ESMAP

Energy Sector Management Assistance Program

Briefing Note 009/11

Transition to a Low Carbon Economy in Poland

LOW CARBON GROWTH COUNTRY STUDIES PROGRAM

MITIGATING CLIMATE CHANGE THROUGH DEVELOPMENT

CARBON FINANCE ASSIST

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TABLE OF CONTENTS

TRANSITION TO A LOW CARBON ECONOMY IN POLAND

After 500 years, the global average temperature is projected to increase by 6.2°C over the 1900 global climate. While we have only the foggiest idea of what this would imply in terms of ecological, economic, and social outcomes, it would make most thoughtful people—even economists—nervous to induce such a large environmental change. Given the potential for unintended and potentially disastrous consequences, it would be sensible to consider alternative approaches to global [climate] policies.

William Nordhaus, 1997

Transition to a Low Carbon Economy in Poland is a study by the World Bank for the Polish Government, supported by the UK Department for International Development and donors to the Energy Sector Management Assistance Program (ESMAP). The study poses the question of how Poland, an European Union (EU) member state, an industrialized "Annex 1"[1] country for the purposes of international climate discussions, and an Organization for Economic Co-operation and Development (OECD) member, can successfully transition to a low carbon economy as successfully as it underwent transition to a market economy in the early 1990s.

Policymakers may find reassuring the main message that Poland's transition to a low carbon economy, while not free or simple, is affordable. However, capturing the full package of technologically feasible and economically sensible abatement measures requires coordinated and early action by the government.

- Poland can cut its greenhouse gas emissions (GHG) by almost a third by 2030 by applying existing technologies, at an average cost of €10 to 15 per ton of carbon dioxide (CO_2). In particular, decisions will rapidly need to be made to accelerate energy efficiency, to determine the share of nuclear in the energy supply and to plan for low carbon transport options.

[1] Annex 1 countries are 37 industrialized countries and economies in transition parties to UNFCCC which have agreed to emissions reduction targets.

- Costs to the economy will peak in 2020, but by 2030, the shift towards low carbon will augment growth. Overall, this abatement will lower gross domestic product (GDP) by an average 1 percent each year through 2030.
- The economic cost in output and employment of Poland's required abatement by 2020 under EU rules is higher than for the average EU country, and the restrictions on emissions trading between sectors aggravate that cost.
- The energy sector currently generates near half of Poland's emissions, but the transport sector—with precipitous growth and the need for behavioral change rather than adoption of new technologies—may end up posing the tougher policy challenge.

With the objective of assessing not only the net costs and investment demands but also the macroeconomic implications of GHG mitigation policies, the study uses an integrated approach that combines "bottom-up" engineering analysis with "top-down" economy-wide modeling.

The Need to Reduce GHG Emissions

There is a broad consensus that an international coordinated response to the threat of climate change is needed. Evidence that the world is warming and that human activity is primarily to blame has continued to accumulate in recent years, as has the understanding that a lack of action will impose very high costs, especially on poorer countries.

Under the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC), richer countries, including Poland, committed to reduce GHG emissions by about 5.2 percent during 2008-12 compared to 1990. While Europe will not be among the worst harmed, the EU has taken a proactive stance within the international community's ongoing negotiations by setting a unilateral target of a 20 percent reduction in emissions by 2020. EU members such as Poland therefore face specific obligations for climate action. Poland faces a particular challenge in CO_2 mitigation because of its heavy reliance on abundant domestic coal.

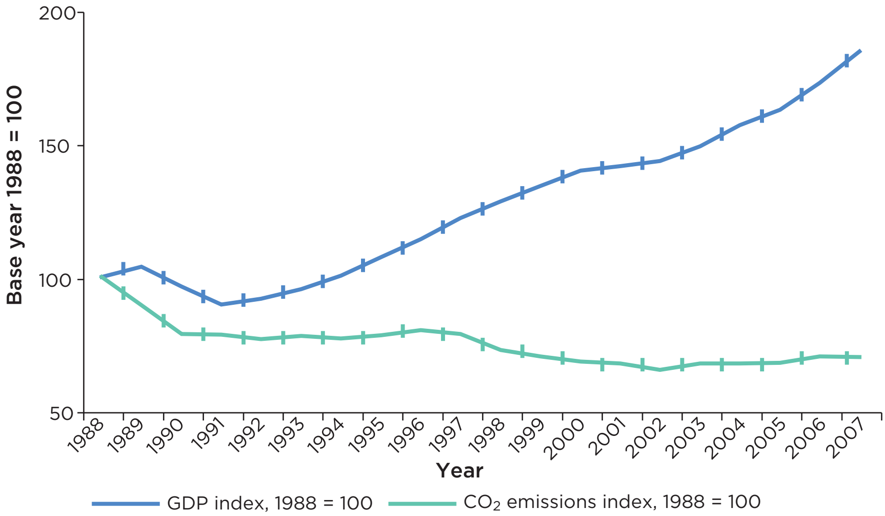
Poland's GHG Emissions

Poland is not among the largest emitters of GHG globally, but its economy is among the least carbon-efficient in the EU. Poland's global share in GHG emissions is just 1 percent, and its per capita emissions are similar to the EU overall. With 10 tons of carbon per capita in 2007, Poland is exactly at the level of the EU27[2] average, but given its lower income level, the Polish economy is one of the least carbon-efficient.

Poland's transition to a market economy since 1989 has a co-benefit of sharply reduced carbon emissions (Figure 1); however, the link between growth and emissions has re-emerged in recent years. A critical difference in the make-up of Poland's emissions is the dominance of the power sector and its extraordinary dependence on coal. Over 90 percent of electricity in Poland is generated

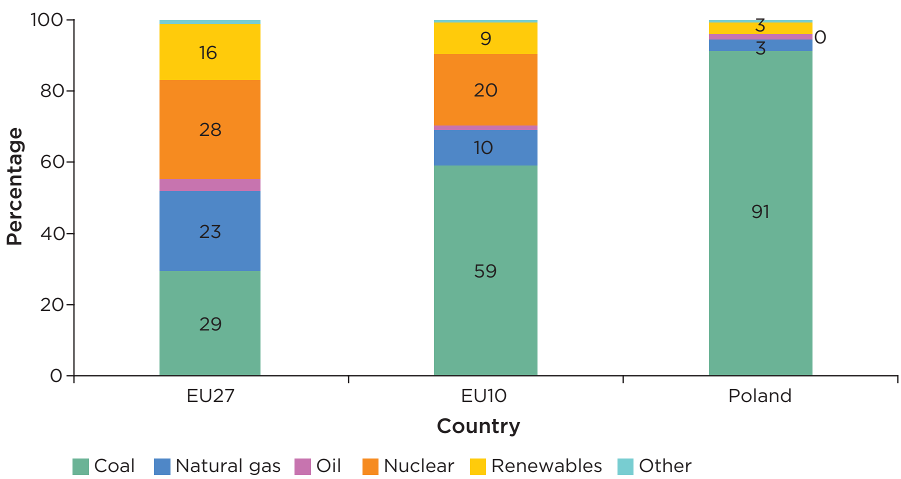
[2] EU27: Austria, Belgium, Bulgaria, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Italy, Latvia, Lithuania, Luxembourg, Malta, the Netherlands, Poland, Portugal, Republic of Ireland, Romania, Slovakia, Slovenia, Spain, Sweden, and the United Kingdom.

Figure 1: Economic Growth and GHG Emissions in Poland, 1988–2008



Source: World Bank, 2011.

Figure 2: Electricity Generation by Fuel, 2007



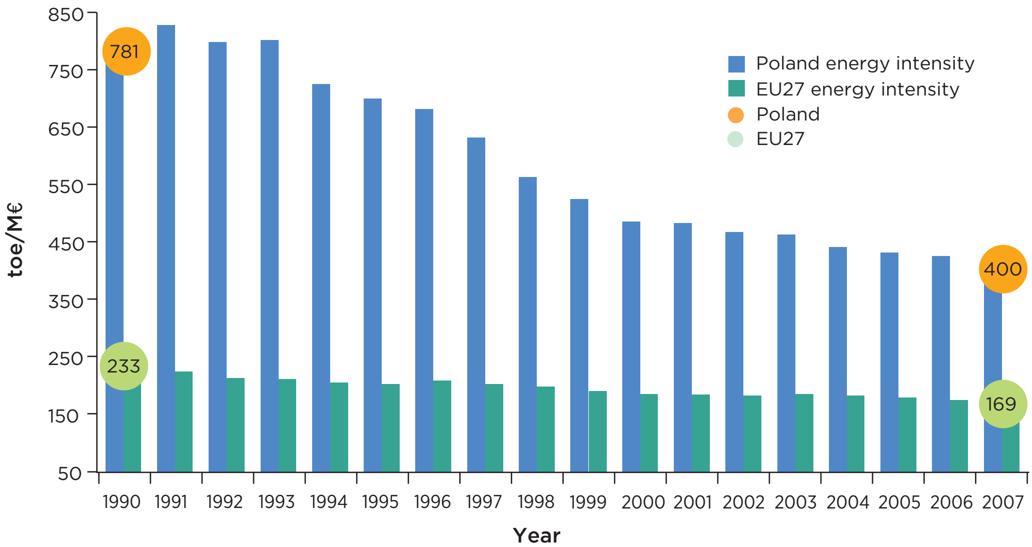
Source: World Bank, 2011.

Notes: (1) Energy consumption is gross inland consumption of energy, and (2) EU10 refers to the 10 new member countries of the EU from Central Europe which joined in 2004 and 2007.

from coal and lignite, the highest share in the EU, and makes Poland an outlier in both Europe and globally (Figure 2). Outside the energy sector, Poland's transport sector has experienced very high rates of emission growth. Energy efficiency, although considerably improved over the past 20 years, has not yet reached Western European standards.

