October 2011

The Demand for Greenhouse Gas Emissions Reduction Investments: An Investors' Marginal Abatement Cost Curve for Kazakhstan

Prepared for EBRD

NERA
Economic Consulting

Bloomberg
NEW ENERGY FINANCE

Project Team

Daniel Radov (NERA)

Per Klevnäs (NERA)

Martina Lindovska (NERA)

Adil Hanif (NERA)

Guy Turner (BNEF)

Christos Katsileros (BNEF)

Christian Lynch (BNEF)

Manon Dufour (BNEF)

Lyubov Inyutina

NERA Economic Consulting
15 Stratford Place
London W1C 1BE
United Kingdom
Tel: +44 20 7659 8500
Fax: +44 20 7659 8501
www.nera.com

Contents

Acknowledgments i

Disclaimer ii

Executive Summary iii

1. Introduction 1

2. Emissions and Sector Background 3
2.1. National Energy and Emissions Profile 3
2.2. Power Generation Sector 7
2.3. Heat and Buildings 18
2.4. Industry 23
2.5. Other Major Emitting Sectors 29
2.6. Summary 33

3. Overview of Approach 34
3.1. Policy Scenarios and Assumptions 34
3.2. Investor Assumptions 40
3.3. Fuel Price Assumptions 42

4. Policy "Status Quo" Scenario 44
4.1. Policy Status Quo: Overall Cost Curve 44
4.2. Cross-Cutting Scenario Assumptions 48
4.3. Power Generation 49
4.4. Heat and Buildings 54
4.5. Industry 61
4.6. Other Major Emitting Sectors 64

5. Planned Policies Scenario 70
5.1. Planned Policy Scenario: Overall Cost Curve 70
5.2. Cross-Cutting Scenario Assumptions 72
5.3. Power Generation Sector 72
5.4. Heat and Buildings 76
5.5. Other Major Emitting Sectors (Industry, Transport, Waste and Oil and Gas) 79

6. Enhanced Policy Scenarios 81
6.1. Enhanced Policy Scenarios: Overall Cost Curve 81
6.2. Cross-Cutting Scenario Assumptions 82
6.3. Power Generation Sector 84
6.4. Heat and Buildings 88
6.5. Industry 91

6.6. Other Major Emitting Sectors 94

7. Conclusions 95
7.1. Emissions Pathways 96
7.2. Options for Additional Emissions Reductions 97

Appendix A. Detailed Sector Assumptions 99
A.1. Power 100
A.2. Heat and Buildings 102
A.3. Industry 104
A.4. Transportation 109
A.5. Agriculture, Forestry and Land Use 111

Appendix B. Transaction Costs, Discount Rates, and Payback Assumptions 113
B.1. Project Transaction Costs 113
B.2. Summary of Estimates 117

Appendix C. Energy Price Assumptions 122

Appendix D. MAC Curve Data 127

Acknowledgments

This report was funded by the European Bank for Reconstruction and Development ("EBRD"), and has benefitted significantly from the contributions of its staff. The Project Team would like to thank, in particular, Grzegorz Peszko, the operational leader at EBRD, as well as Anvar Nasritdinov, the project liaison at EBRD in Kazakhstan, for their analytical insights and guidance on relevant policy. Various other members of EBRD staff were also generous with their time and knowledge, including Alexander Chirmiciu, Aleksandar Hadzhiivanov, Janina Ketterer, Manuela Naessl, Ioannis Papaioannou, and others. This study has been substantially improved by their experience and feedback. In addition to contributions from EBRD, a wide range of industry and government stakeholders also provided input to the study, which would not have been possible without their cooperation. The Project Team is grateful for the contributions of all of these stakeholders. Valentina Kryukova and Sergey Vassilyev of the Climate Change Coordination Centre ("C4") in Astana also provided support to the project. Of course, responsibility for any errors rests with the Project Team.

Disclaimer

NERA shall not have any liability to any third party in respect of this report or any actions taken or decisions made as a consequence of the results, advice or recommendations set forth therein. This report may not be sold without the written consent of NERA.

This report is intended to be read and used as a whole and not in parts. Separation or alteration of any section or page from the main body of this report is expressly forbidden and invalidates this report.

All opinions, advice and materials provided by NERA are included, reflected or summarized herein as the “NERA Content”. There are no third party beneficiaries with respect to the NERA Content, and NERA disclaims any and all liability to any third party. In particular, NERA shall not have any liability to any third party in respect of the NERA Content or any actions taken or decisions made as a consequence of the results, advice or recommendations set forth herein.

The NERA Content does not represent investment advice or provide an opinion regarding the fairness of any transaction to any and all parties. The opinions expressed in the NERA Content are valid only for the purpose stated herein and as of the date hereof. Information furnished by others, upon which all or portions of the NERA Content are based, is believed to be reliable but has not been verified. No warranty is given as to the accuracy of such information. Public information and industry and statistical data are from sources NERA deems to be reliable; however, NERA makes no representation as to the accuracy or completeness of such information and has accepted the information without further verification. No responsibility is taken for changes in market conditions or laws or regulations and no obligation is assumed to revise NERA Content to reflect changes, events or conditions, which occur subsequent to the date hereof.

Executive Summary

This report investigates the possibilities for reducing greenhouse gas emissions in Kazakhstan, over the period 2010-2030, and estimates their financial costs and benefits, across a range of sectors of the economy. In contrast to other studies of this kind, our analysis is from the point of view of an investor interested in profitable investment opportunities that *also* reduce emissions. We estimate investment opportunities, and calculate the respective costs and benefits of reducing emissions from the perspective of a commercially driven investor.

The main output of this work is an "investors' marginal abatement cost curve", or MACC, showing the volume of emission reductions and the associated cost.

Another key output of this study is an analysis of the impact of policies and market conditions on investors' costs and profits. The study estimates how demand for emissions-reducing investments, and thus abatement, is influenced by specific economic and climate policies that are already planned, or could be contemplated by Kazakhstan.

Summary Findings

The following are high-level findings from the study:

- Kazakhstan has a highly emissions-intensive economy and emissions are on course to continue to increase. Plans for economic growth centre on ambitious industrial expansion that would see a near-doubling of emissions over the next two decades unless the emissions intensity of the economy is reduced.

- Some degree of emissions reductions can be expected under the status quo. Structural changes, the natural turnover of the capital stock, and the impact of currently proposed policies and market reforms will encourage modest emissions reductions in the period to 2030. However, the resulting emissions nonetheless will be substantially higher than current levels, and significantly higher than Kazakhstan's voluntary target of a 15-20 percent reduction relative to 1992 levels in the period to 2030.

- There is significant technical potential to reduce GHG emissions further, through a combination of low-carbon energy supply, improved energy efficiency, and the elimination of fugitive methane emissions. Kazakhstan has ample renewable resources that have the potential to reduce electricity emissions by 40 percent even with significant demand growth. As much as 60 percent of primary energy use in the district heating and buildings energy supply chain could be cut even as service is improved. There is also significant potential to reduce emissions in industry. Many industrial processes currently in use are 75 percent more energy-intensive than international benchmarks of efficient production.

- Reducing emissions as outlined would require considerable investment, with higher initial capex in exchange for future cost reductions, particularly through reduced fossil fuel expenditure. Some investments appear profitable already even with the policies currently in place – notably more efficient new capacity, as well some modernisations and retrofits that have been held back by barriers including regulation and lack of investment. However, Kazakhstan's very abundant and low-cost coal resources mean much of the technical potential in renewable energy and energy efficiency is not currently commercially viable. Sufficient demand for the low-carbon investment required to meet targets therefore will depend on additional policy.

- We sketch a more ambitious Enhanced Policy scenario that could generate significant demand for low-carbon investment. The policies required include regulatory reform in heat and electricity supply; price support for renewable energy; a carbon price (or, alternatively, an economy-wide capital grants scheme) to improve the financial case for low-carbon options; low-cost finance for energy efficiency measures; and sector-specific initiatives to overcome various specific barriers. In addition, this scenario depends on a credible commitment to safeguarding investors' returns, including a stable policy and regulatory environment.

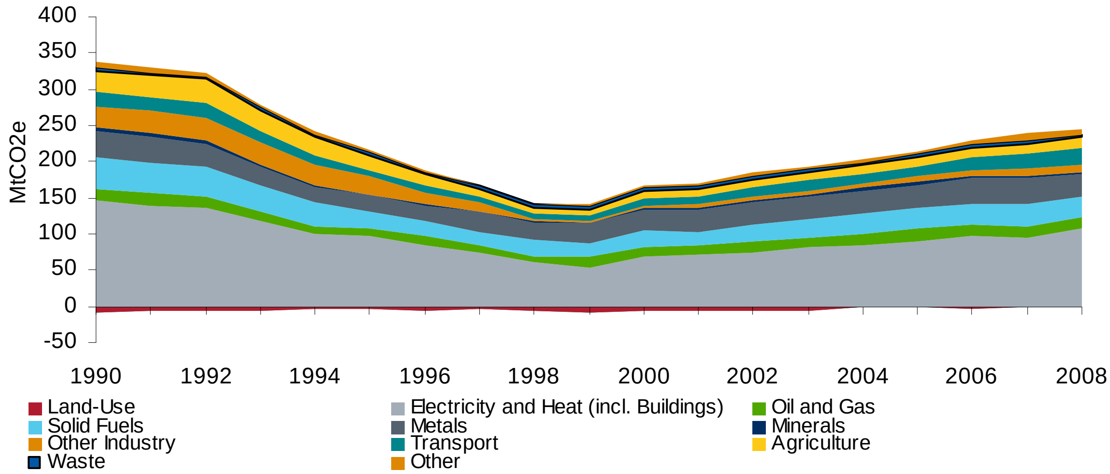
- This Enhanced Policy scenario could produce a structural break with past emissions growth. Our analysis suggests that Kazakhstan can meet the 2020 target with the Enhanced Policies that we consider. By 2030 emissions growth is 100 $MtCO_2$ (50 percent) lower than under the status quo. However, emissions nonetheless continue grow in absolute terms in the 2020s. Deploying further measures identified in this study could keep emissions nearly flat, albeit at costs as high as €200/tCO_2 for the most costly measures that would be required.

- Still more ambitious emissions reductions could be achieved through significant infrastructure realignment. This could include major pipeline investments to make natural gas available to industrial production and electricity generation in the North. If carbon capture and storage could be commercialised this would present yet another option for deeper emissions cuts.

Overview of historical emissions in Kazakhstan

In 1990 Kazakhstan's emissions were 329 $MtCO_2e$. By 2008 they were 26 percent lower, at 244 $MtCO_2e$, following first a rapid fall during the 1990s and subsequent recovery during the 2000s. Over the past decade, emissions have grown steadily at a rate of just under 6 percent per year, and are on track to resume this growth following a temporary check in the recent economic downturn.

Figure ES.1
Kazakhstan GHG Emissions, 1990-2008

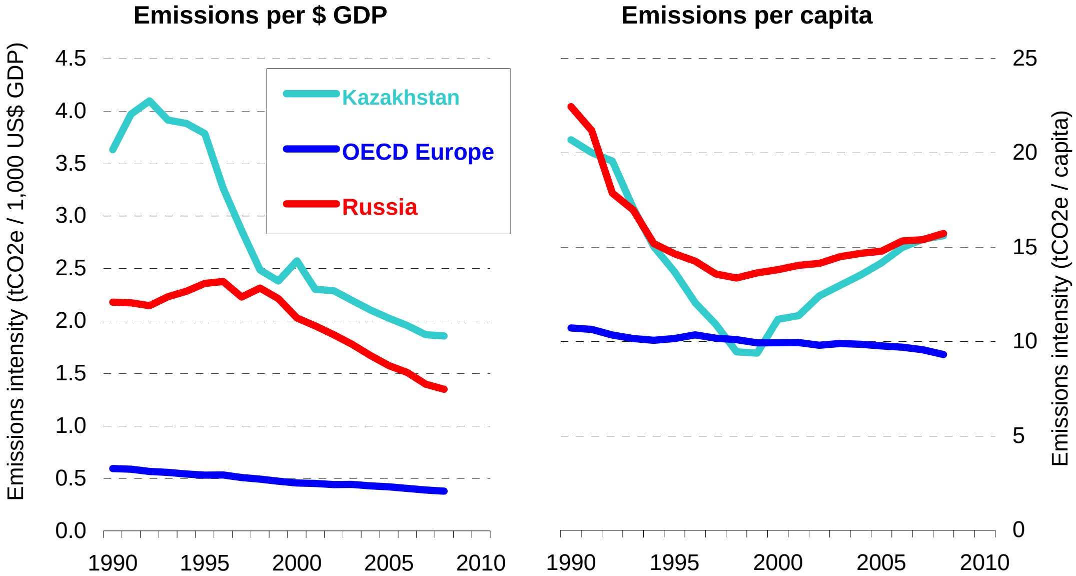


Note: Including land use and land use change, excluding F-gases
Source: UNFCCC inventory

Emissions are dominated by the power and heat sector, with 110 $MtCO_2e$ or 44 percent of the total. Industry as a whole accounted for direct emissions of around 45 $MtCO_2e$, or just under one-fifth of the total, but also is the source of a large share of indirect emissions from electricity and heat consumption; overall, energy for industrial processes accounts for three-quarters of electricity demand and two-thirds of total energy demand. Fuel use for transportation accounted for another 24 $MtCO_2e$, while agriculture accounted for 15 $MtCO_2e$ and the waste sector just under 5 MtCO2e (UNFCCC 2010).

These emissions levels reflect a highly energy- and emissions-intensive economy. Emissions per unit GDP were 1.9$kgCO_2e$/US$ in 2008, which despite a sharp fall since the 1990s is more than four times the current average for the OECD Europe. In per-capita terms, the emissions intensity has largely followed the total emissions trend, more than halving in the 1990s but subsequently recovering to a level of 16 tCO_2e/capita, close to the 2008 emissions per capita of a Russian citizen and more than 50 percent higher than those of a European OECD citizen. Underlying these emissions is a high energy intensity, in large part reflecting high industry energy use. This has fallen from 1 tonne of oil equivalent (toe) per 1,000 US$ GDP at its peak in 1992, to 0.54 toe / 1,000 US$ GDP in 2008 – this represents a peak-to-trough decrease in Kazakhstan's energy intensity of 46 percent.

Figure ES.2
Emissions Intensity in Kazakhstan, Russia and OECD Europe (1990-2008)



***Source**: IEA and UNFCCC; GDP is in 2000 prices, and PPP-adjusted*

Investor Costs

In modelling investors' decisions we assume that producers or end-users choose the technologies that deliver the goods / services they require at the lowest cost. This takes into account technical and cost characteristics (such as equipment lifetime and up-front and operating costs) for a large number of production methods and across all key sectors of the economy. In addition, we account for a range of other factors that influence the attractiveness of investments in low-carbon and energy-saving technologies, including the costs of credit and other costs of capital, attitudes toward risk, and various transaction costs. We distinguish *project* transaction costs, which are likely to be incurred to some extent for most investments, from *policy*-related transaction costs, such as the cost of participating in an emissions trading scheme. We also develop estimates of the "hurdle rates" for different technologies, reflecting a range of different factors, including:

- Cost of capital and terms of project finance
- Risk associated with country, sector, technology and policy setting
- The "option value" of delaying investment when faced with uncertainty
- Various categories of opportunity costs (of time, management attention, or other investments in the context of scarce capital)
- Individual preferences (of households)
- Organisational failures and information asymmetries (split incentives, incomplete capture of benefits, etc.)

The table below summarises our assessment related to how the above factors affect decisions about which technologies to choose. The table shows the basic assumptions that we apply to sample investments involving low, medium, and high transaction costs and hurdle rates, and gives selected examples of abatement measures with these characteristics. Other technologies are included in our full analysis.

Table ES.1
Summary Investor Costs

Hurdle / discount rates (Capital cost, risk, option values, etc.)	Transaction costs (share of capex): **Low** (10%) →		**High** (25+%)
	Large size (> €500k / > 5 MW) and established supply chains and track record of past projects	*Medium size (< €500k / < 5 MW) or larger projects facing weak supply chains or with low priority for organisation*	*Small scale (<€10k) and/or facing communal / dispersed / split property rights or first-of-a-kind investments*
Low (10%)	▪ New cement and steel capacity ▪ Industry Energy Efficiency measures	▪ Energy management systems ▪ Process control / automation	
↓	▪ New conventional power plant ▪ New conventional heat plant	▪ Public passenger and freight transport ▪ Cement waste-firing	▪ Low-emitting car ▪ Gas leakage ▪ Communal buildings heat-efficiency ▪ Transmission grid updates
High (25+%)	▪ Wind-farms ▪ Hydroelectric power ▪ Nuclear ▪ Carbon capture and storage	▪ Waste handling ▪ Coal mine methane	▪ District heating rehabilitation

Policy Scenarios

The relative costs of different investment options can be heavily influenced by policy and market conditions. We consider three illustrative policy scenarios, ranging from current conditions to ambitious energy and climate policy aimed at reducing emissions. Each scenario is benchmarked against a hypothetical baseline under which Kazakhstan's economy grows as expected, but where emissions intensity remains "frozen" at current levels. The three policy scenarios we consider include:

- ***Status Quo***: Under this scenario current policies and institutions continue as they are now. No new policies are put in place to encourage energy efficiency, renewable energy, or other emissions abatement. Where policies and measures are already in place, they are not strengthened, and their effectiveness does not improve. We assume that nuclear power is not favoured by any Government support (despite the Government's ongoing negotiations regarding several nuclear sites), and assume that government targets (e.g. for renewables) are not automatically met, unless policies that are currently implemented would deliver them. Planned rehabilitations to increase the efficiency and extend the life of existing capacity come forward where attractive. We assume continued limited enforcement of energy efficiency rules for buildings, and no dedicated policies to reduce emissions in industry or the waste sector. Very low fossil fuel prices persist, particularly the price of low-quality coal without export potential, and end-users including industry and heat consumers thus face low costs of energy which contribute to the high costs of emission abatement.

- ***Planned Policies***: The Government supports the development of a renewable electricity programme through feed-in-tariffs or equivalent price-support scheme available to a limited amount of renewables, in line with recent announcements. There continues to be limited scope to extend gas networks to the Northern regions (or upgrade the power interconnection further), where coal remains the dominant fuel. Energy efficiency requirements, including enforcement of building regulations, are tightened, so that current rules are adhered to and the most inefficient building options are not permitted. Consumption-based billing, a pre-requisite for many measures to reduce energy use in the buildings sector is gradually deployed and end-user heat prices increase to allow the necessary investments to be made in the generation and distribution sectors.

- ***Enhanced Policies***: There are two variants of the "Enhanced Policies" scenario which incorporate a range of additional policies designed to promote energy efficiency and reduce emissions across the economy. The two variants share most features in common. In particular they broaden the range of technologies eligible for price support for renewable electricity. Nuclear power is favoured by government support through guaranteed price and off-take agreements. For buildings, policies are established to require energy suppliers to promote energy efficiency in homes and other buildings, including wide deployment of heat metering and consumption-based billing. They make credit for energy efficiency investments available on favourable terms, while the establishment of resident associations enables more effective coordination of these investments. Higher heat prices, resulting from carbon prices and from regulatory reform to allow higher tariffs by generators and distribution companies, motivate end-user investment in energy efficiency measures. In industry, the scenarios include targets to encourage benchmarking and sharing of best-practice, and the policies also tighten the waste regime to encourage alternative uses of waste and less carbon intensive disposal.

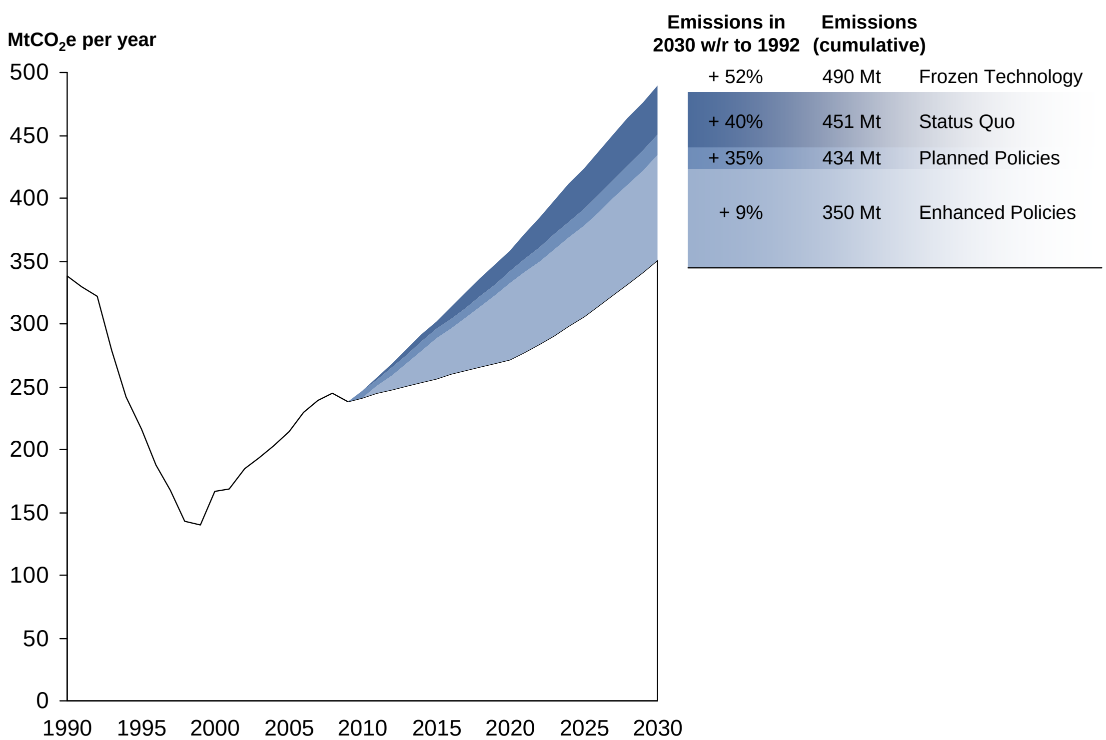
  – The two "Enhanced Policy" variants differ, however, in one of the mechanisms by which low-carbon technologies are supported. In the first ("Carbon Prices") variant, a carbon price is applied to the sectors that would be covered by the current proposals to establish a cap-and-trade emissions trading scheme in Kazakhstan. The scenario assumes a link to the EU Emissions Trading System (EU ETS), resulting in a price of €40/tCO_2e. In addition, a carbon price of €20/tCO_2e is applied to sectors potentially eligible for emission reduction credits for sale in international carbon markets, or which may be exposed to the proposed "carbon fee" that under current proposed regulations would apply to emissions sources not covered by emissions trading.

– In the second variant ("Capital Grants"), instead of applying a carbon price to relevant sectors, this scenario supports abatement technologies using direct capital grants. These grants are assumed to cover 20 percent of the *incremental* capital cost of abatement technologies, relative to the capex of higher-emitting alternatives, across all relevant sectors.

Emissions Pathways

Based on the investment data and policy scenarios we estimate pathways for overall emissions. If the Kazakhstan economy grew as projected over the period 2010-2030, but remained frozen at its current carbon intensity, its emissions would increase from the current level of just under 250 MtCO_2e to more than 350 MtCO_2e in 2020 and 490 MtCO2 in 2030. Under the Status Quo scenario, technological improvements for new and replacement equipment reduces these emissions to less than 340 MtCO_2e in 2020 and 450 MtCO_2e in 2030. The Planned Policy scenario reduces emissions further – by around 17 MtCO_2e by 2030 – primarily as a consequence of investment in renewable power, as well as some increased uptake of building energy efficiency measures. The largest impact is in moving to the Enhanced Policy scenario, which renders additional investment opportunities corresponding to emissions reductions of over 80 MtCO_2e attractive by 2030. As we show below, these reductions come from a variety of sectors, with the most significant of these a large-scale shift away from solid fuels (mostly coal) in the power sector.

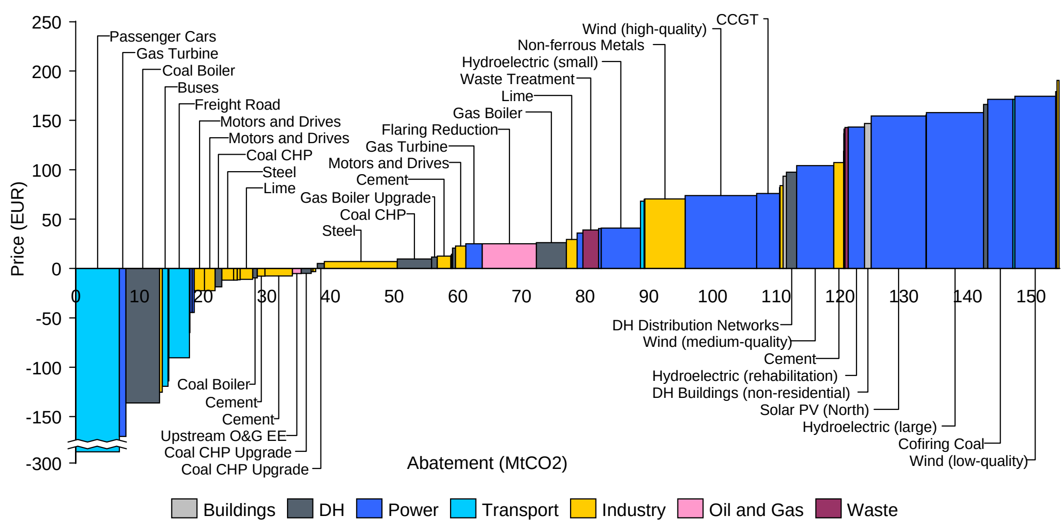
Figure ES.3
Emissions Pathway under Different Policy Scenarios



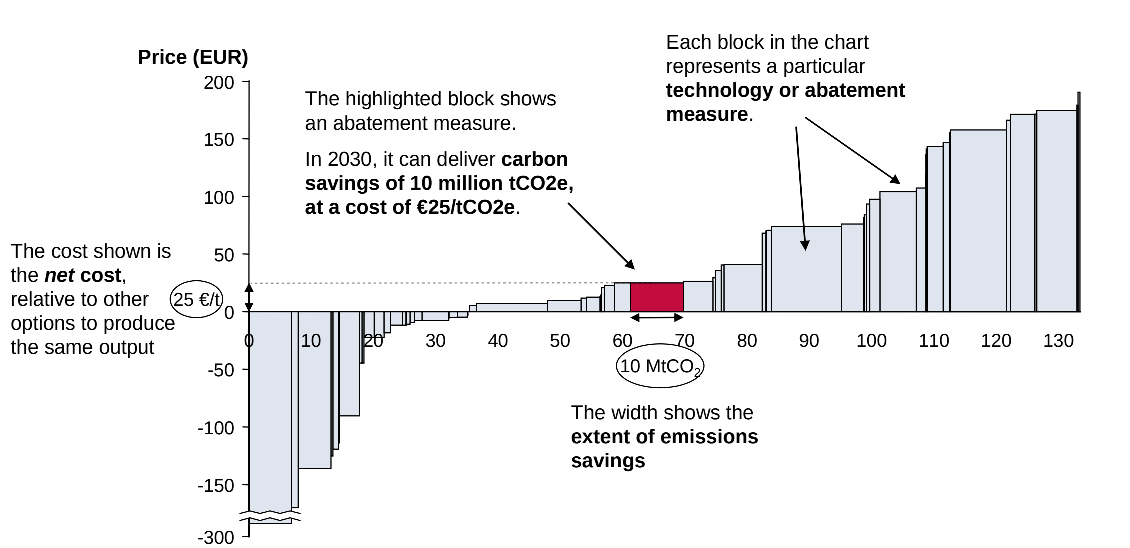
Cost Curves for Investment in Emissions Reductions

We present in Figure ES.4 a high-level summary of the cost curve of investment opportunities for the *Status Quo policy scenario*. The width of the curve shows the volume of emissions reductions that can be achieved by investments in different technologies across the economy. The height shows the corresponding net cost of reducing emissions–more specifically, the cost per tonne of CO_2 emissions at which the particular technology (e.g. a wind farm) becomes a more attractive option to investors over other, more polluting options. A negative cost implies that, on average, investors are likely to prefer the low-carbon technology because of its superior financial viability over its lifetime.

