Costs and potentials of greenhouse gas abatement in the Czech Republic

– Key findings

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Foreword

Climate change has become a business reality, irrespective of one's viewpoint on the science behind this issue. A large number of scientists, policymakers, business leaders, and consumers worldwide believe in climate change, think it is caused by greenhouse gas emissions, and want to see significant measures taken to prevent severe environmental changes. Although agreement is not universal, many industrialized countries are adopting stringent greenhouse gas reduction targets. In the European Union, these targets will likely amount to a 20 to 30 percent reduction in current EU emissions by 2020 to 2030.

This topic is increasingly important for the Czech Republic for two main reasons. Firstly, policymakers and business leaders need to understand the impact of potential reduction targets on the Czech economy and individual businesses. Secondly, a challenging period of post-Kyoto discussions and negotiations of Phase III of the European Trading System is underway and is set to continue with increasing intensity. During this time, the Czech Republic will play a leadership role while holding the EU presidency.

This report neither evaluates the science of climate change nor its possible causes. It intentionally avoids any assessment of policies, political implementation programs, and other governmental interventions. It is strictly intended to provide an objective fact base of the potential and costs of reductions in greenhouse gas emissions in the Czech Republic that can serve as a starting point for further discussions and decisions. The study also marginally addresses the global context of the Czech Republic's role in climate change.

We have adopted this standpoint because in the debates about climate change and its implications, including those for the economy, the facts are often missing. To fill this gap, McKinsey & Company has undertaken an independent, self-financed study using a fact-based methodology to investigate over a hundred reduction measures in all areas of society.

To support our research and develop an understanding of possible actions to reduce greenhouse gas emissions and their associated costs, we have leveraged the work that McKinsey & Company has done with leading institutions and experts over the past three years: initially, at a global level, and later through industry- and country-specific analyses. During the past five months, we have combined this experience with the Prague office's deep knowledge of local conditions.

We would like to thank all of the experts for their valuable insights over the past several months. We believe that this fact-based report will serve as a useful basis for guiding the Czech Republic's policy choices and business leaders' responses to the business reality of climate change.

Prague, October 2008

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Summary of findings

This independent, fact-based perspective on emissions reduction levers in the Czech Republic reveals that abatement potential and costs depend on capturing energy efficiency opportunities, the choice of power mix, and the future feasibility of carbon capture and storage.

What was the methodology used (level of detail and sources of data)?

This report analyzes the potential and costs of greenhouse gas emissions reduction in the Czech Republic, drawing on our experience conducting similar analyses in the United States, United Kingdom, Germany, and other countries combined with the Prague office's deep knowledge of local conditions.

The costs and abatement potential of more than 100 levers across six industry sectors have been analyzed using a four-step process. First, a reference case was constructed to serve as a baseline for current and future emissions reductions. Second, a range of emissions reduction opportunities were identified and estimates were made of the costs and potential abatement volume represented by each. Third, these costs and volumes were combined to create the Czech GHG abatement cost curve, a tool reflecting the costs and abatement potential for GHG reductions by arraying increments of the available potential of individual levers at cost. The final step was to analyze the impact of likely regulatory and technological scenarios on costs and abatement potential, and to quantify the probable economic implications for the Czech Republic.

This is a tested approach that McKinsey has used to analyze the global economy as a whole, the economies of a dozen countries, as well as individual sectors.

What are the main observations about the individual abatement levers?

The individual abatement levers can be reviewed in response to four key questions. Firstly, which economically beneficial opportunities can the Czech Republic capture? Secondly, what are the Czech Republic's choices for its future fuel mix? Thirdly, to what extent must the country rely on the development of carbon capture and storage technology (CCS)? Finally, based on previous decisions, which other measures can the country pursue, and at what costs?

- Various levers are available that can simultaneously reduce GHGs and create economic benefit for society. These diverse opportunities, spread across a wide range of sectors, are related to increasing energy efficiency. Levers with the highest impact include insulating buildings, using LED and compact fluorescent lights, and driving more energy-efficient cars. Such levers are financially beneficial because the energy savings they yield more than offset the cost of implementation. Of the 16 Mt of these energy efficiency opportunities, roughly half are in the buildings sector, a quarter in the transport sector, and a quarter in the industry sector. However, barriers such as the short payback period required by consumers, the existence of more attractive investments, agency issues, lack of awareness or information about opportunities, perception, and convenience costs often stand in the way of taking these actions. Our analysis does not include transaction and program costs, as they would depend on policy choices.

- The power sector offers numerous significant abatement opportunities, but choosing among opportunities involves complicated trade-offs outside the CO_2 solution space, such as security of supply, nuclear energy risks, and villages demolished by coal mining. Nuclear reduces GHG emissions the most, but it is distrusted by a certain share of the population. Renewables have high abatement potential until they reach their natural potential, when they become more expensive than gas. Gas may reduce GHG emissions per MWh by half the potential of nuclear, though at significant cost and raising concerns about energy security, as the Czech Republic mostly depends on one source of gas:

- Several levers could present a net cost to society. Due to the large size of coal-fired power generation in the Czech Republic today (roughly 60 percent of production) it is highly relevant to assess carbon capture and storage technology. The cost of implementing CCS after 2020 is estimated at approximately EUR 44 to 57 per ton. However, the technology has yet to be proven economically and practically viable.

- If uncertainties about CCS technology remain (e.g., leakage issues) or the technology does not prove economically viable, the alternatives for achieving the same abatement potential, such as using the biofuels or hybrid-car levers, could be rather costly. Other, albeit smaller, opportunities are spread across the agriculture, forestry, industry, and transport sectors. In an extreme case, their total cost could reach EUR 2.3 billion, equivalent to roughly half of Czech public spending on education or roughly half of the net profits of the ten largest companies.

What are the holistic insights into the Czech cost curve?

Each of the four groups of levers discussed in the previous chapter requires different enablers. Depending on a range of factors (e.g., the successful implementation of the levers, their net economic benefits, the choice of power mix, the success of CCS technology), the overall cost to Czech society of achieving significant emissions reduction may be as low as zero or as high as EUR 2.3 billion per year. To decide appropriately, the implementation timeline has to be taken into account, as the costs of the individual levers will be different in 2030 than they are today. The Czech abatement cost curve, although similar to its global counterpart and to the cost curves of other countries, has several notable differences.

- *Enablers.* By plotting the levers on a cost curve, we are merely indicating all the options available in a scenario. However, we are not making a judgment on which levers to implement. All of the abatement levers would require some kind of action, because any reduction that would happen on its own is, by definition, already included in the reference case. Even though we have not examined actions supporting each abatement opportunity in detail, from a high-level perspective, very different types of actions would likely be effective for different opportunities (e.g., transport efficiency relies on EU-wide regulation, opportunities in residential buildings could be achieved through standard setting, and those in the power sector depend on national fuel mix decisions). Levers with net economic cost would require appropriate policy, such as regulation or R&D support, to stimulate them.

- *Total cost of reaching emissions reduction targets.* In terms of the total costs, two scenarios representing extreme cases can be imagined. In the first scenario, even a high 32 percent GHG reduction target could be met with as little as zero total cost to society, provided the Czech Republic successfully implemented all of the levers with net economic benefit and reached agreement on pursuing nuclear. In the second scenario, should agreement (e.g., internally or with neighboring countries) on nuclear energy fail and should uncertainties about CCS remain (e.g., leakage issues) or the technology not prove economically viable, even reaching the medium reduction target might be a challenge.

- *Timing of implementation decisions.* The lever implementation timeline is crucial to the total cost of abatement. Technology developments make several abatement levers more affordable in the future, although they may be more costly today. Therefore, the 2030 abatement cost curve should guide forward-looking decisions.

- *Comparison of the Czech Republic to other countries*. The Czech abatement cost curve is similar to its global counterpart and to the cost curves of other countries. However, several notable differences exist.

Most significantly, the Czech Republic has a larger than usual abatement opportunity in the power sector due to the large leeway available for future fuel mix decisions that might have high reduction potential. Differences from the global cost curve also exist in terms of levers having different fundamentals in the Czech Republic (e.g., solar and wind, due to lower radiation yield and less windy conditions in the country).

Methodology and assumptions

The abatement cost curve represents the combined potential of over a hundred emissions reduction levers, ranked according to their costs, which have been determined using a methodology proven on a global level and tailored to local conditions.

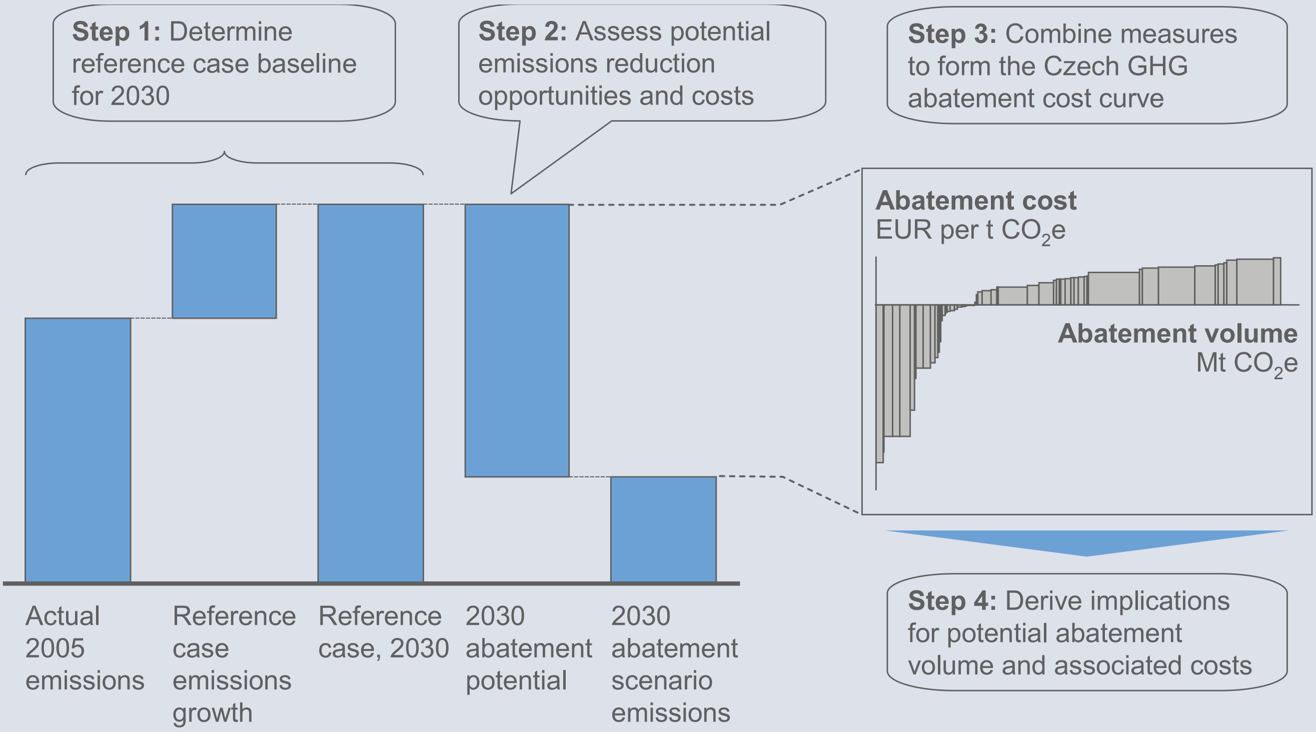
To be able to make rational decisions on how to achieve GHG reduction targets set by policymakers, it is necessary to understand all available abatement levers and their costs, not only on an individual basis but also in combination. McKinsey has adapted its proven methodology to perform such analyses for the Czech Republic.

To analyze the potential for greenhouse gas reductions in the Czech Republic, the costs and abatement potential of more than 100 levers across six industry sectors have been analyzed using a four-step process (Exhibit 12). First, a reference case was constructed to serve as a baseline for current and future emissions reductions. Second, a range of emissions reduction opportunities were identified and estimates were made of the costs and potential abatement volume represented by each. Third, these costs and volumes were combined to create the Czech GHG abatement cost curve, a tool reflecting the costs and abatement potential for GHG reductions by arraying increments of the available potential of individual levers at cost. The final step was to analyze the impact of likely regulatory and technological scenarios on costs and abatement potential, and to quantify the probable economic implications for the Czech Republic.

This is a tested approach that McKinsey has used to analyze the global economy as a whole, the economies of a dozen countries, as well as individual sectors (Exhibit 13). We have combined this experience with our detailed knowledge of the Czech context.

Exhibit 12: 4-step process of quantifying carbon abatement opportunities

Mt CO_2e per year



Step 1: Determine reference case baseline for 2030

Step 2: Assess potential emissions reduction opportunities and costs

Step 3: Combine measures to form the Czech GHG abatement cost curve

Step 4: Derive implications for potential abatement volume and associated costs

Exhibit 13: McKinsey work with abatement curves

	Description	Key sponsors
Global	• Initial cost curve released in 2007 • Revised version due in late 2008	• Client in energy sector • McKinsey
National	• Completed in Germany, UK, USA, Australia, Sweden, Japan, South Korea, Czech Republic • Underway in Italy, China, New Zealand, Ireland, Czech Republic	• Companies • Industrial organizations (e.g., Confederation of British Industry, German Industry Association) • Non-governmental organizations (e.g., Environmental Defense Fund) • McKinsey
Sectoral	• Chemicals • Forestry and land use • Power • Basic materials • ICT sector • Automotive …	• World Economic Forum • McKinsey • Clients in relevant sectors

Step 1: A reference case baseline for emissions through 2030 was constructed, drawing on a number of governmental and other public sources. These forecasts represent the emissions trajectory that would occur under current trends, as well as all government policies and regulations in place as of 2007, but with no additional efforts made to address climate change. Thus, for example, the reference case includes current automobile efficiency regulations but not the stricter limits currently under discussion in Brussels. Emissions are forecast to grow slightly under current trends to 149 Mt by 2030, or 3 percent above 2005 levels, at a rate of 0.1 percent annually (see Exhibit 10), compared to a projected annual economic growth rate of 3.3 percent, meaning that the CO_2 intensity of the economy (i.e., the economic output per unit of CO_2 emissions) will continue to decline, consistent with the long-term trend among developed countries worldwide. This trend is driven by the relative growth of the services sector and other reference case decarbonization effects. Note that this baseline accounts for direct emissions; thus, the power sector includes all emissions from power-generating activities, even if the power is exported and consumed outside the Czech Republic.

Step 2: Potential emissions reduction opportunities and costs were assessed. We first identified potential actions that could reduce GHG emissions in the Czech Republic, and then we quantified the amount of reduction possible and the cost per ton of eliminated GHG emissions.

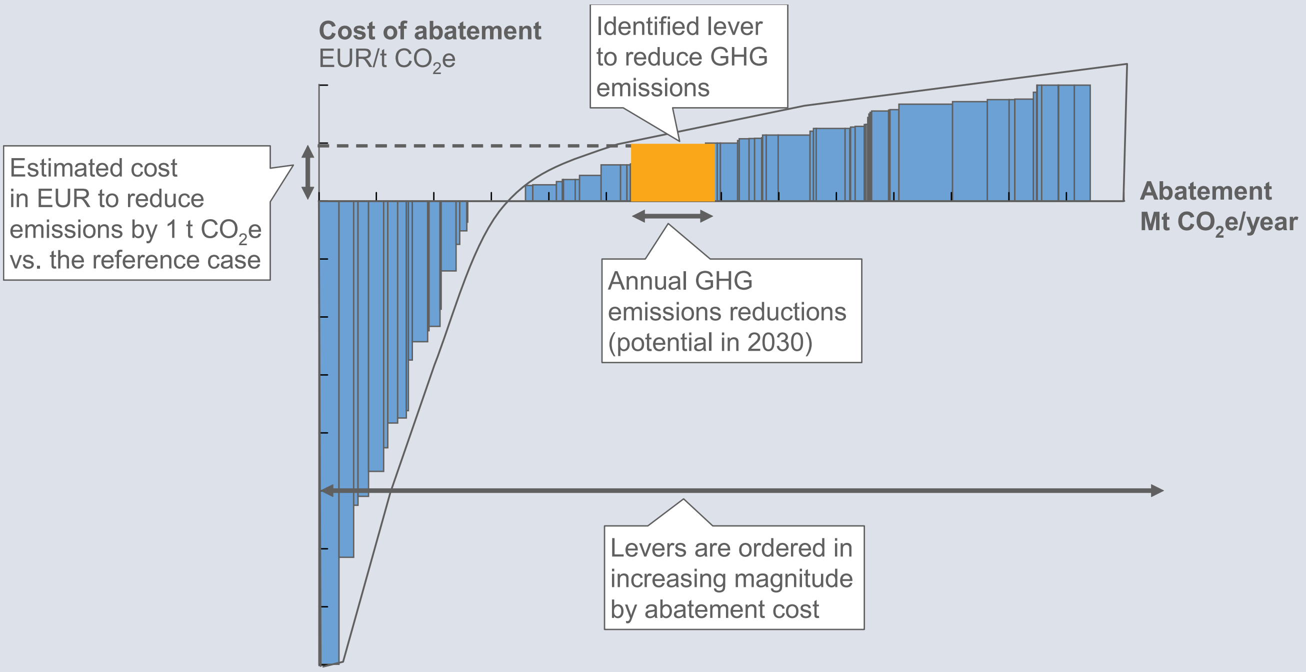
To identify potential abatement opportunities, McKinsey’s local team, with the assistance of global experts, looked at a wide range of options – including renewable energy sources, alternative fuels, energy efficiency measures, and new technologies – to examine ways that GHG-generating activities could be replaced by reduced-emissions, or so-called “carbon neutral,” alternatives. Measures considered included those requiring present-day technologies as well as a limited number of maturing new technologies.

