McKinsey&Company




Pathways to an energy and carbon efficient Russia

Opportunities to increase energy efficiency and reduce greenhouse gas emissions

ABOUT THIS STUDY

In autumn 2009, as part of its efforts to quantify energy efficiency and greenhouse gas abatement measures across major economies, McKinsey & Company conducted an independent and self-financed study on the related topics of increasing energy efficiency and reducing greenhouse gas emissions in Russia. The research team interacted with more than 50 experts, among them some of the leading specialists in Russia, and gratefully acknowledges their input.

This study does not assess science, policies or regulatory choices related to energy efficiency and greenhouse gas emissions. Rather, the purpose of the study is to identify opportunities in Russia to improve energy efficiency and reduce greenhouse gas emissions. The study focuses on quantifying and prioritizing these opportunities based on purely economic considerations, starting with those measures that would give the best economic return per unit of energy saved and per tonne of CO_2 equivalent (CO_2e) abated.

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1. Summary

RUSSIA HAS SIGNIFICANT OPPORTUNITIES TO IMPROVE ENERGY EFFICIENCY AND REDUCE CARBON EMISSIONS TO THE BENEFIT OF ITS ECONOMY

Energy efficiency now stands at the forefront of Russia's national agenda. To modernize, the Russian economy must find ways to grow more productively. In other words, it must generate more goods and services per worker employed (labor productivity), per ruble invested (capital productivity) and – a major focus of this report – per unit of energy consumed (energy efficiency).

At the same time, a closely related topic stands at the forefront of the global agenda: the reduction of greenhouse gas emissions, primarily CO_2. Russia could play an important role in contributing to the global effort to reduce emissions, on account of its physical size, the extent of its population, the energy-intensive structure of its economy, and its old and relatively inefficient production capacity.

As newer, more energy-efficient equipment and buildings replace older installations, Russia's GDP becomes less energy intensive. Taking this trend into account, we project that if Russia were to fulfill its aspiration of up to 6% per annum growth in GDP, which means the economy more than doubles by 2030, its energy consumption would increase by only 40%, to 1,325 million tonnes of coal equivalent (Mtce)[1] between 2005 and 2030. Its greenhouse gas emissions over the same period would also increase by only 40%, to 2,990 million tonnes of carbon dioxide equivalent (Mt CO_2e), leaving the country's overall emissions close to its benchmark 1990 emissions level. This anticipated development has been forecast as the "reference case", as it is based on natural growth patterns without any specific intervention.

As this report shows, however, Russia can go further by actively undertaking numerous measures to improve energy efficiency and reduce emissions without inhibiting its rapid growth. Not only is Russia blessed with highly diversified and self-sufficient energy resources, the country also has the potential to grow in an energy- and emissions-neutral way. In fact, Russia has the largest relative potential among all the BRIC countries to reduce emissions through implementing only measures that are economically attractive.

This study identifies 60 measures that could be implemented in order to enable Russia to achieve its economic growth aspirations with energy consumption and greenhouse gas emissions remaining at current levels. The measures identified in this report are not likely to happen without deliberate action. The program would require some €150 billion (bn) in investments over the next twenty years, but would bring savings of up to €345 bn over the same period. Compared with the levels projected for 2030 as per the reference case, these measures could reduce Russian energy consumption by 23% (to 1,020 Mtce) and greenhouse gas emissions by 19% (to 2,425 Mt CO_2e).

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1 In this report, we adopt the standard Russian definition of tonne of coal equivalent as 7.0 Gigacalories, equivalent to 873 m^3 of natural gas, 27.8 MMBtu, 0.7 toe.

The largest opportunities are in the following sectors:

- **Buildings and construction.** By implementing energy efficiency measures, Russia has the potential to save about 180 Mtce (13% of total energy consumption in 2030) and to cut emissions by 205 Mt CO_2e (7% of total emissions in 2030). Implementing these measures would require over €70 bn in investments, which would result in €190 bn in savings over twenty years.

- **Fuel and energy.** In the petroleum, gas, power and heat sectors, it is possible between now and 2030 to achieve more than €60 bn in savings through just over €20 bn in investments in energy efficiency measures. These measures would provide almost 80 Mtce of energy savings (6% of total consumption) and 160 Mt CO_2e of emissions reduction (5% of total emissions).

- **Industry and transport.** Although most energy efficiency gains in these sectors occur through natural replacement, there are additional opportunities for savings of about 50 Mtce (4% of total consumption) and a reduction of 200 Mt CO_2e (7% of total emissions). These measures require about €60 bn in investments and would bring €80 bn in savings over twenty years.

Agriculture and forestry offer an additional potential to reduce greenhouse gas emissions – and measures in these sectors are the least capital intensive ones. With investments of about €20 bn over the next twenty years, Russia could further reduce emissions by 340 Mt CO_2e, or 11% of its total reference-case emissions in 2030.

If Russia were to pursue fuel diversification – already a stated goal in the country's energy strategy – it could invest in nuclear energy, large hydro and renewable sources of energy. Whilst fuel diversification over the next twenty years would require high investments (€170 bn) relative to the cost saving potential (€20 bn), they would yield an additional abatement of 220 Mt CO_2e, or more than 7% of the total emissions in 2030.

For these measures to be realized, a timely and targeted government effort would be required to support the private sector in overcoming the substantial existing barriers, such as high upfront investments, limited information, and misaligned incentives. Legislators are currently putting in place the necessary legal framework, but actually implementing the identified measures would require strong, coordinated action on the part of Russia's policy-makers. Such efforts could have a major impact on Russia's competitiveness and standard of living for many years to come.

2. Greenhouse gas emissions reduction – relevance for Russia

Global trends

In many countries today, decisions are being made to limit greenhouse gas emissions by regulation or by investing in new technologies. These decisions are driven by scientific evidence of undesirable consequences from increases in global temperatures, along with the expectation that a drastic reduction in emissions could prevent the most severe negative impacts.[1]

An increase of global temperatures by more than two degrees compared to pre-industrial times will have severe negative consequences for many regions of the world, according to world scientists as reported by the Intergovernmental Panel on Climate Change. These consequences include flooding, water shortages, and reduced crop yields, which in turn could lead to major ecological and social disruptions. Some scientists further believe that an increase of more than two degrees could make global warming self-perpetuating due to the further releases of greenhouse gases from melting permafrost soils, changes in vegetation, and the rise of ocean temperatures.

The possibility of humans preventing the most severe consequences of global warming by drastically reducing global greenhouse gas emissions (see box on p. 10) provides the stimulus for many countries to take action to limit their emissions. The lower the volumes of additional greenhouse gases emitted in the future, the higher the chance that global warming will stay below, or at least at, the two-degree threshold.

Thus, climate change has become a relevant factor in regulatory, industrial, and private decision-making, especially in developed economies. Countries are adopting stringent greenhouse gas reduction targets, and business is investing in new green technologies across sectors (e.g., in power generation, car manufacturing, and construction). Many companies are actively adjusting their business strategies in response to the increasing importance of climate change to their business operations and to their customers.

Relevance for Russia

Global warming is both an economics and a foreign policy issue. Greenhouse gas emissions of individual countries, including Russia, are the subject of international discussions and multilateral negotiations. Russia is the world's fifth largest emitter of greenhouse gases, and therefore its positions and actions receive a high degree of attention on the world stage. In turn, the global trend to reduce greenhouse gas emissions affects Russia across multiple dimensions.

Gains from international trading and projects

1. Attracting foreign investors to finance improvements in Russia

Russia can attract foreign investment into greenhouse gas abatement that would finance energy efficiency projects and create jobs (for example, in the construction and forestry

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1 This report, and McKinsey & Company generally, does not advocate a point of view on the science or politics of the question, but seeks instead to provide a fact base to assist decision-makers who are evaluating opportunities to reduce energy consumption and greenhouse gas emissions.

Greenhouse gases

There are three sources of human-produced ("anthropogenic") greenhouse gases:

1. Burning fossil fuels accounts for about 60% of greenhouse gases, mainly in power and heat generation, in industrial processes, and in transportation.
2. Deforestation releases CO_2, and agricultural activities (both livestock and soil) emit other greenhouse gases such as CH_4 (methane from livestock) and N_2O (nitrous oxide from fertilizers). Together with emissions from peat, these sources make up about 35% of global greenhouse gases.
3. The remaining 5% of greenhouse gases mainly stem from industrial processes, where not only CO_2, but also CH_4 and N_2O are emitted.



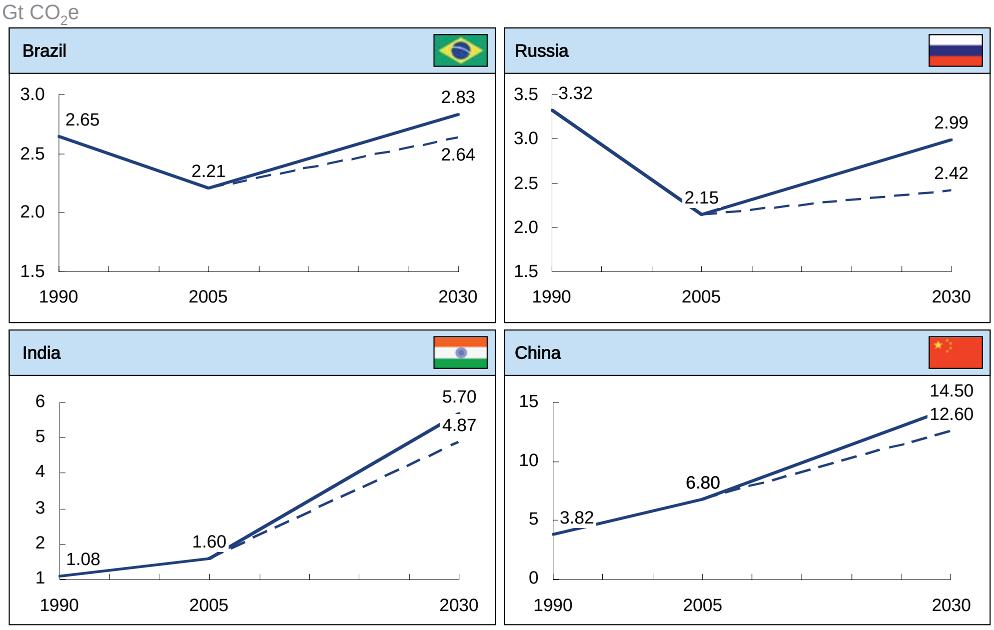

sectors). The Kyoto Protocol provides a specialized instrument for this type of investment called "Joint Implementation" (JI). In JI projects, companies in industrialized countries may invest in emissions reduction projects in other industrialized countries, if it is less costly than reducing emissions domestically. Russia is well-positioned to host JI projects. Not only is Russia blessed with highly diversified and self-sufficient energy resources, the country also has the potential to grow in an energy- and emissions-neutral way. In fact, Russia has the largest relative potential among all the BRIC countries to reduce emissions through implementing only measures that are economically attractive (Exhibit 1).

EXHIBIT 1

Greenhouse gas emissions and abatement potential in BRIC countries in 2030

Gt CO_2e

Reference case
After economically attractive abatement



SOURCE: UNFCCC; CAIT; McKinsey GHG abatement cost curves

So far, no JI projects have passed the application stage in Russia. However, the potential for benefiting from JI projects is high. For example, China received more than €500m in 2008 from comparable projects.

The attractiveness of these instruments is expected to increase. Some estimates predict a future demand from developed countries potentially exceeding 2 Gigatonnes of CO_2e per year – equivalent to €20bn at current carbon prices. And many experts expect far higher carbon prices in the future.

2. Revenues from international emissions trading
Russia has the largest surplus of 2008-2012 emission rights in the world (so-called "Assigned Amount Units" or AAU), equivalent to more than €50bn at an assumed price of €10 per AAU. The reason for this is that emission rights were granted to Russia based on its 1990 level of emissions, but due to the large drop in industrial production in the early 1990s, today's emissions are still about 30% below the 1990 level.

While some other countries, such as Ukraine, the Czech Republic, and Latvia, have already sold emission rights to Japan, Russia has not sold any yet. If this accumulated stock of emission rights can be retained in the post-Kyoto period, Russia would still have the option of selling these emission rights after 2012 to countries that do not meet their emission reduction targets. In this way, the accumulated emission rights could become a valuable and tradable asset – as is the abatement of future greenhouse gas emissions due to improvements described in this report.

Creating jobs in old and new industries

3. Spurring economic growth and employment
The topic of reducing greenhouse gases is sometimes considered from the angle of whether or not countries should sacrifice growth, or in terms of how much it would cost to reduce emissions. But all the measures identified in this report, whether or not they are attractive as stand-alone investments, contribute to economic growth and job creation.

Thus, basic programs like improving building insulation can generate up to 50 thousand seasonal and permanent jobs. The nuclear program involves hundreds of thousands of jobs. The secondary economic effects of emissions reduction programs – although not studied in this report – are undoubtedly a relevant factor in decision-making.

4. Innovation: creating new types of jobs through new technologies
Emissions reduction stimulates low-carbon technologies, including renewable energy, where Russia is not a world leader. Some experts (for example, from OECD and the World Economic Forum), forecast a major shift in the world's economy towards new lower-carbon technologies, and are convinced that there will be winners and losers in this economic transition. Winners would be the countries or companies that adapt faster and become market leaders in green technologies (from wind energy to electric cars) and benefit from an expected high demand in the future.

For example, a US study by Global Insight from 2008 predicts the number of so-called "green jobs" in the US (including workers in renewable power generation, retrofitting of buildings, engineering, and R&D) to increase from 0.7 m in 2008 to 2.5 m in 2018 and even to 3.5 m in 2028. Germany, one of the leaders in renewable power generation, expects 2 m new jobs to be created by 2020, and South Korea hopes to benefit in the coming four years from nearly 1m new "green jobs."

Innovation in the Russian context need not be equated just to new technologies. Necessary changes in the way Russian industrial and non-industrial businesses are managed are also a form of innovation, as they drive increases in productivity and allow the economy to be diversified.

Enhancing competitiveness of key sectors

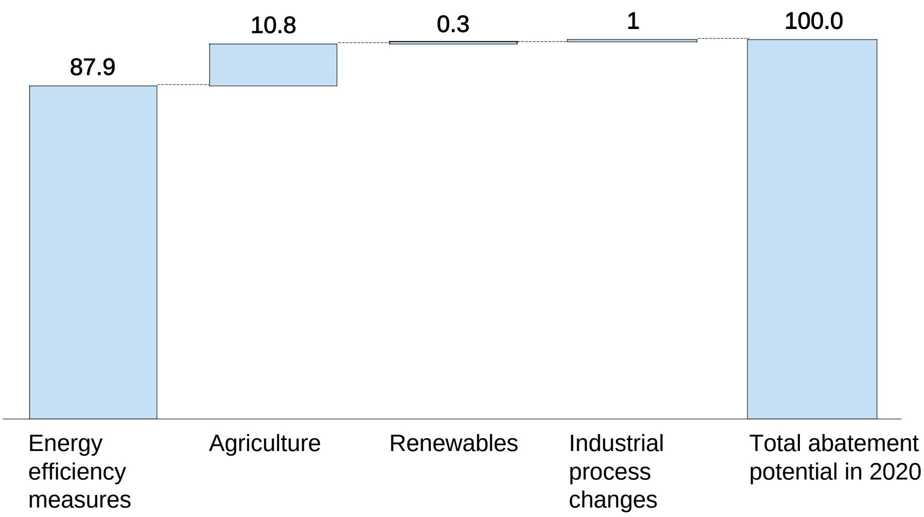
5. Preserving the competitiveness of Russian products

Many measures to reduce emissions – including 60 opportunities identified in this report – would actually result in savings that exceed the required investment. Most of these measures are energy efficiency improvements, which makes the two topics inextricably linked (Exhibit 2). However, there are also some economically attractive measures related to shifts in fuel mix and improvements in industrial processes.

EXHIBIT 2

Energy efficiency measures bring almost 90% of economically attractive greenhouse gas emissions reduction potential in 2020

Percent



SOURCE: McKinsey

Countries that adopt rules to reduce greenhouse gas in effect drive even further efficiency improvements, making their goods structurally more competitive. Also, by participating in greenhouse gas abatement efforts Russia could avoid any CO_2-related trade restrictions that could potentially be imposed by its main trading partners on non-participating nations.[2] That means the issue of greenhouse gas emissions could already become a critical topic for many Russian industries in the near future.

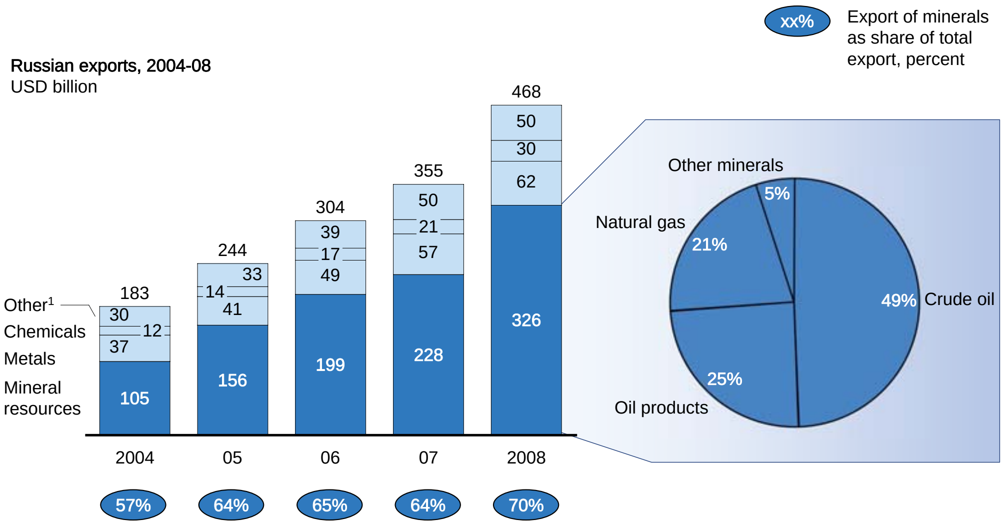
2 Examples of ongoing debates, at the time of publication, related to a "carbon tax" which could affect Russian companies and products, are:
- The EU plan that all airlines landing in and taking off from within the EU receive allowances for their carbon emissions beginning in 2012, as these allowances decrease 3-5% per year, airlines either have to reduce emissions or buy additional allowances.
- Public statements made by European heads of state that shifts in production from Europe to countries that do not have strict regulations on emissions need to be avoided; and that countries that are not committing to CO_2 reductions should face tariffs on all products they export to the EU.
- The "Waxman-Markey Act" in the US proposing, among other measures, that a "carbon border tax" be imposed on all products imported into the US.

6. Russia's oil and gas industry: reducing greenhouse gases can help increase exports or reduce investment needs

Russia's oil and gas industry today is responsible for more than two-thirds of Russia's exports (Exhibit 3). The more stringent the internationally-agreed targets for emissions reduction, the lower will be the global demand for fossil fuels. Although a major exporter, Russia is not a cost leader in coal, oil, or natural gas, and thus Russian companies run the risk of tightening margins and a drop in exports. Reducing leakages and inefficiencies helps preserve margins and reduce emissions simultaneously.

EXHIBIT 3

Russia's oil and gas industry is responsible for about two-thirds of Russia's exports



1 Other includes export of machinery, equipment, transport vehicles, pulp and paper and other products

SOURCE: Rosstat, Central Bank of Russia

Many measures to reduce greenhouse gas emissions would also reduce the consumption of Russia's natural oil, gas, and coal resources. This could directly benefit Russia, leaving additional volumes of resources available for export or delaying the need for high-cost capital investment in projects to explore new oil and gas fields.

Health and environment

7. Reducing pollutants

Pollution often results from the same sources as greenhouse gas emissions – for example, from the burning of fossil fuels. Thus, reducing greenhouse gas emissions often has the additional benefit of reducing other harmful polluting substances, including NO_x (the precursor of smog), SO_x (which causes acid rain), particulate matter and heavy metals. That is why decreasing greenhouse gas emissions – for example, by reducing the use of gasoline, electricity, and heat, and by reducing the share of coal and gas burned in power generation – would also protect the environment and the health of the Russian population.

□ □ □

From many different angles reducing greenhouse gas emissions is a relevant topic for Russia. The following chapters set out what reductions are possible both in energy consumption and greenhouse gas emissions in different sectors, such as buildings, power, oil & gas, industry, transport, forestry, agriculture and waste, along with the associated costs, investment needs and the hurdles to overcome.

3. Evaluating opportunities to reduce Russia's energy consumption and greenhouse gas emissions: findings

This chapter provides a summary of how Russia's energy use and emissions have evolved since 1990, extrapolates a future reference case, sets forth the most significant opportunities to gain additional energy savings and emissions reduction, and discusses how to overcome the implementation challenges.

RUSSIA'S LARGE DROP IN ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS AFTER 1990 REFLECTS ITS ECONOMIC COLLAPSE

In 1990, Russia consumed 1286 Mtce (million tonnes of coal equivalent), according to the Soviet statistics agency, and emitted 3320 Mt CO_2e (million tonnes of CO_2 equivalent) of greenhouse gases. This made Russia the world's second largest energy consumer after the United States, and the third largest emitter of greenhouse gases after the United States and China. But the collapse of large parts of the Russian economy during the 1990s led to a 30% decline in the use of energy and a resultant reduction in emissions of about 40% by the year 2000. With the rebounding growth of the Russian economy since that time, there have been moderate increases, averaging about 1.5% per year for energy consumption and 1.1% per year for greenhouse gas emissions.

Today, five years after ratifying the Kyoto Protocol, Russia's primary energy consumption is still 20% below its 1990 level. This is because many energy-intensive industries have never recovered their old share of the GDP, or have begun to use new and more energy-efficient technology. Consequently, today Russia's greenhouse gas emissions are still more than 30% below the level of 1990. The 1990 level is significant because it was set in the Kyoto Protocol as the upper limit permissible for Russia's emissions through 2012. Despite a GDP growth of more than 50% between 2001 and 2008, and in spite of the fact that no dedicated government programs were undertaken to reduce energy consumption or greenhouse gases, Russia's emissions over this period have remained relatively stable, for the following reasons:

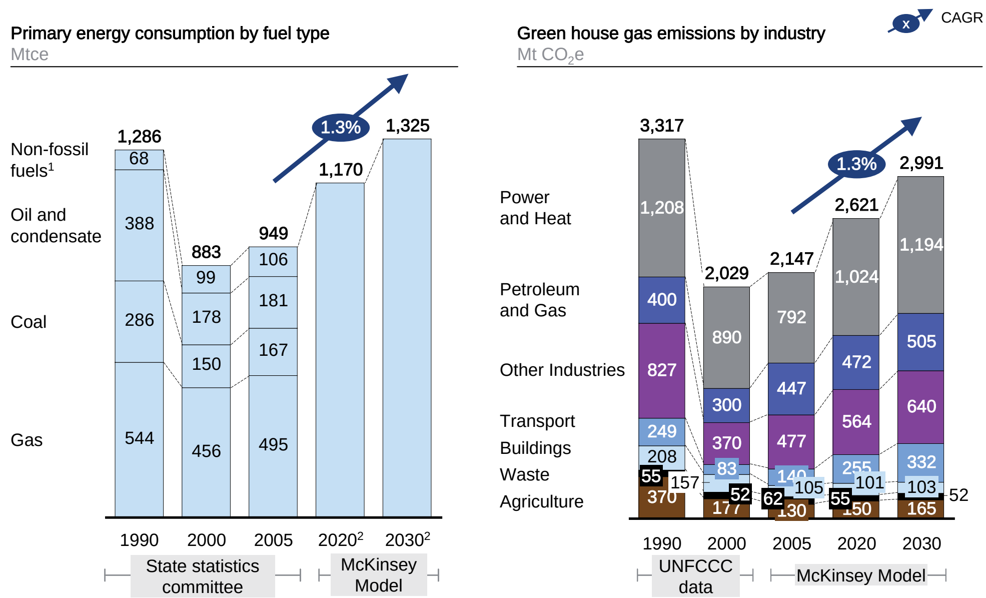
- The shift away from heavy industry (which saw an average annual growth rate of 6.5% between 2001 and 2008) towards lighter industry and the service sector (with an average growth rate of 8.1% for this period) has led to a structural change in the make-up of the Russian GDP, which increased by more than 50%, while emissions from industry increased only by about 40%, or 290 Mt.
- A natural tendency for higher efficiency in new buildings and equipment. For example, direct emissions from buildings dropped by about 50 Mt.
- A switch from oil and coal to gas in electric power production, thanks to which – in spite of an increase in power production of 2.2% annually – emissions decreased by about 70 Mt.
- The ongoing abandonment of Russian agricultural land and the reduction in livestock has led to a further reduction in emissions in the agricultural sector, by about 40 Mt.

THE REFERENCE CASE: RUSSIAN ENERGY CONSUMPTION GROWS 40% OVER 25 YEARS AND EMISSIONS RISE AT SIMILAR RATE, REACHING 90% OF BENCHMARK 1990 LEVELS

As newer, more energy-efficient equipment and buildings replace older installations, Russia's GDP becomes less energy intensive. Taking this trend into account, we project that if Russia were to fulfill its aspiration of up to 6% per annum growth in GDP, which means the economy more than doubles by 2030, its energy consumption would increase by only 40%, to 1,325 Mtce between 2005 and 2030. Its greenhouse gas emissions over the same period would also increase by only 40%, to 2,990 Mt CO_2e, leaving the country's overall emissions close to its benchmark 1990 emissions level (Exhibit 1). This anticipated development has been forecast as the "reference case", as it is based on natural growth patterns without any specific intervention[1]. However, the reference case does take into account a number of energy efficiency improvements that are required by current laws (such as reduction of gas flaring).

EXHIBIT 1

Russian primary energy consumption and greenhouse gas emissions



Note: Forestry (LULUCF, land use, land-use change and forestry) excluded from column chart
1 Hydro, nuclear, and renewables
2 The structure of primary energy consumption in 2020-2030 will depend on future decisions on the fuel mix in the Russian power sector

SOURCE: Rosstat; UNFCCC; McKinsey

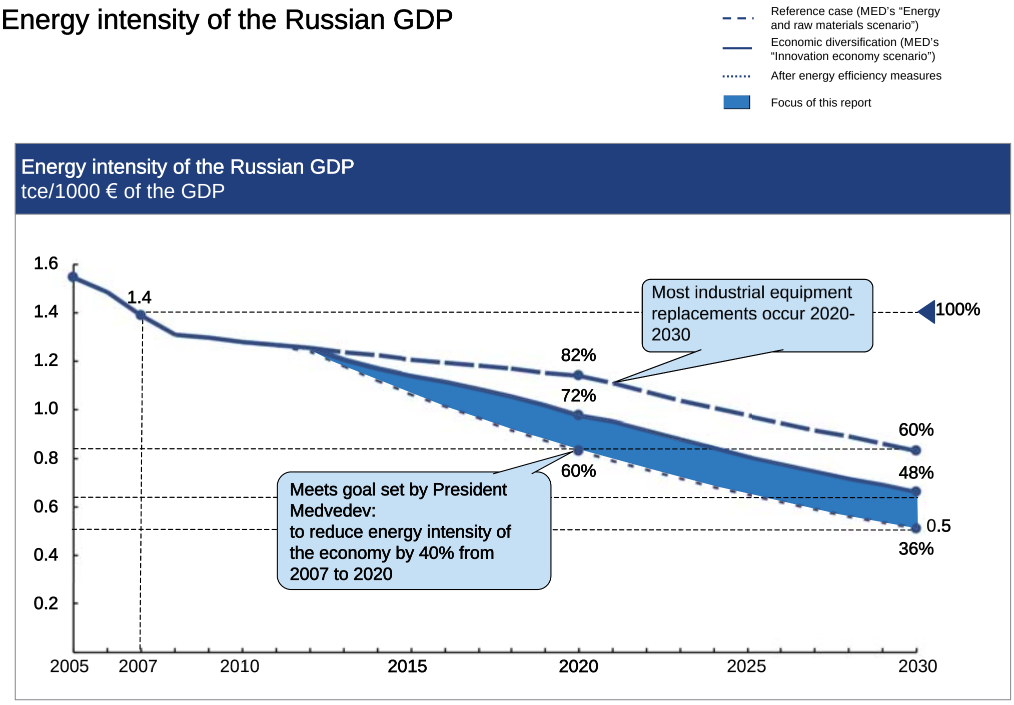
Even without any specific action, the energy intensity of Russian GDP is likely to decrease due to the natural improvement in energy efficiency. Compared to the 2007 level, the energy intensity of Russia's GDP is expected to fall by 18% as of 2020 and 40% as of 2030, assuming economic growth per the government's "energy and raw materials" scenario.

1 Note that some other reports on greenhouse gas emissions and energy efficiency use as a baseline either the current levels or so-called "frozen technology scenarios", extrapolating current emissions from the expected growth (for example, of GDP), while assuming no improvements in technology and efficiency in their baseline. Reduction potentials in this and in other reports are therefore not directly comparable due to the different methodology. The anticipated final energy consumption and emission levels, however, can be compared.

Under the government's "innovation economy" scenario, energy intensity drops by another 10% (Exhibit 2). Based on the published "concept of long term development", the two economic development scenarios lead to different economic structures and energy intensities, but equal total energy consumption in the economy.

EXHIBIT 2

Energy intensity of the Russian GDP



SOURCE: Rosstat; MED; McKinsey

The industrial share of Russia's GDP would be expected to decline from 38% in 2007 to 30-33% in 2020, depending on the scenarios, or approximately the economic profile of Canada and Germany today. Energy use for buildings and transportation is expected to increase more rapidly than energy use in industry. For example, the increase in buildings is driven primarily by the increase in floor space per resident, worker, shopper (e.g., for residential houses 42 m^2/person in 2030 compared to 21 in 2007), but is mitigated by an average increase in energy efficiency (0.17 GCal/m^2 per year in 2030 instead of 0.25 GCal/m^2 today).

Emissions in 2030 will also grow in line with energy consumption, but subject to a high level of uncertainty regarding the future fuel mix in power generation, given that 60-70% of the 2030 capacity still has to be built. Therefore, emissions from the power and heat sector are treated as an uncertainty in the reference case, addressed by four modeling scenarios. If based on a continuation of the current power economics that favor gas, the reference case sees a 1.27% annual growth rate of emissions. Meanwhile, an increasing share of coal in the future would increase the rate to 1.33%. A shift towards nuclear and hydro would reduce the rate to 0.98% per year. In total, the choice of fuel mix can drive emissions as high as 3050 or as low as 2810 Mt CO_2e in 2030.

THE ABATEMENT CASE: WHILE THE ECONOMY MORE THAN DOUBLES BY 2030, RUSSIA'S ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS COULD STAY NEARLY STABLE

Russia can go further by actively undertaking numerous measures to improve energy efficiency and reduce emissions without inhibiting its rapid growth. A systematic program to increase energy efficiency can keep Russia's energy consumption at today's level even while the economy doubles in size. The amount of energy thus saved would be comparable to the total annual consumption of energy in Canada today.

We reviewed more than 150 measures to identify the most significant opportunities for saving energy and reducing greenhouse gas emissions in Russia. We reviewed and prioritized measures purely on the basis of their economic attractiveness – for example, the potential energy reduction volume compared to the costs or savings obtained. Decision-makers will also need to take other considerations into account, such as the ease of implementation, job creation, or the desire to promote certain specific, strategic industries. Assessing such considerations is not part of this study.

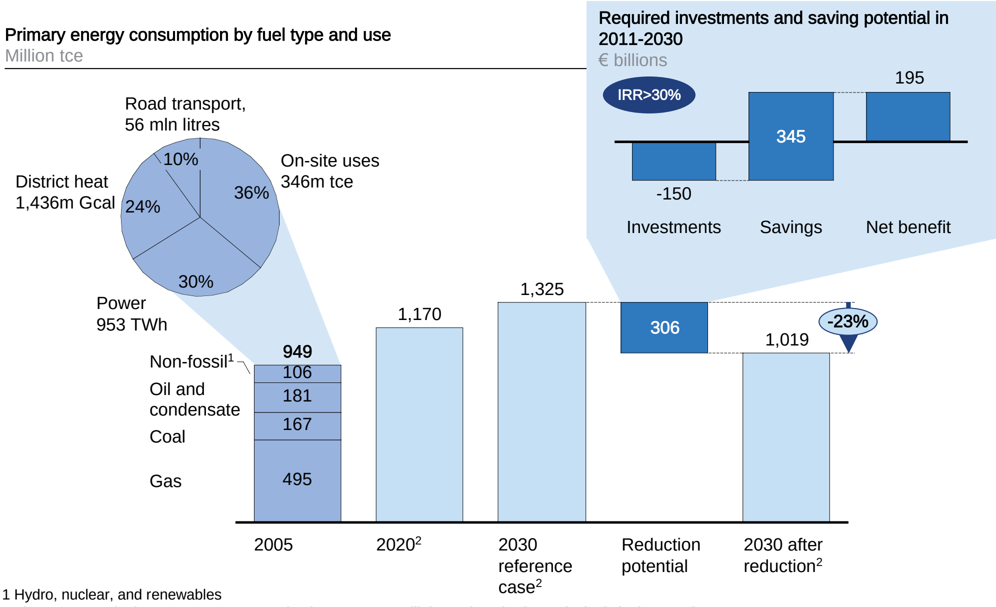
Broadly, two major types of measures are available for Russia:

- **Improvements in energy efficiency that also reduce greenhouse gas emissions.** Based on our analysis, some 60 measures requiring investments of €150 bn would be economically attractive to investors with an average IRR above 30%. These measures reduce energy use compared to the reference case by 23% to 1020 Mtce[2] (Exhibit 3).

- **Measures to reduce greenhouse gas emissions.** These measures require some €410 bn of investments, which on a stand-alone basis are not directly economically attractive to private investors.

EXHIBIT 3

Russian primary energy consumption reduction and saving potential after implementation of economically attractive measures



1 Hydro, nuclear, and renewables
2 The structure of primary energy consumption in 2020-2030 will depend on the future fuel mix in the Russian power sector

SOURCE: Rosstat; UNFCCC; McKinsey

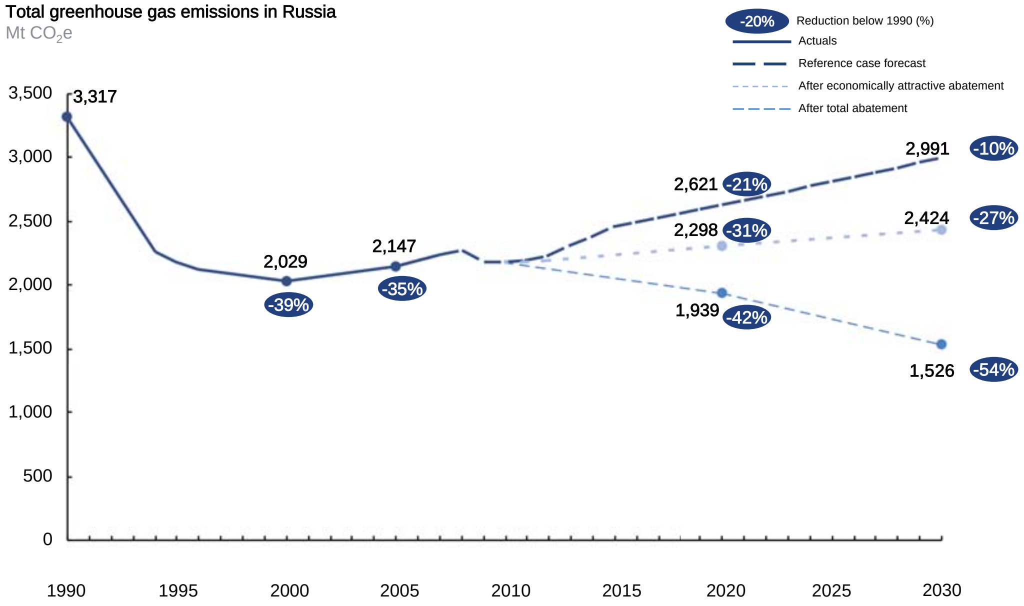
2 Technological improvements and existing regulations are already included in the reference case. This, for example, includes the law on reduced permissible flaring volumes until 2012, but not the new energy efficiency law signed in November 2009.

If fully implemented, all these measures would reduce 2030 energy consumption by 36% and emissions by 51%, compared to the reference case. Thus, by taking significant dedicated steps, including measures costing up to €80 per tonne abated, Russia could bring its emissions down to 1526 Mt, or 46% of 1990 levels (Exhibit 4).

EXHIBIT 4

By 2030, Russia could reduce emissions to below 50% of the 1990 level. Money-saving measures alone would reduce emissions to 27% below 1990

Total greenhouse gas emissions in Russia
Mt CO_2e



SOURCE: UNFCCC, McKinsey

Energy efficiency and four subtypes of emissions reduction measures are shown in Exhibit 5:

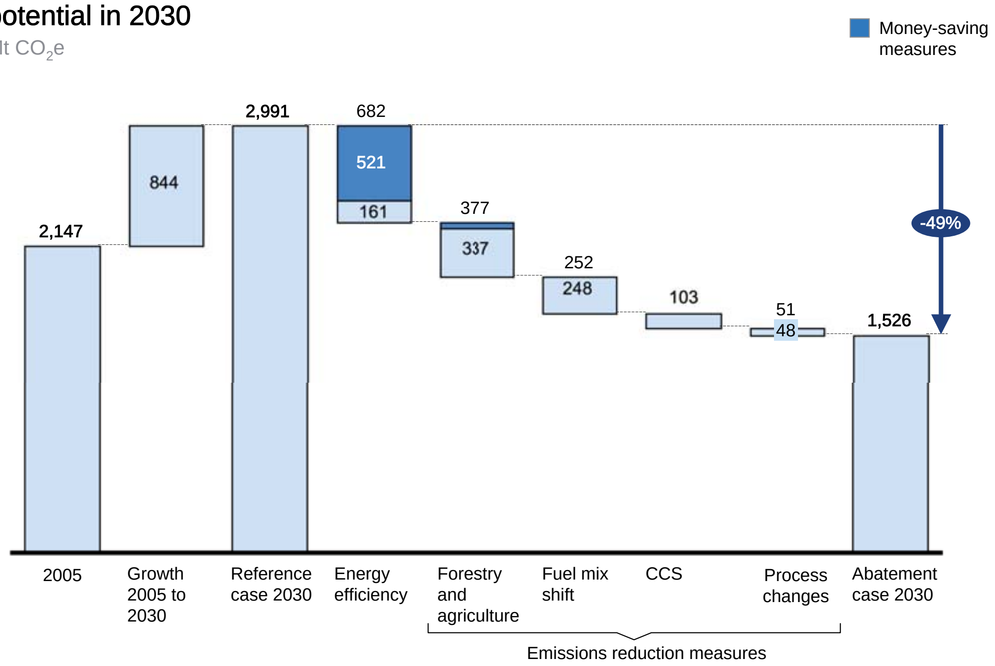
- **Energy efficiency measures** (saving 440 Mtce, 680 Mt CO_2e): Improvements in this category include, for example, the installation of more efficient equipment in power generation, better insulation of buildings, and fixing leakages in gas pipelines. (Because of the considerable potential advantages for Russia, these measures are discussed in more detail in the box on pages 24 and 25.)
- **Agriculture and forestry measures** (saving 380 Mt CO_2e): The abatement effect of these measures in most cases comes from an increase of CO_2 absorption (e.g., forestation) or from lower N_2O emissions from reducing the use of fertilizers.
- **Measures related to fuel mix changes** (saving 250 Mt CO_2e): Measures in this category refer to alternative technologies in power and heat generation to replace gas and coal-fired power plants and to increase the use of cogeneration. Also considered here are burning biomass or waste in industrial processes and the use of ethanol in road transportation.
- **Measures related to process changes** (saving 50 Mt CO_2e): Improved processes in industry (e.g., N_2O decomposition in nitric acid production) and the waste sector (e.g., capturing landfill gases) would lead to reduced greenhouse gas emissions.
- **Carbon Capture and Storage measures** (saving 100 Mt CO_2e) could be applied to large carbon emitters in power generation and industry. All measures tend to have a high cost

of abatement[3] and the technology is still in the developmental stage – but could become available after 2020.