Figure ES.4
Investors' Cost Curve for the Status Quo Policy Scenario (2030)



How to Read the Cost Curve



Box ES.1
Investors' Cost Curve Modelling Methodology

The cost curve is constructed through a dynamic model simulating the decisions faced by investors in key sectors of the economy. The cost represents the carbon cost at which investors find a particular measure—often a production method or technology choice—more advantageous than other ("counterfactual") measures with higher emissions. This thus is the meaning of "profitable" in this context: a technology which, at a given carbon cost, is financially preferred to other options for achieving the same output. The counterfactuals in turn are also dynamically modelled, to ensure that the curve captures the true cost of foregoing other investment opportunities (for example, the counterfactual for a gas-fired power plant could be a coal-fired plant; while the counterfactual for wind power could be gas-fired generation).

For related reasons, the same measure can appear at multiple points in the cost curve. This may represent different grades of the same technology (e.g., wind farms at sites with different wind speeds); the increased penetration or utilisation of technologies with increasing carbon cost; the impact of resource constraints; and various other real-world considerations.

Our analysis suggests that under the policy Status Quo, there is potential to reduce emissions in 2030 (relative to the "frozen technology" baseline) by around 40 $MtCO_2e$ through profitable investments, even without a carbon price or additional climate policies; that is, these investments have lower net cost than other, alternative options for producing the same output, while they also reduce emissions. Taking into account all measures, including those that have a positive cost (i.e. those that are not profitable without additional supporting policy), the abatement potential more than triples to 154 $MtCO_2$ in 2030.

The average cost of profitable abatement measures is - €95/tCO_2e. These measures would attract €21 billion of commercial investments over 2010-2030 and yield a total "surplus" or profit of €0.76 billion (in 2010 Euros) per year in 2030 and thereafter, relative to investments in more polluting alternative production methods. Across the entire MACC up to €200/tCO2 (in real terms), the average cost per tCO2e is €36 in 2030.

By 2030, even under status quo policies and energy prices large improvements in emissions intensity (relative to the current intensity) can be expected from new road passenger vehicles and from the heat generation units, while improvements in energy efficiency in the oil and gas and industrial sectors also is expected over the next twenty years .

- For heat, investments that contribute to lower emissions intensity include the upgrades and gradual replacement of outdated CHP plants and boilers, and investment in more efficient new ones.
- In industry, the key sectors are steel, non-ferrous metals, and cement, with additional potential in a range of smaller sectors. In addition, improvement in the electric efficiency of various motors and drives can be found across the industry sectors.
- In the transportation sector, replacement of road vehicles with next-generation diesel and gasoline vehicles, both in passenger and freight transport results in significant energy intensity reductions.

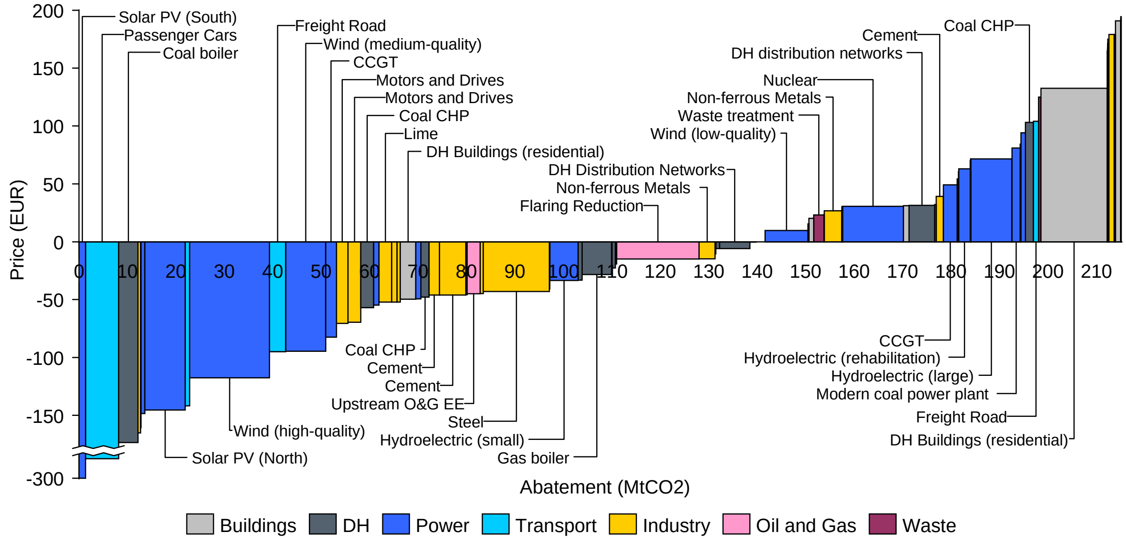
These are expected to be commercially attractive without additional policies, driven primarily by the value of energy savings, the gradual impact of an improved regulatory environment, and technological improvements in combination with capital stock turnover.

There is very significant potential to reduce emissions further through measures that entail a net cost under extrapolation of present policies. Much of this is in the power sector through investments in gas-fired power generation, and renewables, These investments thus would not become commercially attractive without changes to the current regulatory and market framework improves. Further potential for emissions reduction is available in the district heating networks and heat generation, and end-user buildings efficiency, through further investment in the oil and gas sector, and through investments in the waste sector and industry. Many of these projects will depend on ensuring an investment climate that ensures future fuel savings accrue to the parties that undertake the initial investment decisions, especially in regulated sectors.

Under the Planned Policy scenario, 10 TWh of wind power becomes a viable power generating technology because of the price support (e.g. feed-in-tariffs) available to selected projects. Wider deployment of consumption-based billing reduces emission in the end-user heat consumer sector. Improvements in the power distribution system also reduce electricity losses and result in emissions reductions. These policies make viable additional investments delivering a further 17 $MtCO_2e$ of emissions reductions by 2030.

Under the Enhanced Policy scenario a large volume of additional measures that reduce emissions become viable investments. These include investment in additional (relative to the Status Quo scenario) hydro (7.6 TWh/year), solar (14 TWh/year), and wind (32 TWh/year) capacity, and in gas-fired power stations (7 TWh/year), which lead, together with a reduction in coal-based output, to 43 Mt reductions in CO_2 emissions from the power sector. Further investments in heat generation and distribution become viable, further reducing emissions from those sectors. Significant energy efficiency improvements in buildings and industry also become commercially attractive. We show the MACC results for the Enhanced Policy scenario below.

Figure ES.5
Investors' Cost Curve for the Enhanced Policy Scenario (2030)



The policies that most affect the scope for investment include the following:

- In the **power sector** price support for renewable energy sources, such as feed-in tariffs (FITs) or green certificates, play a significant role. At the price levels similar to those offered in European countries a significant share of the potential for wind (32 TWh/year) and solar (14 TWh/year) can be made commercially viable. The carbon price signal further underpins this, and also contributes to a greater shift from coal-fired towards gas-fired generation (7 TWh/year), relative to the Status Quo scenario. In addition to these financial signals, decisions about the future extension of the transmission network will be of importance for the viability of key emissions-reducing options. In particular, developing the wind resource in Kazakhstan—much of which is of very high quality, but some of which is not necessarily located near the existing grid – will require coordination with transmission capacity extension. Although the costs of extension and connection will be borne by the system as a whole rather than individual investors, transmission planning capable of accommodating access to high-quality sites will be a key aspect of ensuring that the extent of the transmission grid does not become a constraint on the low-carbon resource.

- In the **heat and buildings** sectors a key factor is regulatory and institutional reform. Regulation needs to ensure that district heating companies undertaking efficiency-enhancing investments reap the reward of the energy saved, and that end-users see bills reduced when they consume less energy (consumption-based billing). Higher initial end-user prices are likely to be required to finance the capex to rehabilitate and modernise district heating networks. Meanwhile, the viability of many building efficiency measures depends on this price signal, as well as on passing on the carbon cost arising from fuel use in heat generation. Access to low-cost finance also will be important to realise the significant potential represented by dispersed small firms and households, as will the introduction of institutions (such as residents' associations) with the capability to coordinate investment decisions in multi-occupancy buildings.

- In **industry** policy needs both to unlock existing potential and to introduce new incentives to reach the potential indicated in the MACC. Existing potential is particularly relevant for new capacity, where higher initial efficiency can give significant subsequent gains, especially given large projected increases in output. Given the legacy of low energy prices and low efficiency, there also is potential for substantial improvements to efficiency of legacy capacity in several sectors, including cement, iron and steel, and non-ferrous metals. A carbon price could be decisive in shifting much of the diverse set of potential energy efficiency measures from marginal or unviable to commercially viable investments. At the same time there also is a significant challenge of raising awareness of the available scope for improved efficiency. A policy of benchmarking (which could be extended to an emissions trading scheme) and voluntary covenants has helped achieve such improvements in other countries, especially where initial voluntary energy intensity commitments have been linked to more stringent regulatory measures such as taxes or penalties. Such policies could also be effective in Kazakhstan. Finally, the high share of electricity consumption by industry means that decarbonisation of electricity supply also is a key aspect of reducing emissions arising from industrial production.

- In **other sectors** policies are likely to need a combination of regulation and financial incentives, which could range from subsidies to charges on emissions. The oil and gas sector already faces regulatory requirements to reduce flaring, while abatement in the transport sector depends heavily on the level of fuel taxes along with the natural turnover of the vehicle stock. Several sectors where energy savings have low value or are inapplicable – notably, coal mine methane, agricultural emissions, gas network leakage, and release of methane from landfill gas – are amenable to a combination of regulatory requirement and project carbon credits, which may in turn be lined to international carbon markets if Kazakhstan were to achieve access to carbon markets under future international or bilateral climate agreements.

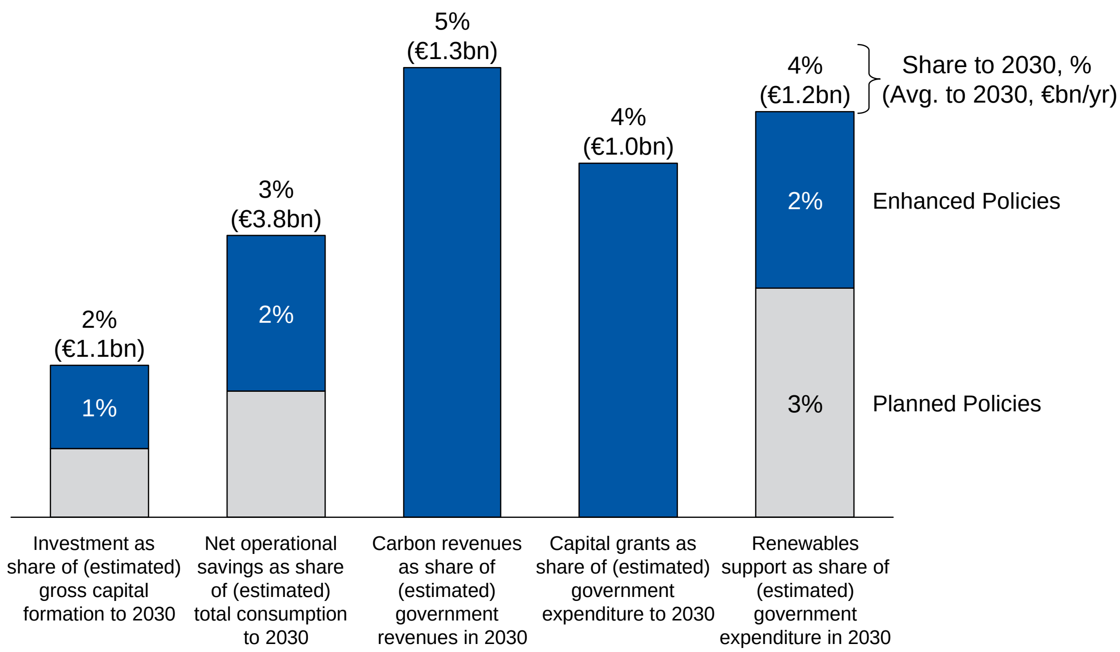
For all of these sectors the cost of abatement depends heavily on reducing investors' perceived risk of investment. Where commercial viability depends on ongoing policy support (FITs, carbon prices, etc.) and regulatory reform (heat prices, etc.) a key requirement is a stable and credible policy regime to reduce regulatory risk and bring down the cost of capital and investors' hurdle rates, in turn reducing the need for subsidies or carbon prices. Increased deployment also will reduce transaction costs and the risk from limited infrastructure and supply chain availability that initially can significantly increase the cost of abatement. Policy intervention can help encourage initial investment and the development of supply chains.

Finally, the Enhanced Policy scenario investigates the different uptake that may result depending on whether carbon prices or capital grants are used to support emissions reductions. Carbon prices provide ongoing incentives to all sectors subject to the policy, both positive incentives to reduce emissions, and negative incentives against keeping emissions high. In contrast, the capital grants approach can be thought of as providing positive and one-off benefits to measures amenable to initial subsidy of equipment, but without any negative sanction for remaining emissions. Because only a positive incentive is offered, and also because the payment per tonne emissions reduced varies much more across measures, the measures undertaken will be less efficient at reducing emissions and capital grants requires comparatively greater financial inducements to achieve similar abatement. Moreover, the level of support would need to be targeted and specified for the technologies of interest, which would present formidable administrative requirements and high transaction costs. Finally, the policies differ in the source of capital. Carbon prices rely on private sector capital mobilisation, whereas capital grants require very extensive direct state budget expenditure to incentives of similar strength.

Some of the macroeconomic implications of the policy scenarios are summarised in Figure ES.6., In the Enhanced Policy scenario the *incremental* commercially viable investment associated with the low-carbon measures amounts to €1.1bn per year in the period 2010-2030, corresponding to 2 percent of total estimated gross capital formation over the period. The opex savings are €3.8bn, or 3 percent of total estimated consumption. The carbon revenues (defined as the volume of eligible emissions *reductions* evaluated at the price of carbon allowances or credits) corresponds to 5 percent of total estimated government revenues (this is for comparison only; the revenues may accrue to other parties, including firms, depending on the policy implemented).[1] The capital grants programme would require €1 bn per year, on average, or an average of 4 percent of estimated government expenditure over the period to 2030. Finally, the price support for renewables would be €1.2 bn per year, again close to 4-5 percent of estimated government expenditure.

[1] This denomination is relevant to an arrangement whereby Kazakhstan could obtain payment for the emissions *reductions* relative to Status Quo, through international carbon markets or bilateral agreements. The associated revenue could accrue to government, or could be distributed to firms undertaking investments to reduce emissions. Note that the value of *remaining* emissions once emissions reductions have taken place is substantially higher. A carbon tax (or auctioning of allowances) at the prices assumed thus would result in substantially higher revenues, accruing in this case to government. With (some degree) of free allocation, some of this value could instead be captured by firms.

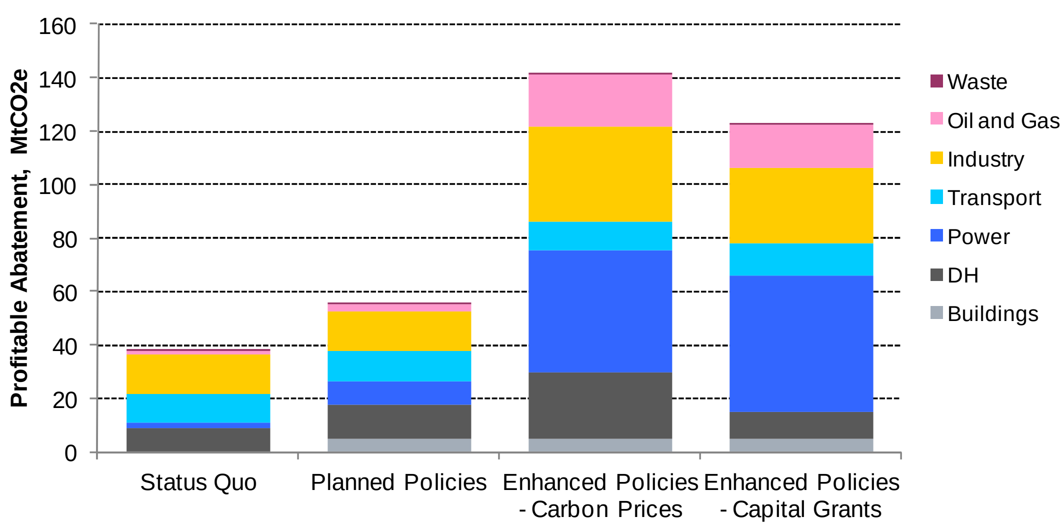
Figure ES.6
Summary Aggregate Economic Indicators



Notes: The percentages show the total shares in the period 2010-2030, based on a continuation of current shares of capital formation, consumption, revenues, and expenditure in GDP. Opex savings exclude avoided carbon taxes and subsidies.

The below figure summarises the extent of profitable abatement opportunities by sector in the different scenarios.

Figure ES.7
Summary of Profitable Abatement



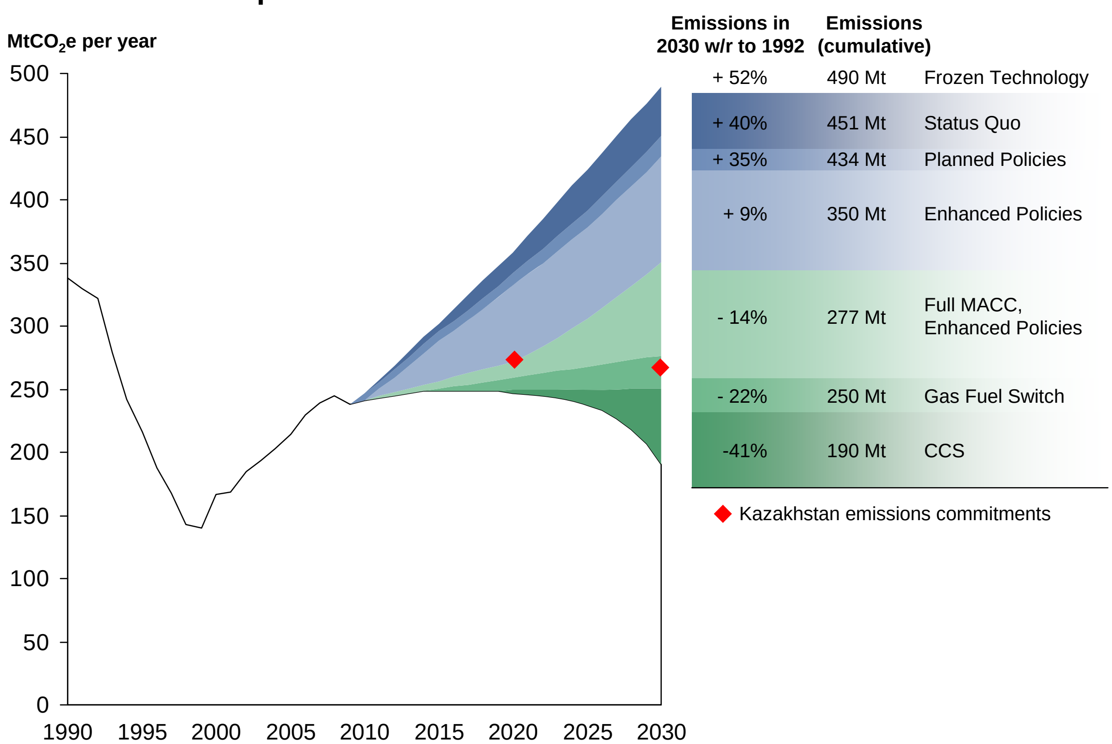
Note: Includes abatement from profitable measures.

Options for Additional Emissions Reductions

The pathway under Enhanced Policies brings 2020 emissions to a level similar to the commitment adopted by Kazakhstan, at 15 percent below 1992 levels. However, with the projected continued growth across emissions-intensive sectors, emissions are on an upward trajectory even in this scenario. Additional action therefore would be required to meet 2050 commitment of a 25 percent reduction on 1992 level.

Figure ES.8 outlines aggregate emissions under three potential additional sets of measures that could contribute to such scenarios, compared to Kazakhstan emissions reduction commitments.[2] These are either more expensive or more speculative than the measures analysed above, but are presented here to indicate the developments required for more ambitious emissions cuts.

Figure ES.8
Options for Additional Emissions Reductions



The additional potential measures fall in three main categories:

- **Higher-cost measures ("Full MACC").** In addition to the measures that are profitable in the Enhanced Policy scenario, the analysis identifies a number of additional opportunities that would require further policy support to be viable—corresponding to the "positive" portion of the Enhance Policy scenario cost curve presented above. Major

[2] The figure illustrates a linear pathway from the 2020 to the 2050 commitment. This study has not evaluated pathways to reach 2050 commitments. The most cost-effective pathway may involve reductions through the 2020s, or may instead be characterised by higher emissions in the 2020s followed by subsequent reductions in later decades.

remaining options include nuclear, renewable, and gas-fired power generation; reductions of emissions from oil & gas extraction; and additional building and district heating network efficiency measures. These and other measures could reduce emissions to 277 $MtCO_2$ by 2030 or 14 percent below 1992 levels, consistent with a linear trajectory to the 2050 commitment level. However, these measures would have an implied cost of carbon reduction of up to €200/tCO_2 in addition to the €40/tCO_2 carbon price included in the Enhanced Policy. The measures would require additional policy support—either in the form of higher carbon prices to the level indicated on the MACC, or through equivalent additional subsidies, regulatory requirements, etc.

- **Gas fuel switch:** Further reductions also could be achieved through increased use of natural gas. If residual coal use remaining after the higher-cost measures are implemented was phased out in favour of gas, total emissions could be brought down to 250 $MtCO_2$ by 2030. However, such large-scale fuel switching would require a major realignment of Kazakhstan's energy infrastructure, from the long-distance transport of electricity to long-distance gas transmission. In addition to this infrastructure cost of the pipelines required, incentives equivalent to an additional implied carbon cost of €40-70/tCO_2, would be required for gas to be preferred by end-users, on top of the €40/tCO_2 already included in the Enhanced Policy scenario. These figures change under different international gas price assumptions, of course.

- **Carbon capture and storage.** A final set of opportunities could become available if progress were made in the commercialisation of carbon capture and storage (CCS). Kazakhstan has significant emissions from large point sources in the power, heat, and industrial sectors of sufficient size to be candidates for CCS. If the technology were to become viable and ambitiously deployed in the 2020s, emissions could be brought down further to by an additional 60 $MtCO_2$ by 2030. Cumulatively with the other higher-cost measures and gas fuel switching, total emissions could then be brought down to 190 $MtCO_2$, or 41 percent below 1992 levels.

With these measures Kazakhstan has the potential to effect deeper emissions reductions and achieve an emissions trajectory consistent with its 2050 commitment, but the analysis shows that significant policy support would be required, beyond the already ambitious policies modelled in the Enhanced Policy scenario and involving measures with rapidly increasing cost.

1. Introduction

The purpose of this study is to investigate the potential to reduce greenhouse gas emissions in Kazakhstan through investigation of abatement opportunities in individual sectors. The approach evaluates the abatement opportunities from the perspective of a potential investor who is interested reducing emissions, but who is primarily interested in earning a return on these (emissions reducing) investments.

We consider the abatement investment opportunities first in the context of the existing policy and institutional environment, and then under increasingly ambitious policies to reduce emissions. In each scenario, we consider what abatement opportunities investors would find attractive given the policies in place.

The model that we use was originally developed by Bloomberg New Energy Finance, and has been modified and updated over the course of the project. It represents the major sectors relevant to emissions across the economy. It can therefore be used develop projections of emissions, energy use, technology deployment across specific scenarios, and to compare difference scenarios to each other. It uses this underlying framework to create “Marginal Abatement Cost Curves” (MACCs) showing the emissions reductions that can be achieved at different carbon prices with different “abatement measures”. MACCs can serve an important role in policy analysis by identifying cost-effective opportunities to reduce emissions. They can also be used for a similar purpose by investors, to identify attractive investments in emissions reductions.

Box 1.1
Illustration of a Marginal Abatement Cost Curve

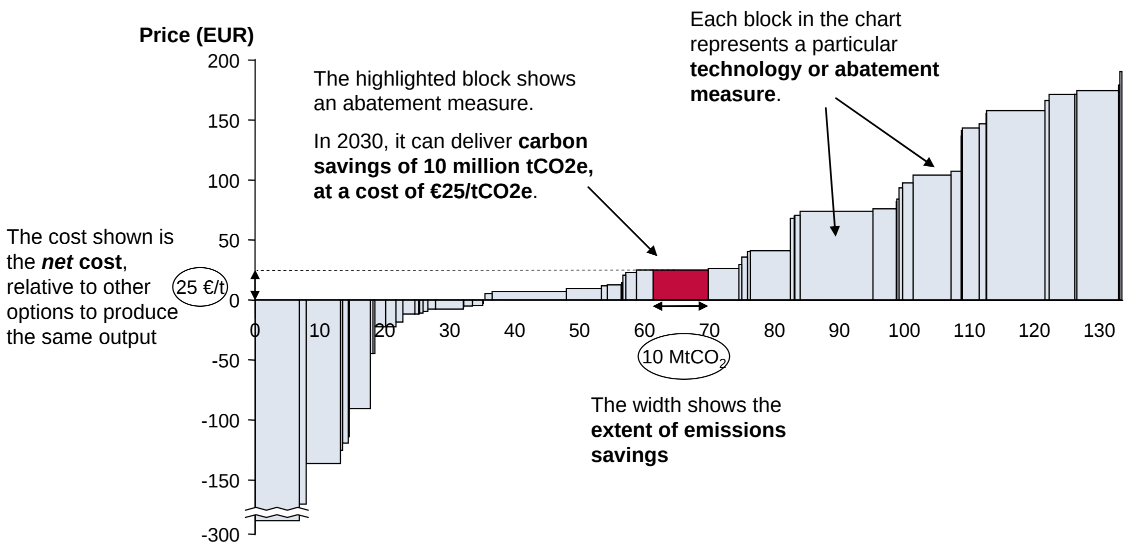
A MACC provides a convenient way of visualising opportunities to reduce emissions ranked in order of financial attractiveness. Each block in the MACC chart represents a particular technology or abatement measure. The width of the block indicates the volume of emissions reductions (i.e. “abatement”) that can be achieved through this measure. The height of the block represents the cost, per tonne of emissions reduced, of the measure. This cost should be understood as the cost *relative to another option with higher emissions* that the MACC measure is replacing. The cost is also a net cost that reflects differences – whether positive or negative – in both up-front and ongoing costs. For example, the higher incremental capital cost of more efficient equipment is offset, to varying extents, by savings on energy expenditure. The height of each block can be thought of as the “price of carbon” at which the given measure is preferred to the higher-emitting alternative.

The costs reflected in the MACC therefore must be calculated using as the starting point underlying engineering or project feasibility cost estimates, but taking into account the alternative technology, fuel prices, and other factors. Box 4.1 provides further details about how the alternative or “counterfactual” option (to which the abatement option is compared) is determined in our analysis.