There are two groups of levers that were not included, however. Firstly, speculative technologies or those requiring significant future breakthroughs were not considered. Although we analyzed a wide range of abatement opportunities, we concentrated on measures with a cost of less than EUR 50 per CO_2e ton, the range for which reliable research and information have been developed, both locally and globally.

Secondly, we did not consider any lever that would require significant lifestyle changes. For example, while fuel substitution and improving vehicle efficiency was in the research scope, promoting public transport or bicycle riding to replace private vehicles was not. Similarly, increasing the efficiency of residential heating was considered, but reducing average home temperatures was not. Opportunities involving lifestyle and behavioral shifts were kept out of scope not because they are undesirable, but because their costs or benefits are largely non-financial and thus difficult to quantify. In fact, many of these out-of-scope shifts may be attractive, and some are likely to occur automatically in response to carbon price signals in the economy. We believe that, on balance, our modeling is conservative, since it does not take behavioral

Exhibit 14: How to read the abatement cost curve

The cost curve displays abatement potential and cost for each abatement lever relative to the reference case



shifts and technological developments that are almost certain to arise into account.

For each analyzed lever, the abatement cost was taken to be the additional cost of implementing the opportunity compared to the cost of the activity that would otherwise be incurred (i.e., in the reference case). Thus, for example, the abatement cost of wind power is calculated as the additional generation cost over and above the average generation cost of power assets in the reference case, while also taking the quantity of emissions avoided by each produced unit of wind energy into consideration. These costs are modeled on a full cost basis over the lifecycle of the asset or lever in question. Throughout the report, all costs are expressed in 2008 prices.

It is important to note, however, that we do not make any assumptions about who bears these incremental costs. Whether they are subsidized by government, passed on to consumers, or paid for by businesses, we assume that the underlying economic costs remain the same.

These costs constitute the vast majority of costs to the Czech economy. Obviously, there are some smaller costs and benefits, some of which are difficult to quantify, such as the management time required to implement such changes, the likely costs of “doing nothing,” and the anticipated economic value of related newly created business opportunities.

The volume of each initiative is its potential to reduce greenhouse gas emissions. This is not a forecast, but rather an estimate of what is deemed feasible within the timeframe of the cost curve. Volumes are sensitive to the order of implementation. For example, since energy demand reduction initiatives reduce the total amount of energy produced, they reduce the additional abatement potential of the power sector as well. To avoid double counting, we attribute the GHG emissions associated with lever implementation to the relevant producing industry (e.g., GHGs emitted during production of photovoltaic solar panels are not attributed to this lever itself, but to the manufacturing industry).

Analyzing the in-scope measures involved making a range of assumptions, including power capacity forecasts, expected learning curves, and initial generation costs. Where applicable, we tailored the insights of McKinsey's global studies to the Czech context (e.g., global capital investment costs and learning curves were assumed for carbon sequestration and photovoltaic solar power). Thus, our assumptions remain consistent with ongoing McKinsey global studies, as well as those undertaken in the UK, the US, Germany, Italy, Sweden, and several other countries. These assumptions have been reviewed by scientists, academics, and industry experts. Wherever possible, unique Czech considerations have been factored into underlying cost and volume calculations. The complete list of these considerations is long and includes such items as the low level of insulation in typical prefab tenement houses, the high prevalence of district and co-generated heating, the current penetration of efficient lighting in Czech households, the expected rate of convergence between Czech and EU-15 wages and consumption, and so on.

Step 3: Measures were combined to form the Czech greenhouse gas abatement cost curve. The various abatement measures were ranked from lowest to highest in terms of cost, adjusted to eliminate double counting, and their costs and volumes plotted to create a Czech greenhouse gas abatement cost curve for 2030. This cost curve represents one scenario for emissions reduction in the Czech Republic.

The actual emissions reductions from various levers could be somewhat higher or lower than indicated in the chart. The adoption rate of new technologies depends strongly on energy prices and on cost and performance improvements, neither of which can be predicted with precision.

Step 4: Implications for total potential abatement volume and associated economic costs were derived. We used the cost curve for 2030 to calculate the abatement levers achievable and the associated costs. We also modeled the likely costs of the range of reduction targets proposed by the IPCC, which are currently the subject of international negotiations, and calculated the cost per household and the total gross cost to the Czech Republic for achieving the stated emissions reductions. We extracted insights from this fact base to make high-level recommendations for government, business, and consumers. We emphasize, however, that the intent of this report is to determine what is possible, when, and at what cost. Further work would be required to advise in a more detailed, sector-specific way on how Czech society could make this happen.

Reducing GHGs in the Czech Republic

What net economic benefit opportunities can be captured? What are the power generation trade-offs to be made? How much can the Czech Republic rely on CCS technology development? What other levers can be invested in?

The previous chapter described the methodology used to derive the Czech cost abatement curve. In the following section, the individual abatement levers are examined by their location on the cost curve and their mutual dependencies.

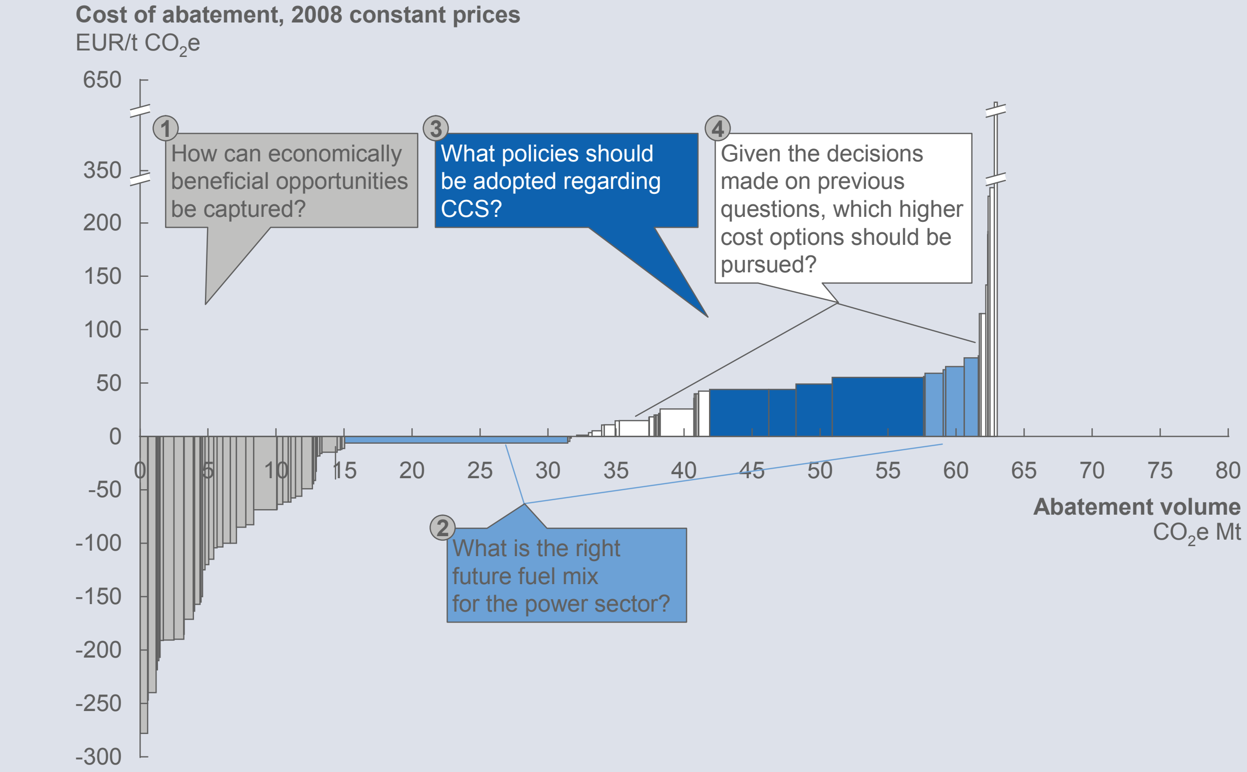
The individual abatement levers can be reviewed in response to four key questions (Exhibit 15):

- Firstly, which economically beneficial opportunities can the Czech Republic capture?
- Secondly, what are the Czech Republic's choices for its future fuel mix?
- Thirdly, to what extent must the country rely on the development of carbon capture and storage technology?
- Finally, based on previous decisions, which other measures can the country pursue, and at what costs?

MEASURES WITH NET ECONOMIC BENEFIT

A set of levers are available that can simultaneously reduce CO_2 and create economic benefit for society (refer to the far left side of the chart under the x-axis). These diverse opportunities, spread across a wide range of sectors, are related to increasing energy efficiency (Exhibit 16). Levers with the highest impact include insulating buildings, using LED and compact fluorescent lights, and driving more energy-efficient cars. Such levers are financially beneficial because the energy savings they yield more than offset the cost of implementation.

Exhibit 15: Four main questions for the Czech Republic to meet potential targets

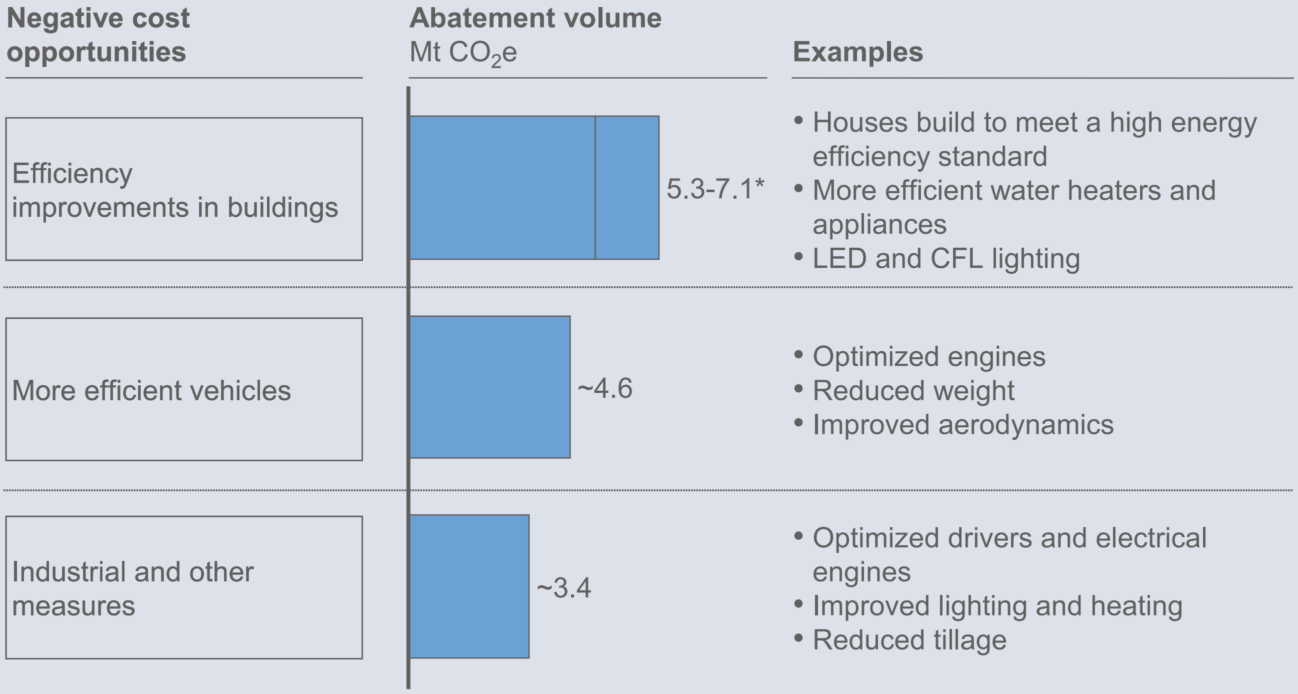


Of the 16 Mt of energy efficiency opportunities, roughly half are in the buildings sector, a quarter in the transport sector, and a quarter in the industry sector. However, barriers such as the short payback period required by consumers, the existence of more attractive investments, agency issues, lack of awareness or information about opportunities, perception, and convenience costs often stand in the way of taking these actions.

Buildings

The buildings sector offers numerous abatement opportunities, many at low or even negative cost. Insulation of existing residential and commercial buildings (retrofits) to meet the currently approved heat consumption standard of several Austrian states (e.g., Upper Austria, Vorarlberg) of 50 kWh per m^2 per year would result in annual savings of 2.6 Mt by 2030. Requiring all new Czech buildings to meet the same standard would result in annual CO_2 savings of 0.5 Mt by 2030. Achieving almost full penetration of efficient lighting (i.e., compact fluorescent lamps and LEDs) by 2030 would save 0.7 Mt per year. Numerous smaller levers (e.g., adopting energy-efficient appliances and space and water heaters, switching from coal to gas heaters, and reducing standby losses in electronics) could save a total of 3.2 Mt annually. Taken together, these actions could reduce the total emissions of the buildings sector by over 20 percent. Many of these efficiency measures are “perishable”: once a building is completed, it is generally much more expensive to retrofit.

Exhibit 16: Example of net economic benefit levers



* Depends on power mix carbon intensity

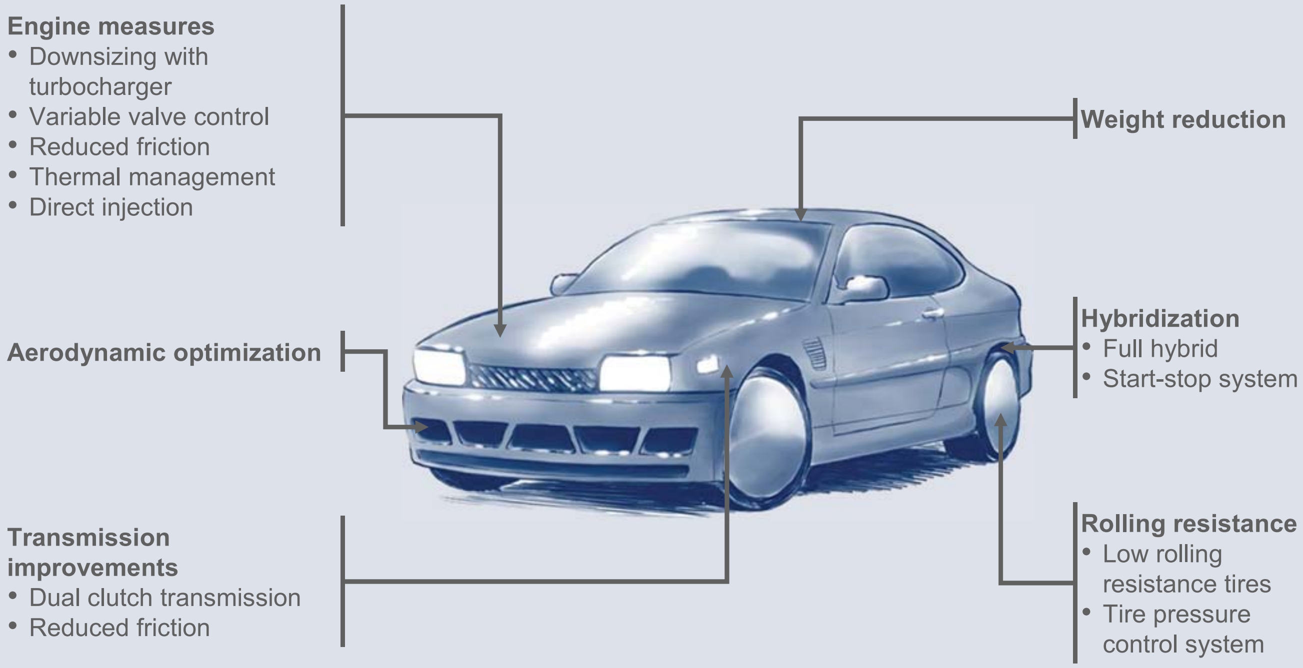
A number of barriers have historically prevented these opportunities from being captured:

- **Costs.** Consumers require household investments to have short, two- or three-year payback periods, implying a discount rate of nearly 40 percent. In addition, lack of investment funds may reduce consumers' ability to take actions offering greater efficiency, even if the financial benefits are adequate.

- **Agency issues.** The owner, operator, occupant, and bill payer (i.e., benefit capturer) of a building may be separate entities or may not be involved for the entire relevant time period. As a result, they may not have the same interest in supporting energy efficiency and GHG abatement. For example, property owners have little incentive to add extra insulation to their buildings when the resulting savings go to their tenants.