EXHIBIT 5

Russia's baseline greenhouse gas emissions and the abatement potential in 2030

Mt CO_2e



SOURCE: McKinsey

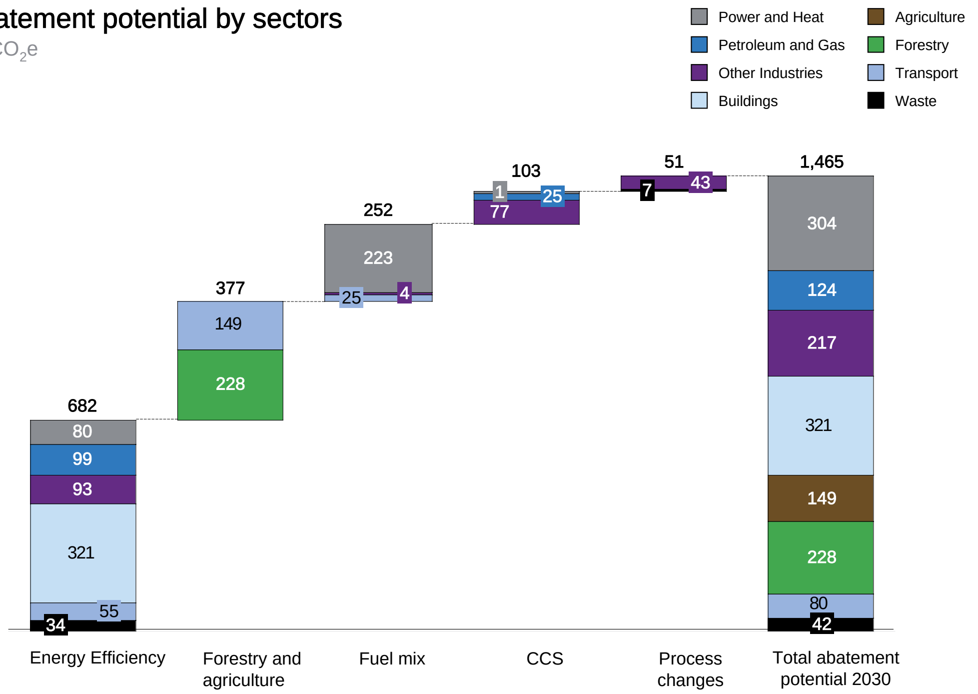
Exhibit 6 shows how the abatement potential in different categories is distributed among the various sectors of the Russian economy: about half of all energy efficiency improvements (320 of 680 Mt CO_2e) comes from residential and commercial buildings, while power and heat generation, the petroleum and gas industry, and other industries contribute 80-100 Mt CO_2e each. The power and heat sector, naturally, with 220 out of 250 Mt CO_2e, is the main contributor to emissions reduction through fuel mix shifts, followed by the road transport sector with 30 Mt CO_2e.

3 All CCS measures typically exceed €30/t CO_2e.

EXHIBIT 6

Abatement potential by sectors

Mt CO_2e



SOURCE: McKinsey

MONEY-SAVING IMPROVEMENT MEASURES DECREASE ENERGY CONSUMPTION BY 23%, GREENHOUSE GAS EMISSIONS BY 19% AND YIELD ANNUAL NET SAVINGS OF €24 BN IN 2030

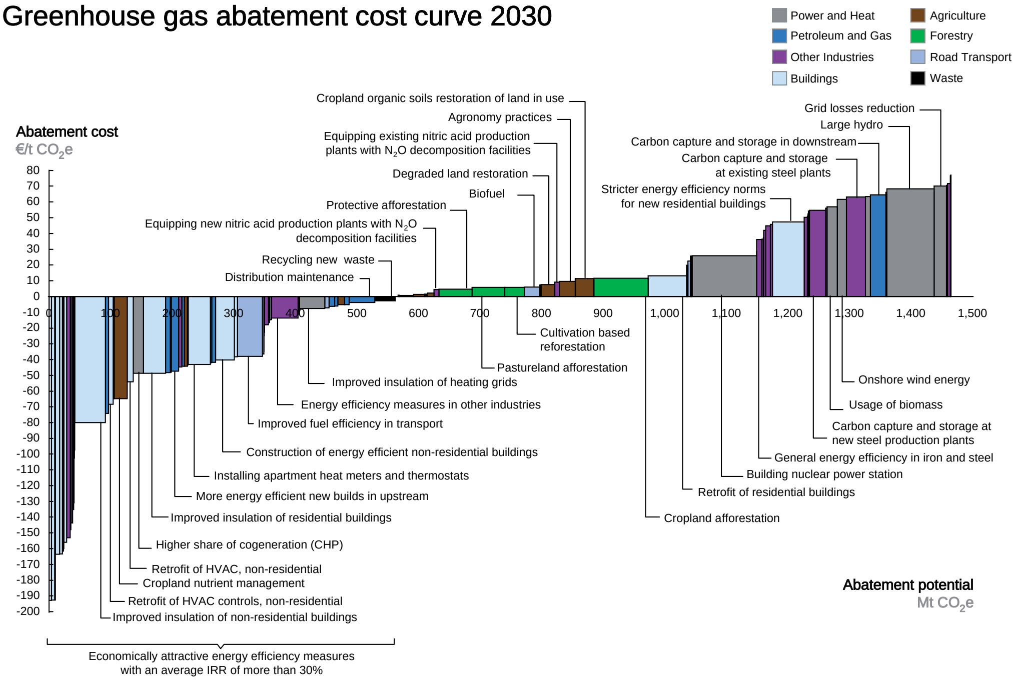
Reducing energy consumption and CO_2 emissions would in many cases be profitable overall. When implementing only the 60 so-called “money-saving measures”[4], emissions would be 2420 Mt CO_2e, or 19%, lower than in the reference case, and 27% below the 1990 level. These measures are shown on the left side of the cost curve (Exhibit 7), represented by negative bars. The total annual saving expected in 2030 from implementing money-saving measures is €24bn.

Most of these savings would come from measures related to energy efficiency, which in 2030 would provide an energy reduction of 306 Mtce (23% of reference case) and an emissions reduction of 520 Mt CO_2e (17% of reference case), while the remaining money-saving measures from other categories in 2030 would in total contribute another 50 Mt CO_2e (2%).

4 Measures are considered “money-saving” (or “economically attractive”) when the net savings over the lifetime exceed the required investments, based on an overall national or “societal perspective” (see Section 5). The real cost of capital is assumed to be 8%. Based on this approach, the term “money-saving” is used when looking at individual projects – for example, a single building. Note that transaction and project costs, which can be significant where, for example, millions of apartment owners would have to improve insulation, are not taken into account.

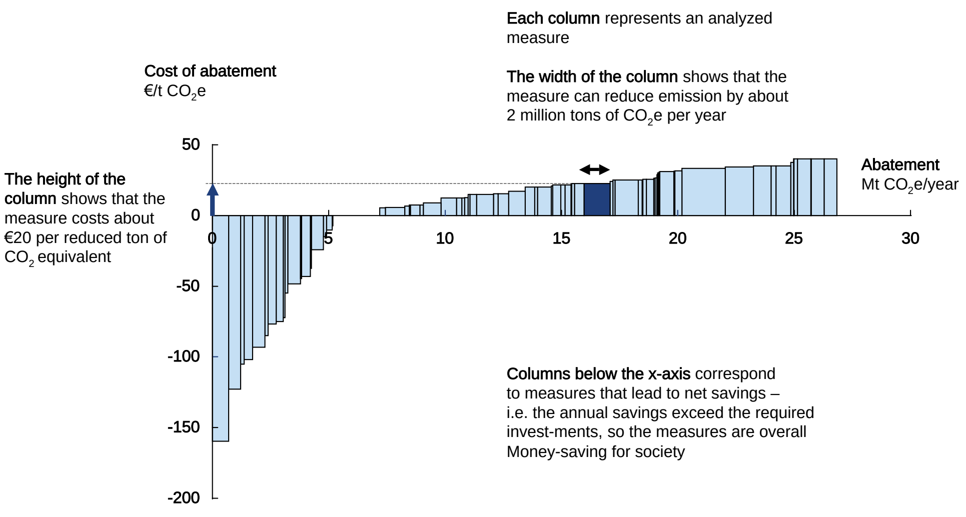
EXHIBIT 7

Greenhouse gas abatement cost curve 2030



SOURCE: McKinsey

How to read the cost curve



SOURCE: McKinsey

SIGNIFICANT CAPITAL INVESTMENTS: TO BRING ABOUT SAVINGS OF €345 BN THROUGH 2030, €150 BN OF INVESTMENTS ARE REQUIRED

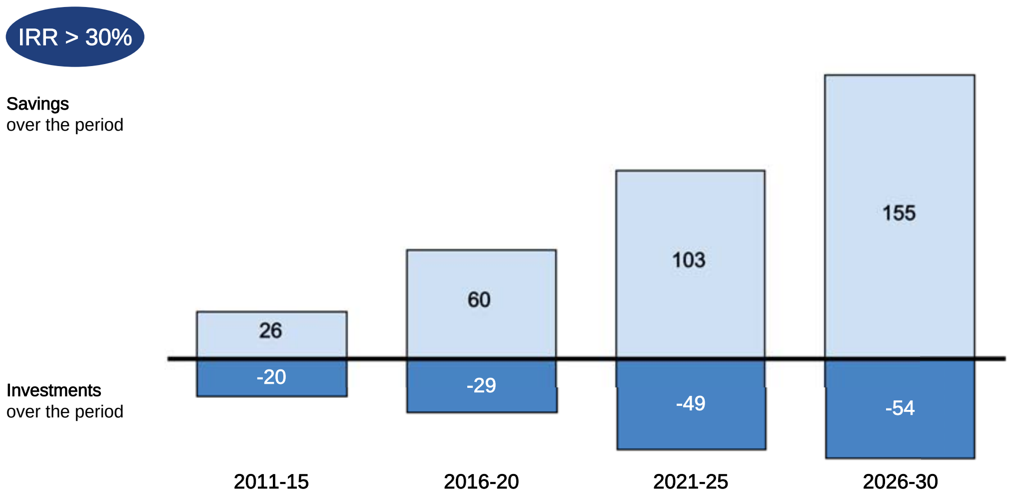
Implementation of money-saving measures would require some €150 bn in investments over the next twenty years, but would bring savings of up to €345 bn over the same period. That equates to an average annual investment of €7.5 bn per year[5]. Implementing all the abatement measures would require an average capital expenditure of almost €30 bn per year over the period 2010-2030. By comparison, anticipated overall national investments are about €200-350 bn per year (i.e., €225 bn in 2015, €300 bn in 2020, as forecasted by the Russian government). Therefore, implementation of economically attractive abatement measures would be about a 2% increase or redirection of the nation's overall investments, but investing in all measures would be a much more significant (~10%) increase or reallocation.

Required investments are unevenly distributed over the period, with the greater portion needed after 2020. High savings potential in the final period is explained by the cumulative effect of the investments made over the previous fifteen years, mainly from measures in the buildings sector (Exhibit 8).

EXHIBIT 8

Economics of the implementation of energy efficiency measures over the period from 2011 to 2030 and resulting savings

€ billions



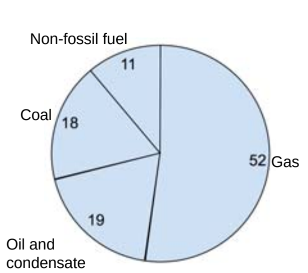
SOURCE: McKinsey

Exhibit 9 shows how this average annual investment would be spread across the sectors. The largest incremental investment would be required in the buildings sector to implement energy efficiency measures.

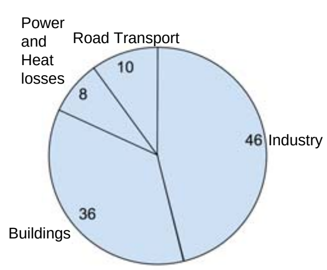
5 The projected capital expenditures and savings are subject to significant uncertainties and should be understood as estimates, not precise forecasts. Real numbers will largely depend, among other things, on the pace of energy market liberalization, the development and costs of relevant technologies, and on the order of implementation of the proposed measures. For measures related to technologies that are not commercially used today, such as LED lighting and carbon capture and storage, estimates for the capital required are based on assumptions about declining costs for certain technologies.

Facts about Russia's energy consumption and efficiency improvement potential

Share of primary energy by source, 2005
Percent



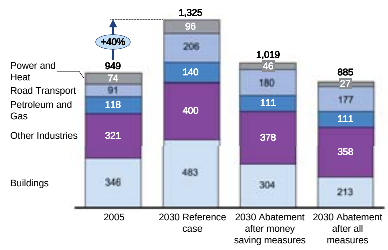
Share of primary energy by end user, 2005
Percent



As shown below, energy consumption is expected to increase by 40% in the reference case, but could stay flat in the abatement case if all money-saving energy efficiency measures were to be implemented.

The largest improvement potential exists in the building sector (where heat plays a large role, as does power), in industry (with a focus on equipment efficiency), and in power and heat (addressing internal consumption and losses).

Energy efficiency breakout
Energy consumption by sector
Mtce



SOURCE: McKinsey

Increasing energy efficiency is the largest and most economically beneficial way to reduce Russian CO_2 emissions

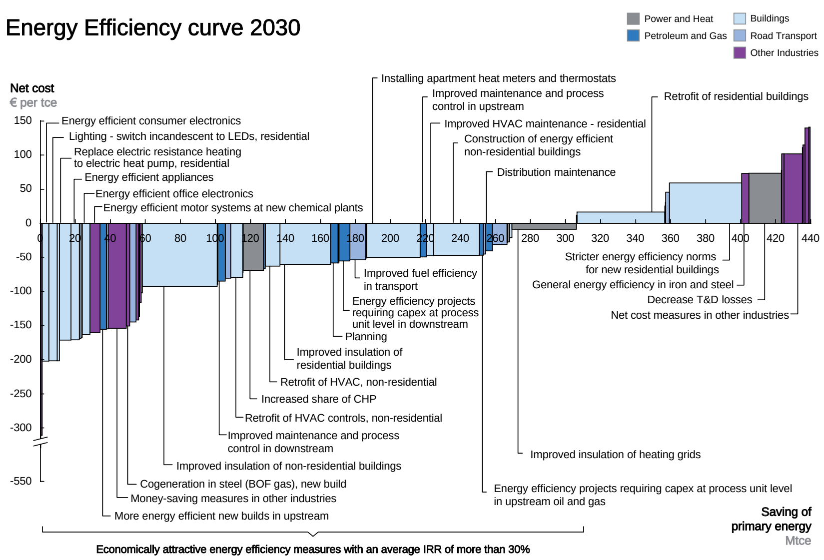
More than half of the 120 greenhouse gas reduction measures identified in this report are related to increases in energy efficiency. Without them, energy consumption in Russia is expected to increase by about 40%, from 949 Mtce in 2005 to 1325 Mtce in 2030 in the reference case.

Most of the energy efficiency measures are econimically attractive overall on a national level for Russia. Implementing all the energy efficiency measures would reduce 2030 energy consumption by 440 Mtce (33%). Implementing only those measures whose cost savings exceed investments would result in a reduction of 306 Mtce (23% below the consumption assumed in the 2030 reference case) and savings of €24 bn per year in 2030.

The main categories in this group of economically attractive improvements are:

- **Improvements in buildings (saving 178 Mtce):**
  Improving insulation in residential and commercial buildings and installing heat meters and thermostats would have the largest impact, but more efficient appliances, electronic devices and lighting would also save energy. These measures would all reduce emissions, and be profitable overall.

Energy Efficiency curve 2030



SOURCE: McKinsey

- **Insulation of heating mains (saving 37 Mtce):**
  Renewing and improving insulation with modern materials (polyurethane insulation) could reduce current losses of about 25% in district heating network to about 12%.

- **Improved gas pipeline management (saving 10 Mtce):**
  Reducing leakages, improved maintenance, and better planning of gas transmission volumes could save about 8 billion cubic meters (bcm) of gas per year.

- **Other categories (saving 81 Mtce):**
  Additional money-saving measures include a wide range of possibilities from more fuel efficient cars to increased levels of cogeneration.

By implementing these money-saving energy efficiency measures, in addition to anticipated natural development, the energy intensity of the Russian economy would decrease by 52-64% – from 1.39 tce per thousand euros of GDP in 2007 to 0.51-0.67 tce by 2030. This means that the country's energy use in absolute terms would increase by only 2% while the economy more than doubles.

The resulting effect on greenhouse gas emissions is similar: carbon intensity would decrease by more than 50% from 3.1 tonnes of CO_2e per thousand euros in 2007 to 1.5 tonnes in 2030.

So instead of increasing by almost 40% (expected in the reference case without any measures), greenhouse gases would hold nearly steady, from a level of 2.1 Gt CO_2e in 2005 to 2.3 Gt in 2020 and 2.5 Gt in 2030.

The remaining net cost energy efficiency measures would reduce energy consumption by another 134 Mtce by 2030, or an additional 10%. Examples include capital repairs of residential buildings and the construction of new high-voltage transmission lines. Implementation of these measures is still possible in spite of the net costs, as discussed later in this chapter.

Comparing this report's findings on energy efficiency with the results of other publications

- This report compares a "reference case" for 2030 with an "abatement case" for the same year (see Section 5). The reference case, as a baseline, already includes all improvements which are expected to happen without external support, such as the replacement of equipment and plants with more efficient technology. So, unlike reports that start from a "current technology scenario" and current efficiency levels, this report does not discuss in detail those measures which are expected to happen "on their own." Instead, this report focuses on those measures which might require regulatory, financial, or other support to overcome existing obstacles to implementation, such as the high initial investments or the lack of sufficient incentives. Owing to this focused approach, results are not directly comparable with figures published in other reports on Russia.

- Potential effects from changes in lifestyle and behavior are not included in this report. Measures such as the purchase of more fuel efficient cars, increased use of public transport, and active energy savings by households could make significant contributions (estimated at about 50 Mtce per year in 2030). However, their costs or benefits are not largely financial and thus difficult to quantify. Therefore, these types of measures are not included in this report.

International examples for regulation-driven

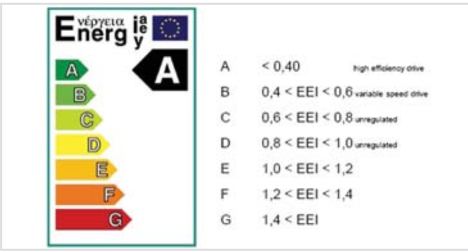
EU: Energy labels for appliances

Regulations

- Light bulbs and most white goods must clearly display the EU Energy Label when offered for sale or rent
- Energy efficiency ratings are classed from A to G

Impact

- Hardly any goods in classes E-G offered for sale anymore
- Of all fridges offered in 2008, about 98% were in classes A, A+, or A++



Japan: Top runner program for appliances

Regulations

- Mandatory energy efficiency targets set for different product categories, such as cars, TVs, fridges, air conditioning
- The most efficient model on the market today becomes the base for the target in 4-8 years time

Impact

- Company brand image benefits from becoming the standard for targets
- Energy consumption of appliances were reduced by 60-80% in the past decade

Denmark: Comprehensive government program to reduce energy consumption

Regulations

- Tighter insulation norms for building
- Strict appliance standards
- Use of resources forms a basis for taxation

Impact

- 0.8% average annual decline in energy demand over the past two decades (compared with 0.3% decline in other European countries that have also introduced some energy efficiency measures)

Finland: Energy audit program

Regulations

- Voluntary audit program in energy sector, industry, and service sector
- Audit costs subsidized by 50%
- Subsidies available for investments in identified energy saving opportunities

Impact

- Estimated savings of more than 2% of the total energy consumption of the country in 2007

improvements of energy efficiency

Germany: Support for wind power

Regulations

- Access to grid and attractive feed-in tariffs provided for all energy producers (private and business)
- Low interest loans available

Impact

- Largest installed wind power capacity in the world (2007 figures)
  - 19,500 turbines
  - 22 GW of installed capacity
  - 7% of total energy generated

Brazil: Launch of world's largest biofuel program

Regulations

- 'Proalcool' program started in the 1970s, aimed at replacing gasoline fuels with biofuels made from domestic sugarcane
- Mandatory ethanol blend requirements
- Subsidies for sugar cane producers
- Limits and duties on gasoline imports

Impact

- More than 90% of passenger cars sold today can run on gasoline and ethanol
- Ethanol share of fuel consumption in vehicles above 50%

Japan: Clean vehicle incentive program

Regulations

- Production subsidies available
- Subsidies to consumers of up to 5% of vehicle price

Impact

- Hybrid vehicle sales in Japan increased from 60,000 in 2005 to 90,000 in 2006
- Domestic support created the basis for international growth – by August 2009 more than 2m Toyota Prius cars sold worldwide

USA: Dedicated lanes for pooled cars and 'clean' vehicles

Regulations

- Dedicated lanes reserved for "Highly Occupancy Vehicles" (HOV) and, in California, for low-emission vehicles
- Lower toll fees for vehicles meeting specified emissions standards

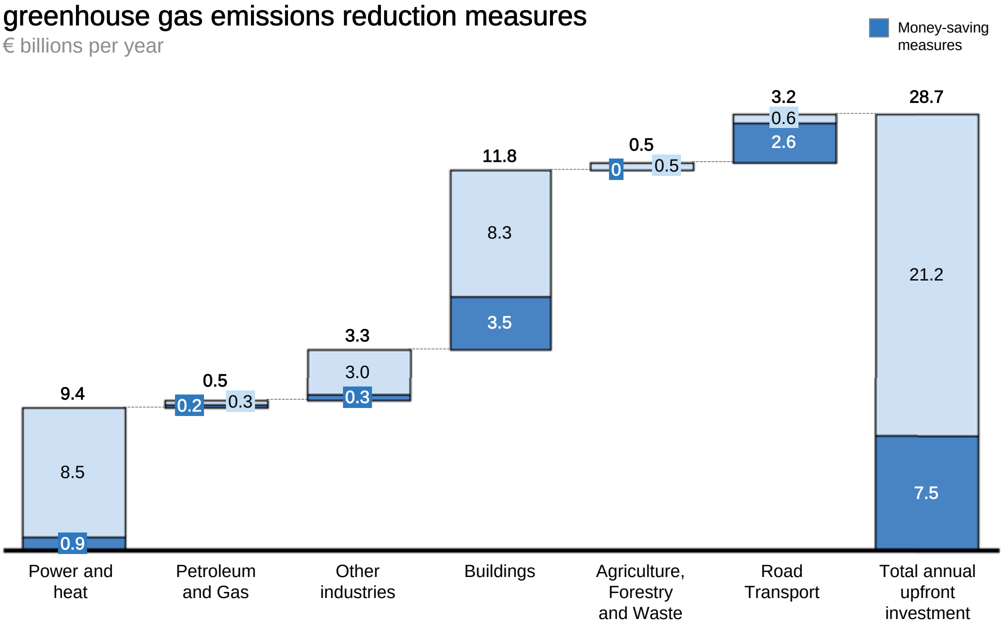
Impact

- Reduction of overall number of cars on the street, especially during rush-hours
- An increase in sales of hybrid cars

EXHIBIT 9

Average annual investments required in 2010-30 for implementation of greenhouse gas emissions reduction measures

€ billions per year



SOURCE: McKinsey

By category, investment needs and savings differ, as follows:

- Implementing only money-saving (mainly energy efficiency) measures would require about €7.5 bn per year and generate an average annual saving of €17 bn. Cumulatively, the investment amounts to €150 bn over the period 2010-2030. This group of money-saving measures includes some of the measures with the largest capital requirements, such as the installation of apartment heat meters and thermostats. Yet investments for this measure (€11bn over the period 2010-2030) are expected to pay back in only two to three years.
- Implementation of all measures related to nuclear, hydro and renewable power generation would require a cumulative investment of €175 bn. Associated savings would amount to only €20 bn on a cumulative basis, which reflects the fact that nuclear and large hydro plants require massive investments and that renewable sources are in general more costly than energy from fossil fuels.
- Agriculture and forestry measures are the least capital intensive and would require €20 bn over the period 2010-2030, more than half in forestry, related to the planting of trees.

Implementing the full set of identified measures would require strong, coordinated action on the part of Russia's policy-makers. The measures described in this report are unlikely to be implemented without explicit support from policy-makers. Even those opportunities to increase energy efficiency that are economically attractive, are unlikely to happen if left to the private sector alone. Significant upfront investment requirements are only one barrier for private sector players. There are others that also need to be addressed.

While changes to the national fuel mix, for example, could be implemented by a limited group of decision-makers, millions of Russians would need to be involved in household decisions such as switching light bulbs or insulating their buildings, and an entirely new type of business – energy service companies – would have to emerge to capture some of the opportunities. Such measures would potentially touch about 15 thousand multifamily, residential homes, or 4.5% of the national housing stock, each year. The overall implementation effort would create about 100 thousand permanent and seasonal jobs, including the mobilization of 50 thousand people for forestation efforts in rural and agricultural areas.

Therefore, in line with the examples from many countries around the world, Russian policy-makers should consider setting up numerous programs to address the barriers to implementing energy efficiency and abatement measures:

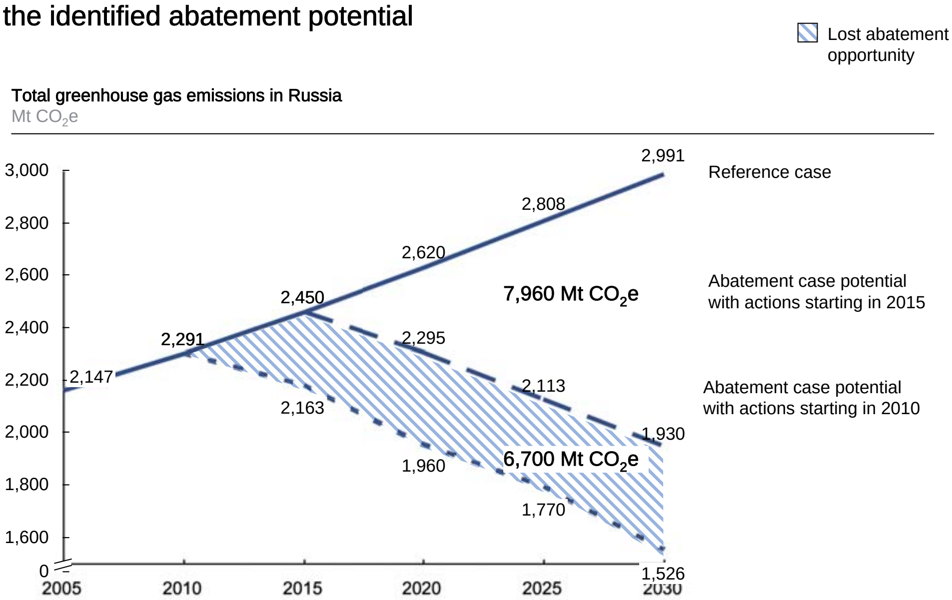
- **Incentives to ease upfront investments.** In total, some €150 bn is needed over the 2010-2030 period to implement economically attractive measures that both improve energy efficiency and reduce greenhouse gas emissions. Consumers tend to be reluctant to invest in energy efficiency improvements where the payback period exceeds one or two years; and in Russia, more often than in Western countries, businesses also tend to refrain from high investments with long payback periods as a result of higher market and economic uncertainties. Therefore, energy efficiency measures could be promoted through targeted loan programs that create the necessary incentives.
- **Building awareness and providing information.** Measures in agriculture and in residential buildings, where actors are widely dispersed, would be stimulated by additional investment to educate consumers about existing money-saving opportunities. In many countries around the world, governments are investing in creating more awareness of the importance of saving energy, and in educating the public on the economics of such investments.
- **Correcting market imperfections.** Companies' inefficiencies, for example in failing to control gas distribution leakages, are currently fully passed on to consumers. Installing metering devices could create the right incentives for companies to reduce leakages and losses in their distribution networks. Another example is the current tariff system, which in many locations is subsidized, so that tenants have insufficient incentives to act alone. Here, government can foster holistic solutions that spread the benefits among tenants, building managers, and energy companies.
- **Setting standards.** Developers are often not interested in investing in expensive energy saving technologies and instead tend to prefer low-cost solutions. To address this, stricter regulations and enforcement could be introduced. For example, some countries have introduced building codes that dictate insulation, HVAC controls, windows, lighting, and appliance standards. In some countries developers are required to use state-of-the-art construction materials that provide energy savings.
- **Accounting for emissions abatement.** To get credits for emissions reduction it is necessary to create a robust international system that could track forestation and agriculture measures. It would benefit Russia to contribute to the establishment of such a system, as it would allow Russia to take credit, for example, for the carbon sinks that forestation opportunities in the country provide.

TIMELY ACTION IS CRITICAL: A DELAY OF FIVE YEARS WOULD SET RUSSIA BACK BY A DECADE AND REDUCE BY HALF THE CUMULATIVE ABATEMENT ACHIEVABLE BY 2030

To seize the energy saving and emissions reduction opportunities that are available to Russia, timely action is critical. If the implementation of improvement measures were delayed until 2015, Russian energy consumption and greenhouse gas emissions would continue to rise, as assumed in the reference scenario. So while in 2010 improvements would start from a level of 2290 Mt CO_2e, the starting point in 2015 will have already increased by about 7% to 2450 Mt (Exhibit 10). Some new investments will have been made in this period without considering opportunities to reduce energy consumption and greenhouse gas emissions. As a result, Russia will find itself in 2015 with some infrastructure that is new but not energy- and carbon-efficient.

EXHIBIT 10

A five-year delay in implementation leads to a loss of almost half of the identified abatement potential



SOURCE: McKinsey

It is difficult to make up for this delay by increasing speed of implementation. For example, every year only a certain share of apartments can be renovated, only a certain number of trees can be planted, and only a limited number of new cars will be bought.

Were implementation to start only in 2015, Russian emissions by 2020 will have decreased only to a level of 2295 Mt CO_2 – the same level as 2010 emissions. By waiting five years Russia will have effectively lost a whole decade. In terms of the total effect achievable, a five year delay would reduce by 48% the cumulative energy saving over the period 2010 to 2030, and the cumulative greenhouse gas emissions abatement by 46%. Exhibit 10 shows this loss of cumulative abatement potential, illustrated by the shaded area.

Therefore, to avoid losing a large part of the existing overall abatement potential and to achieve the ambitious energy efficiency targets set by the Russian president, most measures should be planned for and started in the near future. This is possible for all but three types of abatement measures, as the measures required for these improvements are based on technologies which have already been proven on a commercial scale. The exceptions are the measures related to new technologies, which make up only about 7.5% of the overall abatement potential (mostly from carbon capture and storage), and less than 1% of the energy saving potential (from LED lighting)[6].

Therefore, Russian policy-makers should not delay in taking strong, coordinated, and economy-wide action that will positively benefit Russia's economic competitiveness and standard of living for many years to come.

THE SECTOR PERSPECTIVE: MAIN FOCUS ON BUILDINGS, BUT SIGNIFICANT POTENTIAL IN FUEL AND ENERGY AND IN AGRICULTURE AND FORESTRY

The main economically attractive energy efficiency and emissions abatement measures for Russia are concentrated in three areas: 1) buildings and construction; 2) fuel and energy; and 3) industry and transport. Below are the key opportunities in each of these areas:

- **Buildings and construction.** Russia has the potential to save about 180 Mtce (13% of total energy consumption) and 205 Mt CO_2e (7% of emissions) annually from 2030 in the building sector. The well-known energy efficient light bulbs are an example of an attractive measure with low investments and relatively fast payback, but it only captures about 2% of Russia's total energy reduction potential. Another key measure is the installation of thermostats and heat meters. Experience around the world shows that using thermostats in apartments to regulate heat levels and installing meters at least in individual houses could save 20% of the residents' heating bills by permitting residents to pay only for the amount of heat actually consumed on-site. Basic insulation measures (sealing baseboards and other places where air leaks, adding weather-strips to doors and windows, additional insulation for attics and wall cavities, etc.) save another 20%. This translates into a saving of 600 rubles per family per month.

- **Fuel and energy.** In the petroleum, gas, power and heat sectors, measures provide the potential to save almost 80 Mtce (6% of total energy consumption) and 160 Mt CO_2e (5% of total emissions) annually from 2030. Key opportunities are in improved maintenance, leakage reduction and more even in operation of the gas delivery system, in reducing internal consumption within power plants, and in decreasing losses in heating mains.

- **Industry and transport.** Opportunities here amount to about 50 Mtce (4% of total energy consumption) and 200 Mt CO_2e (7% of emissions) over and above the measures that occur due to natural replacement of industrial stock. Energy saving and greenhouse gas abatement in industry do not mean additional costs. On the contrary, in many cases Russian companies could increase their competitiveness by becoming more energy efficient. For example, steel players could reduce their energy consumption by up to 6% by reusing the gas that is emitted in basic oxygen furnaces for power and heat production.

Additional net-cost measures are concentrated in three main categories, as follows:

- **Agriculture and forestry sector investments.** These measures offer an annual saving potential of 340 Mt CO_2e by 2030 (11% of total emissions), provided that an international

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6 In general, this report considers only technologies that either are available today or offer a high degree of certainty about their potential in a 2030 time horizon, such as light-emitting diodes, antimethanogen vaccine for livestock, and carbon capture and storage (CCS). According to leading world experts' consensus, these technologies are likely to be commercially available by 2020.

verification system is put in place. Examples of such measures are: restoring organic soils and forests as they absorb more carbon than they emit; and reducing or improving the use of fertilizers. Together these measures would make up about 23% of Russia's overall potential for abatement in 2030.

- **Fuel mix changes in power and heat sector.** Increasing the capacity of nuclear plants (by 50-60 GW) and hydro generation (by 40 GW), as is envisaged in Russia's 2009 energy strategy, would potentially reduce emissions by up to 220 Mt CO_2e annually as of 2030 (7% of total emissions). These measures would reduce the carbon intensity of Russian power and heat generation in 2030 by 28% as compared to a scenario that uses natural gas generation.

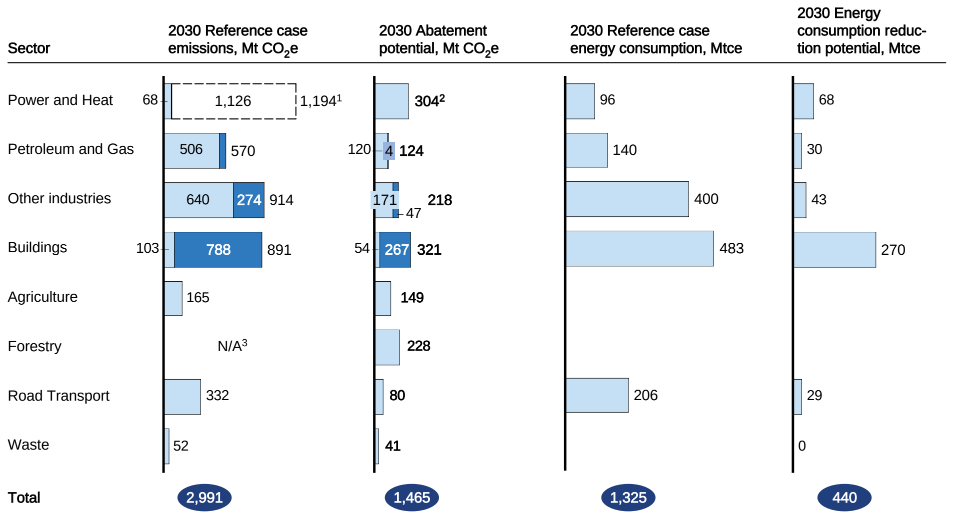
- **Other measures.** Remaining measures would offer an annual saving potential of about 335 Mt CO_2e (11% of total emissions) and 134 Mtce in 2030. These include: capital-intensive energy efficiency measures, which do not pay back at expected energy prices; changes in industrial processes; fuel mix changes in industry and transportation; and, if they become technologically proven, carbon capture and storage technologies. Implementation of these measures could be stimulated by some sort of subsidy or an effective carbon price in Russia.

Exhibit 11 shows that industry and buildings are the biggest emitters of GHG because of indirect emissions from use of power and heat. In terms of improvements, the highest energy saving and abatement potential is in the buildings sector, followed by power and heat and industries. In terms of CO_2 abatement forestry and agriculture could significantly reduce greenhouse gas emissions.

EXHIBIT 11

Sector split – reference case energy consumption, emissions and abatement potential

Indirect emissions from use of power and heat



1 Baseline emissions include internal consumption (68 Mt CO_2e) and emissions from the production of power and heat for other sectors (shown there as indirect emissions)
2 Total emissions in the power and heat sector (1194 Mt) are reduced in three ways: 1) Reduction of consumption in other sectors, shown as abatement of 267 Mt in buildings and 51 Mt in industry. 2) Reduction of losses and internal consumption, addressing the 68 Mt for power and heat consumed within the sector. 3) By changes of fuel mix towards less carbon intensive fuels and efficiency increases in power generation (e.g. higher share of cogeneration). The last two effects are shown in the power and heat sector abatement potential (304 Mt in 2030, or 25% of the total emissions in the sector).
3 Baseline emissions in forestry sector not included due to high uncertainty and lack of reliable measuring techniques

SOURCE: McKinsey

Key insights from the different sectors analyzed in this study are summarized here. The following chapter gives a more detailed overview of findings, including a discussion of different scenarios for Russia's future fuel mix in the power and heat sector.

Buildings

Buildings account for 36% of national energy use and 30% of greenhouse gas emissions, more than half of it in residential houses. Half the energy is delivered in the form of district heating, while the other half is divided between electricity consumption and on-site heating and cooking. To address the high losses and the relatively low energy efficiency in Russian buildings, 18 money-saving and three other measures have been identified. Together, those measures could reduce energy consumption by more than 50% and overall emissions by about 36%, with almost two-thirds of the improvements coming from residential buildings.

Power and heat

The power and heat sector in Russia consumes more than half of primary energy and produces about one-third of carbon emissions. Half of these emissions come from the generation of centralized heat for Russia's district heating system. Direct opportunities to reduce energy use include reducing the sector's currently quite high auxiliary consumption and transmission losses (20% for power, 30% for heat). Further opportunities to reduce emissions are to be found in reducing the share of fossil fuels used in power and heat generation, which currently stands at 80%. Indirect energy consumption and emissions reduction would come from reducing power and heat demand in all other sectors supplied by power plants and boilerhouses.

Petroleum and gas

The petroleum and gas industry is the second largest energy consumer and the third largest emitter of greenhouse gases in Russia. About half of its emissions come from methane (CH_4) leakages in gas distribution and transmission systems. Due to its comparatively high losses and low energy efficiency, the sector has already been subject to regulatory measures demanding large improvements in the coming years, especially a drastic reduction in flaring. Nevertheless, a further ten money-saving measures have been identified, which would significantly reduce the industry's energy losses and CO_2 emissions, mainly through improved maintenance of the gas distribution network and better planning of transmission volumes.

Iron and steel

Steel production is one of the major industries in the Russian economy. Russia is the fourth largest steel producer in the world. Iron and steel is an energy- and carbon-intensive sector. In 2007 it contributed 3% to Russia's GDP, but was responsible for 5% of the country's total energy consumption and 7% of total greenhouse gas emissions. Ten measures have been identified which could reduce the industry's energy consumption by more than 20% and emissions by about 40% in 2030 compared to the reference case; however, only a small share of these measures would be economically attractive.