The MACCs that we present in this report show the economically feasible abatement potential, in a particular year, at different costs of abatement. This is different from some MACCs, which show the *theoretical* abatement potential independent of time. For example, while it may theoretically be possible to replace all of the industrial capacity in a particular sector with the latest, most efficient technology, as a practical matter such replacement will occur over time and depending on economic circumstances – and ultimately, on the financial decisions of the investors who will actually finance the uptake of measures to reduce emissions. Our results therefore tend to show greater abatement potential over time, because there is greater opportunity to replace higher emitting technologies.

Figure 1.1 below shows a hypothetical MACC for a single year. The highlighted block shows an illustrative measure that improves energy efficiency. In the relevant year, it can deliver carbon savings of 10 million tonnes of CO2-equivalents, at a cost of €25/tCO2e.

Figure 1.1
MACC Illustration



2. Emissions and Sector Background

This section provides background on the overall energy emissions profile of Kazakhstan. We first outline the overall national profile, and then give additional detail on individual sectors, including current emissions and production, high-level opportunities for emissions abatement, and regulatory and other barriers to investments that could reduce emissions.

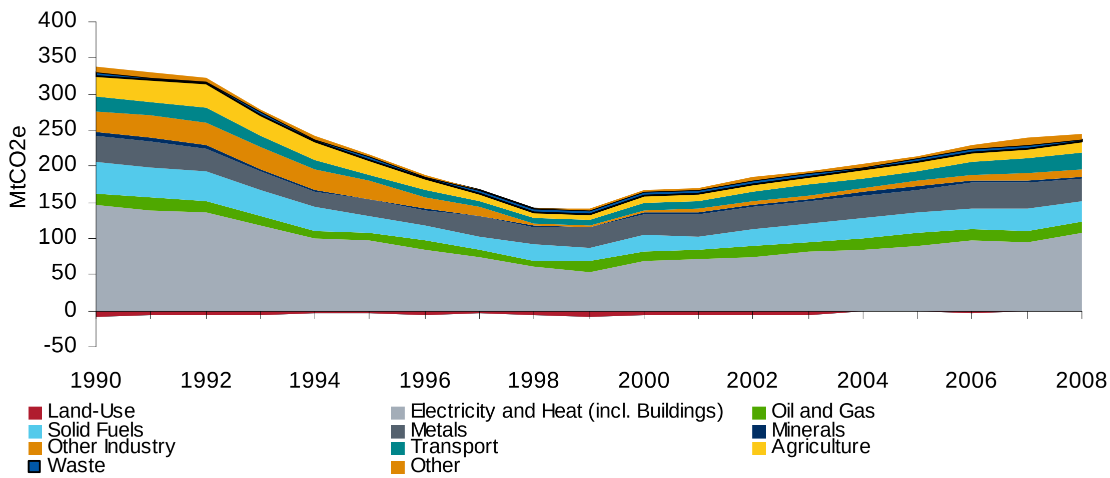
2.1. National Energy and Emissions Profile

2.1.1. Historical Emissions Trends

Kazakhstan prepares its greenhouse gas inventory and National Communication in line with the requirements of the UNFCCC. The 2010 inventory shows that in line with the decline in overall economic activity in the first half of the 1990s, Kazakhstan's emissions fell sharply between 1990 and 1999, from 329 MtCO2e in 1990 to 133 MtCO2e in 1999, a decrease of 60 percent. Emissions have since grown, reaching 244 MtCO2e in 2008, 26 percent below the 1990 level.

The power and heat sector accounts for the largest share of emissions, with just under 90 $MtCO_2e$ from public power and heat production, and additional 18 $MtCo_2e$ in the Commercial and Residential sectors, in total close to 45 percent of emissions in 2008. Industry as a whole accounted for around 86 $MtCO_2e$ (35 percent) with large contributions from fugitive emissions from solid fuels extraction as well as from metals production. Fuel use in transportation accounted for just under 10 percent year, or 24 $MtCO_2e$. Finally, the agriculture sector accounted for 15 MtCO2e, and the waste sector just under 5 MtCO2e. [3]

Figure 2.1
Historical Emissions Trends



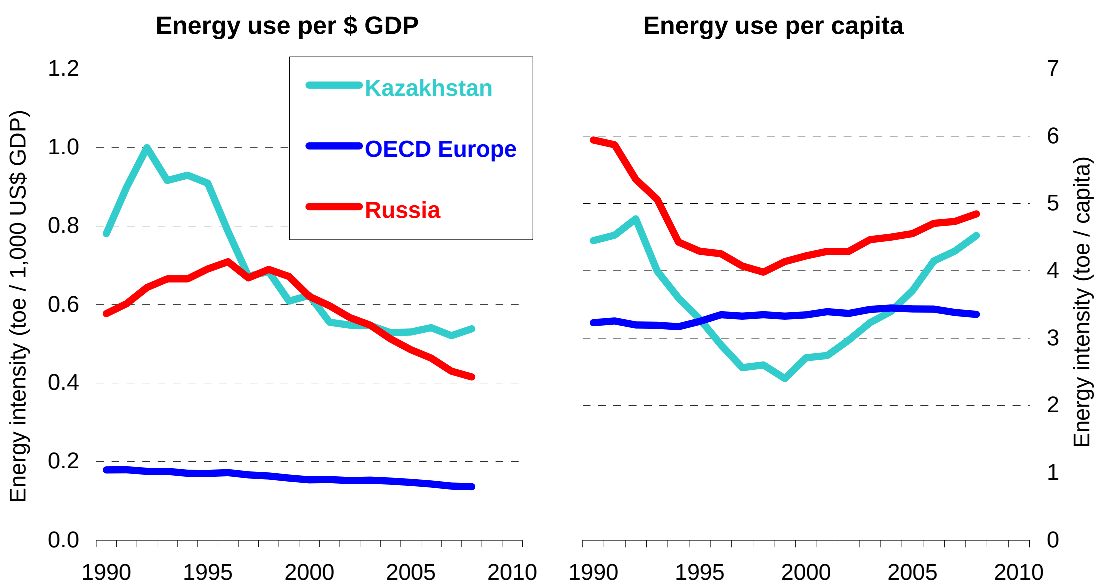
***Notes**: The data include land use and land use change but exclude F-gases*
***Source**: UNFCCC inventory*

[3] These figures exclude land use and land use change (including forestry), which accounted for net emissions reductions of 0.6 MtCO2e, down from 8.8 MtCO2e in 1990

2.1.2. Energy and Emissions intensity

Kazakhstan's energy intensity per unit GDP has been declining over the last two decades. Figure 2.2 shows the overall trend, as compared with OECD Europe. Kazakhstan's energy intensity fell from its 1992 peak of 1 toe/ 1,000 US$ GDP to 0.6 toe/ 1,000 US$ GDP in 1999 and has continued to decline much more gradually thereafter (to 0.54 toe/ 1,000 US$ GDP in 2008 – this represents a peak-to-trough decrease in Kazakhstan's energy intensity of 46 percent). Per capita energy intensity fell sharply in line with overall macroeconomic output between 1992 and 1999 (from 4.8 to 2.4 toe/capita, or 50 percent), but then increased to reach 4.5 toe/capita in 2008 (only 5 percent below the 1992 level). The development of Kazakhstan's energy intensity is similar to that of Russia, although Kazakhstan's energy performance appears to be slightly worse even than Russia's over the past decade (energy use per unit GDP has not declined as much, and energy use per capita has grown much more quickly than in Russia, although Kazakhstan still has slightly lower energy consumption per capita than Russia).

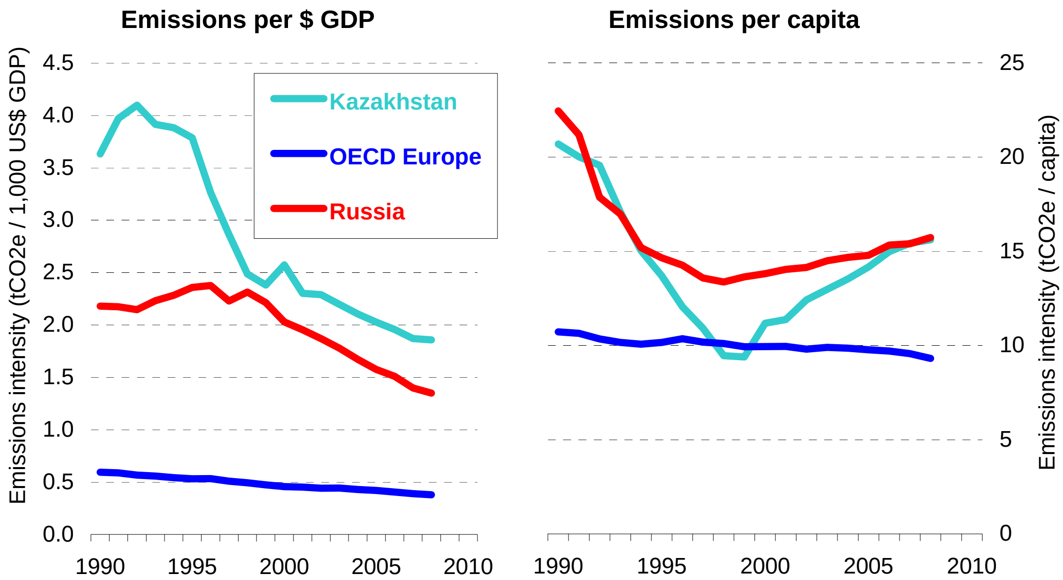
Figure 2.2
Energy Intensity in Kazakhstan, Russia and OECD Europe (1990-2009)



***Source**: IEA, UNFCCC. GDP is in 2000 prices, and PPP-adjusted*

Kazakhstan's emissions intensity, shown in Figure 2.3 displays trends similar to its energy intensity. Emissions per unit GDP declined between 1992 and 1999 (by 42 percent), and continued declining thereafter, to around 1.9 kgCO2e/US$ of GDP. In per capita terms, the emissions intensity has largely followed the total emissions trends (as mentioned above, this is largely due to nearly constant population over the observed period). The emissions intensity thus fell from 20.7 to 9.4 tCO2e/capita between 1990 and 1999, and then increased back to 15.6 tCO2e/capita in 2008, 25 percent below the 1990 level. Again, Kazakhstan and Russia show similar trends over time, with a collapse and then recovery in emissions per capita, although emissions in Kazakhstan per person dropped and subsequently rose more quickly than occurred in Russia.

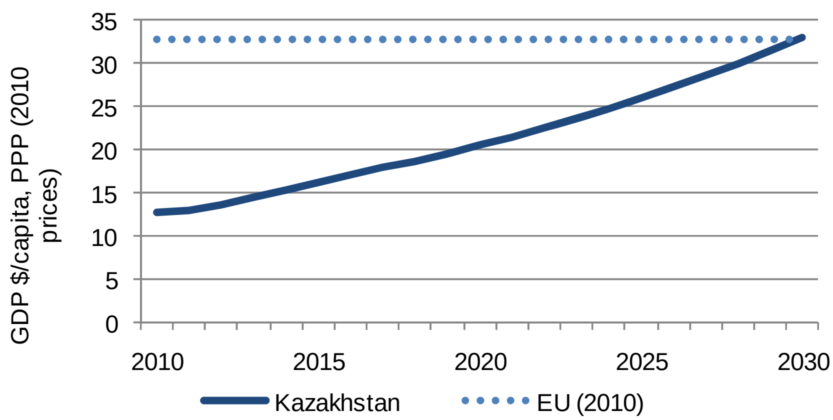
Figure 2.3
Emissions Intensity in Kazakhstan, Russia and OECD Europe (1990-2008)



Source: IEA and UNFCCC. GDP is in 2000 prices, and PPP-adjusted

Kazakhstan's GDP per capita is projected to continue to approach the EU levels. The trajectory of GDP per capita assumed in this report is shown below in Figure 2.4, in relation to the GDP levels in the EU as of 2010.

Figure 2.4
Kazakhstan GDP per Capita (2010-2030)



Source: CIA factbook, IMF WEO, IEA, NERA assumptions.

2.1.3. Emissions Targets

Kazakhstan has signed (1999) and ratified (2009) the Kyoto Protocol, and is currently in the process of applying for the Annex I and Annex B status.[4] Consequently, Kazakhstan does not have a formal emissions target assigned under Annex B.

Nevertheless, Kazakhstan has recently proposed to aim for 0 percent increase in emissions over the 2008-2012 period (over the 1992 baseline), for a 15 percent reduction in 2020 emissions relative to the 1992 baseline, and for a 25 percent reduction in emissions relative to the 1992 baseline by 2050.[5] The first of these targets would allow an increase of close to 30 percent relative to 2008 emissions, from 244 MtCO2e to 316 MtCO2e during 2008-2012.[6] The subsequent target for 2020 would allow for a 10 percent increase on 2008 levels, whereas the 2050 target would require a reduction of 3 percent.

The IMF forecast that Kazakhstan's real GDP would grow by 35 percent (cumulatively) between 2009 and 2015, or at a rate of 5.2 percent annually. This means that emissions intensity per unit GDP would need to be reduced significantly if the 2012 and 2020 targets were to be achieved. Assuming that real GDP continues to grow (as forecasted by IMF for 2014-2015) at an average rate of 6 percent year on year between 2015 and 2020, the GDP emissions intensity would need to be reduced by 39 percent (from 1.9 to 1.1 kgCO2e per 2000 US$) between 2008 and 2020, or 4 percent annually.[7] The forecasted GDP growth, the emissions target, and their implications for emissions intensity are illustrated in the Figure 2.5 below.

---

4 While the country is included in Annex I for the purposes of the Kyoto Protocol in accordance with Article 1 (7) of the Protocol[4], it is not included in Annex I for the purposes of the Convention.

Article 1(7) defines "Annex I country" as either one that is listed as Annex I in the Convention (which Kazakhstan is not), or a country that made a notification under the Convention article 4(2g) (which is what Kazakhstan did).

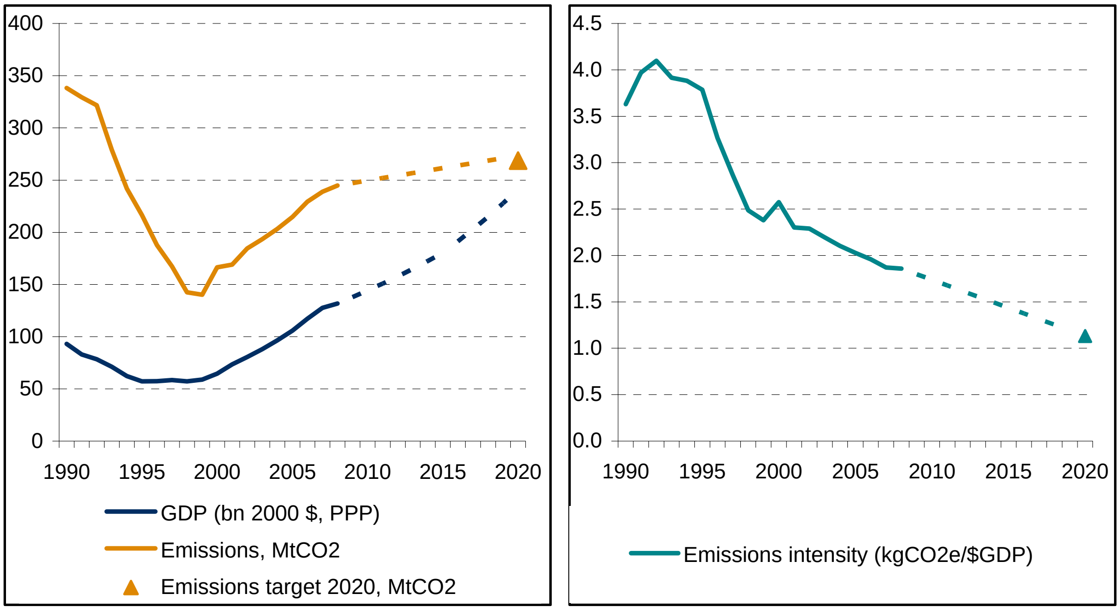
"Convention" means the United Nations Framework Convention on Climate Change, adopted in New York on 9 May 1992. Kazakhstan has made a notification under the article 4(2g) of the Convention that they wish to be bound by article 4 (2)(a) and (b) of the Convention despite not being an Annex I country – these articles provide a commitment to adopt policies and measures aimed at reducing anthropogenic GHG emissions and to report these emissions.

5 http://unfccc.int/files/meetings/application/pdf/kazakhstancphaccord_app1.pdf, http://unfccc.int/resource/docs/2010/awg12/eng/inf01.pdf

6 These figures are inclusive of LULUCF.

7 This compares to an 11 percent annual decrease in emissions intensity per $ GDP during the steepest decline between 1995 and 1999. The average annual decline in the total emissions between 1992 and 2008 was 4.8 percent, lower than the required 5.3 percent described above. And between 2000-2007 (i.e. ignoring the period of most severe downturn due to economic restructuring) the average annual decline in emissions intensity was just 4.5 percent.

Figure 2.5
GDP and Emissions forecast and targets



Source: UNFCCC inventory 2010, data excluding LULUCF, IEA, IMF, and NERA Calculations.
***Notes**: The GDP series is actual PPP-adjusted GDP series, in 2000 US$ from 1992 to 2008. Growth for 2009-2015 is based on IMF projections and the 2015-2020 growth is based on extrapolation of the IMF forecast (6 percent year on year).*

2.2. Power Generation Sector

The power sector is the largest single source of emissions in Kazakhstan. Not only is electricity demand very high, at 87 TWh or 5 MWh / person, but 70 percent of this is met through highly emissions-intensive coal-fired generation. Total emissions from the sector (including CHPs, which also serve the heat sector) amounted to 91 $MtCO_2$ in 2010.

Electricity demand has grown quickly in Kazakhstan the last decade, rising from 54 TWh in 2000 to 87 TWh in 2010. This study uses KEGOC's forecast of future demand growth, which sees demand increase to 130 TWh by 2025, or 2 percent per year. The forecast extrapolates this to 144 TWh per year by 2030. With the current profile of generation, this would grow to an estimated 178 $MtCO_2$ by 2030.

Kazakhstan's total installed generating capacity at the beginning of 2010 was 19 GW. However, much of capacity was taken out of operation in the 1990s, and only some 15 GW of the nameplate capacity is in fact available for generation, while the remaining 4 GW would require extensive rehabilitation before it could be brought back to serviceable status. Much of the available plant has low efficiency, typically some 10-15 percentage points lower than a new coal plant.[8]

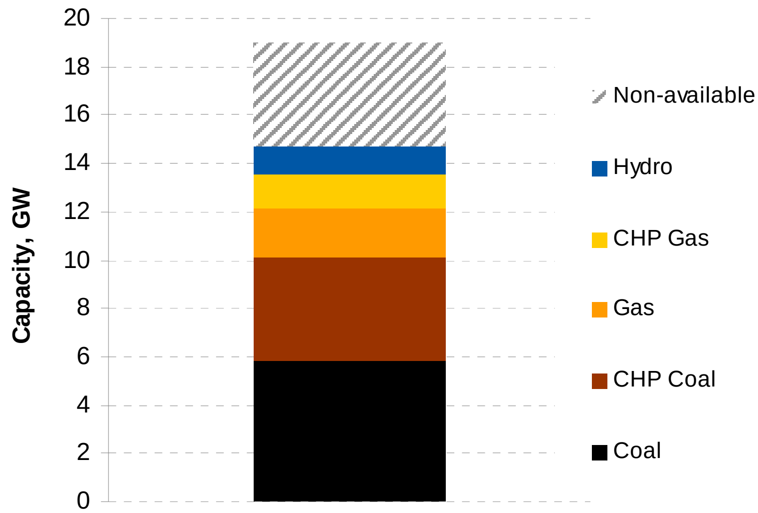
8 AF Consult report for the EBRD (2009): Thermal Power Plants: Rehabilitation and Efficiency Improvement; Market and Investment Needs. May 2009.

Of the available capacity, 92 percent is thermal power plants, dominated by coal. Moreover, as much as 5.7 GW, or 38 percent, of capacity is accounted for by combined heat and power (CHP) plant serving both district heating networks and industrial end-users. The need to serve local heat loads influences running patterns as well as the feasible location of plant. In addition, CHP applications limit generation to thermal power generation options.

The remaining eight percent of generation come from hydroelectric plant. Production from other renewable sources is negligible, although there are some renewable projects in pilot stages.[9]

Figure 2.6 shows the composition of capacity, split into available and non-available, as well as type.

Figure 2.6
Power capacity indicators



Source: EBRD and National Electrobalance statistics, 2009.

Industrial applications, especially in the country's extensive mining and metallurgy sector, account for as much as three-quarters of electricity demand. For comparison, in 2008 the residential sector accounted for 11 percent of demand, with the remaining 13 percent accounted for by transport and other sectors. A significant share of the generation plant is owned by industrial conglomerates, and vertically integrated with industrial processes.

Major potential opportunities for investment to reduce GHG Emissions in power generation include:

- Improving or replacing currently operating capacity that has low thermal efficiency;

9 A solar heating system installed in Kyzylorda in 2002 (http://sgp.undp.org/download/SGP_Kazakhstan2.pdf), or a planned Djungar Gate 50MW wind farm (Clean Technology Fund, 2010).

- Switching from coal to fuel sources with lower emissions intensity, including gas, renewables, and nuclear;
- Raising electricity prices to increasing end-user incentives to invest in electricity-saving measures; and
- Investing in distribution and transmission grid infrastructure to reduce losses, and as required to facilitate other abatement (notably, connection of renewables).

We discuss the opportunities for each of these categories of abatement briefly below, along with the key considerations and barriers that affect the realistic prospect of undertaking the associated investments.

2.2.1. Generation market

Kazakhstan effected an early and far-reaching deregulation and privatisation of its electricity system, with a market design similar to that operating in many Western European countries. A bilateral contracts market has been in place in 1997, complemented since 2000 by a centralised market run by the market operator KOREM. The overall market design also foresees system services provided by the transmission system operator KEGOC, as well as a balancing market and a market for ancillary services. The latter markets are still under development.

Recently there has been concern that previous market arrangements provide insufficient incentives for investment in new capacity. Critics have pointed to continued use of obsolete equipment, declining capacity margins, a downward trend in net plant efficiency, and an increased frequency of outages and emergencies as indicators that the previous market arrangements resulted in insufficient investment in both new and existing plant and other equipment.

In particular, wholesale prices have been low, offering limited margins above short-run marginal cost to finance investment in new capacity or rehabilitation. This has immediate implications for GHG abatement. As noted, the current generation fleet has low overall electric efficiency, with resulting high emissions per unit output. Investment in rehabilitation and new, more efficient capacity thus could constitute a key element of GHG abatement potential in the Kazakhstan power sector.

Low wholesale market prices also have important implications for the incentives to invest in measures to reduce electricity consumption in industry, which accounts for as much as 75 percent of total electricity demand in Kazakhstan. Industrial users typically pay prices near wholesale price levels, and even though high transmissions charges have meant mean that end-users can be captive to local generation sources, prices have been very low.

The regulatory system was overhauled in 2009 to introduce a form of regulation of wholesale prices under the aegis of the Ministry of Energy and Mineral Resources (MEMR). This defines price caps for 13 categories of generators, defined by fuel type and other elements of the cost structure. Caps are defined until 2015, growing by 10 percent on average, with some residual potential for competition for supply at levels below the caps. In keeping with the original intention to promote investment, generators can apply for increases in their individual caps to finance specific investment programmes.

2.2.2. Electricity distribution and end-user tariffs

Electricity distribution and retail supply in Kazakhstan is unbundled from generation, with 24 Retail Electricity Companies (RECs) with mixed private and public ownership. Electricity tariffs paid by customers with base load of 1 MW or less are regulated by AREM. Formally, the regulatory system should allow for the recovery of cost as well as a rate of return on approved investment. In practice, however, the process for tariff reviews has been infrequent, slow, and administratively cumbersome, and outcomes sometimes unpredictable. Past concerns have included both that RECs have been prevented from fully passing through the full wholesale price of electricity to retail tariffs, and that the distribution tariff has been insufficient to finance the major investment programmes that could improve service and reduce physical and commercial losses. These features of the regulatory system have been compounded by the influence of efforts to reduce inflation by keeping prices down. There have been some recent reforms aimed at improving the regime, including a 2010 amendment to the Law on Natural Monopolies, aimed at eliminating some of the delays and unpredictability caused by the previous lengthy formal tariff review process.

This regulatory situation has two main implications for investments in GHG abatement. First, the regulatory limitations have resulted in underinvestment in the distribution network. Losses have continued at a high level, with total (physical and commercial) losses ranging from 15 percent to as much as 40 percent in some areas, and average physical losses of around 15 percent. With the right institutional incentives, investment to reduce these losses could form a major opportunity for GHG abatement.

Second, prevailing regulatory practice has meant that end-users face lower prices than they would with recovery of long-run marginal cost. They therefore also face a weaker price signal to undertake investments to reduce electricity consumption.

2.2.3. Transmission regions and grid interconnection

The Kazakhstan power grid consists of three transmission areas – North, South, and West – with varying degrees of interconnection. Transmission tariffs are set by the Kazakhstan Electricity Grid Operating Company (KEGOC). Tariffs previously varied significantly between eight separate zones, depending on the zonal generation deficit and transmission grid structure. In 2010 these were reformed to move towards a more uniform system of charges.

The North transmission area is home to three-quarters of electricity demand as well as the large majority of generation capacity. The area has substantial interconnection with Russia, to which it has been a net exporter in recent years.

The transmission capacity between the North and South areas was recently increased from an inadequate 630 MW to 1,350 MW, alleviating some of the pressure on the very low capacity margin that had developed in the South. The South in turn is interconnected with Kyrgyzstan (2,460 MW) and Uzbekistan (940 MW), with net imports from the former. By contrast, the West transmission area has no interconnection with the rest of the country on the territory of Kazakhstan, although interconnection with Russia forms an indirect link to the North.

Despite the large distances involved, transmissions losses in Kazakhstan are modest, at 6-7 percent. Opportunities for emissions abatement through investment in transmission thus are much more limited than those represented by the potential to reduce distribution losses.

However, as we discuss below, the system of transmissions charges can heavily influence the feasibility of individual generation projects with implications for emissions, notably the location of wind farms.

2.2.4. Fuel availability and fuel prices

The structure of the power transmission grid—in combination with the extent of the gas transmission network system and distribution of natural resources—places important restrictions on the technical (and economical) potential to reduce emissions through fuel switching, i.e., replacing high-emitting coal-fired generation with generation using lower-emitting fuels or energy sources.

2.2.4.1. Coal

The current make-up of the electricity sector is in large part a reflection of the availability in the North of the country of cheap coal. Although Kazakhstan exports higher-quality coals, the high ash content and low heating value of much of the coal resource of the Karaganda and Ekibastuz fields mean the fuel is effectively stranded. At the same time, the opportunities for surface mining mean production costs are very low. Although mines are privately owned, prices are regulated by the anti-monopoly authorities. Regulation has at times been influenced by concern about the impact that increasing fuel prices would have on the overall inflation rate. The combination of limited opportunities for export and low production cost has resulted in very low prices – as low as 10-15 percent of those in international coal markets.

The low price and abundance of coal is a key feature of the Kazakhstan electricity sector with direct implications for the attractiveness of investments to reduce emissions. Low-cost coal makes fuel switching as well as renewable energy more expensive. Similarly, the low fuel prices result in low wholesale prices for electricity (as well as heat – see below). Abatement through downstream energy savings therefore also is more expensive.