- **Lack of information.** Although energy labeling is mandatory on appliances and will become mandatory on buildings as well, lack of information still leads to unnecessary inefficiencies. Heaters and air conditioners may operate well below their nominal efficiency due to improper installation or maintenance. Consumers often do not understand the true added cost of incremental appliances, such as spare refrigerators. Architects, engineers, builders, contractors, installers, and building operators may omit simple changes that could increase efficiency because they are not aware of the savings potential.

Exhibit 17: Examples of reduction opportunities in transport



The persistence of buildings sector energy inefficiencies worldwide suggests that some form of policy intervention or innovative private sector initiatives may be necessary to unlock the abatement potential in this area. Potential actions could include strengthening building codes; offering subsidies, rebates, or low cost loans for energy-efficient purchases; mandating annual commercial building inspections; and continuing to educate consumers. Governments worldwide are taking many of these actions. For example, Germany and France are discussing adopting a 50 kWh per m^2 new building insulation standard, which is roughly twice as efficient as current Czech standards, and Australia, Canada, and the United States have passed laws mandating the phaseout of incandescent lighting.

Transaction and program costs are not included in the abatement cost curve. The primary reason is that these costs reflect a political choice regarding what policy and programs to pursue. For example, to capture the abatement potential of energy-efficient light bulbs, policymakers can either mandate that only energy-efficient bulbs are sold (a less expensive but more intrusive option) or they could try to convince consumers through education campaigns to voluntarily switch (a more expensive but less intrusive option). These options have been adopted by various governments, though it should be noted that the transaction and program costs vary considerably between the two cases.

Transport

Under our abatement scenario, measures with net economic benefit in the transport sector include increasing vehicle fuel efficiency. Fuel efficiency can be increased by a wide range of technological improvements, such as reducing vehicle weight, improving aerodynamics, improving the efficiency of internal combustion engines, and automatically monitoring tire pressure. McKinsey's collaborative work with automobile manufacturers suggests that these measures could reduce average fuel consumption per kilometer by more than 50 percent with net economic benefit to consumers. This would result in a net savings of 1.1 Mt CO_2e annually if a quarter of new cars met this standard by 2030.

The extent to which these opportunities are captured will largely depend on decisions made in other countries, since the Czech Republic does not have the scale to motivate market changes in the automotive sector. The availability of more efficient gasoline-powered and diesel vehicles will likely be driven by planned EU regulations on the maximum allowed fleet-average CO_2 emissions per kilometer. However, if national and local governments decide to support this lever, they may come up with additional steps of their own. For example, the UK ties vehicle sales tax and annual licensing fees to CO_2 emissions levels, the United States offers tax rebates of up to USD 3,000 for hybrid purchases, and the State of California pays motorists to retire older, more polluting vehicles. If executed properly, such actions have the potential to stimulate the economy, since they can result in new car purchases supplanting older, inefficient cars and reducing the level of imports of used cars from neighboring countries. Similarly, if plug-in hybrids become economically viable, the government may play an important role in developing the required local infrastructure.

Improving efficiency in industry

The primary levers with net economic benefit in industry lie in improving the energy efficiency of buildings and processes (e.g., load-size matching and speed control for electric motors, advanced process controls, heat and energy recovery, preventive maintenance). Because these levers are economically beneficial, some are likely to be captured without further intervention, as demonstrated clearly by the gradual long-term improvement in industrial energy efficiency worldwide. However, two persistent barriers are likely to prevent fully capturing these opportunities unless further steps are taken:

- **High investment hurdles.** Industrial companies typically require relatively rapid payback (i.e., within one to two years) on investments in energy and process efficiency. Compared to other capital projects, energy efficiency projects are frequently not pursued because of their lower anticipated rate of return and companies' capital constraints. This is especially true as price volatility in the energy supply increases the risk of efficiency projects not paying off. They also tend to be widely distributed, requiring a disproportionate amount of human resources, including management attention, to capture them.

- **Poorly understood energy efficiency opportunities.** "The more you look, the more you find" is an oft-repeated and empirically substantiated observation of business leaders who have enjoyed significant gains through energy and process efficiency improvements. However, many business leaders are not sure where to begin looking for energy savings, nor are they confident enough in the expected benefits to come up with a compelling financial case for action.

Addressing these barriers will be especially important for small- and medium-sized businesses, since most of the largest emitters will be covered by the ETS and will have strong financial incentives to maximize efficiency. One approach is to run awareness and education programs to help industry sector participants identify and capture opportunities across their facilities and manufacturing processes. The UK's Carbon Trust has achieved some success in this way, sponsoring events, conferences, publications, and websites for businesses and organizations, and bestowing Carbon Trust Innovation Awards. Other options include stricter regulations (e.g., on building efficiency) and subsidies or low interest loans for energy efficiency improvements.

FUEL MIX IN THE POWER SECTOR

The power sector offers numerous significant abatement opportunities, but choosing among opportunities involves complicated trade-offs outside the CO_2 solution space, such as security of supply, nuclear energy risks, and villages demolished by coal mining. Nuclear reduces GHG emissions the most, but it is distrusted by a certain share of the population. Renewables have high abatement potential until they reach their natural potential, when they become more expensive than gas. Gas may reduce GHG emissions per MWh by half the potential of nuclear, though at significant cost and raising concerns about energy security, as the Czech Republic mostly depends on one source of gas.

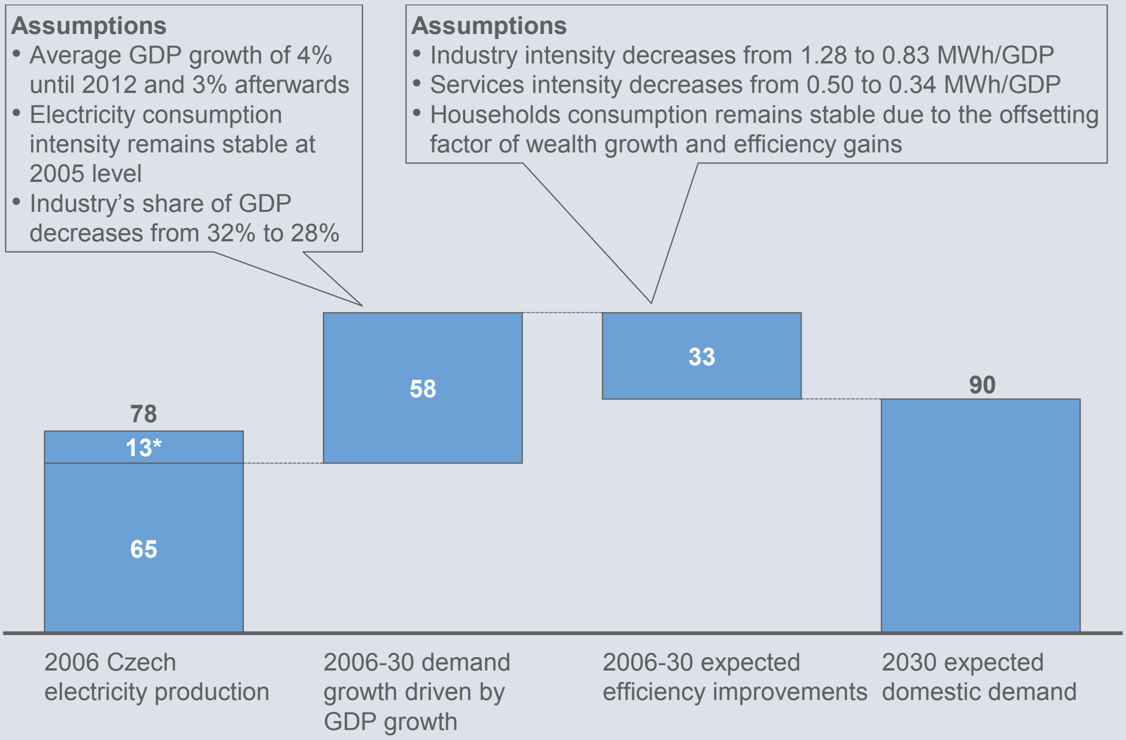
The coming years will be critical for determining the future fuel mix of the Czech power sector. On the one hand, from 2008 to 2030, annual domestic electricity demand is projected to grow from its current 65 TWh (the remaining 13 TWh produced is currently exported) to 90 TWh in 2030 (Exhibit 18). The demand projection is driven by GDP growth adjusted by expected changes in industry share of GDP and a decrease in electricity intensity for both the industry and services sectors.

On the other hand, during the same period, coal-fired power plants responsible for generating 23 TWh per year (28 percent of the Czech Republic's current electricity production, and almost half of its coal) will reach the end of their useful lives. This will leave the Czech Republic with an electricity supply of 55 TWh. To satisfy projected demand of 90 TWh, power plants capable of generating 35 TWh per year will need to be constructed (Exhibit 19). The fuel mix chosen for these plants will have large, lasting implications for CO_2 emissions in the Czech Republic.

Within the Czech power sector, the largest abatement opportunities per MWh lie in increasing the share of nuclear, renewables, and gas. Finding the right fuel mix will require balancing multiple factors. Numerous concerns will come into play in addition to CO_2 emissions: for example, energy security, the economic cost to various stakeholders,

Exhibit 18: Electricity demand in the Czech Republic

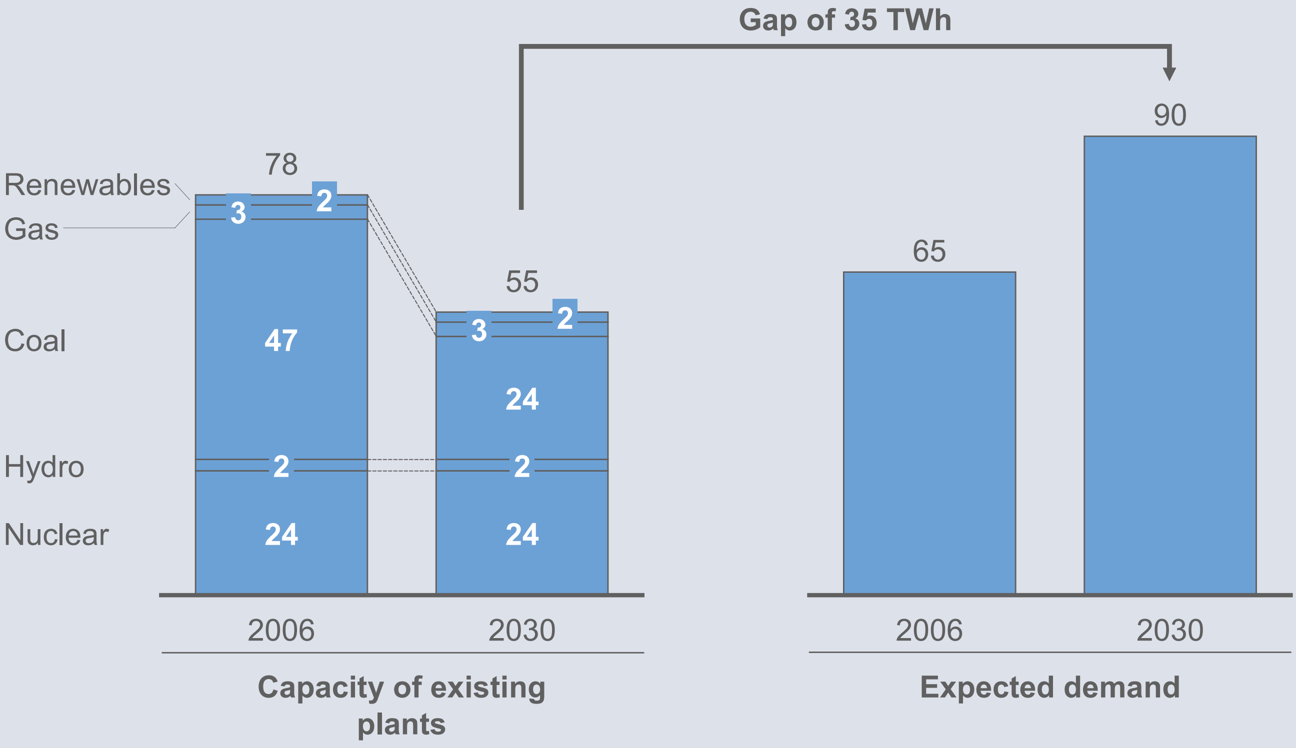
TWh



* Export

Exhibit 19: Expected development of power demand by 2030

TWh



and safety. Balancing these factors appropriately is one of the bigger challenges facing the Czech Republic.

The reference case already assumes some abatement potential in the power sector versus the current situation. Total abatement of 14 Mt CO_2e can be achieved through retrofitting lignite power plants, constructing new gas power plants, and expanding renewables. In the reference case, we assume that the Czech Republic will reach the renewables target level agreed to at EU accession (i.e., 8 percent share of electricity in 2010). Realistically, however, this target might be achieved a little bit later.

We have modeled six scenarios for the power sector to help illustrate what is at stake:

- **Maximum coal.** In this scenario, all incremental power is generated by coal plants, typically major retrofits of aging plants near lignite mines that would otherwise be retired. By 2030 the Czech power mix in this scenario would be 54 percent coal, 29 percent nuclear, 10 percent gas, and 8 percent renewables. Coal supplies for the power plants would require expanding existing mining limits in 2018, with likely adverse effects on settlements near the mines. Annual CO_2 emissions of 45 Mt would be a 20 percent decrease from current levels, mainly due to the increased efficiency of retrofitted coal and the increased share of renewables. At EUR 47 per MWh, the average cost of generating power would be relatively low, but from 2013 onwards, power generation companies would likely need to purchase emissions allowances at auctions for more than EUR 30 per ton (according to some forecasts). This would significantly increase the average generation cost to EUR 69 per MWh. This is the reference case we have adopted for the power sector. We have adopted it not because we think it is the most plausible scenario, but because it roughly maintains the current fuel mix and, therefore, serves as a useful base case for judging other, lower emissions scenarios.

- **Maximum coal with carbon capture and storage**. This scenario is identical to the preceding one, except that all coal-fired plants built or retrofitted after 2020 are assumed to receive carbon sequestration technology. Compared to the reference case, CO_2 emissions would be reduced by 15 Mt per year, or 33 percent. Although the cost of sequestration in the period after 2020 is uncertain, most experts expect EUR 44 to 57 per ton, implying an incremental generation cost of EUR 30 to 40 per MWh versus the reference case. However, carbon sequestration would reduce the required purchase of emissions allowances by a similar amount, partially offsetting costs. Because CCS technology has not been proven economically viable, this scenario carries considerable economic and environmental risk. If CCS fails to become commercially viable by 2030, or if suitable storage is unavailable, emissions would equal those of maximum coal. In this case, costs could far exceed the reference case due to abandonment of partially built CCS infrastructure.

- **Maximum gas** (Exhibit 20). In this scenario, no coal retrofits or new plants would occur beyond those already in the planning stages today. Instead, new combined-cycle gas turbine plants would be rapidly installed across the Czech Republic. By 2030, the power mix would be 37 percent gas, 27 percent nuclear, 26 percent coal, and 10 percent renewables. Relative to the reference case, annual CO_2 emissions in 2030 would be reduced by 9 Mt, or 20 percent. Ignoring the cost of emissions allowances, the average generation cost would be EUR 58 per MWh, a 23 percent increase over the reference case. However, the difference in cost is much lower when the cost of emissions permits is taken into account (EUR 74 per MWh for this scenario versus EUR 69 per MWh for the reference case). Cost differences are strongly dependent on the assumed price of oil (Exhibit 23), but in all cases, this scenario is more expensive than the reference case.

- **Renewables and gas.** In this scenario, capacity expansions in the power sector would be focused on renewable fuel sources with gas covering the capacity gap. Although this scenario seems highly unlikely due to the extremely high share of renewables and the high volume of gas imports, we modeled it because it reflects the goals of certain NGOs. We assumed that biomass would be the primary fuel source, as no other renewable looks like a candidate: hydroelectric potential is already almost fully exploited, wind seems incapable of supplying more than 4 TWh per year, and the average generation cost of solar photovoltaic in the Czech Republic is likely to remain significantly higher than biomass, even after making optimistic assumptions about the solar learning curve (i.e., EUR 130 versus EUR 87 per MWh). We adopted 13 TWh as the Czech Republic's maximum biomass generating capacity, since this would require roughly 15 percent of the country's agricultural land for producing fuel for power plants, and we assumed that gas power plants would account for the remaining capacity expansion. As a result, the net power mix in 2030 would be 30 percent renewables, 28 percent gas, 28 percent nuclear, and 14 percent coal. Annual CO_2 emissions would be 24 Mt less than in the reference case. The generation cost would be EUR 24 MWh higher; however, since the EU considers biomass to be CO_2 neutral, this would be partialy offset by the reduced cost of emissions permits.