Despite dramatic advances during 1988 to 2000, Poland's economy is still more than twice as energy intensive as the EU average (Figure 3).

Figure 3: Energy Intensity: EU27 and Poland



Source: World Bank, 2011.

Note: Energy intensity is the ratio of gross inland consumption of energy (in tons of oil equivalent) to GDP (in millions of euros at 2000 prices).

Poland's Carbon Abatement Targets and Policy Challenges

The international agreement on climate change that will eventually supersede the Kyoto Protocol and, more immediately, compliance with EU policies on climate change, pose policy challenges for Poland. Poland has been an active participant in international negotiations on climate change, in particular as a signatory to the Kyoto Protocol (Box 1), and as host to the 14th Conference of Parties of the UNFCCC in December 2008. The contraction of GHG emissions that accompanied economic restructuring in the 1990s caused Poland to outperform against its Kyoto commitments, and the country continues to exceed its Kyoto targets by a large margin. The most demanding of commitments on emissions, however, comes from EU policies on climate change mitigation. The EU climate change and energy package, or the "20-20-20" targets, requires comprehensive action by EU members to achieve a 20 percent reduction in GHG emissions by 2020, renewable energy making up 20 percent of energy consumption, and a 20 percent improvement in energy efficiency.

The 20-20-20 package requires Poland's energy-intensive sectors to contribute to the EU target of a 21 percent reduction (compared with 2005) while allowing emissions from Poland's non-energy sectors to increase by 14 percent. The EU package segments sectors into two groups and sets multiple targets. Large installations in energy-intensive sectors are covered by the EU-wide Emissions Trading Scheme (the ETS sectors), a regional carbon market. Energy, heavy industry, and fuels are ETS sectors. In Poland, approximately 60 percent of CO_2 emissions in 2005 were generated in the ETS sectors (compared with about 40 percent in the EU as a whole). For the less energy-intensive non-ETS sectors, the package requires a reduction in emissions by 10 percent compared to 2005 in the EU27. That EU-wide target was translated into a national target for Poland as an increase in its non-ETS emissions by 14 percent (Figures 4 and 5).

BOX 1.

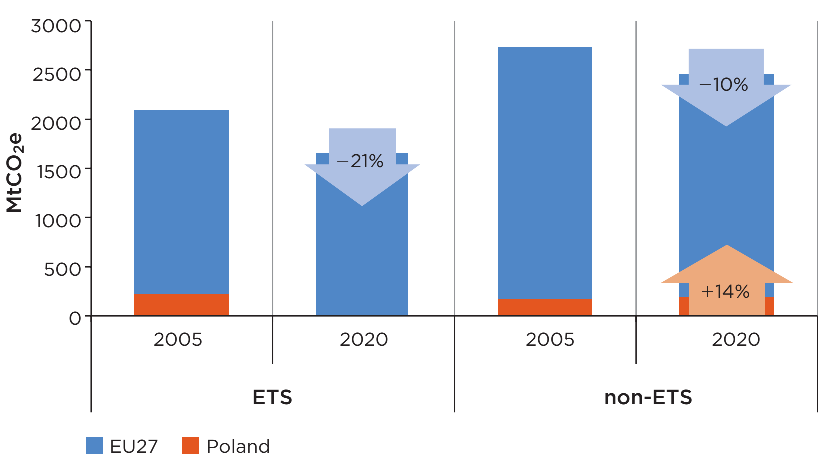
The Kyoto Protocol of the UNFCCC

The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change (UNFCCC). While the UNFCCC encouraged industrialized countries to reduce GHG emissions, the Kyoto Protocol set binding targets for Annex 1 Parties—37 industrialized countries, including all members of the European Union—by an average of 5 percent against 1990 levels over the five-year period 2008-2012. Some countries with economies in transition negotiated a pre-transition base year: Bulgaria (1988), Hungary (average of 1985 to 1987), Poland (1988), Romania (1989) and Slovenia (1986). The Protocol was adopted in Kyoto, Japan, in December 1997 and entered into force in 2005. Among industrialized countries, only the United States failed to ratify the Protocol. Countries must meet their targets primarily through national measures, but the Protocol offers three alternative (or flexibility) mechanisms:

- ***International Emissions Trading*** ("the carbon market"). Annex 1 countries that have emissions permitted but not "used" are allowed to sell excess capacity to other Annex 1 countries. Because CO_2 is the principal greenhouse gas, the market is called the "carbon market." At present, the European Union Emissions Trading Scheme (EU ETS), established in 2005, is the largest in operation.
- ***Clean Development Mechanism*** (CDM). Annex 1 countries can meet part of their caps using credits generated by CDM emission reduction projects in developing countries.
- ***Joint Implementation*** (JI). Annex 1 countries can invest in JI emission reduction projects in any other Annex 1 country as an alternative to reducing emissions domestically.

Source: UNFCCC website.

Figure 4: EU and Polish 2020 Targets, ETS and Non-ETS Sectors



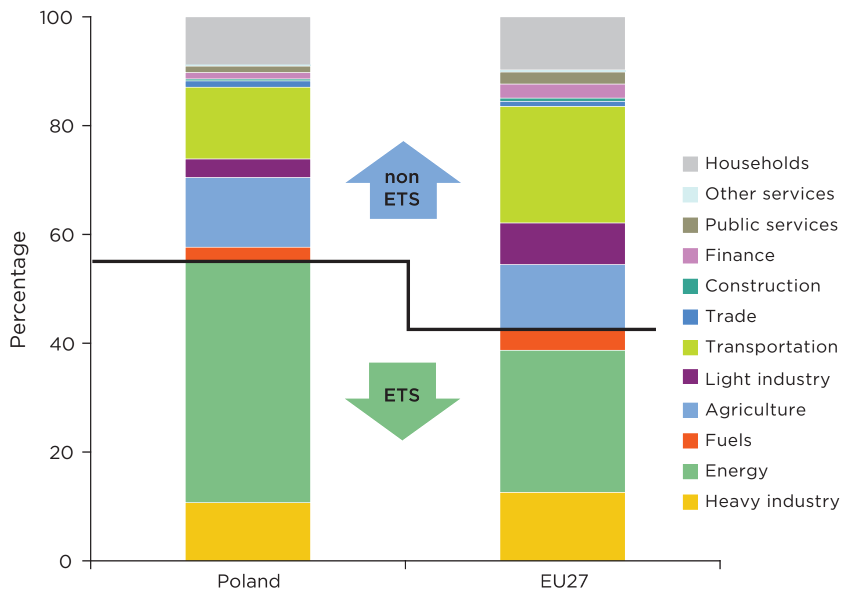
Source: World Bank, 2011.

Table 1: Breakdown of EU 20-20-20 Regulations by Sector Groups

ETS SECTORS (must use the EU Emissions Trading Scheme for CO_2 permits)		NON-ETS SECTORS (with national targets)
POWER	NON-POWER	
Power stations and other large fuel combustion installations	Oil refineries, coke ovens, iron and steel, cement, glass, lime, bricks, ceramics, and pulp, paper and board, petrochemicals, ammonia, aluminum, acid production, and aviation (possibly covered from 2011 or 2012).	Transport, construction, services, smaller industrial and energy installations, agriculture, and waste.

Source: World Bank, 2010.

Figure 5: GHG Emissions by ETS and Non-ETS Sectors, 2005



Source: World Bank, 2011.

These sectors (including transport and energy end-use in buildings and households) will require national policies to restrain emissions growth. The EU scheme's auctions of emission allowances will raise significant revenue for the Polish government in the future, estimated at roughly 1 percent of GDP. This revenue will be inversely related to the share of allowances that the government decides to allocate for free to support the competiveness of affected industries. More importantly, this segmented approach raises the cost of mitigation because of diverging marginal abatement costs across emission sources and sectors.

Assessing the Impact of Carbon Abatement

With a broad consensus that global coordinated action is needed to prevent dangerous climate change (estimated to cost about 1 percent of global GDP) and with EU policies on climate change already in place, Poland faces immediate policy questions:

- Could the country commit to more ambitious overall GHG mitigation targets for the longer term?
- What technological options are available and how expensive are they compared with existing technologies?
- Will there be high costs in lost growth and employment?
- Over a shorter horizon, to 2020, what are the implications for Poland of implementing EU policies on climate change?

Transition to a Low Carbon Economy in Poland uses four complementary and interlinked models (Box 2), combining a "bottom-up" engineering analysis with "top-down" economy-wide modeling to quantify the economic impact of CO_2 mitigation in Poland. This overview highlights the main findings of this analysis.

BOX 2.

Low Carbon Modeling Suite for Poland

Four complementary and interlinked models for Poland were developed to quantify the economic impact of CO_2 mitigation, taking advantage of available data and leveraging existing models. The models complement each other; by ensuring that sectoral work provides specific recommendations for actions at the sector or subsector level while the macroeconomic modeling ensures consistency of projected sectoral growth rates, with energy demand and other key macroeconomic variables.