Chemical

Chemical production in Russia consumes about 2% of the country's total primary energy and emits 2.5% of total greenhouse gas emissions, about 60% of them as direct emissions of CO_2, methane and N_2O, the rest indirectly via electricity and heat consumption. Economically attractive measures were identified, which could reduce the chemical industry's energy consumption by almost 20% and emissions by 12%, in comparison to the reference case. Additional measures targeted at reducing emissions of N_2O and capturing and storing CO_2 would further reduce emissions by almost 45%.

Cement

Cement production in Russia today is still lower that in the early 1990s, when Russia was one of the leading cement producers in the world. However, the sector is now growing rapidly again. By 2030, both energy consumption and greenhouse gas emissions are expected to roughly double, starting from a current share of 2% of Russia's total. Seven improvement opportunities have been identified, with the largest contribution coming from the substitution of clinker in the calcination process – a measure that would be highly profitable for cement producers.

Road transport

Russia's rapidly growing road transport sector will become increasingly more important in terms of energy consumption and CO_2 emissions. Without dedicated abatement measures, both emissions and fuel consumption are projected to more than double from 2005 to 2030, thanks to a 3.5% average annual increase in vehicles on the road. Changes to the fuel efficiency and the share of alternative fuels used in new cars to be bought in the future could reduce total energy consumption by 14% and emissions by 24% in 2030, compared to the reference case. More than 90% of energy reduction and 60% of emissions abatement would be money-saving, as fuel savings over the lifetime of the vehicles would exceed the higher upfront investment cost.

Forestry

In Russia, which has the most expansive forests in the world, a large amount of emissions are absorbed every year by growing trees. However, maturing trees and increased logging will reduce this trend and could even make Russian forests a net source of CO_2 emissions by around 2025. Measures identified in forestry make up the largest overall CO_2 abatement opportunity identified in this study. If all abatement opportunities were implemented, then by 2030 these would absorb about 8% of total Russian emissions. However, all the measures involve costs for each tonne of CO_2 abated.

Agriculture

For the last 20 years, the use of cropland, grassland and livestock in Russia has been constantly declining, with livestock seeing the largest reduction, about 60%. In 1990, agriculture contributed 11% to Russian greenhouse gas emissions. By 2005 the absolute emission volume from agriculture had dropped by nearly two-thirds and agriculture's share of emissions to only 6%. About half of today's emissions are soil emissions of N_2O gas, mostly from the use of fertilizers. By 2030 emissions are expected to grow again by about 30%, unless dedicated steps are taken to reduce this growth. Twelve potential measures have been identified which would reduce greenhouse gases emissions by about 90%. About a quarter of the potential would come from money-saving measures, while the others would incur abatement costs.

Waste

The waste sector is the only sector in Russia where today's emissions, making up 3% of Russia's total greenhouse gases, exceed the 1990 level. The main reason for this increase is a sharp increase in solid waste volumes in the past decade. Also, management of this solid waste is underdeveloped in Russia, with only 3-4% being processed, while the rest is directly landfilled. Improved waste management, mainly through better recycling, could reduce emissions from the waste sector by more than 80%. Furthermore, the utilization of landfill gases could be a profitable way to generate additional energy.

Sensitivity analysis: Influence of energy prices, tariffs and cost of capital on the findings of this report

OVERALL, THE "ECONOMICALLY ATTRACTIVE" ENERGY SAVING AND EMISSION ABATEMENT POTENTIAL IDENTIFIED IN THIS REPORT IS ONLY MODERATELY SENSITIVE TO ENERGY PRICES AND COSTS OF CAPITAL; THE SAME APPLIES TO INVESTMENT NEEDS.

The findings in this report depend only to a limited degree on the basic input assumptions, such as the future rate of economic growth in different industrial sectors, future energy prices, and costs of capital. This is because:

- Economic growth affects energy use and emissions in the reference case, and therefore has an impact on abatement potential, but it does not directly affect the identified savings and costs.
- Assumed energy prices and cost of capital affect do not affect the abatement potential, but influence the expected savings (or cost). Some measures shown in this report to come at net cost would become economically attractive if energy prices were to increase beyond the levels assumed in this report. Conversely, a higher-than-assumed cost of capital could make some measures no longer attractive.

The following **energy prices** are assumed for the period 2010 to 2030 (all in real terms based on 2005 Euros and an exchange rate of 1.5 $/€):

- **Oil:** $60-62 per barrel, with oil prices continuing to drive the European and thereby in the future also the Russian price for natural gas.
- **Natural gas:** For gas producers €80-82 per thousand cubic meters, based on increasing marginal production costs in new gas fields. For gas consumers tariffs rise to €91-96 per thousand cubic meters, based on estimated "netback prices" from 2015, which are the expected European market prices, reduced by transportation costs and a 30% export duty imposed by the Russian government.
- **Electric power:** national average wholesale prices for electric energy and capacity of €52/MWh were modeled until 2015, with accelerated increases after 2015 up to €77/MWh in 2030, reflecting the investment costs of newly built power plants.
- **District heat:** tariffs of €21-23/GCal (2010-2030) are assumed, using average production and distribution costs in Russia, rather than subsidized consumer tariffs (in line with a societal perspective approach – see Appendix 5.1).

The **weighted average cost of capital** (WACC) is taken to be 8% in real Euro terms, in line with the societal perspective approach.

In the report, **no carbon price** has been assumed in Russia – in other words, we have assumed no added costs for emitters of greenhouse gases and no added financial benefit for reducing emissions.

The sensitivities analyzed
To test the sensitivity of the findings in this report to changes in energy prices and cost of capital, the following changes in assumptions were analyzed, both stand-alone and in combination:

- Energy prices 50% higher – $90/bbl for oil instead of $60 (both values in real terms) and a similar increase of natural gas, power, and heat prices
- Cost of capital 50% higher – 12% instead of 8% (again, both values in real terms)

In addition, we modeled the effect of a "tariff freeze", when heat and electric power prices remain at their 2010 level.

Influence of assumptions on the economically attractive greenhouse gas abatement potential
At $60/bbl oil, the cost of capital does not change the fundamental conclusions of the report. The sensitivity to a 50% change in WACC is only about 4% (reducing the profitable abatement potential from 567 to 548 Mt CO_2e).

Raising oil price by 50% also yields a relatively modest increase in "economically attractive" abatement potential of 15% (from 567 to 650 Mt). Raising both indicators by 50% has a countervailing effect, with the net result being just a 2% difference in abatement potential (from 567 to 580 Mt CO_2e).

A “tariff freeze” does not have any influence on the total economically attractive abatement volume. However, it significantly decreases savings per tonne of CO_2e abated, first of all, for measures in the buildings and power sectors, as these measures are heavily tariff-dependent.

Influence of assumptions on the economically attractive energy saving potential

The economically attractive energy saving potential presented in this report is only moderately sensitive to changes in energy prices and costs of capital. An increase in costs of capital would reduce the potential by less than 3%, (from 306 to 298 Mtce), while energy prices increasing by 50% would increase the “economically attractive” energy saving potential by 17% (from 306 to 359 Mtce). If applied together, increased energy prices and cost of capital would cancel each other out.

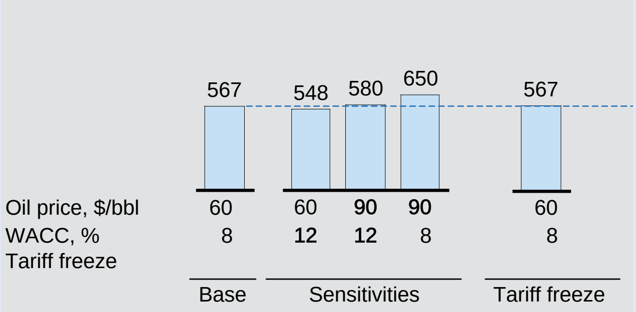
Here again, a “tariff freeze” does not influence energy saving potential but significantly decreases savings per tce.

Influence of assumptions on the required investments and the resulting savings from economically attractive measures

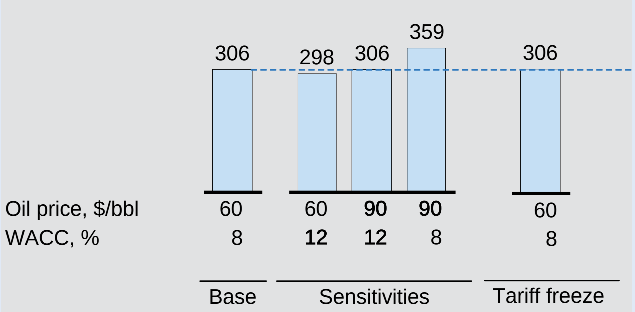
A look at the required cumulative investments to implement all economically attractive improvement measures and the resulting savings from these measures over the period 2010 to 2030 shows similar patterns. Higher energy prices make more opportunities economically attractive, thereby increasing both the required investments (by 56%, from €150 to 235 bn) but even more so the annual cost savings (by 65%, from €344 to 565 bn). Higher costs of capital would make some measures which promised small savings unprofitable, thereby reducing both the overall savings achievable (by 4%, from €344 to 332 bn) and, by a more significant amount, the required investments (by 22%, from €150 to 117 bn).

A “tariff freeze” decreases the total savings over the period. While required investments remain the same, savings are reduced from €344 bn to €272 bn (21%). As a result, the average IRR for economically attractive measures becomes only slightly above 20%.

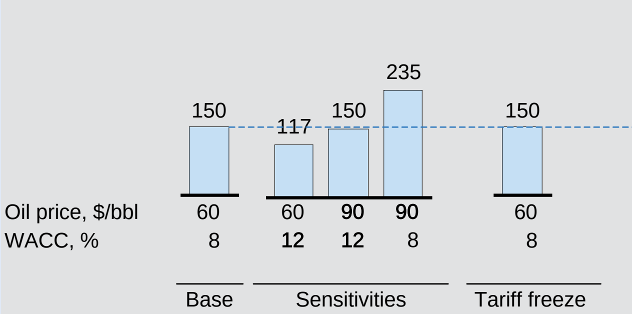
Greenhouse gas abatement from economically attractive measures, 2030
Mt CO_2e



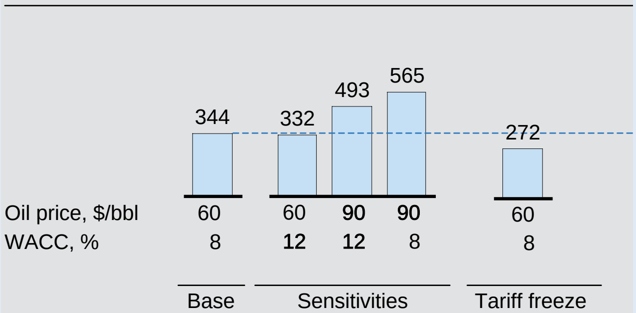
Energy saving potential from economically attractive measures, 2030
Mtce



Cumulative investments for economically attractive measures, 2010–2030
€ billion



Cumulative gross savings from economically attractive measures, 2010-2030
€ billion



4. Detailed findings for individual sectors

4.1 Buildings Sector

Buildings account for 36% of national energy use and 30% of greenhouse gas emissions, more than half of it in residential houses. Half the energy is delivered in the form of district heating, while the other half is divided between electricity consumption and on-site heating and cooking. To address the high losses and the relatively low energy efficiency in Russian buildings, 18 money-saving and three other measures have been identified. Together, those measures could reduce energy consumption by more than 50% and overall emissions by about 36%, with almost two-thirds of the improvements coming from residential buildings.

RUSSIANS LIVE ON ONLY 21 SQUARE METERS PER PERSON BUT EXPEND TWICE THE ENERGY THAT SCANDINAVIANS DO PER SQUARE METER

For historical reasons, such as the availability of cheap and subsidized energy and a focus on low investment costs and quick construction, most buildings in Russia today use significantly more energy for heating per square meter than buildings in other countries with a comparable climate (annually 0.25 GCal/m² in Moscow vs. 0.11 GCal/m² in Finland – see Exhibit 1). Today the total energy consumption of the sector is 346 Mtce, which is 36% of Russian energy consumption.

The Russian building sector today contributes 29% of the country's total greenhouse gas emissions, which is higher than the world average for buildings (15%), thanks to a combination of a cold climate and energy-inefficient construction. But 29% is nevertheless lower than the share in some developed nations (for example, 33% in the USA), which is due to a larger floor area per person in the USA (86 m² vs. 21 m² per capita in Russia) and the still relatively low penetration of electronics and appliances in Russia.

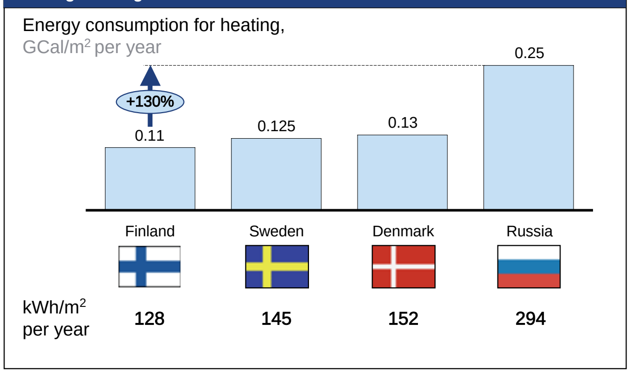
Of the 29% emissions share, only 5% occurs onsite, while 24% occurs at power plants and boiler houses that produce electricity and district heat. 73% of Russian houses use district heat (compared to only 12% in Germany).

General sector information (2007)

Share of construction in Russian GDP	6%	
Energy consumption (Mtce and share of total Russia)		
• 2005	346	(36%)
• 2030 Reference case	483	(36%)
Energy savings from identified emission reduction measures (Mtce and share of 2030 reference case)		
• With positive return	178	(37%)
• All measures	270	(56%)
Emissions (Mt CO_2e and share of total Russia)		
• 2005	617	(29%)
• 2030 Reference case	891	(30%)
Emission reduction potential (Mt CO_2e and share of 2030 reference case)		
• With positive return	207	(23%)
• All measures	321	(36%)

EXHIBIT 1

Existing buildings



REFERENCE CASE:

- RESIDENTIAL FLOOR SPACE WILL INCREASE BY 94% AND NON-RESIDENTIAL BY 56% BY 2030
- ENERGY CONSUMPTION AND EMISSIONS IN THE BUILDING SECTOR WILL INCREASE BY ABOUT 40%

Russia's program for housing aims to increase the average floor space for every person from 21 m^2 in 2005 to about 30 m^2 by 2020. By 2030 the average floor space will reach almost 42 m^2 per capita, which means 94% growth in residential housing compared to 2005, and a similar tendency is expected in non-residential floor space, leading to 56% growth in non-residential floor space over the same period.

Assumptions for the 2030 reference scenario also include some improvements in buildings due to stricter standards for new construction and to the natural pace of renovation, which also improves energy efficiency. All things considered, energy use and emissions in the building sector in the reference scenario are expected to grow by 40% and 44%, respectively. Energy consumption is expected to increase from 346 Mtce in 2005 to 483 Mtce in 2030, and emissions – from 617 to 891 Mt CO_2e in the same period.

OPPORTUNITIES EXIST TO REDUCE ENERGY CONSUMPTION BY HALF AND EMISSIONS BY ALMOST 40%, WITH THERMOSTATS, INSULATION IN OLD BUILDINGS, AND HIGHER STANDARDS IN NEW CONSTRUCTION CARRYING THE LARGEST POTENTIAL

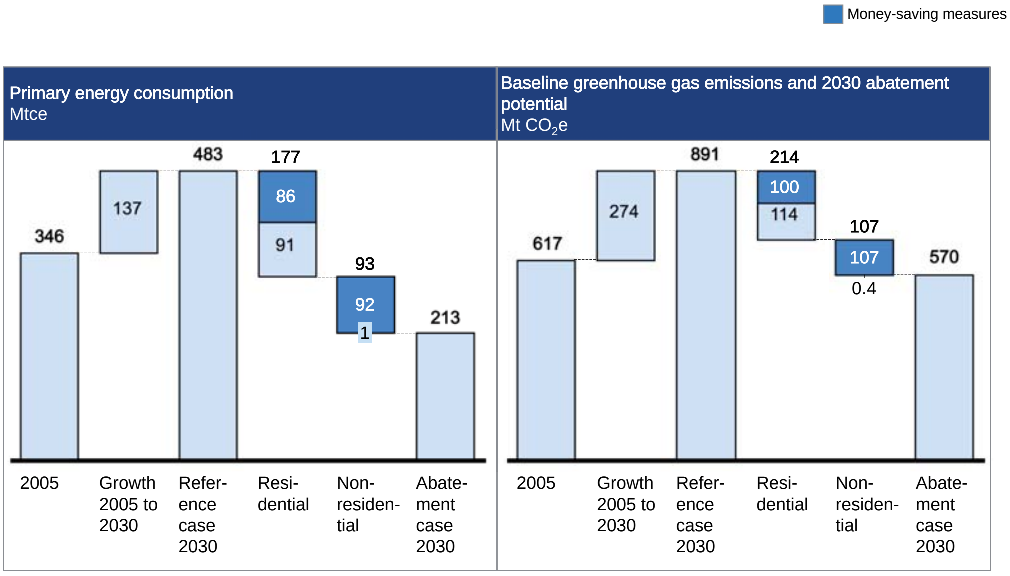
Eighteen measures have been identified that could bring both energy and economic savings, while also reducing CO_2 emissions. If fully implemented, these measures would result in annual energy savings of 178 Mtce in 2030 (Exhibit 2); representing 36% of primary energy used in the building sector, and abatement of 207 Mt CO_2e or 23% of the reference scenario emissions from the buildings sector. This high potential for reductions reflects poor construction standards and the low priority assigned to energy efficiency in the past, and points to the future improvement potential in standards for new buildings. An additional 114 Mt CO_2e and 92 Mtce could be saved with three other measures that come at a cost (Exhibit 3).

Identifying the largest money-saving abatement opportunities:

- Installing thermostats (heat regulation devices) in apartments and heat meters in residential buildings could lead to annual savings of 31 Mtce (€1.5 bn in 2030) and reduce emissions by 36 Mt CO_2e in 2030 (about 11% of overall abatement in the sector). Such a large saving would result from reducing the amount of heat delivered to multifamily residences, which are typically overheated and "regulated" by opening windows. The IRR would be about 24% when considering only the direct savings from not overheating existing flats. This measure will also be essential to realize savings from improving building insulation, as discussed below.

EXHIBIT 3

Energy consumption and greenhouse gas emissions by the buildings sector



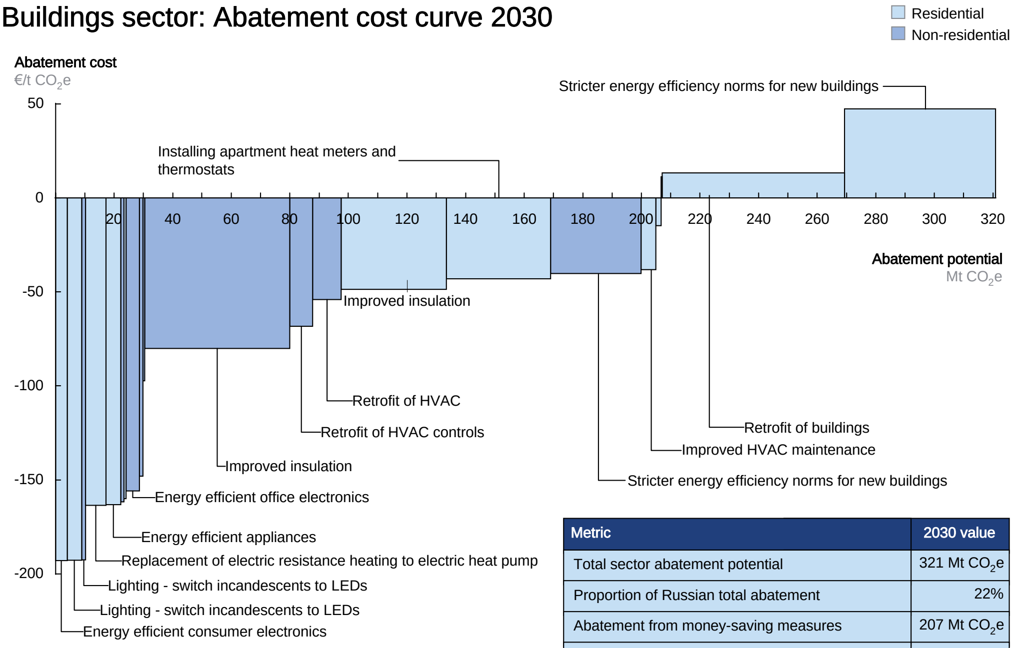
SOURCE: McKinsey

- Improving insulation in existing buildings could lead to annual savings of 72 Mtce from reduced heat demand (€5.7 bn in 2030) and reduce emissions by 85 Mt CO_2e in 2030 (about 26% of the overall abatement in the sector). At energy price levels equal to the average production cost, IRR for the assumed investments required per square meter (€3.4 for non-residential buildings and €4.6 for residential) is more than 70% for non-residential and 19% for residential buildings.

Additional economically attractive measures include installing more efficient electronic equipment and appliances; installing more efficient heating and air conditioning equipment, and switching to LED lighting.

EXHIBIT 3

Buildings sector: Abatement cost curve 2030



Metric	2030 value
Total sector abatement potential	321 Mt CO_2e
Proportion of Russian total abatement	22%
Abatement from money-saving measures	207 Mt CO_2e
Economically attractive share of sector abatement	64%

SOURCE: McKinsey

NUMEROUS PROGRAMS WOULD BE NEEDED TO ADDRESS IMPLEMENTATION BARRIERS, INCLUDING A LACK OF ALIGNED INCENTIVES, LACK OF AWARENESS, AND LOW ENERGY PRICES

Decision-makers in the building sector are residents, building owners, energy companies, and local governments. Tariffs for heat as well as power remain regulated and in most regions do not reflect production cost, hence are not on their own sufficient to stimulate the implementation of the measures. Thus, measures in this sector are among the most difficult to implement, especially the ones related to heating.

A coordinator (for example, an energy service company) would need to structure a deal in which tenants, building associations and residents pay less, in which energy companies can reduce costs as well as cross-subsidies to heat. This is only likely to happen with active involvement of local governments and through the use of instruments that align incentives, e.g. long-term tariffs.

The overall program to overcome investment barriers is described in Chapter 3. It includes incentives to ease upfront investments, building awareness and providing information, correcting market imperfections and aligning incentives. In the case of the complicated building sector, the energy efficiency measures fall into three distinct groups:

- The most attractive measures with low costs and high energy savings and hence short payback times would require information campaigns to create awareness among consumers, especially residents.
- For a second group of measures, which have longer payback times, holistic arrangements will be necessary, such as the long-term tariff, or public funding, or other incentives.

- A third group of measures was identified that have high abatement potential, but as they would not pay back at assumed levels of future energy prices, they may not be worth pursuing. If they are pursued, enforced measures such as stricter building regulation in addition to holistic incentives might be needed.

□ □ □

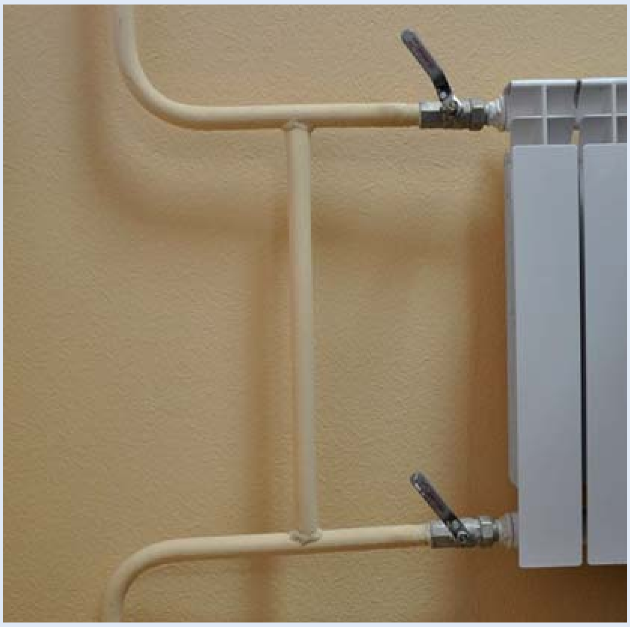
In all, the buildings sector – which is closely tied as a common system with the power and heat sector – is the centerpiece of Russian national energy efficiency efforts. It carries more than half of Russia's energy efficiency potential and about a quarter of the emissions potential. It is the most visible but also the most difficult sector to organize in order to seize the energy saving and emissions reduction opportunities that are available to Russia.

More than half of the country's energy saving potential is in the building sector

Buildings provide the largest energy-saving potential among all the sectors: a reduction of 270 Mtce, or more than 20% of total energy consumption in the reference case in 2030.

Here is a detailed description of four groups of measures that are responsible for more than 80% of the energy saving potential: installing heat meters and thermostats; improving insulation in existing buildings; building retrofits and construction of energy efficient new buildings.

EXHIBIT 1



1. Installing heat meters and thermostats (31 Mtce)

Most of the existing residential buildings in Russia (around 90%) do not have thermostats or heat meters, and tenants have no other way to regulate temperature in their flat but to open windows when the apartment is too warm or switch on electric heating devices when it is too cold.

The existing heating system in Russian houses is not designed to carry heat meters for individual flats. Most of the houses have a vertical pipe system, meaning that one pipe goes through several floors, but radiators inside an apartment are unconnected to each other. To measure heat consumption of a single apartment every radiator would need to be equipped with a heat meter, which is neither economically attractive nor technically justified. To account for heat consumption in most existing residential buildings the only practical solution is installation of heat meters for whole houses.

For thermostats, an added complication is that about 20% of all residential buildings do not have bypasses for hot water (a system with a bypass is shown in Exhibit 1). In these cases, even if there is a thermostat it cannot be used, as it will cut off the neighbors who live below.

Therefore, the following assumptions have been used for the measure:

- By 2030 all buildings that don't have thermostats and heat meters will be equipped with them. New buildings all come with heat meters in the reference case. Homes demolished before 2030 will not be equipped with heat meters.
- Thermostats are installed for every radiator. However, in 20% of cases additional works on building bypasses in the heating system in an apartment are required.
- Saving potential from this measure is based on research results that show 20% decrease in heat consumption (on average about 0.05 GCal/m^2 per year) due to the lower amount of hot water needed to heat the apartment.

This measure is economically attractive, with total investments of €11 bn over the period but savings of almost €28 bn with an IRR of 24%. It is also a necessary precursor to the realization of other measures to improve energy efficiency of existing buildings.

2. Improving insulation of existing residential buildings (72 Mtce)

This measure includes a variety of "low-cost solutions," such as sealing baseboards and other places where air leaks; adding weather-strips to doors and windows; additional insulation for attics and wall cavities, and adding or fixing a basic mechanical ventilation system to ensure air quality (otherwise, residents open windows for air quality). The simplified variant is windows insulation with duct tape – a solution widely used in Russia for winter by people living in old and energy inefficient buildings.

The following assumptions have been used for the measure:

- Over the period of 20 years 90% of the existing floor space could be covered by the measure (the remaining will be demolished or rebuilt). It means that every year 4.5% of the current housing stock, or about 15,000 buildings, need to undergo some repairs.
- The average cost for this measure is € 3-5 per square meter, averaging to about €4.6 for residential and €3.4 for larger non-residential buildings.
- The result is an average 20% reduction of heat consumption in residential buildings (on average about 0.05 GCal/m^2 per year) and almost 50% due to big volumes that are usually heated in non-residential buildings. (Many such buildings – such as warehouses - usually have high ceilings and therefore contain more cubic meters per square meter of floor space than residential ones.)

In sum, the measure requires investments of almost €11 bn and gives savings of about €24 bn over 20 years for residential buildings. For non-residential buildings investments of €5.3 bn result in potential savings over 20 years reaching €43 bn, an even more robust business case.

3. Retrofit of residential buildings (50 Mtce)

This measure involves capital overhaul of the whole building, including installation of tighter-fitting, better-insulated windows and doors, attic and basement insulation and putting additional covers on walls (different insulation materials could be used depending on the project). It could be applied instead of simple insulation improvements in buildings, but implementation costs are higher.

The following assumptions have been used for the measure:

- The average incremental cost is around €54 per m^2 in 2005 (10% of new construction cost) going down to €35 by 2030 (the cost is only for energy saving measures, costs for other measures during capital overhaul not improving energy efficiency are not included).
- Energy saving potential ranges from 0.04 up to 0.13 GCal/m^2 per year

Even with high energy saving potential this is not a money-saving measure. The required investments over 20 years are €74 bn, which is €26 bn higher than the potential savings.

4. Energy efficient new buildings (67 Mtce)

This measure involves the use of energy efficient materials and better building techniques. Residential floor space is expected to increase by more than 90%, and non-residential space by more than 50%, making this measure very important in achieving energy savings.

However, today there are no standards for non-residential buildings, and not every region in Russia has energy efficiency standards for new

Sensitivity analysis: Influence of energy prices, costs of capital on the findings in the building sector

To test the sensitivity of the findings in the sector for the period 2010-2030 we increase electricity and heat prices by the factor of 1.4 and the cost of capital by 50%. (Detailed methodology regarding electricity and heat prices and the cost of capital for the report may be found on pages 95–98.)

With increased energy prices, overall energy saving and emissions reduction potential remains the same. However, the share of money-saving measures goes up, leading to 30% (up to 230 Mtce) increase in the economically attractive energy saving potential.

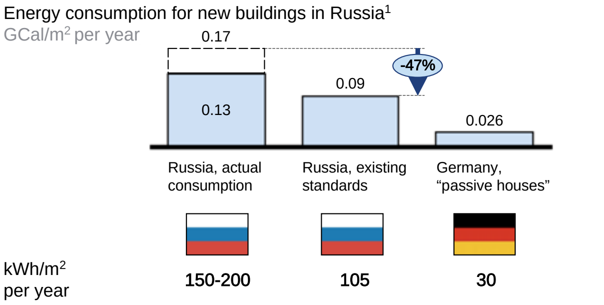
Higher cost of capital doesn't change the potential for money-saving measures but the total abatement potential decreases by 50 Mt CO_2e as the cost of implementation of "Stricter energy efficiency norms for new residential houses" exceeds 80 per tonne of CO_2e.

If applied together, increased energy prices and cost of capital would cancel each other out.

residential buildings. Furthermore, not even in those regions that have such standards they are systematically followed. The main reasons are poor quality of design, poor quality of the materials and low skills of the workers. As a result, in the majority of new houses energy consumption is 50%-100% higher than the existing norms (Exhibit 2).

EXHIBIT 2

Energy consumption for new buildings in Russia[1]



1 Figures for Moscow actual consumption and standards are used

According to expert' estimates, significant improvements in energy efficiency for new buildings would increase the cost of a square meter by 10%-20%. This increase would be passed on the consumers who in most cases would not be ready to pay for it as the measure is not economically attractive.

The following assumptions have been used for the measure:

- First and foremost, building norms are followed, and this is already part of the reference case.
- The current cost is around €55 per m² for residential and €32 per m² for non-residential, and by 2030 is expected to decline to €44 and €24, respectively. The higher costs for residential reflect the fact that standards already exist for those buildings.
- 50-60% energy savings compared to the existing practices for non-residential and building norms for residential (high variability depending on the particular region).

For residential, total investments needed for the implementation of the measure exceed €90 bn over the next 20 years, whereas savings would only be €28 bn over the same period.

The remaining measures yield a little less than 20% of the sector's energy saving potential. They could be put into three groups: appliances and electronics, HVAC systems and lighting.

1. Appliances and electronics

Four measures in this group assume replacement of existing consumer appliances and electronics (refrigerators, freezers, washing machines, computers, TV sets), commercial appliances and office electronics with high efficiency models instead of less expensive standard ones. As old equipment is retired it is replaced by new energy efficient equipment. Total energy saving potential is 14 Mtce, or 5% of the potential in the buildings sector.

2. Improvements in HVAC systems

Five different measures in this group provide 27 Mtce, or 10% of the energy saving potential in the buildings sector. Possible actions include installation of state-of-the-art systems, when a pre-existing HVAC system is retired, improvement of HVAC control systems to adjust for building occupancy and minimize re-cooling of air, improved HVAC maintenance and installing electric heat pumps.

3. Lighting

The switch to more efficient lighting – the well-known case of energy saving lamps – is largely achieved in the reference case. For example, more than half of incandescent light bulbs are assumed to be replaced by more energy efficient CFL bulbs by 2030. Hence, the measures in this group account only for 2% of the remaining energy saving potential. Beside the replacement of light bulbs by LED technology, these measures also include installation of new light control systems.

4.2 Power and heat sector

General sector information (2007)

• Share of Russian GDP:	3.2%	
• Employment:	2 million people	
Energy consumption		
(Mtce and share of total Russia)		
• 2005	512	(54%)
• 2030 Reference case	724	(55%)
Energy savings from identified emission reduction measures		
(Mtce and share of 2030 reference case)		
• With positive return	50	(7%)
• All measures	68	(9%)
Emissions		
(Mt CO_2e and share of total Russia)		
• 2005	792	(37%)
• 2030 Reference case	1194	(40%)
Emission reduction potential		
(Mt CO_2e and share of 2030 reference case)		
• With positive return	60	(5%)
• All measures	304	(25%)

The power and heat sector in Russia consumes more than half of primary energy and produces about one-third of carbon emissions. Half of these emissions come from the generation of centralized heat for Russia's district heating system. Direct opportunities to reduce energy use include reducing the sector's currently quite high auxiliary consumption and transmission losses (20% for power, 30% for heat). Further opportunities to reduce emissions are to be found in reducing the share of fossil fuels used in power and heat generation, which currently stands at 80%. Indirect energy consumption and emissions reduction would come from reducing power and heat demand in all other sectors supplied by power plants and boilerhouses.

RUSSIA'S POWER AND HEAT SECTOR WAS DESIGNED WITH EFFICIENCY IN MIND, BUT LACK OF INVESTMENT HAS LED TO LOSSES BIG ENOUGH TO SUPPLY A COUNTRY LIKE POLAND

Russia has inherited the biggest[1] district heating system in the world, generating about 1400 million GCal of heat per year and supplying 70% of the country's population, including commercial and industrial buildings.

Approximately half of heat is produced by about 800 combined heat and power plants (CHPs), the other half by approximately 66,000 boilerhouses. Because of the extent of district heating cogeneration in Russia, heat and power in this report are dealt with as one industry sector.

In terms of electric power, Russia is the fourth largest producer in the world, generating about 1000 TWh per year. More than 70% of this power is consumed by industry, which is characterized by very high electric intensity, amounting to 3.3 kWh/€ of GDP, about seven times higher than in the US or Europe.

The power and heating sector in Russia was designed with efficiency in mind. District heating enables more efficient use of building space, and cogeneration (accounting for half of the country's district heat production and one-third of its power production) is superior to a system that relies upon separate boilers and power plants.

1 Russia is home to 60% of the world's district heat production, a volume four times higher than in all European OECD countries put together.

Since the early 1990s, however, Russia's tariff-dependent power and heat industry has received little investment. One of the main reasons for this was that the remaining capacity from Soviet times far exceeded demand, which had dropped significantly due to the collapse of the economy. As a result, 40% of today's thermal power capacity is more than 40 years old, compared with 28% in the US, 22% in Europe, and 12% in Japan. The average efficiency of Russian plants today is substantially below industry benchmarks[2], with the result that efficiency is well below what it could be, notwithstanding the benefits of cogeneration.

Another statistic indicating the low overall efficiency in the sector is that as much as 120 Mtce, a quarter of the total primary energy transformed into power and heat, a number comparable to the annual consumption of a country like Poland, is consumed by power stations, or lost in power and heat grids. Russia has among the highest rates of grid losses in the world –12% in power and 25% in heat distribution. This is two or three times the levels in other developed countries. Even allowing for the greater length of Russia's heating grids; its losses could be cut by more than half.

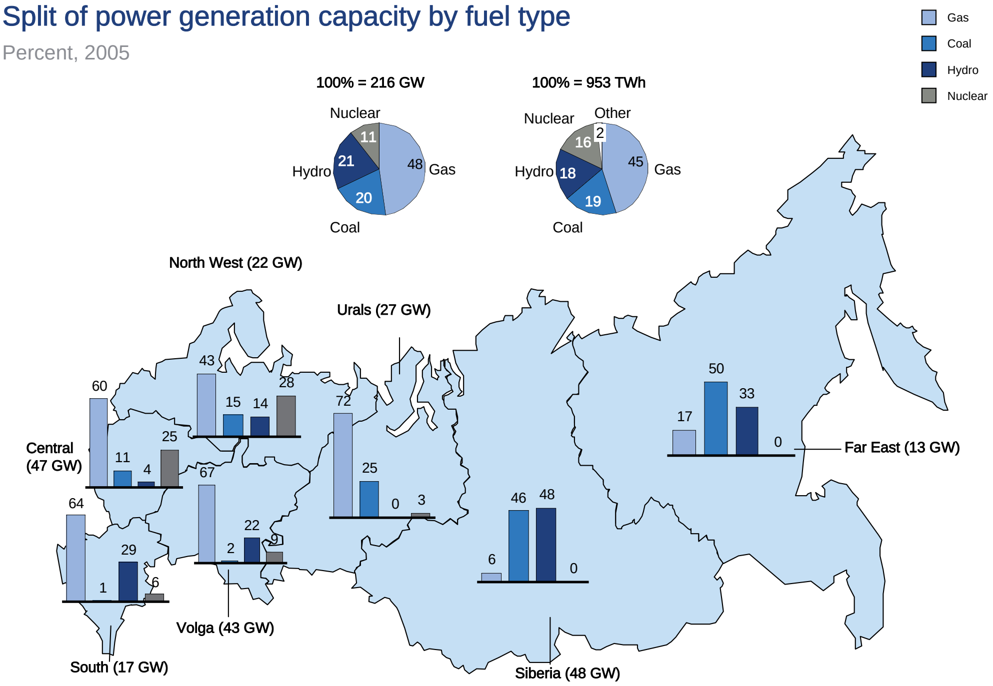
RUSSIA IS A COUNTRY WITH A HIGHLY DIVERSE FUEL MIX

Current overall fuel mix in power production is dominated by gas (45%), followed by coal (19%), large hydro (18%) and nuclear energy (16%). However, Russia is characterized by significant regional differences in fuel mix – the European part of the country is dominated by gas and nuclear-powered capacity, while in Siberia and the Far East the largest share of production comes from coal and large hydro plants (Exhibit 1).

EXHIBIT 1

Split of power generation capacity by fuel type

Percent, 2005



SOURCE: McKinsey

2 Average efficiency levels in Russia are 33% for coal and 36% for gas-fired plants, compared to 45% for high efficient coal plants and 58% for modern combined cycle gas turbine (CCGT) plants.