- **Maximum nuclear** (Exhibit 21). This scenario assumes that two additional blocks at Temelín would become functional by 2022 and that an entirely new 3.6 GW nuclear plant would come online in 2028. Maintaining sufficient generating capacity prior to 2025 would require extending the lifetimes of 2.5 GW of coal-fired capacity by an average of 11 years. With a net generating cost of EUR 46 per MWh, a minimal need for emissions allowances, and large carbon abatement of 40 Mt annually, this option has a lower cost per ton of emissions reduction than any other scenario we considered. As all other scenarios, this scenario has several serious disadvantages.

- **Gradual fuel shift** (Exhibit 22) This scenario represents a moderate outcome where the fuel mix gradually becomes cleaner. Initially, lignite-fired power plants would be rebuilt rather than retired, but no expansion of the mining limits would take place and, as a result, lignite power generation would steadily decline after 2014. Two additional nuclear blocks would come online

Exhibit 20: Abatement cost curve: maximum gas

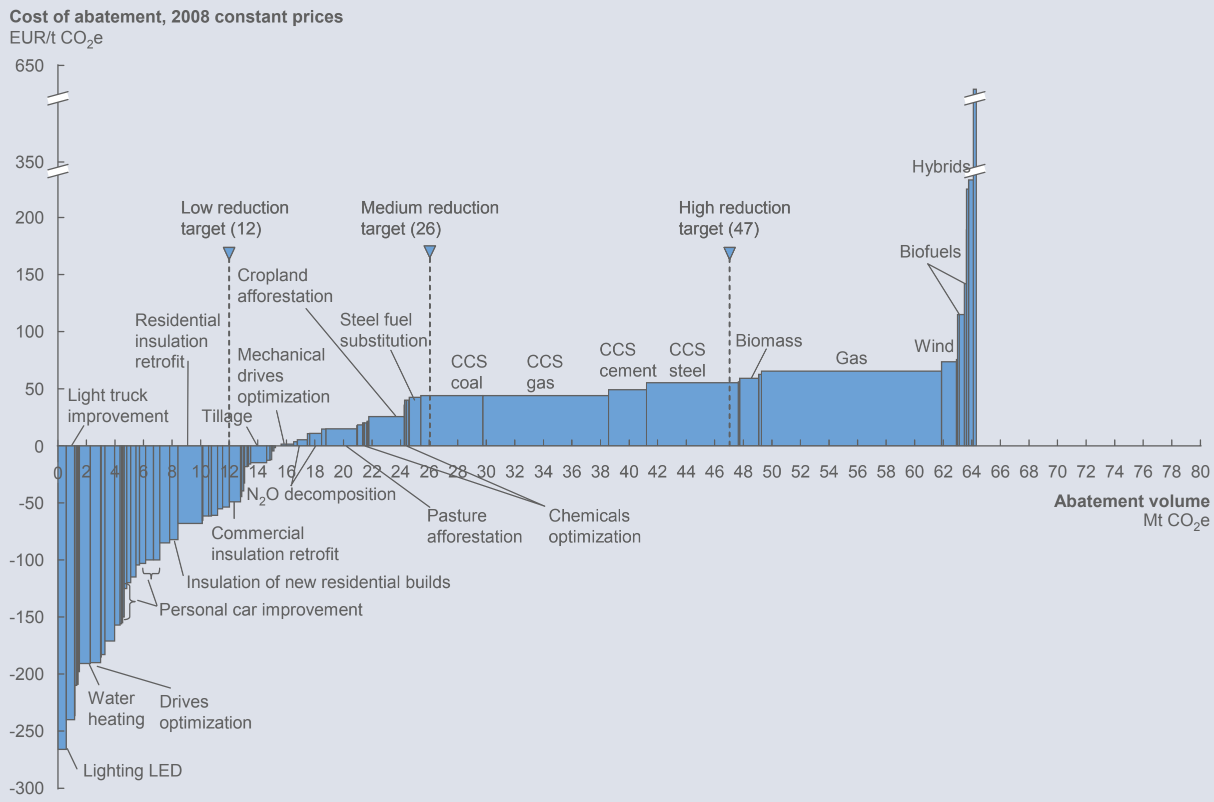


Exhibit 21: Abatement cost curve: maximum nuclear

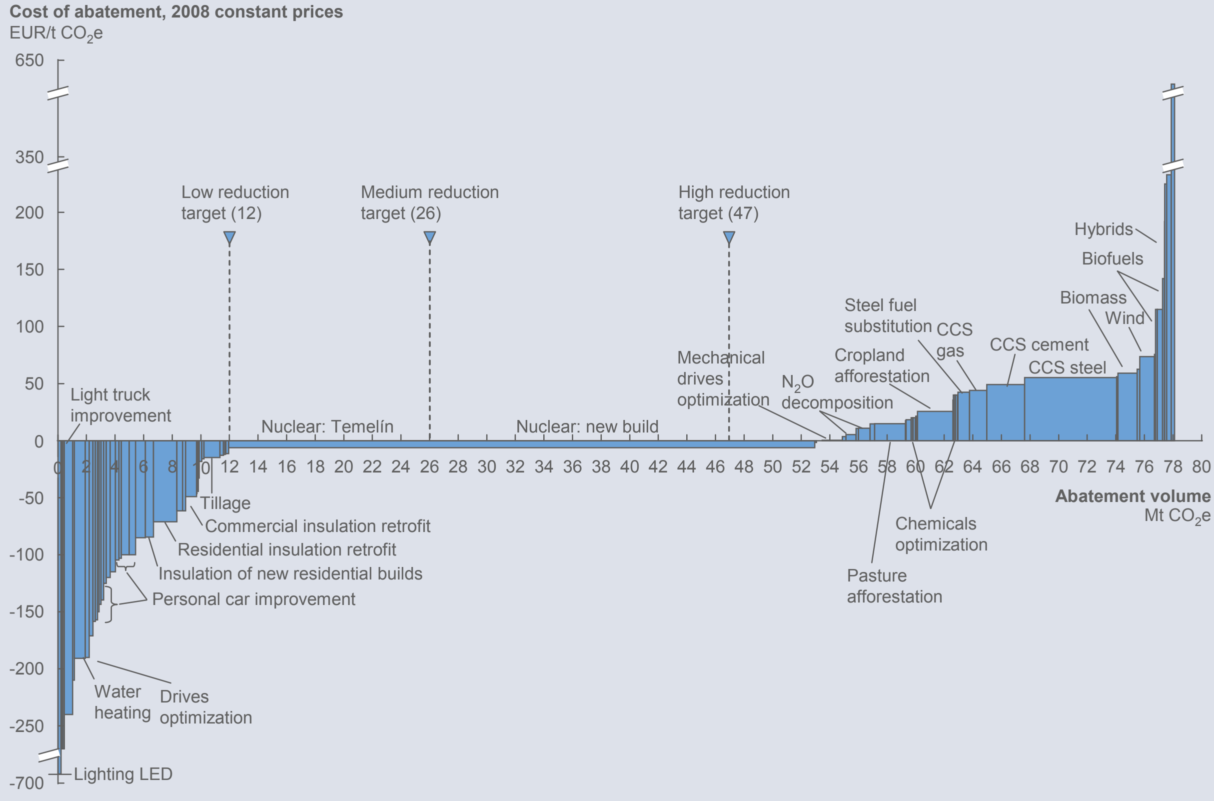
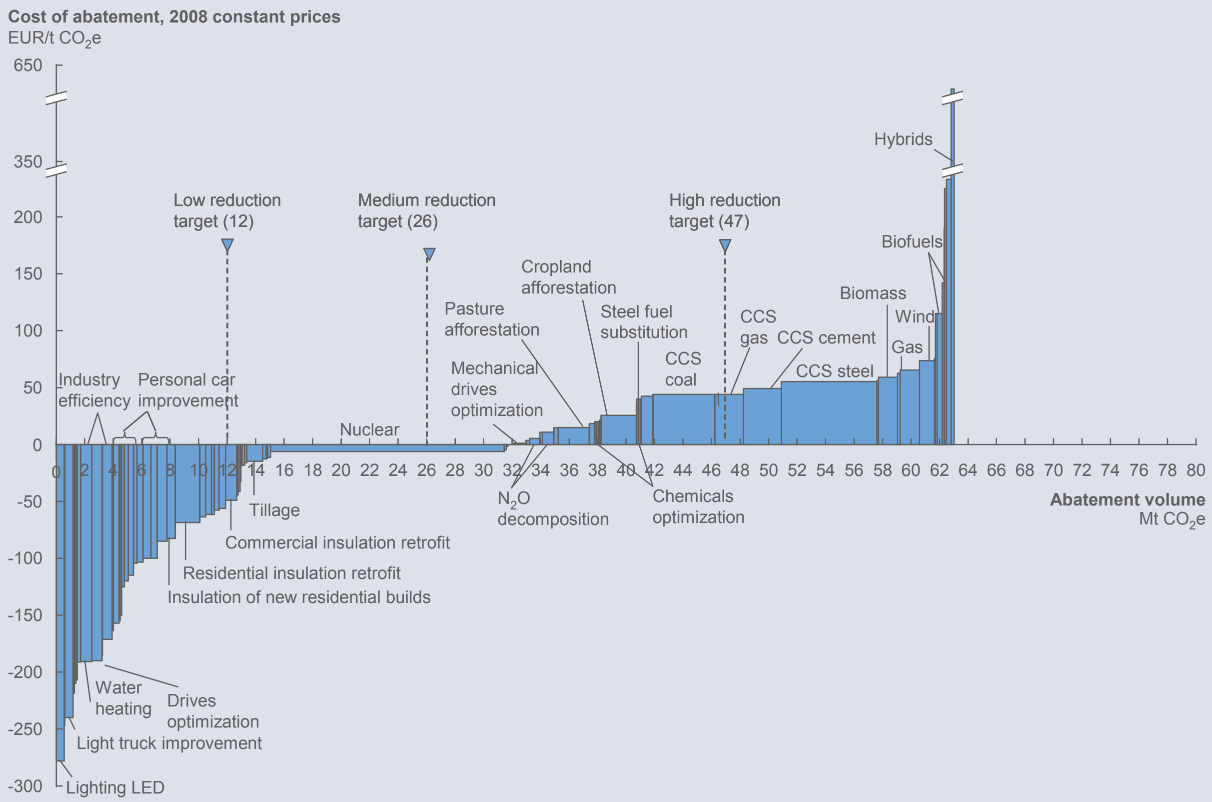


Exhibit 22: Abatement cost curve: gradual fuel shift



at Temelín in 2022, but there would be no further nuclear construction. Remaining power demand would be filled by a moderate expansion of gas generating capacity. By 2030, the power mix would be 50 percent nuclear, 27 percent coal, 12 percent gas, and 11 percent renewables. Annual emissions of 28 Mt would represent a reduction of 38 percent versus the reference case. If the emissions allowances are included, the average generation cost of EUR 62 per MWh would be below the reference case of EUR 69 per MWh.

Each scenario has different costs, benefits, and risks. Exhibit 23 summarizes the costs and level of CO_2 reduction in each scenario, but multiple additional factors affect which fuel mix is right for the Czech Republic. There is no obvious winner, as the individual scenarios score low or high on different criteria:

- **Cost.** The differences in generation costs between scenarios are substantial. Taken at face value, the nuclear scenario could power the Czech Republic at an average generation cost per household of EUR 903 per year, roughly EUR 30 to 530 lower than other scenarios. As we will see, the actual cost increase of other scenarios could be even higher due to the need to reduce CO_2 emissions through other, higher cost means. Although it is unclear which stakeholders might bear the cost, a non-nuclear option could involve significant financial sacrifice. This conclusion is very sensitive to the assumed expenditures of nuclear expansion, however. Capital cost overruns like those experienced elsewhere could erode nuclear's cost advantage, as could unexpectedly high waste storage charges.

- **Execution risk.** This is a significant concern for biomass and coal with CCS, since both rely on the development of new technologies that have not yet been demonstrated at scale. The limited recent experience with nuclear construction and the limited number of players on the market add some execution risk for nuclear as well. Gas should offer few challenges.

- **Greenhouse gas reduction.** Each of the options results in large reductions relative to the reference case, but the nuclear and renewables scenarios reduce significantly more due to the near zero emissions from these fuel sources.

- **Other environmental concerns.** Gas appears to be the most attractive in this regard. Each of the other fuel sources is accompanied by serious environmental concerns: waste storage and potential radiation leaks for nuclear, air pollution for coal, damage to ecosystems at home and potentially abroad from the widespread cultivation required for biomass generation, potential long-term CO_2 leaks from coal with carbon sequestration, and so forth.

- **Safety.** Although a serious nuclear accident has not occurred in decades, this risk will need to be factored into any decision on the power sector.

- **Energy security.** Coal and biomass feedstocks appear reasonably secure in the mid term, with significant domestic sources for each. Nuclear would probably require uranium imports, but the supply should be reasonably secure given the wide range of potential sources, including several stable democracies. Gas could be vulnerable to disruption given the concentration of the available supply.

When faced with uncertainties and complicated trade-offs, it can be difficult to justify a large bet on any single fuel source. Power generation companies in similar circumstances have often opted for a balanced portfolio. The Czech Republic will need to decide whether this is also the right choice for the country. A key question will be the extent to which the country is willing to forego the potential financial and emissions reduction benefits of nuclear power to reap the benefits of other fuel sources.

CARBON CAPTURE AND STORAGE

Several levers could present a net cost to society (refer to the right-hand side of the abatement cost curve). The large size of coal-fired power generation in the Czech Republic today (roughly 60 percent of production) means that carbon capture and storage could be a large opportunity. The cost of implementing CCS after 2020 is estimated at approximately EUR 44 to 57 per ton (Exhibit 25). However, the technology has yet to be proven economically and practically viable.

While CCS is still in its technological infancy, it is rapidly developing. Our assumptions have been guided by the best available viewpoints on its viability and likely learning curve, but significant uncertainty remains. Even if carbon capture technology sufficiently matures, its economical deployment in the Czech Republic will