2.2.4.2. Gas

Kazakhstan is home to very substantial oil and gas reserves in the West of the country, but natural gas does not play an important role in power generation. Moreover, the technical potential for it to do so is limited by geography and available infrastructure, as well as by the demand for reinjection of associated gas for enhanced oil recovery. The map in Figure 2.7 shows the location of the main natural gas pipelines in Kazakhstan, as well as dashed line indicating various proposed potential future gas pipelines.

Figure 2.7
Kazakhstan Natural Gas Pipelines

Source: EIA (citing Kazakhstan Energy Ministry)

There are two separate natural gas distribution networks in Kazakhstan, one supplying the country’s oil producing region in the West, and a second supplying mostly imported gas to the South of the country, including the major cities of Shymkent and Almaty. The two systems are not currently connected, and the absence of domestic gas pipeline infrastructure capacity means that the producing region in the West cannot currently supply major cities and southern industrial region in the south, nor the major sources of demand in the North. Instead, gas in these regions is imported from Uzbekistan.[10]

This situation is set to change with the construction of a pipeline connecting the West and South regions (Beyneu to Shymkent, marked as “Proposed route 1” in the map). This is included in the Strategic Plan of Kazakhstan (2010-2015), and construction started in 2011. This will link gas production in the West with the existing Central Asia – China gas pipeline. In addition, it will have the potential to supply the South region with gas (the Strategic Plan indicates up to 5 bcm of natural gas by 2014. The pipeline’s total capacity is intended to be 10 bcm/year initially, with plans to increase this to 15 bcm/year, but much of this capacity – which is joint-funded by the China National Petroleum Corp – is intended for export.

Other extensions to the pipeline network have been mooted. A West Kazakhstan – China pipeline (indicated on the map above as “Proposed Route 2”) was proposed in 2005, but the plan has not been taken forward, possibly due to high costs and concerns about sufficient gas availability. Many assessments do not consider it likely, in large part because gas demand for

[10] The main current exception to the use of imported gas is the Amangeldy gas field, which currently is producing a reported one bcm / year. Despite its local significance for Almaty, however, this does not currently play a significant role in the country’s overall gas consumption.

enhanced oil recovery might make insufficient volume available for export.[11] The possibility of a further connection to the North of the country also has been mooted, as a speculative long-term possibility should the West Kazakhstan – China pipeline be built.[12]

The lack of access to gas in the North, in combination with the limitations imposed by transmissions capacity, has important implications for the technical potential to reduce GHGs in the Kazakhstan power system. Switching from coal to gas has been a key method of abatement in many other countries (e.g., Germany, United Kingdom) but this option is not currently available at all in the North, which is home to the large majority of power production, demand, and emissions in Kazakhstan. Meanwhile, the pipelines currently under construction would make it possible keep the current share of gas in gas generation in the West and in the South, and possibly also reduce import dependence somewhat. However, use of the gas for power generation would need to compete with other uses and may be better suited for heating—where the co-location with major cities means gas has the additional advantage of reduced local pollution.

In sum, significant switching from coal-fired to natural gas-fired generation would require very significant investment in gas pipelines – starting with the West Kazakhstan – China gas pipeline, and then extending to the possibility of a branch to the north of the country. This would come not only at the high cost of building the initial pipeline, but also of foregoing other uses for the gas, including its reinjection for enhanced oil recovery in the Western oil fields, and would be further hampered by the need to displace very low-cost coal in the North. We regard this option as highly speculative, and do not include it in our main assessment, which instead allows existing pipeline projects to enable Kazakhstan to preserve its current share of gas in power generation. However, we analyse the emissions reduction implications of a more significant gas-switching scenario in section 7.2

2.2.5. Low-carbon generation

With the exception of large hydro installations, which generate around 8-9 TWh electricity per year, renewable energy sources (RES) and nuclear play only a negligible part in the Kazakhstan power sector. However, the available renewable resource is very large, and renewables have significant technical (and if financial and other barriers could be overcome, economic), potential as a source of emissions reductions. The Government also has aspirations for a nuclear power programme, which could further reduce the power sector's emissions intensity.

2.2.5.1. Wind power

Kazakhstan has very significant wind resources. Wind speeds are high over large areas, a large number of suitable sites can be found relatively close to existing transmission lines, and there is a good correlation between seasonality of wind availability and power demand. With vast technical potential (estimated at some 1,800 TWh, or around 760 GW[13]) the relevant

---

11 E.g., PetroMin Pipeliner 'China's Pipeline Gas Imports: Current Situation and Outlook to 2025', 2011.

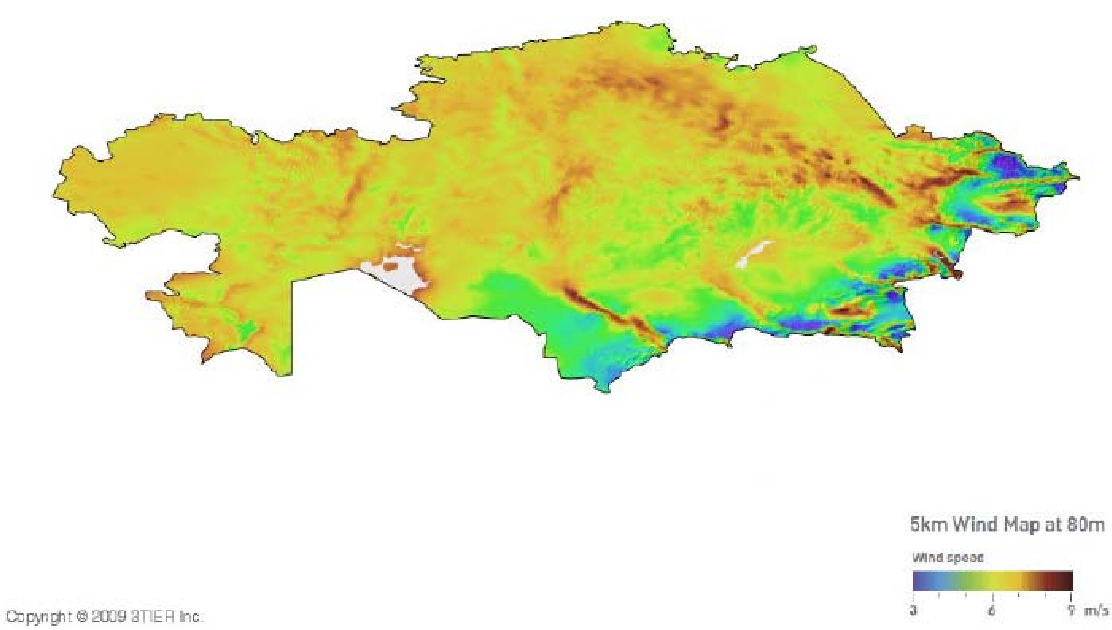
12 http://kaz-news.info/2011/07/kazaxstan-plavno-perevedet-otoplenie-s-uglya-na-gaz/

13 UNDP (2004) suggests the technical potential of wind power is 1,800 TWh. Assuming a load factor of 27 percent, this implies 760 GW capacity.

limitations on wind power development are first financial viability, and secondly the implications of integrating large volumes of wind in the overall transmissions system. Existing hydropower has the potential to mitigate intermittency to a degree, but with larger swings the system would likely feel the impact of limited availability of flexible gas-fired generation, which in most power systems is seen as the most promising route for system balancing in the context of significant shares of wind power.

A wind map of the country showing average wind speeds is reproduced below in Figure 2.8.[14]

Figure 2.8
Wind map of Kazakhstan



Source: Reproduced from EBRD (Country Profile)

The Kazakhstan wind resource is spread out but with a particular concentration of high-speed locations in the North of the country, which also is the area with the highest co-location of current transmissions and distribution infrastructure with wind resource. However, there also are significant areas with high wind speeds in the western Atyray and Mangistay oblasts, in Akmola and Karaganda oblasts in the centre of the country, as well as some areas in the South, including including the Djungar Gates area, where a pilot 50MW wind power station is planned[15], and the Chilik Corridor. All in all, analysis of the Wind Atlas shows that around half of the country's very large area has average wind speeds at 30 metres of 4-5 m/s, which

---

14 For small wind turbines, 4m/s speed is required (6m/s for utility-scale wind power plants) (http://www.awea.org/faq/wwt_basics.html)

15 Clean Technology Fund, 2010

internationally is regarded as the lower range of good wind potential, with substantial areas in excess of 6 m/s, particularly in the North and the West.

This distribution of wind resources points to the potential for wind power to make an important contribution even in the South, which is less well-endowed with fossil fuel resources. However, the optimal siting of wind farms will depend on detailed appraisal of a variety of trade-offs associated with wind investments in different locations and regions. For example, one option would be to expand existing transmission capacity to allow wind farms at high wind-speed sites in the North to serve demand; another option would be to extend capacity to more remote locations through incremental additions to transmission capacity elsewhere. The current system of uniform transmission charges generally tends to make long-distance transport of electricity more likely (provided sufficient inter-regional transmission capacity is indeed made available); whereas the previous transmission charging system, which took account of regional power deficits, would make generation nearer areas of demand deficits more attractive.

This issue is not particular to wind power, as it also applies to other key generation investments—notably, the use of the Ekibastuz and Karaganda coal resources for generation to meet demand in the rest of the country. Nonetheless, ensuring that transmission capacity is added efficiently to enable the utilisation of regional high-wind resources will be an important enabling factor required for the cost-effective development of Kazakhstan's wind resource.

2.2.5.2. Other renewables

The technical potential for the use of biomass in Kazakhstan has been estimated at around 30 TWh of technical potential, based on an assessment of the average size of farms, numbers of animals, crop sizes, and forest production.[16,] However, much of this is dispersed, and costs of bringing biomass to market for large-scale power generation could be substantial.

Kazakhstan also has areas with high insolation that could be suitable for solar power. The direct insolation in Kazakhstan is shown below in Figure 2.9. Some reports have also suggested that solar thermal and geothermal energy could also provide a contribution to the energy needs of Kazakhstan, but these resources have not yet been exploited.[17] We consider 8 GW technical potential of Solar PV, distributed across the country (the technical limitation arises primarily from the ability of the power system to support the intermittency of the solar resource, similar to wind). In principle, two methods of supporting Solar PV deployment are

---

16 EcoHarmony (2007) Opportunities for Biomass Energy Programmes – Experiences & Lessons Learned by UNDP in Europe & the CIS

17 ADB (2006) reported that currently

"the practical use of geothermal energy is of certain interest to communities in remote or desert and mountain areas. However, it is necessary to note that the use of available geothermal resources in Kazakhstan is very insignificant and limited to agricultural and household needs."

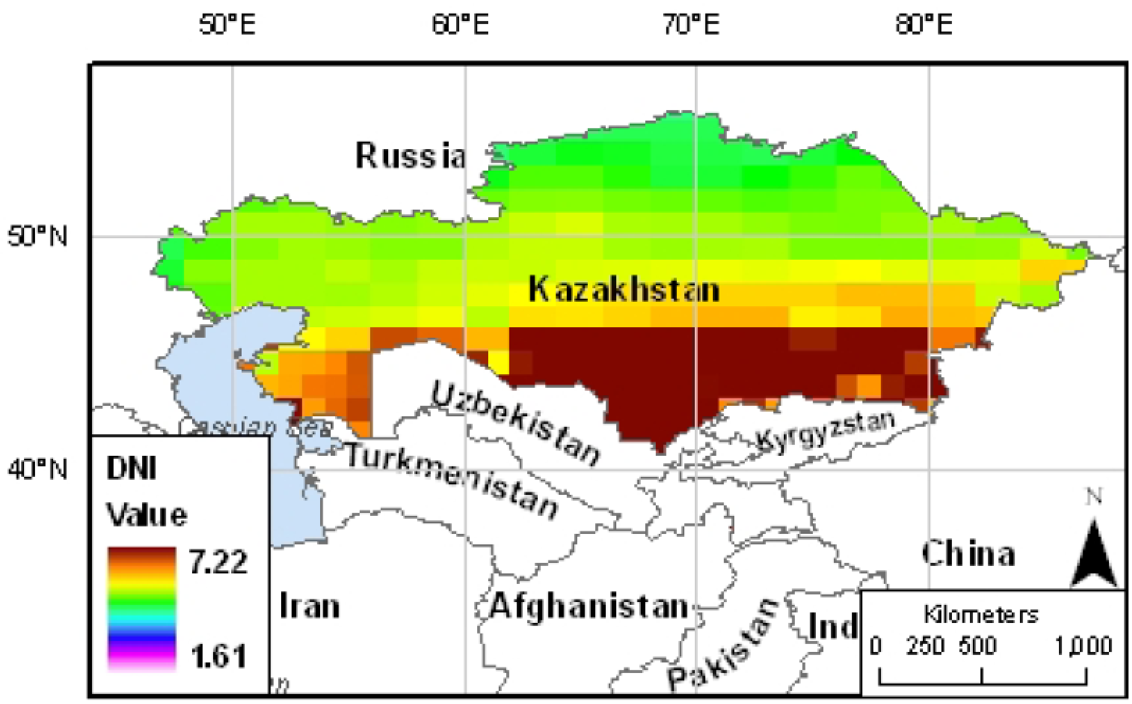
As much as 92 percent of the geothermal electric sources are concentrated in the Western regions, with access to gas, which makes the investment in geothermal energy relatively less attractive.

http://www.adb.org/Clean-Energy/documents/KAZ-Country-Report.pdf possible – feed-in tariffs or carbon price – these would have different impacts, depending on the location (and the relevant counterfactual fuel displaced) of the installation.

- The level of Feed-In Tariff required to displace coal in the North would be higher than the level required to displace more expensive power (for example, from gas) in the South.
- In contrast, if a carbon price were used as the support mechanism, a higher price would be required to displace gas (e.g. in the South), due to the lower carbon intensity of gas relative to coal.

A combination of both policies, as modelled in the Enhanced Policy scenario below, could result in both regions being attractive locations for investment.

Figure 2.9
Kazakhstan Solar Direct Normal Insolation



Source: NASA (cited by Inogate[18])

Kazakhstan also has significant geothermal resources, but we consider these as speculative[19], as the proximity to a source of heat demand (in the case of geothermal) is crucial, and the costs of connecting remote locations are likely to be prohibitive.

18 http://www.inogate.org/index.php?option=com_inogate&view=countrysector&id=30&Itemid=63&lang=en

19 A recent paper by GTZ (2009) suggested that the most recent geothermal potential estimates are around 54 TWh, from a 1996 study by Dukenbaev; but that "There is, however, no information available how much of this potential is technically usable."

http://www.gtz.de/de/dokumente/gtz2009-en-regionalreport-kazakhstan.pdf

There is further technical potential for hydroelectric power, both small- and large-scale, as well as some potential for rehabilitation of the existing capacity. Some reports indicate that the potential could be as high as 170 TWh / year. However, current government plans indicate new build of hydro plants of under 1.5 GW, and other sources indicate that the total investment potential in hydroelectric capacity is limited to 4 GW in total.[20] In this report we assume that the technical potential for small hydro is 2.4 GW and for large hydro 3.3 GW indicated in the Electricity Development Program until 2030, cited by PEEREA.[21]

2.2.5.3. Policies for the promotion of renewables

Incentives for the exploitation of RES have been limited to date, but the government has recently shown interest in achieving a higher share of RES in the overall generation mix. The Concept of Transition of Kazakhstan to Sustainable Development in 2007-2034 identified the use of RES as an important objective. More concretely, the State Programme for Industrial and Innovation Development (2010-2014) aims for 1 TWh of electricity from RES by 2014. As a longer-term objective, the government aims for 6 percent of generation (c. 7.8 TWh) to come from RES by 2024.

To promote these objectives, a Renewable Energy Law came into force in 2009. This includes a system of obligations on local network companies and the System operator to purchase the output from RES facilities, obligations on network companies to connect RES facilities to the wider network, and price support through guaranteed prices for the electricity produced. Obligations apply for an amount corresponding to up to half of network losses (around 6-7 percent, depending on area). Although this has some similarities to a system of feed-in tariffs (FITs), there are important differences to FIT systems as implemented in Western Europe and elsewhere. In particular, the price received depends on the outcome of individual negotiations with MINT, thus creating substantial uncertainty for potential investors. Investors also are likely to face limitations on where they can locate potential projects, which need to conform to the MINT plan for RES facilities. It is too early to evaluate the effectiveness of the framework, but overall there is a risk that these features mean the support system will fail to deliver the investment that is hoped for or lead to a need for very high support levels to compensate for the risk to investors.

2.2.5.4. Nuclear power

Kazakhstan currently does not produce any power from nuclear capacity. The only nuclear capacity in Aktau was temporarily closed in 1994 and finally closed in 1999 after having had the operational lifetime extended beyond the originally planned 20 years (1973 – 1993). The only nuclear reactor in Kazakhstan is currently used for research purposes.

In the last decade Kazakhstan has been discussing the options for constructing new nuclear capacity, including proposals for a plant near Balkhash, in Aktau, and other locations. However, there have been few tangible results to the date, due to several agreements and

---

[20] Bloomberg newswire http://www.bloomberg.com/news/2010-12-13/kazakhs-say-germany-s-pne-to-invest-1-3-billion-in-hydropower.html

[21] PEEREA, Regular Review of Energy Efficiency Policies, 2006.

proposals falling through due to inadequate financing or state guarantees .[22] We are not aware of any nuclear plant being currently under construction or at an advanced stage of planning with a realistic prospect of completion over the next 20 years.

The feasibility of an extended nuclear programme has been further weakened by a recent accident in Japan, so we believe a comprehensive shift of Kazakhstan power generation to nuclear generation would require very concerted government policy intervention.

2.3. Heat and Buildings

Kazakhstan's climate creates significant demand for heating, with heating required for seven months of the year, with some regional variation. To this high underlying demand for heat is added a legacy of low efficiency in heat generation as well as significant heat losses from supply infrastructure and buildings. According to national statistics, some 110 TWh of heat (served through large district heating networks or through smaller local ones) is consumed per year, with additional heat in individually heated buildings.[23] Of this, around 75 TWh is consumed by residential, public and commercial buildings; the remainder being accounted for by industrial heat consumption.[24] The associated emissions are close to 20 percent of the national total, at 47 $MtCO_2$.

2.3.1.1. Heat supply and fuel mix

Kazakhstan has 42 major district heating networks, served by a combination of 38 CHPs and 30 large heat-only boilers ("HOBs"). These play a key role in heat supply, accounting for some 60 percent of total end-use. The remaining 40 percent of heating is produced through decentralised heating, much of which in turn is in the form of communal heating through smaller heat networks served by local HOBs. Even in these smaller networks boilers can be of significant size, however, and there are around 200 boilers of more than 20 MW as well as a large number of smaller units.[25] In the residential sector, individual heating systems serving single houses thus are a small minority of total heat supply, although building-level heating is more common in commercial and public buildings. Around half of heat networks and generating units are privately owned, with the remainder under public ownership and management.

Coal is the dominant fuel, representing 65 percent of generated heat at the end of 2009. In large-scale installations, the same fuel constraint applies as was noted above for the electricity sector. However, heat (other than industrial heat) demand is much less

---

[22] World Nuclear Association

[23] Some other sources give significantly higher estimates; for example, UNDP (2006) estimated that energy used for heating amounted to around 190 TWh. However, this is inconsistent with both National Statistics and with the energy use and emissions data in Kazakhstan's 2010 UNFCCC submission. To ensure consistency with published sources, we have relied for this project on these latter sources. We do so with the caveat that official heat statistics as well as UNFCC data imply very low heat consumption per capita or unit of floor area, especially given Kazakhstan's cold climate and the state of the building stock.

[24] There is uncertainty surrounding the measurement and reporting of heat consumption in industry, as much of the heat production takes place on-site. The assumptions above are based on NERA analysis of the national statistics and average heat consumption in buildings – residential and commercial – sectors.

[25] UNDP and GEF (2006) Kazakhstan: Removing Barriers to Energy Efficiency Municipal Heat and Hot Water Supply.

concentrated in the north of the country, and the opportunities for abatement through fuel switching (in the west and south of the country) therefore also are higher. In some locations with access to natural gas (notably, in Almaty), fuel switching has taken place as a way to reduce local air pollution.

2.3.1.2. Demand projection

We project future heat demand for all buildings based on convergence to a benchmark consumption of 0.21 Gcal / m^2 / year in the "static" scenario where the current energy performance of the building stock continues into the future. This consumption level is significantly higher than implied by some data on current consumption, and the projection thus is consistent with an increase in heating service and comfort levels as incomes increase. In addition, by 2030 we project a significant increase in absolute consumption resulting from a combination of growth in service sector activity, population growth, increased floor area per dwelling, and smaller household size. The cumulative effect is growth to a consumption of 155 TWh per year (a more than twofold increase), which at current emissions intensity would imply emissions of around 77 $MtCO_2$. There are significant opportunities to reduce the emissions intensity, as we note below, although not all of them may be profitable without further government support or a carbon price.

2.3.1.3. Emissions abatement opportunities and drivers

Broadly speaking, investment opportunities to reduce emissions from heat supply and buildings fall in the following categories:

- Improving the efficiency of CHPs and boiler capacity by either replacing or (in the case of larger units) rehabilitating existing units.
- Switching to less emissions-intensive fuels, including gas and bioenergy.
- Reducing losses in the heat transmission and distribution grid through a combination of pipeline insulation, improved substations, and better control technology for dispatch and network balancing.
- Improving of the thermal performance of buildings through measures ranging from draft-proofing; insulation of walls, roofs, and floors; and glazing.
- Increasing end-user control over consumption through heat meters, heat allocators, and thermostatic radiator valves.
- Changing the denomination of billing to create incentives for improvements in energy efficiency.

Cumulatively, these opportunities have the technical potential to make very deep cuts in energy use and emissions – corresponding to up to two-thirds of primary energy input. The technical measures are well-established and in use in many other countries, so do not rely on further technological improvements. Moreover, the investments also have the potential to significantly improve the service to end-users.

However, the investment required is very substantial, while both the value of the fuel savings and the incentives faced by heat suppliers and consumers are heavily circumscribed by the prevailing institutional arrangements. Realising the abatement potential therefore depends heavily on institutional reform. We discuss the key barriers to each of the abatement measures below.

2.3.2. Heat distribution and end-user tariffs

2.3.2.1. Tariff levels and network investment incentives

District heating network losses in Kazakhstan are as high as 25-30 percent of the heat transported. For comparison, modern networks in Western Europe can achieve losses less than 10 percent. The high level of losses reflects the age of equipment and long record of underinvestment and lack of maintenance. It also is a function of intrinsically inefficient network design with separate pipes for space heating and hot water supply and extensive use of open-loop systems.

The technology to reduce losses – including improved insulation of pipes, upgraded heat exchangers, and improved network control equipment – is well-established and mature. The improvements have the twin benefit of saving energy and reducing emissions, and also improving the often unreliable or inadequate service provided to end-users. However, overall the investment requirements are very large. Some estimates suggest that as much as 60-80 percent of network pipes and equipment are obsolete or in need of replacement in order to preserve the level of service, let alone improve system efficiency.

Some limited investment has taken place in recent years through publicly financed projects administered by the Agency for Construction, Housing and Communal Services. However, the pace of investment under these mechanisms is slow, In recent years, official data suggest some 140 km of network pipelines were rehabilitated in 2009 (and 144 km newly built); the two together would represent 2,4 percent of the total existing DH network. Local experts indicated to us that over 7,000 km need to be rehabilitated (e.g. typically they would be replaced by pre-insulated pipes and / or buried underground). At recent rates, and assuming that no further pipelines would need to be rehabilitated over the period, it would take over 50 years to rehabilitate the required length of the pipelines.

Public funding moreover is vulnerable to shifting budget priorities and many competing demands for public funds, as well as the difficulty of committing to future investment. Overall, this experience suggests that if rapid and extensive improvement is to occur, it will depend on the ability to attract other sources of capital to the sector. This includes investment by network companies as well as end-users.

Tariff regulation and low end-user charges are a major obstacle to investment by network companies. Although tariffs nominally are set through a cost-based approach, historically they have lacked specific elements required to promote investment (an insufficient rate of return on investment and inadequate allowance for the depreciation of assets), as well as suffering from a more general tendency not to cover key costs. In part, the tendency to keep tariffs down reflects the vital role of heating for social welfare in Kazakhstan's climate.

A further complication for energy efficiency improvements is that the large majority of heat consumption is billed on a flat-rate basis, using standardised consumption estimates ("norms") based on the characteristics (chiefly, area) of buildings. The norms were established in Soviet times, and there frequently are discrepancies with actual consumption.[26] In addition, companies often face problems with non-payment ("commercial losses") and have limited options for legal redress.

As a result of these factors, it has not been unusual for tariffs to fail to cover even short-run operating costs. In several cases local authorities have maintained DH company solvency either through periodic recapitalisation, or (less commonly) by absorbing the companies.[27] Cumulatively, these practices amount to an implicit subsidy of heat consumption, depressing prices below their long-run level and at the same time impeding the investments required to improve the level of service and system efficiency.

Companies also find it difficult to raise finance. Legal encumbrances mean that DH companies cannot use their physical assets as collateral, even where the assets are privately owned. More generally, access to finance is impeded by the uncertainty of tariff regulation and general lack of experience of the financial sector with private investment in DH infrastructure. As a result, banks typically impose stringent requirements –high expected rates of return, high interest rates, high collateral requirements, short payback periods, and / or high debt service coverage ratios – that make project finance practically unavailable to many companies. International development banks have been an important source of funds to bridge the gap.

There are some signs that the regulatory situation may be improving. In recent years authorities in some areas have shown increased willingness to allow the increases in heat tariffs that are necessary to finance investment programmes. Part of this is a change of practice within existing regulatory framework; for example, the heat tariff in Almaty was recently increased. There also have been changes to regulation intended, among other things, to improve the prospects for investment (e.g., the 2008 Heat Law).

2.3.3. Buildings sector

Buildings in Kazakhstan generally have poor thermal performance relative to heating needs. Although detailed data are lacking, a common estimate is that buildings consume as much as twice the amount of energy of modern buildings in Western Europe.[28] Improvements to the building fabric as well as changes to end-user behaviour offer very significant scope for reductions in energy consumption and, through the impact on upstream heat generation, GHG emissions.

---

[26] Norms can give either over- or under-estimates, and not enough is known to be certain what the net aggregate effect is. There have been cases where under metering consumption is higher than what was assumed based on norms. See UNDP "Mid-term Evaluation Report of the UNDP-GEF Project in Kazakhstan 'Removing Barriers to Energy Efficiency in Municipal Heat and Hot Water Supply'" (2009) and NEEG (2006) 'Market Study on Demand for Energy Saving Investments in Kazakhstan and Kyrgyzstan'. On the other hand, some consumer rights NGOs claim that norms over-estimate the amount of heat used.

[27] GEF (2009)

[28] UNDP (2010) Kazakhstan: Energy Efficient Design and Construction in the Residential Sector gives verage heat consumption in the existing stock of Kazakhstan buildings is around 0.214 Gcal/m2. Other sources imply higher numbers still. By contrast, in Sweden the average consumption is 0.12 and 0.14 Gcal/m2 for individual and multi-occupany buildings, respectively. (Sweden national statistics: Summary of energy statistics for dwellings and non-residential premises for 2001-2005.

As with networks, the amount of investment required can be very substantial, and incentives are limited by three key factors: the denomination of heat tariffs, and the transaction costs associated with improvements to buildings with multiple occupants, and the incentives for the energy efficient design of new buildings.