- **MicroMAC Curve**—The most familiar of these models is the widely-used Marginal Abatement Cost (MAC) curve which provides a simple first-order ranking of technical options for GHG mitigation by sector based on the net present value of costs and savings per metric ton of CO_2 equivalent avoided.
- **Macroeconomic Mitigation Options (MEMO)**—A dynamic stochastic general equilibrium (DSGE) model of Poland revised to include energy and emissions, assesses the macroeconomic impact of the options costed in the MicroMAC curve. It is linked to the MAC curve via a Microeconomic Investment Decisions (MIND) module which groups the technology levers into seven packages, including an optimized package of options for the energy sector.
- **Regional Options of Carbon Abatement (ROCA)**—A country-level computable general equilibrium (CGE) model for energy and GHG mitigation policy assessment adapted to Poland, analyzes implementation of the EU 20-20-20 policy in the context of global policy scenarios, with an emphasis on spillover and feedback effects from international markets.
- **TREMOVE Plus**—This last model is a detailed sectoral approach for road transport, the sector with the fastest growing emissions and central to Poland's commitments under EU 20-20-20 (as a non-ETS sector). It makes use of the EU transport and environmental model, TREMOVE, updated with the latest information and policy intentions, here denoted as the TREMOVE Plus model.

All four use very similar "business-as-usual" reference scenarios (within the limitations of data) against which to measure policy changes. The innovative linking of the MEMO economy-wide model with the bottom-up engineering approach of the MicroMAC curve model allows analysis of the varying macroeconomic implications of GHG abatement measures, across four public financing options. Figure 6 summarizes the modeling approach.

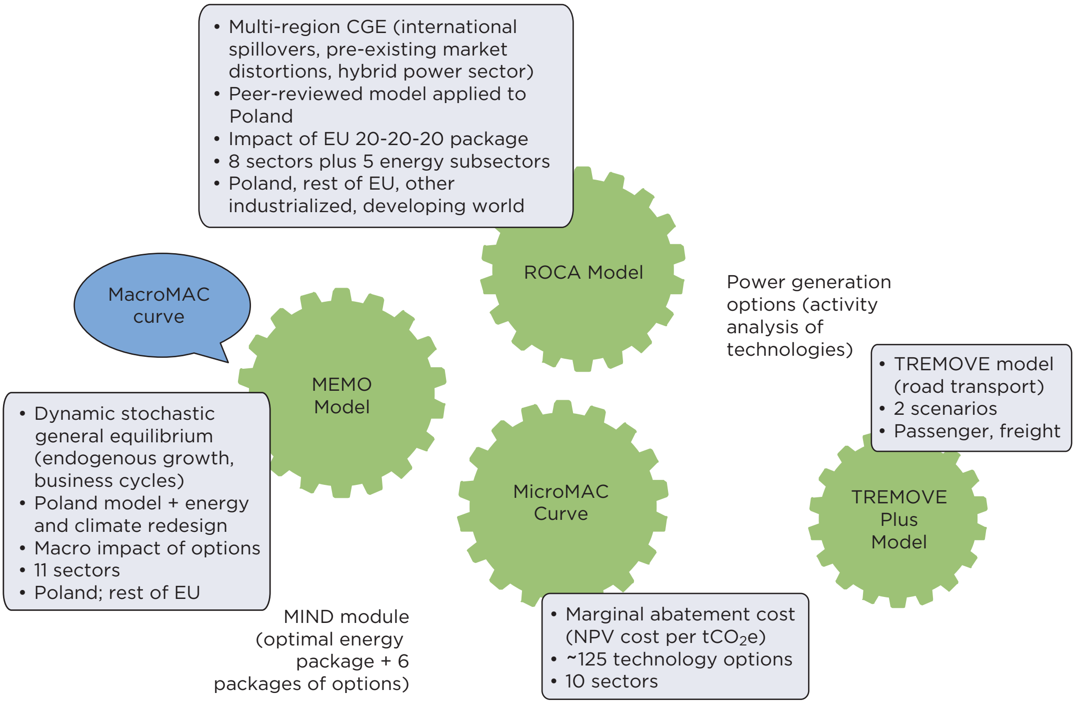
Source: World Bank, 2010.

POLAND'S GROWTH PATH WITHOUT A LOW CARBON STRATEGY

A business-as-usual scenario is fundamental to the calculation of costs of carbon abatement. If Poland were to take no action (the "business-as-usual scenario"), the models developed (Box 2) suggest that overall emissions in 2020 will stand roughly 20 percent above 2005, while 2030 levels will be 30 to 40 percent higher (Figure 7).

However there are significant differences in sectoral details in the reference scenario generated by each model over the 15–25 year analysis (Box 3). This draws attention to the fact that, since each of the models illuminates important aspects of the economics of GHG mitigation, policymakers will need to consider

Figure 6: Low Carbon Modeling Approach for Poland



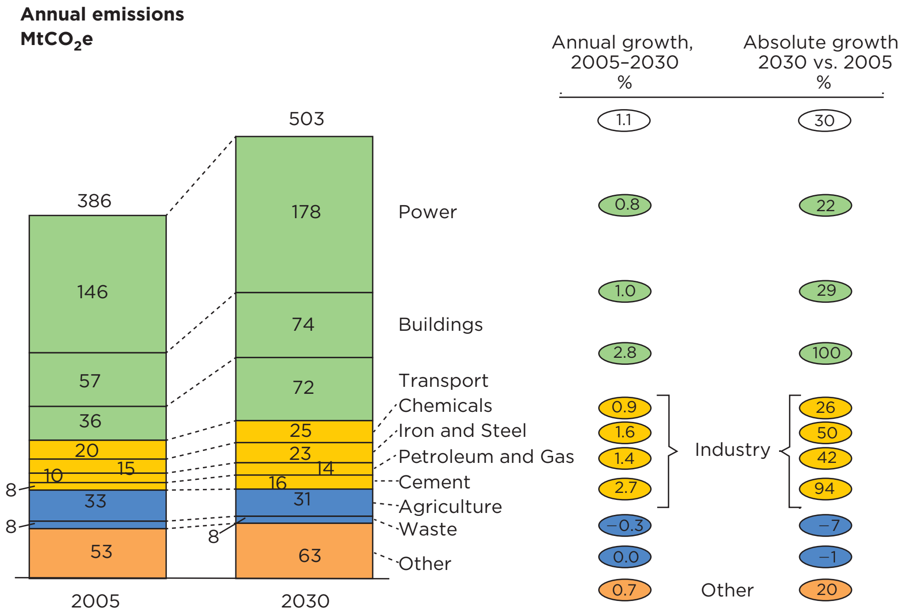
Source: World Bank, 2010.

multiple model results, rather than a single answer. Also, over a period of decades, assumptions about efficiency improvements within sectors and shifts towards less carbon-intensive sectors as part of normal development have a large impact (Figure 8): policymakers need to think carefully about country-specific sectoral development in far more detail than economy-wide models such as MEMO and ROCA can manage.

POLAND'S ABATEMENT OPTIONS

Poland can reduce emissions by 30 percent by 2030 compared to 2005 at an average cost of €10 to 15 per metric ton of CO_2 equivalent, according to the MicroMAC curve, a bottom-up engineering approach. This approach creates a ranking by net cost of about 120 emission reduction options based on existing technologies and presents the measures via a well-known visual summary tool—the MAC curve. When measured against the level of emissions that would otherwise occur in 2030, the reduction is even more significant—47 percent (see Figure 11).

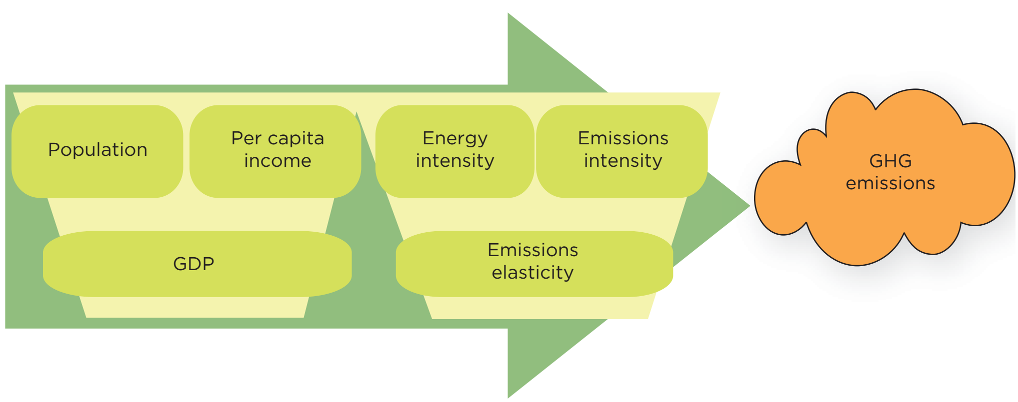
Figure 7: MicroMAC Curve: Business-as-Usual Emissions Growth



Source: World Bank, 2011.

Notes: Industry, buildings, and transport sectors do not include indirect emissions from electricity consumption and well-to-tank emissions for fuel; these are accounted for in the power and P&G sectors respectively; buildings sector includes emissions from heat. Other includes: mining, light industry, food and beverage industry, glass production, colored metals, off-road transport, and other sectors.

Figure 8: Basic Drivers of GHG Emissions Growth



Source: World Bank, 2011.

Note: Countries with higher population growth or higher income growth will face faster rising emissions. The emissions elasticity of GDP growth will need to be reduced by even more to offset GDP growth.

BOX 3.

A Comparison of Reference Scenarios for Poland

The projected pattern of emissions across sectors varies across models driven by the use of alternative methodologies and separate datasets. This has important implications for the kind of mitigation options that will be relevant for Poland, and therefore, the ease of the shift toward a low carbon path.

While the overall projections of emissions for 2020 are similar across models, the MEMO projections indicate a heavier burden for ETS sectors, while according to ROCA projections, the major challenge will be faced by the non-ETS sectors. While the MEMO scenario projects ETS sectors to expand by 20 percent relative to 2005 by 2020, the ROCA scenario predicts constant emissions during the period. The MEMO projections seem to indicate Poland will have little problem fulfilling the country-specific target for the non-ETS sectors under the EU 20-20-20 package (since the projected 15 percent increase under business-as-usual is very close to the 14 percent increase ceiling). In contrast, the ROCA projections warn of a significant challenge for non-ETS sectors, with emissions increasing by 46 percent between 2005 and 2020 (Figures 9 and 10).

