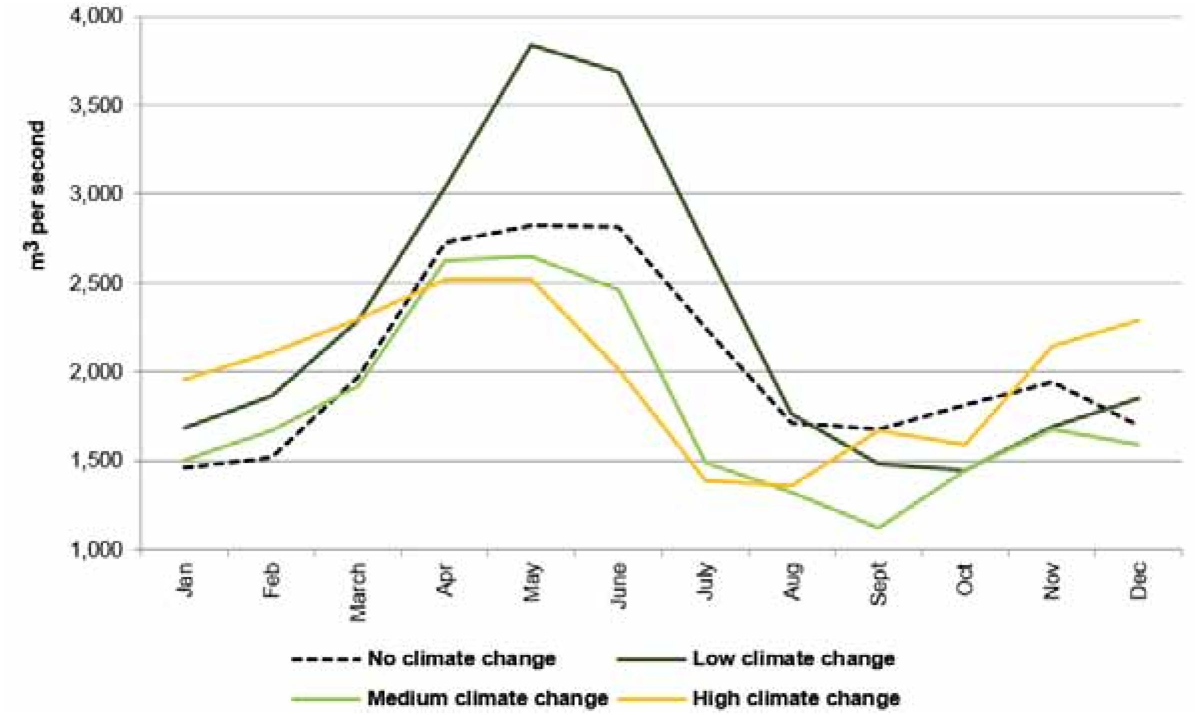
Findings

Unmet Water Demand

Climate change will have a negative impact on water availability in all climate scenarios by the 2040s, suggesting rising unmet demand for all types of water users. Water availability (mean annual runoff) improves in early decades under the low climate change scenario, but suffers a generally negative effect under the medium and high climate change scenarios, particularly in the 2040s. In the 2020s, the projected changes in annual runoff compared to 2014 range from a decrease of seven percent to an increase of 20 percent. By the 2040s, the changes are dampened somewhat at the national scale but are universally negative, ranging from a reduction of 0.7 percent to 8 percent. Monthly figures tell a more nuanced story. Figure 6.4 shows total mean monthly runoff across the 91 subbasins under both the 1961–2000 observed trend and under the three climate change scenarios during 2030–50. During April to September, runoff changes range from a 30 percent reduction to a 30 percent increase. Importantly, the majority of months under two of the climate scenarios show falling runoff throughout the April to September period.

FIGURE 6.4. Climate change will threaten water availability during the primary growing months

Sum of mean monthly runoff across 91 subbasins, observed trend (1961–2000) versus three climate projections (2031–2050)



Source: Water Sector Technical Report.

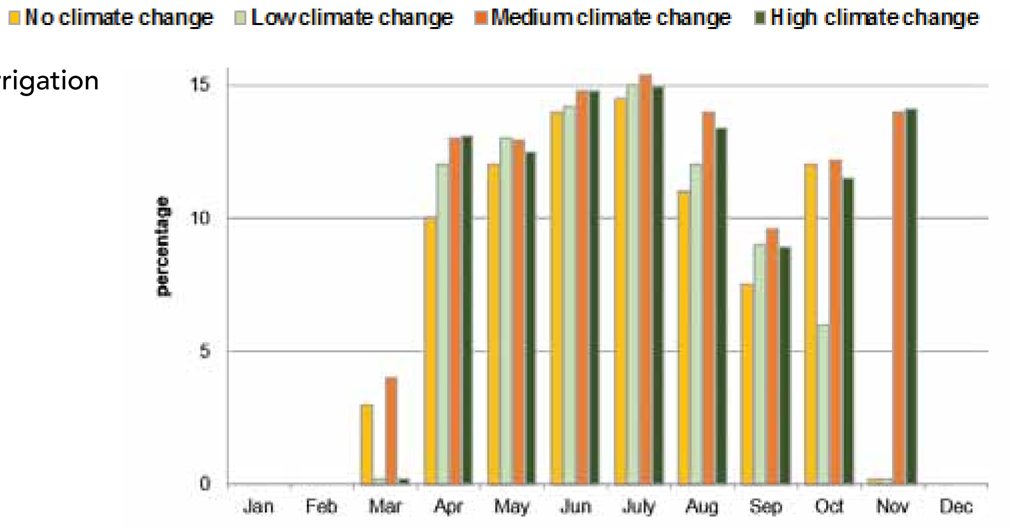
Climate change will threaten water availability for agriculture during the primary growing months, while raising irrigation water demand, resulting in larger unmet irrigation needs for a majority of months for all climate scenarios. Falling runoff throughout the agricultural growing period of April to September emerges in two of the three scenarios, suggesting threats to irrigation water availability. (Figure 6.4). On the other hand, all climate change scenarios show a rising irrigation water demand due to the uniformly increasing temperature effect. Under the high climate change scenario, there is more than a doubling of demand of irrigation water in the more arid months between 2014 and the 2021–2050 period. Although demands fall in the eastern part of Romania under the low climate change scenario, all subbasins show increasing irrigation water demand of between 10 and 100 percent under the medium and high climate change scenarios. As a result, unmet irrigation increases in the majority of months for all scenarios, starting at between 5 and 14 percent in the observed 1961–2000 trend between April and September, and rising to between 9 and 17 percent under the climate change scenarios. (Figure 6.5.a) The majority of unmet irrigation water demands occur in the western part of Romania, and severe unmet water demands are confined to only a few subbasins.

Unmet municipal demands are modest but industrial activities (as well as agriculture) may be adversely affected by climate change without adaptive efforts. Figure 6.5.b–c presents the percentage of mean monthly industrial and municipal demand that is unmet, within the observed 1961–2000

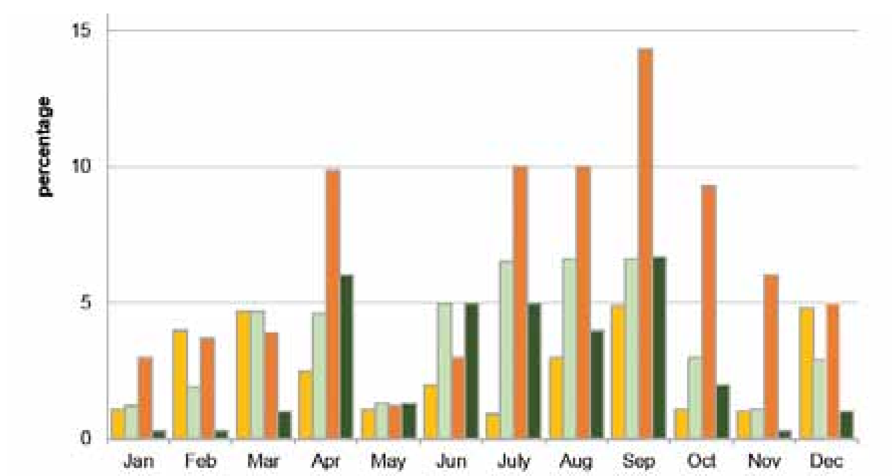
FIGURE 6.5. Unmet municipal demands are modest but irrigation and industrial activities may be adversely affected by climate change without adaptive efforts

Percentage of irrigation, industrial and municipal demand that is unmet under the observed trend (1961–2000) and three climate scenarios (2021–2050)

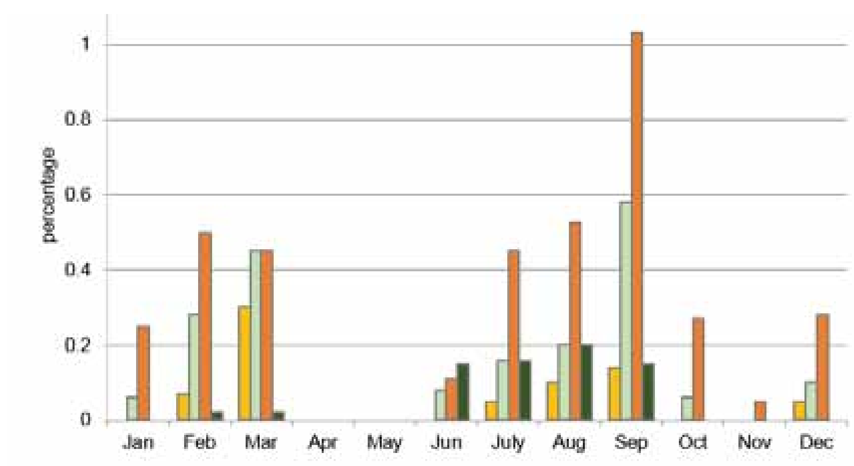
a. Irrigation



b. Industrial



c. Municipal



Source: Water Sector Technical Report.

period and under each of the climate change scenarios. Unmet municipal demands are fairly modest, ranging from zero to approximately one percent under the medium climate change scenario. On the other hand, unmet industrial demands are more significant, particularly considering that they constitute approximately 75 percent of the total water withdrawals of Romania. Under the observed conditions, the unmet industrial demands are fairly constant over the year, and remain under five percent. Under the low climate change scenario, unmet demand reaches nearly 15 percent in September, suggesting that many industrial activities may be adversely affected by climate change without adaptive efforts. Unmet demands are as high as 25 percent in some subbasins, and increase significantly between the observed conditions and three climate change scenarios.

Hydropower will also be affected by the decreased river runoff. At 19 terawatt hours in 2012, hydropower generation accounts for approximately one third of total electricity generation in Romania, and is therefore an essential component of energy security. Mean annual hydropower generation is projected to increase in the 2020s and 2030s under the low climate change scenario, due to the projected increases in river runoff.[4] However, hydropower generation declines under the other seven scenario-decade combinations, most significantly in the 2030s and 2040s under the medium climate change scenario where hydropower production falls by nearly 10 percent. Also of significance is that hydropower generation decreases in the 2040s under all three climate scenarios. Within individual subbasins, decadal average hydropower generation is projected to fall by a maximum of 50 percent, and increase by a maximum of 30 percent.

While water sector modeling shows a decrease in water availability for all types of use including hydropower generation, it did not aim at evaluating whether expansion of hydropower in the future would be beneficial. Such analysis requires considering all sources of power generation as a system, taking into account available energy resources. The energy supply analysis (Chapter 3) aimed to find the least-cost solutions for the future structure of power supply taking into account multiple constraints, including resource limitations. This analysis was done using an optimization system model, TIMES. The findings showed that hydropower plants will still be producing power to satisfy approximately one-third of the total power demand in Romania in 2050 under all three scenarios—Baseline, Green, and Super Green. In each of the three scenarios, nine megawatts of new hydro capacity would be constructed by 2050. This analysis took into account Romania's current hydropower potential and applied a low capacity factor of 35 percent to future hydropower generation, accommodating the water sector modeling projections of decreased river runoff.

The focus of the water sector investments was primarily on water demand management, rather than on available augmentation alternatives. The investment options include improved irrigation efficiency, municipal and industrial delivery efficiency, and municipal water use efficiency. Irrigation efficiency options included both conveyance improvements (e.g., lining irrigation canals), and field level improvements, such as converting from flood to sprinkler irrigation. Municipal and industrial efficiency improvements would focus on repairing leaking delivery systems and potentially installing leak prevention systems. However, the reductions in unmet demands resulting from these

4. Note that hydropower results are only presented under the "no investment" policy scenario, because differences in generation under the 'no investment' and under the Super Green policy scenario were minimal. The effect of the Super Green irrigation expansion is minor because (a) most of the expansions are anticipated to occur in basins with lower levels of existing hydropower capacity and (b) the consumptive use of projected irrigation represents a small portion of the overall water budget of Romania. The future development of hydro generation capacity was modeled using an energy system model, TIMES (see Chapter 3 (Energy)). The outcomes show that hydropower generation will constitute approximately 30 percent of total generation capacity in Romania by 2050 in both the Green and Super Green Scenarios. There are no investments envisaged under either Scenario.

investments were minimal because the existing unmet demands in the system occur during years when extremely low flows occur and are dedicated wholly to meet minimum environmental flow requirements. If little or no water is available to be used consumptively, then decreasing withdrawal requirements through efficiency improvements will have limited effect. More effective alternatives may include increased basin storage, interbasin transfers, conjunctive use between surface water and groundwater, improved reservoir management practices, or potentially allowing periodic relaxation of environmental flow requirements as needed.

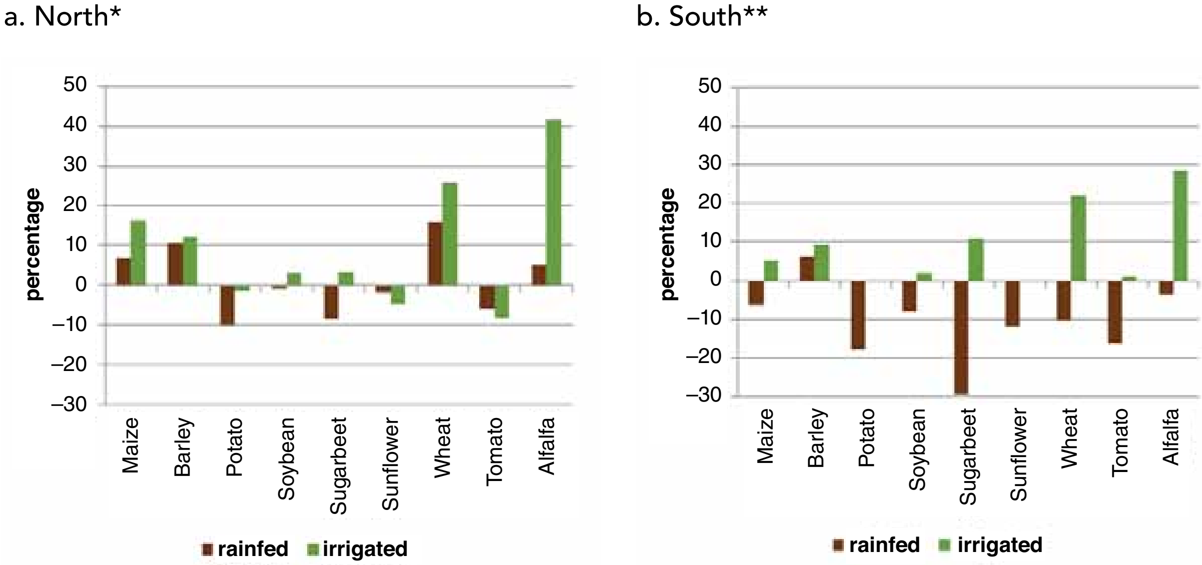
Impact of Climate Change on Crop Yields

In the agriculture sector, analysis considered impact of climate change on yields of irrigated and rainfed crops across administrative regions of the country and by type of crop. It is clear that rainfed crops will be negatively affected by higher temperatures and lower precipitation, and the analysis of green scenarios aims at evaluating how to target adaptation efforts geographically and by crop. Climate change affects crop yields through changes in soil moisture, direct temperature effects on crop growth, and changes in the evapotranspiration requirements of the crop, among other effects. Under the medium climate change scenario (which is considered to be the most likely one), rainfed yields will generally decline but irrigated yields will tend to improve due to climate change, and this effect is exacerbated over time.

The yields of rainfed crops differ significantly by crop and by region. Certain rainfed crops such as maize, barley, and winter wheat tend to perform well in some regions. Some crops, such as rainfed winter wheat in northern and some western mountainous regions, stand to gain as much as 20 percent in yield increases from climate change in the 2040s owing to more mild and damp winters. The most sensitive crops to forecasted climate change, with forecast yield reductions of 10 percent or greater, are rainfed sugar beets, particularly in the Southeast, South Muntenia, and Bucharest development regions (up to 35 percent yield reductions); rainfed potatoes and tomatoes in all regions (up to 19 percent yield reduction in southern regions); rainfed alfalfa (lucerne) in southern and western regions (up to 13.5 percent yield reductions); and rainfed maize in South Muntenia and Bucharest

FIGURE 6.6. The South is affected more by climate change and enjoys significant benefits from irrigation; crops differ in reaction to irrigation in the North

Percentage increase in rainfed and irrigated crop yields in 2040–2050: North and South



*"North" includes the regions where yields are affected less by climate change: North-West, Center, North-East, West.
**"South" includes the regions where yields are affected more by climate change (all located in the south of the country): South-East, South-Muntenia, Bucharest-Ilfov, South-West Oltenia.
Note: Results for the medium climate change scenario.
Source: Water Sector Technical Report.

(about ten percent yield reduction). In economic terms, the maize reductions are a great concern (the reductions occur in the southern regions).[5] (Figure 6.6)

There are substantial crop yield benefits from irrigation. Irrigated yields will tend to improve under climate change. This finding indicates that if water stress is removed by irrigating, then the direct temperature effects of climate change may have a positive effect on future crop yields. Climate change expands the differential between rainfed and irrigated yields for almost all regions and for almost all crops. The largest positive gains are in winter wheat, alfalfa, maize, and barley, while sugarbeets and tomatoes are projected to experience the largest declines. As a result of this general finding, the primary investment option considered in Super Green was a significant expansion of irrigated areas. By moving from rainfed to irrigated hectares, farming would become much more resilient to the effects of climate change.

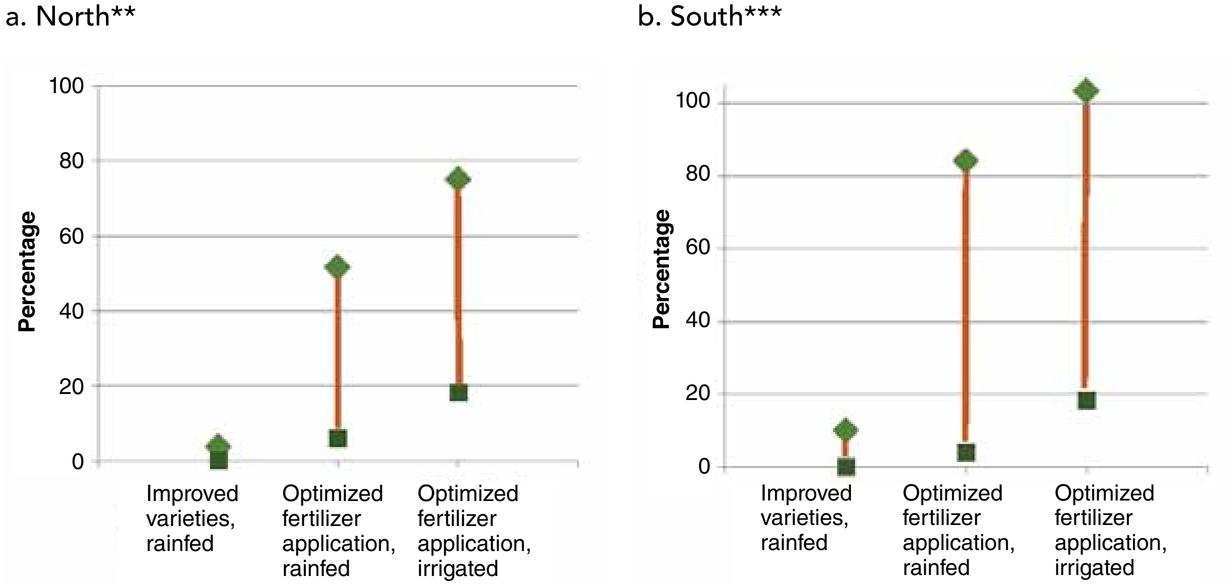
Off-setting Climate Impact on Crop Yields with the Help of Adaptation Measures

The most promising green growth investments for yield improvement are (1) rehabilitating irrigation infrastructure to restore irrigation production to certain currently rainfed areas, (2) optimizing agronomic inputs, including fertilizer inputs, and (3) adopting improved, drought tolerant, crop varieties. The latter two measures form the basis of the Green scenario, and all three options are the focus of the Super Green scenario. Improved rainfed crop varieties generate between 0 and

5. These results coincide well with previous climate change analyses for the agriculture sector conducted jointly by the National Meteorological Administration and the National Research and Development Institute for Soil Science Agrochemistry and Environment—ICPA Bucharest.

FIGURE 6.7. Optimized agronomic inputs, including fertilizer application, is a most promising adaptation measure

The range of percentage changes in yields as a result of the adaptation measures, 2040–50*



**Range across crops and regions within the North and South.*
***"North" includes the regions where yields are affected less by climate change: North-West, Center, North-East, West.*
****"South" includes the regions where yields are affected more by climate change (all located in the south of the country): South-East, South-Mutenia, Bucharest-Ilfov, South-West Oltenia.*
Note: Results for the medium climate change scenario.
Source: Water Sector Technical Report.

10 percent yield increase, whereas optimizing fertilizer application can produce anywhere from a 4 percent to a 70 percent yield improvement, depending on crop, region, and whether the farm is rainfed or irrigated. A number of farm-level investments were evaluated for their potential yield improvements, including adopting improved drought tolerant crop varieties, converting from rainfed to irrigated, improving soil drainage, improving soil aeration, optimizing fertilizer application and optimizing the timing of irrigation water application. The yield improvements generated from improved varieties and fertilizer application for each crop and administrative region (for 2040s) are presented in Figure 6.7. Impact of improved crop varieties are presented for rainfed crops only, while optimized fertilizer application is shown for both rainfed and irrigated crops.