2.3.3.1. Tariff denomination and consumption-based billing

As noted above, heat tariffs are paid on a flat-fee basis, denominated on a per-m^2 basis. Occupants of a building therefore pay the same amount for heat regardless of any steps they may take to increase or reduce their consumption, and thus face no financial incentive to save energy. Although there may be other motivations – notably, to improve comfort where service is inadequate – the denomination of heat tariffs is a significant obstacle to investment in the energy efficiency of buildings.

Current regulations are unlikely to result in widespread adoption of metering. The Law on Natural Monopolies nominally required the introduction of basement heat meters by 1999. However, there is little enforcement, as well little clarity about who carries the obligation to finance the installation of meters. In contrast to some other countries with extensive district and communal heating (e.g., Bulgaria) there is no requirement for the use of heat allocators to determine use at the level of individual dwellings. Overall, the prevalence of metering still is at very low levels.

Experience from other countries demonstrates that a transition to billing based on actual consumption volumes is an important step in creating investment incentives. Such regulatory change has technical pre-requisites, and presents a particular challenge when retrofitted to a system not designed for individual metering in the first place. The transition would require first building-level and then apartment-level metering or allocation of heat consumption. It also requires the ability to control the amount of heat received—again, first at the building level and then at apartment level. (Notably, it is necessary that reductions in consumption by one party do not limit heat supply to other occupants or end-users on the same heat network loop.)

2.3.3.2. Residents association

Apartments and houses in Kazakhstan are overwhelmingly privately owned. This means that the scope for government- or municipality-run programmes to increase energy efficiency is low. Instead, improvements will need to be made through private decisions. With a large share of dwellings in multi-occupancy buildings, a key step towards the adoption of energy efficiency measures is the institutional capacity to take decisions for the building as a whole.

In the Kazakhstan residential sector the main potential vehicle for decisions of this type are associations of apartment owners (“KSKs”), which exist for a large share of the relevant building stock. However, KSK structure governance has been identified as unsuited in many cases for the investment decisions to improve the building fabric, and sometimes command low trust among residents.[29] Strengthening the decision-making and investment capacity of KSKs therefore is likely to be a key part of increasing uptake of energy efficiency measures.

---

[29] [Ref. UNDP, ENSI]

2.3.3.3. New building energy efficiency

The total floor area of buildings is projected to increase significantly in Kazakhstan with service sector growth, growing population, increased area per dwelling, and longer-term reductions in family size. By 2030, new buildings will represent a significant share of total demand for heating service, and the thermal performance of new construction an important determinant of future energy consumption and emissions.

Minimum standards for new buildings is an important way to reduce long-term energy demand and therefore also emissions. Kazakhstan has existing (from 2004) regulations governing the energy efficiency of new buildings in the form of normative heat resistance values of various building components (such as walls, windows etc), which depend on the location's degree days. These were recently strengthened.

However, the indication is that, even though regulations often are followed on the design stage of buildings, the measures that improve energy performance often are not carried through to execution. UNDP indicates that the thermal efficiency implied by the current 2004 building code is 40 percent lower than the average efficiency of the existing stock.[30] Moreover, energy efficiency objectives are in conflict with other regulations and objectives. For example, state support for new construction requires that costs do not exceed $\$400/m^2$, which is too low for the construction of highly efficient buildings.

One route to abatement thus would be to strengthen and enforce regulations.

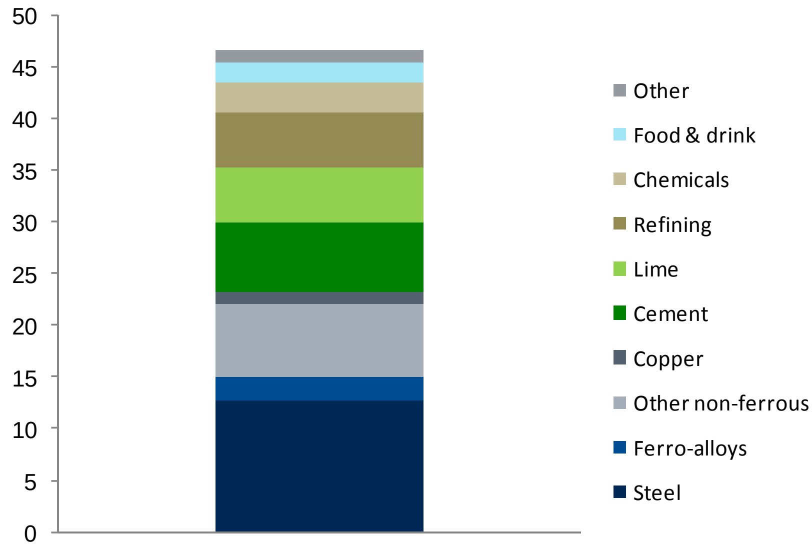
2.4. Industry

Direct emissions from Kazakhstan's industry amounted to over 45 $MtCO_2$ in 2008. Most of this was accounted for by emissions from fuel combustion, but with significant contributions also from process emissions from minerals, metals, and chemical production.

Figure 2.10 shows a breakdown of 2008 direct emissions from industry. Metals account for 50 percent of the total emissions of 47 $MtCO_2$, with 27 percent of total emissions from iron & steel production and 23 percent from ferro-alloys and a range of non-ferrous metals. Another quarter of emissions arise from the production of cement and lime, where the large majority of the latter is consumed in metallurgical processes. The remaining quarter is a mix of emissions from petroleum refining, chemicals, food and drink, and other sectors (including bricks and ceramics).

[30] UNDP (2010) Kazakhstan: Energy efficiency design and construction in Residential Sector. Table F.5.

Figure 2.10
Industry and Refining Direct Emissions



***Source**: UNFCCC, Agency of Statistics of the Republic of Kazakhstan, and NERA research and calculations*

The emissions intensity of much of industry is very high, reflecting both old equipment and a history of abundant cheap energy. For example, the vast majority of Kazakhstan cement production uses wet production methods (with a recent new addition of some dry capacity), with significantly higher energy consumption than modern dry methods. Similarly, steel production has high emissions intensity compared to much of international production. Lime production is similarly inefficient, as the combustion emissions are higher than international benchmarks due to old, poorly insulated kilns and outdated processes. The intensity of metals production is significantly harder to compare to benchmark levels, as the energy intensity in many cases depends heavily on the characteristics of the ore. The comparison of Kazakhstan industry energy intensity to international benchmarks is shown in A.3.3.

The Kazakhstan government has ambitions plans for expansion of industrial activity[31], and this (alongside growth in oil & gas extraction) also underpins much of the independent GDP growth forecast. Ambitious government targets for 2014 production for Cement and Steel mean that the average growth rate over the 2010-2030 period is 5.7 – 5.9 percent per year. We have assumed that other industry sectors grow at around 4 percent per year, reflecting a slow shift of the economy away from industry towards lighter manufacturing and services, with the growing GDP. Refining is assumed to grow at an average rate of 6 percent per year, reflecting rapidly increasing demand for transport, particularly road transport and the associated refined oil products.

[31] These plans were developed before the 2008-9 global financial crisis and are therefore unlikely to reflect realistically the scope and appetite for potential industrial activity expansion.

Without reductions in emissions intensity, emissions also would expand substantially, and keeping today's emissions intensity constant would see an increase to 125 $MtCO_2$ by 2030. As we discuss below, there are several ways in which emissions could be reduced.

As noted above, industry – and especially the large metallurgical and mining sectors – also gives rise to indirect emissions through the use of electricity. In particular, Kazakhstan is a major producer of copper, zinc, and ferrochromium, all of which are highly electricity-intensive. Reflecting this, much of the metallurgical industry is carried out by vertically integrated conglomerates that also own electricity and heat generation capacity.

2.4.1. Industrial abatement measures and investment drivers

Emissions abatement opportunities in Kazakhstan industry fall broadly in two categories:

1. New capacity to meet additional demand. Both natural attrition of existing capacity and the need for capacity to meet new demand mean that significant new investment in new plant will be required across a range of industry. This offers the opportunity to transition to production capacity with lower emissions intensity than the current average, reflecting a general trend towards more energy-efficient production techniques. New investment thus is a significant source of abatement relative to the static case.

The extent of proportional abatement available through this channel depends on the characteristics of current plant. As noted, current Kazakhstan emissions intensity in key sectors is very high, and ensuring higher efficiency at new capacity therefore could provide substantial opportunities for abatement.

2. Retrofitting and changes to existing production techniques. The second major category of abatement is various measures to improve the energy efficiency and the emissions intensity of existing production capacity. This spans a very wide range of heterogeneous abatement measures which often are highly specific to the particular production processes of different sectors. However, they can be broadly categorised in the following categories:

- **Energy efficiency – fuel.** These include a wide range of sector-specific measures, with important cross-cutting measures including energy management systems, process optimisation, waste heat recovery, and more efficient furnaces and boilers.
- **Energy efficiency – electricity**. These include several cross-cutting measures such as more efficient motors and drives, more efficient pumps, and improvements to compressed air, but also a range of sector-specific measures especially in the metallurgy sector (smelters, electric-arc furnaces, refining processes, etc.).
- **Fuel substitution.** Abatement also is available by switching to less carbon-intensive fuels. This includes a switch from coal or oil to natural gas; or from fossil fuels to waste fuels (particularly in the minerals sector) or biofuels.
- **Raw material substitution.** Emissions from the calcination of limestone ("process emissions") in the cement and lime sectors are substantial sources of emissions, with some process emissions also in glass production. In the case of cement, these can be reduced by substituting other materials for clinker.

- **Non-CO_2 gases.** Various sectors, and especially chemical industries, offer opportunities for the abatement of non-CO_2 greenhouse gases. In Kazakhstan the relevant chemical industry (notably adipic and nitric acid) is relatively limited, however.

- **Carbon capture and storage.** The use of CCS for industrial emissions is significantly more speculative than other measures, but if the technology and associated infrastructure is sufficiently developed could offer the potential for deep emissions cuts. The measure would likely be limited to sectors with large point-sources of emissions, notably integrated steelworks and large cement plants, as well as dedicated power / large-scale CHP plants serving industrial loads. However, because the technology is speculative at this stage, we do not include it in the main scenarios investigated here.

These different categories of abatement measures respond to different drivers of investment.

Investment to improve energy efficiency depends in the first instance on the value of the fuel savings that investments can bring. Higher fuel prices thus contribute to higher profitable abatement potential; correspondingly, the low fuel prices in Kazakhstan pose a significant challenge to abatement. In addition, firms' willingness to incur the up-front cost of improving energy efficiency depends on a number of factors, starting with the access to and cost of capital, but in the short term especially also including factors such as awareness and availability of suppliers, technical expertise, and advice.

Fuel substitution, by contrast, depends more on the *relative* cost of higher-polluting fuels (coal, oil) and lower-polluting options (gas, biofuels, waste). As importantly, widespread adoption of lower-emitting fuels depends on reliable supply. Kazakhstan industry is heavily reliant on coal, so fuel substitution towards gas, waste or biofuels, would offer substantial emissions reductions. This is limited by the often substantial cost advantage of using coal where this is feasible, and by the limitations on fuel availability discussed in section 2.2.4 above (notably, the lack of natural gas in the Northern region of Kazakhstan where much of heavy industry is concentrated). Drivers for further fuel substitution correspondingly include increased availability of lower-emitting fuels, higher coal prices relative to gas, and improving the prospects for use of alternative fuels, including biofuels and waste fuel supply chains.

The incentives for raw material substitution are closely linked to the cost of production. In the case of both cement (clinker substitutes) and glass (increased use of recycled material, or cullet) the price of energy is a key factor, with drivers similar to those for energy efficiency. In addition, raw material substitution depends on achieving a reliable supply chain for the relevant waste materials. Current waste regulations in Kazakhstan do not provide any external drivers for waste re-use, and with very low population density and high availability of low-productivity land, the drivers for more stringent waste regulation are limited.

In contrast to the above abatement options, both carbon capture and storage and abatement options relating to non-CO2 gases are motivated not by savings on energy expenditure, but depend on a value associated with avoided GHG emissions. In both cases, investments therefore would be motivated only where reduced GHG emissions brought a direct financial advantage.

We discuss individual options to reduce emissions in some individual sectors below.

2.4.1.1. Cement

Much of the currently operating cement capacity in Kazakhstan is very old, characterised by out-dated production technologies and with energy intensity very significantly higher than that of best-practice plants of recent construction. Production has undergone drastic swings in the past two decades. Total output fell to minimal levels in the 1990s, and has since gradually recovered. In the course of this process, much of the capacity has been poorly maintained, or in some cases taken out of operation entirely. Growth since resumed, with capacity gradually being into service in response to the significant expansion of construction that took place in the 2000s. Prior to the onset of the economic downturn in 2008 there were projects for several new plants, but many of these have been temporarily or permanently abandoned.

The main abatement measures in the cement industry fall in the following categories:

- New capacity: modern kilns and dry production technologies can be significantly more energy efficient than older capacity. The very high energy consumption of existing plants in Kazakhstan makes the contrast especially stark, and new plants with energy efficiency similar to recent additions in other parts of the world could halve energy consumption per unit output. However, the additional investment to reach this level of energy performance depends on financial incentives, which with low fuel prices are weaker in Kazakhstan than in many other locations. Even so, given the low starting point in energy performance, and the significant increases in capacity over the next two decades, the sector could see a significant reduction in average energy intensity through new entry.

- Energy efficiency measures: a range of measures could be applied to improve the performance of existing plant, including preventative maintenance, new energy monitoring systems, improvements to kiln combustion, reductions in shell heat loss / heat recovery, replacement of grate coolers, and the use of indirect firing. The applicability of these measures depends on the pre-existing configuration of individual plants. Where the configuration and underlying kiln technology are amenable to these improvements they can reduce energy consumption by 20 percent or more.

- Fuel use: cement manufacture can make use of a range of fuels, and in particular has the potential to make use of waste fuels from a range of sources. For example, switching from coal to gas can reduce emissions by some 18 percent—but it has to be said that cement production using natural gas is an exceptional occurrence only taking place in locations with a legacy of gas subsidy. A more economically viable option often is the use of waste fuels or biomass, which can reduce emissions by 5 percent or more, depending on the share of waste fuels and type of fuel used.

- Clinker substitution: substituting other materials for clinker can reduce both process and combustion emissions, with key options including blast furnace slag and pulverised fly ash (PFA). A maximum practical limit is substituting 30 percent of clinker with other materials, which could reduce emissions by 23 percent.

- Carbon capture and storage: cement has been proposed as one of the sectors with point source emissions sufficiently large to potentially motivate the use of carbon capture and storage. However, the application of this technology in industry remains speculative at this point in time, and we do not include it in our main analysis.

2.4.1.2. Steel

Kazakhstan is a major regional iron and steel manufacturer, and among the top-30 producers globally. Its 2008 production amounted to 4.8 Mt crude steel, with production concentrated at the Termirtaue steel plant, with theoretical production capacity of 5 million tonnes per year, though there also is smaller electric arc-furnace capacity. In addition to crude steel, Kazakhstan has significant production of ferroalloys. The sector has seen significant investment in recent years, with additional plans for capacity expansion and modernisation under way. Available data suggests the current energy intensity of production is high by international standards.

The energy intensity of steelmaking can vary significantly with the technology used. Generic control technologies include energy management systems, preventative maintenance, and improved process control / automation. More specific measures relevant to integrated steel plants include pulverised coal injection, efficient use of BOF gas and heat recovery, coal moisture control, and sinter plant heat recovery. However, the retrofitting of measures can be challenging at plants not originally designed to incorporate them. For example, there may be limitations to feasible heat recovery that can be fully elucidated only through detailed analysis. The cost of abatement is strongly linked to the wider coal energy costs.

2.4.1.3. Other metallurgy

Kazakhstan produces significant volumes of non-ferrous metals, notably copper, zinc, alumina (aluiminium oxide), chromium, and ferro-alloys. The various metallurgical processes are highly energy intensive throughout the calcining/roasting, sintering, smelting, and refining stages, and in addition to direct emissions from pyrometallurgical processes consume very large amounts of electricity where electrolytic refinery production methods are used.

Nearly all of the relevant metallurgical processes show significant variability in the amount of energy used, depending both on the composition and concentration of the ore used, and on the production process used. As an example, electricity used in copper production can vary from less than 400 to 900 kWh / tonne. Some of this variability is directly attributable to the equipment used, and the use of flash smelting processes instead of traditional roasting and smelting in reverbatory / electric furnaces can reduce energy use by as much as 30-50 percent. However, a range of other factors ranging from pollution control requirements, the quality of raw materials, and overall plant design can be important contributors.

Similar heterogeneity applies to the production of other metallurgical products. Energy requirements for alumina production also can vary between 2-9 kWh/kg alumina, with variability attributable both to different bauxite quality and to refinery design. In the case of ferrochromium smelting, the use of pellets and preheated / pre-reduced charges, and closed furnaces can reduce energy use by 30 percent compared to conventional submerged arc furnace processes.

In general, the importance of local specific factors makes the development of standardised abatement measures for non-ferrous metallurgy more challenging than for many other sectors. "Best available techniques" can be highly plant-specific.

2.4.1.4. Cross-cutting: motors and drives

Motors and drives are used across many industrial sectors, and through their impact on electricity consumption can account for very significant emissions. Based on typical usage patterns across sectors, we estimate that total consumption in Kazakhstan is in the region of 28 TWh per year, leading to emissions from electricity generation of 21 $MtCO_2$.

Highly efficient motors and drives often are among the most cost-effective investments for emissions reductions, with reductions in energy use of up to 12 percent often feasible.

2.4.1.5. Other industry sectors

Lime. Kazakhstan produced 3.4 Mt of lime in 2008, accounting for emissions of approximately 5.4 Mt CO_2, or 11 percent of the total Industry emissions. A large share of emissions from the lime sector is attributable to irreducible process emissions arising from calcination of limestone. However, combustion emissions depend significantly on the production technology used, including the type of kilns as well as the application of various energy efficiency measures. The more important include control of shell heat loss, kiln combustion improvements, and maintenance and process control measures, all of which offer the technical potential to reduce expenditure on coal, the key fuel used in the industry. The application of these measures in new and existing capacity could reduce emissions by 15-20 percent by 2030, where much of the potential improvement would depend on the adoption of more energy efficient varieties of kiln in new capacity.

Bricks. Brick production in Kazakhstan is relatively small, at around 1 Mt per year, and with emissions of around 0.3 $MtCO_2$. There is scope for significant improvements in energy performance by adoption of modern tunnel furnaces, with typical improvement in energy performance of 30 percent or more. Within each basic kiln design, there also is scope for various measures to reduce energy consumption in the firing and drying processes, and with an inefficient starting point, reductions in energy intensity by as much as 50 percent could be feasible, albeit only with significant investment. In addition, the sector relies heavily on lignite and coal.

2.5. Other Major Emitting Sectors

2.5.1. Upstream Oil & Gas

Alongside mining and metals, the oil sector is a key contributor to Kazakhstan's GDP as well as public finances. Production has been rising sharply at over 8 percent per year since 2000 to reach current levels of around 78 Mt of oil per year in 2009. With continued investment there is scope for continued increase in production to between 150 and 175 Mt Oil/year by 2030.[32]

[32] CERA (2010) Kazakhstan's Oil Export Capacity and Potential. Presentation by Katherine Hardin.

2.5.1.1. Oil extraction

Emissions from the sector arise from two main sources: oil / gas extraction and gas flaring. Oil extraction consumes energy for electricity generation, drilling, pumping, compression, and other activities. UNFCCC data indicate that current oil extraction emissions are limited, at up to 8 $MtCO_2e$ in 2008. However, international comparisons of energy efficiency are not meaningful, as energy requirements are highly specific to local circumstances, including the depth at which deposits are found, the age of individual fields, the ratio of oil to gas, etc.

The opportunities for emissions abatement in extraction include more efficient pumps, motors, turbines, heaters and drives, measures to avoid pipeline fouling, and process controls including optimised pressure maintenance. The financial attractiveness of these investments depends strongly on the value of the fuel.

2.5.1.2. Gas flaring

The other main source of emissions from the oil and gas sector stems from the flaring of natural gas. Nearly all of the gas production in Kazakhstan is “associated gas”, i.e. gas released largely as a by-product of oil extraction. According to the US Energy Information Administration 70 percent of the gas produced in Kazakhstan in 2009, or 25 bcm, was re-injected to maintain well pressure and enable enhanced oil recovery. Exports amounted to 10 bcm, although there are plans to increase gas extraction as the required expansion in gas processing and export infrastructure is constructed.[33]

In addition, significant quantities of gas currently are vented or flared. Technically, the non-emergency flaring or venting of gas is already illegal in Kazakhstan. The 1995 Law “On Petroleum” No 2350, as updated in 2004/5, prohibited both the development of new oil and gas fields unless associated gas is utilised, and also the non-emergency flaring of gas from existing fields. However, for much of the period since its introduction it appears that this regulation was largely ineffective in reducing flaring volumes. The United States National Oceanic and Atmospheric Administration (NOAA) estimated based on satellite imagery that 5.2 bcm of natural gas were flared in Kazakhstan in 2008[34], giving rise to around 10 $MtCO_2$ of emissions. Without a reduction in the rate of flaring on the 2008 level, emissions would be close to 24 $MtCO_2$ by 2030. The latest NOAA data indicate a drop in flaring in 2009 to 3.8 bcm, although it is difficult to assess the precise reasons for this. One possibility is that investments to reduce flaring are coming online, but given the lack of data it has not been possible to establish this.)

Reduction of flaring requires investment to enable additional capture of gas, either for reinjection or for further processing and use as fuel for power generation or other application.

Wood Mackenzie (2009) Oil Supply-Demand Imbalances and Trade Flows for Turkey and the Atlantic Basin and Implications for Oil Terminal Business. Presentation by Ben Holt.

[33] EIA (2010) Country Analysis Briefs. Kazakhstan brief, updated October 2010. http://www.eia.doe.gov/cabs/kazakhstan/Full.html

[34] NOAA (2009) Improving Satellite Data Estimation of Gas Flaring Volumes. Year Two Final Report to the GGFR. August 2009.

2.5.2. Refining

Kazakhstan has three refineries, at Pavlodar, Shymkent, and Atyrau. Total capacity is around 21 Mt of crude oil per year, but for much of recent decades actual throughput has been significantly lower than this, and it currently stands at around two-third of nominal capacity. Emissions stand at 5 $MtCO_2$ per year. A high-level comparison suggests that the energy intensity of production is not far higher than international averages, but this reflects in part the simple (hydroskimming) configuration of production, which is not designed to transform crude oil into as great a share of higher value products.

The low utilisation stems from old and poorly maintained capacity, as well as a mismatch of the refining capacity configuration with local needs, both in terms of product requirements and feedstock needs. This reflects in part the fact that the capacity originally was built as part of a regional network of Soviet refineries, rather than to serve local needs. In consequence, the sector has experienced problems both with product quality and insufficient production to meet demand. In 2008, concerns about rising prices resulted in a ban on the export on refined petroleum products from Kazakhstan.

In response to these concerns, a significant investment programme is planned to upgrade and expand capacity. KazMunaiGaz is scheduled to start a major investment programme in 2011, committing US $4 billion to upgrade capacity and increase output. The aim is to fully meet domestic demand by 2014, and in the case of Atyrau to meet European fuel standards.

The investment in new capacity also offers the opportunity to reduce emissions. Measures to reduce emissions in refineries centre on optimisation of the overall process to increase the overall product yield per unit of crude oil processed. Key measures include improved process integration, maintenance and cleaning / fouling mitigation, process control, as well as good energy management systems and systems for waste heat recovery. Refining also is a sector where improvements to motors, drives, and compressed air can offer abatement opportunities

The industry has strong inherent incentives to improve efficiency; indeed, the use of (complexity-weighted) energy benchmarking (such as the Solomon system) has become a standard management tool in international refining industry, and is in itself a very important tool in enabling emissions abatement. Incentives to invest in efficiency improvements will depend strongly on the price of crude oil and the price that can be commanded for the output. It also will depend on the extent of market pressure and competition from efficient competitors.

2.5.3. Coal mining

Another major source of GHG emissions arises through coal mine methane released in the process of coal mining. Kazakhstan is a major coal producer, and total emissions were almost 21 $MtCO_2e$ in 2008.

Surface mining of the type that dominates Kazakhstan coal extraction typically have releases only a small amount of methane in comparison to underground mining. However, the Kazakhstan coal fields – and Ekibastuz in particular – are unusually prone to methane release. It therefore could present opportunities for some of the mitigation measures that otherwise are normally only applies in underground mining. These include various degrees of "degasification" of deposits prior to mining. Even if the gas if flared, this reduces emissions (compared to venting) by as much as 95 percent. Additional reductions are possible by using the captured methane as fuel for power generation.

2.5.4. Transport

The transport sector (excluding pipeline transport) emitted 24 $MtCO_2$ in 2008, the large majority of which was accounted for by passenger and freight road transport. Although distances travelled are necessarily relatively large in Kazakhstan, given the size of the country, the transport emissions are a small share of the total, at 10 percent. The current road transport fleet (both freight and passenger) is relatively old and has high emissions intensity. The main abatement measure therefore is the progressive replacement of old vehicles with newer, more efficient vehicles.

2.5.5. Waste

Emissions from waste amounted to 4.9 $MtCO_2$ in 2008. These arise largely from methane release from landfill. Abatement opportunities include waste separation and composting, incineration, landfill gas capture and utilisation, and advanced conversion technologies to produce biogas. However, as noted above the underlying drivers for changes to waste handling are relatively weak in Kazakhstan.

2.5.6. Agriculture and Forestry

Kazakhstan is a major wheat producer, ranking 12th in the world, and accounting for 2.5 percent of global wheat production.[35]

Emissions from agriculture amounted to 14.5 MtCO2, the majority of which were methane emissions from livestock (both enteric fermentation and manure management), but almost 2.5 MtCO2 were from energy use.

Forested areas in Kazakhstan accounted for over 12 million hectares in 2010, or 4.5 percent of the territory, although the entire area of Kazakhstan's Forest Fund, which is responsible for forest management, exceeds 26 million hectares. This includes non-forested areas, some of which may be suitable for afforestation.

The "carbon sink" function of forests has been declining in Kazakhstan: in 1990 LULUCF absorbed almost 8.8 MtCO2, but by 2008 this has been reduced to just 0.6 MtCO2. This was due to a combination of factors, including more intensive exploitation of existing forests, reduced planting of new forests (planting rates more than halved between 1992 and 2005), and to major fires between 1996-2003.

Recent government plans[36] aim to increase the forest plantation areas by up to 65 thousand hectares (i.e. a small increase of 0.5%), and to convert up to 6.5 thousand hectares of previously non-forested areas.

[35] FAO statistics, 2009.

2.6. Summary

Kazakhstan has a highly emissions-intensive economy. Recent growth forecasts reinforce this tendency, with growth concentrated in power demand and industry with high energy intensity. This in turn reflects the country's very significant endowment of rich mineral and fossil fuel resources. Across many sectors, the abundant availability of low-cost coal creates a substantial barrier to the adoption of less emissions-intensive technologies and processes.

In addition, much of the legacy capacity and capital stock – in power generation, buildings, district heating networks, and basic industry – is old and poorly maintained. Compared to modern international capacity many sectors have high energy intensity and emissions. There are notable exceptions, and the extractive industries (metals and oil) in particular have seen substantial recent investment. Nonetheless, overall, there remain significant opportunities for investment in more efficient production methods.

The generation of power and heat accounts for almost half of total Kazakhstan emissions. At the same time, these sectors face significant barriers to abatement. In the case of power, the key issues are the limitations on fuel availability and low cost of high-emitting coal, coupled with inadequate regulatory incentives to reduce distribution losses as well as to reduce end-use consumption. In the case of heat, regulatory and institutional barriers are even more substantial, with lack of cost recovery for investments to improve generation and distribution efficiency, lack of metering and flat-rate charges to end-users, and limited institutional capacity to undertake investments, particularly in multi-occupancy buildings.