The projections for 2030 are somewhat divergent: the MEMO business-as-usual scenario for 2030 emissions is 9 percentage points higher than the projection made in the MAC curve model.

Figure 9: GHG Emissions in Poland, 2005 and 2020 Scenarios

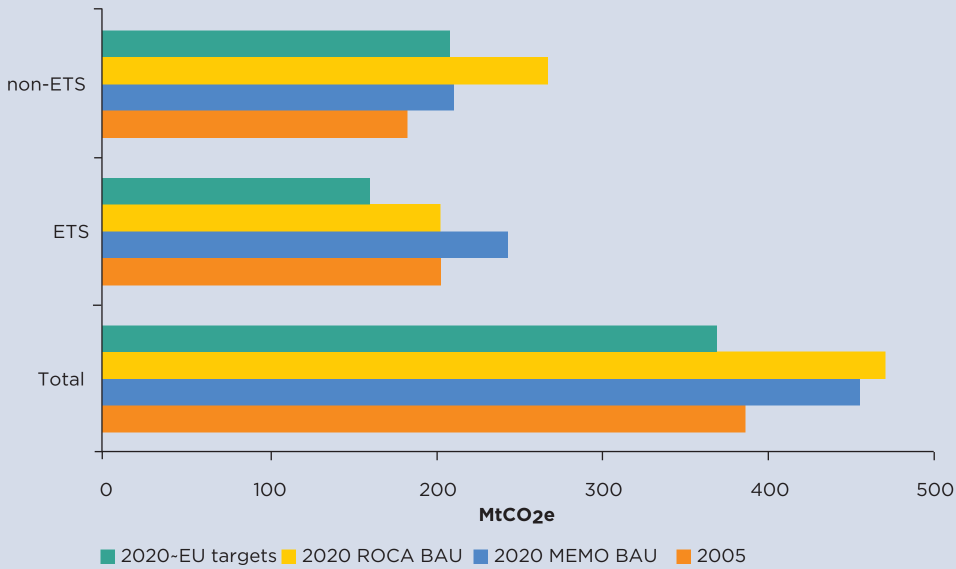
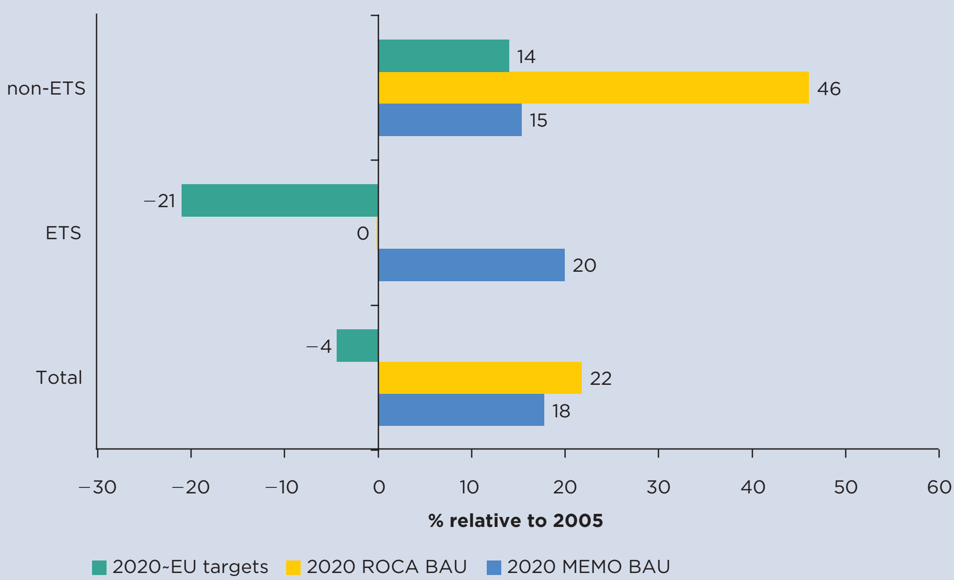


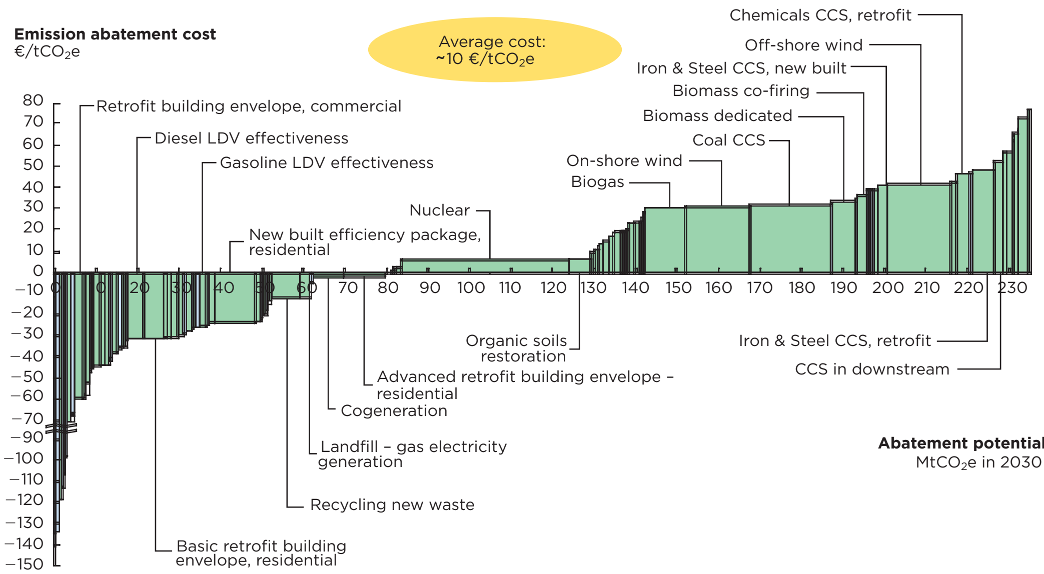
Figure 10: Changes in GHG Emissions in Poland, 2020 Scenarios vs. 2005



Source: World Bank, 2010.

Notes: The MEMO ETS and non-ETS projections are corrected for small energy installation. The ROCA model produces CO_2 emissions so equivalent GHG emissions were estimated. Poland's EU ETS target is assumed to be the same (as a percentage change) as the EU-wide target.

Figure 11: Microeconomic Marginal Abatement Cost Curve for Poland, 2030



Source: World Bank, 2011.

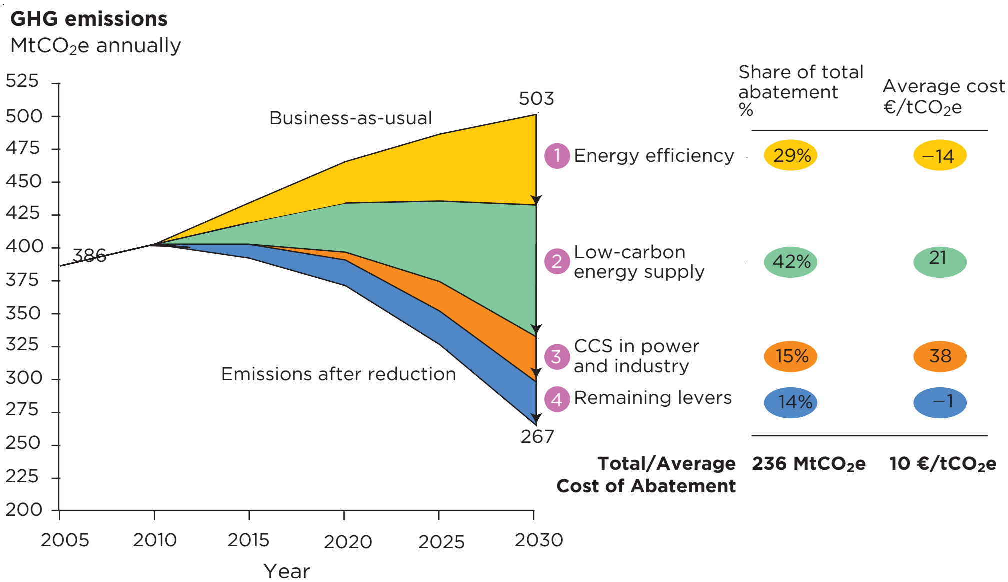
Note: Each column is one of about 120 abatement measures. The height of the columns is the cost in € per abated tCO_2e. The width is the amount emissions can be reduced against business-as-usual levels projected for 2030. Some measures are shown with net benefits (negative costs).

The MAC curve identifies that the majority of Poland's abatement potential is associated with the switch to low carbon energy supply and with energy efficiency improvements (Figure 12). After implementation barriers are addressed and removed, the abatement measures do not have negative net costs and the overall cost of implementing the MAC curve levers will rise by at least 50 percent. To implement all the low carbon levers, additional investment of about 0.9 percent of annual GDP will be needed during 2011–30 (Figure 13). Moreover, mitigation measures will take some time to deliver lower emissions, and despite the all-out effort of this abatement package, Poland will just meet its 2020 EU targets (with overall emissions reduction projected for 2020 at about 3 percent below 2005 levels).