Financial Assessment of the Proposed Adaptation Measures

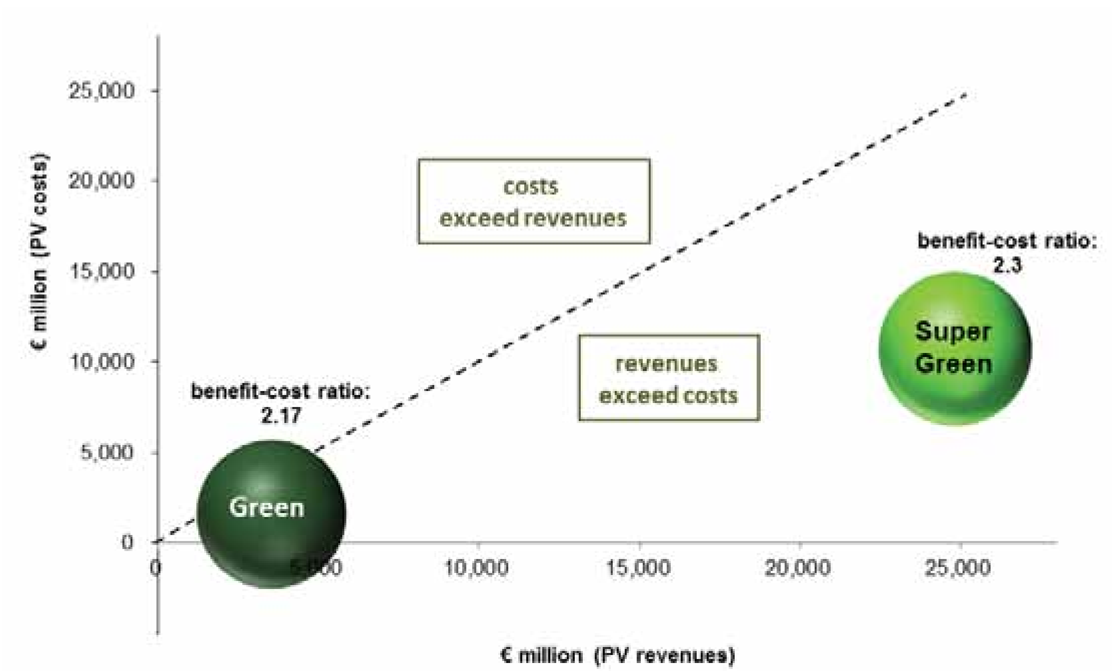
Financial assessment estimated the costs of the identified adaptation measures and the resulting revenues. Benefit-cost calculations suggest that the largest gains from the green investment would be in the Southeast and South-Muntenia regions; the next tier of good investment potential is found in the Northeast and West regions. The highest investment payoffs for optimized fertilizer application programs are in the South-Muntenia, Northeast, and Northwest Development Regions. In general, fertilizer programs show strong returns to investment throughout Romania, and for best results could be targeted for the farms of medium size (roughly 10 ha), to ensure that the measures encourage consolidation of the smallest farms while also avoiding provision of an unnecessary subsidy to the largest farms, which are already quite productive. These investments are consistent with those being considered as part of Romania's National Rural Development Plan, but would likely require a larger investment in adaptation measures than is currently contemplated if they are to be deployed at a sufficient scale to counteract the negative risks of climate change.

In both the Green and Super Green scenarios, revenues will exceed costs resulting in a significant positive net present value of the overall investment (Figure 6.8 and Table 6.2). The overall net present values of the proposed adaptation measures for Romania under the Green and the Super Green investment options are projected to be positive at €1.8 billion and €11.0 billion, respectively.[6] With Super Green investments, the net present value is dramatically higher due to the broader set of investment options that are considered. The schedule of investments puts a higher burden on the period 2015–2030 when approximately 65 percent of the total required investment is made. The benefit-cost ratio of the investments is above 1 in both scenarios, demonstrating that benefits exceed costs: it equals 1.8 in the Green and increases to 1.9 in the Super Green scenario. While financial outcomes are positive at the scenario level, they vary across the selected green measures. Two of the measures—enhanced fertilizer application and rehabilitated irrigation—have positive net present values and benefit-cost ratios exceeding 1 (benefits outweigh costs) in both scenarios and across regions, while with the third measure—improved crop varieties—costs tend to outweigh

6. At five percent discount rate.

FIGURE 6.8. Super Green costs are higher than in Green, but so is the return on investment

Green and Super Green scenarios: cost, revenues and benefit-cost ratio



Note: Results for the medium climate change scenario.
Source: Water Sector Technical Report.

TABLE 6.2. Water investments are significantly higher in Super Green than in Green, and the burden is greater in the first half of the modelled period

Schedule of water investments by scenario, € billions and percent of GDP*

	2015–2020	2020–2030	2030–2040	2040–2050	TOTAL 2010–2050
	NOT DISCOUNTED				DISCOUNTED
€ billion					
Green	541	614	377	231	**1,763**
Super Green	2,917	4,077	2,503	1,537	**11,034**
Percent of GDP					
Green	0.07	0.05	0.04	0.04	0.05
Super Green	0.45	0.36	0.29	0.24	**0.32**

**Constant 2010 Euros.*
Source: Marginal Abatement Cost Curve Technical Report.

benefits in most regions. However, there are exceptions: clearly positive financial outcomes are shown for improved crop varieties in two regions—South Muntenia (the benefit-cost ratio is 2.0 in the Green and 2.3 in the Super Green scenario) and Bucharest-Ilfov (benefit-cost ratios in the Green and the Super Green scenarios are 2.6 and 2.8 respectively),—as well as for particular crops, mainly maize and wheat.

CONCLUSIONS AND RECOMMENDATIONS

Climate change presents a substantial risk to agricultural production, irrigation, municipal and industrial water uses, and hydropower generation in Romania. However, these risks can be addressed by green growth investments. The greatest investment potential exists for optimizing agronomic inputs, including fertilizer inputs, and rehabilitating irrigation infrastructure to restore irrigation production to currently rainfed areas. This would significantly counteract the negative impact of climate change on crop agriculture in most regions and even increase the crop yields beyond current levels. The highest net present value results for irrigation investments are in the Southeast and South-Muntenia regions; high values were also found for the Northeast and West regions. The second measure—optimized agronomic inputs—would require investment in high-quality extension services, as well as increased and/or subsidized availability of fertilizers, with the payoff being a significantly increased crop yield. Fertilizer programs show strong returns to investment throughout Romania and for best results could be targeted to the farms of medium size (approximately 10 ha) to encourage consolidation of the smallest farms while avoiding subsidization of the largest farms, which already have high productivity.

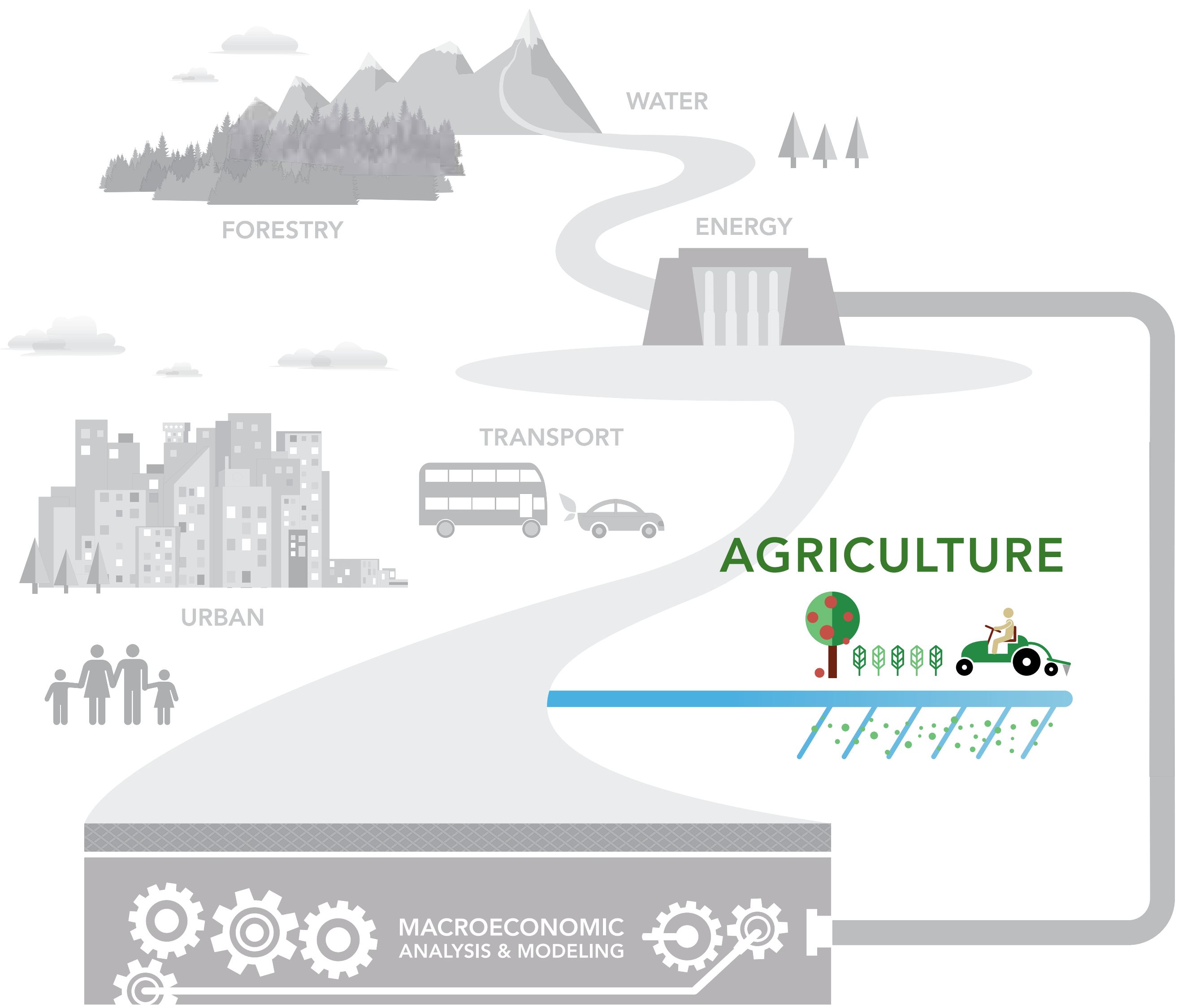
A targeted approach to improved crop varieties—focused on particular regions and crops—is likely to be most successful. Modeling shows that using this measure will lead to positive outcomes in South Muntenia and Bucharest-Ilfov regions: net present values of investment are positive and benefit-cost ratios range from 2.0 to 2.8. Positive financial outcomes of the implementation of this measure are also observed with particular crops: maize (especially in selected southern regions) and wheat. At the same time, other regions and crops generally show negative financial results in response to this measure. Therefore, implementation of the improved crop varieties measure should be well targeted by both region and crop because in many other regions and for many other crops, the present values were negative and the benefit-cost ratios were below one.[7]

As a result of this assessment, a set of tools for water sector investment analyses has been developed and transferred to local counterparts in the Ministry of Environment, as well as other local stakeholders. These tools can be applied to further assess the irrigation and other water and agriculture investment options, both individually and in combination with water-use efficiency options. They can also be used to assess multi-sectoral water use strategies. The results developed in this assessment, as well as further assessments using the tools transferred to local counterparts, can have lasting benefits for evaluation and prioritization of a broad range of water and agriculture sector investment options.

The required investment in the Green scenario amounts to €1.8 billion (present value[8]) or 0.05 percent of GDP, while a more aggressive Super Green scenario requires €11.0 billion in investment costs (present value) or 0.32 percent of GDP. The schedule of investments puts a higher burden on the period 2015–2030 when approximately 65 percent of the total required investment is made. It is also worth noting that the Green investments would be a manageable increase from 2013 levels of agricultural sector support of €1 billion direct payments, and €1.3 billion of rural development expenditures. By contrast, Super Green investments would represent a substantial increase from current spending and would quickly exhaust the 2014–2020 National Rural Development Plan's financial allocation for irrigation infrastructure, which is over 400 million or about 65 million annually.

7. See Water Sector Technical Report for details.

8. At five percent discount rate.


WATER
FORESTRY
ENERGY
TRANSPORT
URBAN
AGRICULTURE
MACROECONOMIC
ANALYSIS & MODELING

CHAPTER 7

Can Agriculture Flourish in a Changing Climate While Aiding Mitigation?

CHAPTER SUMMARY

Despite being endowed with high quality agricultural resources, Romanian agriculture has low productivity and high employment, rural populations are poor, and the country now faces the joint challenges of greenhouse gas mitigation and adapting to a changing climate. Agriculture in Romania remains important to overall economic production and the leading sector for employment, despite poor crop yields and low farm incomes. An important cause of low productivity is the large share of subsistence agricultural holdings. The ageing farm population and out-migration will likely trigger commercialization of the sector over time, but effective policies will be essential to address the risk of land abandonment and the issue of land fragmentation. The sector needs to consider adaptation to a changing and less favorable climate going forward, made more difficult by insufficient agricultural extension and inadequate information on new research and techniques. At the same time, agriculture (which accounts for 17 percent of Romania's emissions of greenhouse gases, GHGs) needs to contribute to their containment into the future. Although the sector stands at the bottom of the EU ranking of agriculture emissions intensity due to the low productivity of the sector, this performance will worsen once agriculture becomes more efficient, unless mitigation measures are taken. Romania's National Rural Development Program already specifies some measures for mitigation and adaptation in agriculture and provides some funding, but more is needed.

The impact and costs of green adaptation policies and investments on sectoral outcomes in agriculture was assessed through joint modeling of water and agriculture. A suite of interlinked models was used in this analysis, including General Circulation Models (GCMs), the Water Evaluation And Planning (WEAP) model, a climate runoff (CLIRUN) model and an agricultural yield model (AquaCrop). The green scenarios applied in the models include the following measures: rehabilitation of irrigation infrastructure, adjustment of crop varieties, and improvement of fertilizer application. Analysis was concluded with a Marginal Abatement Cost Curve, where two measures, currently

supported by the EU via the National Rural Development Program 2014–2020, were considered: minimum tillage and manure management. The outcomes of modeling show the negative impact of climate change under a baseline scenario on yields and the improvement in yields that can be achieved using green measures. Irrigation was found to provide the largest gains in yields. A modest 'Green' scenario will require an expenditure of about two billion $US (discounted to present value) and generate revenue of over four billion. In the more ambitious 'Super Green' scenario, costs rise to over $US 13 billion while revenues rise to $US 31 billion. In both cases, benefits outweigh costs by more than a factor of two.[1]

The recommendations emphasize the importance of rehabilitated and modernized irrigation, specifically in rainfed areas, as well as optimization of agronomic inputs such as fertilizer. Fertilizer programs show strong returns to investment throughout Romania, and, for best results, could be targeted at farms of medium size (roughly 10 hectares) to ensure that the measures encourage consolidation of the smallest farms while also avoiding provision of an unnecessary subsidy to the largest farms, which are already quite productive. Recommendations also include encouraging forest belts[2] and soil management to reduce soil erosion; promoting renewable energy sources, organic farming, and good farming practices; improving awareness of climate change and of the need for adaptation; and strengthening policy and institutional capacity. Financing needs for the two key recommended measures—no tillage agriculture and manure management—total €516 million or 0.01 percent of GDP. Most of the financing needs will occur during the last two decades of the period analyzed, 2030–2050.

CHALLENGES FOR GREENER GROWTH

Overview

Romania is endowed with high quality agricultural resources, has a history of being "the bread basket of Europe," and tops the EU ranking by the share of the agriculture sector in the economy.[3] Romania is among the best endowed European countries in terms of its agricultural land, fertile *chernozem* soils, and water resources, and agriculture has traditionally been the backbone of the Romanian economy.[4] While the share of agriculture in total gross value-added fell over the last decade by more than 50 percent, to six percent in 2012, it remains the highest share in the EU (where agriculture averages less than two percent of gross value-added). Romania ranks eighth in the European Union in value of total agricultural output.[5] Agricultural employment constitutes about 29 percent of Romania's total employment (even after dropping by one-quarter over the last decade), compared to the average of about five percent across the EU. Romanian agriculture is crop-oriented: near three-quarters of agricultural output derives from crops, the highest share in the EU, where the average

1. Unless noted, all multi-year costs are discounted to present value using a four percent discount rate; costs include investment and operations and maintenance.

2. See a detailed discussion of the importance of forest belts in Chapter 8 on Forestry.

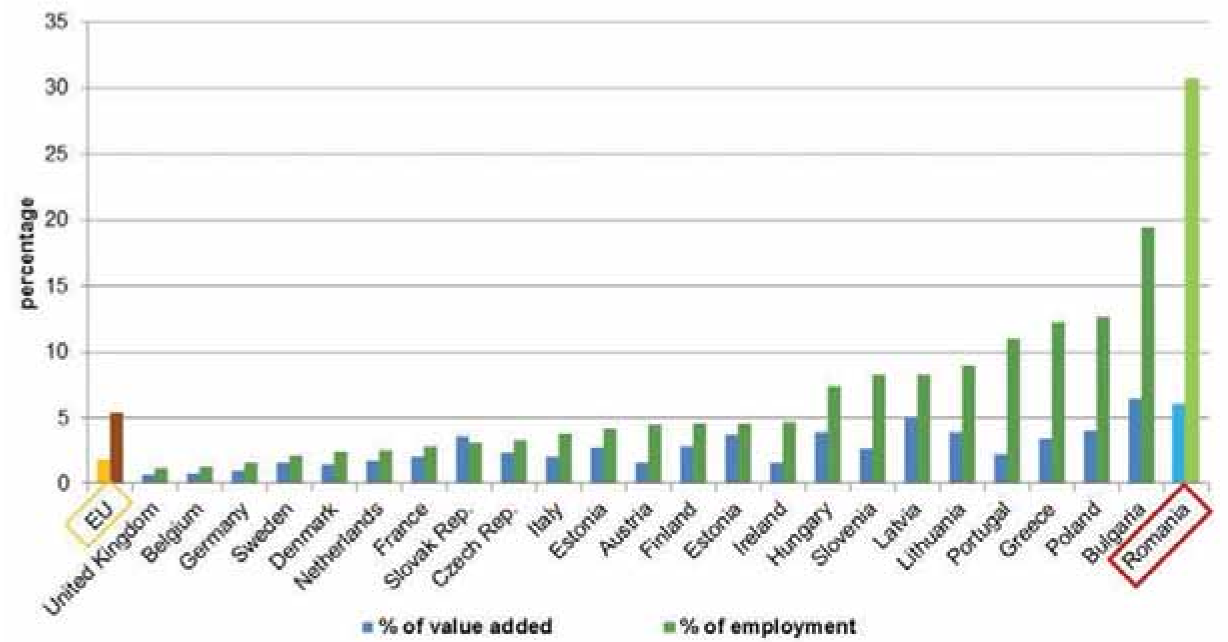
3. In particular, Romania was known for having very high quality wheat prior to World War II.

4. Although the quality of the famously fertile *chernozem* soils worsened after the introduction of intensive agricultural practices which sharply decreased the soil organic matter content. After 1990, poor and unbalanced fertilization caused serious deficiencies in macro- and micro-elements in the soil, especially for phosphorus. From Prof. Catalin Simota, Research Institute for Soil Sciences, Bucharest.

5. Total agricultural output in Romania amounted to €15.48 million in 2014. Eurostat. 2014. *Agriculture, Forestry and Fishery Statistics.*

FIGURE 7.1. Agriculture is a significant part of the Romanian economy, but its productivity is lagging

Agriculture as percentage in total gross value-added and total employment, 2012



Note: Agriculture includes agriculture, forestry, and fishing.
Source: Romanian Ministry of Agriculture and Rural Development Strategy, using data from Eurostat.

is about half. Agricultural land occupies almost 62 percent of Romania's total land area, and nearly two-thirds of the 13.3 million hectares, which are considered highly-productive arable land, are used mainly to grow maize and wheat (see Figure 7.1).[6]

Despite high quality land resources, Romanian agriculture is characterized by low productivity, and rural areas have much higher poverty incidence. The modest contribution to national output but a high share of employment points to the low productivity of the sector. In fact, average crop yields in Romania are 30–50 percent below the EU average, and labor productivity per full time equivalent in farming is four times lower than the EU average. The country was importing 70 percent of its food in 2011[7] and consistently had a negative agriculture trade balance (i.e., imports exceeded exports) during 1990–2012. While the 2013 trade balance was positive and there are preliminary estimates that it will stay positive in 2014, it is unclear if this represents a stable trend, especially considering the long-term downward drift in agricultural production (see Figure 7.2). Also, the structure of agricultural trade shows a prevalence of commodities in export and a domination of final products in imports.[8] Agricultural incomes are low, and the rural population is poor. Romania has the lowest agricultural incomes in the EU, amounting to only 22 percent of the average EU farm income per

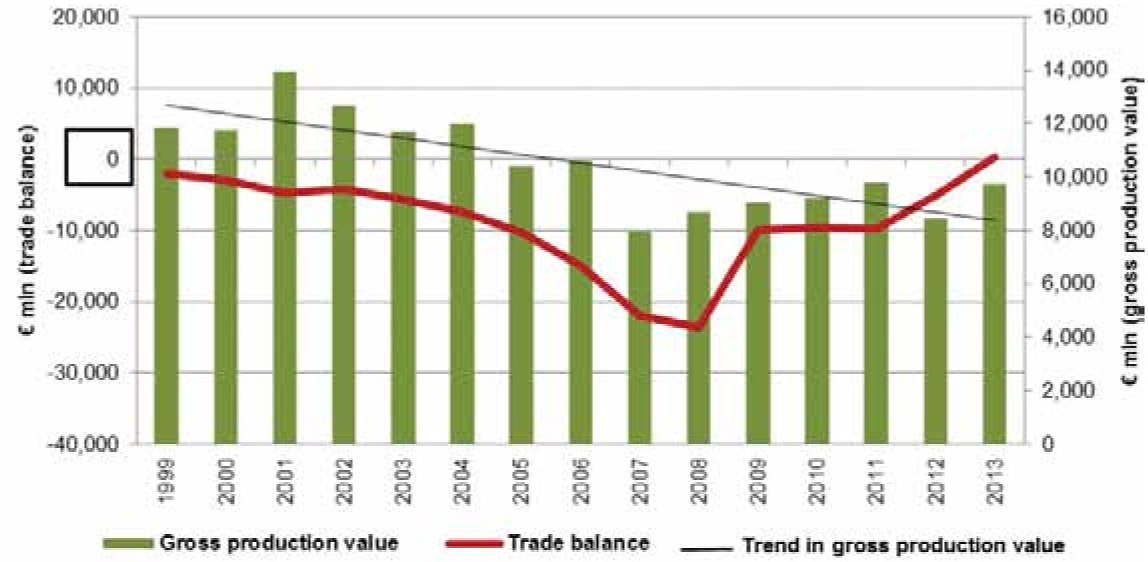
6. Eurostat. *Agricultural Census 2010.*

7. World Bank. 2013. *A Country Economic Memorandum. Romania: Reviving Romania's Growth and Convergence Challenges and Opportunities.* Available at: http://documents.worldbank.org/curated/en/2013/06/18028709/reviving-romanias-growth-convergence-challenges-opportunities-country-economic-memorandum.