These circumstances present both challenges and opportunities for a shift to less emissions-intensive production technologies as the economy grows. However, significant institutional reform required, and costs are in all cases increased by the availability of attractive high-emitting alternatives, in turn ultimately stemming from very low-cost local fuels.

[36] The Strategic Plan of the Ministry of Agriculture of the Republic of Kazakhstan for 2010-2014 is approved in December 2009

3. Overview of Approach

3.1. Policy Scenarios and Assumptions

We consider three scenarios to estimate the potential for emissions reductions in Kazakhstan under different very high level policy settings.

- "Status Quo" scenario, in which policies and institutions in Kazakhstan continue as they currently are over the next two decades, but technological improvement and natural turnover of equipment is allowed to occur.
- "Planned Policy" scenario, in which planned but not-yet-implemented policies to reduce emissions are included.
- "Enhanced Policy" scenario, in which additional policies to spur emissions reductions are reflected.

In addition to these three, we also refer to a "Static Technology" baseline, which like the Status Quo freezes policies at their current levels, but which also freezes technology, maintaining the same emissions factors and efficiencies. The "Static" case is used as a reference to create some of the information that is presented in the MACCs, but is not intended to represent a real future scenario.

Some details of the three main future policy scenarios are provided below, with a summary of the key differences between them.

3.1.1. Status Quo Scenario

The "Status Quo" scenario is intended not as a projection, but as a baseline against which improvements in other scenarios can be assessed.

Our base scenario is the "Status Quo". It assumes that over the next two decades current policies and institutions continue as they are now. No new policies are put in place to encourage energy efficiency, renewable energy, or other emissions abatement. Where policies and measures are already in place, they are not strengthened, enforcement is not increased, and their effectiveness does not improve. Thus, this scenario is intended not as a projection, but as a baseline against which the improvements in other scenarios can be assessed.

3.1.2. Planned Policies Scenario

The "Planned Policies" is intended to reflect the prospects for investment in emissions reductions given effective enforcement of currently announced policies and enacted regulations.

The second scenario takes into account major policies that are in place or announced that are likely to have an effect on emissions. Where policies currently exist but are not well enforced (as in the case of building standards) we assume that they are enforced more strictly.

Differences between this scenario and the status quo include:

- Higher heat tariffs, more often based on actual metering of heat consumption
- Greater scope for heat and power transmission and distribution networks upgrades and operators are allowed to charge higher fees.
- Feed-in-tariffs available to selected renewables such as pilot Wind projects.
- Resident associations enabled to make investment decisions and coordinate more effectively.

3.1.3. Enhanced Policies Scenario

In Enhanced Polices scenario, we consider the implications of a range of policies designed to promote energy efficiency and to reduce emissions from the power and other sectors. In particular:

- "Soft loan" programs and expansion of commercial lending opportunities to support household energy efficiency measures, including insulation and double glazing;
- Incentives for energy suppliers to deliver energy efficiency measures – e.g. via quotas, demand-side management, or white certificate programmes to further support energy efficiency measures in the household and commercial sectors.
- Industrial benchmarking program designed to share best practice and focus management attention on efficiency improvements (reduces informational transaction costs and reduces hurdle rates by 3%).
- Feed-in-tariffs as well as implicit support for grid connection available for a broad range of renewable technologies.
- Extended nuclear programme, facilitated through government support, including guarantees for waste disposal.
- Applying a significant carbon price. Kazakhstan is currently drafting legislation for an emissions trading scheme (ETS) which would create and obligation for large emitters (over 20 thousand tCO2e/year) to purchase emissions allowances if their emissions exceeded their initial quota. Assuming a binding emissions cap, this would create an effective carbon price for a number of sectors such as power and heat generation, as well as heavy industry. For these sectors that would be covered by the ETS this is assumed to be €40/tCO_2 in real terms – this price level is based on the assumption that this trading system would be compatible with the European Union Emissions Trading System, and therefore could be linked to it. We also assume that, as Kazakhstan is preparing legislation to be able to participate in Joint Implementation (a Kyoto mechanism), for sectors that would be eligible to earn ERUs (or equivalent credits such as CERs from CDM mechanism), the price (or opportunity cost) is assumed to be €20/tCO2e. The difference between the two prices reflects the risks and transaction costs associated with primary credits.

Finally, we also consider a variation on the Enhanced Policies scenario, in which instead of applying the above carbon prices, we assume that a capital grant subsidy is available to all technologies that reduce emissions. This subsidy reduces the up-front capital cost of these technologies to investors by 20 percent. The source of the capital required to finance the capital grants is not specified.

3.1.4. Summary Overview of Scenarios

An overview of the scenarios is provided in brief summary below.

Table 3.1
Summary of Modelling Scenarios

Policy	Status Quo	Planned Policy	Enhanced Policy	Enhanced Policy – Capital Grants
Fuel market structure and subsidies				
Coal	”Stranded” coal remains easily available and non-exportable	As in Status Quo Scenario	As in Planned Policy Scenario	As in Enhanced Policy Scenario
Electricity cross-subsidy	Electricity prices remain below the LRMC of new capacity build.	As in Status Quo Scenario	Electricity prices increase to allow generators recover their LRMC	As in Enhanced Policy Scenario
Heat tariffs	Heat prices remain below the LRMC of new capacity build. Most tariffs are flat.	Progressive shift towards marginal-cost heat tariffs and gradual tariff increase.	Faster tariff increase and shift towards marginal heat tariffs.	As in Enhanced Policy Scenario
Distribution (Heat and Power)	Misaligned regulatory incentives limit investment to reduce losses	Regulatory incentives gradually improved to enable return on investment; uptake of measures depend on commercial viability.	As in Planned Policy Scenario	As in Enhanced Policy Scenario
Gas market structure	Limited use of associated gas from oil extraction.	As in Status Quo Scenario	As in Planned Policy Scenario	As in Enhanced Policy Scenario
Power Sector				
Gas share of generation	Continued lack of transmission capacity between regions limits gas use to West and South.	As in Status Quo Scenario	As in Planned Policy Scenario	As in Enhanced Policy Scenario
Feed-in tariffs	No FITs	Recently announced FITs, available only to a small share of renewables	FITs available to a broader range of renewables, including wind, small hydro, solar PV, and biomass.	As in Enhanced Policy Scenario
Renewables grid connection and transmissions charges	No support	Implicit support by imposing no additional grid connection or transmission charges for an amount corresponding to half of transmissions losses.	As in Planned Policy Scenario, with effective planning to enable incorporation of large quantity of renewables into transmissions grid.	As in Enhanced Policy Scenario
Grid capacity	Current grid constraints	Regional extensions as required to connect renewables corresponding to up to half of transmissions losses.	Grid extensions and strengthening, both intra-regionally and inter-regionally, as required to incorporate a large quantity of renewables.	As in Enhanced Policy Scenario

Policy	Status Quo	Planned Policy	Enhanced Policy	Enhanced Policy – Capital Grants
Nuclear power	No nuclear power programme	State support through loan guarantee and "soft" support for offtake risk and waste liability for planned construction of a 300 MW nuclear plant	Support as in Planned Policy Scenario for more ambitious policy up to 2 GW of capacity..	As in Enhanced Policy Scenario
Carbon pricing	No carbon price	No carbon price	Inclusion of sector in EU ETS with exposure to €40 / tCO_2 carbon price	No carbon price
Capital grants for abatement technologies	None	None	None	In alternative "Capital Grants" Enhanced Policy scenario, carbon price on emissions is replaced by 20% capital grant for abatement technologies
Heat and Buildings Sector				
Gas share of generation	Continued lack of transmission capacity between regions limits gas use to West and South, and gas share to current levels.	As in Status Quo Scenario, but with increased availability in the South.	As in Planned Policy Scenario	As in Enhanced Policy Scenario
CHP share of generation	CHP share maintained, implying up to 10-15 GW.	As in Status Quo Scenario	As in Planned Policy Scenario	As in Enhanced Policy Scenario
Resident associations	Institutions are weak and relatively ineffective.	Gradual but slow improvement in coordination and effectiveness of the associations.	Fully empowered associations make active investment decisions in end-user heat measures.	As in Enhanced Policy Scenario
Building regulations	Building regulations for new buildings, boilers, and heat meters not effectively enforced	Effective enforcement of buildings regulations	As in Planned Policy Scenario	As in Enhanced Policy Scenario
Energy efficiency policies	No additional energy efficiency policy	As in Status Quo Scenario	Extensive energy efficiency policy programme through combination of "soft" loans, obligations, and energy audits.	As in Enhanced Policy Scenario
Carbon pricing	No carbon price	No carbon price	Inclusion of large-scale heat generation in EU ETS with exposure to €40 / tCO_2 carbon price; €20/tCO_2 carbon price	No carbon price

Policy	Status Quo	Planned Policy	Enhanced Policy	Enhanced Policy – Capital Grants
			/ tax for other measures	
Capital grants for abatement technologies	None	None	None	In alternative “Capital Grants” Enhanced Policy scenario, carbon price on emissions is replaced by 20% capital grant for abatement technologies
Industry				
Energy efficiency policy	No additional policy	No additional policy	Benchmarking and target programme helps disseminate information about best practice and focus management attention.	As in Enhanced Policy Scenario
Carbon pricing	No carbon price	No carbon price	Eligible sectors included in EU ETS with exposure to €40 / tCO_2 carbon price; €20/tCO_2 carbon price / tax for other measures	No carbon price
Capital grants for abatement technologies	None	None	None	In alternative “Capital Grants” Enhanced Policy scenario, carbon price on emissions is replaced by 20% capital grant for abatement technologies
Transport				
Capital grants for abatement technologies	None	None	None	20% capital grant for abatement technologies
Agriculture, Waste, Forestry				
Carbon pricing	No carbon price	No carbon price	Eligible projects exposed to credit-based emissions trading corresponding to €20 / tCO_2 carbon price	No carbon price
Capital grants for abatement technologies	None	None	None	Carbon price is replaced by 20% capital grant for abatement technologies

3.2. Investor Assumptions

3.2.1. Transaction costs and hurdle rates

In addition to estimates of capex and opex characteristics of investments, we have made estimates of additional costs and other factors that influence the attractiveness of investments in low-carbon and energy-saving technologies. We provide a brief summary below.

We distinguish two main categories of influences:

- **Transaction costs**. These are broadly defined to encompass additional costs incurred in undertaking an investment. We distinguish between the following:
  - Project transaction costs. These may include investment appraisal (time costs, consultancy fees, feasibility studies, overheads), procurement and legal costs (contracts, negotiation, search for vendors), compliance costs (e.g., permits, applications) and bribes.
  - Policy-induced transaction costs. Costs that arise because of a policy intervention or requirements. These include a range of administrative costs under credit-based emissions trading, as well as costs of adhering to administrative costs arising from subsidy programmes or regulatory requirements.
- **Hurdle / discount rates.** A variety of factors influence the (implied) hurdle / discount rates applied by households and firms when evaluating investment options. Important factors include:
  - Cost of capital and terms of project finance
  - Risk associated with country, sector, technology and policy setting
  - Option value of waiting
  - Various categories of opportunity costs (of time, management attention, or other investments in the context of scarce capital)
  - Individual preferences (of households)
  - Organisational failures and information asymmetries (split incentives, incomplete capture of benefits, etc.)

3.2.2. Factors affecting transaction costs and hurdle rates

Our general principles in estimating transaction costs and discount rates have accounted for the following factors:

- **Project size.** Many costs are incurred on a “per-project” basis, so that the costs are proportionately smaller for larger projects.
- **Supply chains and infrastructure:** transaction costs are larger for investment in technologies that do not have an established track record in the country / sector.

- **Ownership structure:** dispersed, split, or communal ownership can substantially increase the transaction cost of investments. This is relevant to measures in agriculture / forestry, rented buildings, or communal buildings.

- **Regulation**: various regulations can increase the cost of projects substantially. An example is the use of any materials classified as wastes, or investments with significant impact on local pollution.

- **Fit with overall organisation activity:** costs are likely to be higher for organisations whose commercial focus is not on emissions / energy, than for energy-intensive industry. Likewise, a large literature documents households' general lack of attention to the potential for savings on energy expenditure.

- **Dependence on policy:** Both costs and risk are likely to be higher when the viability of the investment depends on specific government policies that are subject to change. Examples include renewables whose viability depends feed-in tariffs, or investments that have no benefit other than emissions reductions (e.g., carbon capture and storage). Similarly, investments dependent on international carbon credits incur transaction costs as well as some risk associated with future revenues.

3.2.3. Summary: Investor behaviour

The below table summarises the assumptions, showing low, medium, and high transaction costs and hurdle rates, and gives selected examples of abatement measures with these characteristics.

Table 3.2
Summary Investor Costs

Hurdle / discount rates (Capital cost, risk, option values, etc.)	**Transaction costs** (share of capex)		
	Low (10%) →		**High** (25+%)
	Large size (> €500k / > 5 MW) and established supply chains and track record of past projects	*Medium size (< €500k / < 5 MW) or larger projects facing weak supply chains or with low priority for organisation*	*Small scale (<€10k) and/or facing communal / dispersed / split property rights or first-of-a-kind investments*
Low (10%)	▪ New cement and steel capacity ▪ Industry Energy Efficiency measures	▪ Energy management systems ▪ Process control / automation	
↓	▪ New conventional power plant ▪ New conventional heat plant	▪ Public passenger and freight transport ▪ Cement waste-firing	▪ Low-emitting car ▪ Gas leakage ▪ Communal buildings heat-efficiency ▪ Transmission grid updates
High (25+%)	▪ Wind-farms ▪ Hydroelectric power ▪ Nuclear ▪ Carbon capture and storage	▪ Waste handling ▪ Coal mine methane	▪ District heating rehabilitation

3.3. Fuel Price Assumptions

In general, we follow the following principles to define fuel prices in the different scenarios:

- The coal price is assumed to stay constant in real terms, as most coal used in Kazakhstan is low-quality brown coal that is not suitable for export, and is therefore largely “stranded”.
- The price of mazut (a type of heavy fuel oil) is assumed to grow with international oil prices, although maintaining its lower base.
- Current gas prices are low by international standards, but nonetheless linked to the international markets through exports of (mostly associated) gas from Western regions, and through imports of (mostly Uzbek) gas in the Southern regions. We take the current, low prices as a starting point, and we assume that they gradually converge towards the absolute level of international gas prices, adjusted for transport costs. This convergence is more marked for the large consumers, such as power or heat generators, or the industry.
- Secondary energy prices, such as electricity and heat, are modelled, and linked to the cost of provision and the nature of regulation. In general, the Enhanced Policy scenario sees higher prices, reflecting increased cost recovery by electric and heat utilities.

The fuel price assumptions used in the different scenarios are provided in Appendix C, while additional details for each scenario are provided in the relevant sections below.

4. Policy "Status Quo" Scenario

The Status Quo scenario illustrates the emissions abatement potential faced by investors with current policies and institutional arrangements "frozen" in their current form. It is not a projection, and in particular not intended to capture likely future developments. The role of the Status Quo scenario instead is to provide a baseline against which the improvements in other scenarios can be assessed.

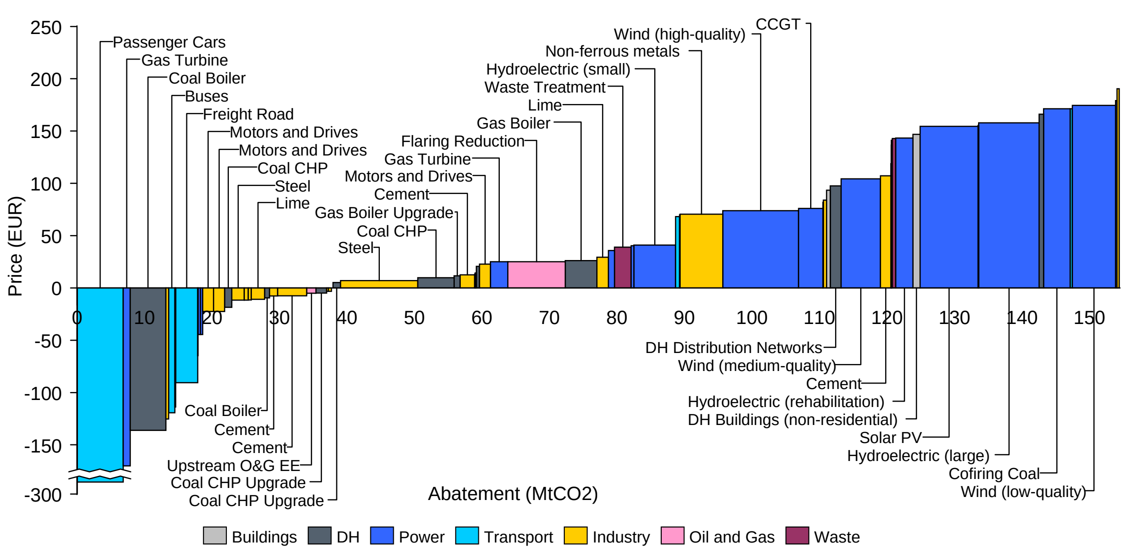
Concretely, the scenario assumes that over the next two decades current policies and institutions continue as they are now. The economy continues to evolve, with emissions abatement potentially available both through the addition of new, more efficient or low-emitting capacity, and through the gradual adoption of technologies and practices to reduce emissions. However, there are no new policies put in place to encourage energy efficiency, renewable energy, or other emissions abatement. Where policies and measures are already in place, they are not strengthened, and their effectiveness does not improve.

We first present an overview of the abatement potential across the economy – including an overview (Box 4.1) of the methodology used to produce the MACCs. Subsequent sections provide further details of abatement cost and potential for the main sectors.

4.1. Policy Status Quo: Overall Cost Curve

We present here the overall marginal abatement cost curve results under the Status Quo scenario. The underlying assumptions, as well as a more detailed presentation of results by sector, are shown in subsequent sections.

Figure 4.1
Full MACC, Status Quo, 2030



Our analysis suggests that under the policy Status Quo, there is potential to reduce emissions in 2030 (relative to the “frozen technology” baseline) by around 38 $MtCO_2e$ through profitable investments, even without additional climate or energy policies. Taking into account all measures, including those that have a positive cost (i.e. those that have a net cost to investors for each tonne of emissions reduced, and thus would be attractive only with additional support), the potential abatement more than triples to 154 MtCO2 in 2030. For comparison, the Static Intensity baseline would imply emissions of 490 $MtCO_2$ in 2030. The opportunities represented in the MACC thus represent a reduction in emissions by over 30 percent.

The currently profitable section of the MACC consists of abatement opportunities across a range of sectors. A common theme is that much of it is accounted for by new capacity, added as demand and production grows. The associated opportunities to deploy new and less emissions-intensive technology make up much of the profitable section of the MACC, reflecting the opportunity to step away from the often very resource-intensive production methods of current legacy equipment. Key examples include more fuel-efficient vehicles, more efficient boilers and CHP for heat generation, and more energy efficient production technologies across steel, cement, lime, and metallurgical industry. (By contrast, for reasons we discuss below, the power generating sector is not projected to become less emissions intensive without additional policy.) Put differently, ensuring that new capacity uses energy efficient technology is a key route to long-term emissions reductions, and can also present attractive investment opportunities.

In addition to new capacity, there is scope to improve the performance of existing capacity, especially in industry, heat networks, and to a limited extent, in buildings. However, although some appear attractive even under prevailing conditions, many of these investments are marginal – as shown by the significant portion of the MACC relatively close to the zero-line. An implication is that policy support could help bring a relatively large share of abatement potential into the territory of attractive investments.

Despite these opportunities, the MACC also shows that as much as a quarter of the abatement volume identified would come at very substantial cost, exceeding €100 / tCO_2. This reflects key features of current conditions in Kazakhstan:

- First, the availability of very low-cost energy reduces the value of the savings that otherwise can make many abatement opportunities attractive. This is particularly striking for the power sector, where renewables come at high cost per tonne of emissions avoided. However, it also affects heat generation measures, opportunities for energy efficiency in buildings and district heating networks, and retrofit measures or choice of highly efficient technologies in industry.

- Second, many of the key sectors have seen only limited investment over the past decades. New projects therefore would take place in an uncertain investment climate. At the same time, the majority of abatement opportunities require commitment of up-front funds in exchange for the prospect of future revenues or cost savings, chiefly from savings on future energy costs. In this situation, bringing down risk premiums, transaction costs, and improving access to finance could be an important enabling factor to make abatement opportunities – as well as other investments – more attractive. In sectors subject to regulation (notably, heat and power) institutional and regulatory reform are key aspects of this transition.

Box 4.1
Explanation of MACC Methodology

In cost curves the height of the bars represents the lifetime cost savings of an investment, expressed per tonne of CO_2e reduced. The curve has two distinct areas: blocks with a cost below zero, and blocks with positive cost. The negative cost portion represents investment opportunities that are commercially attractive given the policies in the given scenario. In contrast, the positive-cost portion shows opportunities that are potentially available, but which would require additional policy support to be attractive to investors.

The methodology for producing the two areas of the MACCs differs. In the positive-cost portion the simulation is carried out by considering the perspective of an investor or producer, at successively higher carbon costs, up to €200/tCO_2. The cost curve represents the level of carbon cost at which a particular production or investment option becomes preferred to *all* other potential methods of producing the same output. For illustration, consider a situation where coal-fired generation is the cheapest option to produce electricity at a zero carbon cost, but where lower-emitting gas-fired generation enters the preferred position at some higher carbon cost level—ahead not only of coal but also other potential technologies. For wind power to appear on the MACC a *still* high carbon cost then is required, defined by the level at which wind is preferred not only to the original coal option, but also to lower-emitting gas, as would be the case in an actual power market.[37] By contrast, an assessment based on comparing wind to coal, but neglecting the gas option, would underestimate the actual carbon cost of wind, and would not represent a realistic assessment of investor options. Finally, the volume of abatement (the width of the bar in the MACC) in the positive portion is determined by comparing the emissions intensities of the low-carbon technology to the technology that it displaces: gas to coal, and wind to gas.

The negative cost portion of the MACC is produced using a different approach – one that is more similar to traditional approaches to calculating abatement costs for a MACC. As a reference point we first characterise what the economy would look like if the technologies used – and their carbon intensity – were identical in every future year to those currently in use. This results in a counterfactual "Static Intensity" scenario. This in turn is compared to an actual projection of future developments in a scenario where investors face no carbon cost beyond those defined by a particular policy scenario. In some cases the most financially advantageous option also will reduce emissions—for example, where ageing stock is replaced by newer and more efficient production methods, or where it is commercially attractive to retrofit existing equipment with measures that reduce energy use or are otherwise financially advantageous. This thus identifies opportunities for emissions reductions that are profitable given the policies assumed. The cost shown in the cost curve is defined by the savings relative to the cost of producing the same output with the technology used in the "Static" case; whereas the emissions savings are calculated by comparing to the corresponding "static" emissions intensity.

[37] This description is simplified for illustration. In practice the model takes account of other key features of technologies, including the lead time to build them, availability, ability to serve baseload vs. peak load, etc.

To calculate the benefit of investing in profitable emissions reductions relative to the "Static Intensity" scenario, we have first selected the relevant “counterfactual technology” in the Static Intensity scenario and compared this to the technologies in each corresponding sector that reduce emissions. For upgrades to existing equipment, the counterfactual should be the existing equipment: the capital cost is then the cost of the upgrade in the year of the analysis (e.g. in 2030), and the annual operating cost savings is the difference between the operating cost of the new and old equipment. The emissions benefit per unit of output is the difference between the emissions intensity of the old and new equipment.

For new (or replacement) equipment, the methodology is somewhat more complicated. The counterfactual here is defined as an “average characteristics” of the capacity that is in place in 2010. So, for example, in the power sector, approximately 70 percent of current electricity production is from coal, 20 percent is from natural gas and 10 percent from large hydroelectric power plants. The Static Intensity scenario is constructed to conform to these shares, with new capacity built in exactly the same proportions to meet any new demand. In the policy scenarios, we therefore compare any new capacity to this “Static Intensity Average”. The emissions savings per unit of new capacity is therefore the difference between the emissions intensity of the new technology and the weighted average intensity of the existing capacity – which does not change over time. The incremental cost of the new technology is calculated as the weighted average of the capital costs of each technology in each year that the MACC is calculated. So the counterfactual cost in 2030 is based on market shares from 2010 but costs in 2030.

The reason for taking this approach is that the current production mix already includes some low-carbon technologies, and these would be part of the hypothetical “Static Intensity” future. If we did not treat the overall average as the counterfactual, for each new scenario we would have to arbitrarily choose which of the existing “Static” technologies was being replaced. So, for example, if the model predicted construction of new efficient gas-fired power plants, we would have to decide whether this was built instead of a new coal plant, or a new hydroelectric plant, or possibly was simply the gas plant that would have been expected anyway under the Static Intensity scenario.

This approach gives the cost of using abatement technologies to reduce emissions, relative to what would have been built instead (on average) in the Static Intensity scenario. Where there is expected to be technical progress in abatement classes that reduces their cost, but more limited progress in more conventional (counterfactual) classes, the methodology allows for the possibility that abatement classes may actually have lower capital costs than the counterfactual. Moreover, because in some sectors the average counterfactual may be a mix of some capital intensive and some less capital intensive measures, it is not always the case that the abatement class will have a higher capital cost than the counterfactual. In some sectors these considerations may reduce the incremental capital cost that would be calculated if a different counterfactual methodology were used.

Overall, the average cost of profitable abatement measures relative to the current stock in 2030 is -€95/tCO_2. As noted above, much of this is attributable to the difference between the current often aged and poorly maintained capital stock, and the superior technologies available when investing in new equipment to serve expanding production and demand over time. Across the entire MACC up to €200/tCO2 (in real terms), the average cost per tCO2 is €36 in 2030.

The below figure summarises key macroeconomic indicators associated with the Status Quo scenario.

In the Status Quo scenario, the incremental commercially viable investment associated with the low-carbon measures amounts to €0.6bn per year in the period 2010-2030, corresponding to just under 1 percent of total estimated gross capital formation over the period. The opex savings are €2.1bn, or 1.7 percent of total estimated consumption. There are no carbon price revenues or capex grants expenditures associated with this scenario.

Table 4.1
Summary Aggregate Economic Indicators, Status Quo

	Average, 2010-2030 (€bn / year)	Share, cumulative to 2030
Additional investment	€0.2bn	0.3% of gross fixed capital formation
Opex savings	€2.1bn	1.7% of estimated consumption

Notes: The percentages show the total shares in the period 2010-2030, based on a continuation of current shares of capital formation, consumption, revenues, and expenditure in GDP. Opex savings exclude avoided carbon taxes and subsidies.

In the sections below we discuss the underlying assumptions as well as the results for each sector in more detail.

4.2. Cross-Cutting Scenario Assumptions

4.2.1. Fossil fuel markets and subsidies

A key feature of the Status Quo scenario is that energy prices are maintained at their current levels. Specifically, we assume the following:

- **Continued low coal prices.** Prices continue at their current levels in real terms, reflecting the cost of coal mining and limited opportunities for export.
- **Gas prices converging to international levels.** Gas prices in Kazakhstan currently are significantly below international gas prices. The status quo scenario assumes that in line with recent trends, gas prices faced by industry consumers and power and heat generators progressively converge to the international prices.
- **No increased availability of natural gas.** The scenario assumes no expansion of the current gas network.

See Appendix C for details of the price levels assumed.