Exhibit 23: Implications of power scenarios on costs and CO_2 reductions

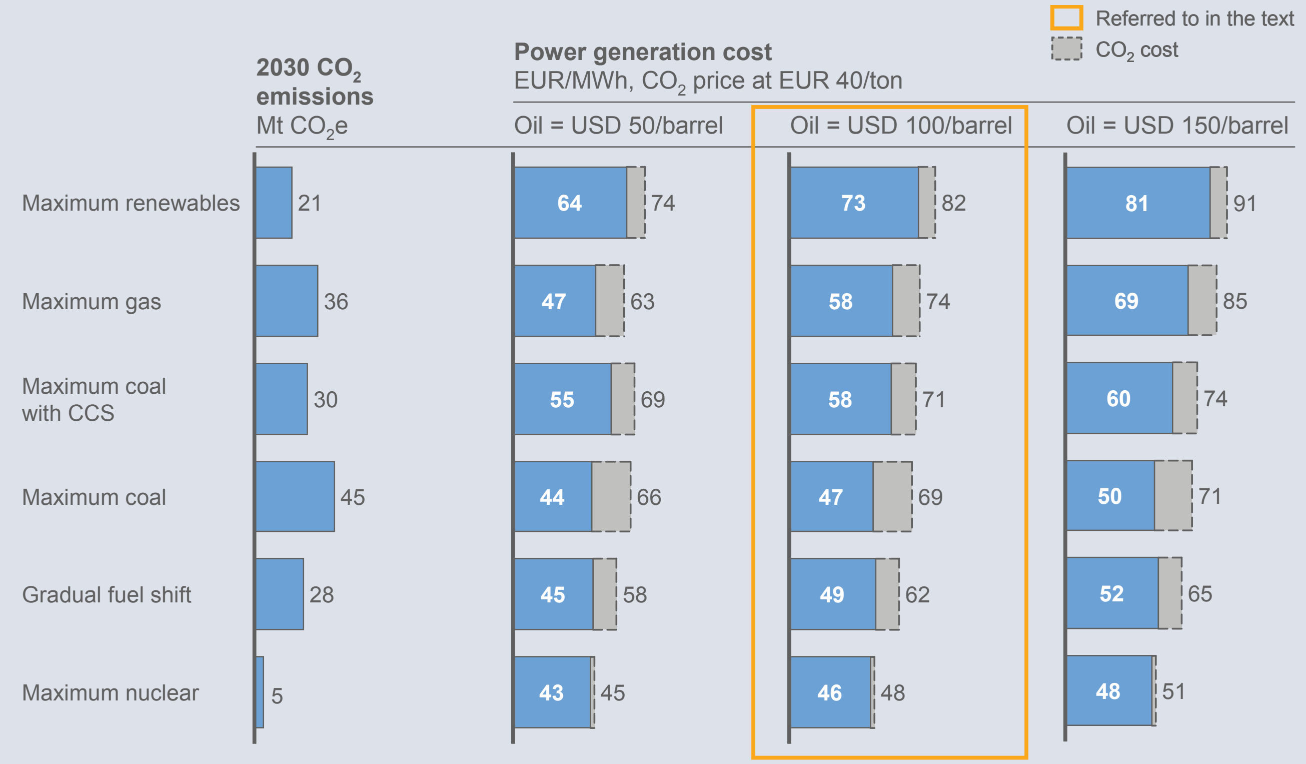


Exhibit 24: Power generation cost per household

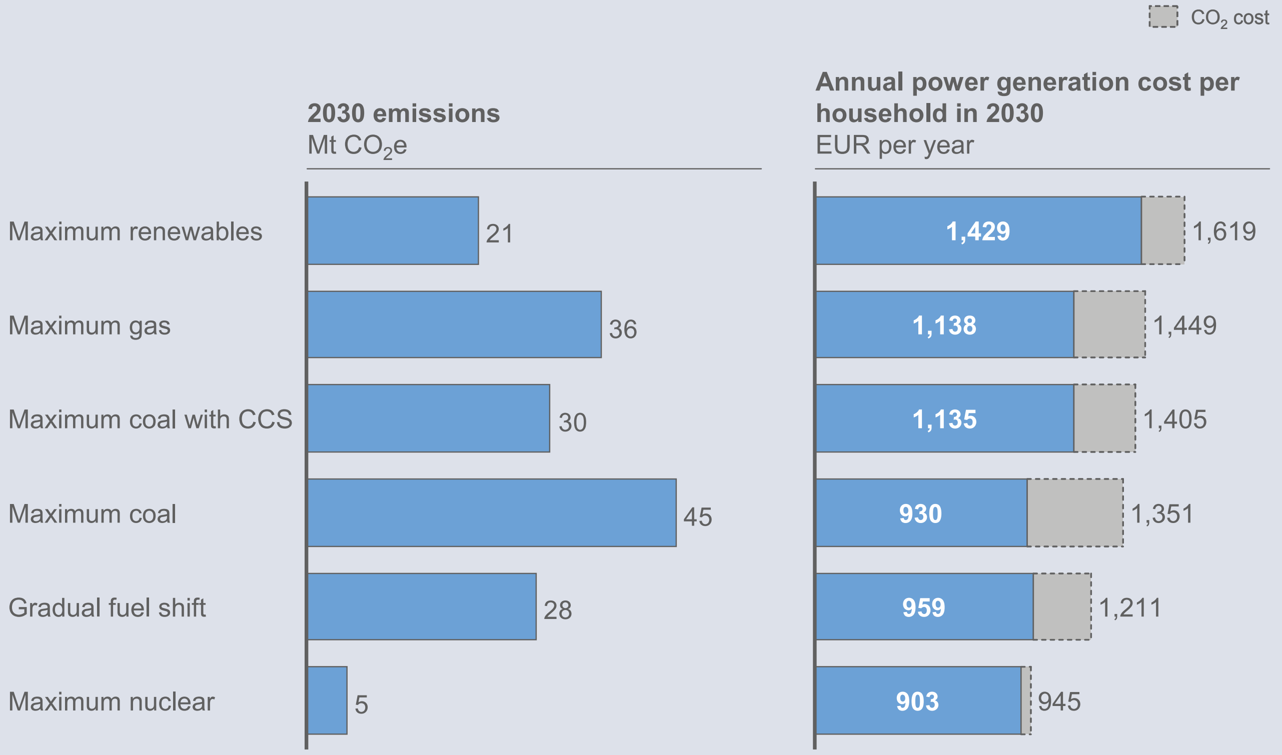


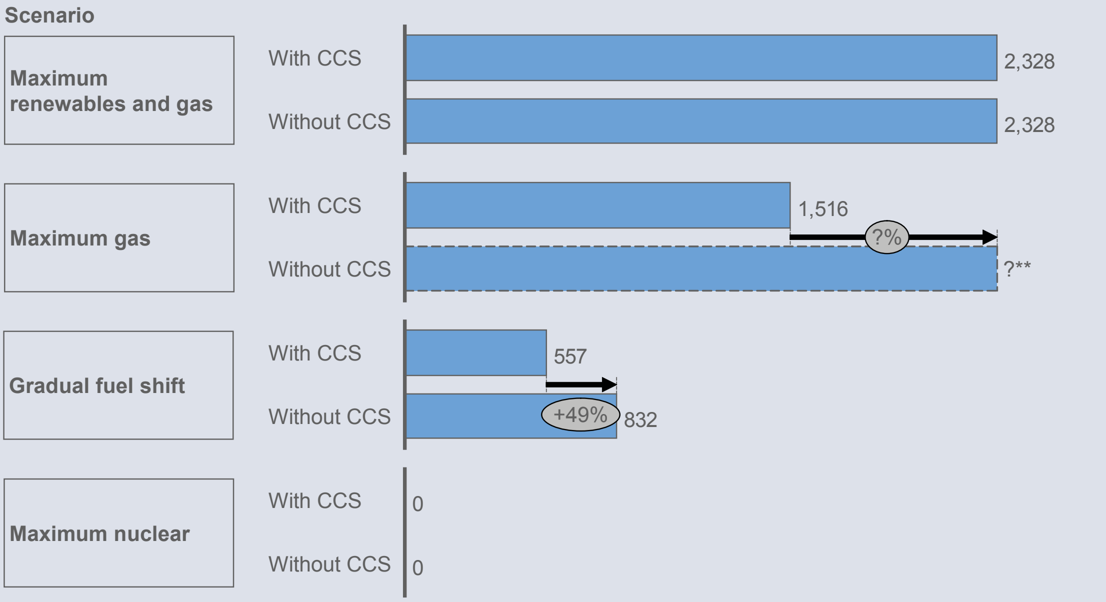
Exhibit 25: Several high-potential technologies for CCS are in the development phase

🔵 Demo plants, 2015
⚪ Early commercial plants, 2020+

	Capture	**Transportation**	**Storage**
Technologies	• **Post combustion** coupled to conventional thermal plants • **Pre-combustion** mainly with IGCC but also with NGCC • **Oxy-fuel** • **Chemical looping** • **Green fuel: algae farm**	• **Pipeline** – **Onshore** – **Offshore** • **Shipping**	• **Underground/geological** – Depleted oil and gas fields – Saline aquifers (on- and offshore) – EOR and EGR – Coal seams: ECBMR • **Ocean storage** • **Mineral carbonization**
Status	• **Technically proven** but not commercially mature • Currently **unclear** which **technologies will come out as the "winner"** • **Several pilots** (also on an industrial scale) under construction	• CO_2 transport similar to natural gas • **Technologies mature and become commercially available**	• **Geological storage in oil and gas fields** seems to be the **first wave** alternative • Other storage alternatives still must be technically proven and validated in terms of potential • Questions of sustainability of capture (longest pilot – 7 years)
Cost range (post-combustion) EUR/t CO_2	🔵 53-58 ⚪ 34-37	🔵 5-10 ⚪ 5-10	🔵 5-10 ⚪ 5-10

Exhibit 26: Comparison of total abatement costs by power scenario at high reduction target, with and without CSS technology

Cost* of reducing Czech emissions by 47 Mt by 2030 (high reduction target)
EUR million per year



* Total cost of all net cost abatement levers
** Reduction target not met (maximum available reduction 42.5 Mt CO_2e)

likely require suitable geological storage either inside the country or nearby (e.g., in Poland).

Exhibits 20 and 22 demonstrate that CCS could play a large role in facilitating cost-effective emissions reduction in the Czech Republic. Exhibit 22 shows that CCS could account for 16 Mt in abatement potential by 2030, roughly 30 percent of the total for less than EUR 57 per ton. Exhibit 26 shows that the total cost of achieving the high reduction target in the gradual fuel shift scenario would increase by up to roughly 50 percent if CCS were not available.

This raises two questions for the Czech Republic:

- Do the large benefits of CCS offset the potential risks? Risks would be involved at every stage. In the development phase, there would be the possibility of significant stranded costs for power plant infrastructure, pipelines, and storage facilities if CCS technologies encountered unexpected hurdles and could not be developed economically. During and after the operations phase, uncertainties would persist for centuries regarding the management of underground CO_2 reservoirs.

- If the benefits do outweigh the risks, what role, if any, should the Czech Republic play in unlocking the potential of CCS, and at what point should the country commit to deploying it? Decisions in the power sector require long lead times, and achieving substantial CCS capabilities by 2030 would likely require action to be taken in the Czech Republic before CCS technology has been fully proven. Key technological developments are likely to be driven by larger-scale power producers elsewhere. However, provided Czech businesses and the government come to the conclusion that the main uncertainties around the technology have been solved to an extent that warrants the investment or R&D, they could play a role in helping to identify and develop potential local storage options, and the Czech government could ease development by clarifying issues surrounding storage liability.

Cautious decisions on investment in CCS development should be taken by business and government while clarifying the potential of CCS and developing an appropriate strategy.

OTHER LEVERS WITH NET COST

If uncertainties about CCS technology remain (e.g., leakage issues) or the technology does not prove economically viable, the alternatives for achieving the same abatement potential could be rather costly. These technologies are relatively well known. However, they come at a significantly higher cost of over EUR 100 per ton. Implementing the biofuels lever and the hybrid-car lever are estimated to cost EUR 115 to 225 and EUR 200 to 600 per ton, respectively. Other, albeit smaller, opportunities are spread across the agriculture, forestry, industry, and transport sectors. In an extreme case, their total cost could reach EUR 2.3 billion, equivalent to roughly half of Czech public spending on education or roughly half of the net profits of the ten largest companies.

Detailed analyses of industries by McKinsey teams in Germany, the US, and elsewhere suggest large potential for GHG emissions reduction in the industry sector. In addition to the opportunities discussed in the energy efficiency section, major identified opportunities include recovering and/or destroying non-CO_2 GHGs such as methane, nitrous oxide, and HFCs/PFCs; implementing CCS at industrial sites; and a range of industry-specific levers, such as clinker substitution in cement production. The emissions reduction potential and economic viability of these levers depend heavily on the specific conditions in particular industries, and even in specific plants. Due to the highly fragmented nature of the levers, we have not comprehensively measured these opportunities in the Czech Republic, but we have estimated their potential and costs by appropriately scaling international estimates to local conditions. Detailed work will be required to identify and capture opportunities at the plant level, but we are confident of two points: firstly, numerous CO_2 reduction levers will be found; secondly, many of them will represent net economic gains (e.g., efficiency improvements, reductions in the waste of useful gases).

In addition to the energy efficiency opportunities discussed in transport, a reduction of 0.2 Mt could be achieved by increasing biofuels usage 4 percent beyond the EU mandate of 10 percent. (Note, however, that this level of biofuel consumption could face opposition if food prices continue to escalate.) To illustrate, if plug-in and conventional hybrid technologies achieved 100 percent penetration in new sales by 2020, 3 to 4 Mt CO_2e could be avoided annually, depending on the carbon intensity of the power supply in 2030. However, these are still expensive levers. Implementation of the biofuels lever is estimated to cost EUR 115 to 225 per ton and the hybrid-cars lever entails costs of EUR 200 to 600 per ton. The economic attractiveness of hybrids also depends strongly on the price of oil and on future improvements in the cost and performance of batteries. Consequently, it is unclear whether such a high level of penetration is realistic. In addition to the technical levers considered in this study, large opportunities would be expected from the promotion of structural shifts in the transport sector, such as increased investment in public transport and increased use of freight rail. However, these opportunities are outside the scope of our analysis.

Although abatement actions in the forestry sector have significant potential globally, within the Czech Republic the potential is limited. Planting trees in marginal grassland or cropland is the primary option. Reforesting 10 percent of Czech cropland and pastureland would result in annual CO_2 absorption of approximately 4 Mt per year for decades. The cost would range from EUR 15 to 30 per ton, depending on the value of the land for other uses. However, converting cropland to forest could be controversial, especially if food prices remain high. In any case, under current conditions it would be economically favorable to use all but the most marginal lands for biofuels rather than for reforestation.

The main opportunities in agriculture are reduced tillage, improved agricultural practices, and lower methane emissions from cattle. The use of conservation tillage (i.e., cultivation of soil with reduced or no plowing prior to planting) helps to retain the CO_2 captured in the soil. Applying this technique to 10 percent of Czech cropland would result in 0.6 Mt CO_2e savings per year. Improved agricultural practices comprise a wide range of activities designed to reduce GHG emissions per unit of produced food. Examples include applying fertilizer more effectively, using improved crop varieties, and avoiding unplanted fallow. Widespread adoption of these practices could lower emissions by up to 2 Mt CO_2e per year.

Feed changes or vaccinations to lower methane emissions from cattle, which are a major source of agricultural GHGs, could bring reductions of roughly 0.5 Mt CO_2e per year, though the cost of these interventions is high compared to other agricultural options.

Bird's eye perspective on the cost curve

The total cost of reaching expected emissions reduction targets could range from zero to more than 2 billion euros annually, depending on the enablers chosen, the choice of power mix, and the timing of implementation.

This chapter looks at the cost curve from a holistic perspective. First, it examines the enablers that have to be put in place to support the abatement levers. Next, the total costs of reaching the potential reduction targets are analyzed. Attention is paid to the fact that decisions have to take a different timeline into account. Finally, a brief comparison is provided to a similar analysis on the global level and for different countries.

Each of the four groups of levers discussed in the previous chapter requires different enablers. Depending on a range of factors (e.g., the successful implementation of the levers, their net economic benefits, the choice of power mix, the success of CCS technology), the overall cost to Czech society of achieving significant emissions reduction may be as low as zero or as high as EUR 2.3 billion per year. To decide appropriately, the implementation timeline has to be taken into account, as the costs of the individual levers will be different in 2030 than they are today. The Czech abatament cost curve, although similar to its global counterpart and to the cost curves of other countries, has several notable differences.

ENABLERS

By plotting the levers on a cost curve, we are merely indicating all the options available in a scenario. However, we are not making a judgment on which levers to implement. All of the abatement levers would require some kind of action (Exhibit 27), because any reduction that would happen on its own is, by definition, already included in the reference case. Even though we have not examined actions supporting each abatement opportunity in detail, from a high-level perspective, very different types of actions would likely be effective for different opportunities (e.g., transport efficiency relies on EU-wide regulation, opportunities in residential buildings – for example, on such levers as standard setting – and improvements in the power sector on national fuel mix decisions). Levers with net economic cost would require appropriate policy, such as regulation or R&D support, to stimulate them.

The levers with net economic benefit on the left side of the cost curve can be stimulated primarily through policies that improve information, set standards, and provide financial incentives and support. Improved information can take various forms, from mandatory energy efficiency disclosure for new buildings to efficiency-related consulting services for industrial companies. For example, the UK's government-sponsored Carbon Trust helps to identify abatement opportunities for small- and medium-sized businesses.

Regulatory standards may significantly influence the European car market in the future. The European Commission is currently proposing a regulation that would force automobile manufacturers to reduce the average emissions of new cars to 120 grams per kilometer. Minimum efficiency standards can be also used for appliances. South Korea, for example, aims to reduce the standby consumption of new electronics to 1 W, compared to the approximately 7 W world average.

Financial support can help to overcome the high consumer discount rate and the required short

Exhibit 27: Examples of enablers

	Enablers	
Sector	**EU ETS**	**Specific potential support and regulation**
Buildings	✓	• Improving information (e.g., labeling for appliances and buildings) • Setting standards (e.g., building insulation) • Financial incentives (e.g., loans, subsidies)
Transport		• Improving new fleet average emissions through EU regulation • Increasing the share of biofuels through blending standards • Incentives encouraging efficient vehicle purchases (e.g., through taxes and rebates)
Industry	✓	• Improving energy efficiency (e.g., through standards and energy audits) • Financial incentives (e.g., loans, subsidies) • Improving information and opportunity identification (e.g., UK's Carbon Trust supports small and medium-sized businesses)
Power	✓	• Political support for fuel mix decisions • Support for renewables (e.g., through feed-in tariffs and subsidies) • R&D support for new technologies (e.g., CCS)
Agriculture		• Political agreement (e.g., on land use changes) • Incentives for afforestation or biomass planting (e.g., subsidies)

payback period. For example, the New York Energy Smart Loan Program motivates people to make energy-efficient building improvements by offering reduced interest rate loans.

Power decisions can be easily influenced by policy, because only a limited number of large players are involved. Policies range from allowing nuclear power generation to supporting renewables (e.g., through feed-in tariffs and green bonuses). The decisions are complicated, however, and often require political consensus. As discussed, power mix options are never black or white and always entail trade-offs, ranging from energy security to the cost of electricity for consumers.

Levers with net cost are not likely to happen without an appropriate policy to stimulate them. The most widespread stimulation system is the EU's ETS, which provides incentives for abatement opportunities through pricing CO_2 emissions. Ideally, all abatement levers in ETS sectors that are below the carbon price are expected to happen. Financial support can be also used outside ETS sectors. For example, farmers can receive subsidies to afforest parts of their farmlands and, as in the US, hybrid cars can be made more attractive through tax rebates.

Other net cost levers can be activated once their economics become attractive. Policies can stimulate further R&D, which can ultimately bring down costs. A prominent example is carbon capture and storage, which might benefit from programs supporting the early launch of demo plants. Further development of CCS can also be stimulated by developing CO_2 transport infrastructure.