8. Eurostat data; Gavrilescu, Camelia. 2014. *Agricultural Commodities and Processed Products Ratio in the Romanian International Agrifood Trade.* Institute of Agricultural Economics, Romanian Academy, Bucharest.

FIGURE 7.2. Agricultural trade balance is recovering, but production is flat

Agricultural output and trade balance



Notes: Gross production value is at constant prices. Trade balance is exports minus imports.
Source: Staff calculations based on data from Eurostat and Food and Agriculture Organization, 2015.

unit of full time employment.[9] Romania's rural population is poorer than the rest of the country: more than 70 percent of Romania's poor live in rural areas, while the share of rural population is 45 percent.

An important factor in low productivity is the large share of small and inefficient agricultural holdings. Romania has the lowest average farm size in the EU, equaling 3.4 ha, placing it only ahead of Malta and Cyprus.[10] It has a large number of very small agricultural holdings: its 3.7 million farms account for one-third of the total number of farms in the entire EU. Behind the averages lies a dual farm structure: a very large number of subsistence and semi-subsistence farms and a small number of large commercial agricultural holdings, with medium-size farms mostly absent. This structure of landholding is a result of the redistribution of agricultural land soon after transition began in the early 1990s. Currently, more than 93 percent of Romanian agricultural holdings, managing over 40 percent of the utilized agriculture area, are subsistence and semi-subsistence farms, while less than 0.4 percent of the farms, averaging over 420 ha each, are large-scale commercial units (see Figure 7.3a).[11]

The ageing farm population and out-migration of the younger generation could trigger a significant change in the structure of the sector in the next 15 years. Today, 40 percent of the farm population is 65 and older, and by 2030, this share will grow to 60 percent (see Figure 7.3b), driving an accelerating natural turnover in farm holdings. Rural out-migration is also high. It is estimated that the population of rural areas is declining by 4.5 percent per year on average, with declines at the county level varying from 1.0 to 11.6 percent.[12] Within the next two decades, over two million

9. World Bank. 2013. *A Country Economic Memorandum. Romania: Reviving Romania's Growth and Convergence Challenges and Opportunities.*

10. Eurostat. Agriculture, forestry and fishery statistics. 2014 edition.

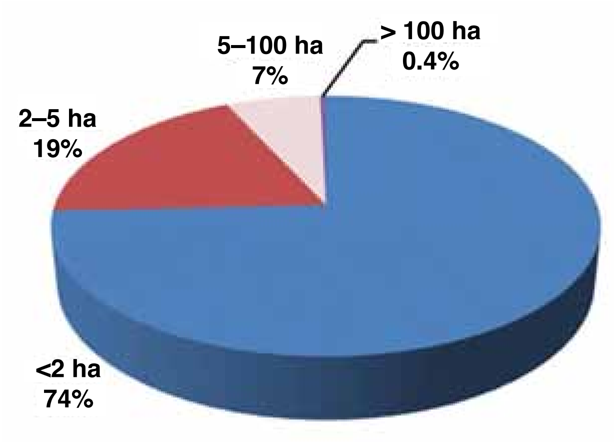
11. Eurostat. Agriculture, forestry and fishery statistics. 2014 edition.

12. National Institute of Statistics. Statistical Yearbook 2011. Available at: http://www.insse.ro/cms/files/Annuar%20statistic/14/14%20Agricultura%20silvicultura_ro.pdf.

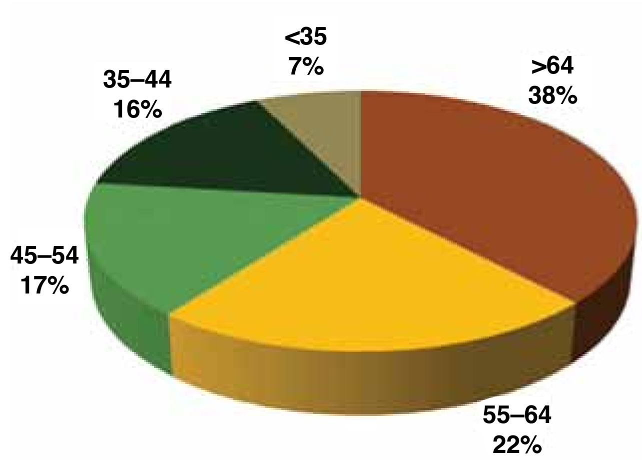
FIGURE 7.3. Romanian agriculture is dominated by subsistence farms today, but ageing farmers may trigger a change in sector structure over the next 15 years

Farm structure in Romania, by size of land and age of holder, 2010

a. by size of holdings (ha)



b. by age of holder



Source: Eurostat, October 2013.

Romanian farms, occupying 75 percent of the utilized agricultural area, will be subject to intergenerational transfer. Considering the high rate of rural out-migration by the younger generations over the last two decades, this transfer will mean that the land will be inherited by non-farmers in many cases. Whether this demographic shift will trigger modernization of the Romanian agriculture sector by allowing the larger consolidated holdings required by a modern commercial sector will be influenced to a large extent by policy choices by government. Effective policies will be essential to address the risk of land abandonment and counter further land fragmentation. The incomplete land reform of the past has become a major hindrance, and transaction costs for land registration today are an almost impossible hurdle to overcome. Policymakers will be challenged to tailor the various instruments available and the financing possible from EU and other sources to promote the transformational process without negative social impacts.

Romania's agricultural agenda is connected to the Common Agricultural Policy of the EU (CAP), which provides a framework for mainstreaming climate change mitigation and adaptation activities. Since EU accession and implementation of the two pillars of the CAP (direct payments and the rural development program), Romanian agriculture has received access to financial support under the CAP.[13] With the reform of the CAP in 2013, climate change mitigation and adaptation has become one of the cross-cutting objectives to be pursued by all member states through all agricultural support measures. The new direct payment scheme obliges member states to spend a minimum of 30 percent of their national envelope for "greening" activities: crop diversification, maintaining permanent grassland and maintaining the ecological focus areas.

13. During the first programming cycle of implementing the EU CAP, Romania was entitled to receive €13.7 billion, of which €5.6 billion was primarily used to support farmers by direct payments (Pillar I of CAP) and €8.1 billion for a co-financed National Rural Development Program (NRDP 2007–13). For the current programming cycle 2014–20, the financial allocation increased to €19.8 billion. European Commission (EC). *Multiannual Financial Framework* 2014–20. Available at: http://ec.europa.eu/budget/mff/index_en.cfm.

Romania's National Rural Development Program (NRDP 2014–20) provides a strategy and measures for mitigation and adaptation in agriculture. The NRDP is eligible for co-financing under the European Agricultural Fund for Rural Development (EAFRD). Within rural development measures, a minimum of 30 percent of the total expenditure in Romania has to be earmarked for mitigation and adaptation.[14] Direct payments are available for holdings with a minimum farm size at one hectare (ha) or the minimum size of the crop parcel at 0.3 ha; over 70 percent of the farms in Romania do not qualify. Only 46 percent of the national envelope for direct payments has been secured by 99 percent of the qualifying farms.

CHALLENGES

Adaptation

Climate change will be a significant factor in the future of Romania's agriculture sector; and the negative impacts of a changing climate are already a reality. The farming (or crops) sector is most vulnerable to climate change, while livestock is less so. It has been estimated that from 1980 to 2011, Romania suffered average annual weather-related losses of $US 8,452 million, or 0.26 percent of GDP, of which 34 percent was linked to drought. The crops that experience the most severe impacts are typically rainfed crops grown in the traditional summer season, such as maize, sunflower, and fruits and vegetables. On the other hand, some crops may benefit from the direct effects of climate change (as well as elevated CO_2 levels), notably those that gain from longer and warmer growing seasons such as autumn-sown winter wheat or pastures (see Findings). The extent of vulnerability is related to farm size. Large-scale crop farms commonly have very specialized production, and low diversification increases the risk of crop loss due to weather variability and localized extreme weather. At the same time, large-scale farmers have better resources to adapt: they have access to financing, and economies of scale allow for the installation of irrigation systems and climate-resilient farming practices and technologies. In contrast, small-scale subsistence farmers are socially and economically vulnerable to climate change. However, in some cases, intrinsic resilience can be found within communities of small farmers due to their low use of inputs and recycling of resources, existing low-carbon economies, diversity of production within the community, strong social relations and (in some regions) alternative sources of off-farm income. The resilience and adaptive capacity of these more diverse communities has the potential to be further developed.[15]

The vulnerability of Romanian agriculture to climate change is worsened by insufficient agricultural extension and inadequate information flow from results of research. The dissolution of the National Agency for Agricultural Consultancy has disabled the effective delivery of advisory services and has deprived the agriculture and rural development administration of its most important information dissemination instrument. Farmers have lost access to government-supported knowledge and support services, which are of greatest importance to subsistence farmers. With inadequate advisory services, farmers benefit only marginally from the results of research, increasing their vulnerability. With-

14. European Commission (EC). Overview of CAP Reform 2014–20. December 2013. Prepared by Directorate Generale Agriculture and Rural Development, Unit for Agricultural Policy Analysis and Perspectives. Available at: http://ec.europa.eu/agriculture/policy-perspectives/policy-briefs/05_en.pdf.

15. Weather variability from year to year is very high, especially in the South, South-East and South-West, making it very difficult to have a farm business plan and increasing the risks for economic failure, especially for small farms.

out government support, the existing research network is failing to provide advice to subsistence farmers that is relevant for the specifics of small-scale agriculture.

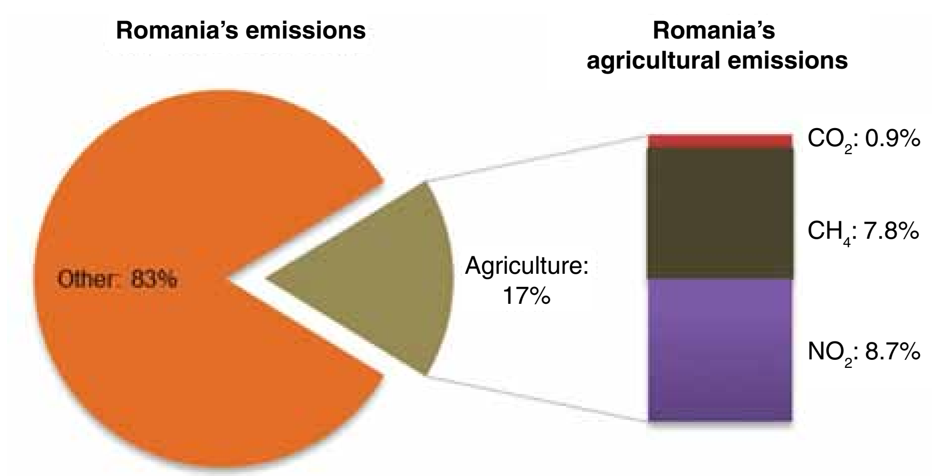
To adapt to the changing climate, Romanian agriculture will need reliable irrigation infrastructure. The existing irrigation systems are old, and only those owned by water-user organizations (WUO) have been recently partially rehabilitated. The infrastructure was built in the pre-transition years for a non-market rural economy based on large state farms and is not fully relevant for today's irrigation demand and farm structure. Also, the infrastructure was built without taking into account the climatic characteristics of various regions nor the cost of water and electricity (for pumping). Much of current irrigation is in the semi-arid areas of the south and south-east, where non-subsidised irrigation can be unaffordable for farmers. Irrigated area significantly declined in the 1990s and, by 2010, covered only 75,000 ha or 0.6 percent of the total utilized agricultural area. A governmental emergency decree in 2013 led to an increase of irrigated area to 180,900 ha.

Mitigation

Agriculture is a significant contributor to overall GHG emissions in Romania, and Romania faces current, imminent, and prospective mitigation obligations. Romanian agriculture accounts for 17.4 percent of the total emissions in the country and is the third biggest emitter after the energy and transport sectors. This level exceeds the EU average of 10 percent.[16] Romanian agricultural emissions are closely connected with the management of soils, livestock numbers, and rural biomass usage: the main components are nitrous oxide (N_2O), which comes from soil nitrification and manure management, methane (CH_4) from enteric fermentation by ruminants, and carbon dioxide (CO_2) from fuel used mainly for heating and for operating machinery (with the overall composition of emissions at 50 percent N_2O, 45 percent CH_4, and five percent CO_2) (see Figure 7.4). Romania already faces obligations to reduce emissions under the EU '2020 climate and energy package' which is under implementation until

FIGURE 7.4. Agriculture contributes significantly to overall GHG emissions in Romania

GHG emissions from Romanian agriculture, total and by gas

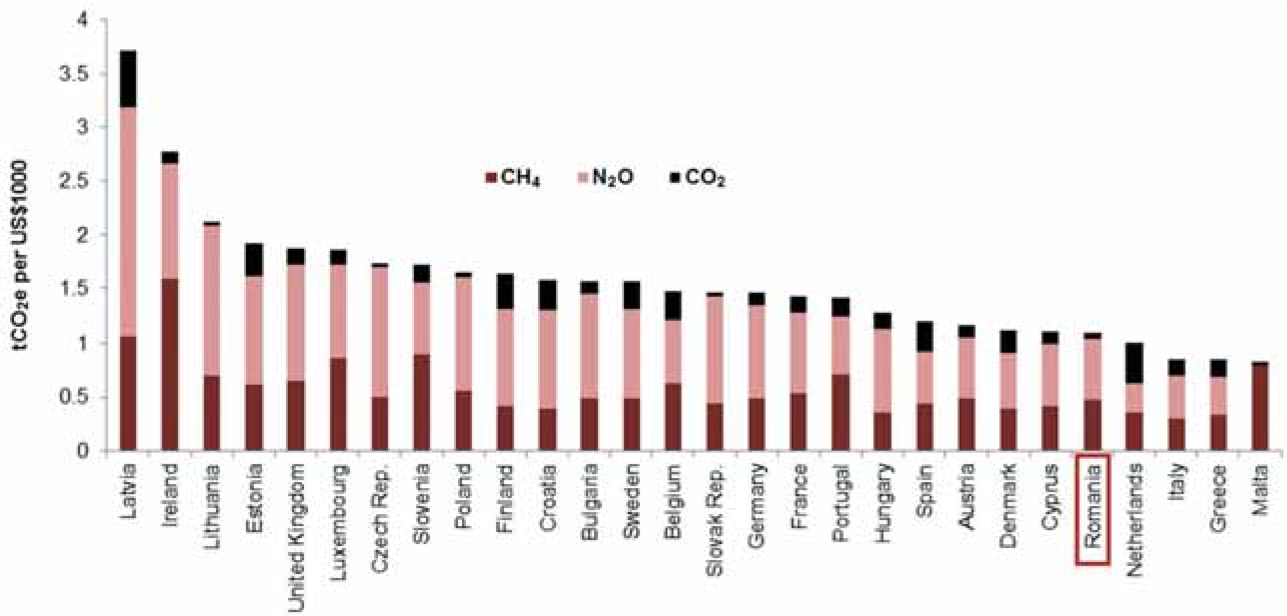


Source: European Environmental Agency.

16. Eurostat. *Agriculture—Greenhouse Gas Emission Statistics.* October 2013.

FIGURE 7.5. Romania ranks fifth lowest in the EU by emission intensity of agriculture

GHG emissions from agriculture as percent of agriculture value added



Notes: CH_4 is methane. N_2O is nitrous oxide. CO_2 is carbon dioxide. TCO_2e per $US 1000 is metric tons of carbon dioxide equivalent per thousand US dollars of agricultural value-added.
Source: Staff calculations using data from European Environmental Agency and Eurostat.

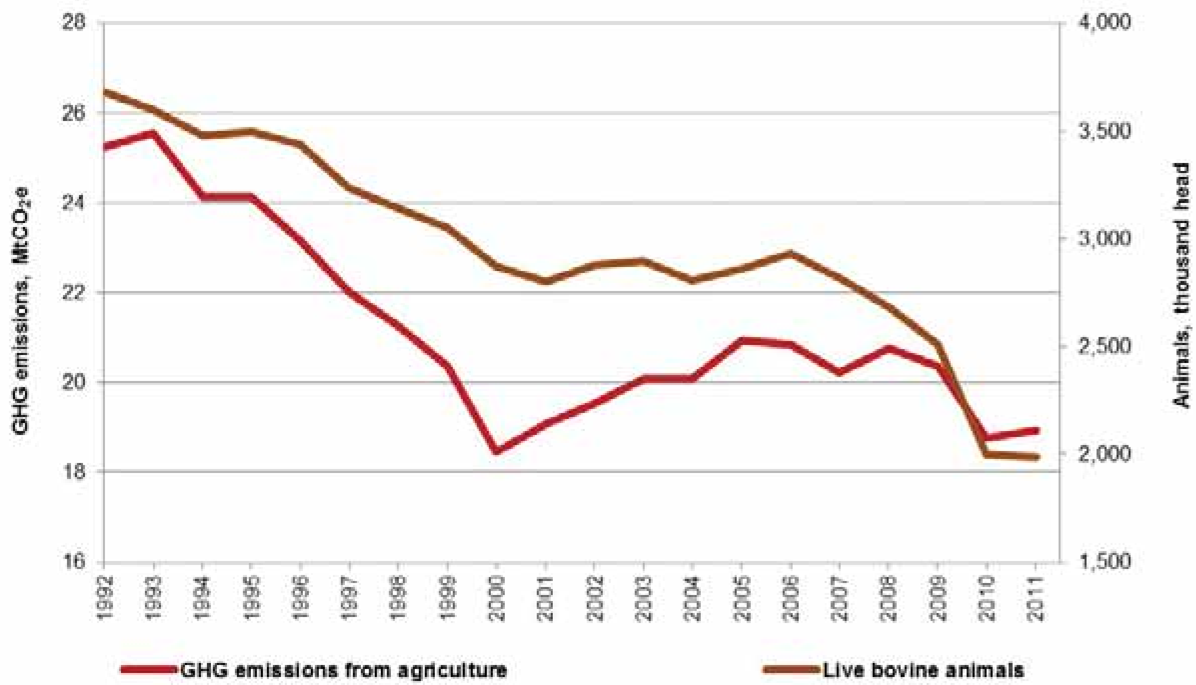
2020. Agriculture is a 'non-ETS' sector, meaning that the sector does not participate in the EU Emissions Trading System. Romania's non-ETS sectors altogether (including housing, agriculture, waste and transport) cannot increase emissions by more than 19 percent by 2020 relative to 2005. (See Chapter 2 for more details on Romania's current and future mitigation obligations.)

Romanian agriculture's current low emissions intensity is driven by the sector's low productivity and will worsen as agriculture becomes more efficient. The country ranks as the fifth lowest in the EU by emissions intensity of its agriculture (see Figure 7.5).[17] It also has relatively low emissions intensity by the main components: it ranks sixth lowest in the EU by carbon dioxide (CO_2), tenth lowest by nitrous oxide (N_2O), and eleventh lowest by methane (CH_4). This outcome is mainly explained by a high share of subsistence farms, which rarely use non-organic nitrogen fertilizers and have low mechanization, by a limited area of rice cultivation (a big producer of CH_4), and by a low share of livestock production. Decreasing livestock numbers show a strong correlation with the reduction of agricultural GHG emissions (see Figure 7.6), and a potential recovery of livestock farming will be accompanied by a rise in emissions. Livestock farming in Romania declined through the 1990s; however, there are signs of recovery. While cattle numbers are still declining (and are projected to decline for the next 10 years), the number of other ruminants (sheep and goats) have been increasing since 2005.[18] Once the livestock sector revives, agricultural GHG emissions will rise unless measures are taken to control them: in particular, changes in livestock feed need to be implemented to mitigate methane emissions.

17. Total GHG emissions from agriculture fell by 53 percent during 1989–2011.
18. Data from the National Research and Development Institute for Soil Sciences.

FIGURE 7.6. Decreasing livestock numbers have been correlated with emissions

GHG emissions from agriculture and evolution of animal stock (1989–2011)



Source: Romanian Ministry of Agriculture and Rural Development Strategy, using data from Eurostat.

METHODOLOGY AND FINDINGS[19]

Methodology

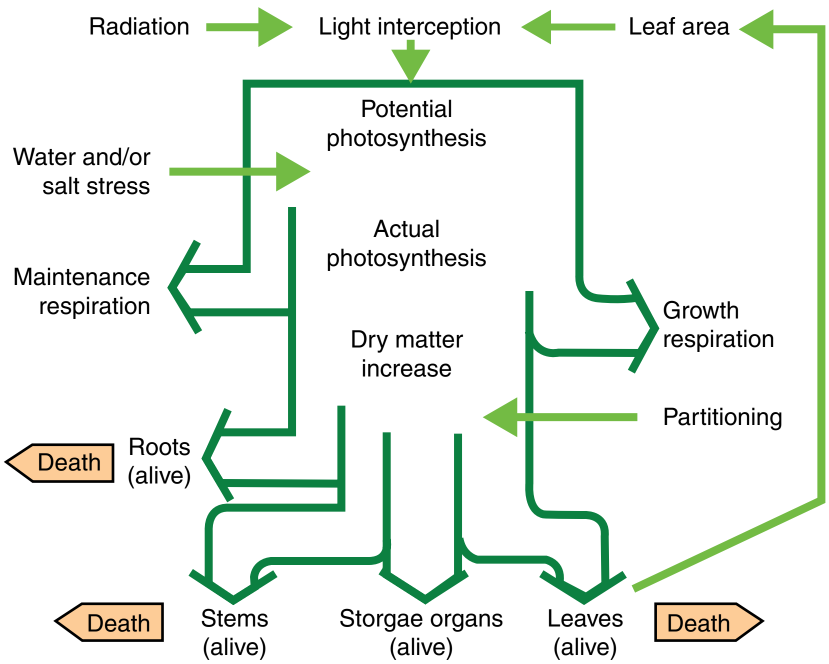
The impact and costs of green adaptation policies and investments on sectoral outcomes in agriculture was assessed through joint modeling of water and agriculture. A suite of interlinked models was used in this analysis, including General Circulation Models (GCMs), the Water Evaluation And Planning (WEAP) model, a climate runoff (CLIRUN) model and an agricultural yield model (AquaCrop). The models forecasted yields and prices of the crops that account for more than 50 percent of Romania's total agricultural production: maize, barley, potatoes, soybeans, sugar beets, sunflower, wheat, tomatoes, and alfalfa. AquaCrop was used to model crop yields and irrigation demand (see Figure 7.7). Last, the Water Evaluation and Planning System (WEAP) model was applied, using the inputs from CLIRUN to analyze potential basin-level shortages in water available to agriculture. Any estimated water shortage from the WEAP model was fed back to the biophysical step to estimate the net effect of the shortage on irrigated crop yields. (See Chapter 6 for more details).