4.2.2. Investment criteria and barriers

We also make assumptions about the investment environment and impact of the various barriers facing abatement investments outlined in section 2. Although the modelling implementation is multi-faceted, the table below summarises some of the key inputs used.

Table 4.2
Hurdle Rates, Status Quo Scenario

Category	**Examples of abatement measures**	**Transaction costs** (% of capex)	**Discount rate** (%)	**Payback period**[38] (years)
General Household-scale / small business, including passenger transport	▪ House insulation ▪ Small-scale heat pumps ▪ Thermostats	30%	20-25%	15
Communal / multiple occupancy buildings	▪ Building fabric of apartment and office blocks	40%	20-25%	15
Waste	▪ Industrial waste firing	15%	20%	15
Energy intensive industry	▪ More efficient motors ▪ Waste heat recovery ▪ Process improvements ▪ Energy management systems	15%	15%	15
Freight transport	▪ Modern vehicles	15%	15%	15
Utilities: conventional technologies	▪ New coal plant ▪ New gas plant ▪ New boilers	10%	15-20%	20
Utilities: renewables	▪ Wind power ▪ Biomass ▪ Hydroelectric	10%	20-25%	20
Agriculture, forestry	▪ Low-tillage; ▪ Precision fertiliser application; ▪ Improved manure management ▪ Ionophores	30%	20-25%	15

4.3. Power Generation

4.3.1. Sector scenario assumptions

The following is a summary of the key scenario assumptions for the power sector:

- **Sufficient incentives for new entry.** The scenario assumes that the new market arrangements and subsequent developments prove sufficient to ensure adequate entry of new capacity. For the purposes of modelling emissions abatement, we evaluate the investment options based on their least cost given technical and other input assumptions.
- **Significant technical potential for rehabilitation of existing non-operational capacity.** The scenario assumes up to 1.8 GW of power-only, and 1.8 GW of CHP capacity at existing plants can be rehabilitated and brought online to provide net capacity additions.
- **Life extension / rehabilitation of existing operational capacity.** The scenario allows currently operating plant to stay open through investment in life extension and

[38] For retrofit measures. New capacity is evaluated at 20 years or the equipment lifetime, whichever is the smallest.

rehabilitation, provided this is the most cost-effective method of meeting electricity demand.

- **Limit on gas-fired generation.** The scenario limits gas-fired generation to no more than its current share of 11 percent of generation, reflecting the underlying transmission and fuel availability constraints. This represents gas-fired generation serving local demand in the West of the country, as well as some implicit interconnection with the North via Russia.
- **Limited expansion of CHP.** CHP is limited to no more than its current share of heat and power generation, or around 15 GWth.
- **No explicit financial support for renewables.** Although Kazakhstan currently has a support regime for renewables, its effectiveness has not been established. With no published tariffs, it is unclear whether the regime would approve sufficient support for the projects required to meet stated Government ambitions. The availability of effective support to reach the stated ambition therefore is not included in the scenario, but is reserved in the Planned Policy scenario described below.
- **Implicit support for grid connection.** The scenario assumes that the cost of connecting renewables to the grid would be borne by the system as a whole, following current uniform transmissions charging.
- **Constraints on wind power.** Wind power is constrained to provide no more than 20 percent of total annual generation, reflecting system balancing constraints.
- **Hydropower potential and rehabilitation.** Technical potential for 2.4 GW of small hydropower and 3.3 GW of large hydropower. No policy support for rehabilitation of existing large hydropower plants.
- **No nuclear power**. Nuclear power is not included in the future generation mix.
- **Limited investment incentives to reduce distribution losses.** The current regulatory structure, including the level of retail tariffs, provides only limited incentives for investments to reduce distribution losses, and these are reflected in the scenario. At most 20 percent of the maximum technical loss reduction potential can be achieved.
- **Maintain current retail energy prices.** Current electricity tariffs are maintained in the scenario.

4.3.2. High-level power sector results

Under the Status Quo scenario the power generation is projected to increase by almost 70 percent, from 87 TWh in 2010 to almost 150 TWh in 2030.

Coal-fired generation continues to be the least cost option for new power plants during the period 2010-2030. There is significant rehabilitation of capacity that is currently out of operation, alongside new entry. Power generation from CHP plants decreases as a proportion of total power production, as rehabilitations and new capacity more or less displaces outgoing capacity, resulting in almost no net additions. There are no additional renewables built in the status quo scenario – as outlined above, making these technologies financially attractive would require additional policy support.

Figure 4.2
Power Capacity, Status Quo

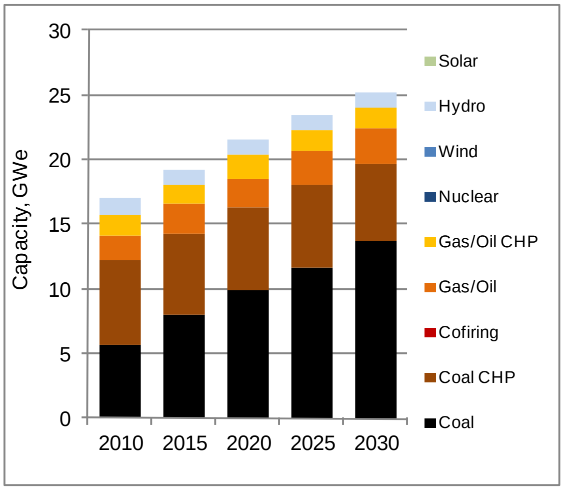


Figure 4.3
Power Generation, Status Quo

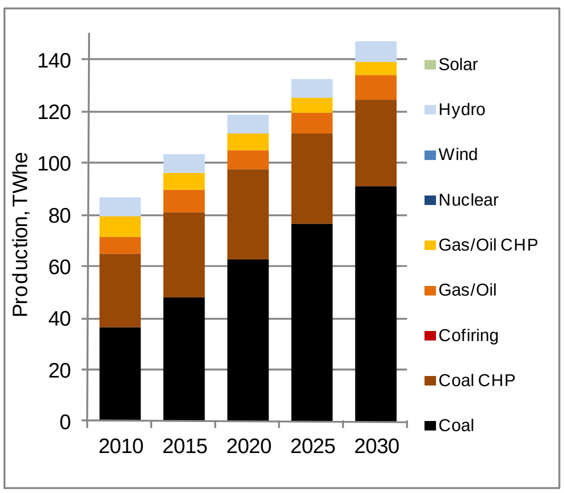
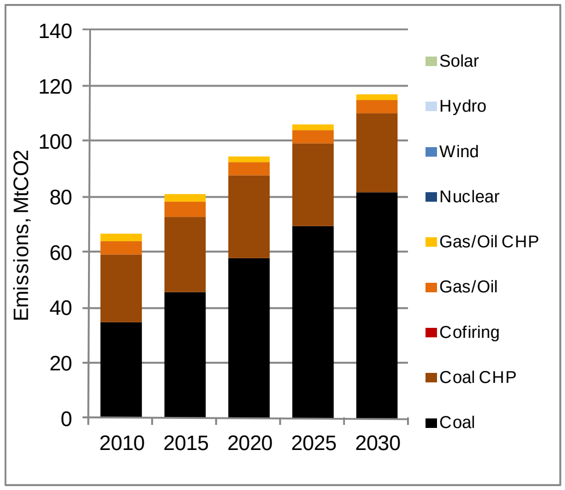


Figure 4.4
Power Emissions, Status Quo

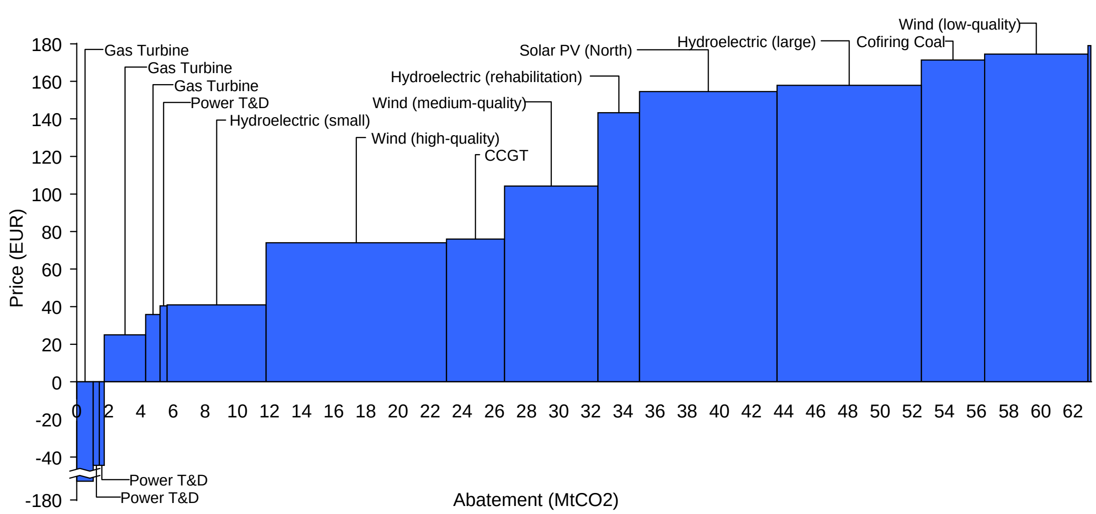


In the absence of incentives for emissions reduction, by 2030 power sector emissions grow to 117 $MtCO_2$, approaching double their 2010 levels, as a result of the addition of significant coal capacity. Although there is some improvement in the generation efficiency of existing plant, as well as entry by new coal plant with higher generation efficiency than much of the legacy capacity, the sector-wide emissions intensity is not substantially reduced. The main reason for this is that there is no expansion of either hydropower or gas-fired generation, both of which decline in their share of the overall generation mix. In addition, in spite of the enormous wind power potential that is technically available in Kazakhstan, no new capacity is built under the Status Quo assumptions.

4.3.3. Cost curves for the power Sector

The figure below presents the results of the MACC modelling for the Power sector, for 2030.

Figure 4.5
Power Sector MACC, Status Quo, 2030



We identify 63 $MtCO_2$ of abatement, corresponding to 56 percent of projected static 2030 emissions. Most of the abatement is not profitable at zero carbon price, with the exception of a small amount of new gas turbines and power transmission and distribution upgrades.

Without enabling climate policies nearly all of this potential comes at a net cost. There is some limited scope for cost-effective emissions reductions through increased use of natural gas. Where natural gas continues to be available at low cost and the entry of new gas plant displaces the entry of new plant, CCGTs can be a highly cost-effective method of abatement. However, under the assumptions about gas availability the extent of abatement is very limited. Additional gas use can be achieved by reducing output from existing coal and oil-fired plant, and switching instead to generation from CCGTs. However, the cost of this option is significantly higher.

Instead, the bulk of the emissions reductions are available through renewable sources. These are dominated by wind power and hydropower, starting at abatement costs from around €40/tCO_2. The cost of wind power varies significantly depending on the sites available. Likewise, the cost of hydro power varies with the suitability of sites, the availability of options for rehabilitation. From the available data, it also appears that smaller hydro is more cost-effective than the relatively limited opportunities for additional large-scale hydropower.

There also is limited potential to reduce emissions by adding biomass to the fuel mix at existing coal plant. However, large scale deployment of this option would require significantly increased concentrations of biomass in areas of current coal plants, and corresponding infrastructure and supply chains. Even at very high carbon prices, achieving a share of more than 10 percent of the fuel in coal plant appears ambitious.

As noted above, the status quo also sees significant addition of efficient coal-fired plant, as well as upgrades to improve the efficiency of current coal plant. These do not show as abatement options in the cost curve. The reason for this is that the emissions intensity of all coal options is greater than the current sector average (which is reduced by pre-existing hydro). Additions of coal thus do not constitute abatement relative to the "static" baseline used to define the MACC.

Finally, there are some limited options at prices higher than those shown in the above MACCs. These include solar power (both PV and thermal), and increased use of biofuels.

In sum, a major conclusion is that the Kazakhstan power sector would require major policy intervention to make the available abatement options attractive. We discuss in subsequent chapters what these policies may include.

4.4. Heat and Buildings

4.4.1. Scenario assumptions

We summarise the key features of the Status Quo scenario for the heat and buildings sector below.

4.4.1.1. Heat generation

Sufficient investment incentives for new entry. We assume that sufficient incentives are in place to enable the construction of new heat generating capacity as it is required. However, this may be funded in part through separate capitalisation of district heating companies, rather than through higher heat tariffs (see below).

Limited gas use. Gas is limited to no more than 19 percent of generation, maintaining the current share.

4.4.1.2. Heat networks and distribution

Slow pace of network rehabilitation. Low heat tariffs provide insufficient revenue to finance significant private investment in heat network beyond essential maintenance and replacement. Additional network upgrades continue at recently observed rates, financed mainly through public funds. Only 20 percent of the technical maximum potential upgrades and replacements are achieved in this scenario.

Slow pace of plant modernisation. Limited regulatory incentives result in slow upgrade of CHP / boiler plant, consistent with completion by 2030.

4.4.1.3. Heat end-use and buildings

Continued flat-rate tariffs for district and communal heating. Consumers continue to face a flat-rate price for heat. There thus is no financial incentive for fuel savings, and costs shown on the abatement cost curve indicate the emissions savings benefits, only. Insulation measures or other energy efficiency measures may be taken up voluntarily by the private sector only in 10 percent of Domestic and 50 percent of Commercial / Public installations.[39]

Continued low heat tariffs. Heat tariffs continue at current low levels, broadly covering short-run costs but with little allowance for network maintenance and investment cost. See Appendix C for more details on the heat tariffs.

Low effectiveness of residents associations. Residents’ associations continue to have difficulty investing in end-user energy efficiency measures in communal buildings. This is reflected in relatively high discount rates (20-25%) and transaction costs (30% or more) faced by the sector.

---

[39] The higher share of insulation feasible in the non-domestic sector reflects the higher pre-existing share of metered and billed heat consumption in the sector.

Weak enforcement of building regulations. Building efficiency standards are not enforced, and uptake of mandatory equipment, such as heat meters in buildings served by shared heating systems, is very slow. Widespread installation of modern building-level substations is not possible, which prevents further uptake of energy efficiency measures, because accurate metering and billing of marginal heat (enabled by the installation of a BLS) consumption is a prerequisite for such heat consumption reductions to be financially attractive.

Continued low electricity prices. Electricity prices continue at current low levels as a result of continued low wholesale prices as well as limited recover of long-run distribution costs in retail tariffs. See Appendix C for more details on the electricity tariffs.

4.4.2. High-level Heat sector details.

Heat demand in the residential and commercial sector is projected to more than triple over the 2010- 2030 period, from 75 TWh in 2010 to 230 TWh in 2030. This reflects several factors, including greater comfort taking (anecdotal evidence suggests that the level of service in dwellings heated by district heating is often inadequate and leaves some consumers, unable to regulate intake of heat, with insufficient heating supply, while other are oversupplied), population growth and increases in living spaces. Like in power, coal remains the main fuel used in generating heat, with gas being limited to the current share of production due to insufficient distribution network capacity.

The existing capacity, often outdated, is progressively replaced by new entrants, or rehabilitated, although much of the current capacity is still assumed to be in operation by 2030.

Figure 4.6
Heat Capacity, Status Quo

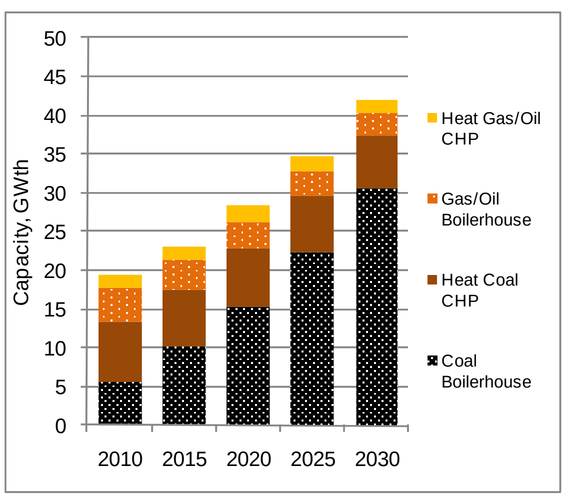


Figure 4.7
Heat Production, Status Quo

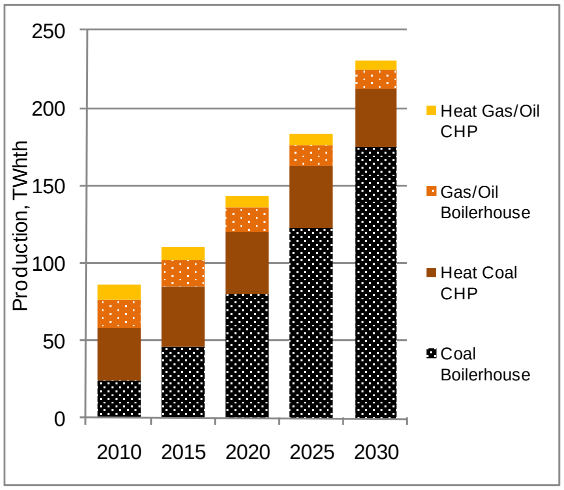
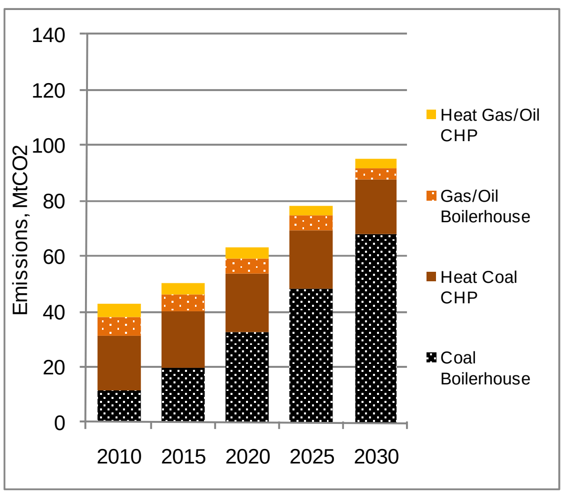


Figure 4.8
Heat Emissions, Status Quo

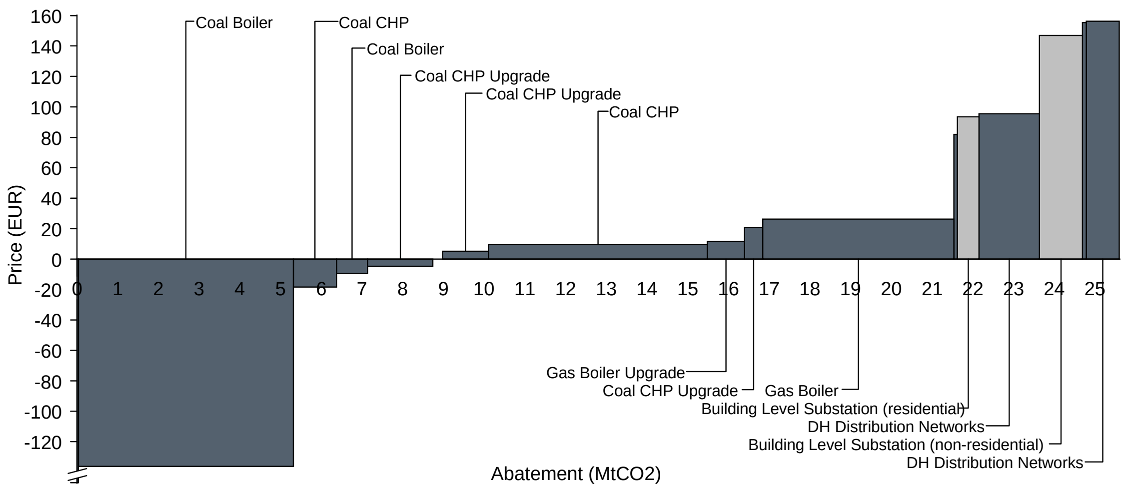


With little incentive for emissions reduction, the emissions from heat production more than double from just over 40 $MtCO_2$ in 2010 to 95 $MtCO_2$ in 2030. The average heat generation emissions intensity fall somewhat over time, as new, rehabilitated and upgraded capacity is more efficient, but it does not reflect the full abatement potential of this sector.

4.4.3. Cost curve for the Heat and Buildings sector

The MACC for the Heat and Buildings sectors for Status Quo scenario is presented below.

Figure 4.9
Heat and Buildings MACC, Status Quo, 2030



The total estimated feasible reduction by 2030 relative to the current emissions intensity of heat supply is 26 $MtCO_2$. Of these, 9 $MtCO_2e$ of emissions reductions are attractive even without additional policy or reform under the Status Quo scenario.

Compared to the size of the sector’s emissions these are significant but not dramatic reductions – roughly 20 percent relative to the static baseline if all measures were taken up. Nearly all of the reductions are in heat generation, with very little profitable potential in networks and buildings, for reasons we discuss below.

We describe below the abatement opportunities in the three parts of the heat supply chain: generation, distribution, and building end-use.

4.4.3.1. Heat generation

The financially attractive opportunities in the Status Quo scenario are nearly all in large-scale heat generation, through the addition of new CHP and heat-only boilers, along with some opportunities to improve the performance and extend the life of existing CHPs. These are attractive relative to the static baseline, i.e., compared to the low-efficiency boilers and CHP currently operating, new heat generation capacity contributes to reduced emissions intensity while also saving sufficient fuels to incur lower cost.

The CO_2 savings per unit of heat output are greater from CHP than from boilers. Additional emissions savings could be made available by increasing the share of CHP in heat generation, but this could potentially limit further decarbonisation of the power sector if zero-carbon technologies are available. That is, more abatement overall may be feasible if heat-only boilers are used and electricity is generated through zero-carbon sources.[40] We describe our approach to modelling CHP and accounting for emissions savings in Box 4.2 overleaf.

Emissions reductions also are available by switching from coal (and mazut) to gas, although this option is not attractive without additional policy support. Thus the associated abatement cost depends chiefly on relative fuel prices.[41]

Finally, the MACC also includes some options to add CHP capacity to replace existing boilers earlier than would be required in a natural lifecycle. However, this comes at significantly higher cost, as it would entail the accelerated depreciation of functioning heat generating capacity.

---

40 New boilers appear as having very low abatement costs in the MACC, but a smaller absolute amount of savings. The large negative value arises through the combination of a modest cost saving but reduction in emissions per unit output. This results in a large ratio and therefore large negative cost per tonne on the MACC. However, the cost saving per MWh of heat generated is in fact relatively small. In reading the MACC, it is important therefore to pay attention also to the width of a segment, which indicates the extent of the emissions savings. The boiler segment is relatively small, despite a large volume of new boilers.

41 The close proximity of boilers and CHP heat generation to cities means that there are also other potential benefits from fuel switching, notably through reduced air pollution. It has not been possible to quantify these benefits in this project, and in keeping with the investor perspective, we do not include them in the cost estimate. Nonetheless, local pollution considerations could become very important to the fuel-switching choice in individual circumstances (the situation in Almaty is an example of where this has already had a significant impact).

Box 4.2
Methodological Note: Approach to Modelling of CHP

There are a variety of ways of representing combined heat and power when modelling the respective sectors, each associated with a different approach to allocating emissions savings and costs. Because electricity and heat are produced simultaneously, there is no clear-cut way of allocating the input fuel and emissions, the original capex, or operation and maintenance costs to the respective outputs. Approaches include allocating all inputs only to one of the outputs, or to both based on the relative energy content of outputs, or on the market value of outputs, or the energy content of inputs in separate heat and power generation, or even based on simple rules of thumb (e.g., allocate two-thirds of input costs and emissions to electricity, and one-third to heat).

For the MACC analysis shown here we have taken an approach based on two principles: a) base allocation on the characteristics of *counterfactual* separate heat and power generation, and b) denominate characteristics, including emissions, using heat as the “unit of account”. As a starting point, we note that whereas electricity could (in principle, and in the longer term) be obtained from other sources on the wider transmission grid, heat can only be obtained from the local CHP. For much of the year CHP serving district heating is effectively “must-run” capacity, and we show CHP emissions savings on the heat rather than power sector MACC, calculating emissions and cost savings *per unit heat*. This requires an analysis of the electricity sector to derive the characteristics of the counterfactual electricity that would need to be generated to replace the CHP’s output if it did not run. In Kazakhstan, the relevant source is likely to be new entrant coal plant.

The advantage of this approach is that it correctly accounts for resource costs (including opportunity costs), while it also reflects actual generation characteristics – including the product mix (heat-to-power ratio) and the overall generation efficiency. One consequence is that new and more efficient CHP, in particular, can obtain very low emissions intensity per unit heat—which accounts for the large emissions savings shown for new entrant CHP on the MACC.

4.4.3.2. Heat networks

Overall, we identify technical potential for improvements to network insulation of 33 TWh of heat by 2030, which would correspond to about 17 $MtCO_2$ assuming the current average heat grid intensity. However, the uptake of this is curtailed in the Status Quo scenario by the limitations of the regulatory regime, as well as by cost. At the current rate of investment, at most 20 percent of the total network would be upgraded by 2030, and the abatement potential correspondingly is small. Moreover, as heat is comparably cheap to generate (the fuel cost is as low as €3.65/MWh heat for coal boilers with access to low-cost fuel), the abatement cost associated with network improvements also is high, starting at €95/tCO_2

4.4.3.3. Building energy efficiency

The MACC also shows very limited opportunities for investment in building energy efficiency. This is not because of limitations to technical potential, which is as much as 45 $MtCO_2$ by 2030, compared to the static emissions intensity. Instead, three key factors combine to exclude these measures from the above cost curve:

- Flat-rate charges for energy mean most end-users connected to communal or district heat networks have no financial incentive to undertake energy efficiency measures. Savings shown on the MACC thus would need to be supported by the carbon savings alone. However, even at a €200/tCO_2 carbon price the payback period for wall insulation is 11-12 years, whereas end-users are likely to require much more favourable conditions to invest in energy efficiency measures.
- Even where energy is charged on a per-unit basis (i.e., some parts of the commercial building stock and individually heated houses) low end-user prices for heat and fuel make insulation measures unattractive. For example, at a zero carbon price, retrofit wall insulation (one of the more cost-effective insulation options) has a payback in excess of 30 years at current heat prices.
- Finally, even if the financial situation were more favourable, the lack of effective residents’ associations or other bodies to coordinate action would limit the rate of uptake

In sum, a combination of low underlying energy costs, regulation keeping prices down, and lack of required institutions mean nearly none of the technical potential for building energy saving

4.4.3.4. Summary

There is significant technical potential to reduce the emissions along the whole heat supply: compared to the static baseline, we estimate that 2030 emissions could be cut by up to two-thirds through a combination of more efficient generation, reduction of heat losses in networks, and improvements to building energy efficiency.

However, under the Status Quo scenario only a fraction of this abatement potential is available and attractive to investors. Improvements to heat generation efficiency offer scope for significant abatement, some of it attractive even in the Status Quo scenario. However, the significant potential for reductions in network losses and improvement of building energy efficiency cannot be realised even at carbon prices up to €200 / tCO_2. Institutional impediments limit both financial incentives and the scope for collective action, while underlying low energy prices mean many measures are not financially attractive. Very significant policy intervention therefore is required to make these measures attractive to investors.