The Macroeconomic Impact of the Abatement Package

Implementation of the full abatement package will reduce growth modestly, costing an average of one percent of GDP each year through 2030. For the comprehensive abatement package, the MEMO model simulations (Box 4) find that GHG emissions will be reduced by 24 percent by 2020 and by 47 percent by 2030, with an economic impact that is generally negative but appears affordable. Not surprisingly, the fall in GDP is driven by recession in emission-intensive sectors, which bear the heaviest burden of abatement. At a more disaggregated level, the model finds that it is the switch to low carbon energy and fuel efficiency measures that provides the bulk of abatement and that the technologies with the largest abatement potential are not necessarily associated with the biggest macroeconomic cost.

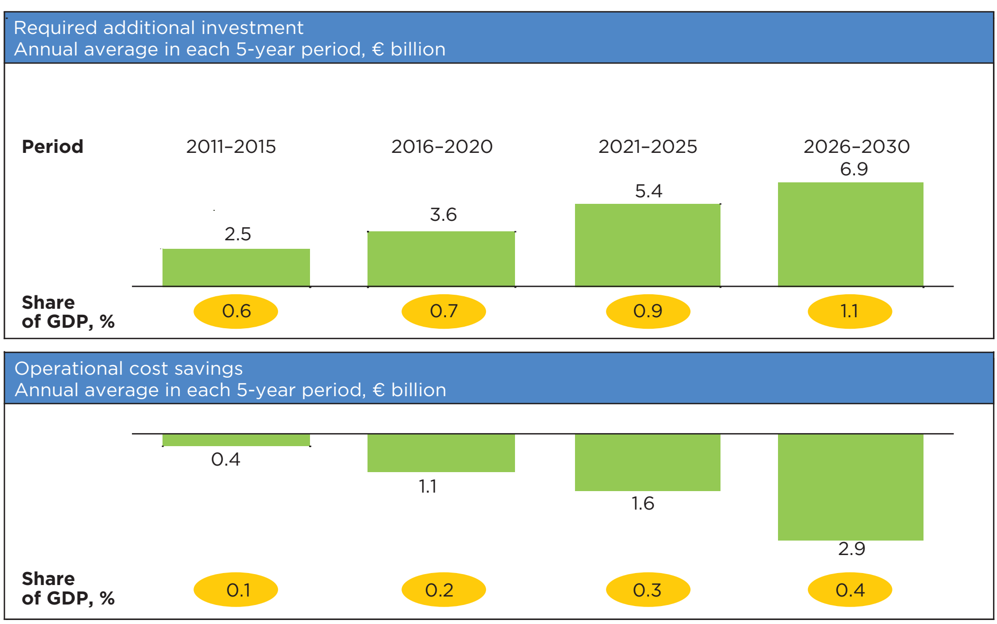
Figure 12: MicroMAC Curve: Abatement Potential for Poland in 2030 by Groups of Interventions



Source: World Bank, 2011.

Note: Energy efficiency includes measures in buildings, transport except switch to biofuels, and a few in industry, such as cogeneration.

Figure 13: MicroMAC Curve: Investment and Operational Cost Savings, 2010–2030



Source: World Bank, 2011.

BOX 4.

How Do the Bottom-up Abatement Opportunities Work in the Top-down Model?

Switching to lower-carbon technologies, such as wind power, means investing in options with lower net present value (NPV) than traditional coal-fired power plants, the business-as-usual or reference technology in the energy sector. It is assumed in the MEMO model, that it is the public sector that covers the additional costs. During the two to five-year construction phase for the new generation plant, investment spending rises in the energy sector. Both the interest rate and the prices of investment goods are pushed up, crowding out capital accumulation in other sectors. Domestic energy prices rise because of higher-priced and expanded private investment in the energy sector, and this more costly energy is detrimental to overall growth. If the public costs are covered by higher taxes, an additional tax distortion is added to the economy. When construction is completed and operations begin, these effects are unwound: energy production becomes cheaper due to reduced fuel costs (since free wind costs less than coal), which leads to lower energy prices. The relative price of investment goods declines, to the benefit of the other sectors which increase their capital accumulation.

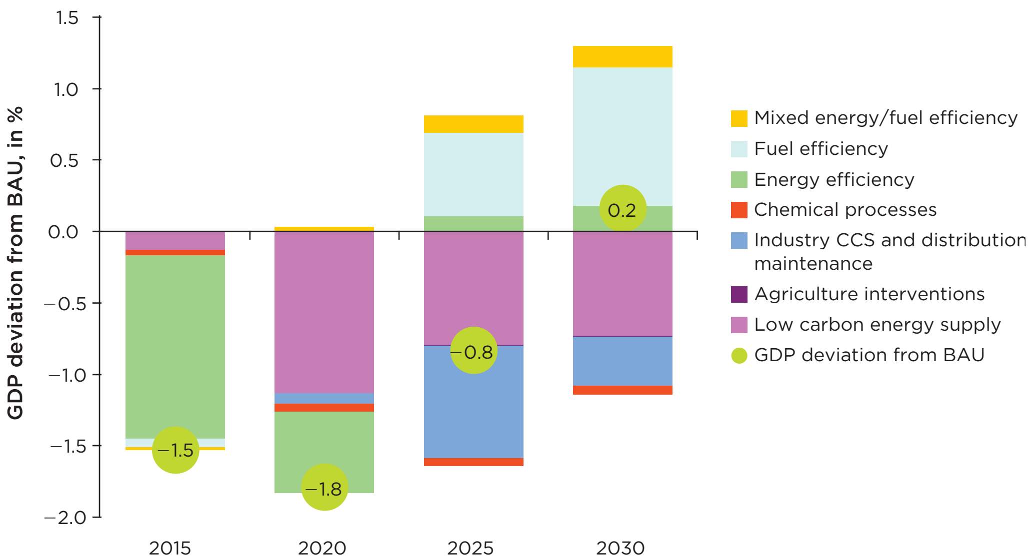
An energy efficiency measure such as switching to efficient commercial lighting will induce broadly similar effects on investment at the beginning of implementation, balanced by later savings on operational costs resulting from lower energy consumption. As noted above, it will be light rather than heavy industry that benefits early on. If the benefits during operation outweigh the initial costs, growth will be enhanced, together with changes in the structure of firms' intermediate consumption. The sectors that have implemented the efficiency measure then enjoy lower costs of production.

Source: Authors, 2011.

The impact of the entire package on GDP is consistently negative over the twenty-year period of the model, but the losses approach zero by 2030. Losses to real GDP peak in 2020 at near two percent and then gradually diminish, leaving GDP slightly above the business-as-usual level by 2030 (Figure 14). The level of real GDP in 2020 would be from 1.8 to 3.1 percent lower than in the business-as-usual scenario, but by 2030 it would recover to 0.7 lower to 0.7 higher. This U-shaped pattern of GDP impact is driven by the need for upfront investments, with benefits materializing in future years, and in particular, the long lead times required by the power sector. Employment would also suffer, with losses of about one percent of jobs (about 140,000 jobs) on average. The overall employment loss ranges from 2.6 to 0.2 percent reduction compared to the business-as-usual scenario. Not surprisingly, the fall in GDP is driven by recession in emission-intensive sectors, which bear the heaviest burden of abatement. Value-added in energy-intensive sectors is projected to shrink by more than 9 percent by 2030, with sectoral employment falling by more than 5 percent.

The technological micro-packages—groups of related mitigation options—with the largest abatement potential do not necessarily impose the biggest mac-

Figure 14: Decomposition of GDP Impact of Low Carbon Package, in %



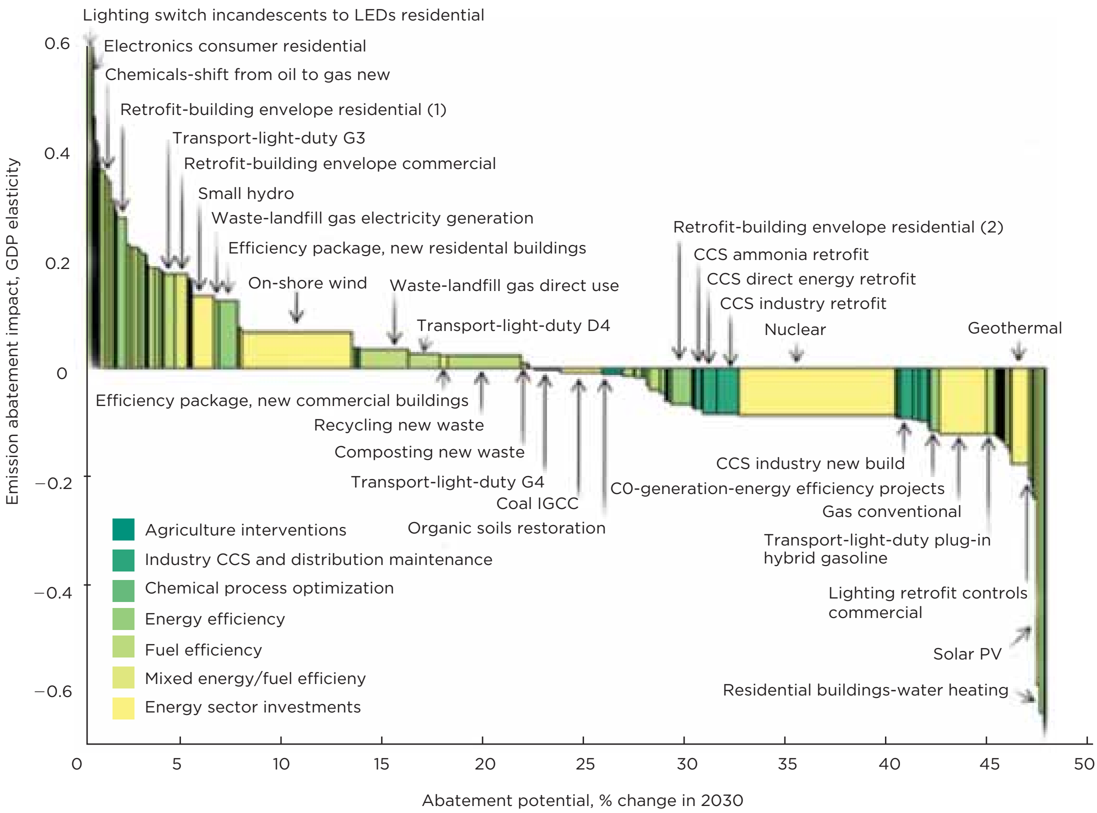
Source: World Bank, 2011.