The agriculture sector modeling addresses the issue of the possible adaptive responses by farmers to climate change and the resulting marginal impact on agricultural production and incomes. Modeling outcomes were measured by crop yields in irrigated and rainfed areas before and after

19. Note that the agriculture sector was modelled together with the water sector, and the methodology and outcomes on adaptation are derived mainly from water sector analysis (see Chapter 6) while outcomes on mitigation are distinct.

FIGURE 7.7. The agricultural yield model assesses crop yields and irrigation demand

Basic design of the AQUACROP model



Source: Chapter 6 on Water and Water Sector Technical Report.

the implementation of green measures and related revenues. Evaluated green investment options included the following:

- adopting improved, drought-tolerant crop varieties;
- converting from rainfed to irrigated crops;
- improving soil drainage;
- improving soil aeration;
- optimizing fertilizer application; and,
- optimizing the timing of irrigation water application.

The most promising options for improving yields were: (i) improving crop varieties, (ii) optimizing fertilizer application, and (iii) converting from rainfed to irrigated farming. The first two options are included in the Green scenario, and all three options are the focus of the Super Green scenario. Importantly, investment in improved irrigation systems was included in the Super Green scenario.

Modeling started with a baseline scenario for agriculture through 2050. This baseline scenario assumes that the economy of today would evolve over the next 35 years according to the pattern of west European countries, while policies would gradually align with regional norms and no significant new infrastructure investments would be made in agriculture beyond those already funded and/or under construction. The baseline scenario incorporates the expected impact of climate change on the demand for irrigation water and the impact of climate on water supply for all demand sectors including irrigation.

Two green scenarios for agriculture—Green (modest adaptation effort) and Super Green (ambitious adaptation effort)—were formed. While the baseline scenario involves no green improvements, the Green and Super Green scenarios include the following adaptation measures:

- In the Green scenario, measures are applied over 530,000 ha identified as medium productivity areas that have potential for high productivity, and include: (i) improved fertilizer application, which results in yield increases in primarily rainfed crops, and (ii) improved drought-tolerant crop varieties (irrigated and rainfed), a measure supported by farmer training in their use.
- The Super Green scenario has: (i) extended application of improved fertilizer and varieties as in the Green scenario but applied over 2.1 million ha identified as areas of medium productivity with potential for high productivity, and (ii) expanded irrigation by 430,000 ha or five times the existing level, in areas identified as viable for irrigation expansion.

In addition to modeling, analysis involved evaluation of infrastructure investment options for agriculture. Financial assessment of several water and agriculture sector investments used in modeling provided a ranking. The financial assessment calculated the benefit-cost ratio and the net present value of the cash flow of benefits and costs. Costs included both capital and annual operating and maintenance costs. Benefits were calculated as direct financial flows that result from the investment.

Analysis of mitigation options in the agriculture sector were undertaken using a Marginal Abatement Cost Curve (MACC). This approach evaluates costs and abatement potential of two mitigation measures included in the NRDP: manure management and no tillage agriculture. The analysis is done using a simple Excel-based tool.

Findings

The projected decrease in water availability due to rising temperatures will push up the demand for water for irrigation, thus increasing the already existing demand-supply gap. Green actions address this issue through several measures. The first set of measures is aimed at increased efficiency of irrigation, e.g., lining irrigation canals and replacing flood irrigation by sprinklers. These measures help reduce losses but are insufficient when not enough water is available for supply. In this case, measures to improve reservoir management, increase basin storage, transfer water from basin to basin, use surface and ground water interchangeably are applied. (See Chapter 6 for details.)

Water sector modeling analyzed the impact of climate change on yields of nine crops over 12 basins in the baseline scenario and found that rainfed yields mostly decrease under all climate scenarios, with a varying severity of impact among types of crops and increasing impact over time. In particular, maize, barley, and winter wheat will experience the least damage and will even have higher yields with climate change in some basins, while sugarbeets, potatoes, and tomatoes will suffer the highest yield loss. The regions that are projected to have the largest declines in yields are South-East, South-Mutenia, and Bucharest-lifov. The pattern is different for irrigated crops: their yields increase due to climate change because the impact of higher temperatures is positive if not accompanied by reduced water availability (see a more detailed discussion of the impact of climate on crops in Chapter 6).

Irrigation was found to be the most significant adaptation measure providing the largest gains in yields. Among the green measures or investments aimed at increasing yields, irrigation is shown to

Source: Tudor Catalin Gheorghe/Shutterstock.com

be necessary for the efficiency of crop farming for most of the crops and in all regions of the country. Also, selecting climate change resistant crops would be important for productivity of agriculture. In addition, optimizing fertilizer application will help achieve even higher yields. Selection of climate resistant crops increases yields by up to 10 percent for rainfed crops, and fertilizer application optimization pushes the yields up by four to 70 percent depending on irrigation availability, region (climate), and type of crop.

What are the costs and benefits of the green adaptation scenarios? Water sector modeling assessed that in the period from 2015 to 2040, the Green scenario will require an adaptation expenditure, additional to any expenditures in the baseline, of $US 2,003 million (discounted to present value) and will bring revenue of $US 4,345. The resulting net income will be $US 2,342 million. In the Super Green scenario, measures applied over the same time period of 2015–2040 require significantly higher investment but also result in much higher revenue than in the Green scenario. Costs are $US 13,304 million, revenues are $US 30,664 million, and net income is $US 17,360 million. In both cases, benefits outweigh costs by more than a factor of two. The benefit-cost ratio is the highest for rehabilitated irrigation and enhanced fertilizer: fertilizer's benefit-cost ratio is 2.4 in the Green Scenario and 2.33 in the Super Green scenario; while irrigation's ratio is 2.59 in the Super Green scenario (a measure not included in the Green scenario).[20]

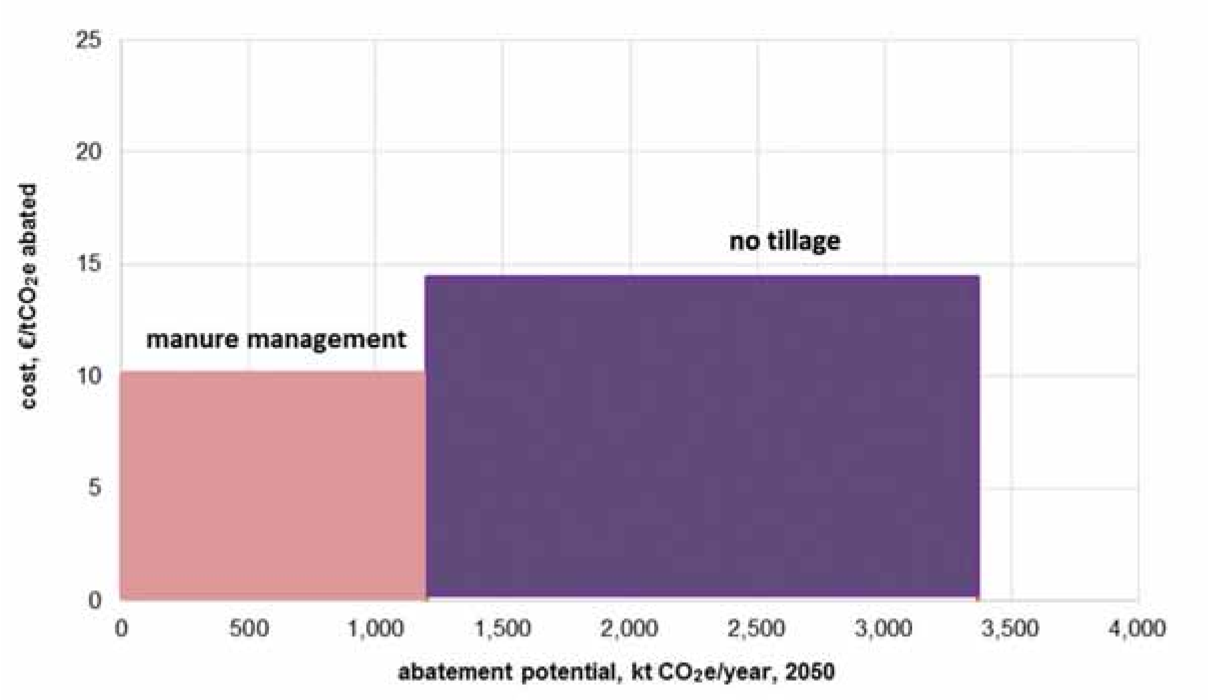
Two mitigation measures are considered in the agriculture mitigation analysis using the Marginal Abatement Cost Curve: minimum tillage and manure management. Both of these measures are supported by the EU and the NRDP. The NRDP program includes afforestation, no tillage or low

20. Unless noted, all multi-year costs are discounted to present value using a four percent discount rate; costs include investment and operations and maintenance.

tillage crop agriculture, crop rotation, manure management (including composting and storage), organic farming, and the promotion of renewable energy sources. Based on the available data, four of these measures are included in the Romania Marginal Abatement Cost Curve: no tillage agriculture, manure management, afforestation, and renewable energy sources. While the analysis of the latter two measures is presented in the Forestry and Energy chapters of this report, the former two measures are presented in the chart below. The 'no tillage' measure reflects the benefits of using no tillage as compared with the current practice of using full tillage in fields. In the baseline scenario, the measure is applied to a limited area of 90,000 hectares. Under the Green scenario, the area where no tillage is applied is expanded to 300,000 hectares in the first five years of implementation and later to 900,000 hectares. The 300,000 ha are based on arable land which is susceptible to desertification. While desertification is the threat and motive of the minimum tillage scheme, the poor manure management (collecting, storage, treating, applying) of the past is the motive for the new measure of "composting manure." Farmers applying this measure implement stringent practices in storage and treatment of manure, which generates GHG savings per animal unit (not per ha). The MACC analysis shows that the two evaluated measures have a low cost of abatement and a reasonably high abatement potential, amounting to 7.6 percent of the total abatement potential from the following sectors and subsectors: power supply, energy efficiency, transport, forestry, and agriculture (see Figure 7.8).[21]

FIGURE 7.8. Measures evaluated for agriculture have low cost and relatively high abatement potential

Romania Marginal Abatement Cost Curve for agriculture



Source: Staff calculations using data from Prof. Catalin Simota, Research Institute for Soil Sciences, Bucharest.

21. See cross-sectoral analysis in Chapter 9 on MACC and in the MACC Technical Report.

TABLE 7.1. Agriculture investments have low cost and are beneficial for the economy

Schedule of agriculture investments by proposed measure, millions of 2010 Euros

	2015–2020	2020–2030	2030–2040	2040–2050	TOTAL 2010–2050
	NOT DISCOUNTED				DISCOUNTED*
Euros, millions:					
No tillage	50	171	248	359	375
Manure management	19	64	94	136	141
Total	**69**	**235**	**341**	**495**	**516**
Percentage of GDP:					
No tillage	0.005	0.009	0.011	0.013	0.008
Manure management	0.002	0.003	0.004	0.005	0.003
Total	**0.008**	**0.012**	**0.015**	**0.018**	**0.011**

Note: *Discounted to present value at four percent rate.
Source: Staff calculations; Chapter 9 on MACC and in the MACC Technical Report.

Financing needs were assessed for the recommended measures that were evaluated no tillage agriculture and manure management (see Table 7.1). The measures are relatively inexpensive, deliver high level of abatement, and are beneficial for sector development. The total discounted net cost of both measures in the period 2015–2050 equals €516 million or 0.01 percent of GDP. The costs increase over the period significantly, and almost half of the total financing will be needed during the last ten years of the period. The benefits appear with a very slight delay, almost immediately after the implementation of the measures.

CONCLUSIONS AND RECOMMENDATIONS

The most effective adaptation measures for Romanian agriculture are rehabilitated and modernized irrigation to restore irrigated production to currently rainfed areas and optimization of agronomic inputs accompanied by high-quality extension services. Expanded irrigation has a very high potential for a positive investment payoff, provided water is available for the irrigation sector, with the highest investment payoffs in the South-Muntenia, Northeast, and Northwest Development Regions. In general, fertilizer programs show strong returns to investment throughout Romania, and for best results could be targeted for those farms of medium size (roughly 10 ha) to ensure that the measures encourage consolidation of the smallest farms while also avoiding providing an unnecessary subsidy to the largest farms, which are already quite productive. A targeted approach to new varieties, focused on the South Muntenia region but also on maize production in selected southern regions, is likely to be most successful. Recommendations also include encouraging windbreaks and soil management to reduce soil erosion, promoting renewable energy sources, promoting organic farming, improving good farming practices, improving awareness of climate change and the need for adaptation, and strengthening policy and institutional capacity is vital to support the recommended interventions.

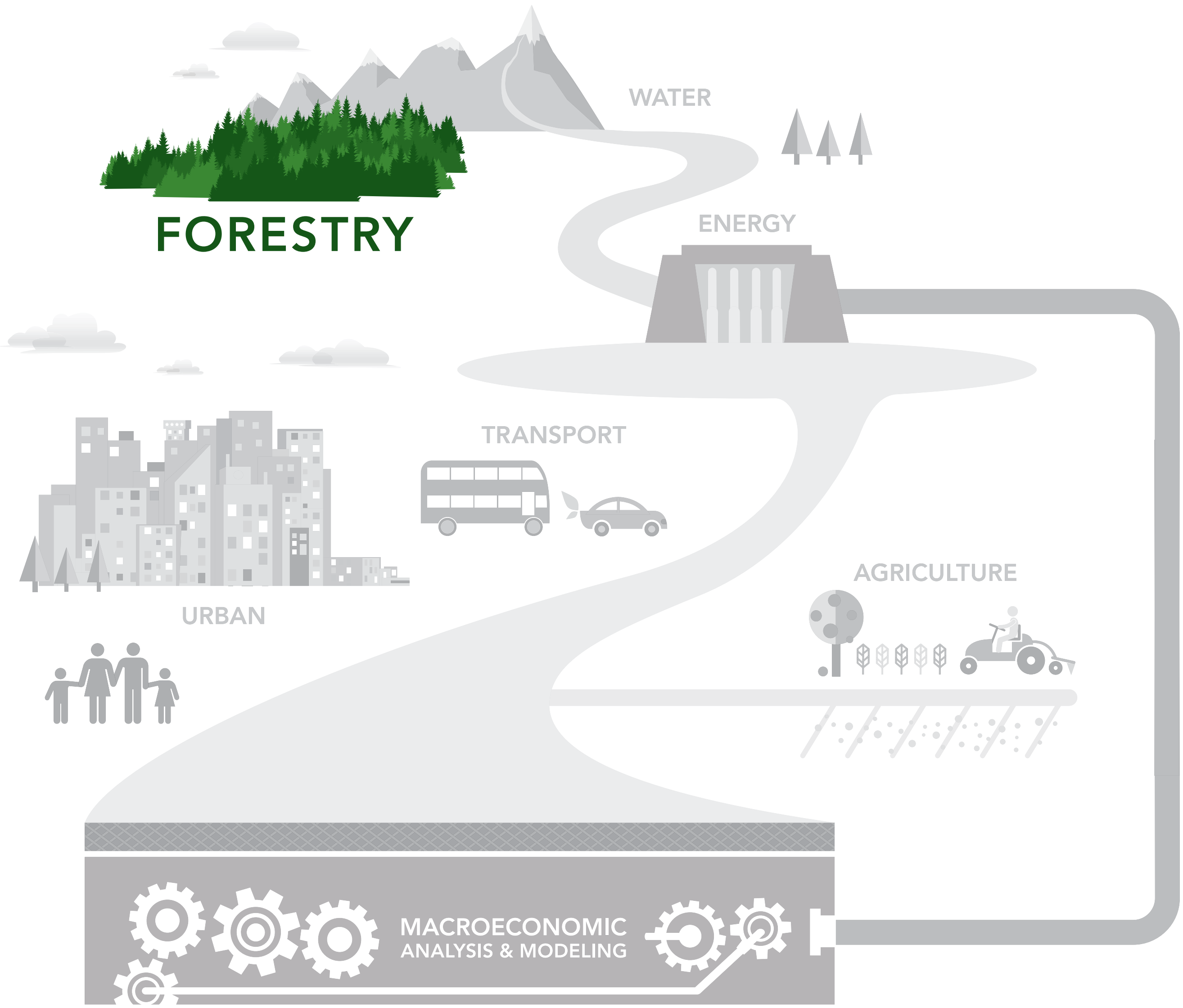
Source: Baciu/Shutterstock.com

Improvements in good farming practices, like manure management and minimizing erosion through afforestation, can also reduce vulnerabilities.[22] Other measures, such as promoting organic farming and renewable energy from biomass, helping farmers and rural communities adapt to climate change, and improving awareness and better management of risks in the agriculture sector, would complement the key investments in adaptation.

Financing needs for the two recommended mitigation measures—no tillage agriculture and manure management—are low and are highly beneficial from the point of view of sector efficiency. Emissions reduction is also relatively high. The total discounted net cost of both measures during 2015–2050 equals €516 million or 0.01 percent of GDP. Most of the costs are incurred later, with 43 percent falling in the last decade. In the first five years, 2015–2020, the implementation of the measures will require only €69 million or six percent of the estimated financing need for 2015–2050. Along with the key adaptation measures, all the measures proposed here are aimed at modernization of agricultural holdings as well as at climate action in agriculture. Therefore, sufficient investment support should be earmarked for these measures within the NRDP 2014–2020.

Strengthening policy and institutional capacity is vital to support the recommended interventions. The capacity of current research and development should be broadened, e.g., to strengthen applied sciences on new climate-resilient crop varieties, but also to improve systematic monitoring of soil, surface water, groundwater, and overall biodiversity. The EU- and national-funded support schemes should be revisited to review how to improve the uptake of all farmers participating in climate change mitigation and adaptation measures.

22. See a detailed discussion and analysis of afforestation measures in Chapter 8 on Forestry.


WATER
FORESTRY
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TRANSPORT
URBAN
AGRICULTURE
MACROECONOMIC
ANALYSIS & MODELING

CHAPTER 8

Can Forestry Realize Its Mitigation and Adaptation Potential?

CHAPTER SUMMARY

Forests provide a substantial contribution to mitigation in Romania by sequestering carbon and so countering carbon emissions from elsewhere in the economy. Romania has the largest remaining intact tract of contiguous natural and naturally-regenerated forest in Europe. Forests are important for sequestering (removing) greenhouse gas emissions from the atmosphere, thus contributing to mitigation. In Romania, the Land Use, Land Use Change and Forestry (LULUCF) has been removing an average annual 27 percent of emissions produced by other sectors during 2000 to 2011 and 24 percent during 1990 to 1999. At the same time, forests in Romania are being negatively affected by a changing climate, and adaptation efforts are needed to preserve them and their ability to sequester carbon.

Sustainable forest management is challenged, in particular, by fragmented ownership and insufficient financial resources. The transition to a market economy in Romania generated significant changes in the forest sector. As a result of the restitution, holdings are now mostly small, and the forest system is fragmented, making sustainable forest management a challenging task. Incentives are not aligned for owners of small private holdings to comply with the forest regulatory framework. Limited road accessibility to forests is another constraint, negatively affecting harvesting, as well as fire and pest control efforts. Lack of adequate financial resources, especially to assist smallholders, is also a barrier to afforestation of agricultural land and establishment of forest belts.

A summary of key existing analytic studies and the construction of a marginal abatement cost curve (MACC) for mitigation actions in the forestry sector were the basis for identifying key adaptation and mitigation measures for Romania's forests. The package of measures that provides for the largest CO_2 removals includes afforestation of degraded lands at the rate of 10,000 ha per year, creation of biomass from fast growing crops at a rate of 5,000 ha per year, implementation of "no-till" practices for 40 percent of the arable land per year, in rotation, and increasing the area of nature

conservation and biodiversity protection. In addition to the national and international analytic outcomes, a MACC was estimated by this Assessment for three measures: afforestation, sustainable management of protection forests, and sustainable management of production forests. These measures can provide cost-efficient abatement for Romania of an estimated 1,828 kt CO_2 per year in 2050 at a total cost of €115 million (discounted) for the period 2015–2050 or just 0.002 percent of GDP. When benefits are taken into account, the total discounted net cost is a negative €86 million.

Recommendations stress the importance of sustainable forest management for Romania and the desirability of the EU's moving rapidly towards defining the rules (including the country level targets and the flexibility rules) for LULUCF-based mitigation within its 2030 Framework. These actions would enable Romania to use forests as an important component of the country's mitigation strategy. Adaptation measures in forestry, including those that benefit other sectors, in particular agriculture and energy, should be supported. Policies aimed at reducing forest fragmentation and engaging smallholders in sustainable forest management activities should be implemented. Creating and implementing a transparent and updated monitoring system for CO_2 removal in forestry together with a review of the modeling and analysis would support climate change mitigation. The system for forest fire detection, monitoring and management should be upgraded. It is critical to improve road accessibility. Necessary financing could be met by mainstreaming forestry actions into the EU-funded programs (such as ecological reconstruction, small and medium enterprises, education and extension, and other aspects of the NRDP), and reforming the policy and regulations for forest management, to bring in private funds.