TOTAL COST OF REACHING EMISSIONS REDUCTION TARGETS

In terms of total cost, two scenarios representing extreme cases can be imagined. In the first scenario, even a high 32 percent GHG reduction target could be met with as little as zero total cost to society, provided the Czech Republic successfully implemented all of the levers with net economic benefit and reached agreement on pursuing nuclear. In the second scenario, should agreement (i.e., internally or with neighboring countries) on nuclear energy fail, and should uncertainties about CCS technology remain (e.g., leakage issues) or the technology does not prove economically viable, even reaching the medium reduction target might be a challenge.

The total cost of reaching a certain emissions reduction target depends largely on the choice of power mix. Firstly, power sector abatement levers have their own costs (e.g., nuclear energy is less expensive than solar). Secondly, the power sector's abatement potential determines the required amount of other net cost levers that need to be activated to reach the reduction target. Exhibits 29 and 31, which show the cost curves for two of the power mix scenarios discussed above, illustrate this. These can be contrasted with each other and with the abatement curve for the gradual fuel shift scenario shown earlier (Exhibit 22).

Exhibit 28 assumes that the Czech Republic commits to gas for most of its power expansion. With the gas lever committed and the nuclear lever out of consideration, the remaining abatement opportunities in the power sector involve limited replacements of coal with

Exhibit 28: Abatement cost curve: maximum gas

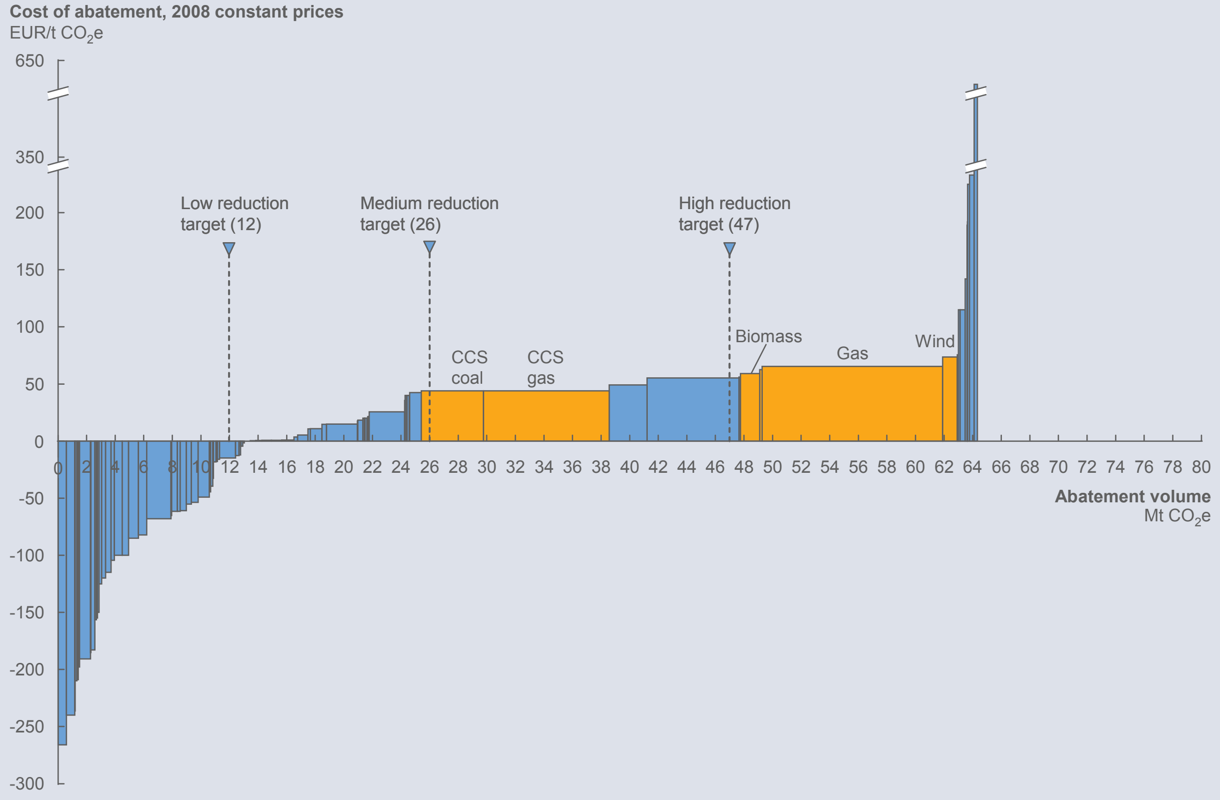
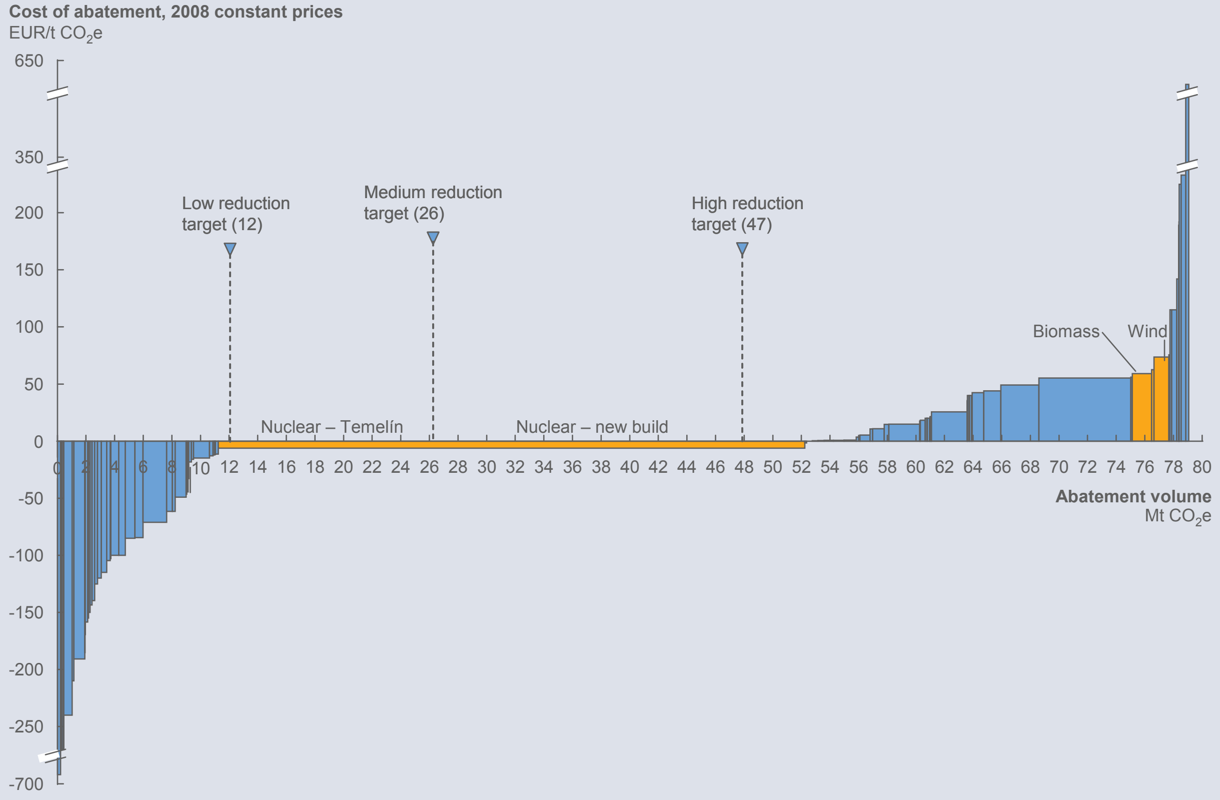


Exhibit 29: Abatement cost curve: maximum nuclear



renewables and installation of CCS at coal plants. Achieving the full abatement required by the various targets would therefore require numerous actions outside of the power sector. Meeting the low target would require little more than financially beneficial efficiency measures, but meeting the high target would require execution of all abatement measures up to a marginal cost of EUR 51 per ton. The total cost for the net cost measures would exceed EUR 1.5 billion per year.

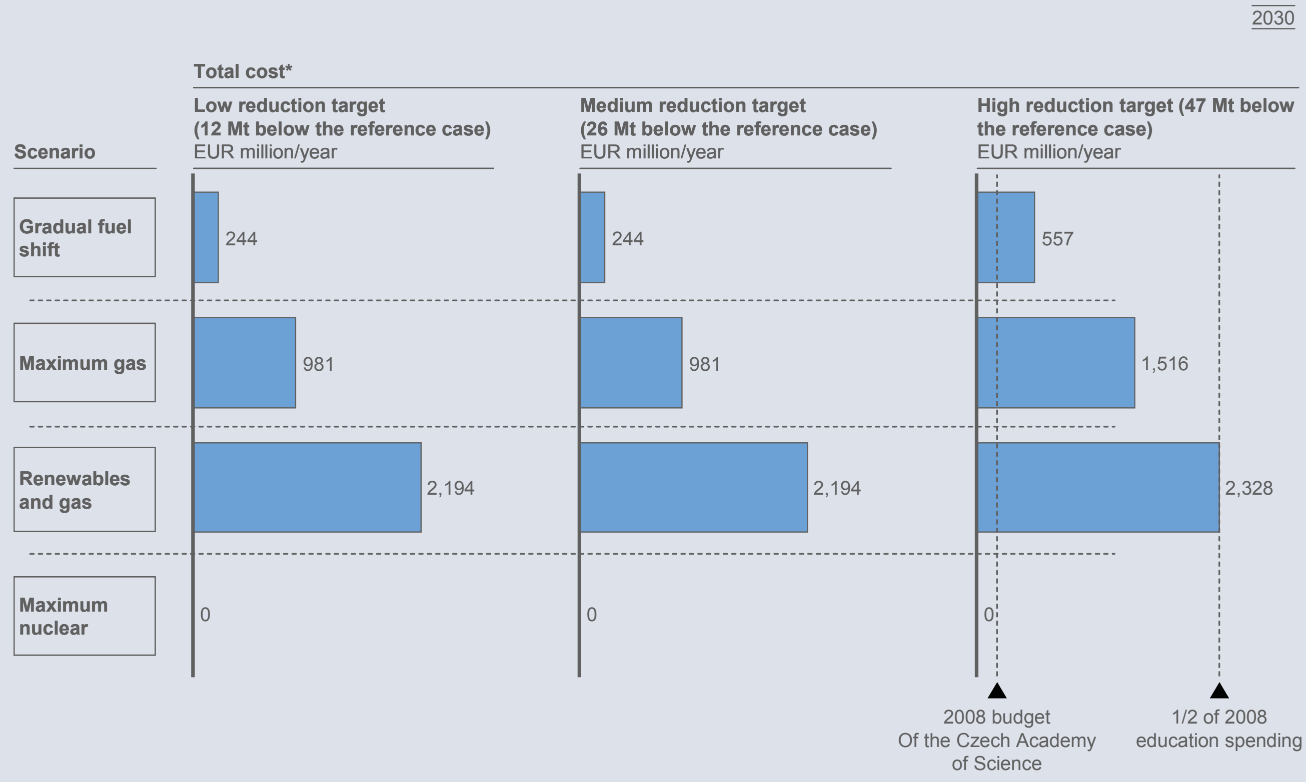
Illustrating another extreme, Exhibit 29 assumes that the Czech Republic commits to nuclear for most of its power expansion. This would result in massive CO_2 abatement of more than 40 Mt annually. If the bulk of cost opportunities with net economic benefit were captured as well, the total abatement would easily surpass all of the three targets considered here without any need for additional measures.

A number of statements can be made based on Exhibits 30 and 31:

- A low emissions reduction target of roughly 10 percent could be met in any scenario through levers with net economic benefit alone. Capturing opportunities with net economic benefit would likely be a challenge, but this level of reduction would not necessary require financial sacrifice from the Czech Republic.

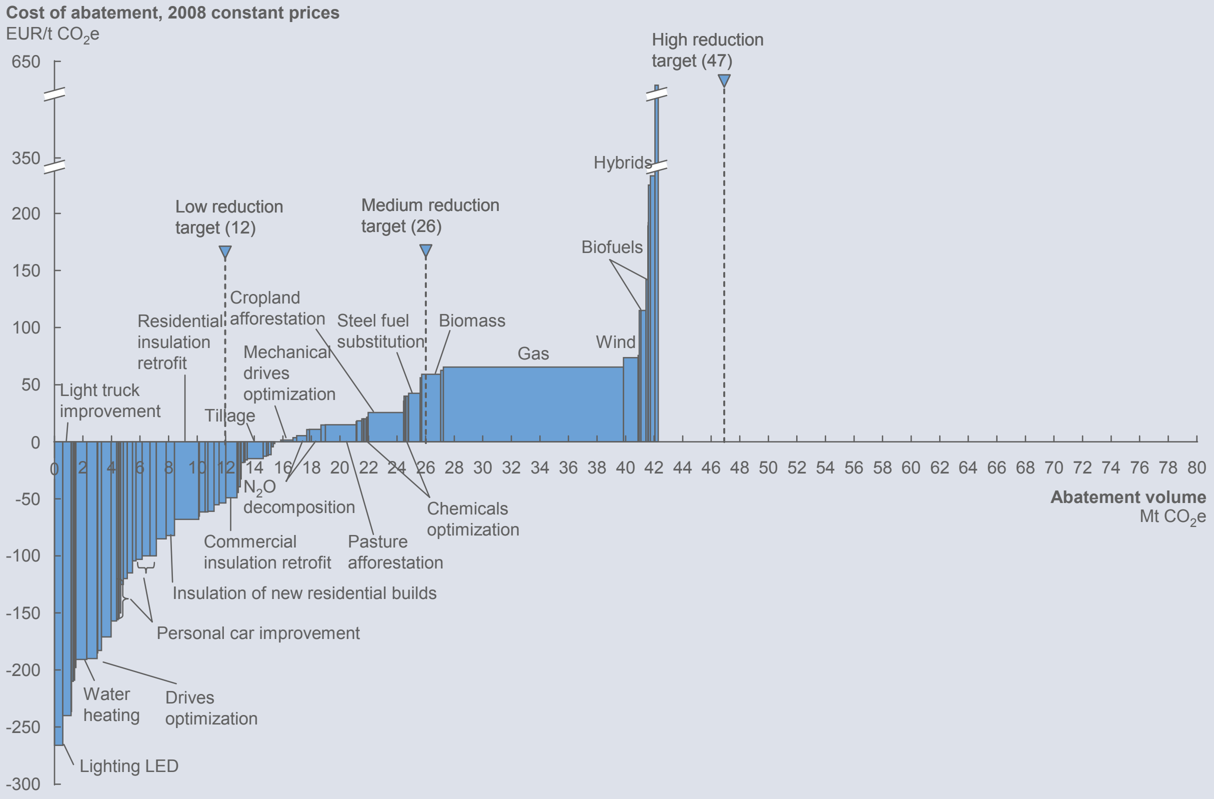
- Emissions reductions ranging from 20 percent (roughly medium target) to 30 percent (roughly high target) would be achievable provided concerted action leads to nearly full capture

Exhibit 30: Total abatement cost by power scenario



* Including power build decision; oil at USD 100/barrel, nuclear investment cost of EUR 2,500/kW; out of 146 Mt in the reference case

Exhibit 31: Abatement cost curve: maximum gas without CCS



of negative cost efficiency opportunities. However, the cost would be strongly dependent on choices made in the power sector (Exhibit 30). For example, the cost of meeting the high reduction target ranges from as low as zero to 250 million (in the nuclear and gradual fuel shift scenarios) to more than EUR 1.5 billion (in the maximum gas scenario). Even for maximum gas, however, the total cost to Czech society appears manageable. EUR 1.5 billion is roughly 0.8 percent of Czech GDP, or EUR 0.40 per citizen daily.

- Larger reductions of up to 33 percent (high target) could be achieved, but the cost would be significantly higher, especially if gas prices remain high and no new nuclear construction occurs.
- Reductions significantly beyond 50 to 60 Mt per year would be difficult to achieve without adopting expensive abatement measures at a marginal cost of over EUR 100 per ton.

Viewed another way, these results suggest that a carbon price of around EUR 40 per ton should accomplish between 40 and 65 Mt of abatement in the Czech Republic. Achieving higher levels of abatement could entail a significantly higher carbon price and cause greater disruption to the economy.

TIMING IMPLEMENTATION DECISIONS

The lever implementation timeline is crucial to the total cost of abatement. Technology developments could make several abatement levers more affordable in the future, although they may be more costly today. Therefore, the 2030 abatement cost curve should guide forward-looking decisions.

If we plotted the cost curve as of today, it would show less abatement potential than the 2030 cost curve on Exhibit 22, and many of the levers would entail higher costs. There are two main reasons for this. Firstly, many levers require significant time to implement. For example, it takes several years to substantially improve an automobile fleet, as only around 5 percent can be replaced by new cars every year. Secondly, technology development plays a major role. Some of the levers are not yet fully available today (e.g., CCS is expected after 2020), and some levers should decrease in price due to economies of scale (e.g., the cost of solar electricity is expected to decrease by 64 percent).