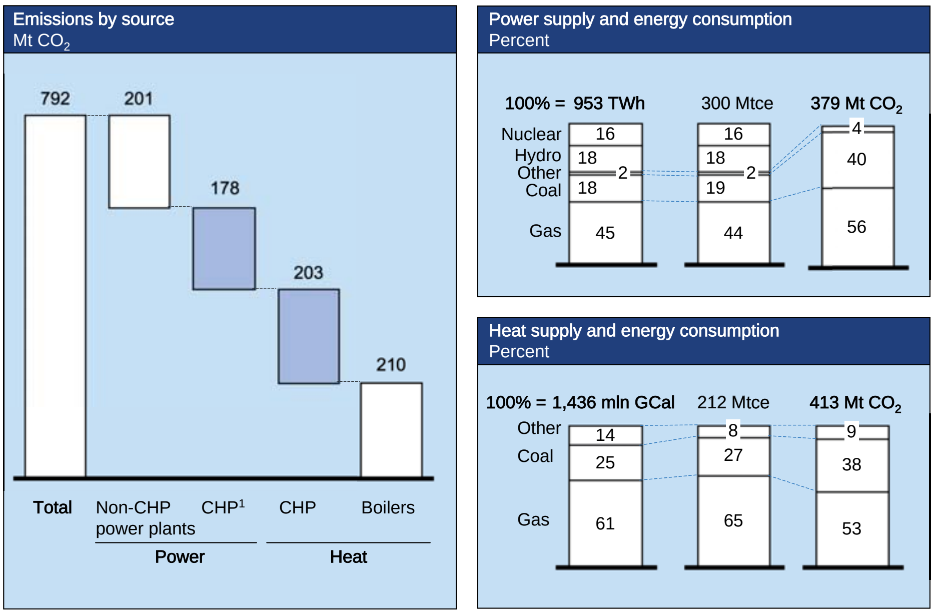
With the low gas prices of recent decades, the limited new construction that has occurred since 2000 has been CCGT plants. In addition, about 15-20% of coal-fired capacity[3] has shifted from coal to gas.

With abundant resources of cheap fossil fuels available and with no special policies to promote alternative technologies, the share of renewables in power generation has never exceeded 1%, comprising primarily small hydro plants and some co-firing of peat and wood in coal plants or boilerhouses.

In 2005 the power and heat sector consumed 512 Mtce of primary energy, of which about 400 Mtce came in the form of fossil fuel[4]. Corresponding emissions were 792 Mt of CO_2,[5] or 37% of Russia's total emissions, resulting from the burning of gas, coal, and residual oil in power plants and boilerhouses. More than half of these emissions related to the generation of centralized heat (413 Mt CO_2) while the rest was for power generation (379 Mt CO_2) (Exhibit 2).

EXHIBIT 2

Emissions split by source and fuel type



1 Combined heat and power plants

SOURCE: EPA UNFCCC emissions inventory; Infotek; GVC; McKinsey

THE REFERENCE CASE – A MUCH MORE EFFICIENT SECTOR BUT WITH MAJOR UNCERTAINTIES ABOUT FUEL MIX

Russia will have to build 200-250 GW of new capacity by 2030 – that is to say, 60-70% of Russia's generation capacity required in 2030 has yet to be built. There are two major implications.

3 7-8 GW (of which 3-4 GW of coal capacity and about 4 GW of dual fuel capacity) was switched to natural gas.

4 The value for non-fossil fuel energy sources (nuclear, hydro and renewable sources of energy) is calculated as the displacement ratio of fossil fuel with the country's average efficiency for fossil fuel power plants.

5 In this chapter emissions are measured in Mt of CO_2, not CO_2e, because in the power sector almost 100% of greenhouse gas emissions are CO_2 emissions.

First and foremost, this means that the power generating fleet will become more efficient. If today the weighted average fleet efficiency is 38% (320 gce/kWh), the expected efficiency in 2030 is about 49% (250 gce/kWh). The country is putting in place a power market that, on the whole, stimulates this improvement, even if many regulatory questions remain open. In the reference case for the country, power production through 2030 is forecast to grow by 95% to 1736 TWh and heat production by 30% to 1840 mln Gcal. However, the reference case assumes no reduction of grid losses, leaving them at the level of 25% for heat and 12% for power until 2030.

Second, it means major decisions need to be made regarding the future fuel mix, which will affect the cost of generating power, the development of the country's natural resources, as well as future emissions of CO_2. The Russian government will shape the future fuel mix mainly through the following decisions:

- **Whether or not to limit domestic gas consumption.** Russia is a leading exporter of natural gas, supplying about 200 bcm per year to the international market in the years prior to the current economic crisis, when demand fell by approximately 40%. On the cost side, the petroleum and gas industry is facing the depletion of existing fields and an unprecedented rise in production costs in new, remote regions which are characterized by harsh climate conditions, increasingly more complex geology, and a lack of infrastructure. On the revenue side, domestic market prices are 30% lower than export prices due to the government's export tariff, a critical revenue source for the government. Thus, gas is a cheaper fuel on a total-cost basis than coal, nuclear and hydro (except in Siberia and the Far East, where coal is the most competitive). Hence, a decision to reduce the domestic power industry's use of natural gas would need to be policy-driven.
- **Construction of new nuclear capacity.** Russia is one of the leading players in the field of civilian-use nuclear technology, with a 15% share of global reactor production and a 45% share of global uranium enrichment. The industry employs a few hundred thousand people and is considered one of the nation's most competitive industries internationally. It is in this context that the Russian government has announced an ambitious nuclear power plant program, aiming to increase domestic nuclear capacity from its current 24 GW to 52-62 GW in 2030. Among experts, however, it is disputed as to what extent such an ambitious program could be implemented: it would require build 1.7-2.7[6] reactors per year, whereas today Russia brings one reactor on-line every two years.
- **Construction of hydro and renewable energy sources.** Russia has the second largest potential for hydro power in the world, but so far exploits only about 20% of its economic potential[7]. Current plans that have been announced assume the construction of about 40 GW of additional hydro capacity by 2030. Renewable sources of energy have also received more attention of late: in the recently approved Energy Strategy 2030, a target of 4.5% of total power production is envisaged, a five-fold increase over today's figure of 0.9%. As with nuclear, the likelihood of the successful implementation of this strategy is also subject to question, particularly since no supporting polices for renewables have yet been adopted.

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6 The actual ratio would depend on what share of current capacity would be phased out by 2030.

7 Considering only the so-called "economic potential", i.e., potential that could be economically utilized in the near future (making up only 15-25% of the total theoretical or "technical" potential).

The future implementation of these policies will affect the Russian economy in many, sometimes interdependent ways – its future fuel mix will determine the amount of investment required, the gas volumes available for export, and the costs which industry and consumers will have to pay for electricity[8]. To take into consideration the existing uncertainties about the future of Russia's fuel mix, four discrete scenarios have been developed in our study, related to the possible outcome of the policy decisions listed above. Each scenario is characterized by a particular fuel mix and level of required capital investments, and shows the resulting differences in gas consumption and CO_2 emissions (Exhibit 3).

- **Fuel mix scenario 1** ("Reliance on coal") assumes limitations on domestic gas consumption and moderate construction rates of nuclear and large hydro capacity (replacement of retiring nuclear capacity, the rebuilding of Sayano-Shushenskaya hydro station, and 7 GW of new hydro plants by 2030). Due to the limits on the use of gas, coal becomes competitive in most Russian regions[9]. In this scenario the share of coal increases from the current 19% to 30%, and therefore this scenario has the highest CO_2 emissions.

- **Fuel mix scenario 2** ("Reliance on gas") assumes the same moderate construction rate of hydro and nuclear as in Scenario 1. In this scenario, however, domestic use of gas is not limited. Given the long-term oil price forecast at $60/bbl, gas remains competitive everywhere west of Siberia[10]. In this scenario, the share of gas-based power generation increases from 47% to 59%. Scenario 2 consequently has the lowest investments, but the highest gas usage. This scenario represents a continuation of current trends, and is therefore used as a reference case throughout this report.

- **Fuel mix scenario 3** ("Minimum gas") assumes an ambitious increase in installed nuclear capacity from 23 to 57 GW and in installed hydro capacity from 53 to 93 GW. Also, it assumes the same natural gas policy as Scenario 1. The future fuel mix in this scenario would be the one closest to Russia's Energy Strategy 2030 (dated 2009). Of the four scenarios, this one has the highest investments, but the lowest consumption of natural gas.

- **Fuel mix scenario 4** ("Minimum emissions") assumes the same ambitious rate of construction of new nuclear and hydro capacity as in Scenario 3, but a liberal approach to gas as described in Scenario 2. In this scenario the share of coal decreases to 12%, while the share of nuclear and hydro increases to 45%, making this scenario the one with the lowest CO_2 emissions.

8 For example, replacing gas with coal for power generation and exporting the amount of gas saved would increase the country's export revenues. Achieving such a saving, however, would require increased capital investments as well as fuel costs for power generation. This would drive up energy prices, affecting industry competitiveness and the real disposable income of the population.

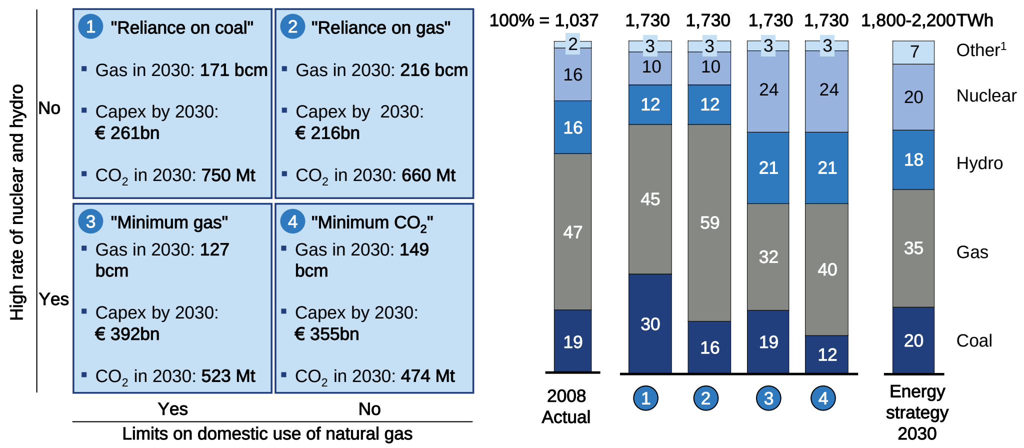
9 Although limitations on gas could take the form of either quotas or pricing policy (surcharges, removal of export duty, etc.) we formulated the scenario around a high gas price, so as to internalize fuel mix decisions in the power industry. The average gas-to-coal price ratio is 2.6:1 by 2020, whereas currently the average gas to coal price ratio is 1.1:1.

10 In this scenario gas-to-coal price ratio is 1.6 to 1.

EXHIBIT 3

Four scenarios for Russia's future fuel mix in power

POWER ONLY



1 Residual oil, renewables

SOURCE: Institute of Energy Strategy; Energy Strategy 2030; McKinsey

The conditions defined for each scenario result in different overall costs of power generation which are determined by the different capital investments required and the specific generation costs of each technology (Exhibit 4), as well as regional specifics.[11]

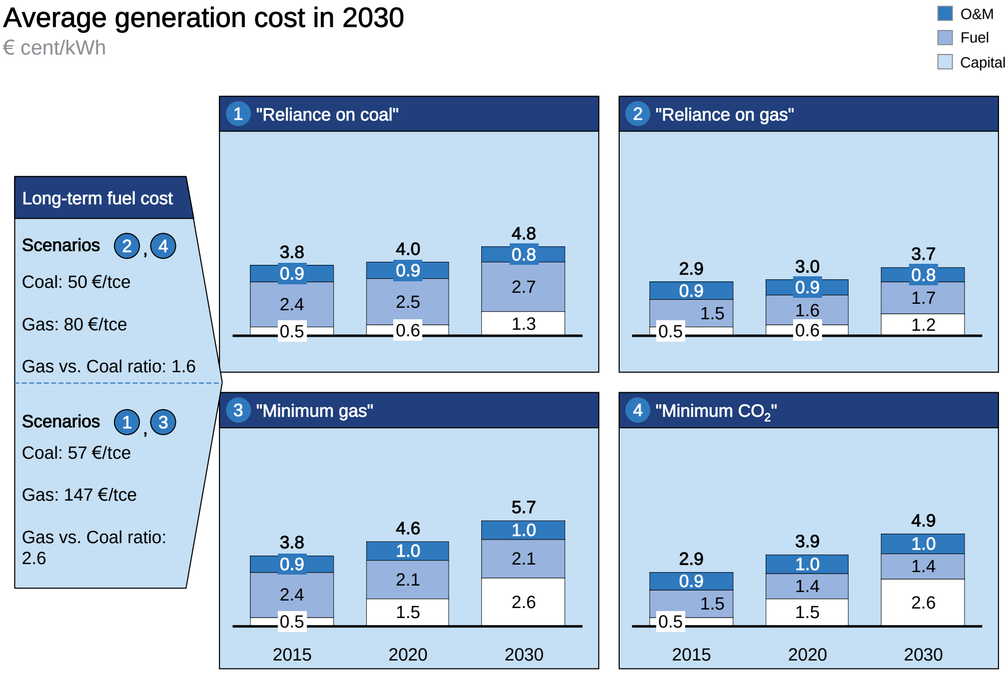
Scenario 3 ("Minimum gas") leads to generation costs 20 €/MWh higher than scenario 2 ("Reliance on gas"), but it would free about 90 bcm of gas per year for export, or alternatively allow a postponement of capital investments in the exploration of new, remote gas fields. The combined power and heat emissions would be 1057 Mt CO_2e (compared to 1194 Mt CO_2e in Scenario 2).

11 To do so, we modeled power and district heat in 21 sub-regions, each with its forecast demand for power, adjusted transportation costs for fuel, and allocation of nuclear and large hydro capacity.

EXHIBIT 4

Average generation cost in 2030

€ cent/kWh



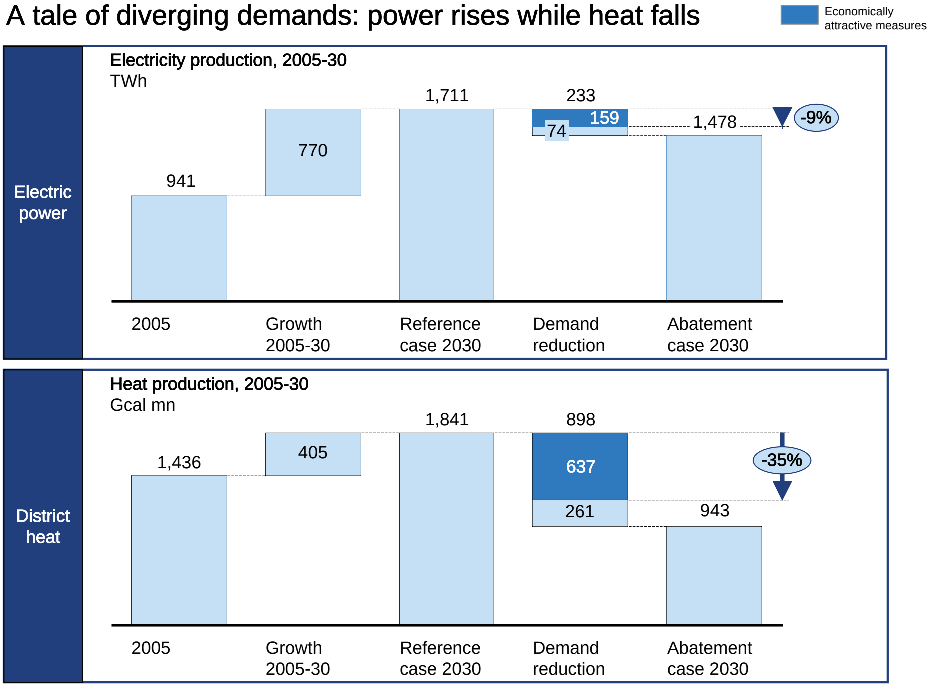
SOURCE: McKinsey

OPPORTUNITIES EXIST TO REDUCE ENERGY CONSUMPTION AND GREENHOUSE GAS EMISSIONS THROUGH ENERGY EFFICIENCY IN OTHER SECTORS, BY REDUCING LOSSES IN PLANTS AND GRIDS, AND THROUGH THE NATIONAL FUEL MIX

If all economically attractive measures were implemented in other sectors, they would reduce demand for power and heat by 9% and 35% (Exhibit 5). In addition to that 3 money-saving measures were identified within the power and heat sector, which can reduce energy consumption by 50 Mtce. An additional 9 measures would reduce CO_2 emissions at costs below €80 per tonne of abatement (Exhibit 6), resulting in a total abatement of 304 Mt CO_2, or 25% of the sector's emissions in the reference case.

EXHIBIT 5

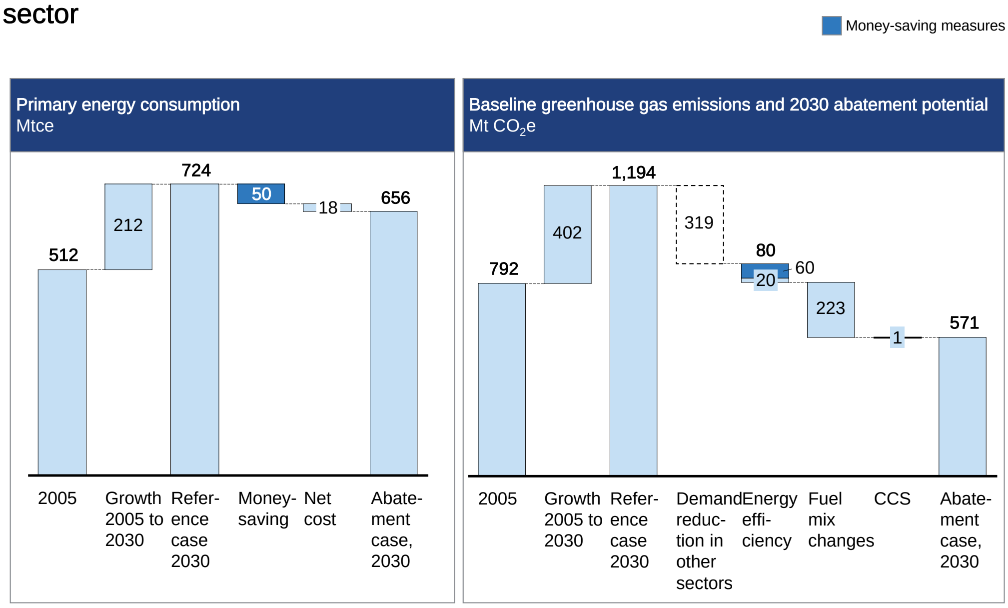
A tale of diverging demands: power rises while heat falls



SOURCE: McKinsey

EXHIBIT 6

Energy consumption and greenhouse gas emissions by the power and heat sector

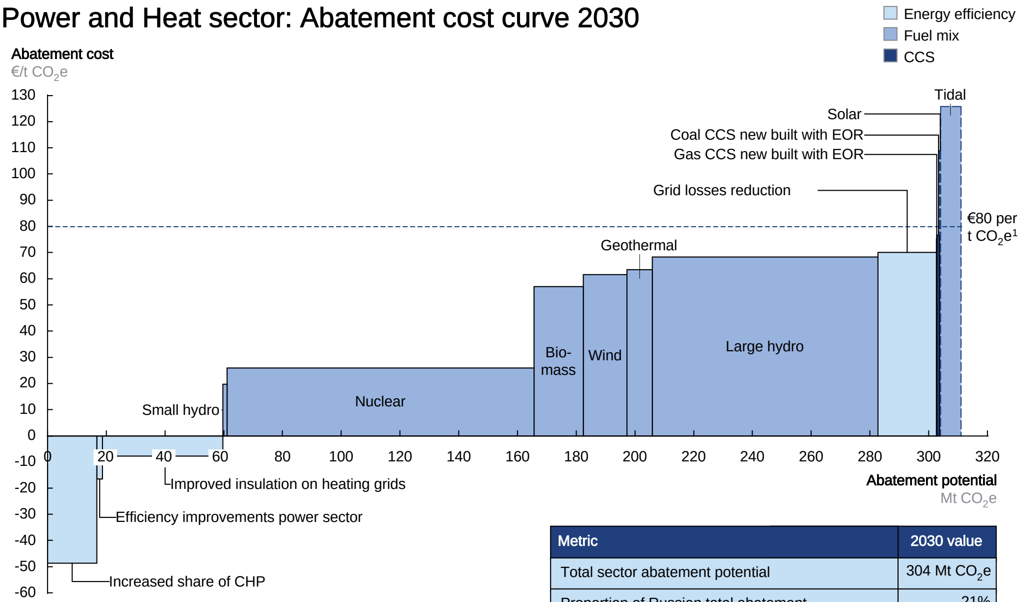


SOURCE: McKinsey

Reductions in CO_2 emissions and energy consumption within the power and heat sector would result from efficiency improvements, mainly by decreasing the internal consumption of power plants and losses in heating mains. Additional CO_2 reductions would result from changes in the fuel mix, after 2020, and could come from carbon capture and storage facilities CCS (Exhibit 7).

EXHIBIT 7

Power and Heat sector: Abatement cost curve 2030



Metric	2030 value
Total sector abatement potential	304 Mt CO_2e
Proportion of Russian total abatement	21%
Abatement from money-saving measures	60 Mt CO_2e
Economically attractive share of sector abatement	20%

1 Measures above 80 €/t CO_2e not included into the overall abatement potential

SOURCE: McKinsey

- **Efficiency improvements.** The three economically attractive measures in this category decrease energy consumption by 50 Mtce and CO_2 emissions by 60 Mt in 2030, or 7% of that in the reference case for energy and 5% for emissions. With the investment of about €18 bn from 2010 to 2030 these measures give savings of about €38 bn over the period. The largest measure in this category is “Improved insulation of heating grids” (37 Mtce, 41 Mt CO_2) which involves the use of modern polyurethane-based insulation, decreasing losses in the district heating system from the current 25% down to 12%. The next two measures by economic attractiveness are “Increased share of CHP” (12 Mtce, 17 Mt CO_2), which involves the gradual replacement of about 16% of the existing boilerhouse capacity with cogeneration plants, and efficiency improvements in the power sector (1.2 Mtce, 2 Mt CO_2), based on a 2% efficiency increase in existing thermal power plants through better operational management[12]. One additional measure “Grid losses reduction”, which would require costs of €70/t CO_2 abated, offers energy savings of about 18 Mtce per year in 2030. The reason for the poor economics of this measure is the substantial investment required to increase the density of power grids, the key driver for reducing losses. This measure may be worth pursuing based on its cumulative economic and reliability effect.
- **Changes in fuel mix.** The six measures in this category could abate 223 Mt of CO_2 (19% of the reference case), by a larger share of non-fossil fuel plants. Even assuming decreases in the future costs associated with alternative technologies, all fuel mix measures would imply net costs, as nuclear, hydro, biomass, wind and geothermal-based power generation would be more costly than gas- and coal-fired generation. The largest measures in this category are the construction of new nuclear and large hydro power plants, with an increase in installed capacity from 23 to 57 GW (nuclear)

12 While this measure accounts for only 1.2 Mtce savings in 2030, it brings 2.7 Mtce savings in 2020 and 3.8 Mtce as soon as in 2010. Therefore, it should be a short-term priority for energy generation.

and from 46 to 93 GW (hydro) by 2030[13]. As a result, an additional 270 TWh of nuclear power and 206 TWh of hydro power would take the place of power that would otherwise be generated by gas. Russia also has a potential to develop renewables – in particular biomass and wind. The national target, per the Energy Strategy 2030, is 4.5% of the fuel mix. Based on the available estimates, we have identified a somewhat higher share, 7.5%. However, of these, 15% are solar and tidal plants, which have costs above €80/t CO_2, and therefore were not included in the national cost curve. The resulting reduction in CO_2 emissions would be 104 Mt CO_2[14] accounted for by nuclear plants, 77 Mt by large hydro, and 42 Mt by all other alternative sources.

- **Carbon Capture and Storage measures.** Carbon capture and storage (CCS) can cut emissions by 2 Mt CO_2e in 2030, but the technology is not yet mature and uncertainty exists about future costs (for details see page 125 in the appendix). Three types of CCS technologies were considered in the power sector: CCS newbuild (i.e., in newly built plants), CCS newbuild with EOR (enhanced oil recovery) and CCS retrofit. Costs for all measures are estimated to be in a range of €60-80/t CO_2 after 2020. Only limited abatement volumes are assumed in the cost curve, since no implementation of the CCS technology is assumed until 2020, and cheaper fuel mix measures would be used first, thereby leaving only low volumes of new build fossil power plants where CCS measures could be implemented. The CCS retrofit opportunity is limited for two major reasons: first, existing thermal plants are already old, and a significant number of them will be retired soon. Thus installing the CCS technology for a short period would not be sensible. Secondly, this would decrease efficiency of these plants, which is already 30-40% below benchmarks. Conversely, at a newly built power plant the efficiency penalty is not as great. In summary, these measures are the least certain and highest-cost in the cost curve.

FOR IMPLEMENTATION, SPECIAL FOCUS COULD BE PLACED ON REGULATORY, FINANCING AND HEAT METERS

Power and heat are highly centralized sectors, in which a relatively small number of large players would be capable of making the critical investment decisions to shape the energy intensity and emissions profile of the sector for years to come. However, major challenges lie ahead in implementing the improvement measures discussed:

- **Regulatory issues.** Russia continues to follow an evolving, changing approach to the design of its power industry and market. This approach reduces the degree of certainty and confidence of investors regarding their potential investments. For example, no permanent system for financing capacity has been put in place as of the writing of this report, even though plans for a "capacity market" have existed for several years.

- **Financing.** The biggest implementation challenges relate to the costs involved. In total, investments required for implementation of all power and heat measures in the cost curve would be €190 bn. Of that amount, about €140 bn are for investment in nuclear and large hydro capacity and an additional €26 bn for renewables. Government needs to decide how the expansion of these – mostly publicly owned – generating fleets will be financed.

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13 In Fuel mix scenarios 3 and 4 this measure was already included in the reference case.

14 Assuming CO_2 intensity of CCGT to be 0.38 Mt CO_2/TWh. For nuclear €26/t CO_2 abatement cost calculated as a difference in full generation cost (€38/MWh for nuclear, €29/MWh for CCGT), divided by CO_2 intensity of CCGT. For hydro €68/t CO_2 abatement cost.

- **Transition to metering in district heat systems.** To date tariffs for heat have been based on a “cost plus” logic and applied per square meter or per person, none of which creates no incentive to reduce losses in the system. With liberalization and growth of fuel prices, the financial benefits of reductions would make more sense, but without metering there is still no incentive to reduce losses, and the transition period is particularly tricky, as all metered sections of the system are expected to have a lighter tariff burden, while unmetered sections pay for the residual, creating a higher burden.

□ □ □

To summarize, individual players can play a role to significantly improve energy efficiency in the sector, but only the Russian government can take the steps that are needed to encourage the modernization and future growth of the sector. In doing so, government would act both as the regulator that decides on any further liberalization of the power market, and in its capacity as a stakeholder, being the owner of the main energy companies, including nuclear and large hydro plants, as well as the national power grid.

The Russian government is the main decision-maker on the future fuel mix of the country. Given the sheer size of the sector, which accounts for more than half of Russia’s primary energy consumption – and which at the same time is responsible for about one third of the country’s emissions – any decisions by Russia’s policy-makers affecting the future of the sector will be critical for the country as a whole.

4.3 Industry

For Russian industry, the dramatic decline of the 1990s was followed by a decade of strong growth. However, different sectors recorded varying rates of both decline and recovery; consequently, their energy consumption and greenhouse gas emission profiles developed differently, as well.

In 2005, Russian industry as a whole consumed more energy (440 Mtce) and emitted more greenhouse gases (1150 Mt CO_2e) than any other sector. The oil and gas industry, which emitted 495 Mt CO_2e, plays the greatest role in this picture, but the iron and steel, chemicals, and cement industries together emitted 238 Mt CO_2e in 2005 and have therefore also been analyzed in detail in this chapter.

The largest opportunities to reduce energy consumption and greenhouse gases have been identified in the petroleum and gas industry (30 Mtce, 125 Mt CO_2e) and iron and steel (12 Mtce, 82 Mt CO_2e). Although significant reductions in emissions from petroleum and gas have already been included in the reference case, large opportunities remain, of which 80% would be profitable from society's perspective.

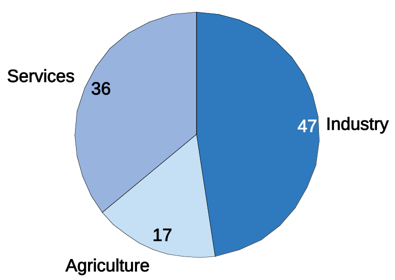
Russia's industry decline and recovery

In the 1990s, Russia experienced a major decline in industrial production, with average capacity utilization falling from almost 90% in 1990 to only 45% by 1998. The rapid growth of the Russian GDP subsequently did not translate into equivalent growth in industrial production, mainly due to the increasing share of services as a percentage of the GDP (Exhibit 1).

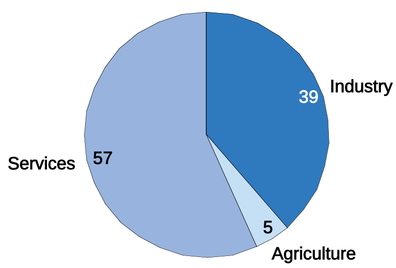
EXHIBIT 1

The share of services in Russia's GDP grew significantly while industry and agriculture declined

Structure of Russia's GDP, 1990
Percent



Structure of Russia's GDP, 2007
Percent



SOURCE: Global insight

In 2007 Russian industry was dominated by the oil and gas industry and mining, which together made up almost 20% of total GDP. However, but if the tendency of the past 10 years continues the share of services and light industries, which are less energy-intensive and less carbon-intensive, will increase at the expense of heavy, more energy-intensive industries.

The future structure of Russian industry depends heavily on the country's future economic development path. Forecasts see oil refining, machinery, non-metallic minerals, chemicals, and car manufacturing with the highest growth rates. However, the goal defined by the Russian government to double per capita GDP by 2020 (compared to 2007) would require a significant shift from a largely resource-oriented economy to a more innovative one.

Following the trend of falling industrial production during the 1990s, Russian industry's energy consumption decreased by almost 30% between 1990 and 1999, while its direct greenhouse gas emissions fell by 55% over the same period. Energy consumption started to increase again in 1999, with a subsequent annual average growth rate of 1.3%, while direct greenhouse gas emissions from industry started to rise in 2000 and have since grown at an average of 1.1% annually.

As of 2005, total direct annual industry emissions stood at 925 Mt CO_2e, still almost 25% lower than in 1990. However, greenhouse gas emissions have developed at very different rates in different industries. For most industries, emissions grew only slightly after the massive downturn of the 1990s, although the petroleum and gas industry recovered quite quickly. The sector's emissions fell by only 25% between 1990 and 1995 and then began to grow again, in 2005 exceeding the 1990 level of emissions by 10%. Across all other industry sectors the average drop was 56% between 1990 and 1995, and current emissions on average are still more than 40% below the 1990 level. The financial crisis, which resulted in a more than 10% industrial output drop in 2009, implies an energy use and greenhouse gas emissions decline in 2009-2010, which will be followed by a period of growth, as Russia's GDP growth rate returns to the pre-crisis level.

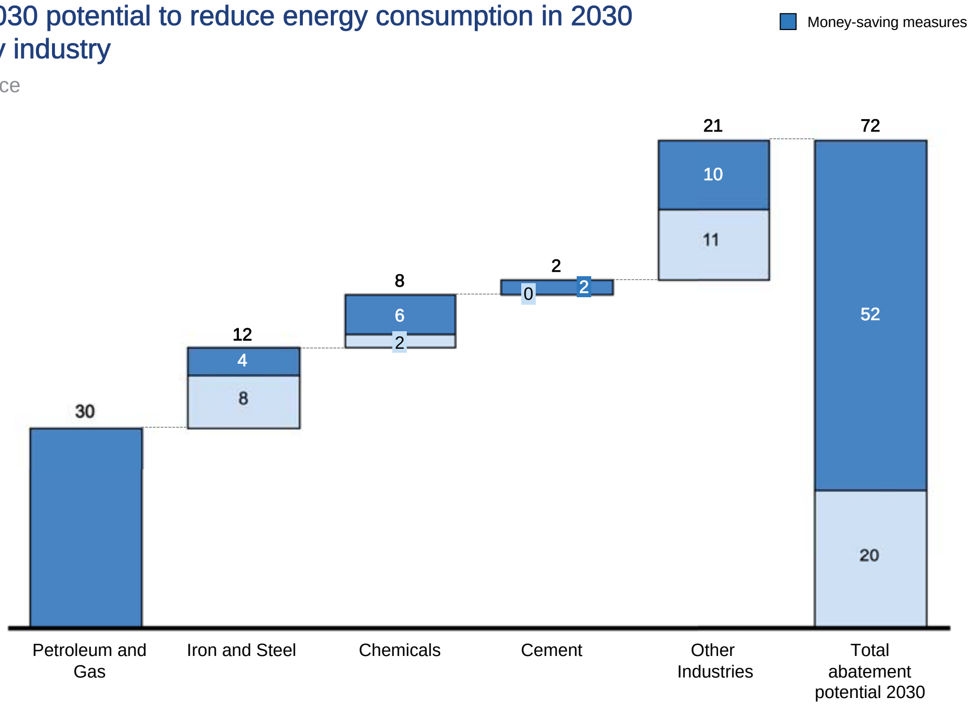
Approach in this report

This report provides a detailed analysis of the opportunities to reduce energy consumption and greenhouse gas emissions in petroleum and gas, iron and steel, chemicals, and cement – the four industries that are the largest contributors in terms of greenhouse gas emissions (Exhibit 2 and 3).

EXHIBIT 2

2030 potential to reduce energy consumption in 2030 by industry

Mtce



SOURCE: McKinsey

All remaining industries produce only 13% of the total emissions, with shares below 2% each, and have therefore been bundled as “other industries” in this report. For them, the energy reduction and abatement potential was estimated based on the average reduction potential identified in the four industries analyzed in detail.

Main findings for Russian industry

The results of the analysis show that, in the reference case, energy consumption in Russian industry is expected to grow by 23% by 2030 (Exhibit 4), from 440 Mtce in 2005 to 540 Mtce in 2030. Here, cement and chemicals show the highest growth, at 90% and 71%, respectively. By pursuing money-saving mainly energy-efficiency measures, energy consumption in 2030 could be reduced by 52 Mtce, driven primarily by the petroleum and gas industry contributing 30 Mtce.

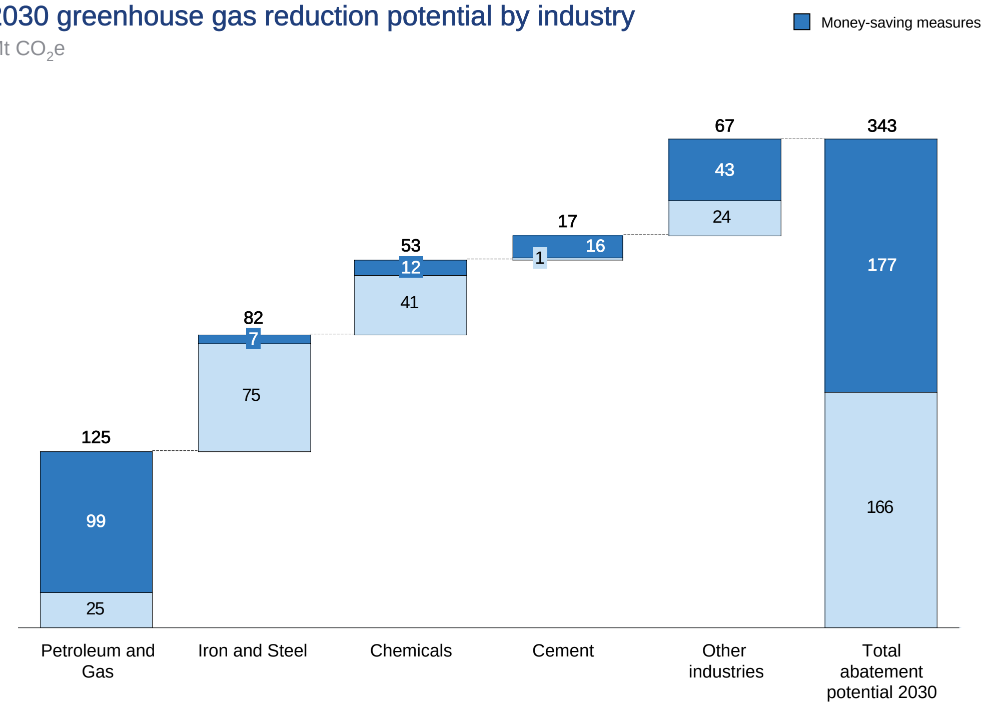
Greenhouse gas emissions from Russian industry are expected to grow in the reference case by 29% – from 1150 Mt in 2005 to 1485 Mt in 2030. There again, cement and chemicals are expected to see the highest growth rates: 135% and 85%, respectively. Implementing economically attractive measures leads to abatement of 177 Mt CO_2e.

Across the sectors, 343 Mt CO_2e was identified as Russian industry’s total abatement potential in 2030 (23% of the total sector emissions in the reference case). Half of this potential lies in money-saving measures, mostly in petroleum and gas and cement .

EXHIBIT 3

2030 greenhouse gas reduction potential by industry

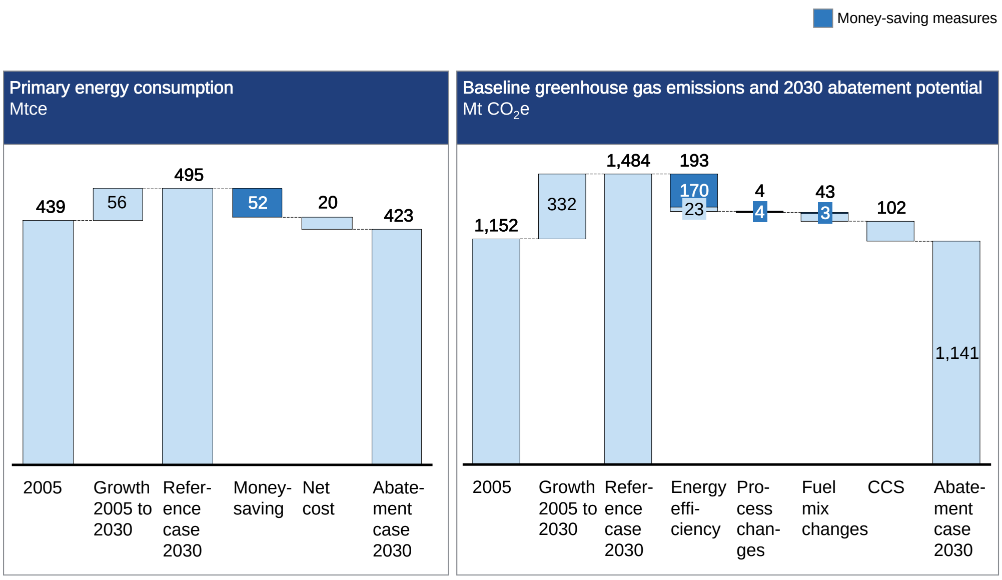
Mt CO_2e



SOURCE: McKinsey

EXHIBIT 4

Energy consumption and greenhouse gas emissions by industry



SOURCE: McKinsey

The following sub-chapters provide further detail on the potential identified in the petroleum and gas, iron and steel, chemicals, and cement industries.

Petroleum and gas

The petroleum and gas industry is the third largest emitter of greenhouse gases in Russia. About half of its emissions come from methane (CH_4) leakages in gas distribution and transmission systems. Due to its comparatively high losses and low energy efficiency, the sector has already been subject to regulatory measures demanding large improvements in the coming years, especially a drastic reduction in flaring. Nevertheless, a further ten money-saving measures have been identified, which would significantly reduce the industry's greenhouse gas emissions and further improve energy efficiency, mainly through improved maintenance of the gas distribution network and better planning of transmission volumes.