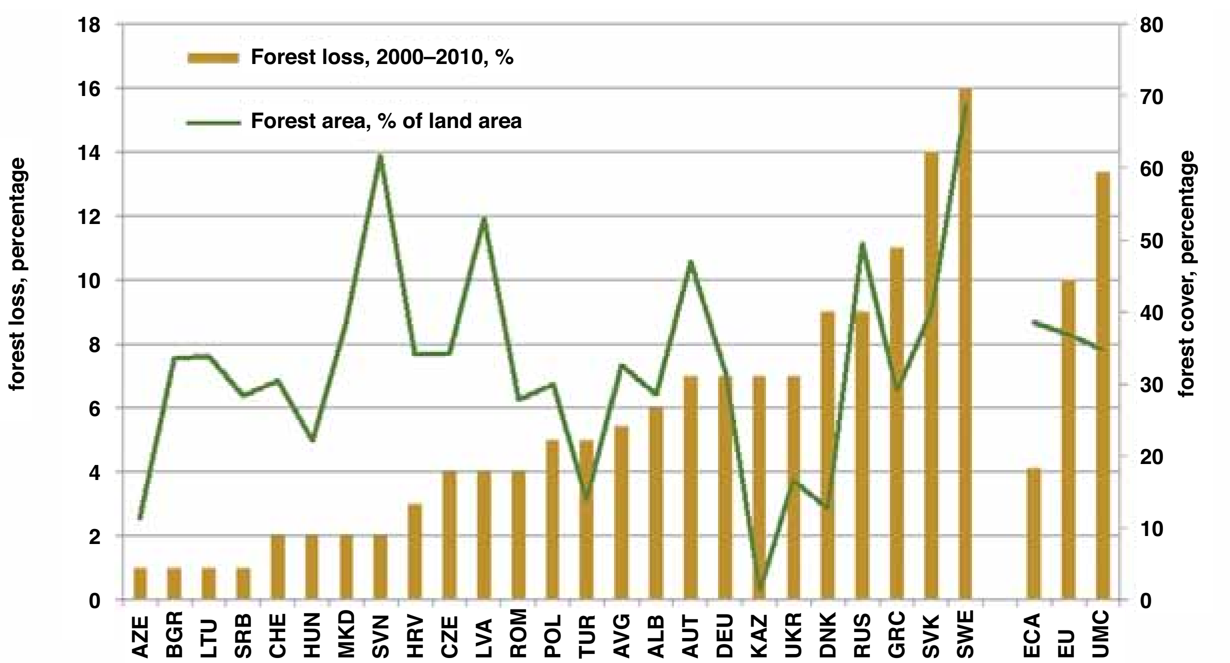
CHALLENGES FOR GREENER GROWTH

Overview

Romania has the largest remaining intact tract of contiguous natural and naturally-regenerated forests in Europe. Forest removals are below the allowed annual cut level of 22.3 million ha: in 2013, only 59 percent of the growing stock volume was removed (Figure 8.1). Romania's forest stock is young and, therefore, has a high potential to absorb CO_2. The Romanian Network of Protected Areas includes areas of national importance, reserves, parks and Natura 2000[1] sites, covering approximately 23 percent of the forest area. More than 693 nature reserves and natural monuments are outside the large protected areas and cover 102,534 ha.[2] The biomass potential of Romania is estimated at 88,000 GWh per year. The forestry sector in Romania, including industry, contributes between two and five percent of Romania's GDP.[3] It is also an important employer, especially in rural areas. Export of logs is a significant part of total forestry exports. At the same time, there has been a decline in the wood processing industry. The reasons include poor road accessibility, outdated technology, and inefficient production processes. An increasing part of the valuable wood resources has been used for heating.

FIGURE 8.1. Romania's forest coverage is relatively high and forest removals low

Forest area as percentage of land area and forest loss over 2000–2010



Sources: World Bank and Environmental Performance Index.

1. Natura 2000 is an EU network of nature protection established under the 1992 Habitats Directive with the aim to protect Europe's most valuable and threatened species and habitats.

2. Borlea GF, Ignea G. 2006. Lucrările sesiuni ştiinţifice Pădurea şi dezvoltarea durabilă (The Present Forest Policy and the Market for Forest Products). Braşov, Romania: 2005–2006. 633–638; Abrudan, I.V., Marinescu, V., Ignea, G. and Codreanu, C. 2005. «Present situation and trends in Romanian forestry» in Legal Aspects of European Forest Sustainable Development: Proceedings of the 6th IUFRO 6.13.00 Group Meeting. Editura Universitatii Transilvania din Brasov, Romania:157–171.

3. See Forestry Sector Technical Report for details.

Challenges

Sustainable forest management has been made more difficult by the fragmentation of forest land ownership that accompanied economic transition. The restitution process has fragmented the forest system and raised challenges for ensuring sustainable forest management. Restitution of forest land ownership completely modified its structure: holdings are now predominantly small, and the forest system has been left fragmented, making sustainable forest management a challenging task.[4] By 2013, 36 percent of forest land was privately owned, while 64 percent remained in the public domain, including state and municipal ownership. There are an estimated 830,200 forest owners, and most of them (99.8 percent) own small forest parcels under 10 ha (Table 8.1). Incentives are not aligned for owners of small private holdings to comply with the forest regulatory framework. The main reason for poor performance of the afforestation programs was that the owners were not properly compensated.

Coupled with fragmented ownership, the lack of resources to approve and subsequently implement available management plans, is a serious challenge for sustainable forest management. There are 272 management plans covering the protected areas, of which only twelve have been approved. This also has consequences for flood management as investments in flood management in upper forested watersheds were traditionally done by the forest administrators within forested areas. Without approval and budget these areas cannot have flood management. Investments in implementing the management plans are important for decreasing the incidence of the flooding, water turbidity and regulation of debris. However, due to the changes in ownership and the lack of budgetary allocation to National Forest Administration (NFA) to continue those investments, the incidence of flooding and fast moving water is increasing.

Limited road accessibility to forests is a significant constraint to sustainable forest management in Romania. As a result, harvesting levels are below the recommendations of forest management plans in inaccessible areas, while accessible forest stands are over harvested. Fire and pest control are inefficient due to lack of access. The average road density for Romania is 6.4 m/ha, which is significantly below other European countries with broadly similar topography.[5] A low density of forest roads implies the lack of access to timber resources in inaccessible sites, and/or the need to skid logs for longer distances from the point where they are felled to roads where they can be loaded onto trucks. Exploitation costs are higher since they increase with the length of skidding. Longer skidding distance also results in erosion and soil compaction on arterial skidding trails.

TABLE 8.1. The forest system is fragmented

Distribution of forest land by size among private owners (without forests owned by local authorities)

SIZE OF FOREST LAND PARCEL	NUMBER OF OWNERS	TOTAL AREA (million ha)
Forest < 10 ha	828,000	0.85
Forest > 10 ha	2,200	1.35
Total	830,000	2.20

Source: Forestry Sector Technical Report: Opportunities for Mitigation and Adaptation through Forests.

4. World Bank. 2011. Romania Functional Review: Environment, Water and Forestry. Vol 2: Forestry.

5. World Bank. 2011. Romania Functional Review: Environment, Water and Forestry. Vol 2: Forestry. Austria 36 m/ha, Switzerland 40 m/ha and France 26m/ha.

Adaptation

Projected changes in precipitation and temperature in Romania are anticipated to weaken forest systems and decrease forest growth. Climate change causes shifts in ecozones, and the new ecozones can be unsuitable for the existing trees. Climate change also compounds biological risks to forests including pest infestation. Climate change can cause the drying of plants and species and decrease the growth of forests. Already, approximately 1 million m^3 of timber in Romania is lost annually to wind and snow, and approximately 130,000 ha of the designated forest areas in the lowland are affected by drying due to soil water deficit. Up to 30 percent reduction in tree population and a decrease in growth, especially for forests in the plain areas, has been projected.[6] With climate change, ecozones shift, and previously planted trees might now be in an ecozone not suitable for them. Tree species outside of their natural areas are more susceptible to negative biotic factors—pests, water stress, and so on. Also, regeneration patterns change. In the mountains, forests are invading pastures. In some places, the naturally regenerated areas at the border of forests and alpine pastures are afforested with resinous species that now require special management. In the plains, non-native species are invading natural forests. An example of climate change-related pest infestation is an increase in outbreaks of the bark beetle at higher altitudes and latitudes.[7]

Forest fires are intricately linked with forest pests and diseases-infested forest, with dying trees more susceptible to forest fire, and fire damaged stands more prone to pest infestation. Forest fires incidence in Romania under current climatic conditions is rather low. In the future, however, the

6. Forestry Sector Technical Report.

7. Hlásny T and Turčáni M. 2009. "Insect Pest as Climate Change Driven Disturbances in Forest Ecosystems" in Strelcová et al. (eds) Bioclimatology and Natural Hazards, Springer Nederlands pp. 165–178.

occurrence of forest fire in the south and southwest of the country is highly likely.[8] This area is similar to the area with the biggest incidence of forest fires in Europe (the Mediterranean region), where 85 percent of the forest fires are presently recorded, in its exposure to drought and its level of management.[9] The current forest fires' monitoring and intervention system is capable of coping with the present level of fire incidence, but its effectiveness is negatively affected by many issues including forest accessibility.

In the face of climate change, Romanian forest managers need to improve and choose the appropriate management approaches for maintaining and increasing ecosystem services from forests. Romania has a national strategy for combating drought, land degradation and desertification. Activities included planting of trees to reduce soil erosion and restore degraded lands. The draft of the New Forest Development Strategy (2013) envisages a role for forests in climate change mitigation and highlights necessary measures for adapting forests. A new Forest Code was adopted by the Romanian Parliament in March 2015. The key changes include: (1) judicious administration of national forest on the principle of territoriality, with solutions for managing small forest properties which are currently not covered by forest management and services; (2) establishment of national targets for afforestation; (3) differentiation in the requirements for management planning based on the size of the property; (4) restrictions on the total quantity of wood (per species and varieties) that can be processed by companies to avoid monopolistic situations. Also, a new Government Decision seeks to prevent illegal harvesting of wood, by establishing a system for control and supervision of wood material traceability.

Forests are important in ecosystem-based adaptation strategies for other sectors, such as agriculture In particular, forest belts should be used more to provide climate resilience and benefit agricultural systems. Forest belts can help improve microclimatic conditions of growth for protection of agricultural crops, up to a distance 25 times the height of belt in the sheltered areas and 5 times in the exposed areas, due to the reduction of wind speed by 31 to 55 percent in the sheltered area and by 10 to 15 percent in the exposed one. Belts are estimated to sequester 40 tCO_2e/ha/year. Other benefits include increased humidity and level of ionization of air at soil level, which enhances soil fertility, reduces depth and duration of freezing, and decreases evapotranspiration. However, in Romania, forest belts are not used enough and are even being eliminated.

Mitigation

Forests are important for sequestering (removing) CO_2 emissions, and Romania's forests are contributing significantly to emissions reduction. Romania's LULUCF sector (mostly its forestry component) removed an annual average 27 percent of emissions produced by other sectors during 2000 to 2011 and 24 percent during 1990 to 1999 (Figure 8.2). Romania's 2013 National Inventory Report shows that from 1989 to 2011, GHG emissions calculated without taking LULUCF into account decreased by 55 percent; however, when factoring in LULUCF, they decreased by 61 percent.[10] LULUCF sector emissions are largely a result of land conversion to settlements, industrial uses, and similar uses, while forest land is the largest contributor of emission removals. In particular, afforestation of degraded lands with limited agricultural potential offers the opportunity to reduce GHG emissions while generating

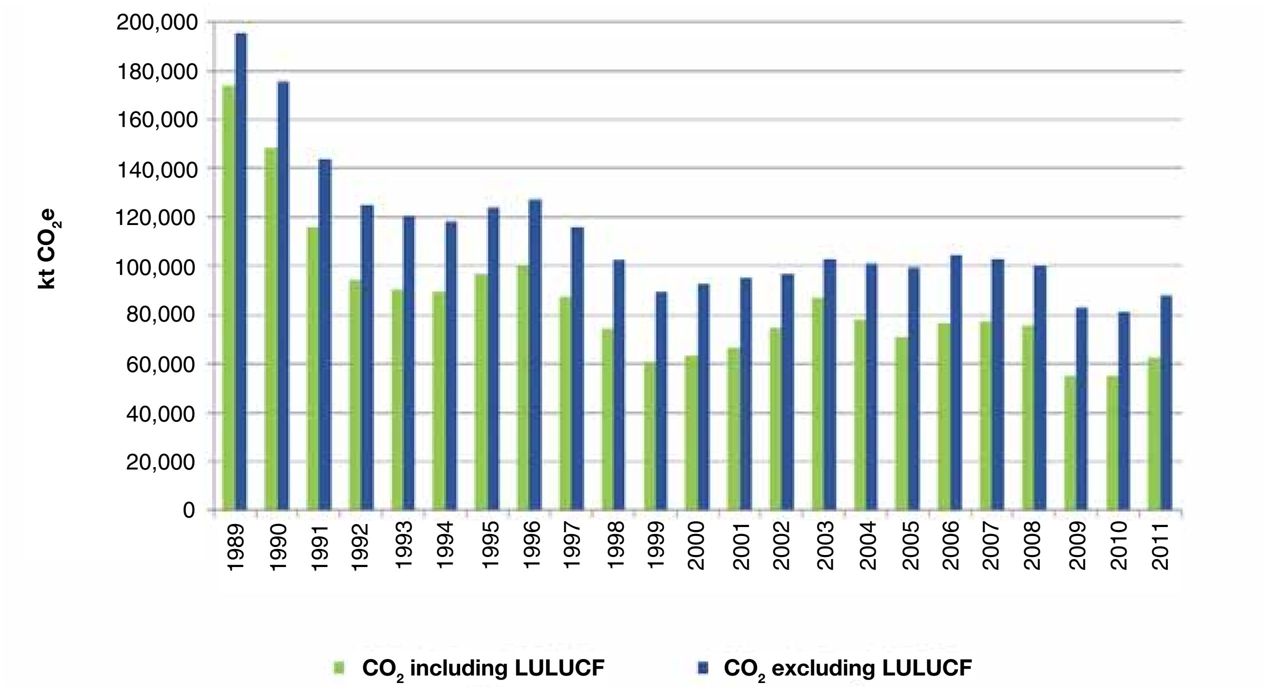
8. Forestry Sector Technical Report.

9. Ibid.

10. Ministry of Environment and Climate Change (MECC). 2013. Romania's Greenhouse Gas Inventory 1989–2011. Bucharest. Estimated using methodology presented in Good Practice Guidance for LULUCF, IPCC, 2003.

FIGURE 8.2. LULUCF sector (mostly its forestry component) is significantly contributing to emission reduction

Emissions removals by LULUCF



Source: Forestry Sector Technical Report.

adaptation co-benefits and strengthening climate resilience. Converting land to forest (afforestation) also contributes significantly to sequestration (Table 8.2).

METHODOLOGY AND FINDINGS

A summary of key existing analytic studies and the construction of a marginal abatement cost curve for forestry mitigation actions serves to identify key adaptation and mitigation measures in Romanian forestry.

The Joint Research Center of the European Commission and the Romanian Forest Research and Management Institute (Institutul de Cercetări şi Amenajări Silvice, ICAS) undertook a forestry sector modeling exercise in 2012, constructing a baseline and three green scenarios. The baseline included a projected shift of trees to older age classes under current forest management norms and accessibility conditions, a large scale investment in forest infrastructure, and natural disturbances resulting in larger cuttings—all this will reduce carbon sequestration.[11]

11. It should be noted that a recent submission on LULUCF actions to the European Commission (dated January 2015) noted that what has to be avoided is the lack of enforcement of laws that facilitate sustainable forest management across both private and public forest lands. The main concern is related to practices that delay biomass regeneration and encourage larger emissions from bare forest soils, stand degradation by selective cuts, and regeneration with native forest growing low wood-density tree species.

TABLE 8.2. Converting land to forest contributes significantly to sequestration

Net GHGs emissions for the LULUCF Sector in 1989, 2010 and 2011

IPCC SUBCATEGORIES	EMISSIONS (+) / REMOVALS (–), GT CO_2E			
	1989	2010	2011	2012
Forestland remaining Forestland	–18,863	–22,263	–20,384	–19,672
Land converted to Forestland	–122	–2,498	–3,061	–3,048
Cropland remaining Cropland	–5,784	–2,336	–3,223	–1,661
Land converted to Cropland	–17	18	20	31
Grassland remaining Grassland	NA	NA	NA	NA
Land converted to Grassland	–654	130	118	138
Wetlands remaining Wetlands	NA	NA	NA	NA
Land converted to Wetlands	–215	–126	–130	–53
Settlements remaining Settlements	NA	NA	NA	NA
Land converted to Settlements	4,125	419	410	411
Other land remaining Other Land	NA	NA	NA	NA
Land converted to Other Land	–30	789	835	767

Source: MECC (2013) and MECC (2015): Ministry of Environment, Waters and Forests. 2015. Information on LULUCF Actions in Romania. Report under art. 10 of Decision 529/2013 of European Parliament and the Council, Bucharest, http://mmediu.ro/new/wp-content/uploads/2014/12/Report-LULUCFart.10Decision-529.pdf.

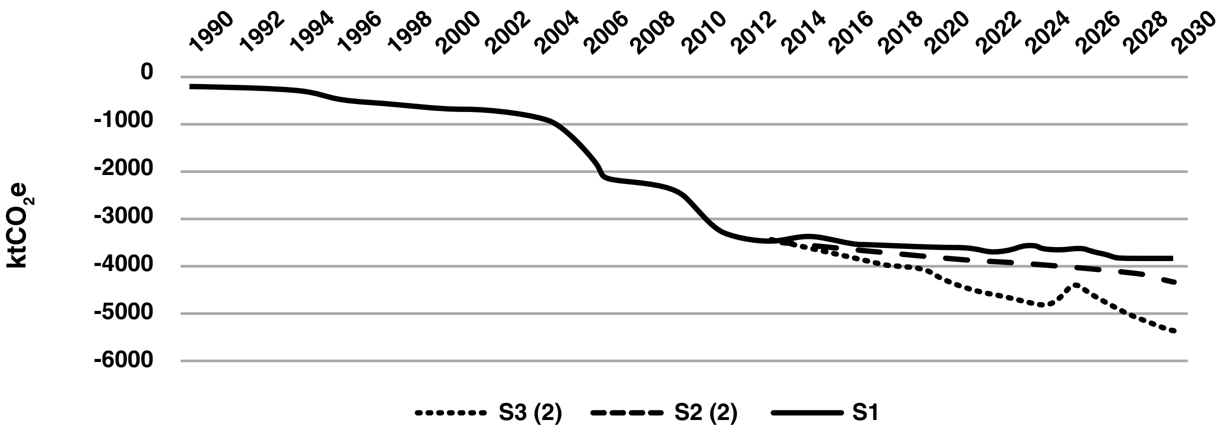
A second study, led by ICAS, examines GHG projections for 2015–2030 under three scenarios:

- Scenario 1 (S1) assumes the current practices of resource management for all types of lands. This scenario also includes afforestation of 2,000 ha annually.
- Scenario 2 (S2) includes measures to improve land use by increasing annual harvest of wood to the pre-1989 levels, when there was excessive logging, and allowable annual extraction levels were constantly exceeded by 15–30 percent.[12] The other measures included in the scenario are afforesting degraded lands at the rate of 5,000 ha per year, including re-vegetation and forest belts, from 2012 to 2030; and implementing "no-till" practices for 30 percent of the arable land per year, in rotation.
- Scenario 3 (S3) includes interventions to improve land use and additional financial incentives for specific public good services. In particular, it combines measures to increase annual harvest of wood to pre-1989 levels through intensification of forest management; afforestation of degraded lands at a rate of 10,000 ha annually, including re-vegetation and forest belts; creation of woody biomass from fast growing crops at a rate of 5,000 ha/year; implementation of "no-till" practices for 40 percent of the area of arable land per year from 2015 to 2030, in rotation; and increasing the protected area of nature conservation and biodiversity protection.

12. Bohateret V.M. 2012. "Readjusting Romania's Forestry Policy with a View to the Year 2050" in *Journal of Settlements and Spatial Planning:* 1/2012.

FIGURE 8.3. Green scenario S3 has highest sequestration potential

Graphical representation of the removals of CO_2 by lands converted to forestland in the three scenarios



Source: Forestry Sector Technical Report.

This study concludes that for the timeframe considered (2015–2030), the highest benefit (most CO_2 removal) is under scenario S3, while the benefits under scenarios S2 and S1 are lower (Figure 8.3).

Based on recent projections, the highest CO_2 removal benefits of Romania's forests will continue coming from the existing forests and their sustainable management. Afforestation (including conversion of all other types of land to forest land and reforestation) is projected to bring significant gains as well. Managing the existing forest resources is critical to maintain their sequestration potential. Projections show that forest management efforts will continue adding most value to the total CO_2 removals in forestry going forward, followed by keeping the existing forest intact. However, other actions are also important. In particular, afforestation (conversions of land to forestland) will be adding more value with time, after the initial investment is made. A projected decrease in the absolute level of sequestration from the existing forest reflects a slightly diminishing value of the forest stock going forward and the need to improve its management. (Figure 8.4).