Note: Change in real GDP is measured against business-as-usual scenario. Categories are micro-packages (mitigation options grouped by economic characteristics).

roeconomic cost. Energy efficiency measures are most important in the early years, contributing 20 percent of mitigation in 2015, but costing over one percent in GDP losses (Figure 15). From 2020 onward, about 40 percent of potential mitigation derives from energy sector investments and another one-third from fuel efficiency. The switch to low carbon energy (via energy sector investments) and industry carbon capture and storage (CCS) measures together cost about 1 percent per year in lower GDP after 2020, by which time fuel and energy efficiency measures have begun to contribute positively to GDP.

Onshore wind and small hydropower plants are superior to many energy efficiency measures by the metric of GDP growth. Nuclear power offers the biggest abatement potential but remains a drain on growth even with a twenty-year horizon—still myopic for plants with 60-year lifespans. Using a macroeconomic version of the MAC curve allows detailed examination of the impact on growth associated with the implementation of specific abatement measures (Figure 11). The Macroeconomic Marginal Abatement Cost curve (MacroMAC curve) presents the marginal abatement impact in terms of GDP of each abatement option, making it easy to see which measures are "cheaper." The area under the MacroMAC curve defines the overall impact of the entire abatement package on the level of real GDP, an interpretation similar to that of the bottom-up Microeconomic Marginal Abatement Cost curve (MicroMAC curve) (in which the area under the curve equals the financial cost of the abatement package). This curve is also generated for 2020, revealing that the impact on GDP of abatement options shifts over time and becomes more positive, flattening the MacroMAC curve as investments are completed and operations begin.

Figure 15: Macroeconomic Marginal Abatement Cost Curve, 2030



Source: World Bank, 2011.

Note: Each column is one of about 120 abatement measures. The height of the columns is the marginal abatement impact in percent of GDP (for each percent of GHG abatement) compared to business-as-usual in 2030. The width is the percent emissions can be reduced. The area of any rectangle equals the GDP impact (loss or gain) of carbon abatement via any specific lever.

IMPLEMENTING THE EUROPEAN UNION CLIMATE POLICY

In complying with the requirements of the EU's 20-20-20 package, Poland bears a higher economic burden than the average EU country because of the predominance of coal in power generation and the expected strong baseline emissions growth in sectors such as transport. The ROCA model (Box 2) considers several variations on EU climate policy design that meet the same emission reduction targets to further illuminate the impact on Poland's economy in 2020.

The "Main"' scenario (Table 2) demonstrates this increased economic burden because of Poland's dependence on coal in power generation. The market segmentation created by the EU's division of economic sectors according to energy intensity greatly elevates the marginal cost of abatement for less energy-

Table 2: Summary of Scenario Characteristics Simulated in the ROCA model

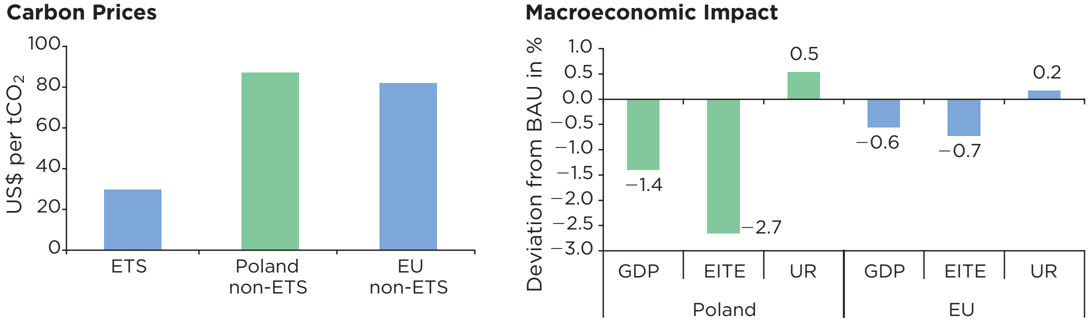
Scenario	Basic assumptions
All scenarios	1. Emission reduction targets for 2020 are set as in EU climate package and Copenhagen pledges: • Poland must reduce emissions in ETS sectors by 21 percent compared to 2005 and may increase emissions in non-ETS sectors by no more than 14 percent; the EU26 (for the "rest of the EU") faces 21 and 12.5 percent reduction targets for ETS and non-ETS sectors respectively. • Other industrialized countries must achieve 4.8 percent reduction as compared to 2005 levels, roughly corresponding to pre-Copenhagen official pledges. This region represents key other Kyoto Protocol Annex 1 countries: Australia, Canada, Japan, New Zealand, Russia, and the United States. • The remaining region, developing countries, has no emissions target.
	2. Emissions trading focuses on the existing EU carbon market: • There is EU-wide emissions trading for energy-intensive industries (ETS sectors). • Access for EU non-ETS sectors varies according to scenario. • The other regions do not participate in international emissions trading.
	3. Flexibility in the form of CDM offsets is included: • For the EU, varying access according to scenario. • Other industrialized regions do not have access to CDM offsets. • Developing countries supply CDM offsets.
	4. Domestic carbon taxes: • For EU non-ETS sectors, each EU country imposes a domestic tax. • Other industrialized regions set a uniform domestic carbon price. • Revenue recycling varies by scenario.
Main	1. No access for EU non-ETS sectors to carbon market.
	2. Limits to CDM offsets for EU as prescribed by the EU climate package: non-ETS sectors are allowed to offset up to 33 percent of emission reductions, ETS sectors, 20 percent.
	3. Lump-sum recycling to households of revenues from carbon tax and auctioning of allowances in carbon market.
	4. Bottom-up activity analysis characterization of power supply technologies in the EU.
	5. Restricted use of nuclear power at business-as-usual capacity level.
Flexible emissions trading	Like Main but with access for EU non-ETS sectors to carbon market.
Flexible trading and offsets	Like Main but with EU non-ETS sector access to carbon market and no CDM limits.
Renewables target	Like Main but with target quota for renewable power generation in EU.
Wage subsidy	Like Main but with revenue recycling via wage subsidies.
Unrestricted nuclear	Like Main but without nuclear expansion ceiling in Poland.
Restricted gas	Like Main but with ceiling on gas use in Poland's power generation at business-as-usual level.
Free 30 percent allowances	Like Main but with output-based allowance allocation to energy-intensive and trade-exposed (EITE) sectors in EU (free allocation of 30 percent of EITE sectors' 2005 emission level).
Free 70 percent allowances	Like Main but with output-based allowance allocation to EITE sectors in EU (free allocation of 70 percent of 2005 emission level).
Top-down power sector	Like Main but with top-down characterization of power production.
Small open economy	Like Main but without international terms-of-trade effects (Poland is treated as a small open economy).

Source: Authors, 2011.

intensive industries: marginal abatement costs in these sectors for both Poland and the rest of the EU are almost three times the cost for energy-intensive sectors. Removing that segmentation reduces overall compliance costs for Poland. Similarly, allowing emission reductions in the least-cost locations dramatically reduces compliance costs and the need for adjustment, as most abatement is off-shored.

An additional aspect of EU policy is incorporated into the ROCA model—overlapping regulation in the form of an EU target for renewable energy sources—to determine conditions in which it may be welfare-improving. The model considers various policy choices under the control of the Polish government. First, alternative revenue recycling via wage subsidies are analyzed, which generates a weak "double dividend" (reducing emissions while easing distortions in the labor market) and lower unemployment. Then, the loosening of restrictions on the scope of nuclear power is found to cut compliance costs for Poland by about one-third. Lastly, the granting of free emission allowances to energy-intensive and trade-exposed sectors, which might be vulnerable to carbon leakage, preserves sector output but generates overall losses in GDP.

Figure 16: EU 20-20-20 Package: Carbon Prices and Macroeconomic Impact



Source: World Bank, 2011.

Note: EU26 is the rest of the EU excluding Poland. The carbon price in non-ETS sectors is a shadow price. EITE is energy-intensive and trade-exposed sectors. UR is the change in unemployment rate in percentage points.

The findings of the "Main" scenario illustrate that Poland bears a higher economic burden than the average EU country because of its relatively high abatement targets for non-ETS sectors with strong baseline emissions growth. Setting a non-zero price of carbon generates a negative shock to emissions-intensive sectors. Since power generation in Poland is predominantly coal-based, it will be hard hit. CO_2 reduction from the sector takes place through rising electricity prices (by about 20 percent, much more than in the rest of the EU), a decline in output by about 10 percent, the expansion of CO_2-free renewable power production, and, to a more limited extent, fuel shifting to gas (since nuclear power is assumed restricted to business-as-usual levels). 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, depressing production. In the new equilibrium, real wages are lower, and unemployment rises marginally by only half a percentage point. The effects on real GDP are modest but more than twice as high for Poland as for the rest of the EU (with a loss of 1.4 percent of GDP) (Figure 16).