General sector information (2007)		
• Share of Russian GDP	19%	
• Share in budget revenues	50%	
Energy consumption		
(Mtce and share of total Russia)		
• 2005	118	(12%)
• 2030 Reference case	140	(11%)
Energy savings from identified emission reduction measures		
(Mtce and share of 2030 reference case)		
• With positive return	30	(21%)
• All measures	30	(21%)
Emissions		
(Mt CO_2e and share of total Russia)		
• 2005	495	(23%)
• 2030 Reference case	570	(19%)
Emission reduction potential		
(Mt CO_2e and share of 2030 reference case)		
• With positive return	99	(17%)
• All measures	124	(22%)

P&G IS RUSSIA'S MOST VALUABLE SECTOR, BUT HAS A 22% HIGHER LEAKAGE RATE AND 44% HIGHER BURN RATE THAN THE US

The petroleum and gas (P&G) sector has a 12% share of Russia's primary energy use, but a 23% share of emissions (495 Mt CO_2e). Partly, the numbers are explained by Russia's high production volume – 9.9 million barrels per day (12% of world production) and 602 billion cubic meters of natural gas per year (20% of world production) – leading to the sector's 19% share of GDP and 50% of budget revenues.

But the emissions rate is also a consequence of the direct leakage of methane, which amounts to about 13 bcm (15 Mtce) per year. This is enough gas to supply St. Petersburg and its region for a year. It also constitutes about 40% of sector emissions, since methane is 21 times more powerful then CO_2 in terms of greenhouse potential. The Russian gas pipeline system leaks 22% more gas per unit transported than does the USA's system.

Methane leaks are not the only type of energy loss and emissions source. There is also flaring of associated petroleum gas (upstream), gas transmission and distribution systems (midstream), and refining (downstream).[1] For different historical reasons (low domestic gas prices, intention to limit the volume of steel used in construction) gas transmission in Russia, compared to the US, burns 44% more gas for pumping per unit of gas transported.

1 The relatively small amounts of greenhouse gases emitted by crude oil exploration are excluded from the scope of this analysis.

REFERENCE CASE: GAS PRODUCTION IS EXPECTED TO RISE BY 36% BY 2030, WHILE ENERGY CONSUMPTION AND EMISSIONS IN THE SECTOR WILL INCREASE BY LESS THAN 20%

The 2030 reference case for the sector already takes into account several critical improvements in energy consumption and emissions reduction. In particular, the reduction of associated petroleum gas (APG) flaring has received wide attention in Russia, and legislation has already included the target that 95% of APG has to be captured and utilized by 2012. Also included as part of the reference case is a 17% reduction of per-unit fuel consumption in gas transmission on account of the planned replacement of old compressors, as well as a 14% leakage reduction in both gas transmission and distribution. These measures will result in an annual energy saving of 32 Mtce and an abatement of 91 Mt CO_2e in 2030.

This improvement in energy efficiency will mean that expected emissions in the reference case grow by only 15%, and energy consumption by 19%, despite an anticipated 36% growth in gas production, and an expected 42% increase in refining output.

OPPORTUNITIES EXIST TO REDUCE THE ENERGY CONSUMPTION BY 21% AND EMISSIONS BY 22%: BETTER MAINTENANCE OF THE GAS DISTRIBUTION NETWORK AND CCS WOULD MAKE UP THE LARGEST CONTRIBUTION

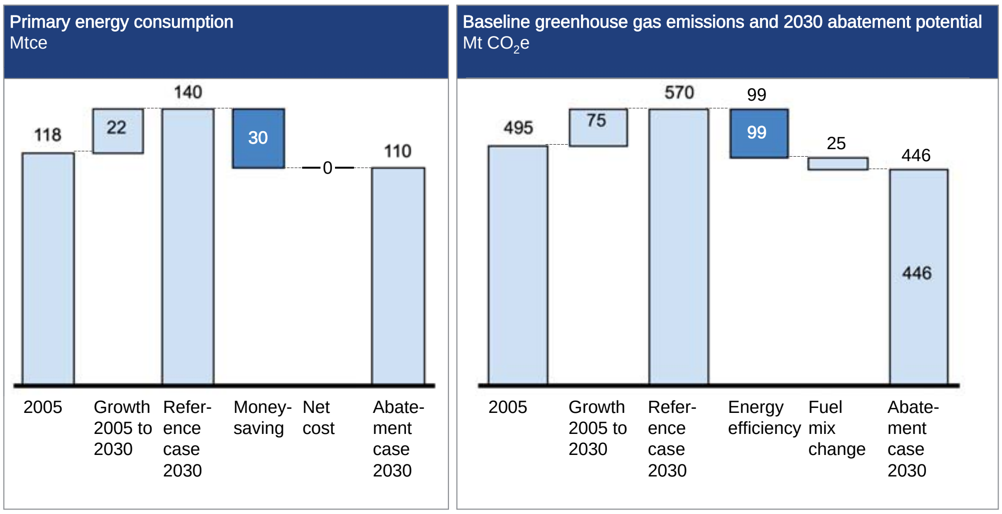
Ten energy efficiency measures have been identified, which have an energy savings potential of 30 Mtce – or 21% of the energy consumption projected for this sector in 2030 (Exhibit 5). If fully implemented, these measures would result in an abatement of 99 Mt CO_2e, or 17% of the reference case emissions in the P&G sector. Compared to other sectors, this abatement potential may seem relatively low, but this is mainly due to the large abatement already included in the reference case. The ten measures require €4 bn of investments but would bring €24 bn of savings through 2030.[2]

2 The is one additional net cost measure in this sector Carbon Capture and Storage (CCS) technology, applied to the exhaust coming from direct energy production in refineries. The use of this technology could abate up to 25 Mt CO_2e in 2030. However, the implementation cost of the measure is highly uncertain.

EXHIBIT 5

Energy consumption and greenhouse gas emissions by the petroleum and gas sector

Money-saving measures



SOURCE: McKinsey

The measures are shown in Exhibit 6. The most economically attractive and the largest opportunities are as follows:

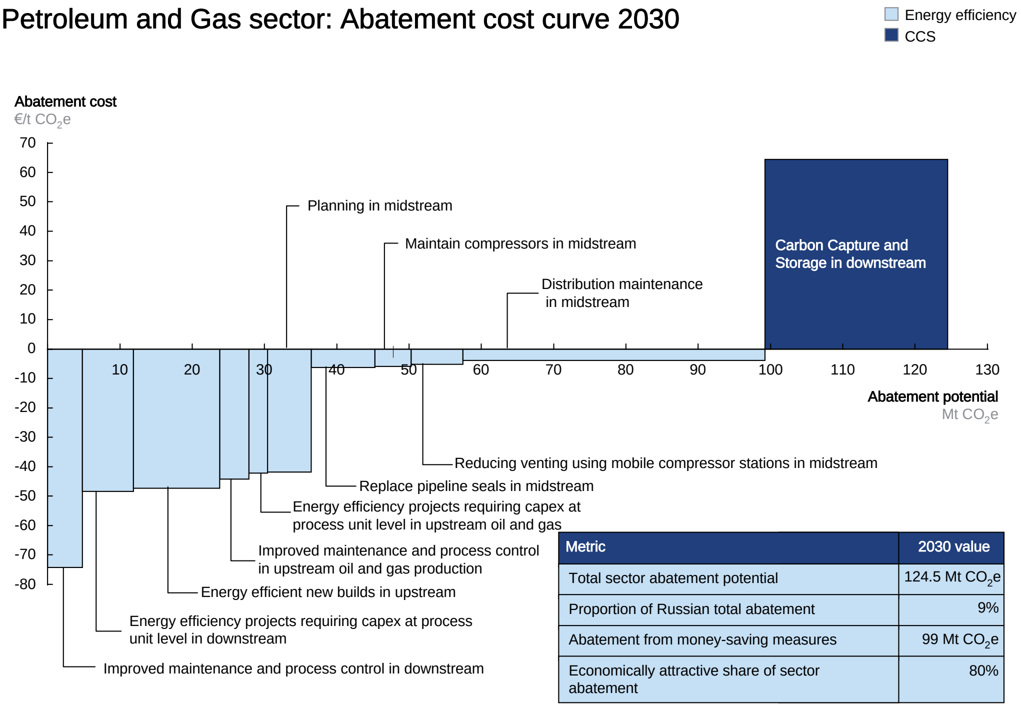
- **Improved maintenance and process control downstream** is the measure with the lowest cost of abatement. It assumes improved maintenance to ensure that equipment stays in optimal condition and improved process control to reduce suboptimal performance. Implementation of this measure could reduce energy consumption by 4.2 Mtce and abate 5 Mt CO_2e. It requires investments of almost €1.5 bn through 2030, but would bring savings of almost €4 bn over the same period.

- **Direct inspection and maintenance (DIM) of the gas distribution network** is the largest measure in the P&G sector. DIM programs include detecting, measuring, prioritizing, and repairing equipment leakages, to effectively reduce methane emissions from the pipelines. By this, direct distribution maintenance could reduce methane leakages in low and medium pressure pipes by 3 bcm per year (4 Mtce), thus abating almost 42 Mt CO_2e per annum in 2030. Savings would exceed the implementation costs by almost €3 bn through 2030.

Additional money-saving measures in the sector include improved maintenance and process controls upstream, improved compressor maintenance, the replacement of pipeline seals, and the use of mobile compressors to reduce venting losses. In all, of the 30 Mtce annual savings in 2030, 19 Mtce are through reduced consumption and 11 Mtce through containment of methane leakages, which equates to 10 bcm per year.

EXHIBIT 6

Petroleum and Gas sector: Abatement cost curve 2030



Metric	2030 value
Total sector abatement potential	124.5 Mt CO_2e
Proportion of Russian total abatement	9%
Abatement from money-saving measures	99 Mt CO_2e
Economically attractive share of sector abatement	80%

SOURCE: McKinsey

GOVERNMENT CAN HELP REALIZE ENERGY EFFICIENCY MEASURES BY LIBERALIZING GAS PRICES, METERING AND INVESTMENT-FRIENDLY POLICIES

Decision-makers are for the most part large state-owned and private companies. Nevertheless, the measures require some supporting stimulus.

- **Liberalization of gas prices.** Domestic gas prices in Russia (below €50/mcm as of September 2009) are still lower than international market prices (above €190/mcm). With further liberalization of the gas market, domestic prices in Russia will reach levels where investments in gas savings will become more profitable, and are therefore more likely to be implemented.

- **Tariff system and metering.** Currently, gas distributors in Russia are paid according to tariffs that also compensate for average levels of losses. Therefore, distributors have limited or no incentives to invest in energy-saving projects. With less than 20% of gas consumers having gas metering devices, the costs of gas losses are usually simply shifted to consumers. The installation of more metering devices (driven by regulation, for example) would increase awareness and make more customers pay only for their actual consumption, not for losses in distribution. This would create increasing pressure on gas distributors to reduce leakages and other sources of loss.

- **Investment friendly policies.** In addition to the usual concerns about capital investments, the P&G sector is partially affected by price volatility of oil and gas, which increases the risk of efficiency projects not paying off or having long payback times. To overcome this hurdle, a regulatory safety net (as has been done, for example, in the case of flaring), targeted loans, or direct or indirect subsidies (for example, through tax incentives) could support implementation and help achieve the overall benefits that are associated with these improvement measures.

The implementation of some measures – in particular those related to methane leakage – could also benefit from establishing an effective legal base for Joint Implementation projects. This would lead to even higher incomes from energy-saving projects, making these measures more attractive, notwithstanding the regulated domestic gas prices and the other implementation barriers discussed here.

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To summarize, the energy efficiency measures identified in the petroleum and gas sector are well-known, are all implementable in the medium term, and are all economically attractive. What is more, they could be implemented by a few large industry participants. These measures would allow the petroleum and gas sector in Russia to have declining total emissions despite significant growth in production. However, funding significant up-front investments and steps to overcome certain market imperfections would be necessary for these improvement opportunities to be realized.

Iron and steel

Steel production is one of the major industries in the Russian economy, making Russia the fourth largest steel producer in the world. Iron and steel is an energy- and carbon-intensive sector: in 2007 it contributed 3% to Russia's GDP, but was responsible for 5% of the country's total energy consumption and 7% of total greenhouse gas emissions. Ten measures have been identified, which could reduce the industry's energy consumption by more than 20% and emissions by about 50% in 2030; however, only a small share of these measures would be economically attractive.

General sector information (2007)		
Share of Russian GDP	3%	
Energy consumption		
(Mtce and share of total Russia)		
• 2005	44	(4.6%)
• 2030 Reference case	49	(3.7%)
Energy savings from identified emission reduction measures		
(Mtce and share of 2030 reference case)		
• With positive return	4	(8%)
• All measures	12	(24%)
Emissions		
(Mt CO_2e and share of total Russia)		
• 2005	145	(6.7%)
• 2030 Reference case	161	(5.4%)
Emission reduction potential		
(Mt CO_2e and share of 2030 reference case)		
• With positive return	7	(4%)
• All measures	82	(51%)

RUSSIAN STEEL IS PRODUCED WITH TWICE THE ENERGY CONSUMPTION OF AMERICAN OR JAPANESE COMPETITORS

Compared with other leading steel producing countries, the Russian steel industry relies on older, Soviet-era production facilities and more energy intensive production technologies overall, including 22% of production from open hearth furnace (OHF), a technology not used today in any of the three largest steel producers in the world, China, Japan and the US. This results in Russia's steel industry being 25% more energy intensive than that of China (0.66 tce per tonne of steel, compared with 0.53 tce per tonne of steel in China) and more than two times more energy intensive than the US and Japan (0.28-0.30 tce per tonne of steel in the US and Japan, in 2005). Replacing OHFs with a more efficient electric arc furnace (EAF) technology would significantly decrease the energy consumed per tonne of steel produced by the industry.

The sector consumed 44 Mtce of primary energy in 2005, or 4.6% of Russia's total energy consumption. Of this amount, about 80% is made up of the on-site consumption of fossil fuels, which is the main source of emissions. Direct greenhouse gas emissions account for more than 90% of the sector's emissions overall.

Compared with large carbon emitting sectors such as power and heat or the oil and gas industry, steel production is a relatively small emitter of greenhouse gases. In 2005, it was directly responsible for about 132 Mt CO_2e, or 6%, of Russian greenhouse gas emissions. In addition, it indirectly contributed 13 Mt CO_2e (about 1%) through electricity and heat consumption.

REFERENCE CASE: ENERGY CONSUMPTION AND EMISSIONS ARE EXPECTED TO GROW 11% BY 2030, WHILE STEEL PRODUCTION INCREASES BY ABOUT 27%

In the reference case, total primary energy consumption in the sector is estimated at 49 Mtce in 2030, which corresponds to a 11% reduction of energy intensity, from 0.66 tce per tonne of steel in 2005 to 0.59 tce per tonne of steel in 2030. Already in this reference case significant efficiency increases are assumed to occur:

- The share of steel production with more environmentally friendly EAF technology is assumed to increase from 16% in 2005 to 35% in 2030, replacing the more carbon-intensive OHF and BOF technologies. However, growth of EAF is limited by availability of scrap – the main primary material in EAF steel production. Due to the economic downturn in 1990s, Russia is expected to experience domestic scrap supply limitations after 2020.
- Steel plants will utilize blast furnace gas (BFG), which can be burned for power and heat production.

As a result, a 27% increase of total production is expected to lead to an increase in emissions by only 11% to 161 Mt CO_2e by 2030.

Steel production technologies used in Russia:

- **Basic oxygen furnace (BOF)** technology is a process of steel production in which pig-iron is made into steel by blowing oxygen through molten pig-iron, and thus reducing the carbon content of the alloy and changing it into low-carbon steel. In 2005, 62% of total steel in Russia was produced with this technology, and its share is expected to increase to 74% by 2015, then receding to below 65% in 2030 in favor of electric arc furnace (EAF) technology.
- **Electric arc furnace (EAF)** steelmaking technology applies to another 16% of the steel produced in Russia. The EAF method is much easier and faster since it only requires scrap steel – recycled steel is introduced into a furnace and re-melted along with other additives using electricity. The growth rate of EAF's is capped by scrap availability in Russia in the future. Steel production in Russia with EAF is expected to see an almost three-fold increase from 11 Mt in 2005 to 29 Mt of steel in 2030.
- **Open hearth furnace (OHF)** is the most inefficient steel-making technology that is no longer used by main steel-producing countries, such as the US. In Russia OHF is still in use, but is expected to be fully replaced by 2015.

OPPORTUNITIES IDENTIFIED COULD REDUCE ENERGY CONSUMPTION BY 24% AND GREENHOUSE GAS EMISSIONS BY 51%

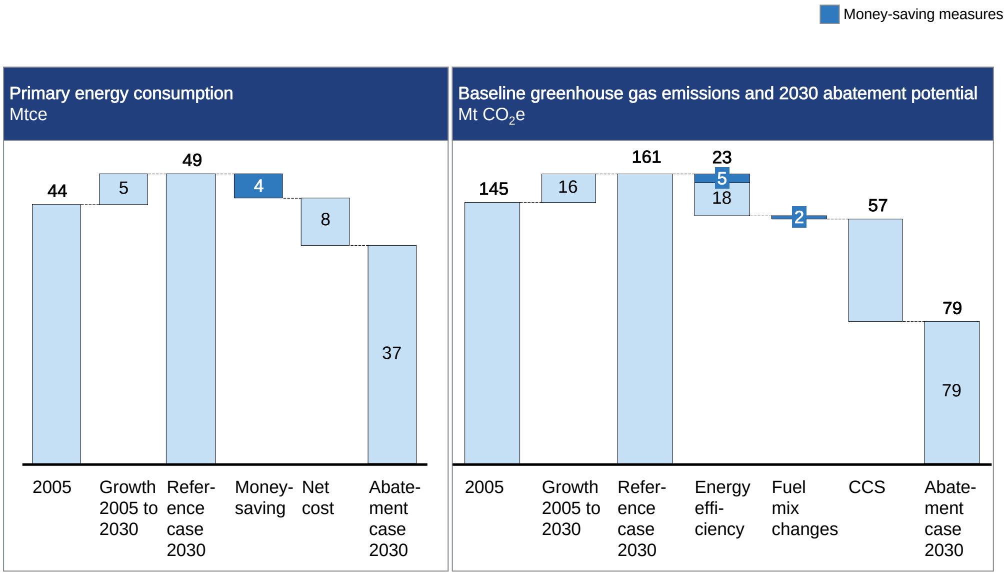
Growth in the steel industry's energy consumption can be neutralized with measures that generate net savings and reversed with additional energy efficiency measures. The predominant abatement measure after 2020 can become CCS (Exhibit 7 and 8).

Leaving out CCS, it is possible to save 12 Mtce of primary energy and abate 25 Mt CO_2e of emissions (respectively, 24% and 16% reductions compared to the reference case). This effort, grouped in eight measures, would require more than €13 bn of investments and generate almost the same amount in savings through 2030.

Energy efficiency measures include the utilization of BOF gas, the integrated preparation of coke with iron-ore reduction, and other improvement measures such as, for example, preventive maintenance, improved process control, installation of better equipment and new, more efficient burners. However, only cogeneration with BOF gas and coke substitution are attractive stand-alone investment: €2.5 bn through 2030 generating savings of €11 bn. Remaining energy efficiency measures offer too little savings for the capital invested, but could still be worthwhile as emission abatement projects.

EXHIBIT 7

Energy consumption and greenhouse gas emissions by the iron and steel sector



SOURCE: McKinsey

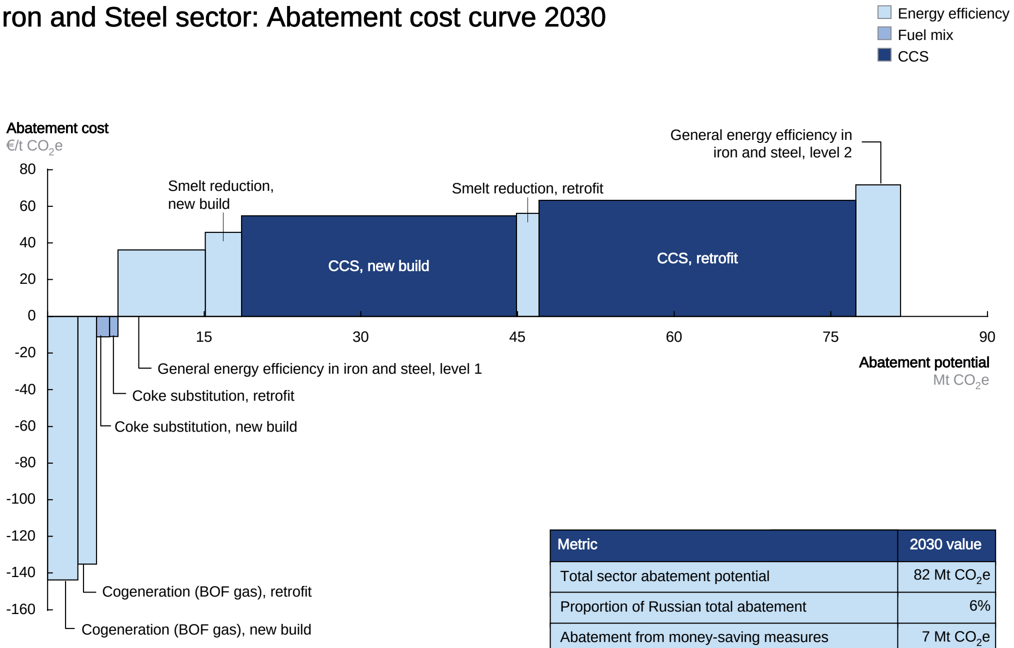
- **Cogeneration with BOF gas.** During the BOF process, the so-called "BOF gas" (mainly a mixture of carbon monoxide and carbon dioxide) is emitted. Currently most steel producers do not capture this gas, although its heat energy could be used in steam turbines for power and heat generation. This not only would reduce CO_2 emissions, but also would be economically attractive for steel companies, as they could replace part of the conventional fuel they buy and burn today for internal power and heat generation.

- **Coke substitution.** Here, the abatement opportunity comes from substituting coke with less carbon intensive fuels such as gas or biomass.

Carbon, capture and storage (CCS), although not assumed to start implementation before 2020, can become the largest emissions abatement opportunity in the iron and steel industry as of 2030. Constructing new steel plants with CCS capabilities and attaching CCS equipment to existing plants would abate emissions by 26 and 30 Mt CO_2e, respectively, but would require investments of more than €8 bn through 2030.

EXHIBIT 8

Iron and Steel sector: Abatement cost curve 2030



Metric	2030 value
Total sector abatement potential	82 Mt CO_2e
Proportion of Russian total abatement	6%
Abatement from money-saving measures	7 Mt CO_2e
Economically attractive share of sector abatement	9%

SOURCE: McKinsey

THE MAIN SUPPORTING MEASURES RELATE TO TECHNOLOGICAL ADAPTATION AND COST

Decision-makers are private steel producing companies, some of which have already started implementing selective energy saving measures as assumed in the reference case, but the majority of whom will need additional incentives or support before implementing them. In the case of cogeneration based on BOF gas, the challenge is helping companies learn about existing applications of this technology and adapt it to their technical conditions. But for most measures, the main issue is high upfront investments that do not bring positive returns on a stand-alone basis. Therefore, implementation of these measures requires external support or a regulatory mandate. Joint-Implementation (JI) projects are one possibility to raise external financing that would provide additional incentives for decision-makers to implement energy efficiency and emissions reduction measures.

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To summarize, in the reference case, steel production is already assumed to become more energy and carbon efficient, mainly due to a major change in steel production technology. There are, however, additional improvement opportunities available, which for the most part come from energy efficiency measures and the installation of carbon capture and storage facilities. By fully implementing all measures that have been identified, the opportunity exists to reduce energy consumption by 24% and to abate 51% of the sector's emissions in 2030. External incentives and regulations would be necessary to achieve this abatement potential.

Chemicals

Chemical production in Russia consumes about 2% of the country's total primary energy and emits 2.5% of total greenhouse gas emissions, about 60% of them as direct emissions of CO_2 and other greenhouse gases, the rest indirectly via electricity and heat consumption. The sector is expected to continue to grow rapidly and will need to employ economically attractive energy efficiency measures to reduce its expected increase in energy use together with additional measures targeted at reducing process emissions and for capturing and storing CO_2. Greenhouse gas emissions in the chemical industry in 2030 could potentially be lower than they are today; without abatement measures, on the other hand, emissions are expected to increase by about 85%.

General sector information (2008)		
Share of Russian GDP	0.8%	
Energy consumption		
(Mtce and share of total Russia)		
• 2005	20	(2.1%)
• 2030 Reference case	34	(2.6%)
Energy savings from identified emission reduction measures		
(Mtce and share of 2030 reference case)		
• With positive return	6	(18%)
• All measures	8	(23%)
Emissions		
(Mt CO_2e and share of total Russia)		
• 2005	53	(2.5%)
• 2030 Reference case	98	(3.3%)
Emission reduction potential		
(Mt CO_2e and share of 2030 reference case)		
• With positive return	12	(12%)
• All measures	53	(54%)

RUSSIAN CHEMICAL SECTOR IS HAMPERED BY HIGH DEPENDENCE ON POWER AND LOW EFFICIENCY OF MOTORS

The Russian chemical industry has only 1% share of global chemical output. During the 1990s, chemical production dropped dramatically to a level 70% below Russia's 1990 production volume. After 1998, the industry started recovering, but today the sector is still 40% below the 1990 production level.

The chemical industry is responsible for 2% of the total primary energy consumed in Russia (20 Mtce). The sector directly contributes 1.5% of Russia's greenhouse gas emissions and contributes an additional 1% indirectly, via electricity and heat consumption.

The direct greenhouse gas emissions derive from chemical production processes. CO_2 is emitted mainly from the combustion of fossil fuels. Particularly potent greenhouse gases such as nitrous oxide (N_2O) are released, for example, in nitric acid production.

Many of the existing chemical plants in Russia are equipped with inefficient equipment, leading to very high electricity consumption. From the 20 Mtce of primary energy consumed in the chemicals sector, more than a half is needed to run electric equipment used in the chemical processes, compared with a 30% share of electricity used for this in the US. An increase in power prices in Russia would put the industry at competitive disadvantage, unless efficiency improvements are implemented.

REFERENCE CASE: ENERGY CONSUMPTION AND EMISSIONS ARE EXPECTED TO GROW BY ABOUT 71% AND 85%, RESPECTIVELY, AS CHEMICAL PRODUCTION MORE THAN DOUBLES

Unlike the energy sector, which has a high degree of leakages and other inefficiencies and unlike the iron and steel sector, which has large opportunities in using by-products instead of conventional fuel, the chemical sector can become more energy efficient primarily by renewing its equipment – an expensive and gradual type of improvement. Each time old production facilities are replaced or new ones are built, the average energy and carbon intensity of the industry declines.

In the reference case, it is estimated that primary energy consumption will increase by 71%, from 20 Mtce today up to 34 Mtce in 2030. Greenhouse gas emissions, grow by 85%, reaching 98 Mt CO_2e by 2030.

A BROAD VARIETY OF ADDITIONAL OPPORTUNITIES COULD REDUCE ENERGY CONSUMPTION BY 23% AND GREENHOUSE GAS EMISSIONS BY 54%. HOWEVER, ONLY A QUARTER ARE MONEY-SAVING

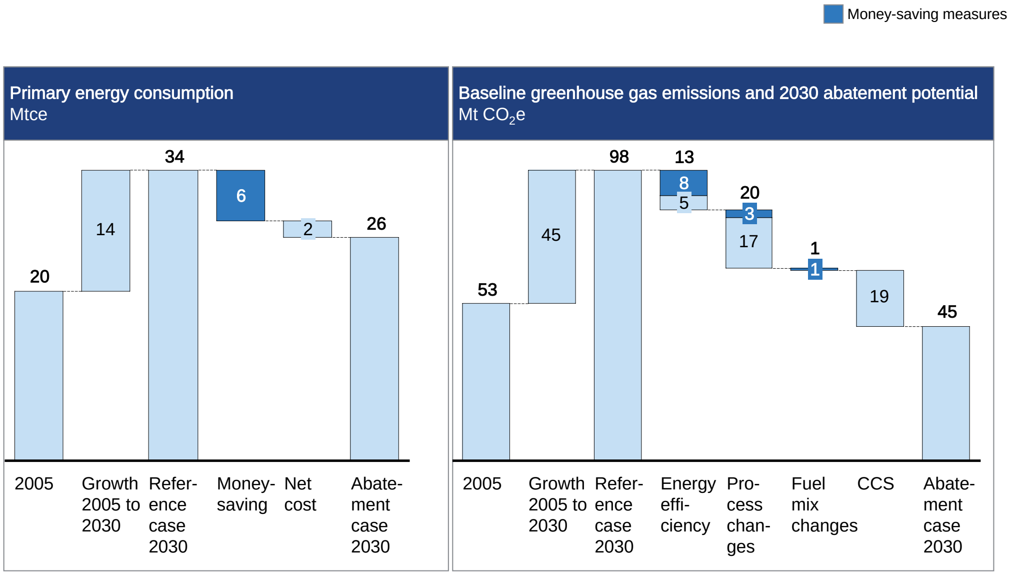
Opportunities in the chemical sector fall into four categories, as shown on Exhibits 9 and 10.

- **Energy efficiency measures** (8 Mtce,13 Mt CO_2e), include installation of more energy efficient equipment in chemical plants, catalyst optimization, and the use of more efficient ethylene cracking techniques which reduce energy consumption. The largest and most economically attractive is from improvements in the energy efficiency of equipment used at chemical plants, including motor systems, conveyors, mixing machines, etc. Implementation of this highly profitable measure would save 6.3 Mtce of primary energy and abate 6.5 Mt CO_2e per year. The measure would require cumulative upfront capital investments of €3 bn over the period 2010-30, but would bring savings of €14 bn over the same period.
- **Process optimization** (20 Mt CO_2e) spans a wide range of production processes and catalyst improvement measures, which would reduce the emission intensity of chemical processes. The main type of measure is decomposition of N_2O in the tailgas of nitric acid production. N_2O (nitrous oxide) is a greenhouse gas that is 310 times more potent than CO_2. Certain filtering techniques (catalytic decomposition or catalytic reduction) increase N_2O decomposition in the tailgas of nitric acid. This measure would avoid 15 Mt CO_2e annually, but will incur net cost of €104 m for the measure to be implemented in 2030.
- **Fuel mix changes** (1 Mt CO_2e) towards less carbon intensive fuels, for example, replacing oil with gas, or replacing coal with biomass, in chemical plants.
- **Carbon Capture and Storage** (19 Mt CO_2e) is expected to develop as a technology that will be able to capture CO_2 emissions from fuel combustion and production processes in chemical plants (for example, to capture CO_2 during ammonia production).

If fully implemented, these measures would result in an abatement of 53 Mt CO_2e, or 54% of the reference case emissions in 2030. However, money-saving measures are four times smaller; they account for 12 Mt CO_2e, or 23% of the total abatement potential in the sector, and promise savings of €15 bn in 2010-2030 at a cumulative capital expenditure of only €3 bn.

EXHIBIT 9

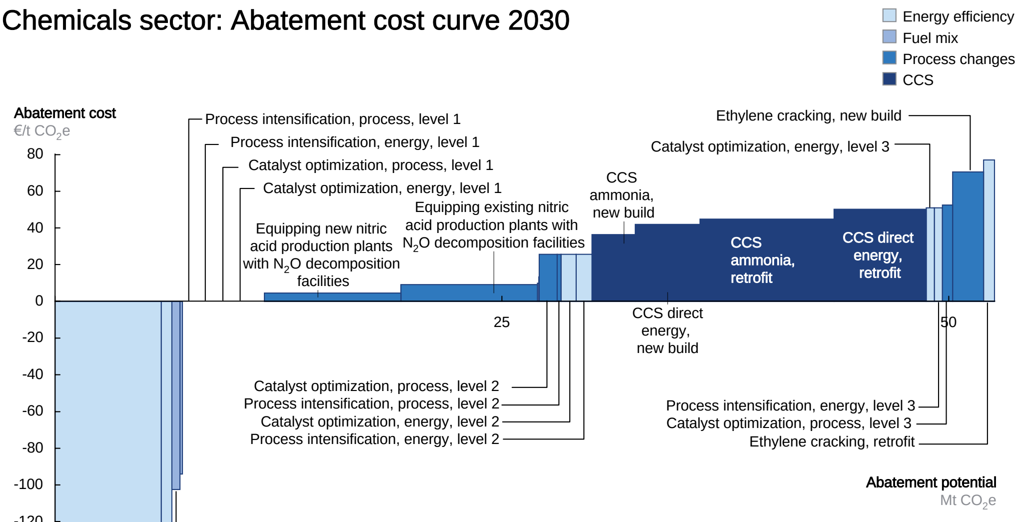
Energy consumption and greenhouse gas emissions by the chemicals sector



SOURCE: McKinsey

EXHIBIT 10

Chemicals sector: Abatement cost curve 2030



Metric	2030 value
Total sector abatement potential	53 Mt CO_2e
Proportion of Russian total abatement	4%
Abatement from money-saving measures	12 Mt CO_2e
Economically attractive share of sector abatement	23%

SOURCE: McKinsey

OVERCOMING OBSTACLES FOR IMPLEMENTATION IS MOSTLY A QUESTION OF ECONOMICS

Decision-makers are private companies. Since many measures would require investments without financial saving, decision-makers could not be expected to implement these measures without financial support or regulatory mandates. These need not be only related to greenhouse gases. For example, in the interest of reducing pollution, the government might support/subsidize certain measures that are costly to implement, e.g. filtering measures to reduce N_2O emissions, since N_2O, like other forms of NO_x, causes ozone depletion and can also be harmful to humans.

Measures that are profitable overall, such as installation of efficient equipment, might also not get implemented on account of the high upfront investment required, which decision-makers with a short planning horizon may opt to avoid. Here Joint-Implementation (JI) projects or similar mechanisms might be potentially useful ways to help with the financing of these improvements. Alternatively, especially for the implementation of energy efficiency improvements, targeted loans could provide financial support.

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To summarize, the chemical industry provides a broad variety of opportunities to abate greenhouse gas emissions. Implementing all the identified measures would reduce greenhouse gas emissions by more than 50% in 2030 compared to the reference case, but only a quarter of the energy consumption. Overcoming substantial implementation barries is mostly a question of economics. The Joint-Implementation mechanism, for example, could provide external financing for projects.

Cement

Cement production in Russia today is still lower than in the early 1990s, when Russia was one of the leading cement producers in the world. However, the sector is now growing rapidly again. By 2030, both energy consumption and greenhouse gas emissions are expected to roughly double, starting from a current share of 2% of Russia's total. Seven improvement opportunities have been indentified, with the largest contribution coming from the substitution of clinker in the calcination process – a measure which would be highly profitable for cement producers.

General sector information (2008)		
Share of Russian GDP	0.3%	
Energy consumption		
(Mtce and share of total Russia)		
• 2005	16	(1.7%)
• 2030 Reference case	31	(2.3%)
Energy savings from identified emission reduction measures		
(Mtce and share of 2030 reference case)		
• With positive return	2.0	(6%)
• All measures	2.2	(7%)
Emissions		
(Mt CO_2e and share of total Russia)		
• 2005	40	(1.9%)
• 2030 Reference case	95	(3.2%)
Emission reduction potential		
(Mt CO_2e and share of 2030 reference case)		
• With positive return	16	(17%)
• All measures	17	(18%)

RUSSIAN CEMENT – A RAPID GROWTH INDUSTRY UNTIL THE CRISIS, BUT WITH TWICE THE ENERGY USE OF CHINA

The cement industry in 2005 consumed 16 Mtce of primary energy, almost 2% of the total primary energy consumption in Russia. The sector was responsible for 40 Mt CO_2e, or 2% of Russia's total greenhouse gas emissions in 2005, with CO_2 being the only greenhouse gas emitted in the sector.

As cement is one of the main materials used in construction, its production has been increasing by more than 9% annually over the period 2000-2007, along with the growth of the construction industry. This has resulted in an 83% increase in emissions from the sector.

The main source of CO_2 emissions in the sector is the production of clinker, the main component of cement. The majority of the sector's emissions – 55% in total – occur in the process called calcination, where calcium-rich materials are heated, producing lime and emitting CO_2 as a by-product.

Energy consumption is the source of the remaining emissions, with fossil fuels combusted in industrial kilns accounting for 90% of total primary energy use (83% gas, 6% coal) and 40% of the sector's emissions. Compared to other countries, Russian cement production is far less efficient, consuming roughly 50% more primary energy per tonne of cement produced than in Germany and twice as much as in China.

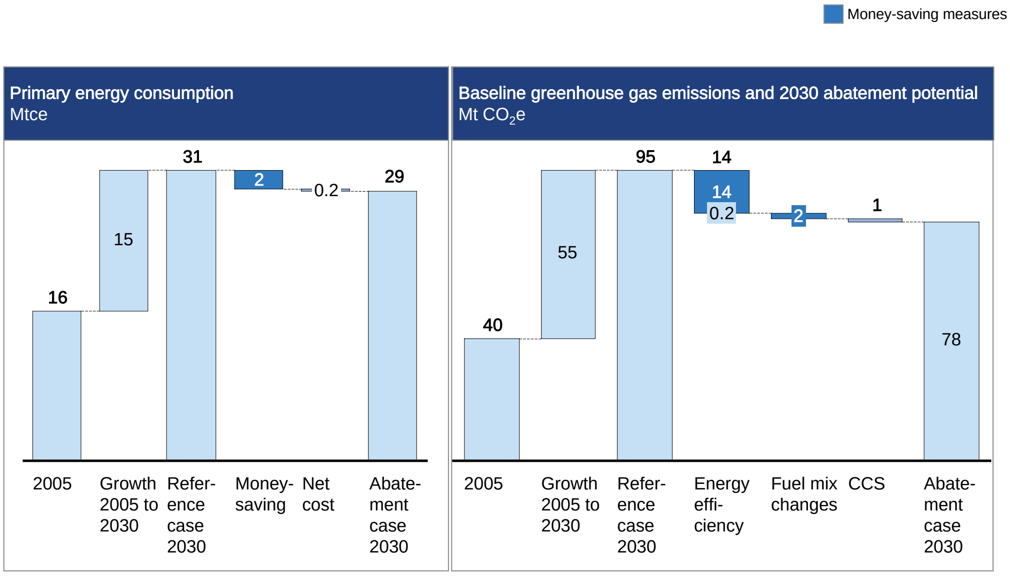
REFERENCE CASE: WITH CEMENT PRODUCTION GROWING BY 147%, ENERGY CONSUMPTION AND EMISSIONS ARE EXPECTED TO GROW BY 90% AND 136%, RESPECTIVELY

The reference case assumes that, after the current economic crisis, the cement industry will continue growing at an average rate of 5% per year as the nation builds homes and infrastructure. Already in the reference case, there will be a trend towards the substitution of carbon-heavy clinker with no-carbon materials, and towards producing clinker with lower-emission intensive, dry technology (from a share below 1% in 2005 to 20% in 2020). So while production is expected to increase by 147% by 2030, energy consumption is expected to grow by 90%, to the amount of 31 Mtce. Greenhouse gas emissions in the reference case are expected to rise by only 136%, to 95 Mt CO_2e, or about 3% of Russia's total emissions in 2030.