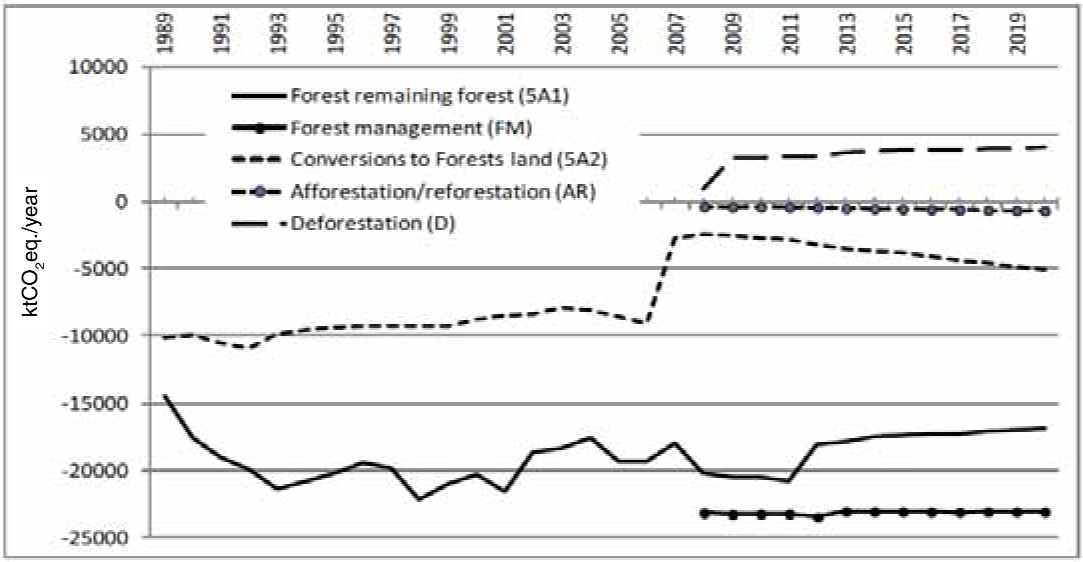
Intensive management of forests and increasing sustainable harvesting of timber can increase the level of CO_2 sequestered compared to maintaining forest stands[13] (see Figure 8.5). The rate at which the forest is growing and thus absorbing CO_2 should be highest when the stand is young, with the exception of the first two or three years. If forests remain unmanaged, there will be more mature trees. As the tree growth slows with maturity, they over-shade and suppress the growth of younger and more vigorous stems. The young stock provides a lower CO_2 removal per ha at an early stage, but their sequestration potential is higher than in the mature stock. Increased management intensity would result in a greater proportion of older trees being removed, leading to a better growth of the younger trees and therefore increased CO_2 removal ability of the forest. Also, trees removed can be used in such carbon beneficial processes[14] as construction using lumber, manufacturing of various wooden products, e.g., chipboard or paper, or replacing fossil fuels with fuelwood.

13. Analysis in Nabuurs, G.J., et. al. 2007. "Forestry" in *Climate Change: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

14. The benefit is carbon storage in the wooden products.

FIGURE 8.4. Romania can improve forestry role in mitigation via various actions

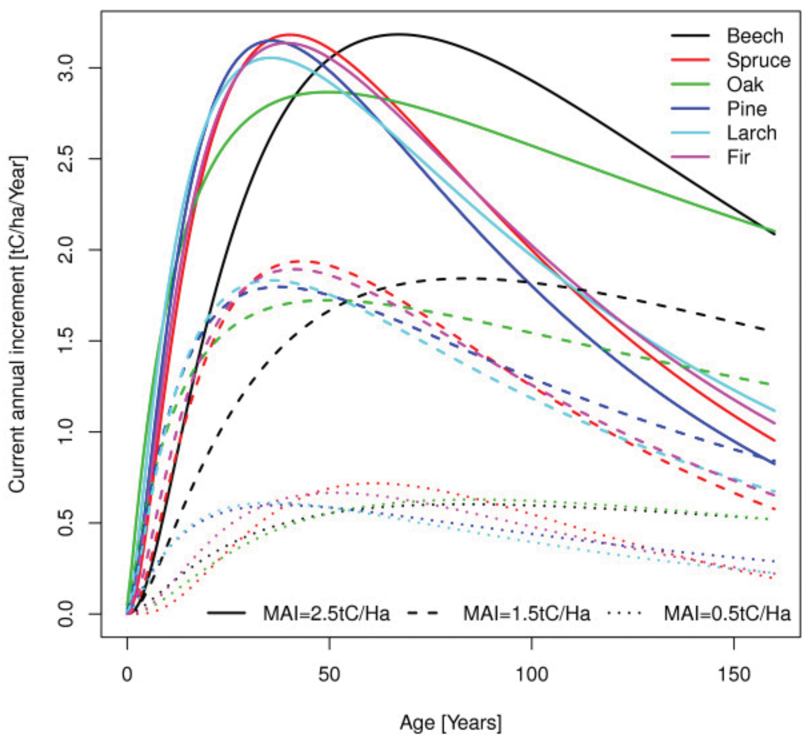
Projections of sequestration, forest emissions, forest conversions, and forest related activities



Note: Projections of CO_2 removals and GHG emissions for forest (5A1), forest conversions (5A2) and forest related activities (FM, AR, D) until 2020.
Source: Ministry of Environment, Waters and Forests. 2015. Information on LULUCF Actions in Romania. Report under art. 10 of Decision 529/2013 of European Parliament and the Council, Bucharest, http://mmediu.ro/new/wp-content/uploads/2014/12/Report-LULUCFart.10Decision-529.pdf.

FIGURE 8.5. Forest grows faster when the stand is young

Growth curves for central region of Europe with Picus model



Source: Kinderman et al.

FIGURE 8.6. Sequestration benefits of afforestation in Romania substantially increase with time

Carbon stock trend for a native Romanian hardwood plantation of 60% oaks, 40% other species

Age of trees (years)	20	25	30	35	40	50
Sequestration benefits (tCO_2/ha)	42	61	82	103	123	152

Source: Estimates made by Dr. Marian Dragoi, University of Suceava, Romania.

Afforestation or conversion of all types of land, including degraded or abandoned lands, to forest, as well as reforestation, is an important option for mitigation in the forestry sector in Romania due to the large area where such measures are applicable. Afforestation represented over 26 percent of the total changed land area in Romania in the period 1990–2006. The National Program for Afforestation projects a 422,000 ha increase in area under forest cover by 2035.[15] Afforestation is a cost effective mitigation measure. In order to estimate the cost of afforestation per hectare and the expected sequestration, four afforestation projects have been analyzed for this Assessment. The resulting growth of the carbon stock, assuming average site conditions, is reflected in Figure 8.6. The average cost, without transaction expenses, is €6,000 per hectare, which corresponds to the unit abatement cost of €120/tCO_2/ha.[16]

A marginal abatement cost curve (MACC) for three key mitigation measures in Romania's forest sector was estimated in addition to the review of analytic studies of forestry.[17] The three main measures examined for the forest sector are afforestation, sustainable management of protection forests, and sustainable management of production forests. The measures examined are presented according to two parameters of the MACC: potential mitigation impact (kt of emissions abated) and the unit cost of abatement (cost per ton of CO_2e abated).[18] The estimates were made on the basis of recent local data, collected and validated by Romanian experts.[19] The outcomes are presented in Figure 8.7, which shows that the proposed measures provide a significant potential abatement level of 1,828 $ktCO_2$ per year in 2050. The examined measures are evaluated as highly cost efficient: two of them—protection forest management and production forest management—have positive net benefits (or negative net costs) while the third measure—afforestation—has negligibly positive net costs (Figure 8.7).

The afforestation measure focuses on degraded lands to address the problem of the declining share of forest land and ongoing land degradation. This focus means higher costs but higher long-term benefits. An average annual growth of 10 m^3 per ha is assumed and an average of 1,000 ha per year is afforested (a conservative assumption), resulting in the abatement (sequestration) of 10,000 tCO_2 per year. The initial cost is €6,000 per hectare, in line with actual current costs in Romania; it is projected to decrease during 2015–2050 to €3,500 per hectare due to increased implementation efficiency and

15. Bohateret V.M. 2012. "Readjusting Romania's Forestry Policy with a View to the Year 2050" in *Journal of Settlements and Spatial Planning:* 1/2012.

16. This estimate is used in the marginal abatement cost analysis produced for this Assessment and presented in this chapter (below), as well as in Chapter 9 and in the Marginal Abatement Cost Curve Technical Report.

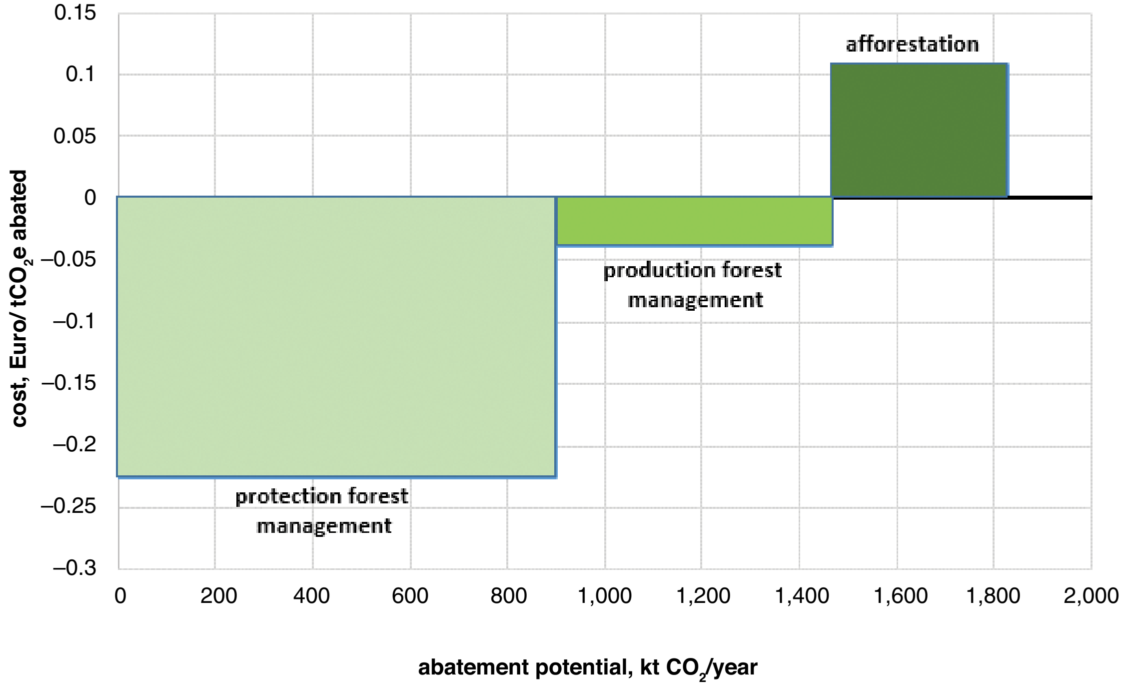
17. See Chapter 9 for details and for a cross-sectoral MACC analysis.

18. The discount rate used is three percent.

19. The estimates were made by Dr. Marian Dragoi, University of Suceava, Romania, in coordination with other local experts.

FIGURE 8.7. The proposed forestry measures are highly cost efficient and provide a significant abatement potential

Marginal abatement cost curve for forestry



Source: Staff calculations based on estimates and research provided by Dr. Marian Dragoi, University of Suceava, Romania.

learning curves for technology. Revenues are also assumed, from fuelwood produced by clearings and non-commercial thinnings. The calculations were made using a composition of species and soil conditions typical for degraded lands.

For sustainable management of production forests, constraints and solutions are considered when estimating the MACC. For example, there is evidence that shorter rotations mean less disturbances, hence more valuable and healthy trees for harvest and a better CO_2 accumulation in wooden construction materials. The measure was estimated for Norway spruce. Shortening its rotation from 110 to 100 years is assumed to result in a wood yield increase of 10 percent (a conservative estimate). The average growing stock in this period is about 650 m^3 and we have assumed that 10 percent more wood will be graded for lumber, having this average growing stock. Having 65 m^3/ha more wood, the abatement potential is 65 tCO_2/ha. The measure would cover 50 percent of the Norway spruce forests, or 850,000 hectares. Considering a 10 percent higher carbon sink, the cost-effectiveness of the shortened rotations is estimated, considering average productivity, harvestable volumes from the yield tables, and operational costs (tending works, thinning and final harvesting operations). The revenues were estimated using data provided by the NFA, current prices for different grades of wood (obtainable from an average stand, with an average productivity), and the average assortment of grades estimated on the basis of yield tables. The operational costs were also documented by Romanian National Forest Inventory harvesting companies.

Sustainable management of protection forests was the third measure considered for MACC. The measure is based on the assumption that Natura 2000 management plans will be enforced, resulting in compulsory environmentally-friendly harvesting operations, the reduction of timber harvested as

salvage product, decreased damage to remnant trees, and less salvage products, in the long run. The impact on CO_2 sink is assumed to equal the amount of timber currently harvested as salvage products from protection forests, which is 5 m^3 per year per hectare. The measure is assumed to be applied on 5,000 hectares per year. Net baseline benefits were calculated based on average cost paid by the NFA for the protected areas. Green benefits (after the implementation of the measure) have two components: the EU level of €33 per hectare from the implementation of this measure and the compensation of €25 per year per hectare, to be paid through the Rural Development National Program.[20] The cost and revenue data were provided by the NFA.

To ensure the long-term maintenance of forest, sustainable management has to occur on both state and private forest lands. The private landholders will need to be provided with the necessary support to comply with the requirements including technical services, markets, and infrastructure. Many of these will require public investments or financial support to buffer the upfront cost. In Romania, climate-sensitive sustainable management of production and protection forests will require reversing existing constraints to technology, infrastructure, knowledge, research, and other enabling conditions. Additional investments in afforestation would enable the Romanian Government to increase harvesting of forest to the annual allowable cut while minimizing any associated reduction in CO_2 sequestration.

20. To compensate the landowners for giving up harvesting operations for a period of 5 years.

TABLE 8.3. Forestry green spending is beneficial for the economy

Schedule of forestry green costs, millions of 2010 Euros

	2015–2020	2020–2030	2030–2040	2040–2050	TOTAL 2010–2050
	NOT DISCOUNTED				DISCOUNTED*
Euros, million:					
Gross costs	37	49	46	47	115
Net costs (net of benefits)	33	6	–116	–145	–86
Percentage of GDP:					
Gross costs	0.0040	0.0026	0.0020	0.0017	0.002
Net costs (net of benefits)	0.0036	0.0003	–0.0049	–0.0052	–0.002

*Discount rate is 3%.

A simplified regulatory regime for small privately owned forest areas that still requires sustainable forest management is required. The simpler regulation should enable owners of forests under 10 ha to adhere to good forest practice and sustainable forest management guidance with simplified requirements for planning, marking, harvesting and sale of timber and non-timber forest products. The technical norms need to be revised to better reflect advances in forest management, forest operations and associated technologies (for example, nursery technology, seed quality, plant handling and site cultivation), and knowledge of climate change and its impacts on forests.[21] Incentives will be important for successful afforestation initiatives. Of the 115,129 hectares of degraded area found suitable for restoration through afforestation in 16 counties (roughly 14 percent of the total land area), more than 80 percent is under private ownership or community management of public lands.

Financing needs for the three priority measures were evaluated: afforestation, sustainable management of protection forests, and sustainable management of production forests. (See Table 8.3). The measures evaluated as highly cost efficient: two of them—protection forest management and production forest management—have positive net benefits (negative net costs), and the third measure—afforestation—has negligible positive net costs. The total discounted net cost of all three measures for the period 2015–2050 is negative (or provides higher revenue than required costs) and equals –€86 million. If benefits are not taken into account, the cost is €115 million for the same period or just 0.002 percent of GDP. The schedule of costs requires approximately equal amounts of funding annually. The benefits, however, appear later in the projected period, mostly after 2030, because forestry measures require significant time to produce benefits.

CONCLUSIONS AND RECOMMENDATIONS

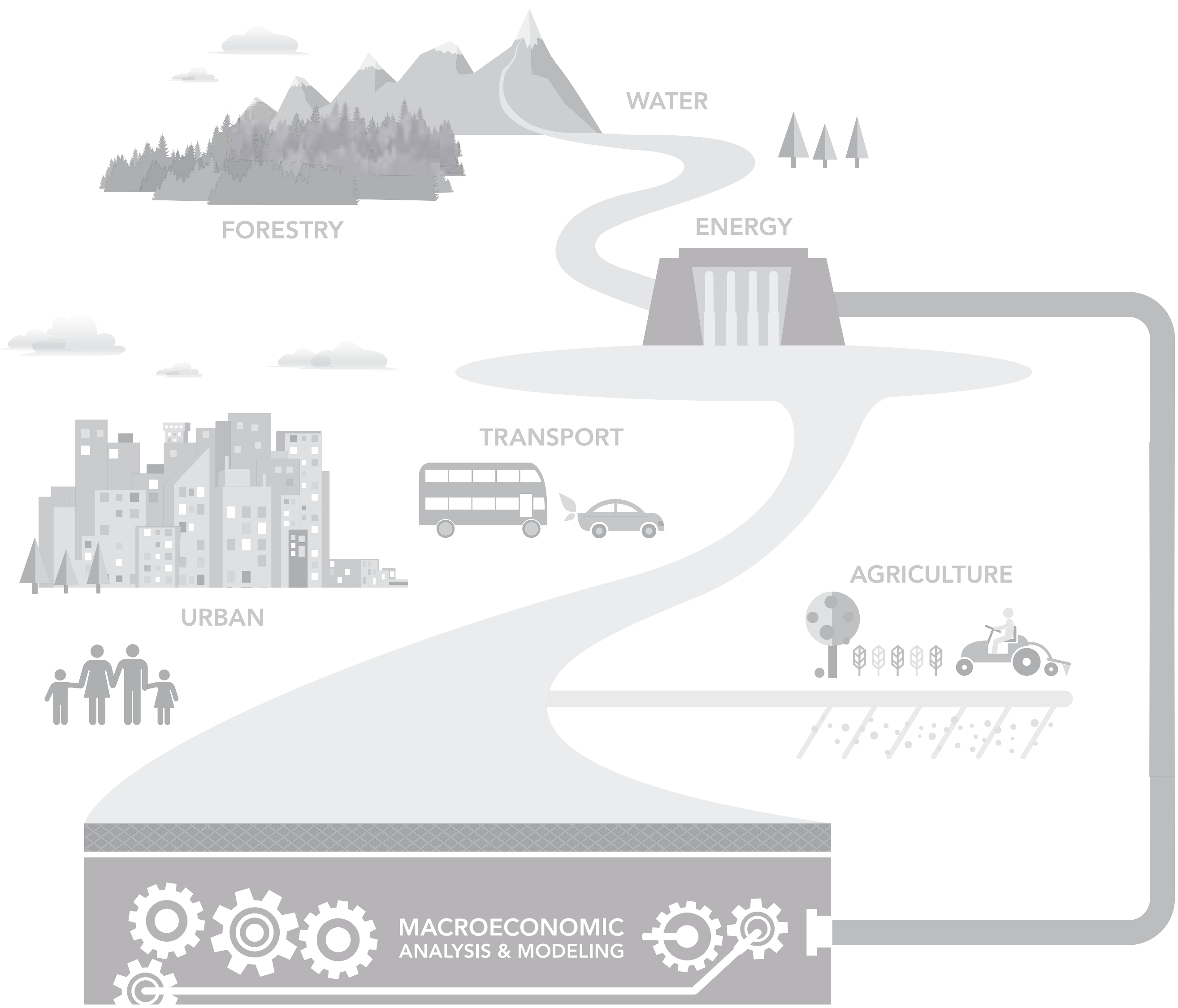
Recommendations stress the importance of sustainable forest management for Romania and the desirability of the EU's moving rapidly towards defining the rules (including the country level targets and the flexibility rules) for LULUCF-based mitigation within its 2030 Framework. These actions would enable Romania to use forests as an important component of the country's mitigation

21. World Bank. 2011. *Romania Functional Review: Environment, Water and Forestry.* Vol 2: Forestry.

strategy. Forestry in Romania is a key sector for mitigating climate change, as it removes 27 percent of GHG emissions annually. Forest based mitigation measures can include conserving existing CO_2 sinks, enhancing carbon sinks and reducing the trade-off between the sinks, and tangible and intangible benefits from other land uses. Adaptation measures in forestry are critical to enhance the mitigation capacity of the forests. These measures also benefit other sectors, in particular agriculture and energy. Romania should promote afforestation outside of forests and invest in afforestation of degraded lands, create forest belts, and enhance management of forests in watersheds to reduce flooding.

Policy measures that mitigate climate change and contribute to growth are critical, as well as capacity building. Policies related to reducing forest fragmentation should be implemented, in particular those aimed at engaging smallholders in sustainable forest management activities. Capacity for monitoring the contribution of forest management to mitigation should also be improved. Creating and implementing a transparent and updated monitoring system for CO_2 removal together with a review of the modeling and analysis would help provide more accurate assessments of the contribution of forests to climate change mitigation. The system for forest fire detection, monitoring and management should be upgraded. It is critical to improve road accessibility. To achieve it, financing provided for forest roads should be based on the economic rationale, including the contribution to climate change mitigation.

A greener path for forest will require additional public spending. Financial support to landholders, especially private ones and in particular small landholders, will be necessary. This could be provided in the form of public investments or financial support to buffer upfront costs associated with generating the larger public benefit. Other financing needs will fall primarily on the private sector, including for forest roads. Necessary financing could be met by mainstreaming some of the necessary forestry actions into other EU-funded programs (such as ecological reconstruction, small and medium enterprises, education and extension, and other aspects of the NRDP), prioritizing where interventions are financed, and making sustainable management of forests profitable by reforming the policy and regulatory requirements for forest management, to help bring in private funds. Financing needs for all three priority measures that were evaluated—afforestation, sustainable management of protection forests, and sustainable management of production forests—equal €115 million (discounted) for the period 2015–2050 or just 0.002 percent of GDP. When benefits are taken into account, the total discounted net cost is a negative €86 million.


WATER
FORESTRY
ENERGY
TRANSPORT
URBAN
AGRICULTURE
MACROECONOMIC
ANALYSIS & MODELING

CHAPTER 9

A Look at Mitigation Across Sectors: A Marginal Abatement Cost Curve

CHAPTER SUMMARY

marginal Abatement Cost Curves (MACC) are commonly used as a tool in evaluating emission reduction technologies in terms of their potential greenhouse gas mitigation impact (emissions abated) and unit cost (cost per ton of CO_2e abated). They are also considered to be a most efficient communication instrument used in discussions of abatement policies. MACC charts are designed to be a "brief": they compare technologies to be considered for implementation in a simple (easy to comprehend in a limited time) but informative way. The technologies can be presented one by one or at various levels of aggregation, including by blocks of technologies, by economic sector, or even by groups of sectors. In the MACC, each technology has two characteristics: the level of abatement expressed as millions of tons of carbon dioxide equivalent ($MtCO_2$e), which equals the difference in emissions produced by the new technology as compared to the technology it replaces (abatement potential) and the cost of the technology per unit of abatement expressed as euros per ton of carbon dioxide equivalent (€/tCO_2e).

The MACC analysis presents a cross-sectoral snapshot of the benefits and costs of the mitigation measures recommended on the basis of the sectoral modeling and analysis. Four sectors (energy, transport, forestry and agriculture) were found to have significant potential for abatement. Sector analysis summarized in the preceding chapters of this report resulted in a selection of a short list of measures that constitute a green policy package in each sector. The mitigation measures from this list are evaluated in the MACC analysis. The timeframe of 2015–2050 is driven by Romania's EU commitments: the current 2030 climate package, for which most details have been agreed, and the Roadmap 2050. The long run target of 2050 is central in the analytic work of the assessment, because the 2030 targets do not require much additional effort from Romania.