Business leaders and policymakers have to keep these facts in mind if they are to decide which levers to implement now and which ones in the future. The power sector serves as a good illustration, because the expected price reduction is most pronounced for renewables. Currently, it makes more financial sense to build gas-fired instead of biomass-fired power plants, because the cost per ton of abated CO_2 is about 40 percent lower. However, by 2030, biomass power generation is expected to become a cheaper option than gas.

COMPARISON OF THE CZECH REPUBLIC TO OTHER COUNTRIES

The Czech abatement cost curve is similar to its global counterpart, as well as to the cost curves of other countries. However, several notable differences exist.

Most significantly, from a global perspective, the Czech Republic has a larger than usual abatement opportunity in the power sector due to the large leeway available for future fuel mix decisions that might have high reduction potential. Differences from the global cost curve also exist in terms of levers having different fundamental factors in the Czech Republic (e.g., solar, due to the lower radiation yield – 70 percent of the average used for global calculations – and wind, because the Czech Republic is one of the least windy countries in Europe). Moreover, the Czech abatement cost curve lacks a large opportunity in forestry, which is an issue in South America and Asia due to deforestation, and has lower potential in transport due to the limited opportunity to expand biofuels. Finally, although high in absolute terms for the Czech Republic, the abatement potential in buildings is relatively low compared to other countries, due to the larger share of people living in apartments as opposed to family houses.

For curiosity's sake, we even compared our analysis to neighbouring Germany. The opportunity to expand nuclear is the biggest difference between the two countries. The opportunity derives from the fact that the Czech Republic will have to renew its generation capacity soon, as two thirds of its coal-fired capacity needs to be replaced in the next ten years. Moreover, the outcome of the German discussion on nuclear power generation is unclear. Also unlike Germany, the Czech Republic has an opportunity to devote 10 percent of its agricultural land to forestry, representing further abatement potential.

* * *

Climate change in a business context is a broad topic relevant to many different audiences, including policymakers, large industrial businesses, financial services companies, academics, and so on. Each of them will be interested in a slightly different side of the issue, be it regulation or mitigation of impact. We hope that the fact base provided in this McKinsey & Company report will help these audiences and other interested parties to make informed decisions and to develop economically sensible strategies.

Glossary

Abatement costs (EUR/t CO_2e)	Additional costs (or savings) resulting from the use of a technology with low greenhouse gas intensity compared with the intensity of the current technology projection (excluding secondary effects from a socioeconomic perspective). In this study, these are assessed from the perspective of the relevant decision maker, i.e., taking into account the specific discount rates and amortization periods
Abatement cost curve	Compilation of abatement potentials and costs for a specific sector
Abatement lever	See “lever”
Abatement lever with a net economic benefit	An abatement lever that results in savings for the decision maker, taking into account the specific amortization periods and discounting rates
Abatement potential (Mt CO_2e)	Potential for reducing greenhouse gas emissions by implementing an abatement lever assuming a penetration rate that is ambitious but feasible in practice
Baseline year	Baseline year for measurement of achieved reduction in greenhouse gas emissions in the context of the Kyoto Protocol (1990 for CO_2 emissions; 1995 for a number of other greenhouse gases); see “Nationaler Inventarbericht” (national inventory report) of the UBA (Dessau, March 2007) for details
CCS	Carbon capture and storage – technologies for capturing and storing CO_2
CDM (projects)	Clean development mechanism – mechanism in the framework of the Kyoto Protocol that gives emitters of signatory states the option of investing in projects in developing countries under specified conditions and receiving CO_2 certificates for this

CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent, i.e., specific value of the intensity of a greenhouse gas, expressed in the greenhouse effect of carbon dioxide, e.g., 21 for CH_4 (methane), 310 for N_2O (nitrous oxide)
Current technology	Average energy/greenhouse gas efficiency in today's (2006) mix of sales or investments
Current technology projection	Projection of the trend in greenhouse gas emissions in Germany based on current economic growth forecasts and gradual penetration of the current stock with today's status of technology (for details see below p. 25 sqq.)
Decision maker	The party that decides on making an investment, i.e., the company (e.g., as owner of an industrial facility) or the individual (e.g., as owner of a car or home)
ETS	Emissions Trading Scheme of the European Union
EUR	Euro
Greenhouse gas	Greenhouse gas in the context of the Kyoto Protocol, i.e., CO_2 (carbon dioxide), CH4 (methane), N_2O (nitrous oxide), HFC/PFC (hydrofluorocarbons), and SF_6 (sulfur hexafluoride)
Gt	Gigaton(s), i.e., one billion (109) metric tons
IGCC	Integrated gasification combined cycle – combined gas and steam turbine system with upstream coal gasification system
kWh	Kilowatt hour(s)

(Abatement) lever	Technological approach to reducing greenhouse gas emissions, e.g., use of more efficient processes or materials
Mt	Megaton(s), i.e., one million (1,000,000) metric tons
MWh	Megawatt hour(s), i.e., one thousand (1,000) kWh
PJ	Petajoule, i.e., one quadrillion (10^{15}) joules
Reference technology	Status of current technology against which an efficient greenhouse gas solution is compared with regard to its abatement costs and potential
Sector	Grouping of businesses in this study, specifically: • Energy: emissions from power generation (centralized, decentralized, industrial) and from generation of heat for local and district heating networks • Industry: direct and indirect emissions of all industrial branches with the exception of power generation and the transport sector; includes industrial heat generation • Buildings: direct and indirect emissions from private households and the tertiary sector (commercial, public buildings, buildings used in agriculture) • Transport: emissions from road traffic (passenger transportation: small, midsize, and large passenger cars; freight transportation: light (“sprinter class”), medium, and heavy trucks; buses), railroad transportation (local and long-distance passenger transportation, freight), and domestic air transportation, including effects of changes in fuel mix (oil industry) • Waste management: emissions from disposal of waste and treatment of sewage

- Agriculture: emissions from livestock farming and soil management

t	Metric ton(s); i.e. 1,000 kg
TWh	Terawatt hour(s), i.e., one billion (10^9) kWh

Bibliography

Ajiboye, Paul. *Implementation of EU Directives on Energy Efficiency into the Czech Republic.* 2005

Ansolabehere, S., Beer, J., and others. *The Future of Coal: An Interdisciplinary MIT Study.* Massachusetts Institute of Technology, 2007. June 2008: <http://web.mit.edu/coal>

Asociace pro využívání obnovitelných zdrojů energie [Association for the Use of Renewable Energy Sources]. *Potential for the Use of Renewable Energy Sources in the Czech Republic.* May 2008: <http://www.env.cz/AIS/web-pub.nsf/8c74f8eb26f7d18bc1256d9d00498f4b/8b871b10fddf1a49c1256e7700365ab2/$FILE/OZE-english.pdf>

Boermans, Thomas. *U-Values for Better Energy Performance of Buildings.* 2007

Capros, P., Mantzos, L., and others. *European Energy and Transport: Trends to 2030 – Update 2007.* Luxembourg: Office for Official Publications of the European Communities, 2008

CBI. *Climate Change: Everyone's Business.* London, 2007

Creyts, J., Derkach, A., and others. *Reducing US Greenhouse Gas Emissions: How Much at What Cost?* McKinsey & Company, 2007

Ellerman, A. D., and Joskow, P. L. *The European Union's Emissions Trading System in Perspective.* Arlington: Pew Center on Global Climate Change, 2008

Gielen, D., and Podkanski, J. *Prospects for CO_2 Capture and Storage.* Paris: IEA, 2004

IPCC. *Climate Change 2007: Synthesis Report.* 2007. April 2008: <http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf>

Klaus, Václav. *Modrá, nikoli zelená planeta [Blue not Green Planet].* Prague: Dokořán, 2007

McKinsey Global Institute. *Curbing Global Energy Demand Growth: The Energy Productivity Opportunity.* 2002

McKinsey Global Institute. *The Carbon Productivity Challenge: Curbing Climate Change and Sustaining Economic Growth.* June 2008

Metz, B. *IPCC Special Report on Carbon Dioxide Capture and Storage.* Cambridge University Press, 2005

Ministerstvo pro životní prostředí ČR [Czech Ministry of the Environment]. *Národní alokační plán České republiky na roky 2008-2012 [National Allocation Plan of the Czech Republic for the Years 2008-2012].* Prague, 2006. June 2008: <http://www.mzp.cz/AIS/web-pub.nsf/$pid/MZPOBFKKRPMF/$FILE/NAP2_FINAL.pdf>

Ministerstvo průmyslu a obchodu ČR [Czech Ministry of Industry and Trade]. *Zpráva o výsledcích analýzy vnitrostátního potenciálu kombinované výroby elektřiny a tepla v České republice podle směrnice 2004/8/ES [Report on the Results of an Analysis of the Domestic Potential of the Combined Production of Electricity and Heat in the Czech Republic under Directive 2004/8/ES].* Prague, January 2006. May 2008: <http://www.mpo.cz/zprava10372.html>

Petersdorf, Carsten. *Mitigation of CO_2 Emissions from the Building Stock.* Ecofys, 2004

Smrž, Milan. *Cesta k energetické svobodě, impulz k přeměně energetiky a hospodářství do udržitelné formy [Path to Energy Independence: Impulse to Convert Energy and the Economy to Sustainable Forms].* Brno: Wise, 2007

Spitz, Jiří, and Pur, Luděk. *Zpráva o potenciálu snížení emisí skleníkových plynů v České republice [Report on the Potential to Reduce Greenhouse Gas Emissions in the Czech Republic].* Prague: Ministerstvo pro životní prostředí ČR [Czech Ministry of the Environment], 2007

Stern, N.H. *Stern Review on the Economics of Climate Change.* London: HM Treasury, 2006

Svaz výrobců cementu [Association of Cement Producers]. *Cementárny a green cement ve 21. století [Cement Factories and Green Cement in the 21st Century].* Prague

Svaz výrobců cementu [Association of Cement Producers]. *Výroba cementu v České republice [Cement Production in the Czech Republic]*. Prague

Ürge-Vorsatz, D., Mez, L., and others. *The Impact of Structural Changes in the Energy Sector of CEE Countries on the Creation of a Sustainable Energy Path.* Budapest: CEU, 2003

Vahlenkamp, T. *Costs and Potentials of Greenhouse Gas Abatement in Germany*. McKinsey & Company, 2007

Various authors. *Obnovitelné zdroje a možnosti jejich uplatnění v České republice [Renewable Sources and Possibilities for their Application in the Czech Republic].* Prague: ČEZ, 2007

Appendix: overview of levers*

Sector	Lever	Description	Cost EUR/ t CO_2e	Volume Mt CO_2e
Power	Small hydro	Small hydropower generation capacity built by 2030 replaces CO_2 intensive coal-fired plants. Gradual fuel shift scenario assumes 0.45 TWh produced by 2030 compared to 0.2 TWh in the reference case.	-11.3	0.2
	Nuclear	Gradual fuel shift scenario assumes construction of two new 1,200 MW blocks at the Temelín power plant. Maximum nuclear scenario assumes construction of three new greenfield blocks. The added nuclear energy replaces CO_2 intensive electricity from coal-fired power plants.	-6.2	0-41.2
	CCS coal	CCS technology installed on coal-fired power plants, effectively reducing their CO_2 emissions. CCS is assumed to be available after 2020 and installed in the coal retrofits that will take place in that period.	44-57	0-15.4
	CCS gas	CCS technology installed on coal-fired power plants, effectively reducing their CO_2 emissions. CCS is assumed to be available after 2020 and installed in the coal retrofits that will take place in that period.	44-57	1.2-8.8
	Biomass	Biomass power generation capacity built by 2030 replaces CO_2 intensive coal-fired plants. Gradual fuel shift scenario assumes 3 TWh produced by 2030 compared to 1.4 TWh in the reference case.	59	1.3-9.1
	Gas	Assumes higher CCGT capacity built than in the reference case (e.g., 11 TWh in the gradual fuel shift scenario compared to 8 TWh by 2030 in the reference case). The added gas-generated energy replaces CO_2 intensive electricity from coal-fired power plants (0.35 CO_2 t/MWh vs. 0.85 CO_2 t/MWh).	66	1.4-12.7

* Descriptions correspond to the gradual fuel shift scenario. Cost and volume figures represent scenario ranges; levers are grouped by sector and ranked by cost.

Sector	Lever	Description	Cost EUR/ t CO_2e	Volume Mt CO_2e
Power	Wind	Wind power generation capacity built by 2030 replaces CO_2 intensive coal-fired plants. Gradual fuel shift scenario assumes 2.2 TWh produced by 2030 compared to 1 TWh in the reference case.	74	1-2.6
	Solar	Solar power generation capacity built by 2030 replaces CO_2 intensive coal-fired plants. Not applicable for gradual fuel shift scenario, but maximum renewables and gas scenario assume 5.5 TWh produced by 2030 compared to none in the reference case.	198.4	0-4.7
Chemicals	CHP, new build	Technical measures help to recover more energy from combined heat and power (CHP) cycles installed at company power plants. 100% of energy produced from CHP is already assumed in the reference case; however, energy recovery efficiency increases under the abatement scenario.	-16	0.2
	CHP, retrofit	Technical measures help to recover more energy from combined heat and power (CHP) cycles installed at company power plants. 100% of energy produced from CHP is already assumed in the reference case; however, energy recovery efficiency increases under the abatement scenario. Applicable for existing facilities.	-1.5	0.1
	Nitric acid production, new build	Application of more efficient filtering techniques than in the reference case in newly built facilities leads to a reduction of nitrous oxide emissions associated with nitric acid production.	5.4	0.7
	Nitric acid production, retrofit	Retrofits of existing nitric acid production facilities and installation of improved filtering techniques leads to a reduction of nitrous oxide emissions from tail gases.	10.9	0.8

Sector	Lever	Description	Cost EUR/ t CO_2e	Volume Mt CO_2e
Chemicals	Ethylene cracking, new build	Ethylene cracking improvements (e.g., furnace upgrades), better cracking tube materials, and improved separation and compression techniques help to lower direct energy in the cracking process.	17.6	<0.1
	Process and catalyst optimization	Process intensification and catalyst optimization in chemical processes leads to lower energy consumption and, thus, to emissions reduction. Improvements are caused by the large number of technical measures focused on process (e.g., steam management, process heating) and energy (e.g., pumping systems, compressed air).	20	1
	Motor systems, new build	Installation of improved motor systems equipped with variable or adjustable speed drives to control the speed of machinery. Industrial processes (e.g., assembly lines) operate at different speeds for different products. Where process conditions demand flow adjustments from a pump or fan, varying the speed of the drive may save energy compared to other techniques for flow control.	21.5	0.1
	Ethylene cracking, retrofit	Ethylene cracking improvements (e.g., furnace upgrades), better cracking tube materials, and improved separation and compression techniques help to lower direct energy in the cracking process.	21.6	<0.1
	Motor systems, retrofit	Retrofits of motor systems and installation of variable or adjustable speed drives to control the speed of machinery. Industrial processes (e.g., assembly lines) operate at different speeds for different products. Where process conditions demand flow adjustments from a pump or fan, varying the speed of the drive may save energy compared to other techniques for flow control.	35.6	<0.1

Sector	Lever	Description	Cost EUR/ t CO_2e	Volume Mt CO_2e
Chemicals	Fuel shift from coal to gas, new build	Shifting from coal-powered systems to biomass-powered systems and from oil-powered systems to gas results in lower emissions due to lower carbon intensity per MWh when produced from gas or biomass.	189.1	<0.1
	Fuel shift from coal to gas, retrofit	Shifting from coal-powered systems to biomass-powered systems and from oil-powered systems to gas results in lower emissions due to lower carbon intensity per MWh when produced from gas or biomass.	192	<0.1
Refining	Energy management system	Includes behavioral and operational changes in energy management, including online monitoring of critical parameters and energy conservation awareness programs.	-44.4	0.1
	Operational improvements	Process improvements within normal operations maintenance, including maintenance and monitoring of steam traps, improved insulation, and more efficient lighting.	-12.1	0.1
	Energy efficiency projects requiring major infrastructural changes	Includes projects that change the refinery layout, such as condensate recovery and shifting from coal to gas.	62.6	0.2
	Energy efficiency projects requiring CAPEX	Includes upgrades and replacements (e.g., waste heat recovery, replacement of motors, heaters, and boilers, and catalysts and reactor modifications) that do not alter refinery process flow.	75.6	0.1