OPPORTUNITIES EXIST FOR REDUCING ENERGY CONSUMPTION BY 7% AND GREENHOUSE GAS EMISSIONS BY 18%, WITH CLINKER SUBSTITUTION PROVIDING THE LARGEST OPPORTUNITY

EXHIBIT 11

Energy consumption and greenhouse gas emissions by the cement sector



SOURCE: McKinsey

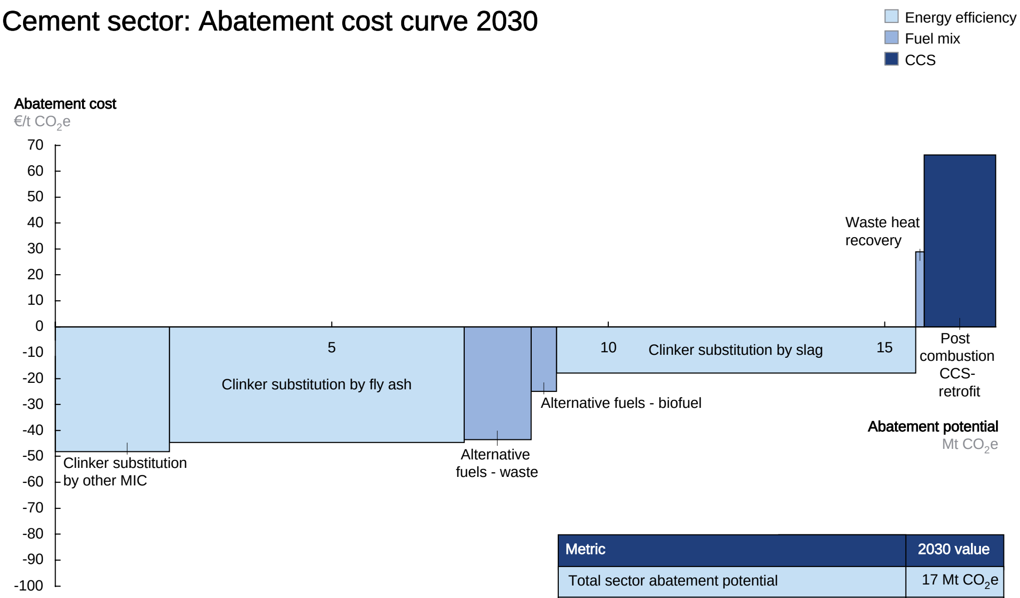
Five money-saving abatement measures have been identified, reducing emissions by 16 Mt CO_2e, which is 93% of the total abatement potential of the sector. These measures would bring cumulative savings of €3 bn through 2030, while reducing energy consumption by 2 Mtce, or 6% of the primary energy consumed in the sector (Exhibits 11 and 12).

The largest opportunity identified (about 80% of the total abatement potential for the sector, and a more than 90% of the energy efficiency improvement) is the replacement of clinker with various substitutes, such as slag, fly ash and other mineral ingredients. If in the reference case, substitute materials account for 16% of the cement compound, in the abatement case 30% is substituted. The substitute materials are by-products of industrial processes (for example, from smelting ore) and do not cause additional CO_2 emissions. Reducing the volume of clinker produced would avoid both emissions from the calcination process and from the fuel used to burn calcium materials in kilns. This measure, which is already widely implemented in countries such as Germany, would save €110 m in annual operational costs (mainly fuel costs) and avoid additional capital investments of €5 bn that would be required to construct new clinker production facilities to satisfy the increasing demand for cement over the next 20 years.

Remaining abatement opportunities come from replacing fossil fuels burned in industrial kilns with waste and biomass, using the heat generated from the clinker burning process for electricity generation, and installing CCS systems in cement plants to capture CO_2 during calcination and fuel combustion. Implementing these measures would abate an additional 3 Mt CO_2e. Whereas using alternative fuels would pay for itself, other measures are estimated to be costly, and would thus require additional incentives to get implemented.

EXHIBIT 12

Cement sector: Abatement cost curve 2030



Metric	2030 value
Total sector abatement potential	17 Mt CO_2e
Proportion of Russian total abatement	1%
Abatement from money-saving measures	16 Mt CO_2e
Economically attractive share of sector abatement	92%

SOURCE: McKinsey

TO CAPTURE ENERGY AND EMISSION BENEFITS IN CEMENT, MATERIAL SUPPLIERS NEED TO RAISE THE QUALITY OF CURRENT MATERIALS AVAILABLE TO SUBSTITUTE CLINKER

Decision-makers are private companies, some of which have already started implementing energy saving measures such as partial clinker substitution. However, the reason why the substitution measure is not implemented at benchmark levels, and why the measure is not included in the reference case, is because today substitution materials, especially slag, are not available in sufficiently high quality. Producers of substitution materials first would have to take specific steps to generate these by-products in a quality that would be adequate for cement production.

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To summarize, both energy consumption and greenhouse gas emissions in the Russian cement industry are expected to roughly double over the next two decades, following a rapid anticipated growth in cement production of 5% per year. Implementing clinker substitution and other measures that were identified could mitigate this increase in energy consumption and in emissions, while resulting at the same time in cumulative savings of €8 bn through 2030, including about €5 bn in the amount of capital investments that would otherwise be required over the same period.

4.4 Road transport

Though still relatively small today, Russia's rapidly growing road transport sector will become increasingly more important in terms of energy consumption and CO_2 emissions. Without dedicated abatement measures, both emissions and fuel consumption are projected to more than double from 2005 to 2030, thanks to a 3.5% average annual increase in vehicles on the road. Changes to the fuel efficiency and the share of alternative fuels used in new cars to be bought in the future could reduce total energy consumption by 14% and emissions by 24% in 2030, compared to the case without dedicated abatement measures. More than 90% of energy reduction and 60% of emissions abatement potential would be money-saving, as fuel savings over the lifetime of the vehicles would exceed the higher upfront investment cost.

Energy consumption		
(Mtce and share of total Russia)		
• 2005	91	(10%)
• 2030 Reference case	206	(16%)
Energy savings from identified emission reduction measures		
(Mtce and share of 2030 reference case)		
• With positive return	27	(13%)
• All measures	29	(14%)
Emissions		
(Mt CO_2e and share of total Russia)		
• 2005	140	(7%)
• 2030 Reference case	332	(11%)
Emission reduction potential		
(Mt CO_2e and share of 2030 reference case)		
• With positive return	50	(15%)
• All measures	80	(24%)

ROAD TRANSPORT IS RUSSIA'S FASTEST-GROWING SECTOR APPROACHING GERMANY IN SIZE

The road transportation sector includes three types of vehicles: light-duty vehicles (LDVs), medium-duty vehicles (MDVs), and heavy duty vehicles (HDVs).[3] LDVs are passenger cars and light trucks, which are mostly owned privately, while MDVs and HDVs are usually trucks owned by commercial enterprises. In 2008, there were 34 million LDVs and 3 million MDVs and HDVs in Russia.

With the rapid growth of the GDP and disposable income, the Russian passenger car market has become the second largest in Europe and one of the fastest growing markets in the world. The number of new passenger cars sold in 2008 reached 2.8 million, just 10% below the number for Germany, growing at an average of 20% per year in 2004-2008, with an increase in LDVs from 26 to 34 million over the same period, or 7% p.a. Along with this increase in sales, the market structure has also changed – the share of domestic brand cars dropped from 80% in 2004 to 20% in 2008.

Rapid growth in the construction industry and in the consumer goods sector has led to an increase in the sales of medium and heavy trucks. Over the period 2004-2008 the truck market grew by 17% per year, reaching 155,000 units by 2008, making Russia the largest truck market in Europe, with 40% higher sales than in Germany. The market is still dominated by domestic-brand vehicles (70% in the case of MDVs and 55% for HDVs), despite their 15-20% lower fuel efficiency against European benchmarks: this disadvantage is outweighed by lower purchase prices and lower maintenance costs for Russian vehicles.

In 2005, the road transport sector consumed 91 Mtce of primary energy, corresponding to 10% of the total primary energy consumption in Russia[4], and emitted 140 Mt CO_2e,

3 LDVs – passenger cars or commercial vehicles of up to 3.5 tonnes gross weight; MDVs – trucks of 3.5-16 tonnes; HDVs – trucks of more than 16 tonnes. Buses were not considered in the analysis.

4 Primary energy is taken to include oil and oil condensate used in refineries for the production of gasoline and diesel.

or 7% of Russia's total emissions. Approximately 60% of emissions came from gasoline-fueled vehicles (mainly, passenger cars and light trucks) and 40% from diesel-fueled vehicles (mainly MDVs and HDVs).

REFERENCE CASE: NUMBER OF VEHICLES, ENERGY CONSUMPTION AND EMISSIONS WILL MORE THAN DOUBLE BY 2030

The LDV fleet is forecast to grow by 140% over the period 2005-2030, or 3.5% p.a., reaching 72 million vehicles by 2030. For passenger cars this would mean a penetration rate of 480 cars per 1,000 people by 2030, about the same as in the US today and 10% more than today's penetration in Germany. The combined MDV and HDV fleet will grow by 120%, or 3.2% p.a., to about 6 million vehicles in 2030.

In the reference case some modernization of vehicles with technological improvements is already assumed, leading to an increase of average fuel efficiency by 13% for LDVs, 11% for MDVs and 13% for HDVs. For LDVs, a 15% increase in annual mileage is also assumed, from 13,000 to 15,000 km annually (compare the case in the US and Canada where annual mileage is already 19,000 km per year today). In addition, an increase in the share of diesel LDVs from around 1% today to 10% in 2030 is assumed, although no use of alternative fuels, such as bioethanol, is assumed. According to the reference case, then, energy consumption and emissions are expected to grow by roughly 126% and 137%, and reach 206 Mtce and 332 Mt CO_2e by 2030, respectively. Penetration of hybrid vehicles is assumed at a level of 0.3% by 2030, or 1 hybrid car per 300 people on average.

OPPORTUNITIES EXIST TO REDUCE ENERGY CONSUMPTION BY 14% AND EMISSIONS BY 24% THROUGH VEHICLE EFFICIENCY IMPROVEMENTS AND USE OF BIOFUEL

The implementation of abatement measures with a cost below €80 per tonne of CO_2e would decrease primary energy consumption in the transport sector by 29 Mtce (14% of the reference case) and reduce CO_2 emissions by 80 Mt (24% of the reference case for 2030 emissions). Abatement measures fall into two major groups: increasing the fuel efficiency of vehicles and using alternative fuel (Exhibits 1 and 2).

- **Increasing vehicle fuel efficiency.** Fuel efficiency measures could save 29 Mtce of primary energy and abate 55 Mt CO_2e, or 69% of the total abatement potential in the transport sector. Fuel efficiency could be increased by a wide range of technological improvements to conventional vehicles with internal combustion engines, such as reducing vehicle weight, improving aerodynamics, improving the efficiency of internal combustion engines, and automatically monitoring tire pressure (Exhibit 3).

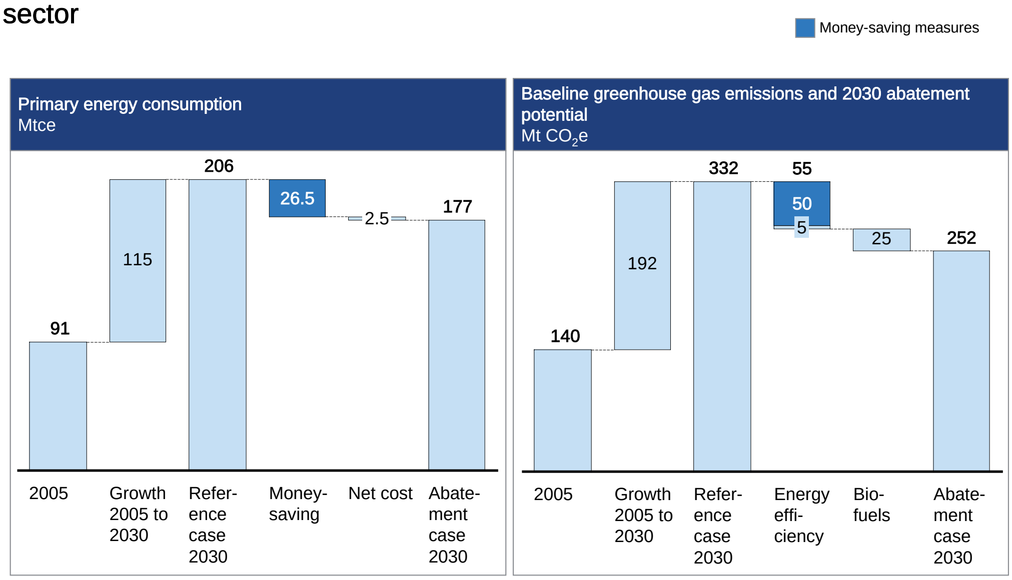
  McKinsey's collaborative work with automobile manufacturers suggests that these measures could reduce the fuel consumption of an average mid-sized passenger car by 35-40% on top of the efficiency improvements included in the reference case. In addition to that, the introduction of hybrid vehicles[5] could reduce fuel consumption by a further 5-10%. Money-saving fuel efficiency measures would reduce energy consumption by 26.5 Mtce and abate 50 Mt CO_2 of emissions. All profitable fuel efficiency measures apply to LDVs, while for MDVs and HDVs fuel efficiency is considered the key buying criterion for business decision-makers. For this reason

5 Full hybrid vehicles have a conventional internal combustion engine plus an electric engine that runs on a battery that is charged by the drive cycle of the car only (e.g., by braking).

economically attractive efficiency measures for trucks are already included in the reference case. Nevertheless, net-cost fuel efficiency measures could contribute to reductions of 2.6 Mtce primary energy use and 4.5 Mt of CO_2 emissions.

EXHIBIT 1

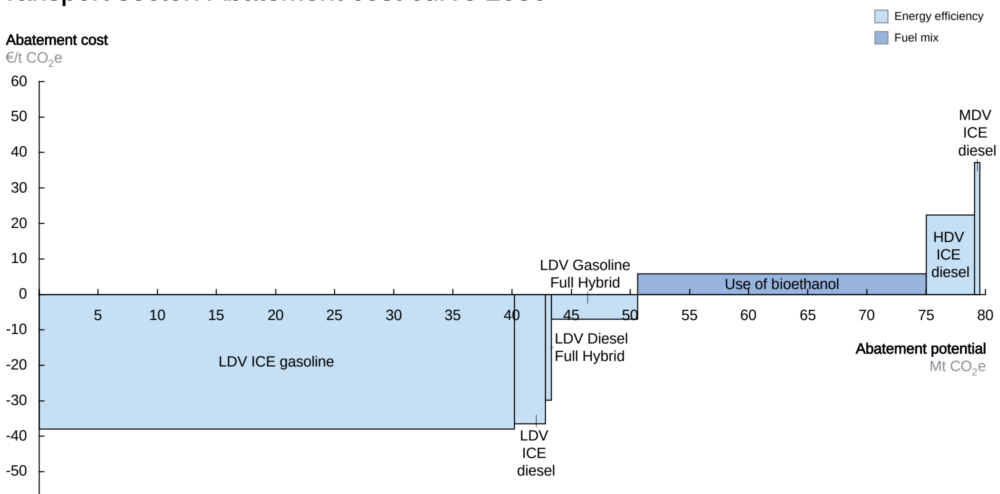
Energy consumption and greenhouse gas emissions by the road transport sector



SOURCE: McKinsey

EXHIBIT 2

Transport sector: Abatement cost curve 2030



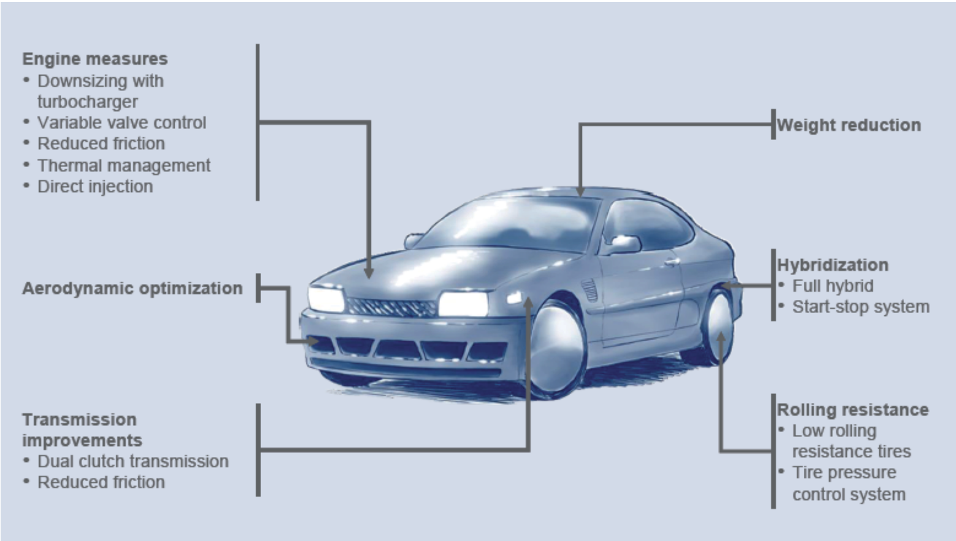
Metric	2030 value
Total sector abatement potential	80 Mt CO_2e
Proportion of Russian total abatement	5%
Abatement from money-saving measures	50 Mt CO_2e
Economically attractive share of sector abatement	63%

SOURCE: McKinsey

- **Use of alternative fuel types.** The overall abatement potential for this category is 25 Mt CO_2e, at a net cost to society. Bioethanol would be the most likely choice of an alternative fuel. In Russia this could be made out of domestically grown corn, wheat, sugar beets, and wood (lignocellulosic biofuel). This measure assumes that by 2030 Russia will use about 15 million liters of bioethanol, corresponding to 15% share of bioethanol in the gasoline-bioethanol mix.

EXHIBIT 3

Examples of energy efficiency opportunities in Road Transport sector



SOURCE: McKinsey

OVERCOMING IMPLEMENTATION BARRIERS WILL REQUIRE CHANGES IN CONSUMER BEHAVIOR AND IN TAX POLICY

The extent to which technologies will be developed to reduce emissions and energy consumption, will largely depend on decisions made in other countries, since Russia today has few local brands and no strong R&D capacity in the automotive sector that could drive large-scale changes in vehicle technology in the near future. The availability of more efficient gasoline and diesel-powered vehicles will in all likelihood be driven by anticipated EU regulations on the maximum allowed average of CO_2 emissions per kilometer for vehicles overall. However, even in the abatement case, we assume that Russia will lag five years behind the levels required by potential global regulations on road transport, as was the case with the implementation of Euro-exhaust norms.

The extent to which these measures will be implemented in different countries largely depends on the actions of individual governments to overcome the reticence of decision-makers to change. For example, the UK ties vehicle sales tax and annual licensing fees to CO_2 emission levels, while the US and Germany plan to offer tax rebates of €2,000 or direct subsidies of up to €3,000 for purchases of hybrid and electric cars. If executed properly, such support has the potential to stimulate the purchase of hybrid or electric vehicles, replacing older, inefficient vehicles and reducing primary energy consumption and emissions in the transport sector. Further implementation obstacles include:

- **Consumer preferences and non-rational economics**
  Many factors influence decisions to buy a new car, including brand, price, driving performance, design, and durability. Thus, fuel consumption is usually only one of several factors affecting consumers when deciding about the purchase of a new car. In addition, consumers do not usually make thorough calculations, nor do they compare the economics of various vehicles. When they do so, they often overestimate the upfront investments compared with the lifetime savings. Besides, many people tend to exchange their cars early in the life cycle, before any investment in improvements has been recouped. Government could act, for example, to inform the consumer more about vehicle economics.

- **Market imperfections**
  The observed behavior on the part of the consumer means that manufacturers cannot assume that buyers will be willing to pay the extra price for fuel saving options. Therefore, at least some fuel-saving options will not be offered by manufacturers. Government can set a goal at least for its own fleet, and that of its subsidiary companies, which could make such options interesting for manufacturers.

- **Taxation of fuel ethanol in Russia**
  In most countries, highly purified drinking quality ethyl alcohol is tightly regulated and highly taxed, while twice-distilled fuel ethanol (“fuel alcohol”) production is not regulated, nor taxed. In Russia, however, both are treated equally for the purposes of taxation. As a result, no significant bioethanol projects have emerged in Russia, despite the ready availability of land, biomass and technological solutions. A change in the tax regime could stimulate this type of production.

□ □ □

To summarize, road transport is the fastest growing sector among all those analyzed, reaching a 16% share of primary energy consumption and an 11% share of Russia’s total greenhouse gas emissions by 2030. The energy efficiency and biofuel measures that have been identified could reduce energy consumption and greenhouse gas emissions substantially. For each of these groups of measures, however, there are different uncertainties with respect to their implementation. Development of fuel efficient cars is largely dependent upon research and development activities outside of Russia, and driven by global climate change regulations, volatility in the oil price, and changes in consumer behavior. Fuel mix changes that favor biofuels, on the other hand, will be driven by the political decisions of national regulators.

4.5 Forestry[6]

In Russia, which has the most expansive forests in the world, a large amount of emissions are absorbed every year by growing trees. However, maturing trees and increased logging will reduce this trend and could even make Russian forests a net source of CO_2 emissions by around 2025. Measures identified in forestry make up the largest overall CO_2 abatement opportunity identified in this study. If all abatement opportunities were implemented, then by 2030 these would absorb about 8% of total Russian emissions. However, all the measures involve costs for each tonne of CO_2 abated.

Emissions

• 2005	-221 Mt CO_2e

Russian forests are a so-called "net carbon sink", i.e., they absorb more CO_2 than they emit.

• 2030 Reference case	0 Mt CO_2e

Emission reduction potential

• With positive return	-
• All measures 2030	228 Mt CO_2e

RUSSIAN FORESTS – THE LARGEST IN THE WORLD – ABSORB 10% OF THE COUNTRY'S EMISSIONS, BUT THE RATE IS SLOWING

Russian forests are the largest in the world, covering an area of 809 million hectares. A total of 164 Gt of CO_2e are contained in the biomass that makes up these forests – three times more than is emitted in the whole world every year. Russian forests continue growing and absorbing carbon from the atmosphere, thus serving as a so-called "net carbon sink". In 2005 Russian forests absorbed 221 Mt, or 10% of total non-LULUCF emissions.

Carbon sequestration rates diminish as forests mature. High logging in Soviet times and substantial reduction in timber harvesting in the 1990s established large areas of relatively young forests, which today absorb carbon at a fast rate. Maturing of those forests will reduce carbon sequestration rates in the future and might thereby lead to higher emissions. In addition, increased logging is expected. Therefore, the annual amount of carbon absorbed by Russian forests is expected to decline in the coming years, possibly turning Russian forest into a net emitter of carbon by 2025[7]. The same two factors have already caused forests in Canada to become a net source of carbon emissions today.

NO REFERENCE CASE FORECASTED DUE TO LACK OF ROBUST MEASUREMENT SYSTEM

One of the important questions with respect to greenhouse gas emission and carbon sequestration is how to account for natural exchange of carbon between plants and the atmosphere. No such measurement system exists today, and for this reason Russia is assumed in the reference case to be neither a carbon sink nor an emission sourse, on net.

6 Forestry emissions are part of the emissions category "Land use, land use change, and forestry" (LULUCF), which also includes cropland and grassland emissions.

7 World Resources Institute: "Carbon Inventory and Mitigation Potential of the Russian Forest and Land Base".

OPPORTUNITIES EXIST TO ABATE 228 MT CO_2 OF EMISSIONS: AFFORESTATION OF ABANDONED AGRICULTURAL LAND WILL MAKE THE LARGEST CONTRIBUTION

Four measures have been identified that would reduce CO_2 emissions; furthermore, the cost would be €4–12 per tonne of CO_2 abated. All measures relate to the planting of new trees. If fully implemented, these measures would result in an abatement of 228 Mt CO_2 – 8% of total Russian emissions in the reference case for 2030 (Exhibit 1). This makes forestry a sector whose abatement potential is on par with power generation or industry.

The **four opportunities** are:

- **Afforestation of abandoned cropland** is the second biggest of all abatement measures identified for Russia (exceeded only by the country's program for investment in nuclear power plants in terms of CO_2 reduction potential). Afforestation of 17.6 million hectares of abandoned cropland will create a carbon sink capable of absorbing an additional 88 Mt CO_2 in 2030, with plantation costs of €200 per hectare (or €12 per tonne of CO_2e abated in 2030 if opportunity cost of land is accounted for). Cumulative cash outlays are thus estimated at €3.5 bn for the 2010-2030 period.

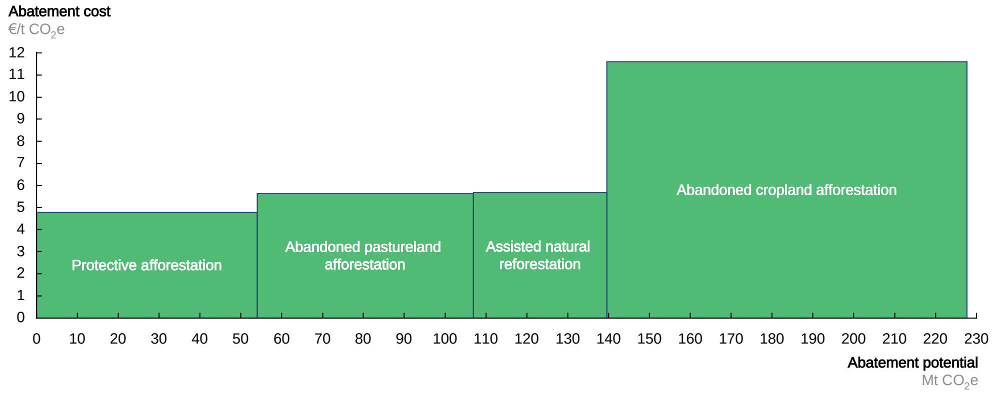
- **Protective afforestation** is the second largest measure in the forestry sector. This could reduce emissions by 54 Mt CO_2, with a cost of €5 per tonne abated. Protective afforestation involves the planting of trees on agricultural land to improve the fertility of cropland and, as such, it has a positive external effect on agriculture. The additional revenues from improved productivity, if accounted for, might lower the net implementation cost of this measure. Overall plantation cost over the 2010-2030 period will not exceed €2.5 bn.

- **Afforestation of abandoned pastureland** involves plantation of forest carbon sinks over previously used but currently abandoned pastureland. This measure is similar to afforestation of abandoned cropland in terms of tree plantation cost, but assumes significantly lower opportunity cost of land. Overall capital expenditure on plantation of trees over the considered period will sum up to €1.8 bn.

- **Assisted natural reforestation** involves plantation of forest carbon sinks over former forestry land and thus does not lead to land use change as opposed to the other measures. It refers to areas that can only be reforested with additional silvicultural effort, such as planting trees. Plantation costs are assumed at the level similar to that of the other measures, while there is no opportunity cost of land. Nevertheless, overall cost per tonne of abatement still slightly exceeds that of abandoned cropland reforestation due to assumed lower carbon sequestration rates. Required cash expenditures over 2010-2030 are estimated at €1.7 bn.

EXHIBIT 1

Forestry sector: Abatement cost curve 2030



Metric	2030 value
Total sector abatement potential	228 Mt CO_2e
Proportion of Russian total abatement	16%
Abatement from money-saving measures	-
Economically attractive share of sector abatement	-

SOURCE: McKinsey

IMPLEMENTING THE MEASURES REQUIRES FUNDING, INFORMATION AND ORGANAZING A MASSIVE PLANTING EFFORT. FUNDING IS THE MAIN SUPPORTING MEASURE

The decision-makers in forestry include not only government but also former state and collective farms, forestry agencies and millions of people who live in the countryside or in towns and cultivate the land or raise cattle. The organisation of a massive planting effort would involve all such land occupants and would create up to 50,000 jobs in rural areas. Information would be a critical tool in advancing this effort.

Furthermore, implementation of the identified forestry measures would require external funding. As the JI project mechanism is typically not available for forestry projects, the most likely source of funding could be programs financed by the central or regional Russian governments to support afforestation to reach certain national emissions reduction targets, or to increase agricultural soil fertility. To get credits for emissions reduction it is necessary to create a robust international system to track forestation and agriculture measures. It would benefit Russia to contribute to the establishment of such a system, as it would allow Russia to take credit, for example, for the carbon sinks that forestation opportunities in the country provide.

□ □ □

To summarize, opportunities to reduce greenhouse gas emissions in the forestry sector are large, making up 8% of the total reference case for Russia, or about 15% of the total identified abatement potential. All the measures identified in this sector come at net costs, but at an average cost of €8/t CO_2e in 2030 are relatively inexpensive when compared to other sectors. The full implementation of the abatement measures would require significant efforts for the afforestation of 2.3 million hectares per year.

4.6 Agriculture

For the last 20 years, the use of cropland, grassland and livestock in Russia has been constantly declining, with livestock seeing the largest reduction, about 60%. In 1990, agriculture contributed 11% to Russian greenhouse gas emissions. By 2005 the absolute emission volume from agriculture had dropped by nearly two-thirds and agriculture's share of emissions to only 6%. About half of today's emissions are direct and indirect soil emissions of N_2O gas, mostly originating from the use of fertilizers. By 2030 emissions are expected to grow again by about 30%, unless dedicated steps are taken to reduce this growth. Twelve potential measures have been identified which would reduce greenhouse gases emissions by about 90%. About a quarter of the potential would come from money-saving measures, while the others would incur abatement costs.

General sector information (2005)		
• Share of Russian GDP	>6%	
Emissions (2005)		
(Mt CO_2e and share of total Russia)		
• 2005	130	(6%)
• 2030 Reference case	165	(5.5%)
Emission reduction potential		
(Mt CO_2e and share of 2030 reference case)		
• With positive return	40	(24%)
• All measures	149	(90%)

RUSSIAN AGRICULTURE – A SECTOR OF CONTINOUS DECLINE THAT ONLY RECENTLY SAW RENEWED INVESTMENT

The agricultural sector contributes 6% of Russia's greenhouse gas emissions, mostly through soil emissions. That is well below the world average of 15%, and is mainly the result of large areas being abandoned and a decline in livestock over almost 20 years. However, in 2007 the agricultural sector reversed its decline, spurred by the demand for energy, biofuels and food. While the crisis has interrupted the agricultural recovery, there are strong fundamental reasons to forecast a stronger future development for Russian agriculture.

The main sources of emissions in the sector are direct and indirect soil emissions of N_2O into the atmosphere (48%). Enteric emissions from cattle represent another 29% of overall emissions in the sector. The rest comes from indirect emissions associated with heating and power, as well as manure-related emissions.

REFERENCE CASE: TOTAL EMISSIONS FROM THE SECTOR WILL INCREASE BY ABOUT 30% BECAUSE AGRICULTURAL RECOVERY WILL BE ACCOMPANIED BY FEW IMPROVEMENTS

Given the expected increase of the underlying emission drivers – land under plough and cattle – emissions are set to increase. Furthermore, in the 2030 reference scenario, little improvement in emissions-related practicies is assumed. For money-saving measures (for example, cropland and grassland nutrient management) low penetration is assumed because of difficulties of implementation. Costly measures are assumed not to be implemented at all. As a result, total emissions are expected to increase from 130 Mt in 2005 to 165 Mt by 2030.

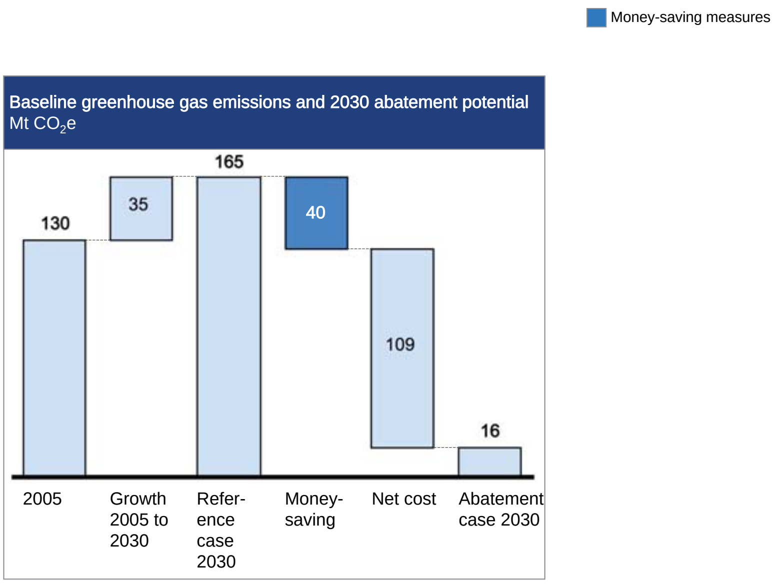
OPPORTUNITIES EXIST TO REDUCE EMISSIONS BY ALMOST 90%, AND NUTRIENT MANAGEMENT AND ORGANIC SOILS RESTORATION OFFER THE LARGEST POTENTIAL

Twelve measures with the potential to reduce greenhouse gas emissions were identified. If fully implemented, these measures would result in an abatement of 149 Mt CO_2e in 2030, or 90% of emissions in the reference scenario for the agricultural sector.

Five of the 12 measures that were identified would be economically attractive. Together, these money-saving measures account for emissions reduction of 40 Mt CO_2e, or 27% of the total abatement potential in the sector (Exhibits 1 and 2).

EXHIBIT 1

Greenhouse gas emissions by the agriculture sector



SOURCE: McKinsey

Our study found the **largest abatement opportunities** in this sector to be nutrient management, organic soils restoration and agronomic practice.

- Cropland and grassland nutrient management would reduce emissions by 23 Mt CO_2e in 2030 (about 15% of overall abatement in the sector). Nitrogen found in fertilizers, manures, biosolids, and other sources can lead to the emission of N_2O. These emissions can be reduced by various measures, including adjusting the rates at which fertilizer is applied based on a precise estimate of crop needs; using slow- or controlled-release forms of fertilizer, or using nitrification inhibitors; applying nitrogen at a time when it is least susceptible to loss; or by applying the fertilizer more carefully in the soil to facilitate ready absorption by crop roots. Implementation would lead to annual savings of €1.5 bn in 2030 by reducing fertilizer use in some areas and from an increase in crop productivity in other areas.

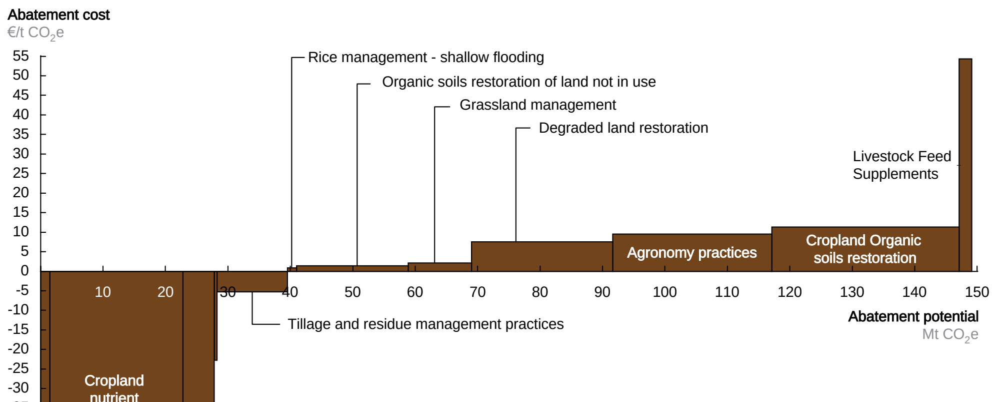
- Organic soils restoration is the biggest measure in agriculture, and would reduce emissions by 48 Mt CO_2e in 2030 (about 32% of overall abatement in the sector), of which 18 Mt is for abandoned land and 30 Mt for cropland. Organic or peaty soils contain high densities of carbon (>30 kg/m^2 of carbon accumulated over many centuries under flooded conditions in which decomposition is suppressed by the absence of oxygen). Drying of these areas over time has led to greenhouse gas emissions in the past. Therefore, restoring organic soils through flooding would stop these emissions and can lead to new rates of absorption.[8] The total annual cost would be €0.3 bn based on an abatement cost of €27 per hectare plus an opportunity cost of €200 per hectare for cropland.

- Improved agronomic practices increase yields and generate higher inputs of carbon residue. This can lead to increased soil carbon storage and abatement of 25 Mt CO_2e in 2030 (17% of overall abatement in the sector). These practices include using improved crop varieties, extending crop rotations, and avoiding or reducing use of bare fallow. Implementation of these practices comes at an average cost of €15 per hectare per year, or €2.6 bn over the period to 2030.

Additional measures in the sector include tillage and residue management practices, grassland management degraded land restoration, and feed supplements and anti-methanogen vaccines for livestock.

EXHIBIT 2

Agriculture sector: Abatement cost curve 2030



Metric	2030 value
Total sector abatement potential	149 Mt CO_2e
Proportion of Russian total abatement	10%
Abatement from money-saving measures	40 Mt CO_2e
Economically attractive share of sector abatement	27%

SOURCE: McKinsey

8 The realization of the measure is often questioned because of the differences in the estimates and difficulties in measuring the effect. In this report, relatively conservative assumptions are used for calculating the abatement potential. Implementation will depend, in part, on making this potential measurable, reportable and verifiable.

EFFORTS TO SUPPORT IMPLEMENTATION NEED TO BE FOCUSED ON ALIGNING INCENTIVES AND CREATING AWARENESS

The dispersed set of decision-makers include agricultural enterprises (most of them former state and collective farms), as well as individual farmers and millions of people who live in the countryside or in towns and cultivate the land or raise cattle. Agricultural enterprises that cultivate more than 75% of cropland and raise almost 50% of cattle have few incentives and lack equipment and funds to implement new technologies and processes. Individual farmers (almost 20% of cropland and less than 5% of cattle rearing) and individuals (less than 10% of cropland and almost 50% of cattle) very often do not have enough information about new technologies and practices, apart from that some technologies are far too expensive for them to implement. Government could promote wide education campaigns targeting individuals and provide initial funding. For example, agricultural subsidies could be linked
to the implementation of emissions reduction measures. If will also be critical that the Russian government helps bring about an internationally recognized tracking and verification system that can give recognition to the measures being undertaken.

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To summarize, more than 40 Mt CO_2e of greenhouse gas abatement potential in the agriculture sector could be achieved through measures which would not require additional investments and would be money-saving overall. In addition, well over 100 Mt CO_2e can be gained at net abatement cost of €1-12 per tonne of CO_2e, but for this impact to be realized, a full range of interventions will be needed: information, financing and an internationally-accepted tracking and verification system.

Russia's land under plough – one of the largest agricultural areas in the world – turns out to be as great an asset in greenhouse gas abatement as, for example, the entire oil and gas sector.

4.7 Waste

The waste sector is the only sector in Russia where today's emissions, making up 3% of Russia's total greenhouse gases, exceed the 1990 level. The main reason for this is a sharp increase in solid waste volumes in the past decade. Also, management of this solid waste is underdeveloped in Russia, with only 3-4% being processed, while the rest is directly landfilled. Improved waste management, mainly through better recycling, could reduce emissions from the waste sector by more than 80%. Furthermore, utilization of landfill gases could be a profitable way to generate additional energy.

Emissions

(Mt CO_2e and share of total Russia)

• 2005	60	(2.8%)
• 2030 Reference case	52	(2.4%)

Emission reduction potential

(Mt CO_2e and share of 2030 reference case)

• With positive return	34	(65%)
• All measures	42	(81%)

WITH 96% OF SOLID WASTE GOING TO LOW-TECH LANDFILLS, THE SECTOR IS A LARGELY UNNECESSARY SOURCE OF GREENHOUSE GAS EMISSIONS

The waste sector is a relatively small source of greenhouse gases in Russia, being responsible for about 3% of total emissions. The main sources of these emissions are solid waste (60%) and wastewater[9] (40%).

Solid waste in landfills produces methane from the anaerobic decomposition of organic material. Emissions from solid waste are determined by the total amount of such waste that is generated and by the waste management system in place to store and control it. The total amount of waste generated in Russia has been increasing due to a significant structural shift in GDP (towards consumer-oriented products) and a surge in packaging materials, which has led to a 54% increase in solid waste emissions from 1990 to 2007.