The Romania MACC ranks the selected measures from most cost effective to least cost effective. The top measures in both cost effectiveness and abatement potential are in energy demand and electricity supply; however, several other measures also provide significant benefits, particularly in forestry and agriculture. Measures in transport are more expensive and provide more limited abatement. Green actions across the four sectors have the potential to reduce emissions in the country by 38 $MtCO_2e$ in 2050, an equivalent of a 23 percent decrease from the level projected in the baseline in 2050. The largest share of abatement—45 percent of the total—is projected for electricity supply. Energy demand will provide a third of the overall abatement, agriculture and transport close to one-tenth, and forestry five percent. The unit cost of abatement ranges from €–78/tCO_2e in energy demand, to €16/tCO_2e in energy supply, €–0.1/tCO_2e in forestry, €12/tCO_2e in agriculture, and € 154/tCO_2e in transport.

CHALLENGES OF GREEN GROWTH ASSESSMENT AND MARGINAL ABATEMENT COST CURVES

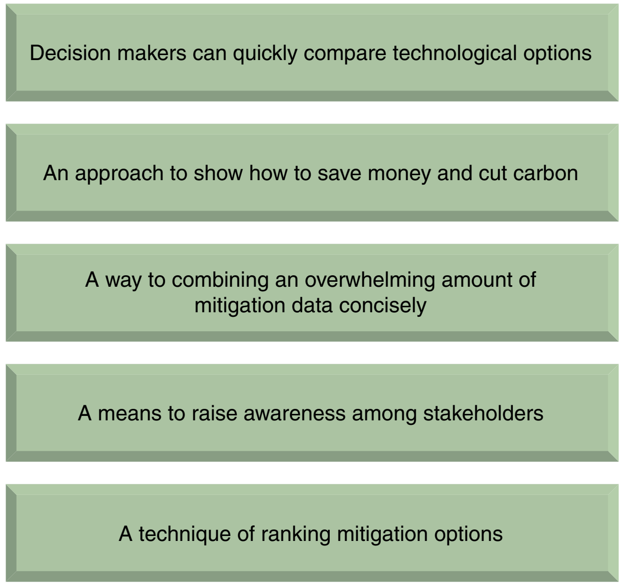
Marginal Abatement Cost Curves (MACC) have become a commonly used tool in evaluating emission reduction technologies, presenting them in terms of their potential greenhouse gas mitigation impact (emissions abated) and unit cost (cost per ton of CO_2e abated). They are also considered to be a most efficient communication instrument used in discussions of the abatement policies. In the 5th Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), published in 2014,[1] MACCs are described as a standard policy communication tool in assessing emission reductions and their cost effectiveness and one of "major approaches to reveal the economic potential of mitigation measures." In addition, they are an efficient way to present complicated mitigation data in a clear way and a concise format, accessible for all audiences, including nontechnical stakeholders. MACCs are specifically useful for decision makers, who, due to time limitations, cannot study the details of research and analysis of green technologies and who usually make decisions on the basis of briefs and summaries. MACC charts are designed to be a "brief": they compare technologies to be considered for implementation in a simple (easy to comprehend in a limited time) but informative way. (Figure 9.1)

How can MACCs increase the quality of decisions regarding prioritizing abatement measures? Clearly, they support budgeting decisions by showing the cost per abatement unit of various measures and compare abatement potential of measures relative to each other and across sectors. MACCs also facilitate more detailed reviews of the mitigation measures. First, the way the measures are presented (ranked by unit cost and not grouped by sector) helps discussions of various combinations of measures cross-sectorally, increasing the efficiency of the resulting mitigation program (lowering its cost and maximizing abatement) and leading to budgetary savings. Second, MACCs produced for different time periods (e.g., 2020, 2030, 2040 and 2050) help to schedule the implementation of the measures, and this is especially important because green growth requires long-term planning and also because the sequence of measures affects the level of the total effort needed, both in terms of the overall cost and institutional support. MACCs produced for different time periods help realize that some measures provide benefits faster than other measures, and the implementation should be scheduled accordingly. For example, energy demand actions provide swift returns, but energy supply actions require large up-front investments with benefits delivered years into the future. Forestry measures require a stable investment flow, and benefits occur with a time lag but increase over a

1. Mitigation volume, Chapters 3 and 7.

FIGURE 9.1. Why are Marginal Abatement Cost Curves used?

A simple graphic of MACCs

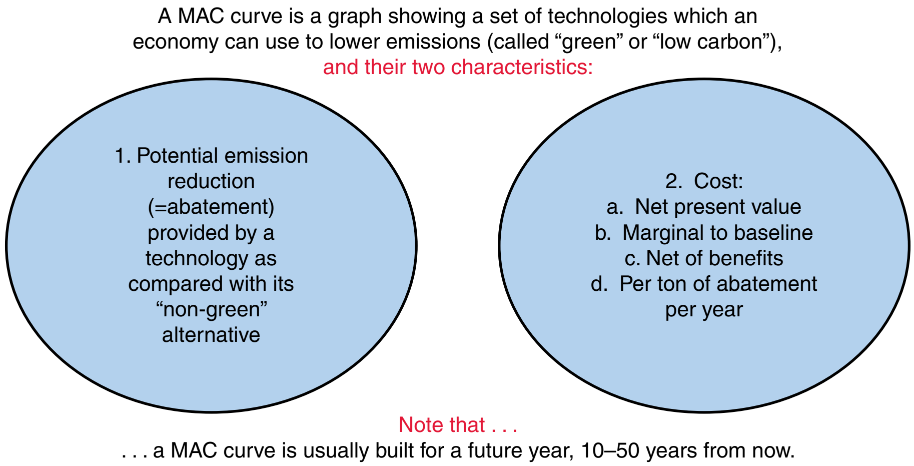


long term. This is reflected in a set of MACCs produced for different periods. With this knowledge, investments can be scheduled in an efficient way to guarantee that the results are achieved sooner rather than later and to maximize the present value of the benefits long term, a standard approach for green growth and climate change studies.

However, MACCs also have several limitations. They do not reflect all costs of the abatement measures. A way to think about it is to rationalize the negative net costs of some of the measures that can be seen in various MACCs. Such negative net costs are typical for energy efficiency and forestry measures, but can appear as characteristics of abatement options found in other sectors as well. If the net costs are negative, does it means that benefits exceed costs and the measures should be implemented with a profit, making them an investment opportunity for the private sector. However, it does not happen because there are hurdles (both financial and nonfinancial) that are not captured by the MACC analysis. First, there is a cost of making an up-front investment. While such cost is lower for energy efficiency measures than for many other types of abatement interventions, it can be quite large for the household or business who would implement a measure. Second, there is a principal-agent problem (such as the owner, operator, occupant, and bill payer of a building are separate entities). Third, there is a problem with information about the measures, the benefits they bring and the ways to receive subsidies. Fourth, there is a cost of implementation among a large number of small entities (households, businesses). In addition to these hurdles, MACCs do not support nonfinancial decisions related to implementation of the abatement measures, including capacity building, behavior change effort, reactions of nongovernmental stakeholders, and other institutional considerations, and this has an implication for ease of implementation. While being useful for decision makers, MACCs do not supply complete information needed to select technologies, but rather provide a quick insight into the subject. More information is needed to make an implementation decision or have an informed discussion.

FIGURE 9.2. What is a Marginal Abatement Cost Curve?

Characterisics of a MAC curve



MACCs are charts showing a set of technologies that would reduce emissions from economic activities. The technologies can be presented one by one or at various levels of aggregation, including by blocks of technologies within a sector (e.g., demand-side energy sector technologies), by economic sector (e.g., energy or transport), or even by groups of sectors (e.g., ETS sectors). In the MACC, each technology has two characteristics: the level of abatement, $MtCO_2e$, which equals the difference in emissions produced by the new technology as compared to the technology it replaces (abatement potential) and the cost of the technology per unit of abatement, €/tCO_2e. The cost is computed in the following way. First, it is calculated as the net present value of the flow of investment and operational costs over the period of time from the base year (today or in the recent past) to a year in the future, which is selected as the final point of time for projections, e.g., 2050 or 2030.[2] Second, the cost is calculated as marginal cost of technology replacement; as such, it equals the difference in cost between the new "green" technology and the current "non-green" options. Usually, the difference in cost is a positive number because new technologies tend to be more expensive than the old ones, but there are exceptions. Third, the cost is computed as net of benefits, which could also push the resulting net cost into negative numbers. In cases when the net marginal cost is negative, the technology is depicted on the left side of the chart, among the technologies that provide net benefits[3] (Figure 9.2). The technologies in the MACC chart are ranked using the second characteristic, the unit cost of abatement. The abatement potential is usually presented for a year in the future, e.g., 2050. It is also common to present cumulative abatement potential, combining expected abatement for all the years between the present and the final year in the projections, e.g., 2015–2050. MACCs are produced using modeling, and an overview of modeling approaches to MACC creation is presented in Box 9.1.

2. MACCs usually have a long timeframe because many of the measures require years or even decades to implement and the benefits are fully realized with a time lag from the conclusion of the implementation.

3. This issue has been extensively discussed elsewhere. A commonly asked question is why the green options that presumably provide net revenue are not being implemented by the private sector. The answer is that they do not provide net revenue: the MACC costs only include direct costs of the technology (e.g., in electricity supply, it would be costs of building and operating a power plant), but do not include other costs, such as transaction costs, financing hurdles, high up-front costs, the costs of information failure, or nonfinancial costs (e.g., in housing energy efficiency, the costs of inconvenience of moving out of one's house or tolerating construction noise).

BOX 9.1. Overview of MACC approaches

Multiple methodologies are available

Marginal Abatement Cost Curves are created through modeling, which is used to calculate two characteristics of the technologies used in MACCs: unit cost and abatement potential. Prior to modeling, a list of technologies should be created, and a baseline defined, since both costs and abatement are calculated marginally to the baseline.

The first stage of MACC analysis is the selection of greenhouse gas mitigation technologies to replace existing or standard ones. MACCs can be built at a sector (or subsector) level, for the economy overall, or even globally. If more than one sector is to be included, then sector selection comes first, followed by selection of technologies within those sectors. It is recommended to involve stakeholders at this step to have in-country information regarding barriers to technology transfer and measures to address these barriers, such as regulation, fiscal and financial incentives, and capacity building. Consultations are usually conducted in the form of workshops. Also, it can be useful to increase awareness using dissemination of technology information, expert lectures, visits, and demonstration projects.

Modeling to estimate the marginal cost and abatement potential of each technology is the second stage of the MACC analysis. Three basic modeling approaches to constructing MAC curves are: a bottom-up individual assessment of technologies/abatement measures, bottom-up system modeling, and top-down macroeconomic system modeling. Hybrid approaches are also being used.

The individual technology approach is the most common, despite some flaws. In this approach, abatement costs are defined at a technology level, commonly using cost-benefit models and often involving expert opinion. Each technology's costs and abatement potential are evaluated separately, and the total is the sum of the individual technology characteristics. The problem with a technology-by-technology approach is that in real life, climate policies overlap, implementation costs vary, and sector-specific policies can interact with each other. As a result, this approach can cause problems such as negligence of technical, behavioral, intertemporal and economic interactions, double counting, limited coverage of costs, path dependency, agency issues, and a limited treatment of uncertainty. On the other hand, this approach is popular and has been widely used, including by McKinsey & Company management consultants and by the Government of the United Kingdom. It is the most common approach to constructing a MACC, mainly due to its transparency, the relative ease in understanding the calculations and outcomes, and lower costs.

System modeling approaches are receiving increasing acknowledgement. System modeling (both bottom-up and top-down) can include interactions among technologies and policies in the construction of a MACC, allowing assessment of the complicated joint impact of many variables that determine costs and emissions. For example, bottom-up models in transport take into account vehicle ownership and travelled distance; include energy demand for all modes of transport (air, cars, buses, heavy goods vehicles, light goods vehicles, rail); and track fuel use by vehicle technology (internal combustion engine, hybrid, plug-in, battery, other).

In a top-down macroeconomic (or computable general equilibrium) model, emissions can be modeled via fuel use, and fuel emission coefficients and then constraints on emissions can be introduced with the price (cost) of emissions balancing demand and supply. However, system modeling is highly complex, often lacking in transparency, and difficult for non-experts to understand.

Recently introduced advanced approaches hold promise but increase the complexity of MACC construction. Such approaches include generating MACCs by combining system modeling, decomposition analysis, and uncertainty analysis. Another recent approach aiming at a better assessment of abatement costs suggests that top-down models should include an explicit representation of abatement technologies with options such as production factor substitution, output demand reduction, and installation of abatement equipment other than fuel substitution.

METHODOLOGY AND FINDINGS

Methodology

The Romania MACC analysis presents a cross-sectoral outlook of the benefits and costs of the green technologies/measures that are recommended on the basis of the sectoral modeling and analysis for the time period 2015–2050.[4] The MACC analysis is the last step in the Romania Green Growth Country Assessment and is connected and coordinated with the preceding modeling and analysis. It uses the technologies/measures recommended by that analysis and the same input data, but only mitigation measures are represented in the MACC: energy supply, energy demand, transport, agriculture, and forestry. Urban measures are not included in the MACC to avoid double counting: urban green measures are mainly a combination of transport and energy sector interventions at the urban level, and these two sectors are already represented in the MACC. The timeframe is driven by Romania's EU commitments: the current 2030 climate package, for which most details have been agreed, and the Roadmap 2050. The long-run target of 2050 is central in the analytic work of the Country Assessment, because the EU's 2030 targets do not require much additional effort from Romania.

4. Chapter 3, Chapter 4, Chapter 7, and Chapter 8.

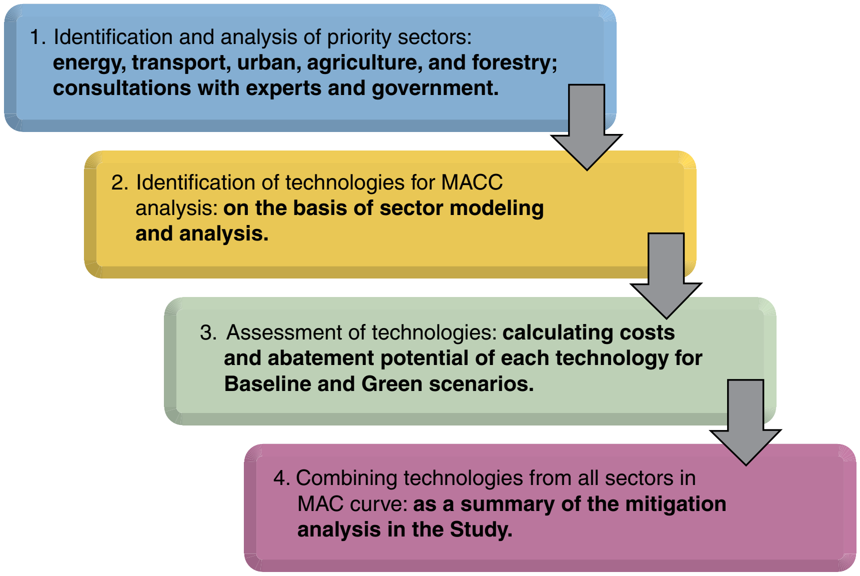
Romania's energy, forestry, agriculture, and transport sectors all demonstrated potential for abatement in the preceding sector analysis. In the energy sector, while the country has a relatively high and growing share of renewable sources in power generation, energy supply remains dominated by fossils fuels, with more than a third of primary energy supply in coal and oil and another third in gas. The remaining third is almost equally divided between nuclear and biofuels. At the same time, the country has some of the best wind resources in Europe, which, combined with the low price of wind power, creates an opportunity for abatement. Also, bioenergy resources are significant and should be utilized to lower emissions from the energy sector (since the emission factor of bioenergy is less than half that of coal). Energy supply-side measures take a long time to implement, but the horizon in the Assessment of 2050 provides enough time for benefits to be realized. Afforestation is a central measure in forestry and promises to provide high abatement at a negative net cost (with benefits exceeding costs in the long term). Forest management is a critical preventive measure, aimed at keeping trees healthy and able to sequester maximum carbon. Agriculture measures would support the abatement of carbon dioxide, methane, and nitrous oxide; these are low cost measures with a high abatement outcome. Finally, in transport, regulatory measures could be used to create incentives for households and businesses to buy less emission intensive vehicles and reduce the frequency and length of driving.

The preceding sector analysis selected a short list of mitigation measures that constitute green packages for 2015–2050 in each sector and that can be evaluated in the MACC analysis. This approach provides consistency between the sector analyses and the MACC analysis. Also, this approach supports a more detailed discussion of the mitigation measures (since the measures are described in detail in the sector chapters), as opposed to a more superficial overview of a broader set of available, but not necessarily recommended, technologies.

Romania's MACC is a combination of sectoral curves, each of which was built using the most appropriate approach for each sector. The approach used in each sector depends on data availability, accessibility and quality, as well as on the availability of the models. For electricity supply, the specifications of the curve (potential abatement and cost of the generation technologies per unit of abatement) were calculated using the TIMES energy supply model, which was also used for energy supply analysis (see Chapter 3). For energy demand, a bottom-up detailed engineering model was used (see Chapter 3). In forestry, agriculture, and transport, a bottom-up Excel-based approach was used, and the measures were evaluated individually. In both agriculture and forestry, the calculations were based on detailed sector data provided by Romanian experts. In transport, local data were not available for many of the measures because there is no experience with these measures in the country; therefore, data from comparator countries were used. As a result, transport sector estimates are based on a combination of local and global data. In all sectors, the timeframe for the analysis was 2015–2050. Discounting was used for both net costs and emissions. The same discount rate used in the sector modeling was applied to the MACC calculations, ranging from three percent in forestry to five percent in energy—typical social discount rates. Costs (before discounting) are in real terms, and the base year for discounting is 2015. The overall process of building a MACC for Romania is reflected in Figure 9.3.

FIGURE 9.3. Building a Marginal Abatement Cost Curve for Romania

Process steps in the MACC



Key green technologies in electricity supply for Romania were identified using a system model TIMES.[5] In the MACC analysis, the model helped determine the marginal cost and abatement potential of each of the following eight green (renewable or low carbon) generation options: solar photovoltaic (solar PV), concentrated solar power (CSP), more hydropower (as compared with installed capacity), more wind, biomass, natural gas plants with installed carbon capture and storage (gas with CCS), coal plants with carbon capture and storage (coal with CCS), and nuclear power. The model constructed the best (minimum cost) mix of generation sources to achieve a desired abatement level in eight different cases, corresponding to eight green generation technologies. This meant eight scenario runs, one for each of the green generation options. The abatement level was set as a constraint, and each scenario maximized generation from one out of the eight generation sources, considering many other variables/constraints in the model: production/transformation facilities; transportation, transmission, and distribution networks; various resource, technical, socioeconomic, environmental and other constraints including the size of the plants, their capacity factor, and the need for back-up capacity. For example, in scenario 1, solar PV was set to be maximized in the electricity supply system, and the rest of the generation technologies were selected by the model. The model also calculated the cost of such a system and the cost of the baseline system. The difference between these two costs constituted the marginal cost, which was then converted into net present value.[6]

5. TIMES (an acronym for The Integrated MARKAL-EFOM System) provides a technology-rich basis for estimating energy dynamics over a long-term, multi-period time horizon. The model performs multiyear optimization (computing the least cost path of an energy system for the specified time frame) and can be used to test a series of policy options, such as CO_2 constraints, taxes or subsidies.

6. The energy sector MACC analysis differs from the energy supply optimization analysis described in Chapter 3. As compared with the MACC approach for energy supply, the energy supply optimization analysis in Chapter 3 uses all available technologies as an input, then optimizes the projected generation structure based on costs, demand and resource constraints and proposes a particular "best" structure of generation, which does not necessarily include all technologies.

The energy supply model is data intensive, and the input data included a number of variables. These variables include those related to energy demand (GDP, population, households, and elasticities of demand), primary energy and material resource potential and costs, policy settings (emission restrictions, emission taxes, and subsidies to technologies), and a description of technologies (or processes) that transform commodities (fuels, materials, energy services, and emissions). The key data sources were Eurostat, the World Bank, International Energy Agency, and World Energy Resources. In addition, the energy demand data from the bottom-up demand model developed in-house to compute energy demand by various types of energy consuming services was used.

Key technologies in energy demand and related calculations for the MACC used an Excel-based bottom-up model and are based on very detailed data. The MACC for energy demand includes end-use energy efficiency improvement to be applied in the household sector, because these measures bring the most immediate and effective (with high potential abatement) results. Energy consumption in the household sector includes all energy using activities except personal transportation. Common end-uses associated with this sector include space heating, water heating, cooking, lighting, air-conditioning, refrigeration and running a variety of electric and nonelectric appliances. Future energy consumption in the residential sector is driven by various factors, including changes in population, urbanization rates, household income, dwelling size and type, dwelling floor area, energy mix, energy efficiency of appliances, appliances diffusion rate and standards, and household preferences and behaviors.

The approach used for energy demand required collecting a wide range of data, which can be grouped into three categories: energy consumption data, socioeconomic and demographic data, and technology data. Socioeconomic and demographic data includes population, household size, and housing stock attributes. Technology data includes technology penetration, emissions intensity, and unit costs. The data were collected from many different sources including several national, regional and international publications and, in particular, Romania's National Institute of Statistics, the EU's Eurostat, and the World Bank's World Development Indicators. Household activity parameters were used to project future end-use service demand. With a base year of 2015, the projections of end-use service demand were made through the year 2050 in five-year intervals.

The energy demand model used a simple Excel-based bottom-up framework for projecting the penetration of each technology during the period of 2015–2050 under two scenarios—Baseline and Green. The Baseline scenario reflects a moderate view of future energy demand based on a continuation of current trends and provides a useful point of comparison for the impacts of choices and/or of changes in alternative low carbon policies. In the Baseline scenario, population increase and economic growth are the key driving factors that influence the outlook of energy demand in the household sector. The Green scenario is designed to reflect the EU's energy and climate strategies, including the 2030 Climate and Energy Policy Framework and the 2050 Roadmap for moving to a low carbon economy. The Green scenario includes two phases: the first one runs from 2015 to 2030 and follows the EU 2030 strategy. The second phase follows the EU's 2050 Roadmap and runs from 2030 to 2050. The Green scenario involves increased (as compared with the Baseline scenario) energy efficiency improvements by households. Major energy efficiency improvement measures include use of more efficient lighting and electric appliances; retrofitting buildings with wall, window and roof insulation; and heating and air conditioning system improvements.