Energy-intensive and trade-exposed (EITE) industries are not devastated by carbon abatement, but market segmentation drives the marginal cost of abatement in non-ETS sectors to almost three times the level in ETS sectors. Even for EITE industries (a subset of ETS sectors) worried about loss of competitiveness, the contraction is still moderate in size (although they are harmed more than the average, with 2.7 percent loss in output in 2020 compared to GDP losses of 1.4 percent). At the same time, marginal abatement costs in the non-ETS sectors for both Poland and the rest of the EU are much higher than the ETS value (at a shadow price of US$80 per tCO_2 for Poland, and US$82 for other EU), revealing less potential for cheap emission abatement in the non-ETS sectors. The differences between ETS and non-ETS prices drive the direct excess costs of EU emission market segmentation, which are alleviated to some degree through limited low-cost offsets from developing countries (via the Clean Development Mechanism of the Kyoto Protocol).

LOW CARBON INTERVENTIONS

Transition to a Low Carbon Economy in Poland identifies energy sector investments, end-user energy efficiency measures and transport policy as the central pillars of Poland's transition to an economy with lower GHG emissions.

Optimizing Future Power Supply Options

The power sector is the dominant source of today's emissions but the sector's large investment costs raise financing challenges while long lead times guarantee that its structure will shift only slowly (Table 3, Figure 17). The combination of technologies chosen or new investments will depend not only on capital costs, operational savings, and carbon abatement potential, but also on energy security, domestic sourcing, and other issues.

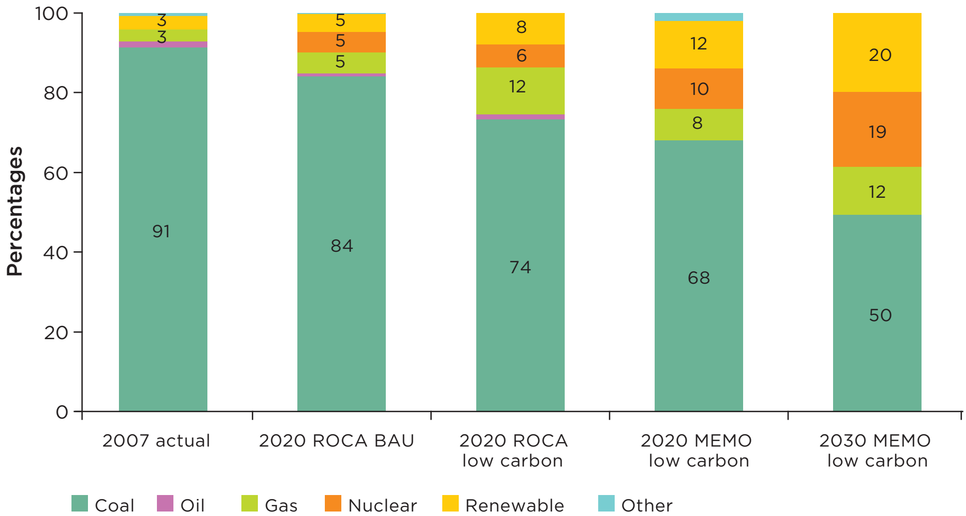
The ROCA model's results argue that a strong shift towards nuclear power is the option most likely to reduce emissions without harming the economy. The MEMO model, which takes the most sophisticated approach to selecting the structure of the sector, uses an optimization model to determine the cheapest feasible energy-mix package within multiple constraints. However, even if a full low carbon package is implemented, coal will likely remain the fuel for half of Poland's electricity in 2030. The average age of Poland's energy infrastructure is high. Replacement of this infrastructure provides opportunities for the country to come in line with the low carbon agenda.

Table 3: Key Features of Energy Sector Technologies Available in Poland Until 2030

TECHNOLOGY	LIFE SPAN	MAX INSTALLED BASE		PRODUCTION UPTIME		INVESTMENT TIME
	YEARS	2005 (GW)	2030 (GW)	2005 (%)	2030 (%)	CONSTRUCTION (YEARS)
Coal CCS retrofit	40	0.0	5.8	38%	64%	4–6
Coal CCS new built	40	0.0	3.5	79%	87%	5–8
Coal IGCC	25	0.0	5.8	90%	90%	4–6
Gas CCS retrofit	40	0.0	2.8	68%	68%	4–6
Gas CCS new built	25	0.0	0.7	29%	35%	4–6
Biomass dedicated	40	0.0	0.9	80%	80%	3–5
Biomass CCS new built	40	0.0	5.8	80%	80%	4–6
Nuclear	60	0.0	6.0	90%	90%	10–12
On shore wind	20	0.1	10.0	24%	24%	2–4
Off shore wind	20	0.0	6.0	32%	34%	3–5
Solar PV	25	0.1	1.7	10%	10%	1–2
Concentrated Solar Power	20	0.0	1.4	91%	91%	5–7
Geothermal	30	0.0	0.7	80%	90%	4–6
Small hydro	25	0.9	1.7	35%	35%	3–7
Coal conventional	45	30.8	32.0	54%	74%	5–7
Gas conventional	25	0.7	3.6	75%	65%	4–6

Source: World Bank, 2011.
Note: Investment time includes obtaining construction permits, tendering and construction.

Figure 17: Current and Projected Electricity Mix in Poland, 2020 and 2030



Source: World Bank, 2011.

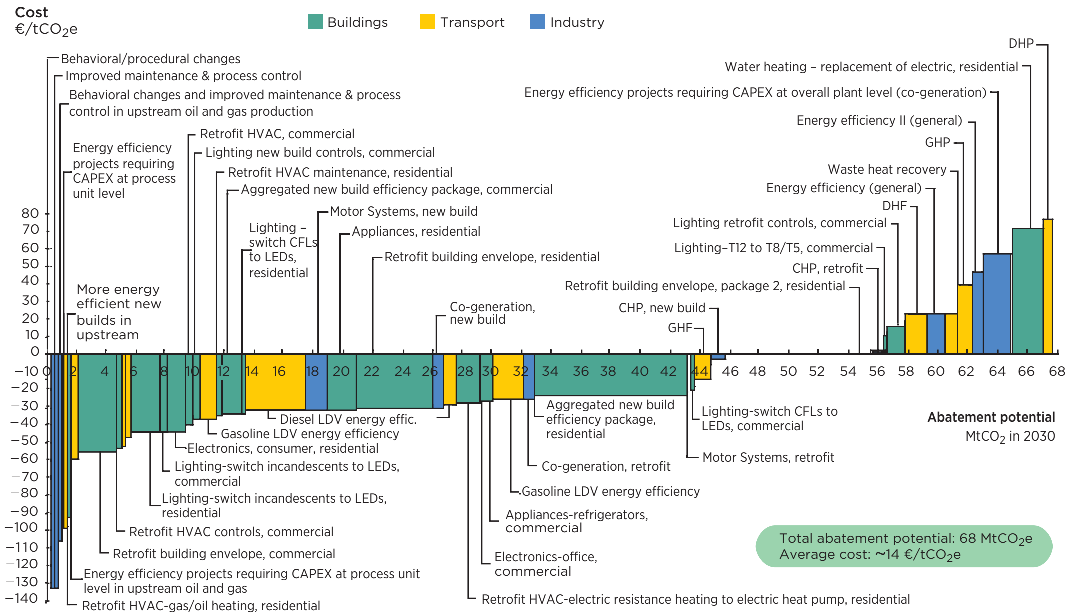
Note: In the MEMO model, Coal is Coal conventional, Coal IGCC, Coal CCS new built, and Coal CCS new built with enhanced oil recovery (EOR); Gas is Gas conventional, Gas CCS new built, and Gas CCS new built with EOR; Renewable is On shore wind, Small hydro, Geothermal, and Biomass dedicated.

Energy Efficiency: Benefits Can Be Realized Relatively Quickly

With lower capital costs and earlier returns, end-user energy efficiency measures[3] hold out the promise of relatively low cost abatement that works directly to delink carbon from growth, the essence of a low carbon economy. Energy efficiency measures play a central role in the MicroMAC curve analysis (Figure 18) because of their substantial potential, apparent low price, and impact on growth. While it is logical that abatement measures cannot in reality have negative net costs, ascertaining the details of the relevant implementation barriers for these measures is a challenge. Exploiting the energy efficiency agenda will not be easy, but it likely does have some opportunities that are "win-win," with benefits realized relatively quickly and relatively low upfront costs. Initial analysis of the macroeconomic impact of energy efficiency measures (Figure 19) in the MEMO model found that although most energy efficiency measures individually have little potential, if they could be grouped together for implementation, they could be an important carbon abatement tool. Deeper detailed analysis of energy efficiency options in Poland is needed to be able to provide more specific recommendations on how to overcome implementation obstacles that are preventing households and businesses from realizing the financial savings embedded in many of these measures.

[3] End-user energy efficiency measures include dozens of measures in commercial and residential buildings, such as improved insulation, more efficient lighting, and more efficient appliances, as well as energy-saving measures in industry, such as co-generation.