Sector	**Lever**	**Description**	**Cost EUR/ t CO_2e**	**Volume Mt CO_2e**
Cement	Clinker substitution	CO_2 intensive clinker component in cement is replaced by substitutes (e.g., fly ash, slag). Clinker component is reduced to 69% compared to 73% in the reference case. Lower clinker production eliminates process and fuel combustion emissions associated with its production. Already considered in the reference case, but clinker content expected to be further reduced to 69% in the abatement scenario.	10.7	0.2
	CCS	Carbon capture and storage technology installed at cement production facilities captures 85% of process and fuel emissions.	49.1	2.7
	Fuel substitution	Higher biomass share in the fuel mix (25% vs. 7% in the reference case) reduces emissions from fossil fuel combustion (biomass entails zero emissions).	56.1	0.1
Steel	Direct casting	Near net-shape casting and strip casting, which integrate the casting and hot rolling of steel into one step, reduces the need to reheat before rolling. Applied to 80% of production compared to 38% in the reference case.	0	0.1
	Smelt reduction	Smelt reduction technology combines coking and iron ore reduction, thus reducing energy demand. Implemented on 51% of capacity compared to none in the reference case.	18.4	0.3
	Fuel substitution	Shifting from coal to gas in factory power plants. 100% gas by 2030 compared to 66% gas and 34% coal in the reference case.	42.5	0.8
	CCS steel	Carbon capture and storage technology installed at steel production facilities captures 85% of process and fuel emissions.	55.2	6.7
Buildings, residential	LED lighting	LED lights replace incandescent bulbs starting in 2020. Penetration reaches 39% by 2030 compared to 0% in the reference case.	-692 to -278	0.2-0.6

Sector	Lever	Description	Cost EUR/ t CO_2e	Volume Mt CO_2e
Buildings, residential	Dishwshers	Faster switch to super efficient dishwashers (0.85 kWh/cycle) results in an average efficiency improvement (31% over the reference case) and, thus, in electricity savings (0.2 TWh in 2030), resulting in CO_2 abatement.	-515 to -218.5	0-0.1
	CFL lighting	Penetration of CFLs reaches 54% in 2030 in the abatement scenario, 7% over the reference case, resulting in 0.3 TWh electricity savings in 2030.	-407 to -206.8	0-0.1
	Water heating	Average heating efficiency of residential water boilers reaches 100% by 2030, compared to 80% in the reference case.	-190.7	0.8
	Insulation, new build	All new residential buildings built to meet the high efficiency standard (50 kWh/m^2/year vs. usual 83-98 kWh/m^2/year) starting in 2020, compared to ~50% in the reference case.	-82.6	0.3
	Insulation, retrofit	Buildings are retrofitted to meet the high energy standard at a faster rate, so that in 2030 only 9% of residential dwellings are at the pre-1990 standard, compared to 38% in the reference case.	-68.6	1.8
	Washers and dryers	Faster switch to super efficient washing machines (0.65 kWh/cycle) results in an average efficiency improvement (31% over the reference case) and, thus, in electricity savings (0.4 TWh in 2030), resulting in CO_2 abatement.	-103 to -41.3	0.1
	Refrigerators and freezers	Faster switch to A++ fridges results in an average efficiency improvement (10% over the reference case) and, thus, to electricity savings (0.2 TWh in 2030), resulting in CO_2 abatement.	-46 to -18.7	0-0.1

Sector	Lever	Description	Cost EUR/ t CO_2e	Volume Mt CO_2e
Buildings residential	Space heating	Increased efficiency of residential heating reduces fuel consumption and results in lower emissions. Increased penetration of condensing heaters leads to 97% average efficiency compared to 82% in the reference case by 2030.	-12.7	0.2
	Stand-by losses	65% reduction of stand-by consumption leads to 0.1 TWh electricity savings in 2030	-12 to -4.7	<0.1
Buildings, commercial	Public lighting	Replacement of mercury vapor lighting systems with highly efficient sodium high-pressure systems reduces electricity consumption by 37%. Abatement scenario assumes 100% penetration compared to 38% in the reference case.	-615 to -247	<0.1
	Wet appliances	By 2030, all washing machines and dishwashers are 30% more efficient than in the reference case, resulting in 0.8 TWh electricity savings per year. The reference case does not assume any improvements with respect to the current state, as no enforcement mechanisms (i.e., energy labeling and standards) exist, as opposed to consumer products.	-476 to -191.2	0.1-0.3
	Gas cooking	By 2030, all cookers are 20% more efficient than in the reference case, resulting in 0.1 TWh electricity savings per year. The reference case does not assume any improvements with respect to the current state, as no enforcement mechanisms (i.e., energy labeling and standards) exist.	-185.3	<0.1
	AC	75% penetration of highly efficient air-conditioning systems (compared to 25% in the reference case) results in 0.3 TWh lower electricity consumption and in reduction of indirect emissions.	-407 to -163.7	0-0.1

Sector	Lever	Description	Cost EUR/ t CO_2e	Volume Mt CO_2e
Buildings, commercial	Insulation, new build	All new commercial buildings are constructed to meet the high efficiency standard (50 kWh/ m^2/year vs. usual 83-98 kWh/m^2/year) starting in 2020, compared to ~50% in the reference case.	-104.7	0.2
	Electrical cooking	By 2030, all electrical cookers are 20% more efficient than in the reference case, resulting in <0.1 TWh electricity savings per year. The reference case does not assume any improvements with respect to the current state, as no enforcement mechanisms (i.e., energy labeling and standards) exist.	-169 to -68.1	<0.1
	Cold appliances	By 2030, all freezers are 30% more efficient than in the reference case, resulting in 1.3 TWh electricity savings per year. The reference case does not assume any improvements with respect to the current state, as no enforcement mechanisms (i.e., energy labeling and standards) exist.	-158 to -63.6	0.2-0.4
	Commercial lighting	Electricity consumption due to lighting in commercial buildings (18% of total electricity consumption) is reduced through lighting systems improvements. The improvements include more efficient fluorescent lamps, automatic lighting/dimming controls, and presence sensors. Electricity reduction in the range from 30-50% is based on real industry examples. 100% penetration assumed in the abatement scenario, compared to 25% in the reference case.	-144 to -57.7	0.1-0.3

Sector	Lever	Description	Cost EUR/ t CO_2e	Volume Mt CO_2e
Buildings, commercial	BEMS	Introduction of building energy management systems further reduces energy for heating, cooling, and lighting. BEMS consists of smart building automation (e.g., adjusting heating and lighting to occupancy). Examples show such systems reduce heating demand by 10%. Abatement scenario assumes 75% penetration compared to 25% in the reference case.	-140 to -56.1	0.2-0.5
	Insulation retrofit	Existing buildings are retrofitted to the high efficiency standard of 50 kWh/m^2/year, representing significant improvement from the current average of 128 kWh/m^2/year for buildings larger than 1,000 m^2 and 237 kWh/m^2/year for buildings smaller than 1,000 m^2	-49.2	0.8
	Space heating	Increased heating efficiency reduces fuel consumption, lowering emissions. Increased penetration of condensing heaters leads to 96% average efficiency compared to 94% efficiency in the reference case by 2030.	-12.7	0.1
	Stand-by consumption	66% reduction of stand-by consumption leads to 0.4 TWh electricity savings in 2030.	-12 to -4.7	0.1
Transport	Technical measures for light trucks	Technical measures for light trucks (i.e., both power train and non-power train) reduce their fuel consumption by 4.5% compared to the reference case.	-240	0.6
	Improved aerodynamics for heavy trucks	Improved aerodynamics of heavy trucks reduces their fuel consumption by 0.9% compared to the reference case.	-210	0.1

Sector	Lever	Description	Cost EUR/ t CO_2e	Volume Mt CO_2e
Transport	Diesel cars, package 1	Engine improvements lower diesel car fuel consumption and CO_2 emissions by 12% compared to the reference case, where consumption in 2030 is 5.4 l/100 km (i.e., 146 g CO_2/km). Improvements include both power train measures (e.g., variable valve control, mild engine friction reduction) and non-power train measures (e.g., low rolling resistance tires, tire pressure control systems, 1.5% weight reduction). Average cost increase per vehicle is EUR 250.	-155	0.1
	Diesel cars, package 2	Engine improvements lower diesel car fuel consumption and CO_2 emissions by 27% compared to the reference case, where consumption in 2030 is 5.4 l/100 km (i.e., 146 g CO_2/km). Improvements on top of those in Package 1 include both power train measures (e.g., medium displacement reduction combined with turbo charging and optimized gearbox ratio) and non-power train measures (e.g., electrification of auxiliaries, improved aerodynamics, start-stop systems, 3.5% weight reduction). Average cost increase per vehicle is EUR 950.	-125	0.2
	Diesel cars, package 3	Engine improvements lower diesel car fuel consumption and CO_2 emissions by 37% compared to the reference case, where consumption in 2030 is 5.4 l/100 km (i.e., 146 g CO_2/km). Improvements on top of those in Package 2 include both power train measures (e.g., strong displacement reduction combined with turbocharger, strong engine friction reduction) and non-power train measures (e.g., electrically assisted steering, improved AC, start-stop systems with regenerative braking, 9% weight reduction). Average cost increase per vehicle is EUR 1,500.	-115	0.4

Sector	Lever	Description	Cost EUR/ t CO_2e	Volume Mt CO_2e
Transport	Diesel cars, package 4	Engine improvements lower diesel car fuel consumption and CO_2 emissions by 41% compared to the reference case, where consumption in 2030 is 5.4 l/100 km (i.e., 146 g CO_2/km). Improvements on top of those in Package 3 include power train measures (e.g., homogenous direct injection, variable compression ratio, optimized dual clutch transmission). Average cost increase per vehicle is EUR 1,900.	-100	0.4
	Gasoline cars, package 1	Engine improvements lower gasoline car fuel consumption and CO_2 emissions by 14% compared to gasoline in the reference case, where consumption in 2030 is 7.7 l/100 km (i.e., 177 g CO_2/km). Improvements include both power train measures (e.g., variable valve control, mild engine friction reduction) and non-power train measures (e.g., low rolling resistance tires, tire pressure control systems, 1.5% weight reduction). Average cost increase per vehicle is EUR 340.	-150	0.1
	Gasoline cars, package 2	Engine improvements lower gasoline car fuel consumption and CO_2 emissions by 32% compared to gasoline in the reference case, where consumption in 2030 is 7.7 l/100 km (i.e., 177 g CO_2/km). Improvements on top of those in Package 1 include both power train measures (e.g., medium displacement reduction combined with turbo charging and optimized gearbox ratio) and non-power train measures (e.g., electrification of auxiliaries, improved aerodynamics, start-stop systems, 3.5% weight reduction). Average cost increase per vehicle is EUR 1,135.	-120	0.3

Sector	Lever	Description	Cost EUR/ t CO_2e	Volume Mt CO_2e
Transport	Gasoline cars, package 3	Engine improvements lower gasoline car fuel consumption and CO_2 emissions by 44% compared to gasoline in the reference case, where consumption in 2030 is 7.7 l/100 km (i.e., 177 g CO_2/km). Improvements on top of those in Package 2 include both power train measures (e.g., strong displacement reduction combined with turbocharger, strong engine friction reduction) and non-power train measures (e.g., electrically assisted steering, improved AC, start-stop systems with regenerative braking, 9% weight reduction). Average cost increase per vehicle is EUR 1,970.	-100	0.6
	Gasoline cars, package 4	Engine improvements lower gasoline car fuel consumption and CO_2 emissions by 51% compared to gasoline in the reference case, where consumption in 2030 is 7.7 l/100 km (i.e., 177 g CO_2/km). Improvements on top of those in Package 3 include power train measures (e.g., homogenous direct injection, variable compression ratio, optimized dual clutch transmission). Average cost increase per vehicle is EUR 2,610.	-85	0.7
	Diesel, additional penetration of biofuels	Biofuels result in lower emissions than oil-based fuels. The lever assumes 14% penetration of biofuels compared to 10% in the reference case.	115	0.1
	Trucks, additional penetration of biofuels	Biofuels result in lower emissions than oil-based fuels. The lever assumes 14% penetration of biofuels compared to 10% in the reference case.	115	0.4
	Gasoline, additional penetration of biofuels	Biofuels result in lower emissions than oil-based fuels. The lever assumes 14% penetration of biofuels compared to 10% in the reference case.	225	0.1

Sector	Lever	Description	Cost EUR/ t CO_2e	Volume Mt CO_2e
Transport	Gasoline hybrids	Hybrid technology lowers fuel consumption and CO_2 emissions by 56% compared to gasoline in the reference case, where consumption in 2030 is 7.7 l/100 km (i.e., 177 g CO_2/km). Hybrid cars have the option of electric driving, which saves fuel, especially in congested traffic, as the engine is switched off while idling. The battery is recharged while the combustion engine is running and through regenerative braking. It also has the same technological features as a regular car in Package 4. Average cost increase per vehicle is EUR 3,650.	233	0.3
	Diesel, plug-in hybrids	Hybrid technology lowers CO_2 emissions by 48% compared to gasoline in the reference case, where emissions in 2030 are 146 g CO_2/km. Plug-in hybrid cars function the same as hybrid cars except that batteries can be recharged from the grid. With a favorable power mix, purely electric driving lowers emissions more than combustion engines. Average cost increase per vehicle is EUR 5,500.	350	0
	Gasoline, plug-in hybrids	Hybrid technology lowers CO_2 emissions by 60% compared to gasoline in the reference case, where emissions in 2030 are 177 g CO_2/km. Plug-in hybrid cars function the same as hybrid cars except that batteries can be recharged from the grid. With a favorable power mix, purely electric driving lowers emissions more than combustion engines. Average cost increase per vehicle is EUR 5,500.	398	0

Sector	Lever	Description	Cost EUR/ t CO_2e	Volume Mt CO_2e
Transport	Diesel hybrids	Hybrid technology lowers fuel consumption and CO_2 emissions by 47% compared to gasoline in the reference case, where consumption in 2030 is 5.4 l/100 km (i.e., 146 g CO_2/km). Hybrid cars have the option of electric driving, which saves fuel, especially in congested traffic, as the engine is switched off while idling. The battery is recharged while the combustion engine is running and through regenerative braking. It also has the same technological features as a regular car in Package 4. Average cost increase per vehicle is EUR 3,650.	628	0.2
Forestry	Pasture afforestation	Afforesting 20% of pastureland results in abatement, as the growing forest captures atmospheric CO_2 and stores it in the form of biomass.	14.9	2.2
	Cropland afforestation	Afforesting 6% of cropland results in abatement, as the growing forest captures atmospheric CO_2 and stores it in the form of biomass.	25.7	2.5
Other industry	Energy savings drives	Introduction of variable and adjustable speed drives in the industry sector results in 11% reduction of electric power consumption and, thus, to reduction of indirect emissions.	-190	0.3-0.7
	Lighting efficiency	Replacement of existing lighting systems with more efficient ones (e.g., fluorescent, LED) in the industry sector results in 10% reduction of electric power consumption and, thus, to reduction of indirect emissions.	-171.3	0.3-0.7
	Ventilation	Improvements in ventilation systems in the industry sector results in 6% reduction of electric power consumption and, thus, to reduction of indirect emissions	-157.1	0.2-0.4

Sector	Lever	Description	Cost EUR/ t CO_2e	Volume Mt CO_2e
Other industry	Heating	Improvements in heating systems in the industry sector results in 6% reduction of electric power consumption and, thus, to reduction of indirect emissions.	-103.5	0.2-0.4
	Mechanical optimization of drives	Mechanical optimization of motor system drives reduces electricity consumption by 13% and, thus, leads to reduction of indirect emissions.	1.1	0.3-0.9
Agriculture	Nutrient	Improved feed composition makes livestock grow faster and, thus, produce fewer emissions for the same amount of products.	-61.4	0.4
	Grassland-nutrient	Reduced fertilizer use and/or splitting fertilization into smaller pieces over time reduce excess nitrogen leakages into the air.	-61.4	0.2
	Enteric fermentation vaccination	Bovine somatotropin vaccination increases milk yield and, thus, decreases emissions per unit of output.	-18.2	0.2
	Tillage	Reduced tillage of agricultural land reduces the emissions of CO_2 buried underground. De facto abatement through buildup of underground CO_2 continues for 20 years. Reduced or low tillage is implemented on 45% of applicable land (i.e., 2/3 of all arable land) vs. 14% in the reference case.	-14.8	1.1
	Grassland	Improved cultivars, rotations, and fertilizer efficiency lead to more output per equal amount of emissions (i.e., through efficiency improvement).	3.6	0.3
	Agronomy	Improved cultivars, rotations, and fertilizer efficiency lead to more output per equal amount of emissions (i.e., through efficiency improvement).	14.7	0.3
	Enteric fermentation propionate	Feedstock supplements (e.g., propionate precursors) reduce the methane produced during fermentative digestion of ruminant animals.	142	0.1

Sector	**Lever**	**Description**	**Cost EUR/ t CO_2e**	**Volume Mt CO_2e**
Waste management	LFG usage for heat	Capture rate of landfill gas (LFG) increases to 95% vs. 79% in the reference case. Landfill gas is composed mainly of methane, which is a strong GHG. 35% is used for heat generation.	5.2	0.1
	LFG usage for electricity	Capture rate of landfill gas (LFG) increases to 95% vs. 79% in the reference case. Landfill gas is composed mainly of methane, which is a strong GHG. 65% is used for electricity generation.	53.5	0.2

Throughout the study, a constant exchange rate of EUR 1 to CZK 25 was used.

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This English version is a translation from the Czech original. As such, certain minor differences and discrepancies might exist.