Key technologies for mitigation in forestry focus on CO_2 sequestration, achieved through planting more trees and supporting forest health through sustainable forest management. The main mitigation measures selected in the Romanian forestry sector as a result of the sector analysis are afforestation, sustainable management of production forests for timber, and sustainable management of protection forests.

- Afforestation of agricultural lands helps with both mitigation and adaptation to climate change. New forests contribute to CO_2 sequestration; they also, if established as forest belts, can support adaptation. Afforestation of degraded or abandoned lands is still the main option for mitigation in the forestry sector in Romania due to the large area where such measures are applicable. The degraded lands inventory, conducted by the Ministry of Agriculture and Rural Development in 2012, estimated that approximately 115,000 hectares or 14 percent of degraded land is suitable for afforestation.
- Improving sustainable management of production forests will increase forest yields. Romania lags behind many EU and other countries in its forest rotation, which is too long and exceeds 100 years for most indigenous species of forest trees. The proposed measure shortens the average rotations for the most important forest species, which will mean less disturbance and more valuable and healthy trees available for harvest. The results could be significant: in 10 years, yields can increase by 10 percent.
- Enhancing protected area management will also improve greenhouse gas mitigation from forests. Romania has an obligation to meet the directives associated with Natura 2000, the network of nature protection areas in the EU. To achieve Natura 2000 objectives, there is the need for Romania to develop a simpler way of compensating private property holders, clarifying how compensation is determined, and identifying a way to compensate communities managing public lands.

Key technologies in agriculture comprise two mitigation measures: minimum tillage and manure management. The 'no tillage' measure reflects the benefits of of avoiding desertification by eliminating tillage in agricultural fields; and the area covered by the measure is based on arable land susceptible to desertification. Manure management or "composting manure" aims to counter the poor manure management (collecting, storage, treating, applying) of the past. Farmers taking up this measure adopt stringent practices on storage and treatment of manure, which generates greenhouse gas savings per animal (rather than per hectare).

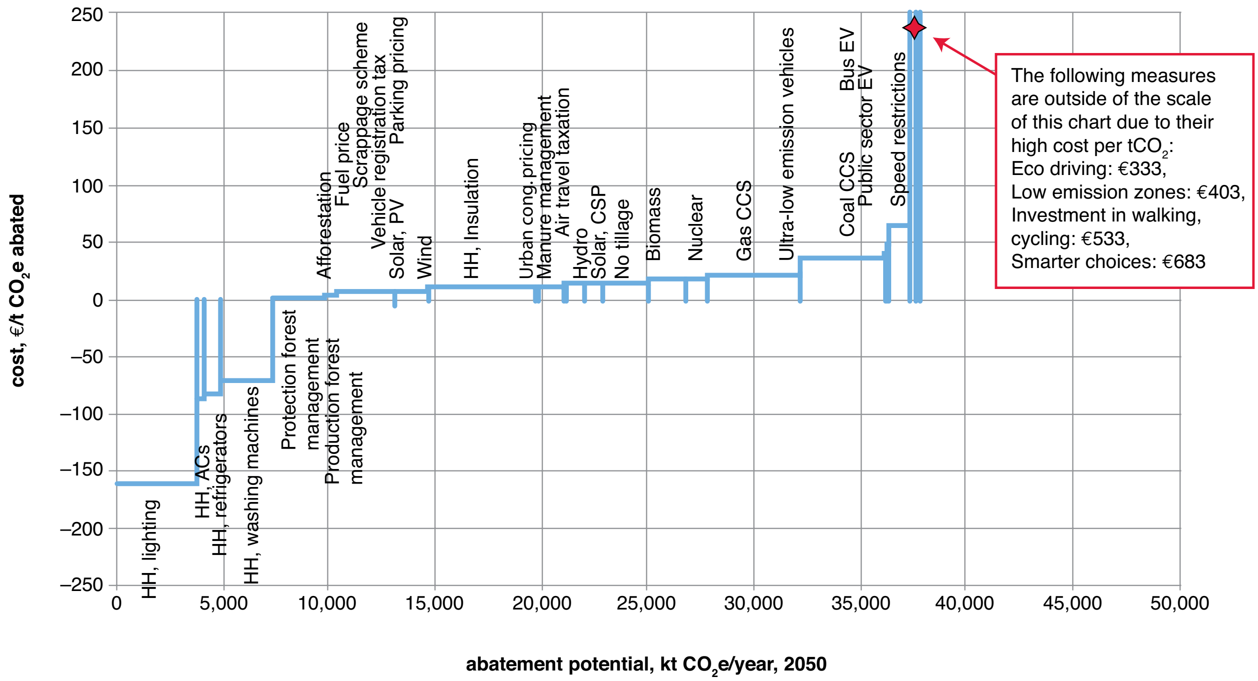
In contrast with the other sectors, key mitigation measures in the transport sector are policies rather than technological interventions. The sector analysis identifies a wide range of measures including pricing instruments, technology, regulatory measures, operational efficiency measures, and investments. The transport MACC data were collected from various sources including the National Transport Model, an EU model TREMOVE, EUROSTAT, and some other sources. Most of the transport measures included in the analysis have high costs of abatement, the average cost is much higher than in other sectors and equals €154/tCO_2e abated, but they also deliver valuable (but difficult to quantify) co-benefits.

Findings

The outcomes of the analysis are presented in the cross-sectoral MACC chart (Figure 9.4) and in Table 9.1. The chart includes the main options for abatement in four sectors—energy, forestry,

FIGURE 9.4. **Energy efficiency and forestry measures deliver net benefits while energy supply measures deliver substantial mitigation**

Romania Marginal Abatement Curve, cross-sectoral, 2050, Super Green scenario



Note: How to read the MACC. The height of each column shows the average cost of abating one ton of CO_2e by 2050. The chart is ordered from left to right from the measures with the lowest cost to the ones with the highest cost. The width of each column shows the GHG emission reduction potential of the measures in year 2050, when all the measures have been fully implemented. See sector technical reports for discussion of technologies. Calculations use a tool developed at the World Bank.
Source: MACC technical report.

agriculture, and transport—and the two characteristics of these options: net present value of their cost over the period 2015–2050 and the abatement they are projected to provide in year 2050 when the implementation is completed and the benefits are fully realized. This longer time frame is necessary to capture the full benefits in the calculations. Total annual abatement in year 2050 reaches 38 $MtCO_2$e. The chart shows that several household energy efficiency and forestry measures have negative net costs (because benefits exceed costs), including energy efficient lighting, energy efficient air-conditioning, energy efficient household appliances (refrigerators and washing machines), and protection and production forest management. Also, several technologies in power supply and demand, forestry, and transport have positive, but very low costs, including afforestation, scrappage scheme, solar PV, wind, and housing insulation. The least cost-efficient technologies are in the transport sector and include eco driving, low emission zones, and walking and cycling zones.

A review by sector shows that energy efficiency measures are most beneficial because they have both high abatement potential and low, even negative, net cost. Electricity supply measures also deliver significant abatement at a relatively low (but positive) cost. Forestry provides large abatement potential. Agriculture measures—no tillage and manure management—are relatively cost efficient; they also promise to provide a significant abatement benefit. Transport measures, however, mostly have very high costs and, at the same time, limited abatement potential. This finding is consistent with transport MACCs constructed for other countries and is explained by the nature of transport mitigation: transport measures have multiple objectives apart from abatement, including reduced pollution, lowered traffic, controlled noise, reduced number of accidents, and improved quality of life. Abatement is not necessarily the main objective or the main benefit of these measures; for example, urban congestion control is generally aimed at economic and social development (urban growth and improved quality of life). Therefore, the transport measures have many valuable co-benefits such as avoided traffic injuries (including saved lives) or potential municipal budget revenue from developing urban business-friendly infrastructure. However, including these co-benefits in the calculation of net cost is outside the scope of this assessment: no precise estimates of most such co-benefits are available.

The energy sector provides the most cost-efficient measures and the highest overall abatement. The most effective measure (providing the highest abatement potential) in energy demand is building insulation, followed by efficient lighting. In electricity supply, the highest abatement can be achieved from electricity generation using natural gas plants with installed carbon capture and storage (gas with CCS), and a similar level of abatement will result from the expanded usage of coal-fuelled plants with carbon capture and storage (coal with CCS). Among renewable energy options, the highest abatement potential is in wind, followed by biomass, then solar PV, then hydropower generation and CSP. Development of nuclear generation could also provide abatement, in an amount comparable to hydropower generation. The most cost-efficient electricity supply options are solar PV and wind, followed by hydropower, solar CSP, biomass, and nuclear. Gas with CCS would require higher expenses, and coal with CCS is the most expensive option, reaching €40 per tCO_2e abated. Several demand-side measures provide absolute net benefits (or have negative net costs); these include the recommended measures to expand usage of efficient lighting, efficient air-conditioning, efficient refrigerators, and efficient washing machines.

CONCLUSIONS AND RECOMMENDATIONS

The MACC work derives from the analysis and modeling of all the relevant sectors in the Country Assessment. The MACC chart is simply a presentation of the findings of the sector work, transformed using the MACC approach. When the MACC data from all sectors is put together in one chart, it creates a clear and simple cross-sectoral picture of the costs and benefits of green measures, relative to each other. The MACC analysis is based on a detailed sector analytic and modeling work that identified the areas where mitigation efforts would be most effective and proposed particular mitigation measures for implementation. For each of the selected mitigation measures, the parameters for the MACC curve—the unit cost of abatement in the period 2015–2050 and the potential for abatement in 2050—were estimated. The resulting MACC ranks the selected measures from most cost effective to the least cost effective. The top measures in both cost effectiveness and abatement potential are in energy demand and electricity supply sectors; however, several other measures also provide significant benefits, this relates to forestry and agriculture. Measures in transport are expensive and characterized by a limited abatement, an outcome that might alter if a reliable methodology of estimating the cost of a wide range of transport sector externalities is developed and applied (a task outside of the scope of this analysis).

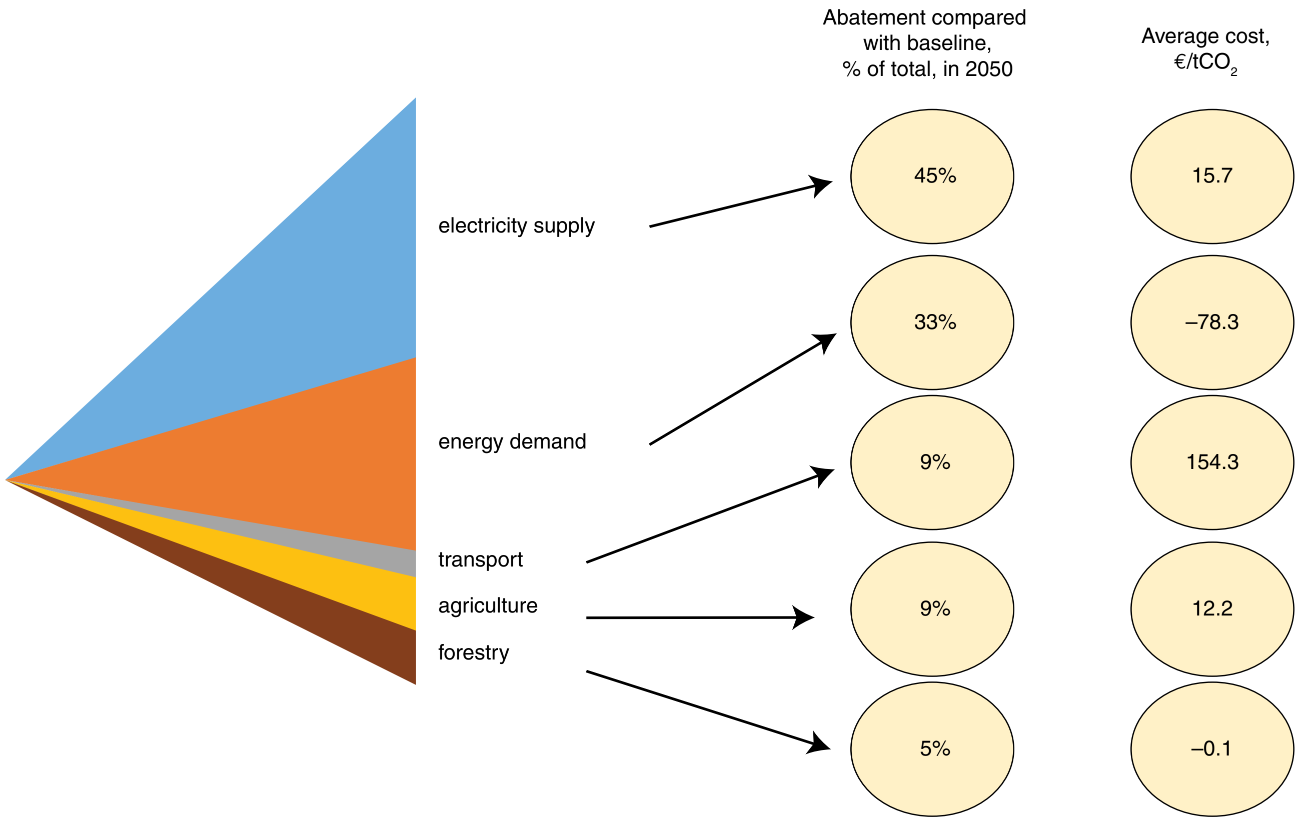
Green actions across the four sectors will reduce emissions in the country by 38 $MtCO_2e$ in 2050, an equivalent of a 23 percent decrease from the level projected in the Baseline for 2050. The largest share of abatement—45 percent of the total—is projected for electricity supply. Energy demand

will provide a third of the overall abatement, agriculture and transport close to one-tenth, and forestry five percent. The abatement potential and the average costs in each of the five sectors analyzed are also reflected in Figure 9.5. They range from €–78 (negative cost) per ton of CO_2e abated in energy demand, to €16/tCO_2e abated in energy supply, to €–0.1/tCO_2e abated in forestry, to €12/tCO_2e abated in agriculture, and to €154/tCO_2e abated in transport (Figure 9.5). Costs of each measure are in Table 9.1.

The Romania MACC can increase the quality of decisions regarding prioritizing the proposed abatement measures. In addition to supporting budgeting decisions by showing the cost per abatement unit of various measures and comparing abatement potential of measures relative to each other and across sectors, it can support decisions regarding the implementation of the proposed green actions. MACCs help realize that some measures provide benefits faster than other measures, and the implementation should be scheduled accordingly. In particular, the Romania MACC can help to schedule investments in an efficient way to maximize the present value of benefits over the long term, a standard approach for green growth and climate change studies. In the case of Romania, not surprisingly, the MACC shows that the scheduling of green actions should start with energy efficiency measures because they have the lowest (negative) net cost, low investment cost, bring benefits very quickly, and have low implementation barriers. Next, the measures in forestry also need to be scheduled to start early on. They have a relatively low annual cost, require no upfront investment, and, while benefits occur with a time lag, they accumulate in the future, so an early start is possible

FIGURE 9.5. The highest abatement potential is in energy supply, and costs in energy demand and forestry

Emission reduction by sector, 2050, Super Green scenario and average cost of the green measures, 2015–2050



and desirable to maximize the benefits. These are no-regret measures. Measures in energy supply, *vice versa*, require large up-front investments with benefits delivered years into the future and implementation requiring strategic, complicated, and politically charged decisions. In the case of energy supply measures, the MACC provides only one element of a very large and complicated picture needed to make decisions. In transport, the proposed measures have high unit cost, and their implementation should be guided by co-benefits (benefits other than emission reduction); they should be implemented where and when they can bring important health benefits (by lowering pollution), reduction in the rate of traffic accidents, decrease in traffic congestion, and improved quality of life.

TABLE 9.1. Abatement costs and abatement potential vary substantially across measures

Abatement cost and potential, by measure

SECTOR/MEASURES	ABATEMENT COST, €/tCO_2e, 2015–2050	ABATEMENT POTENTIAL, SUPER GREEN COMPARED WITH BAU, kt CO_2e/YEAR (2050)
Energy demand		
Households, efficient lighting	–161	3,790
Households, efficient ACs	–87	294
Households, efficient refrigerators	–82	816
Households, efficient washing machines	–71	2,445
Households, Insulation	9	5,037
Electricity supply		
Solar photovoltaic (PV)	5.0	1,552
Wind	6.9	2,686
Hydropower	12.5	896
Concentrated Solar Power (CSP)	14.2	854
Biomass	15.6	1,702
Nuclear	15.9	1,065
Gas with carbon capture and storage	19.7	4,357
Coal with carbon capture and storage	36.1	3,884
Forestry		
Protection forest management	–0.23	900
Production forest management	–0.04	568
Afforestation	0.11	360
Agriculture		
No tillage	14.4	2,172
Manure management	10.0	1,200
Transport		
Fuel price	0.13	581
Scrappage scheme	0.36	1
Vehicle registration tax	2.28	596
Parking pricing	3.01	55
Urban congestion pricing	9.60	143
Air travel taxation	11.84	101
Ultra-low emission vehicles	26.19	89

(continued)

TABLE 9.1. Continued

SECTOR/MEASURES	ABATEMENT COST, €/tCO_2e, 2015–2050	ABATEMENT POTENTIAL, SUPER GREEN COMPARED WITH BAU, kt CO_2e/YEAR (2050)
Public sector electric vehicles	38.54	93
Electric buses	46.77	116
Speed	64.77	956
Eco driving	337.97	241
Low emissions zones	402.72	159
Investment in walking, cycling	533.24	70
Smarter choices	683.31	35

conclusions

The Romania Green Growth Assessment outlines a green growth path for the country for the period from 2015 to 2050. The report was prepared on the basis of technical economic analysis—including macroeconomic modeling, sector modeling and analysis, benchmarking analysis and marginal abatement curve analysis—to recommend particular green measures relevant for Romania and estimate their costs over the modeling timeframe.

This report presents the technical outcomes of the Romania green growth modeling and analysis in language for a non-technical audience of green growth reform stakeholders, both within the government and outside it. In today's world, where climate change has become a serious factor of development, green growth decisions and action are essential for all countries and should be embedded in economic policy making. In the past decades, understanding of climate change mitigation and adaptation has evolved in separate technical disciplines. Translating scientific and socio-economic knowledge into economic policies and actions and integrating knowledge across sectors is essential and there is an urgency for doing so, considering the pace of climatic changes and the expected damage from climate change in the absence of global and local action. This report was designed as a tool for such communication and aims at presenting the outcomes of technical analysis to policymakers, government officials, experts outside of government, and the general public.

Government must make a commitment to ongoing and ever-improving in-country analyses to provide up-to-date assessments for policy decisions. While the outcomes of the Romania Green Growth Assessment are expected to be applied in designing greener economic policies today, policymakers and other stakeholders need to keep in mind that the methodologies used in this Assessment evolve continuously, the situation on the ground changes and data collection techniques improve, and approaches to address uncertainties progress. Analysis needs to be repeated regularly using the newest methods, data, and models. Therefore, the value of this Assessment, in addition to outlining a green growth path today, as a combination of a particular set of recommended actions, is in providing a set of re-usable and updateable assessment tools and models to the government. Using new data, the Romanian government can update the projections and the recommendations. Also, with time, new versions of the tools and models will become available, and the current ones should be updated and eventually replaced.

There are several types of uncertainties in green growth modeling, and repeated updates of the analysis are a reliable way to reduce them. First, technical progress creates an enormous source of uncertainty over the 35-year horizon. Technological breakthroughs could substantially decrease the costs of climate action. Secondly, global developments—on natural resource prices and on global economic growth—will drive local costs and benefits but are almost impossible to predict. Third, projections of the global climate models vary considerably—more pessimistic climate developments translate into higher economic losses in the future and larger benefits of adapting. Fourth, 'adaptive capacity' determines how well countries cope with a changing climate, but a precise definition that would allow this factor to be integrated into analysis is lacking. Updating analysis using new data, methods, techniques, and models is a guaranteed way of significantly lessening the uncertainties of the green growth assessments produced today. Despite technical complexity and the ongoing need for revision, policy makers and other stakeholders need to keep in mind that the value of green growth assessments is continuously translating knowledge into decision making and action.

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Romania faces requirements to cut its greenhouse gas emissions as a member of the European Union and also opportunities for adapting to coming climate change. This Green Growth Country Assessment for Romania draws a green growth path from 2015 to 2050, based on technical economic analysis—including macroeconomic modeling, sector modeling and analysis, benchmarking analysis and marginal abatement curve analysis. The assessment proposes mid- to long-term interventions for the energy, transport, urban, water, agriculture, and forestry sectors while maintaining economic growth.

A greener energy sector needs to accelerate the transition towards low carbon fuels and away from coal while improving energy efficiency (on a path guided by demand and supply-side energy modeling). Limiting the growth of emissions is a tough challenge for the fossil fuel-dependent transport sector, especially as Romania's motorization rate converges with the EU average. New transport policies and significant investments are needed in both public and private transport to limit emissions growth. The challenges of emissions intensity are magnified in urban areas in the wake of fast-sprawling development. Data-intensive geospatial modeling of the Bucharest region estimates the contributions to mitigation of more compact city design, transport-oriented development, and more efficient vehicles and buildings.

At the same time, Romania needs to adapt to coming climate change. A warmer dryer climate will threaten water availability in many river basins in summer when irrigation demands are high and rising. Innovative modeling of water quantifies the tradeoffs that will be needed to balance competing demands from agriculture, the power sector, and municipalities and industry and proposes affordable adaptation actions in water and agriculture. Next, Romania's expansive forests are found critical to removing emissions, but a changing climate threatens forests' ability to sequester carbon, arguing for policy action.

Economy-wide macroeconomic modeling provides an integrated multi-sectoral assessment of a greener and low carbon path, concluding that the upcoming EU 2030 framework for climate policy is affordable although challenging for Romania, but the prospective EU Roadmap 2050 will prove expensive and demanding. To assist with government planning, the investment costs to 2050 of low carbon green growth have been estimated. An average annual 1.2 percent of GDP of additional investment will be needed to meet the EU's 2030 targets and 2.0 percent to meet prospective 2050 targets. Importantly, the likely share of public investment is modest. These estimates are based on available data and today's technology considered practical for green action. New technologies will certainly emerge over coming decades that will change these costs and benefits, providing an important reason why governments need to update such analysis periodically.

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