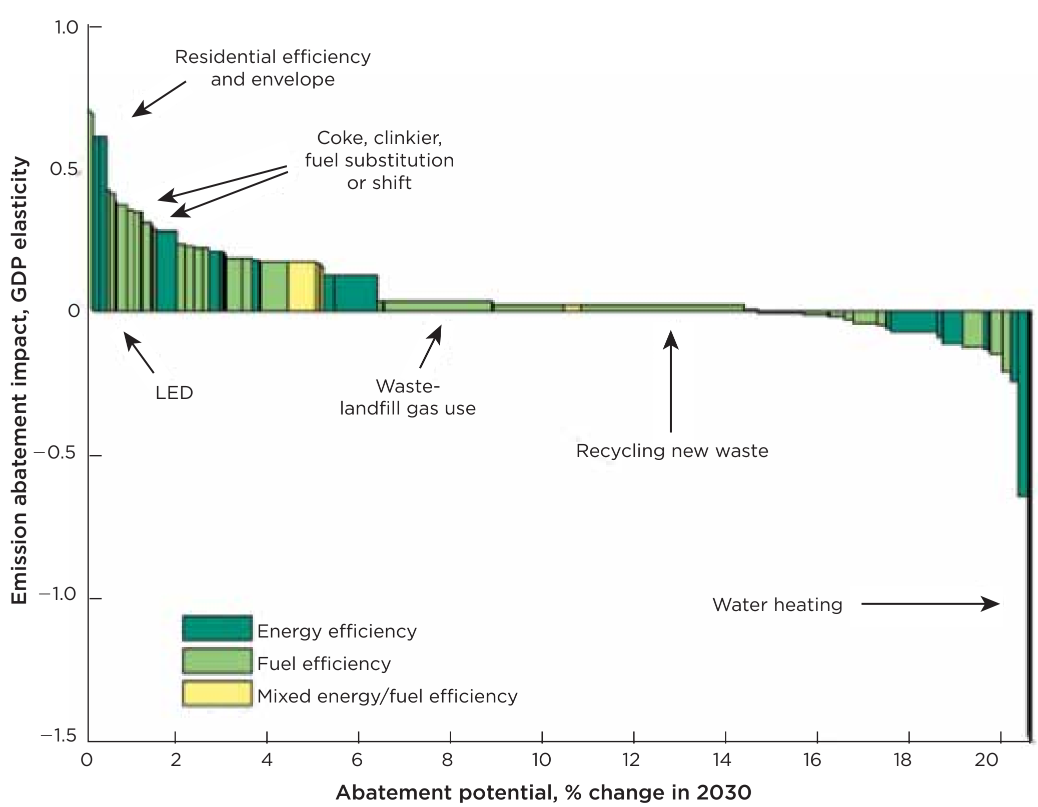
Figure 18: MicroMAC Curve for Energy Efficiency Levers



Source: World Bank, 2011.

Note: Energy efficiency measures include transport sector. Each column is one of about 120 measures (only the most significant ones are named). The height of the columns is the cost in € per abated tCO_2e. The width is the amount emissions can be reduced. Some measures are shown with net benefits (negative costs).

Figure 19: MacroMAC Curve for Energy and Fuel Efficiency Micro-packages in 2030



Source: World Bank, 2011.

Transport: Ensuring Long Term Sustainability

Poland also needs to consider how to address the sector with the fastest growing emissions—transport. Road transport GHG emissions in Poland are converging from a low historic base towards EU averages. While contributing about 10 percent of overall emissions, road transport constitutes about 30 percent of non-ETS emissions. The objective of sustainability and greening of the transport sector is not new for the EU, but the EU 20-20-20 climate package is now the centerpiece.

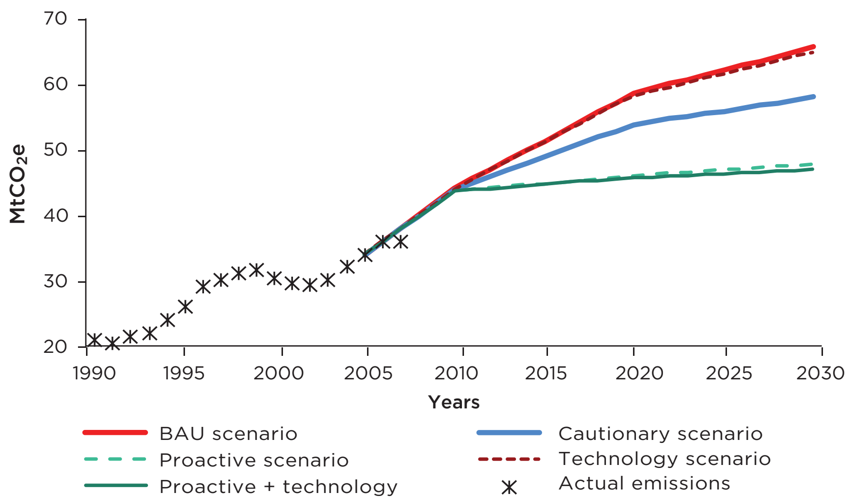
A business-as-usual scenario through 2030 was developed for passenger and freight road transport in Poland, using the TREMOVE Plus model (Table 4, Figure 20). This forecast incorporated key characteristics of Poland's transport sector, in particular, a high number of imported used cars, low motorization rates and low mileage, and a highly competitive freight sector that has been shifting to newer and bigger trucks. Emissions from road transport are expected to almost double between 2005 and 2030. Because steady technological improvements are already incorporated into the business-as-usual projections, the two low carbon scenarios developed by the TREMOVE Plus model include only modest technological improvements and concentrate on other emissions-reducing policy measures. The results of the scenarios present a more worrying vision than previously established for the road transport sector, with abatement unlikely to hold emissions growth below 35 percent through 2020. With most technological solutions already in place, more difficult behavioral change will be needed, such as shifting away from private cars towards public and non-motorized transport. However, even proactive abatement policies are unlikely to hold emissions growth within the EU target for these sectors.

Table 4. Overview of TREMOVE Plus Low Carbon Scenario Policy Measures

POLICY MEASURE	DESCRIPTION	REDUCTION IN 2030 VS. BAU
Road pricing	Introduction of electronic tolling on motor and expressways, and gradual introduction of congestion charging in major cities	4.2%
Fuel tax increase for passenger cars	Gasoline price increase of 10%	5.2%
Fuel tax linked to CO_2 standard for passenger cars	Annual gasoline price increase equal to emissions standard tightening[4]	18%
Fuel price increase for trucks	Diesel price increase of 10%	1.8%
Eco-driving	Introduction of eco-driving course to improve fuel efficiency	4.7%
Parking policies	Parking fees for entire inner city regions of all cities	3.5%
Promotion of non-motorized and public transport	Promotion of walking and cycling; and of metro, trams, and buses; and park and ride	2.3%
Larger heavier trucks and logistics efficiency	More use of larger and heavier vehicles with more efficient logistic chains and distribution efficiency	25%

Source: Authors, 2011.

Figure 20: TREMOVE Plus CO_2e Emissions Projections for Road Transport by Scenario, $MtCO_2e$



Source: World Bank, 2011.

Note: Precautionary scenario contains policy measures such as road pricing, fuel tax increases, and eco-driving. Proactive scenario contains same measures but with greater effort. Technology scenario contains policy measures for modest technological improvement in trucks (medium and heavy duty vehicles).

[4] Passenger cars achieve lower emissions by improving fuel efficiency, but people then tend to drive more. This rebound effect can be eliminated by a fuel tax that is linked to the emissions standard.

CONCLUSIONS

Transition to a Low Carbon Economy in Poland provides a detailed assessment of many aspects of a low carbon growth strategy for Poland, developing insights via a suite of models that should provide ongoing assistance to policymakers. These policymakers may find reassuring the main message that Poland's transition to a low carbon economy, while not free or simple, is affordable. However, capturing the full package of technologically feasible and economically sensible abatement measures requires coordinated and early action by the government.

With an ambitious approach, Poland can aim to reduce its GHG emissions by about one-third by 2030 (relative to 1990) with little cost to incomes and employment. Similarly, meeting the EU targets for 2020, while likely more challenging for less energy-intensive sectors such as transport than for sectors that can access the efficiencies of EU-wide carbon trading, are fully possible for Poland with modest cost. Poland has already weathered one economic transition and emerged with a strong and flexible economy. This next transition—to a low emission growth path—while requiring an evolution in lifestyles and priorities over the next 20 years, may well turn out to be much easier.

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ABBREVIATIONS AND ACRONYMS

BAU	business-as-usual scenario
CAPEX	capital expenditures
CCS	carbon capture and storage
CDM	Clean Development Mechanism
CFLs	compact fluorescent light bulbs
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
DHF	diesel full hybrid
DSGE	Dynamic Stochastic General Equilibrium
EITE	energy-intensive and trade-exposed sectors
ESMAP	Energy Sector Management Assistance Program
ETS	Emissions Trading Scheme of the European Union
EU	European Union
GDP	gross domestic product
GHG	greenhouse gas
HVAC	heating, ventilation, and air conditioning
IBS	Instytut Badan Strukturalnych (Institute for Structural Research), Warsaw, Poland
IGCC	Integrated gasification combined cycle
LDV	light duty vehicle
LED	light-emitting diode
MAC	marginal abatement cost
MacroMAC	macroeconomic marginal abatement cost
MicroMAC	microeconomic marginal abatement cost
MEMO	macroeconomic mitigation options model
MIND module	microeconomic investment decisions module
$MtCO_2e$	millions of metric tons of CO_2 equivalent
MWh	megawatt hours
Non-ETS	sectors not covered by the ETS system
NPV	net present value
OECD	Organization for Economic Co-operation and Development
ROCA	Regional Options of Carbon Abatement model
TREMOVE	traffic and emissions motor vehicle model (approximate)
tCO_2e	metric tons of CO_2 equivalent
toe	tons of oil equivalent
T12	type of fluorescent light bulbs
UNFCCC	United Nations Framework Convention on Climate Change

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Energy Sector Management Assistance Program
The World Bank
1818 H Street, NW
Washington, DC 20433 USA
email: esmap@worldbank.org
web: www.esmap.org

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Carbon Finance-Assist Program
World Bank Institute
1818 H Street, NW
Washington, DC 20433 USA
email: cfassist@worldbank.org
web: www.cfassist.org