Increases in the amount of solid waste generated have not been offset by any improvements in the waste management system, resulting in higher emissions in this sector. Only 4% of total solid waste is processed (i.e., recycled, incinerated or composted) in Russia today, as compared to 76% in Germany. The remaining 96% goes directly to landfills, but there are no landfills in Russia that are equipped with landfill gas capture systems, which means that 100% of landfill gas in Russia leaks into the atmosphere.

REFERENCE CASE: WASTE SECTOR EMISSIONS ARE EXPECTED TO FALL BY 13% AS OF 2030 DUE TO POPULATION DECLINE AND IMPROVED WASTE MANAGEMENT

Assumptions for the 2030 reference case already include some improvements in waste management, anticipating that the share of waste recycled would increase from its current level of 4% to 12% of total solid waste in 2030. Increased levels of recycling and an expected decrease in population are likely to offset any anticipated increases in waste per capita, so that the resulting 2030 waste emissions are 52 Mt, 8 Mt lower than in 2005.

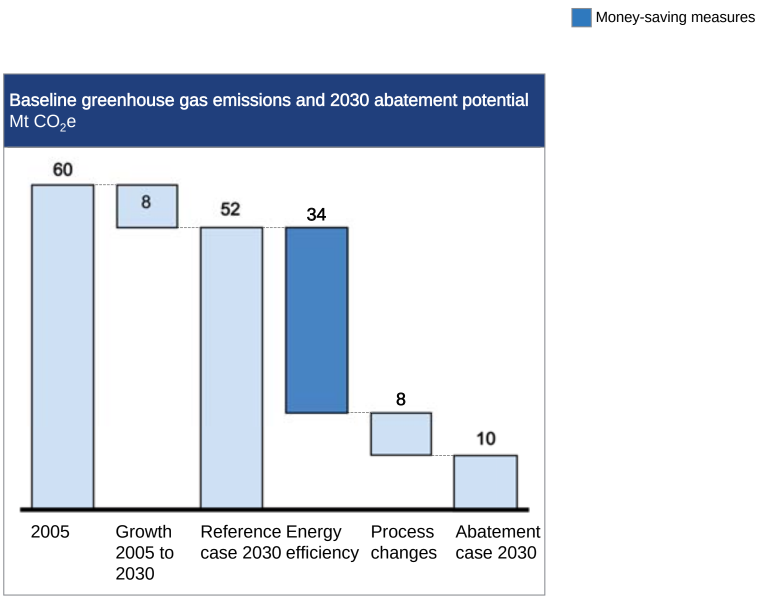
9 Wastewater produces methane through the anaerobic decomposition of organic waste from residential sewage and industrial effluents. The abatement of the greenhouse gases emitted from wastewater has not been assessed in this report due to a lack of reliable information.

OPPORTUNITIES EXIST TO REDUCE EMISSIONS BY 81% IN 2030, MAINLY THROUGH RECYCLING

Four measures with an abatement cost below €80 per tonne of CO_2 have been identified, which would reduce greenhouse gas emissions. If fully implemented, these measures would result in an abatement of 42 Mt CO_2e, equivalent to 1.4% of the country's reference case emissions. Compared to other sectors, this abatement potential is low in absolute terms, but would offer among the largest relative abatement potential across all sectors (Exhibits 1 and 2).

EXHIBIT 1

Greenhouse gas emissions by the waste sector



SOURCE: McKinsey

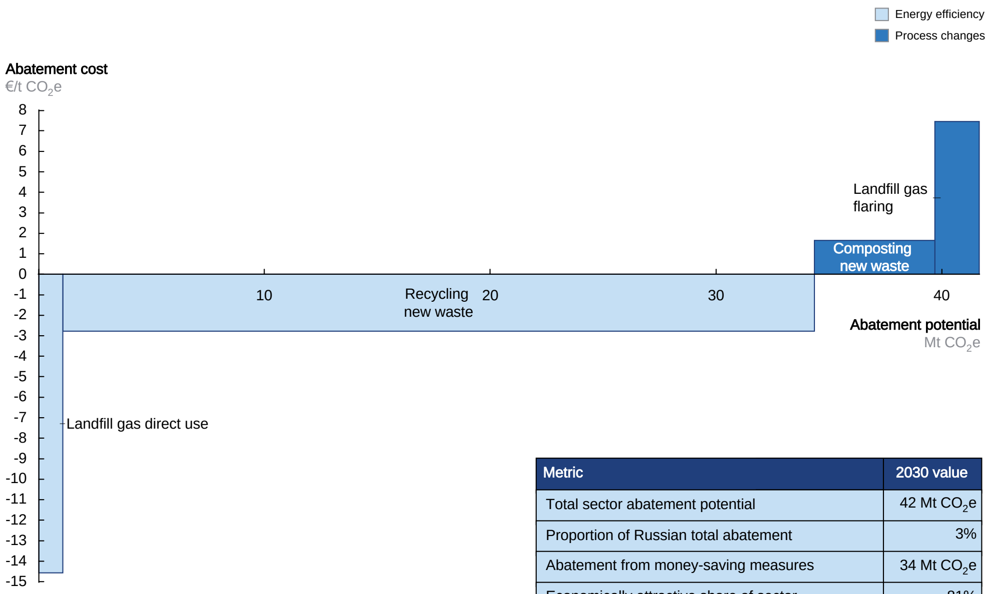
Two of these measures (recycling and landfill gas direct use) would be economically attractive, accounting for 34 Mt CO_2e, or 81% of the total abatement potential in the sector.

Recycling is the largest abatement measure in the waste sector. Its implementation could reduce annual emissions by 33 Mt in 2030 and indirectly could save about 6 Mtce of energy per year. Recycling of raw materials (like metals and paper, for example) for use as resources in new production saves energy, since production from recycled inputs requires much less energy than production using virgin resources.

Other measures include the treatment of landfill gas (to use as a direct source of energy or to flare) and composting, with a cumulative potential from these measures to abate 9 Mt in 2030.

EXHIBIT 2

Waste sector: Abatement cost curve 2030



Metric	2030 value
Total sector abatement potential	42 Mt CO_2e
Proportion of Russian total abatement	3%
Abatement from money-saving measures	34 Mt CO_2e
Economically attractive share of sector abatement	81%

SOURCE: McKinsey

IMPLEMENTING WASTE REDUCTION AND WASTE MANAGEMENT WILL REQUIRE BOTH ECONOMIC AND BEHAVIORAL STIMULUS

Like other sectors, the waste sector will require support, including funding, for the identified measures to actually be realized. In particular, actions to support and stimulate recycling and waste management could be as follows:

- Selective waste collection is a prerequisite for making recycling projects profitable for private investors. Thus, effective regulation fostering selective waste collection has to precipitate any major developments in the recycling industry.
- Educational programs to change individual behavior with regard to waste separation, recycling and composting habits.
- Making the direct land filling of waste reflect its environmental cost through better enforcement of legal requirements. Installation of landfill gas capture equipment, for example, would not only reduce direct GHG emissions at landfills, but also stimulate the recycling of waste.

□ □ □

To summarize, there are small but available and economically attractive opportunities to reduce greenhouse gas emissions in the waste sector. For example, waste recycling alone provides 81% of the total abatement potential in the sector and further promises indirect energy savings through the use of recycled goods in manufacturing. But to implement such measures both economic and behavioral stimulus will be required, which in turn would require appropriate supporting regulations.

5. Appendices

5.1 Methodology

This appendix describes the approach used to identify opportunities to save primary energy and reduce greenhouse gas emissions in Russia, determine the amount of reduction possible, and the cost per tonne of coal equivalent or tonne of CO_2e for each measure. It starts with an overview of the methodology, explains the cost curve diagram used throughout the report, and lists some of the key assumptions made.

Definition of baseline (reference case)

The reference scenario or forecast for 2030 is based on primary energy consumption in 2005 as defined by official statistics (Rosstat) and uses projections by sector in order to forecast primary energy consumption through 2030. These projections are based on internal McKinsey sectoral models (for example, a model for electricity consumption), and are complemented by basic assumptions, such as GDP growth, from a series of documents released by the Russian government (including the 2008 "Concept of long-term development of Russia to 2020" and the 2009 "Russian energy strategy to 2030"). For greenhouse gas emissions additional data from UNFCCC and McKinsey's global studies were used.

The projection makes up the so-called reference case. This scenario represents how energy consumption and emissions would likely develop without any significant changes in existing consumption patterns or legislative initiatives. As a reference case it does, however, include required replacement of infrastructure such as power plants and other technical equipment. For these replacements the reference case assumes that old technology will be replaced by current technology, meeting existing norms for new investments.

The reference case also assumes that previous legislation has been implemented (so that, for example, new buildings are equipped with heat regulation devices; or that associated gas flaring is reduced by 95% by 2012). However, the measures that will arise out of the new energy efficiency law signed by President Medvedev in the end of November 2009 are not considered to be part of the reference case.

Across the sectors, depending on their nature, we used different drivers of energy consumption growth.

- **Buildings.** The main driver for energy consumption is the increase of floor space. Russia's program for housing aims to an increase of the average floor space from 21 to 33 m^2 per person by 2020. By 2030 residential housing is expected to grow by 94%, compared to 2005, and non-residential floor space – by 56%. Counteracting this growth is the efficiency of energy use in new vs. old homes (e.g., 0.09 vs. 0.25 GCal/m^2-year for heating)
- **Industry.** The main driver for different industries is production volumes. Energy consumption is calibrated based on the forecasted mix of production technologies and replacement of old production facilities with newer ones. For example, in the iron and steel sector, the shift from less efficient OHFs to more efficient EAFs and renewal

of production equipment is expected to result in an 11% reduction of the sector's energy intensity from 0.66 tce per tonne of steel in 2005 to 0.59 tce per tonne of steel in 2030 in the reference case.

- **Power and heat.** The internal energy consumption of the sector largely depends on the end-users demand and development of power capacity in the country. We modeled in detail both demand perspective and the supply on a regional level, taking into consideration economic growth, the power consumption split between industrial and non-industrial, replacement speed of current capacity, as well as future fuel mix. Our reference case for the power sector is generally in line with the recently approved Energy Strategy 2030.
- **Transport.** The main driver for energy consumption is fleet growth - i.e. light vehicles assumed to grow by 3.5% p.a., medium and heavy vehicles by 3.2% p.a. At the same time, car fuel efficiency rises by 11-13% compared to 2005, due to technology improvements.

Identification of energy saving and abatement opportunities

To identify potential abatement opportunities, a team from McKinsey & Company's Moscow office, with the assistance of global experts, looked at a wide range of options – including renewable energy sources, new technologies, alternative production processes, afforestation, waste management, and energy efficiency measures. More than 150 opportunities were considered, and 116 measures were selected, after ruling out some as inapplicable to Russia or because they are already accounted for in the reference case for 2030 (based on existing regulation). Measures requiring new innovative technologies are included only if they meet four criteria:

- The technology is at least in the pilot stage
- The measure's technical and commercial viability in the medium term, starting by 2025 at the latest, are widely accepted
- Technological and economical challenges are well understood
- The technology is supported either by policy or industry, or is expected to lead to attractive economics

Measures that would require significant lifestyle changes are not addressed here. For example, using more energy efficient lighting is in the scope of the research, but reducing the average time that lights are on is not. Similarly, increasing the efficiency of residential heating is considered, but reducing average home temperatures in winter is not.

The energy efficiency cost curve for Russia was developed by retaining only the abatement measures from Russian greenhouse gas abatement cost curve that improve energy efficiency. This means that it does not include some energy efficiency measures that do not reduce GHG emissions or reduce GHG emissions at a cost of more than €80 per tonne of CO_2e, for example, leakages in oil pipelines, but we believe that the share of such measures is miniscule compared to the measures that are both energy efficient and reduce emissions.

Energy consumption is expressed in tones of coal equivalent (tce), which corresponds to the amount of energy released by burning one tonne of coal.[1]

1 In this report, we adopt the standard Russian definition of tonne of coal equivalent as 7.0 Gigacalories, equivalent to 873 m^3 of natural gas, 27.8 MMBtu, 0.7 toe.

How to read the energy efficiency and abatement cost curves

The different energy saving or abatement measures are ranked from lowest to highest in terms of cost, adjusted to eliminate double counting, and presented in the energy efficiency and abatement cost curves. Each bar in this curve represents one measure to save energy or reduce greenhouse gas emissions.

- Volume on the X-axis: The width of the bar represents the amount of energy (in million tonnes of coal equivalent) or emissions (in million tonnes CO_2e) that can be reduced in a certain year (2030 is most frequently chosen) through implementing the measure, irrespective of the year when the opportunity was first implemented.
- Costs on the Y-axis: The height of the bar indicates the average cost of reducing 1 tce or 1 tonne of CO_2e through this measure, as compared to the reference case.

Economically attractive measures are those that show a negative value on the Y-aix, i.e. a “negative cost” or savings. This means there is a net financial benefit on an overall societal level over the lifecycle of the reduction opportunity.

Measures with a positive value (costly measures) are ones whereby capturing the opportunity would incur incremental lifecycle costs compared to the reference case.

The potential volume of energy saved and emissions reduced in 2030 assumes concerted action starting in 2010 to capture each opportunity, and reflects the total active installed capacity of that measure in the year 2030, regardless of when that capacity has been installed. Hence, it is not a 20-year curve, but a one-year curve.

The value of the cost curve is that it creates an integrated perspective on the overall saving or reduction potential and the largest opportunities. Therefore, it can help to prioritize measures within and across sectors, and provides a fact base to support the assessment of possible regulatory measures.

The curve focuses on the potential volume and estimated cost levels, but is not a forecast of what will actually happen in the future. The cost curve does not predict the development of individual technologies and does not define any target energy consumption or emissions levels. It also does not give any measure-by-measure evaluation of the likelihood of implementation. To understand measure-specific, region-specific, and sometimes project-specific barriers to implementation, every measure still has to go through additional examination, pre-project work, design, and all related activities.

Calculation of energy saving and emission abatement volumes

Energy saving or abatement volumes represent the potential reduction of primary energy consumption or greenhouse gas emissions that can be achieved by a certain measure compared to the reference case. Since some measures can overlap in terms of their effects, the volumes are sensitive to the order of implementation. For example, since energy demand reduction initiatives in the steel industry also reduce the total amount of electricity required, they reduce the additional energy consumption and abatement potential of the power sector as well. To avoid double counting, primary energy and greenhouse gas emissions associated with certain measures are attributed to the sector where this measure is implemented. For example, reductions of power and heat consumed in buildings are attributed as “indirect emissions” to the buildings sector, despite the fact that the greenhouse gases are physically emitted by power plants. Where measures within one sector overlap, the measure with lowest abatement costs is assumed to be realized for its total potential, thus reducing the potential of all more expensive measures.

Calculation of energy saving and emission abatement costs

For each measure the abatement cost is calculated as the incremental cost of implementing the particular measure, compared to the cost of the activity that would otherwise be incurred. For the construction of new large nuclear plants, for example, the costs considered are the difference in total costs (investments and operational) between a new nuclear plant and a new gas-fired CCGT (reference case) for the same power production. Costs for a certain year (e.g., 2030) are calculated based on the operational costs or savings in this particular year, resulting from the implementation of the measure, and "annualized capital investments" – spreading the investment costs over the full lifetime of the investments, considering the weighted cost of capital.

All costs are averaged across sub-opportunities (e.g., different types of buildings), across Russian regions (which differ in fuel mix and duration of heating periods) and time of implementation. The analysis adopts an overall societal perspective, meaning that taxes and subsidies have not been taken into account, and the WACC for NPV calculations is 8% plus inflation. This perspective allows for comparisons of opportunities and costs across sectors. However, it also means that the calculated costs and benefits of an opportunity may differ from those a company or consumer would recognize, as the latter would include taxes, subsidies, and higher discount rates in their calculations.

Throughout the report, all costs are in 2005 Euro prices.

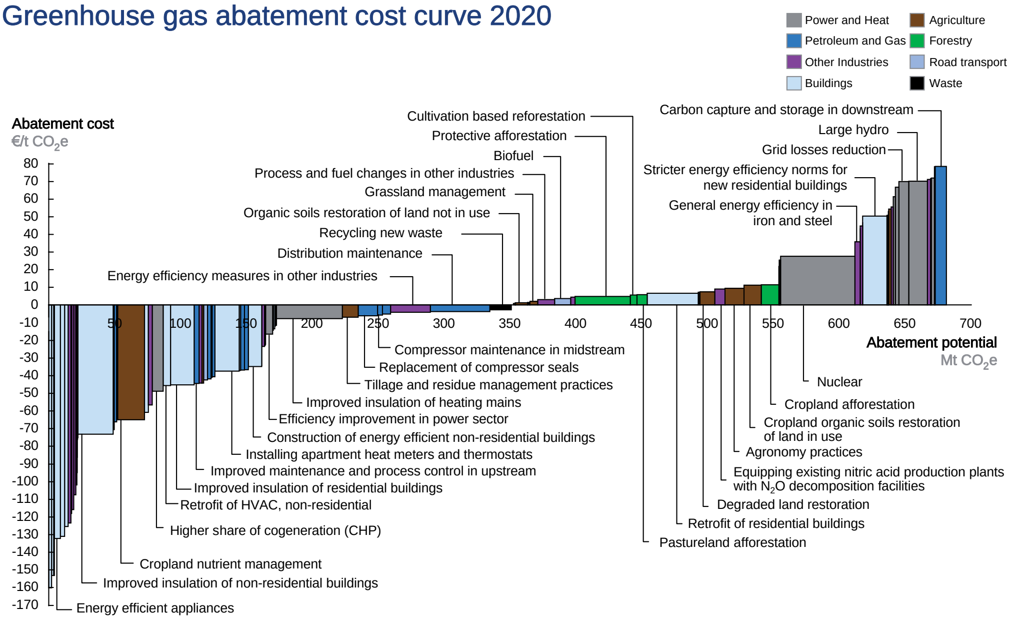
Costs for individual measures are calculated based on a series of assumptions. These assumptions are tailored to Russia and based on the insights from McKinsey's global studies and more than 20 other national studies on greenhouse gas emission reductions. Russia-specific assumptions have been made based on Russian sources and/or have been tested with Russian experts from institutes, NGOs, companies and government representatives. The cost of each opportunity also excludes transaction and program costs such as costs for research and administration.

For the savings calculations the following energy prices are assumed for the period 2010 to 2030 (all in real terms based on 2005 Euros and an exchange rate of 1.5 $/€):

- **Oil:** $60-62 per barrel, with oil prices continuing to drive the European and thereby in the future also the Russian price for natural gas.
- **Natural gas:** For gas producers €80-82 per thousand cubic meters, based on increasing marginal production costs in new gas fields. For gas consumers tariffs rise to €91-96 per thousand cubic meters assumed as "netback prices" from 2015, which are the expected European market prices, reduced by transportation costs and a 30% export duty imposed by the Russian government.
- **Electric power:** without distinguishing between commercial and residential consumers, prices of €52/MWh are assumed until 2015, with accelerated increases after 2015 up to €77/MWh in 2030, reflecting the investment costs of newly built power plants, price liberalization and introduction of return-on-asset-base tariff system in transmission and distribution.
- **District heat:** tariffs of €21-23/GCal (2010-2030) are assumed, using average production and distribution costs in Russia, rather than subsidized consumer tariffs.

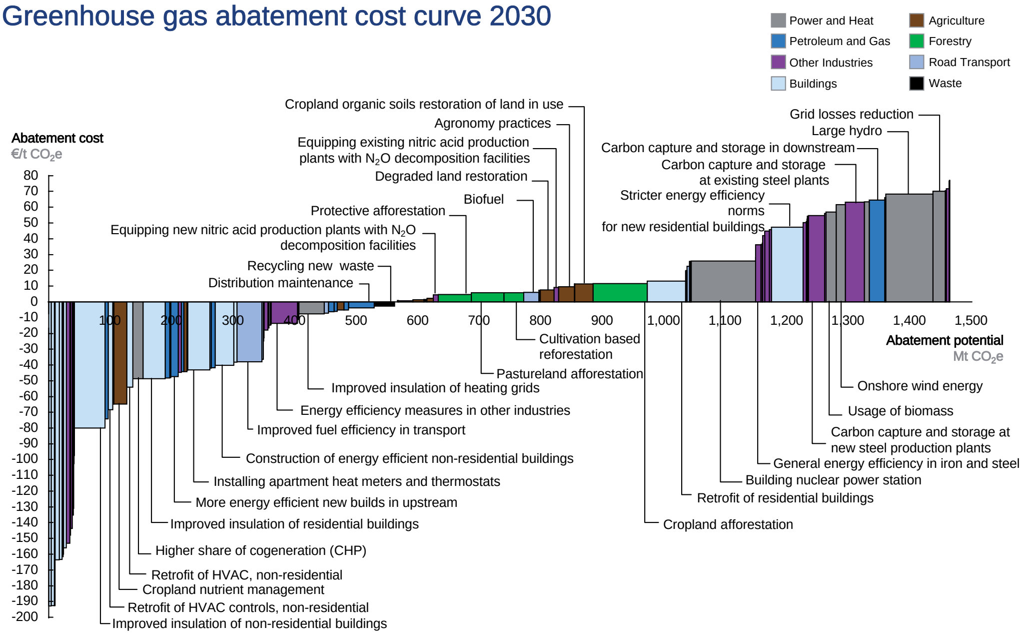
5.2 Cost curves 2020 and 2030

Greenhouse gas abatement cost curve 2020



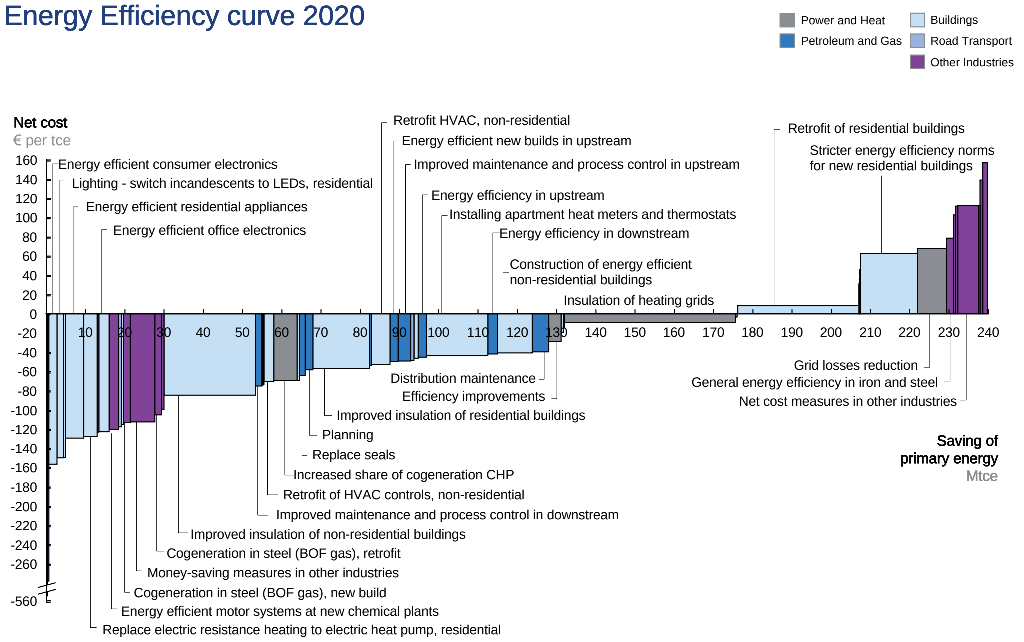
SOURCE: McKinsey

Greenhouse gas abatement cost curve 2030



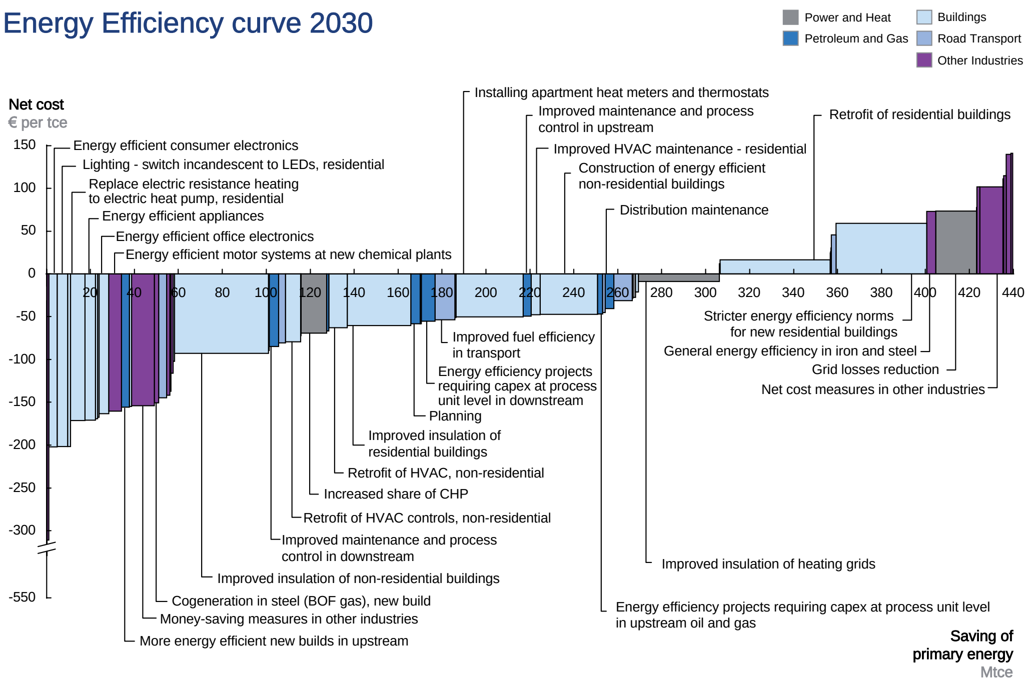
SOURCE: McKinsey

Energy Efficiency curve 2020



SOURCE: McKinsey

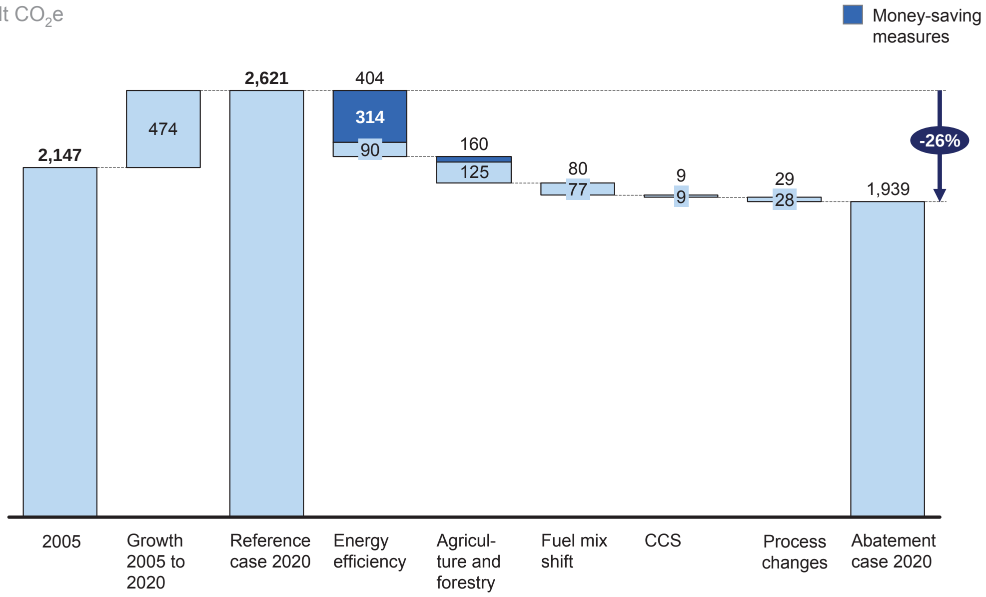
Energy Efficiency curve 2030



SOURCE: McKinsey

Russia's baseline greenhouse gas emissions and the abatement potential in 2020

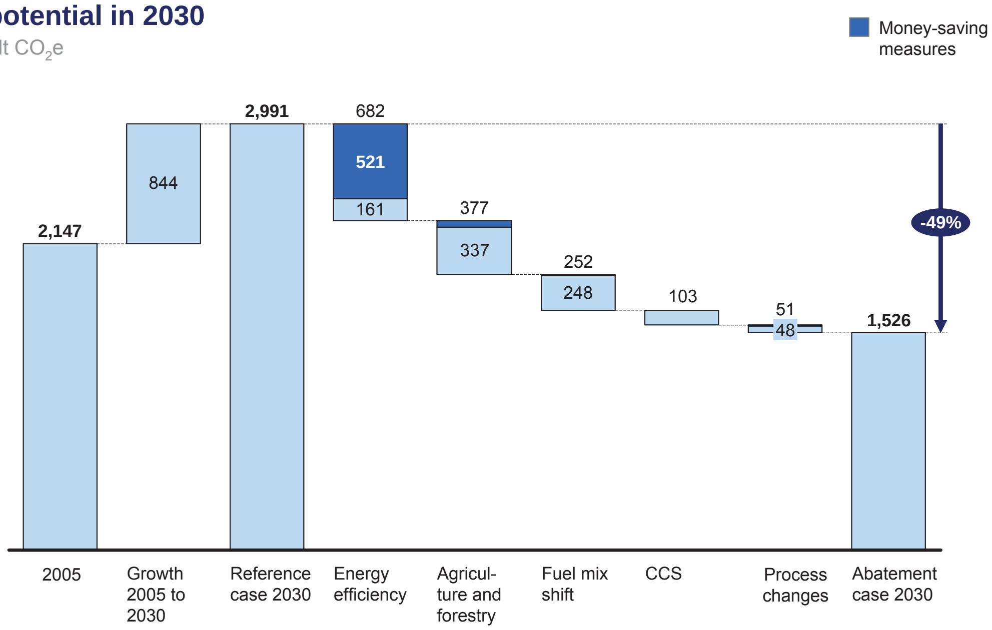
Mt CO_2e



SOURCE: McKinsey

Russia's baseline greenhouse gas emissions and the abatement potential in 2030

Mt CO_2e



SOURCE: McKinsey

5.3 Details of improvement measures

Buildings

Residential buildings

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Energy efficiency norms for new buildings	■ Housing construction with the use of the most efficient materials and technologies to achieve low energy consumption levels comparable to passive housing – Reduce demand for energy consumption through improved building design and orientation – Improve building insulation and airtightness; improve materials and construction of walls, roof, floor, and windows – Ensure usage of high efficiency HVAC and water heating systems *Assumptions:* ■ Reduce heat consumption from 0.09 GCal/m² per year (105 kWh/m²) in the reference case to 0.04 GCal/m² per year (42 kWh/m²) in the abatement case (60% reduction potential) ■ Constructing more efficient buildings requires additional cost of €21 per m² in 2030	**47.3** 59.0	**51.4** 41.2
Improved insulation	■ It includes improvement of building airtightness by sealing baseboards and other areas of air leakage, weather stripping of doors and windows, insulation of attic and wall cavities, add or fix basic mechanical ventilation system to ensure air quality *Assumptions:* ■ 20% heating savings potential at the cost of €4.6 per m² ■ 90% of buildings get better insulation by 2030 in the abatement scenario compared to 6% in the reference case	**-48.6** -60.4	**36.0** 29.0
Retrofit of buildings	■ It means retrofitting existing buildings to reduce energy consumption there to new construction norms. The measure includes installation of high efficiency windows and doors; increasing outer wall, roof, and basement ceiling insulation; installing mechanical ventilation with heat recovery *Assumptions:* ■ Energy consumption level observed in buildings currently constructed in Russia (105 kWh/m², or 0.09 GCal/m² per year – 58% energy saving potential is reached). The average cost is €45 per m² in 2030 ■ 70% of buildings are retrofitted by 2030 compared to 6% in the reference case	**13.3** 16.5	**62.3** 50.2

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Retrofit HVAC	■ Replacement of current gas/oil furnaces or boilers when expired with the highest efficiency models ■ Replacement of current air conditioning unit when expired with highest efficiency model ■ Reduction of energy consumption from HVAC and AC through improved maintenance (e.g., new air filters) *Assumptions*: ■ For standard gas/oil heaters, up to 19% savings potential from improved technology and proper sizing ■ For HVAC maintenance, total 15% savings from proper duct insulation and proper maintenance ■ AC penetration rate in 2030 is 30% ■ €500 premium for high efficiency gas/oil model that covers 150 m² house/flat ■ €500 premium for a high efficiency AC system that covers 150 m² house/flat	**Improved HVAC mainte-nance** **-38.3** -47.5 **Gas/oil heating** **-14.8** -21.3	**Improved HVAC mainte-nance** **5.0** 4.0 **Gas/oil heating** **1.8** 1.3
Retrofit water heating systems	■ Replacement of existing standard gas water heaters when expired with tankless/condensing models ■ Replacement of existing electric water heater when expired with solar water heater or electric heat pumps *Assumptions:* ■ Solar water prices drop at 2.3% CAGR, based on historic improvement form 1984-04	**-163.5** -171.1	**6.9** 6.6
New and retrofit lighting systems	■ Replacement of incandescent bulbs with LEDs ■ Replacement of CFLs with LEDs *Assumptions:* ■ In abatement case, full remaining share of incandescents switch to LEDs, and full remaining share of CFLs switch to LEDs ■ Learning rate for LEDs based on historic 18% improvement in solar cell technology ■ Cost of 1 light bulb at €0.63 (incandescent), €3.17 (CFL), and €31.7 in 2005 declining to €15.5 by 2030 (LED)	**Incandes-cent to LEDs** **-192.8** -201.7 **CFLs to LEDs** **-160.0** -167.5	**Incandes-cent to LEDs** **5.0** 4.8 **CFLs to LEDs** **0.7** 0.7
New efficient appliances and electronics	■ Purchase of high-efficiency consumer electronics (e.g., PC, TV, VCR/DVD, charging supplies) instead of standard items ■ Replacement of refrigerator/ freezer, washer / dryer, dishwasher, and fan when expired with high efficiency model *Assumptions:* ■ High-efficiency devices use 35% (appliances) and 37% (electronics) less energy ■ High-efficiency electronics cost additional €34 per bundle ■ High-efficiency appliances are on average ~12% more expensive	**Appliances** **-163.2** -170.8 **Electronics** **-193.0** -201.9	**Appliances** **5.0** 4.8 **Electronics** **4.0** 3.8

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Installing heat meters and thermostats	■ Installation of heat meters and thermostats to regulate temperature in residential buildings *Assumptions:* ■ By 2030 90% of radiators are equipped with thermostats ■ By 2030 90% of houses are equipped with heat meters (because of the vertical system of heat pipes in most houses heat meters are not installed in flats) ■ In 20% of cases there is a need to conduct additional work on redesigning the heating system ■ Heat saving potential is 20%	**-43.1** -50.1	**35.6** 30.7

Commercial buildings

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Construction of energy efficient new buildings	■ Reduction in demand for energy consumption through improved building design and orientation ■ Improvement of building insulation and airtightness ■ Improvement of materials and construction of walls, roof, floor, and windows ■ Usage of high efficiency HVAC and water heating systems in new buildings *Assumptions:* ■ 55 and 17.5 million m^2 annual construction of commercial and industrial buildings, respectively ■ 47% savings potential on HVAC and water heating for new buildings ■ Additional cost (efficiency package premium) is estimated at €22 per m^2	**-40.2** -47.1	**30.8** 26.3
Improved insulation	■ Basic retrofit package includes improvement of building airtightness by sealing areas of potential air leakage and weather stripping doors and windows *Assumptions*: ■ 6% share of retrofit in 2030 in the reference case, increasing to 90% in the abatement scenario ■ 48% potential savings in heat consumption ■ Cost of retrofit is estimated at €3.4 per m^2	**-80.1** -92.6	**49.5** 42.8
Retrofit HVAC and HVAC controls	■ Installation of highest efficiency system, when current HVAC system expires ■ Improvement of HVAC control systems to adjust for building occupancy and minimize re-cooling of air *Assumptions:* ■ Saving potential at 16% (HVAC retrofit) and 15% (VAC controls) ■ €500 premium for every 5 tonnes (~17,000 W) of capacity installed ■ €5,000 cost for retrofit control system in 1,700 m^2 building	**HVAC retrofit** **-54.2** -62.7 **HVAC controls** **-68.4** -79.1	**HVAC retrofit** **9.7** 8.4 **HVAC controls** **7.8** 6.7

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
New and retrofit lighting systems	■ Replacement of incandescent bulbs with LEDs ■ Replacement of CFLs with LEDs ■ Replacement of inefficient T12s/ T8s with new super T8s and T5s ■ Installation of lighting control systems (dimmable ballasts, photo-sensors to optimize light for occupants in room) ■ Retrofitting of lighting control systems (dimmable ballasts, photo-sensors to optimize light for occupants in room) *Assumptions:* ■ In abatement case, full remaining share of incandescent switch to LEDs (2% by 2030), and full remaining share of CFLs switch to LEDs (11% by 2030) ■ Switch from old T12 and T8s to new T8/T5s: 37% and 60% penetration of new technology in 2030 in the reference case and abatement case, respectively ■ For lighting control systems – Achieve 50% savings potential in new build – 29% savings potential in retrofit	**Incandes-cent to LEDs** **-192.6** -201.6 **CFLs to LEDs** **-161.7** -169.2 **T12 to T8/5** **-97.4** -101.9	**Incandes-cent to LEDs** **1.3** 1.3 **CFLs to LEDs** **1.1** 1.0 **T12 to T8/5** **0.7** 0.6
Energy efficient appliances, electronics	■ Replacement of commercial appliances (refrigerators, freezers) and office electronics with high efficiency models instead of standard models *Assumptions:* ■ 17% savings potential in commercial appliances and 48% potential in office electronics ■ Implementation rates of 43% (appliances) and 29% (office electronics) in 2030 in the reference case and 100% (both) in the abatement case ■ €1.5 price premium per item for high efficiency charging devices and reduction in standby loss ■ €19 premium for every 0.65 m² of high-efficiency refrigeration area	**Appliances** **-148.1** -155.0 **Office electronics** **-156.0** -163.2	**Appliances** **1.1** 1.1 **Office electronics** **4.6** 4.4

Power and heat

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Higher share of cogeneration (CHP)	■ Increased share of cogeneration through building small-scale CHPs instead of boiler houses in small and mid-size cities ■ CCGT-based CHP compared to CCGT and boiler in reference case *Assumptions:* ■ Technical potential is based on cities with large enough heat demand to make boiler-to-CHP conversion attractive ■ 20% of technical potential is utilized by 2030 ■ CCGT-based CHP is 10% higher in capex than standard CCGT but is 10% more fuel efficient over annual cycle	**-48.7** -69.3	**16.8** 11.8

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Increased efficiency of old capacities	■ Overall heat rate of current fleet of thermal power plants could be reduced by 2% through various measures (increase fuel efficiency and decrease internal plant's consumption) ■ Measure applies to remaining old fleet *Assumptions:* ■ 20 GW capacity of old coal-based and 55 GW capacity of gas-based power plants remain in 2030 ■ Investments into more energy efficient equipment are paid off in 2 years	**-16.5** -27.6	**1.9** 1.2
Improved insulation of heating mains	■ Old heating mains being replaced by modern technology (polyurethane insulation) *Assumptions:* ■ Losses in heating grid reduced from current ~25% down to 12% by 2030 ■ Total capex required for the program: €13 bn ■ €2bn annual average savings from fuel economy and decreased O&M cost	**-7.7** -9.0	**41.0** 36.8
Small hydro	■ Small hydro power generation capacity built by 2030 replaces CO_2-intensive fossil-fuel power plants *Assumptions:* ■ 6.1 TWh produced by 2030 compared to 2.8 TWh in the reference case ■ Large variation in capex due to natural conditions. Average of €1,250 per kW ■ Capacity factor is set to 35%	**19.8**	**1.4**
Wind	■ Wind power generation capacity built by 2030 replaces CO_2-intensive fossil-fuel power plants *Assumptions:* ■ 39.4 TWh produced by 2030 compared to 0.1 TWh in the reference case ■ Average 2005 capex of €1,300 per kW ■ Overall cost per unit of electricity produced projected to decrease by ~5% with every doubling of cumulative installed capacity ■ Capacity factor is set to 30%	**61.5**	**14.9**
Solar PV	■ Solar PV power-generation capacity built by 2030 replaces CO_2-intensive fossil-fuel power plants *Assumptions:* ■ 3.1 TWh produced by 2030 compared to 0.0 TWh in the reference case ■ 2005 capex: €3,500 per kW ■ Capacity-driven learning rate at 18% for every doubling of cumulative installed capacity (>20% historically) ■ Capacity factor is set to 10%	**109.0**	**0.3**

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Nuclear	■ Nuclear power generation capacity built by 2030 replaces CO_2-intensive fossil-fuel power plants *Assumptions:* ■ 424 TWh produced by 2030 compared to 173 TWh in the reference case ■ Gradual increase of uptime from 75% in 2005 to 85% in 2030 ■ Due to limited experience with new construction and cost overruns in current projects, there is much uncertainty around capital costs for nuclear plants. A cost of €2,500 per kW in 2005 ■ Opex is estimated conservatively at €18 per MWh, including fuel costs and waste disposal, maintenance costs, insurance, liabilities and decommissioning costs	**25.9**	**104.5**
Geothermal	■ Geothermal power generation capacity built by 2030 replaces CO_2-intensive fossil-fuel power plants *Assumptions:* ■ 22.8 TWh produced by 2030 compared to 0.4 TWh in the reference case ■ Capex: average of €3000 per kW in 2005, with a capacity driven learning rate of 10% ■ Opex: €13 per MWh (range from 8 to 18 due to variations in local conditions) ■ Capacity factor: 80% ■ Large uncertainty around cost development	**63.5**	**8.5**
Gas/coal CCS with EOR (new build)	■ Carbon capture and storage (CCS) is the sequestration of CO_2 from large emission point sources (see page 125) *Assumptions:* ■ In 2030, the cost for CCS in the Power sector is forecast at €30–45/tonne. Base capex for new-build coal-fired power plants equipped with CCS is €2,700–3,200/kW (a 40-year lifespan) ■ CCS-equipped plants that can sell the CO_2 for enhanced oil recovery (EOR) have an additional revenue stream, at €20/tonne	**76.4**	**1.1**
Biomass	■ Biomass power generation capacity built by 2030 replaces CO_2-intensive fossil-fuel power plants *Assumptions:* ■ 49.1 TWh produced by 2030 compared to 5.7 TWh in the reference case ■ Biomass fuel cost and €6 per kW in additional capex for minor modifications of fuel feed system ■ Capex: €1,700 per kW (range from €1,500 to €2,000 per kW) with learning rate of 5%; capacity factor is set to 80%, with a lifetime of 40 years	**56.9**	**16.8**

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Grid losses reduction	■ High cost is due to substantial investments required to build additional grid capacity ■ Measure influence also security of power supply, and therefore could be implemented regardless of energy efficiency benefits *Assumptions:* ■ Decrease of technical losses in power grid from current 12% to 10% by 2020 and 8% by 2030 ■ Power savings achieved through increasing density of grid networks by building more grid lines	**70.0** 73.3	**19.8** 18.6
Large hydro	■ Large hydro power generation capacity built by 2030 replaces CO_2-intensive fossil-fuel power plants *Assumptions:* ■ 407.5 TWh produced by 2030 compared to 206.8 TWh in the reference case ■ Average capex of €2,500 per kW ■ Capacity factor is set to 50%	**68.3**	**76.9**
Tidal	■ Tidal power generation capacity built by 2030 replaces CO_2-intensive fossil-fuel power plants ■ Three known projects of total capacity 6 GW counted: in Barents Sea, White Sea and Okhotsk Sea *Assumptions:* ■ 18.4 TWh produced by 2030 compared to 0.0 TWh in the reference case ■ High uncertainty about future cost development, as technology is not yet mature ■ Average capex of €3,000 per kW ■ Capacity factor is set to 35%	**125.8**	**6.9**

Petroleum and gas

Upstream production and processing

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Energy efficiency from improved maintenance and process control	■ Additional/improved maintenance that ensures equipment stays in optimal condition; i.e., monitoring and reduction of fouling (deposit build-up in the pipes) ■ Improved process control that reduces suboptimal performance, e.g., due to undesired pressure drops across gas turbine air filters, an undesired turbine washout frequency, suboptimal well and separator pressures *Assumptions:* ■ Abatement is estimated at 9.4% of reference case emissions ■ Capex at €16.3m per Mt CO_2e ■ Opex estimated at 15% of total required capex	**-44.3** -49.4	**4.1** 3.6

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Energy efficiency projects requiring capex at process unit level	■ Introduction of efficiency measures that involve replacement/upgrades/ additions that do not alter the process flow of an upstream production site ■ More efficient pump impeller ■ Replacement of boilers/heaters/turbines/motors *Assumptions:* ■ Abatement is estimated at 5.9% ■ Capex assumed at €124 per CO_2e ■ Opex estimated at 5% of total required capex	**-42.1** -46.9	**2.5** 2.3
More energy efficient new builds	■ Program that ensures new built production sites use process units with best-in-class energy efficiency as well as maintenance procedures and process controls that uphold the best-in-class energy efficiency *Assumptions:* ■ Abatement is estimated at 15.3% ■ Capex at €112 per CO_2e ■ Opex estimated at 5% of total required capex	**-47.4** -155.6	**11.9** 3.6

Midstream gas transport and storage

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Replacement of compressor seals	■ Replacement of traditional wet seals, which use high-pressure oil as a barrier against natural gas escaping from the compressor casing, with dry seals reduces methane leakage from compressors *Assumptions:* ■ Volume savings as percentage of total emissions are estimated at 82% of emissions from all dry seals ■ Capex – €160,000/ compressor for dry seals – €40,000/ compressor for wet seals ■ Opex – €7,000/ compressor for dry seals – €49,000/ compressor for wet seals	**-6.3** -66.4	**8.8** 0.8
Compressors direct inspection and maintenance	■ A directed inspection and maintenance (DIM) program is a means to detect, measure, prioritize, and repair equipment leaks to reduce methane emissions from compressors, valves, etc. – A DIM program begins with a baseline survey to identify and quantify leaks. Repairs that are cost-effective to fix are then made to the leaking components – Subsequent surveys are based on data from previous surveys, allowing operators to concentrate on the components that are most likely to leak and are profitable to repair *Assumptions:* ■ 15% leakage (not due to seals) is abated ■ No capex ■ Opex: €133/compressor	**-5.9** -58.1	**5.0** 0.5

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Direct inspection and maintenance (DIM) on distribution network	■ DIM program on the distribution network reduces leakage in a similar way as a DIM program on compressors but with a focus on surface and metering stations *Assumptions:* ■ 80% of the gap between current practice and technical best practice can be reduced ■ Technical best practice is a 10% reduction of emissions in the region with current best practice ■ No capex ■ Opex: €524,000/bcm (based on €1,200 per kilometer of actively maintained pipe)	**-3.9** -40.5	**41.8** 4.0
Reducing venting using mobile compressor stations	■ Use of mobile compressors during the planned maintenance of pipes to prevent gas from being vented into the atmosphere *Assumptions:* ■ 40% of currently vented gas can be saved ■ Capex per compressor – €6.7 m ■ Number of compressors – 10 ■ Opex estimated at 15% of capex	**-5.2**	**7.2**
Improved planning in the transmission sector	■ Decrease of emissions due to transmission combustion – Planning reduces unnecessary (de-) pressurization by actively matching compression needs with natural gas demand – In addition, emphasis is placed on running compressors at their most efficient point, called the working point *Assumptions:* ■ 7% reduction in fuel consumption ■ Capex: €100,000/bcm ■ Opex estimated at 15% of capex	**-41.8** -58.2	**6.0** 4.3

Downstream refining

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Energy efficiency from improved maintenance and process control	■ Additional/improved maintenance that ensures equipment stays in optimal condition; i.e., maintenance and monitoring of steam traps/ steam distribution or monitoring and reduction of fouling (deposit build-up in the pipes) ■ Improved process control that reduces suboptimal performance i.e., due to undesired pressure drops across gas turbine air filters, an undesired turbine washout frequency, etc. *Assumptions:* ■ Abatement is estimated at 6.2% of reference case emissions ■ Capex investment of USD 1m required for a reference refinery (capacity of 180 thousand barrels/day) ■ Opex estimated at 15% of total required capex	**-74.2** -85.0	**4.8** 4.2

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Energy efficiency requiring capex at process unit level	■ Efficiency measures that involve replacement/ upgrades/additions that do not alter the process flow of a refinery – Waste heat recovery – Replacement of boilers/heaters/ turbines/motors *Assumptions:* ■ Abatement volume is estimated at 9.7% of reference case emissions ■ Capex investment of USD 50m required for a reference refinery (capacity of 180 thousand barrels/day) ■ Opex is estimated at 5% of total required capex	**-48.3** -55.3	**7.0** 6.2
Carbon capture and storage (CCS)	■ Carbon capture and storage (CCS) is the sequestration of CO_2 from large emission point sources (see page 125) *Assumptions:* ■ Refineries processing >100 thousand barrels per day are large enough ■ CCS technically feasible in 80% of refineries ■ Capex €552 per tonne CO_2e annual abatement capacity in 2015 decreasing to €115 in 2030 ■ Energy cost depends on fuel mix and electricity prices	**64.5**	**25.3**

Iron and Steel

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Cogeneration	■ Blast furnace/basic oxygen furnace (BF/BOF) steel-manufacturing process generates gas as a by-product ■ This gas can be recovered, cleaned and used for power and heat generation ■ Cogeneration can be integrated in the BF/ BOF steel-manufacturing process to reduce the total energy demand *Assumptions:* ■ In the reference case 10% utilization of gas in 2010-30 ■ Penetration reaches 100% by 2020 in the abatement scenario ■ Capex of €65 per tonne of steel annual production capacity ■ Opex savings are determined by fuel prices	**New builds** **-143.8** -150.7 **Retrofit** **-135.2** -141.5	**New builds** **2.9** 2.0 **Retrofit** **1.8** 1.5
Smelt reduction	■ Smelt reduction is a technique that avoids the coking process by combining upstream hot metal production processes in one step ■ Emission savings are achieved as less direct fuel is used when integrating preparation of coke with iron-ore reduction *Assumptions:* ■ ~8% reduction of BF/ BOF direct energy intensity ■ Capex of €93 per tonne of annual steel production capacity ■ Opex savings are determined by fuel prices	**New builds** **45.9** 114.5 **Retrofit** **56.1** 140.8	**New builds** **3.5** 1.0 **Retrofit** **2.1** 0.7

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Energy efficiency	■ Additional improvements in on-site energy efficiency compared to reference case by a number of individual measures: structural shift from BF/ BOF to EAF production, better preventative maintenance, improved process flow (management, logistics, IT-systems), motor systems, new efficient burners, pumping systems, capacity utilization management, heat recovery, sinter plant heat recovery, coal moisture control, pulverized coal injection *Assumptions:* ■ EE I: 0.3% p.a. general energy efficiency increase above reference case at €80 per tonne of annual production capacity ■ EE II: 0.2% efficiency increase at €160 per tonne of annual production capacity ■ Opex savings are determined by fuel prices	**Energy efficiency I** **36.2** 72.9 **Energy efficiency II** **71.7** 139.7	**Energy efficiency I** **8.3** 4.2 **Energy efficiency II** **4.3** 2.3
Carbon capture and storage (CCS)	■ Carbon capture and storage (CCS) is the sequestration of CO_2 from large stationary emission sources (see page 125) *Assumptions:* ■ 80% of old plants retrofittable due to technical constraints ■ 0.24 MWh energy increase per tonne CO_2 separated in 2030 ■ Capex €552 (new build) and €718 (retrofit) per tonne of CO_2 annual abatement capacity in 2015 decreasing to €115 (new build) and €149 (retrofit) in 2030	**New build** **54.8** **Retrofit** **63.3**	**New build** **26.4** **Retrofit** **30.3**
Coke substitution	■ Substituting coke used in BF/BOF furnaces with fuel based on biomass, with zero carbon intensity *Assumptions:* ■ 10% of coke possible to substitute ■ No substitution in reference case ■ 100% implementation by 2020 ■ Capex of €0.1 per tonne per year	**New build** **-11.2** **Retrofit** **-10.9**	**New build** **1.2** **Retrofit** **0.8**

Chemicals

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Motor systems	■ Installation of more energy efficient equipment in chemical plants, such as motors, conveyors, mixing machines and optimization of mechanical systems *Assumptions:* ■ 25% savings in indirect energy compared to standard systems ■ 10% implementation in the reference case, 100% in the abatement case by 2020 ■ Capex of €50 per MWh ■ Opex savings are determined by fuel prices	**New build** **-153.1** -160.2 **Retrofit** **-131.0** -137.1	**New build** **5.9** 5.7 **Retrofit** **0.6** 0.6

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
N_2O de-composition of nitric acid	■ Nitrous oxide is emitted as a by-product in nitric acid production ■ Applying certain filtering measures (catalytic decomposition or catalytic reduction) increases N_2O decomposition in the tailgas of nitric acid *Assumptions:* ■ Implementation of the measure reduces amount of N_2O per tonne of nitric acid from 8.7 kg in the reference case to only 1 kg of N_2O per tonne of acid ■ Not implemented in reference case, 100% in the abatement case starting 2010 ■ Capex of €9.25 per tonne of acid ■ Additional opex of €10 per tonne of acid	**New builds** **4.5** **Retrofit** **9.1**	**New builds** **7.6** **Retrofit** **7.6**
Fuel shift	■ Replacing direct energy use from coal powered systems to biomass powered systems, and oil powered systems to gas power, thereby lowering the carbon intensity per MWh energy produced, given the lower carbon intensity of gas and biomass *Assumptions:* ■ Reference case: zero penetration of gas and biomass usage ■ Abatement case: penetration of gas and biomass at 80% (new build), 50% (retrofit) ■ Capex of €4.6 per MWh (new build), €18.5 per MWh (retrofit)	**Shift from coal to biomass** **New builds** **9.8** **Retrofit** **13.4** **Shift from oil to gas** **New builds** **-102.6** **Retrofit** **-94.1**	 **New builds** **0.1** **Retrofit** **0.02** **New builds** **0.5** **Retrofit** **0.1**
CCS Ammonia	■ Introduction of carbon capture and storage to the CO_2 emitted as a process emission from ammonia production (see page 125) *Assumptions:* ■ 72% of plants are too small and technically constrained ■ 0.01 MWh energy increase per tonne of CO_2 ■ Capex €552 (new build) and €718 (retrofit) per tonne of CO_2 annual abatement capacity in 2015 decreasing to €115 (new build) and €149 (retrofit) in 2030	**New builds** **36.3** **Retrofit** **44.8**	**New builds** **2.4** **Retrofit** **7.5**
CCS Direct	■ Applying carbon capture and storage to the exhaust emissions coming from direct energy use in the chemical plants *Assumptions:* ■ As above	**New builds** **41.8** **Retrofit** **50.3**	**New builds** **3.6** **Retrofit** **5.1**

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Process intensification	■ Intensification of chemical processes, leading to an annual emission decrease. The improvements are caused by a number of individual measures, including continuous processes, improved process control, preventive maintenance, more efficient burners and heaters and logistical improvements ■ Modeled in three steps, with increasing costs (abatement cost of process level 3 exceeds 80 €/t CO_2e) *Assumptions:* ■ Implementation starts with 1% rate in 2015 and increases to 4% in 2030 ■ Measures in the group are split in two buckets: "process" and "energy", affecting the corresponding emission type in baseline ■ Capex modeled as the net delta per t CO_2e annual abatement potential at €0 (Level 1), 183 (Level 2), and 366 (Level 3) average per tonne ■ Opex modeled as net opex delta per abated t CO_2e at €0 (Level 1), 10 (Level 2), and €20 (Level 3)	**Energy** **Level 1** **0.0** **Level 2** **25.6** **Level 3** **51.0** **Process** **Level 1** **0.0** **Level 2** **25.6**	**Energy** **Level 1** **1.0** **Level 2** **0.9** **Level 3** **0.5** **Process** **Level 1** **1.0** **Level 2** **0.2**
Catalyst optimization	■ Catalyst optimization in chemical processes, leading to an annual process and direct energy emissions decrease above the reference case. The improvements are caused by a number of individual measures, including improved chemical structure of catalysts, design to lower reaction temperatures, and chain reaction improvements *Assumptions:* ■ As in process intensification	**Energy** **Level 1** **0.0** **Level 2** **25.6** **Level 3** **51.0** **Process** **Level 1** **0.0** **Level 2** **25.5** **Level 3** **52.4**	**Energy** **Level 1** **0.9** **Level 2** **0.9** **Level 3** **0.4** **Process** **Level 1** **1.7** **Level 2** **1.0** **Level 3** **0.6**

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Ethylene cracking	■ Ethylene cracking improvement includes furnace upgrades, better cracking tube materials, and improved separation and compression techniques that lower the amount of direct energy used in the cracking process *Assumptions:* ■ 1.1 MWh savings per tonne of ethylene compared to standard cracking processes ■ 0% implementation in RC, reaching 100% in abatement case starting in 2010 ■ Average capex of €46 per tonne of annual ethylene production ■ Additional opex of €25 per tonne of ethylene	**New builds** **70.5** 101.7 **Retrofit** **77.0** 111.1	**New builds** **1.7** 1.2 **Retrofit** **0.6** 0.4

Cement

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Clinker substitution	■ CO_2-intensive clinker component in cement is replaced by substitutes (including fly ash, slag and other mineral ingredient components [MIC]). The substitute materials are by-products in industrial processes (e.g., smelting ore), and do not cause additional carbon emissions ■ Clinker component is reduced to 70% compared to 84% in the reference case ■ Lower clinker production eliminates emissions from process and fuel combustion associated with its production *Assumptions:* ■ Penetration in reference case at 84% (clinker), 4% (slag), 2% (fly ash), 4% (other MIC), 5% (gypsum) ■ Penetration in the abatement scenario by 2030 reaches 70% (clinker), 13% (slag), 9% (fly ash), 8% (other MIC), 5% (gypsum) ■ Slag is preferred filler to start with (after 5% gypsum have been subtracted as general share). Fly ash is used only after all gypsum and available slag have been consumed. Unlimited availability for other MIC ■ Negative capex (€5 bn) represents money that would have been invested in clinker production equipment if no clinker were substituted ■ Material cost: €8/t (slag), €5/t (fly ash), €1.5/t (other MIC)	**Slag** **-17.8** -92.7 **Fly ash** **-44.7** -311.1 **Other MIC** **-48.1** -402.7	**Slag** **6.5** 1.2 **Fly ash** **5.3** 0.8 **Other MIC** **2.1** 0.2
Increased share of waste burned as kiln fuel in industrial furnaces	■ Burning alternative fuels, such as municipal or industrial fossil waste, or biomass instead of fossil fuels in the cement kiln to reduce average fuel combustion emissions of the clinker making process *Assumptions:* ■ Penetration of waste fuel consumption is 0% in 2005-30 in the reference case and reaches 25% by 2030 in the abatement case ■ Capex of €200 per tonne of waste handling capacity ■ Fuel costs of €5 per tonne of waste and €7 per tonne overhead cost ■ Avoided costs for fossil fuels (differs by region based on fuel mix)	**-43.5**	**1.2**

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Increased share of biomass as kiln fuel	■ Replacing fossil fuels used today by biomass fuels, which are CO_2e neutral, based on a life-cycle perspective for biomass and alternative usage considerations for waste fuels *Assumptions:* ■ Penetration of biomass fuel consumption 0% in 2005-30 in the reference case and up to 8% by 2030 in the reference case ■ Capex and fuel costs as above	**-24.9**	**0.5**
Post combustion CCS (retrofit)	■ Carbon capture and storage (CCS) is the sequestration of CO_2 after it has been emitted due to fuel combustion and the clinker calcination process (see page 125) *Assumptions:* ■ Share of retrofitted capacity at 4% in 2030 ■ Capex €780 per t CO_2 annual abatement capacity decreasing to €260 in 2030	**66.2**	**1.3**
Waste heat recovery	■ Usage of excess heat from the clinker burning process for electricity generation, using steam turbines driven by the flue gas exhaust stream *Assumptions:* ■ 33% of clinker production capacity to be equipped with waste heat recovery starting 2015 in the abatement case ■ 15 kWh electricity generated per tonne of clinker ■ Capex of €12.9 per tonne of annual clinker capacity equipped ■ Opex savings based on electricity cost	**28.8** 30.2	**0.1** 0.1

Transport

Light duty vehicles (LDV): gasoline, diesel

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
ICE fuel efficiency improvements – gasoline Bundle G1	■ Efficiency improvements to gasoline vehicles that based on both power train and non-power train technical improvements ■ Variable valve control ■ Engine friction reduction (mild) ■ Low rolling resistance tires ■ Tire pressure monitoring system ■ Mild weight reduction *Assumptions:* ■ Penetration of vehicles fleet: 3% in 2015, 25% in 2020, 24% in 2025, 0% in 2030	**-38.1** -62.8	**40.2** 24.3

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Bundle G2	■ Bundle G1+ ■ Medium displacement reduction (“downsizing”) ■ Medium weight reduction ■ Electrification (steering, pumps) ■ Optimized gearbox ratio ■ Improved aerodynamic efficiency ■ Start-stop (smart electronic Start/Stop system that switches off the engine if the vehicle is standing still, e.g., in a traffic jam or at a red light) *Assumptions:* ■ Penetration of vehicles fleet: 2% in 2015, 13% in 2020, 12% 2025, 0% 2030		
Bundle G3	■ Bundle G2+ ■ Strong displacement reduction (“downsizing”) ■ Air conditioning modification ■ Improved aerodynamic efficiency ■ Start-stop system with regenerative braking *Assumptions:* ■ Penetration of vehicles fleet: 0% in 2015, 7% in 2020, 32% 2025, 25% 2030		
Bundle G4	■ Bundle G3+ ■ Direct injection (homogeneous) ■ Strong weight reduction (9%) ■ Optimized transmission (including dual clutch, piloted gearbox) *Assumptions:* ■ Penetration of vehicles fleet: 0% in 2015, 0% in 2020, 17% 2025, 44% 2030		
Gasoline – Full hybrid	■ Full hybrid vehicles have a conventional ICE plus an electric engine that runs on a battery. ■ The battery is charged by the drive cycle of the car (e.g., by braking) only ■ Bundle G4 + Full hybrid *Assumptions:* ■ Penetration of vehicles fleet: 0% in 2015, 3% in 2020, 8% in 2025, 18% in 2030	**-7.1**	**7.3**

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
ICE fuel efficiency improvement – Diesel Bundle D1	■ Efficiency improvements to gasoline vehicles that based on both power train and non-power train technical improvements ■ Medium downsizing ■ Engine friction reduction ■ Low rolling resistance tires ■ Tire pressure monitoring system ■ Mild weight reduction (1.0%) *Assumptions:* ■ Penetration of vehicles fleet: 12% in 2015, 30% in 2020, 24% in 2025, 0% in 2030	**-36.5** -54.2	**2.6** 1.8
Bundle D2	■ Bundle D1 + ■ Piezo injectors ■ Medium downsizing ■ Medium weight reduction ■ Electrification (steering, pumps) ■ Optimized gearbox ratio ■ Improved aerodynamic efficiency *Assumptions:* ■ Penetration of vehicles fleet: 4% in 2015, 15% in 2020, 13% in 2025, 0% in 2030		
Bundle D3	■ Bundle D2 + ■ Torque oriented boost ■ Air conditioning modification ■ Improved aerodynamic efficiency ■ Start-stop system with regenerative braking *Assumptions:* ■ Penetration of vehicles fleet: 0% in 2015, 7% in 2020, 20% in 2025, 13% in 2030		
Bundle D4	■ Bundle D3 + ■ Increase injection pressure ■ Strong downsizing (instead of medium downsizing) ■ Strong weight reduction *Assumptions:* ■ Penetration of vehicles fleet: 0% in 2015, 0% in 2020, 29% in 2025, 64% in 2030		

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Diesel – Full hybrid	■ Full hybrid vehicles have a conventional ICE plus an electric engine that runs on a battery. ■ The battery is charged by the drive cycle of the car (e.g., by braking) only ■ Bundle D4 + Full hybrid *Assumptions:* ■ Penetration of vehicles fleet: 0% in 2015, 3% in 2020, 8% in 2025, 15% in 2030	**19.6**	**0.5**

Medium duty vehicles (MDV)

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
MDV ICE fuel efficiency improvements Bundle 1	■ Efficiency improvements that based on both power train and non-power train technical improvements ■ Rolling resistance reduction *Assumptions:* 30% in 2015, 30% in 2020, 10% in 2025, 0% in 2030	**37.4** 60.3	**0.4** 0.3
Bundle 2	■ Rolling resistance reduction ■ Aerodynamics improvement *Assumptions:* 0% in 2015, 30% in 2020, 10% in 2025, 0% in 2030		
Bundle 3	■ Rolling resistance reduction ■ Conventional ICE improvement including mild hybrid *Assumptions:* 0% in 2015, 20% in 2020, 40% in 2025, 50% in 2030		
Bundle 4	■ Rolling resistance reduction ■ Aerodynamics improvement ■ Conventional ICE improvement including mild hybrid *Assumptions:* 0% in 2015, 20% in 2020, 40% in 2025, 50% in 2030		

Heavy duty vehicles (HDV)

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
HDV ICE fuel efficiency improvements Bundle 1	■ Efficiency improvements that based on both power train and non-power train technical improvements ■ Rolling resistance reduction *Assumptions:* 27% in 2015, 30% in 2020, 6% in 2025, 0% in 2030	**22.4** 42.3	**4.1** 2.7
Bundle 2	■ Rolling resistance reduction ■ Aerodynamics improvement *Assumptions:* 3% in 2015, 30% in 2020, 14% in 2025, 0% in 2030		
Bundle 3	■ Rolling resistance reduction ■ Conventional ICE improvement including mild hybrid *Assumptions:* 0% in 2015, 20% in 2020, 24% in 2025, 25% in 2030		
Bundle 4	■ Rolling resistance reduction ■ Aerodynamics improvement ■ Conventional ICE improvement including mild hybrid *Assumptions:* 0% in 2015, 20% in 2020, 56% in 2025, 75% in 2030		

Biofuels

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Biofuels	■ Biofuels can replace fossil gasoline (replaced by bioethanol) and fossil diesel (biodiesel) ■ Modeled as ethanol (26 gCO_2e per MJ) *Assumptions:* ■ Gasoline biofuel volume: 0% in reference case, 15% in abatement case (made out of domestically grown corn, wheat, sugar-beets and wood)	**5.9**	**24.4**

Forestry

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Afforestation of abandoned cropland	■ Plantation of forest carbon sinks over abandoned cropland ■ "Carbon graveyard" forest case, where forests are not harvested *Assumptions:* ■ Total area available – 30 million hectares (15% of Russian cropland) ■ Afforested area by 2030 – 17.6 million hectares ■ Plantation cost – €200 per hectare ■ Sequestration rate – 5 t CO_2e per hectare/year ■ Rental cost of land – €33 per hectare per year	**11.6**	**88.2**
Afforestation of abandoned pastureland	■ Plantation of forest carbon sinks over abandoned pastureland ■ "Carbon graveyard" forest case assumed, where forests are not harvested *Assumptions*: ■ Total area available – 10 million hectares ■ Afforested area by 2030 – 8.9 million hectares ■ Plantation cost – €200 per hectare ■ Sequestration rate – 6 t CO_2e per hectare per year ■ Rental cost of land – €13 per hectare per year	**5.6**	**52.9**
Cultivation based reforestation	■ Plantation of forest carbon sinks over former forest land ■ Refers to areas that can only be reforested with additional silvicultural effort (planting trees) ■ "Carbon graveyard" forest case assumed, where forests are not harvested *Assumptions:* ■ Total area available – 9.5 million hectares ■ Afforested area by 2030 – 8.8 million hectares ■ Plantation cost – €200 per hectare ■ Sequestration rate – 3.7 t CO_2e per hectare per year	**5.7**	**32.6**
Protective afforestation	■ Plantation of forest carbon sinks over agricultural land to improve fertility of cropland ■ Refers to regions where substantial soil degradation has occurred and the forests can help rehabilitate the landscape ■ Based on a "carbon graveyard" forest case, where forests are not harvested *Assumptions*: ■ First afforestation measure to be implemented because of positive side ancillary effect on agriculture ■ Total area available – 10.8 million hectares ■ Afforested area by 2030 – 10.8 million hectares ■ Plantation cost – €233 per hectare ■ Sequestration rate – 5 t CO_2e per hectare per year ■ Rental cost of land – €33 per hectare per year	**4.8**	**54.0**

Agriculture

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Improved grassland management practices	■ Increased grazing intensity, increased productivity (excluding fertilization), irrigating grasslands, fire management and species introduction *Assumptions*: ■ No capex; €5/hectare cost of applying the measure ■ Penetration in the reference case at 0%. Penetration in the abatement scenario reaches 100% by 2030	**2.2**	**10.2**
Improved grassland nutrient management practices	■ More accurate nutrient additions: practices that tailor nutrient additions to plant uptake, such as for croplands ■ Increased productivity (through better fertilization). For instance, alleviating nutrient deficiencies by fertilizer or organic amendments increases plant litter returns and, hence, soil carbon storage *Assumptions*: ■ No capex; €5/hectare cost of applying the measure ■ Penetration in the reference case at 0% penetration in the abatement scenario reaches 100% by 2030	**-64.9**	**1.5**
Conservation tillage/residue management	■ Reduced tillage of the ground and reduced residue removal/ burning. *Assumptions*: ■ 1/3 of cropland is considered suitable for the measure, evenly divided between no till and reduced till ■ Penetration in the reference case at 8% for reduced till and 8% for no till ■ Penetration in the abatement case by 2030 reaches 45% no till and 45% reduced till ■ No capex; €20 /hectare cost of applying the measure	**-5.3**	**11.3**
Improved agronomy practices	■ Improved productivity and crop varieties; extended crop rotations and reduced unplanted fallow; less intensive cropping systems; extended use of cover crops. *Assumptions*: ■ 1/3 of cropland is available for agronomy practices ■ Penetration in the reference case 5%, 75% by 2030 in the abatement case ■ No capex; €20/hectare cost of applying the measure	**9.5**	**25.5**
Improved nutrient management	■ Adjusting application rates, using slow-release fertilizer forms or nitrification inhibitors, improved timing, placing the nitrogen more precisely *Assumptions*: ■ 1/3 of cropland is available for nutrient management ■ Penetration in the reference case 13% and 100% by 2030 in the abatement case ■ No capex; €20/hectare cost of applying the measure	**-64.9**	**21.4**
Improved rice management practices	■ Mid-season and shallow flooding drainage to avoid anaerobic conditions *Assumptions:* ■ No capex; €20/hectare cost of applying the measure ■ Penetration in the reference case at 0%, going up to 100% by 2030 in the abatement case	**0.9**	**1.4**

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Improved rice nutrient management practices	■ Use of sulfate fertilizer instead of traditional nitrogen fertilizer *Assumptions:* ■ No capex; €20 per hectare cost of applying the measure ■ Penetration in the reference case at 0%. Penetration in the abatement case reaches 100% by 2030	**-22.8**	**0.4**
Organic soils restoration	■ Soils with high organic content are drained to be used for agriculture. High organic content of the soils favors decomposition and therefore, high CO_2 and N_2O fluxes. The most important mitigation practice is to avoid the drainage of these soils or to re-establish a high water level *Assumptions*: ■ 4.4 million hectares in agriculture are organic soils, 1 million hectares went out of use since 1990. Abatement potential is estimated at 20 t CO_2e per hectare. ■ No capex; cost is estimated at €0.8 per tonne of abatement for land not in use and €6.8 per tonne for land in use to cover opportunity cost of its use for crops ■ Penetration in the reference case at 0% for both organic soil in use and not in use. Penetration in the abatement case reaches 100% by 2030 for organic soil not in use and 50% for organic soil in use.	**Land in use** **11.3** **Land not in use** **1.3**	**Land in use** **30.0** **Land not in use** **17.9**
Degraded land restoration	■ Land degraded by excessive disturbance, erosion, organic matter loss, acidification, etc. Abatement practices include re-vegetation (e.g., planting grasses); improving fertility by nutrient amendments; applying organic substrates such as manures, biosolids, and composts; reducing tillage and retaining crop residues; and conserving water *Assumptions*: ■ No capex; €50 /per hectare cost of applying the measure ■ Penetration in the reference case at 15%. Penetration in the abatement case reaches 80% by 2030	**7.6**	**22.6**
Increased use of livestock feed supplements	■ Use of a wide range of specific agents or dietary additives, mostly aimed at suppressing methanogenesis ■ Propionate precursors, which reduce methane formation by acting as alternative hydrogen acceptors. But as response is elicited only at high doses, propionate precursors are, therefore, quite expensive *Assumptions:* ■ Penetration in reference case at 0%. Penetration in the abatement case reaches 100% by 2030	**54.3**	**2.0**
Use of livestock enteric fermentation vaccines	■ Vaccines against methanogenic bacteria which are being developed although not yet available commercially *Assumptions:* ■ Penetration in reference case at 0%. Penetration in the abatement case reaches 100% by 2030	**-44.2**	**5.0**

Waste

Measure	Description	Costs €/t CO_2e €/tce	Volume Mt CO_2e Mtce
Flaring of landfill gas	■ Burning captured landfill gas to prevent methane from entering the atmosphere *Assumptions*: ■ Flaring to cover the landfills remaining after the implementation of the “Direct use of landfill gas” measure ■ Capture rates over the lifetime of the landfill at 75% ■ Capex: €71 per t CO_2e of abatement capacity ■ Opex: €0.55 per t CO_2e	**7.5**	**2.0**
Direct use of landfill gas	■ Capturing landfill gas and selling to a captive player *Assumptions*: ■ LFG direct use is limited to a technical potential of 30% of all sites ■ Capture rate over the lifetime of the landfill at 75% ■ Capex: €109 per t CO_2e of abatement capacity ■ Opex: €0.5 per t CO_2e ■ Revenues from energy sales: €60 per t CO_2e	**-14.6**	**1.1**
Composting new waste	■ Producing compost through biological process where organic waste biodegrades *Assumptions*: ■ Abatement potential at 1.08 t CO_2e per tonne of waste composted ■ Capex for composting at €45 per t CO_2e ■ Opex for composting per tonne of organic waste: €13 per t CO_2e ■ Revenue from composting per tonne of organic waste: €16 per t CO_2e	**1.7**	**5.3**
Recycling	■ Recycling raw materials (e.g., metals, paper) for use as inputs in new production *Assumptions:* ■ Abatement potential per tonne of waste recycled: – Paper: 4.8 t CO_2e – Cardboard: 5.6 t CO_2e – Plastic: 1.8 t CO_2e – Glass: 0.4 t CO_2e – Steel: 1.8 t CO_2e – Aluminium: 13.6 t CO_2e ■ Capex for recycling at €13 per t CO_2e ■ Opex for recycling per tonne of waste : €5 per t CO_2e ■ Revenues from recycling: – Paper: €7 per t CO_2e – Cardboard: €13 per t CO_2e – Plastic: €30 per t CO_2e – Glass: €7 per t CO_2e – Steel: €13 per t CO_2e – Aluminium: €133 per t CO_2e ■ No recycling of previously generated waste iccurs, only waste that is generated after 2010	**-2.8**	**33.3**

Carbon capture and storage (CCS)

Technology description

- Carbon capture and storage (CCS) technology aims to capture ~90% of CO_2 emissions from large stationary sources (e.g., coal-fired power plants) and permanently prevent its release into the atmosphere
- Capture technologies are already proven but not economically justified, whereas storage technologies are still under development

Global assumptions

- CCS manufacturing industry is assumed to be able to grow by 30% through 2030, potentially supplying up to 4.5 Gt CO_2e of abatement globally in the most aggressive case. Based on the model dynamics and the availability of plants, CCS ends up using 3.3–4.1 Gt CO_2e of that potential across all sectors by 2030 globally
- Implementation of CCS measures starts after 2015
- Cost assumptions:
  - CO_2 transportation cost – €6 per tonne of CO_2
  - Storage cost – €12 per tonne of CO_2 in 2030
  - Overhead cost – €15 per tonne of CO_2 in 2015, decreasing to €6 per tonne of CO_2 in 2030

5.4 Glossary

Abatement	The purposeful reduction of greenhouse gas emissions
Abatement costs (€/t CO_2e)	Additional costs (or savings) from implementation of an abatement measure
Abatement cost curve	Compilation of abatement potentials and costs for a specific sector
Abatement potential	Potential for reducing emissions versus a business-as-usual baseline
Afforestation	The natural or human-induced spread of forest to previously unforested land, such as fields and pastures
bcm	Billion cubic meters
Business-as-usual (BAU, reference case)	The projected path of emissions over time prior to emissions-reducing activity
Carbon sink	Process by which more carbon is absorbed than released into the atmosphere.
CCS	Carbon capture and storage
CDM	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
CFL	Compact fluorescent lamp
CHP	Combined heat and power, the use of a heat engine or a power station to generate electricity and steam from a single fuel at a facility near the consumer
CO_2e	Carbon dioxide equivalent
Gt	Gigatonne(s)
Decision maker	The party that decides on making an investment, i.e., a company (e.g., as owner of an industrial facility) or an individual (e.g., as owner of a car or home)
Degree day, heating and cooling	The difference between a reference temperature and the mean temperature for the day, times the number of days in the period
District heat	A system for distributing heat generated in a centralized location for residential and commercial heating requirements
EU ETS	Emissions Trading Scheme of the European Union
ERU	Emission reduction unit(s)
GHG	Greenhouse gas in the context of the Kyoto Protocol, i.e., CO_2 (carbon dioxide), CH_4 (methane), N_2O (nitrous oxide), HFC/PFC (hydrofluorocarbons), and SF_6 (sulfur hexafluoride)
Flaring	The burning off of unwanted gas associated with petroleum production
HDV	Heavy duty vehicle
HVAC	Heating, ventilation and air conditioning: climate-control systems for commercial and residential buildings
IGCC	Integrated gasification combined cycle, an advanced design for higher-efficiency power plants that generate and burn synthetic gas from coal, heavy petroleum residues or biomass

JI	Joint Implementation
kWh	Kilowatt hour(s)
LED	Light-emitting diode
LDV	Light duty vehicle
LULUCF	Land use, land-use change and forestry
MDV	Medium duty vehicle
Measure (abatement)	Technological opportunity to reducing greenhouse gas emissions
Mt	Megatonne(s)
Net cost measure	An abatement measure without savings or with savings not exceeding the required costs for investments
“Money saving” or economically attractive measure	An abatement measure that results in savings for the decision maker, taking into account the specific amortization periods and discounting rates
Retrofit	To add or substitute new components to an existing building or industrial installation
Societal perspective	The perspective of costs and benefits to society; does not include program costs, taxes or subsidies
TWh	Terawatt hour(s)
(M)tce	1 (million) tonne(s) of coal equivalent, a conventional value with 1 tce = 7 GCal (IT) = 29.3076 GJ usually used in Russia as a unit of energy; 1.43 tce = 1 toe (tonne of oil equivalent)

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This report exists in an English and a Russian version. Certain minor differences and discrepancies between the two versions may exist.