4.5. Industry

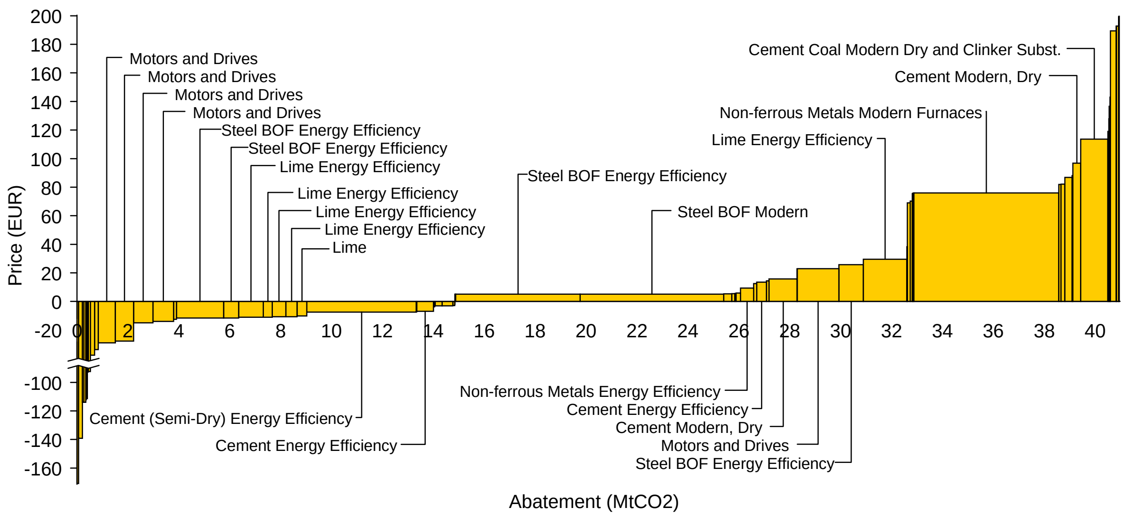
4.5.1. Sector scenario assumptions

- **Low awareness of energy efficiency and limited supply chain.** This increases transaction costs as the implementation of measures become more complex and uncertain.
- **Stringent criteria applied to investments.**
- **Cement clinker substitution.** Little scope for substitution of clinker, most production continues with a share of clinker of over 85 percent.

4.5.2. Overall industry cost curve

The marginal abatement cost curve for industry is shown in the below figure.

Figure 4.10
Industry MACC, Status Quo, 2030



The MACC identifies 41 MtCO2 of abatement, or a reduction of 35 percent on the emissions that would be implied by the static intensity projection for 2030. Much of the abatement potential is steel and cement sectors, with potential also in the lime and copper sectors. In addition, there are cross-cutting opportunities to reduce electricity consumption, notably through the use of more efficient motors and drives.

Low-cost options for abatement are dominated by new capacity. Current steel, cement, and lime production are highly inefficient. In comparison, new capacity therefore offers the opportunity to achieve higher energy efficiency at relatively small incremental cost—but as with other energy efficiency the cost of energy is a key driver in these investment decisions.

There also are significant opportunities to reduce emissions relative to the static case at existing capacity, through maintenance, refurbishment, capacity expansion, as well as discretionary upgrades and adoption of energy efficiency improvements. Again, cement and steel contain many of the lowest-cost retrofit options identified. However, many of these measures are marginal, and several opportunities not attractive under the Status Quo assumptions.

As noted above, we do not include carbon capture and storage in this abatement cost curve, as we regard the technology as speculative and costs are highly uncertain. However, there are significant emissions from cement, steel, and refineries which could be amenable to the application of CCS, should the technology prove viable. Unlike energy efficiency or fuel switching, CCS would increase energy costs (as well as entailing high up-front capital investments), and would be motivated only if there were offsetting incentives to reduce GHGs, through regulation or carbon prices.

We provide a more detailed discussion of the abatement options and potential for the more important sub-sectors below.

4.5.3. Cement

Overall, we identify abatement of 9.5 $MtCO_2$, or close to 40 percent of "static" 2030 emissions that would ensue if production expanded at current emissions intensity. The relatively sharp reductions in energy intensity are dominated by the opportunities presented by new capacity, which is brought to the fore by the combination of high current fuel intensity and significant expansion in production. The higher cost and greater inertia associated with retrofitting existing capacity means most of these measures appear as measures that are not financially attractive under the status quo assumptions, although some options (starting with heat recovery and energy monitoring systems) are marginally profitable. More generally, the fact that half of the potential is not currently financially attractive illustrates the importance of the price of coal for the viability of investment in industrial abatement. Low costs in Kazakhstan mean that many energy efficiency options that would be attractive in other countries are either not economically viable or marginal in Kazakhstan.

The attractiveness of investing in greater clinker substitution and use of waste fuels depends not only on the cost of coal, but also on the institutional and regulatory framework for waste handling:

- Expanding clinker substitution would likely require regulatory changes. In the Status Quo scenario we have assumed that a loose waste regulatory regime permits at most 25 percent of production to transition to 20 percent clinker substitution by 2030; however, as we discuss below, significant additional abatement could in principle be made available under stronger policy incentives.

- Similar considerations apply for waste fuels, with candidate substances spanning a broad range including tyres, solvents and other chemical waste streams, and some organic waste. Unlike in Western Europe, there currently is nearly no use of such fuels in the industry, reflecting very limited incentives and barriers similar to those noted for clinker substitution. In the Status Quo scenario we have assumed no use of waste firing; again, additional abatement could be made available with more conducive policies.

4.5.4. Steel and metallurgy

We identify abatement of 14 $MtCO_2$ in the Steel sector by 2030, or around 30 percent of the “static” emissions. Only some of the potential identified (around 2.5 MtCO2e) is profitable in the Status Quo scenario without a carbon price.

Most of the profitable potential is for measures that upgrade or retrofit relatively less efficient steel plants (“laggards” – see A.3.3 for more details on international benchmarking) using more modern equipment. Simple abatement measures in these types of plants would typically include preventative maintenance (which would prevent unnecessary disruption to the production, and the opportunity cost of lost production), and improved energy monitoring and management system.

There are also abatement opportunities from improving the energy efficiency of existing capacity beyond the basic profitable measures – these would, however, not be viable without additional policy support.

Both the profitable and unprofitable measures have an abatement cost close to zero (with the bulk of measures identified between -12 and +12 €/tCO_2e), suggesting that only a small financial incentive would be needed for most of the abatement to come forward (although other, non-financial barriers may exist that would prevent the measures from being taken up). Investment in new, modern steel capacity would also reduce emissions intensity.

For non-ferrous metals we use direct estimates of abatement costs and potential identified for copper and aluminium production. As noted above, data on the cost and potential of emissions reductions in other non-ferrous metals is scarce, and we therefore use copper and aluminium data as approximations also for other key metals sectors (notably, zinc, chromium and ferro-alloys). Based on this, we identify emissions abatement of 7 $MtCO_2$, at costs ranging from -3€ /tCO_2 for measures such as process optimisation and heat recovery, to €82 / tCO_2 for the replacement of old furnaces with new designs (typically highly capital-intensive measures).

Total emissions reductions in this sector are closely connected to the carbon intensity of electricity supply. These emissions reductions are represented in the overall power cost curve above.

4.5.5. Lime

For lime, we identify abatement of over 4 MtCO2e, or one third of the “static” emissions in 2030, of which 2.4 MtCO2, or 40 percent, is profitable without a carbon price.

The emission reduction opportunities are concentrated in reducing the energy intensity of fuel combustion. Much of the abatement identified comes from building new capacity with modern kilns and with lower average energy intensity. Significant opportunities also exist to upgrade the existing production capacity – for example by improving kiln combustion, and insulating kiln shells. Preventative maintenance of both new and existing capacity, as well as improvement in the monitoring and optimisation of feedstock can also lead to energy intensity reduction.

4.5.6. Other industry sectors

One important abatement option we identify, that cuts across a number of industry sectors, is improvement in the efficiency of electricity usage: replacement of motors, variable speed drives, pumps and other electric equipment with their modern equivalents, as well as replacing them with a more suitable sizes (e.g. downsizing unnecessarily large engines) may provide significant reduction in power demand from industry. In total we identify almost 5 $MtCO_2$ of abatement from improving the industry electricity efficiency. Only around 3 $MtCO_2$ of that potential is commercially attractive in the Status Quo scenario, largely due to relatively low electricity prices faced by Industry consumers.

Other smaller industry sectors such as Refineries, Pulp and Paper, Bricks and Ceramics or Ammonia production have only limited abatement potential (both among profitable and unprofitable measures), of around 1.4 $MtCO_2$.

4.6. Other Major Emitting Sectors

4.6.1. Sector scenario assumptions

4.6.1.1. Oil & Gas

Continued moderate enforcement of flaring regulations.

4.6.1.2. Transport

Continued taxes and road transport dominance. In the transportation sector, the scenario includes continuation of prevailing high fuel taxes, as well as vehicle taxes. There is no policy to change the current heavy reliance on road transport for freight and passenger traffic.

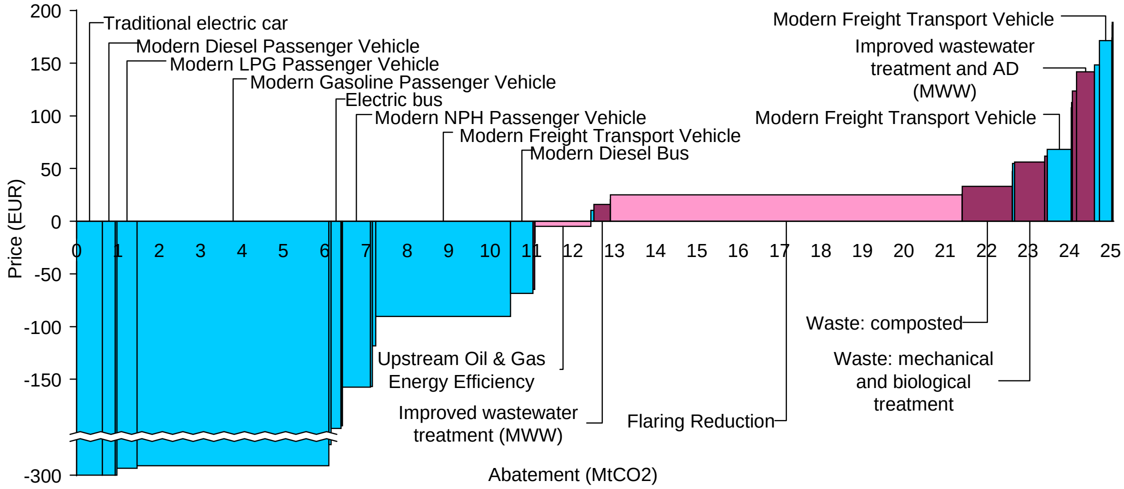
4.6.1.3. Waste

Weak waste regulations and institutions. Current waste regulation and infrastructure is assumed to be insufficient to enable many of the technical potential abatement options that rely on special treatment of various waste streams. This includes insufficient institutions to support landfill gas capture or energy from waste. Similarly, we assume no significant availability of waste streams for combustion in industrial processes, or substitution in cement blending.

No specific industrial energy policy. Industry is assumed not to be subject to any additional incentives or enabling factors to reduce emissions beyond those provided through the price of energy.

4.6.2. Overall cost curve for other sectors

Figure 4.11
Other Sectors MACC, Status Quo, 2030



Notes: NPH = Non plug-in hybrid. MWW=Municipal Wastewater. AD = Anaerobic Digestion.

4.6.2.1. Transport

Even without any specific policies to reduce carbon emissions in place, several abatement options come forward between 2010 and 2030 to reduce emissions by 11 $MtCO_2$, at an average cost of -€209/tCO_2. If we include the abatement potential that is not profitable (but that could be with a positive carbon price or other policies), the total abatement potential increases to over 12 $MtCO_2$ in 2030.

The profitable abatement potential is concentrated in road transport, and specifically in passenger road transport. Of the total abatement potential identified, 7 $MtCO_2$ comes from individual passenger transport, and another 1 $MtCO_2$ from public passenger transport.

Advanced Freight road transport, shown as “Modern Freight Transport Vehicle” in the MACC, includes among others, better and more frequent vehicle maintenance, tyre pressure checks and similar. In 2030, this leads to emissions abatement of around 4$MtCO_2$.

For freight road transport, we expect that in reality the cost of abatement will vary depending on the nature of the freight traffic. This is because the benefit of a better-maintained or more efficient vehicle would depend on the average yearly mileage of individual trucks. Long-distance (i.e. international) freight vehicles typically drive substantially more tonne-kilometres over their lifetime than medium distance (inter-city) and short-haul (intra-city) freight vehicles, so the benefits of fuel savings will vary.

4.6.2.2. Waste

Emissions from the Waste sector in 2008 were 4.9 MtCO2e, as reported in the UNFCCC inventories. Most of these were methane emissions from solid waste disposal, but there were also significant N2O emissions from landfills, as well as methane emissions from waste water.

Kazakhstan currently produces over 4 million tonnes of municipal waste every year. Only 15% of the total waste generated per year is used by enterprises; the rest is landfilled (often at un-licensed sites – only 6.8% of landfills are operating legally.[42] In the Status Quo scenario, this trend continues until 2030, as there are few incentives to limit waste or emissions from waste. The amount of waste produced grows at the same rate as GDP.

With the Status Quo policies there are almost no abatement options that would be commercially viable without additional support (whether this took the form of external carbon price or other policies to reduce waste or encourage energy recovery from waste). This reflects the relatively limited requirements for waste disposal and limited policy directed at reducing waste generation. Without additional policies to reduce the amount of waste going to landfill or open dump sites and to reduce the amount of organic material that is disposed of, most abatement opportunities are not immediately profitable. The current levels of support available for use of biogas recovered from waste disposal (for example, for electricity generation) are generally not sufficient to stimulate widespread adoption. At positive costs of abatement, there is 3 $MtCO_2$ of abatement potential from the Waste sector 2030.

The cheapest options, below 50 €/tCO_2, are improved wastewater treatment (municipal), and waste composting Mechanical and biological treatment of waste, and anaerobic digestion is an option at carbon prices over 50 €/tCO_2.

4.6.2.3. Agriculture

The agriculture sector emitted almost 14.5 $MtCO_2e$ in 2008, or 6 percent of total emissions, excluding land use, land-use change and forestry (LULUCF).[43] On the other hand, LULUCF was a net carbon sink, absorbing around 0.6 $MtCO_2e$. Within this, forests were a net carbon sink of around 0.7 MtCO2, while cropland and grassland sources and sinks roughly cancelled each other out.

The key abatement measures in Agriculture and Forestry include:

- **Conservation Agriculture.** This measure covers several measures, including reduced tillage, residue management and crop rotation. Less mechanical disturbance of soils increases the soils' retention rate of carbon, mainly by creating a layer of soil with high content of organic matter, including dead animals and plants. In addition, fossil fuel (mostly gasoil) consumption is reduced through less tillage, as agricultural machinery is used less.

  Penetration of minimum / zero tillage in Kazakhstan is estimated to have reached around 1.2 million hectares in 2008 (doubling from the previous year) due to high uptake particularly in Northern regions. Conservation agriculture therefore represented just over 5 percent of total land.[44] It is estimated that in the medium term Kazakhstan could adopt conservation agriculture on about 30-40 percent of the cereal cropped area (3 to 4 million

[42] Source: Data provided by Climate Change Coordination Centre ("C4").

[43] UNFCCC inventory

[44] Total Arable land and permanent crops area in Kazakhstan in 2008 was 22.8 million hectares.

ha), provided adequate finance is available for investment. The rate of return on these investments is estimated to be between 18-23 percent. [45]

Zero-tillage sequestration technical potential has been estimated (with very wide site-specific estimates) to yield 1-3 tCO2/ha/year of reductions in emissions.[46] However, it is important to note that the direct (soil) abatement can be only expected during the initial 20 or so years, with the long-term (100+ years) abatement from zero tillage approaching zero. [47]

Assuming up to 30 percent (6.8 million hectares) of total arable land in Kazakhstan could convert to zero tillage agriculture, and considering up to 2 tCO_2e/hectare/year technical abatement potential, the total abatement could be up to 13.6 $MtCO_2e$/year by 2030.

The cost of the abatement from zero-tillage has been estimated at around -6 €/tCO_2e.[48]

- **Snow trapping.** Related to the Conservation agriculture described above, snow-trapping (particularly when this is done using residual stubble as opposed to mechanical ploughing of snow) can further increase agriculture yields by increasing the water retention, which is beneficial in itself, but which also, as a secondary effect, reduces soil erosion.

- **Land conversion.** Degraded land can be converted into carbon-retaining soils by suitably modifying the landscape, for example by terracing a hillside that was previously subject to erosion. This allows soil to accumulate on previously bare land, and to retain carbon in the form of soil and plants.

- **Pasture management.** The carbon content of soils depends on the frequency of removing excess vegetative matter, typically grazing. The total amount of carbon absorbed can be increased by improving the pasture management – if over-grazed pastures are left to re-grow, while under-grazed pastures are grazed upon, the rate at which plants grow and act as a carbon "sink" can be maximised.

- **Biogas.** Conversion of agricultural waste into bio-methane can lead to additional abatement, by displacing conventional natural gas or other fossil fuels. The main limitation is the economic feasibility of using the produced bio-methane. The options include direct on-site combustion (typically for agricultural processes such as food treatment), on-site use for power generation, or injection of upgraded bio-methane into the gas grid. Power generation seems to be the most accessible of these options.

- **Fertiliser use.** Reduction in fertiliser use is a common abatement measure in many countries. However, average fertiliser use in Kazakhstan is low by international standards, and we do not estimate any abatement from reduced fertiliser use.[49]

---

45 Turi Fileccia (2009), Importance of zero-tillage with high stubble to trap snow and increase wheat yields in Northern Kazakhstan, FAO Investment Centre Division, June 2009.

46 European Conservation Agriculture Federation (ECAF) Position Paper: The importance of the conservation agriculture within the framework of the climate discussion. http://www.ecaf.org/docs/ecaf/positionpaperco2ecaf.pdf

47 ADAS and Rothamsted. Report for DEFRA: The effects of reduced tillage practices and organic material additions on the carbon content of arable soils. http://randd.defra.gov.uk/Document.aspx?Document=SP0561_6892_FRP.doc

48 FAO (2011) Economic analysis of AFOLU Low Carbon options: Use of Marginal Abatement Cost Curves to appraise climate smart agriculture policy options.

- **Livestock management.** Enteric emissions account for a majority of non-soil emissions. Improving livestock diet could reduce these emissions. Assuming that the diet of all livestock in Kazakhstan is improved in line with international best practice, up to 27 $MtCO_2e$ of emissions could be avoided in 2030. Improved manure management could reduce emissions by further 4 $MtCO_2e$. The average carbon cost at which such abatement would be commercially viable at different locations (e.g. different types of farms) is highly idiosyncratic, and also varies across different types of livestock. On average, we expect that the cost could be around 1 €/tCO_2 for dairy cattle, and over 3 €/tCO_2e for other types of livestock (including non-dairy cattle).[50]
- **Forestry – Degraded forest restoration and afforestation.** Improved forest management can increase the rate of carbon retention of existing forests. Afforestation increases the rate of carbon absorption further. However, scope for afforestation is very site-specific and we have not identified any nation-wide potential. Specific projects that have been sponsored by the government in Kazakhstan and by international bodies include:
  - Government-sponsored programmes, as part of the long-term (2000-2012) “Ensuring the preservation and development of especially protected natural territories “, focusing on forest protection and reforestation, training of new personnel for forestry management and other more targeted projects related to seed cultivation or plantations in individual cities – e.g. Astana. For example, as part of the Zhasylel (2008-2010) programme, 20.9 thousand hectares of forests were planted in 2009, representing a 30 percent increase over the planting rate in 2008.
  - We assume the cost of afforestation of around 200 €/hectare, although it is expected that economies of scale and improvement in the supply chains could reduce this cost to up to €90/hectare. If, by 2030, the forested area of Kazakhstan were increased by 1.5 percent of the country’s total area (from the current 4.5 percent to 6 percent), this would imply additional forested area of 4.1 million hectares. Based on the above cost, this would require an investment of about €0.9 billion. Over the lifetime of the planted forest, the total abatement would be around 1,400 $MtCO_2$ or 47 $MtCO_2$/year over a 30-year period, implying the abatement cost of afforestation of around €0.6 /tCO2, and even lower if the value of logged timber were included.[51]

---

49 OECD (2010) Country Capability Survey, 2010, cited by OECD, Competitiveness and Private Sector Development Kazakhstan. Sector Competitive Strategy.

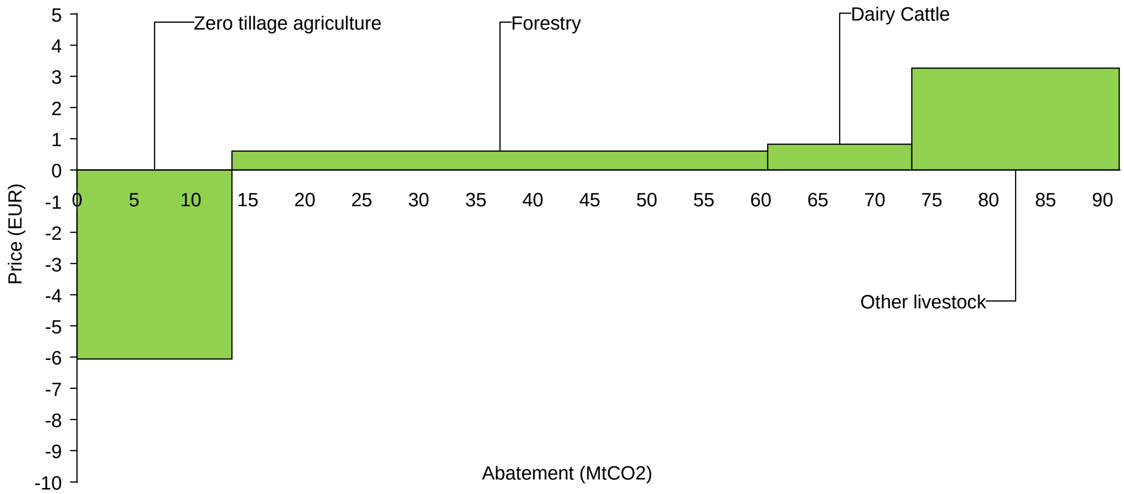
Average fertiliser use in Kazakhstan (average 2006-2007) is reported to be around 5 kg/hectare of cropland, less than half of that in Russia (13 kg/ha) or Ukraine (30kg/ha).

50 Source: BNEF database

51 World Bank and GEF (2005) Project document on a proposed loan in the amount of US$30 million and proposed grant from the Global Environment Facility Trust Fund in the amount of US$5 million to the Republic of Kazakhstan for a Forest Protection and Reforestation project. The value of logged timber varies by species. The exact abatement cost also depends on the mix of species used in afforestation, particularly on how fast they grow.

The abatement cost curve for Agriculture and Forestry is shown below.

Figure 4.12
Agriculture MACC, Status Quo, 2030



***Notes**: Dairy Cattle and Other livestock include emissions reductions from enteric fermentation (e.g. diet improvement) as well as from manure management.*

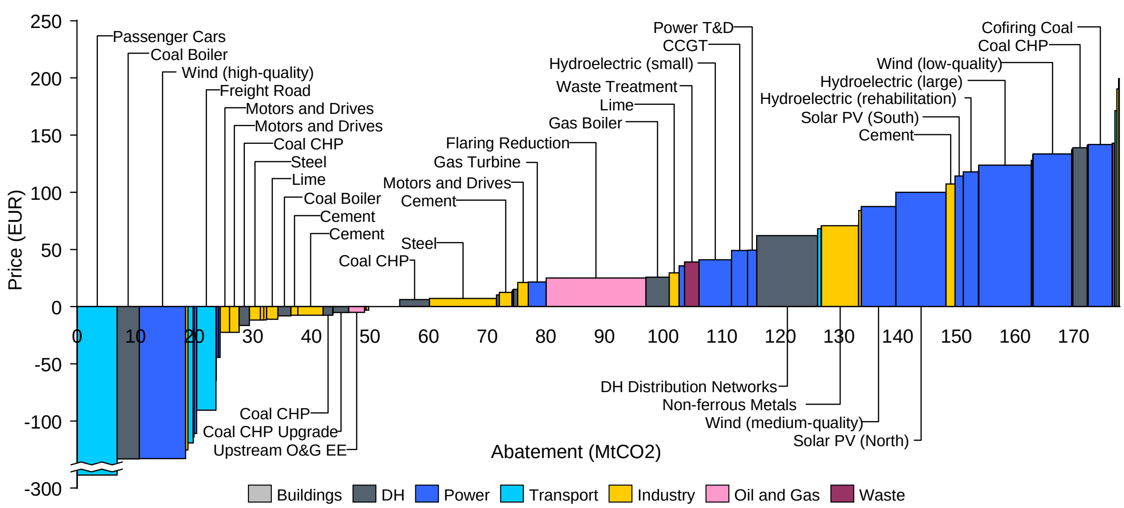
5. Planned Policies Scenario

The second scenario takes into account significant policies that are in place or announced that are likely to have an effect on emissions. Where policies currently exist but are not well enforced (as in the case of building standards) we assume that they are enforced more strictly.

5.1. Planned Policy Scenario: Overall Cost Curve

The economy-wide MACC for the Planned Policy scenario in 2030 is presented below.

Figure 5.1
Full MACC, Planned Policy, 2030



Our analysis suggests that under Planned Policies, there is potential to reduce emissions in 2030 (relative to the "frozen technology" baseline) by around 55 $MtCO_2e$ through profitable investments, even without a carbon price or additional climate policies. Taking into account all measures, including those that have a positive cost (i.e. those that are not profitable without a carbon price or further policy changes), the potential abatement more than doubles to 178 $MtCO_2$ in 2030.

The average cost of profitable abatement measures is -€79/tCO2. Across the entire MACC up to €200/tCO2 (in real terms), the average cost per tCO2 is €19.

The Table 5.1 below summarises key aggregate economic indicators associated with the Planned Policy scenario. The incremental commercially viable investment associated with the low-carbon measures amounts to €1.4bn per year in the period 2010-2030, corresponding to 2 percent of total estimated gross capital formation over the period. The opex savings are €1.7bn, or 1.4 percent of total estimated consumption. There are no carbon price revenues or capex grants expenditures associated with this scenario. The price support for renewables would be €0.7 bn per year, or 2.5 percent of estimated government expenditure to 2030.

Table 5.1
Summary Aggregate Economic Indicators - Planned Policies

	Average, 2010-2030 (€bn / year)	Share, cumulative to 2030
Additional investment	€0.5bn	0.8% of gross fixed capital formation
Opex savings	€1.7bn	1.4% of estimated consumption
Renewables support	€0.7bn	2.5% of government expenditure

Notes: The percentages show the total shares in the period 2010-2030, based on a continuation of current shares of capital formation, consumption, revenues, and expenditure in GDP. Opex savings exclude avoided carbon taxes and subsidies.

Box 5.1
Interpreting the Cost Curve Blocks

In the cost curves above there are instances where the same technology is repeated at different carbon price points. This arises because for abatement costs above zero, the cost and emissions savings are calculated relative to a *counterfactual* that is not fixed, but modelled dynamically.

For example, the 2030 Planned Policies cost curve shows Coal CHP at both €6/tCO2 and €140/tCO2. Thus $6/tCO2 is the price required to cause new coal-fired CHP to be built instead of the building of new (coal-fired) heat-only boiler. By contrast, the higher price is that required to motivate the construction of new CHP capacity to displace *existing* heat generation capacity.

More generally, technologies may appear in multiple blocks for the following general reasons (analogous issues arise for sectors other than the power sector):

- ***Technologies are split into tiers.*** Several technologies are represented in tiers with different cost characteristics and performance. For example, the modelling includes three categories of wind power sites with different cost and load factor.
- ***Different counterfactual technologies.*** A given technology (e.g., nuclear power) can displace multiple other technologies (e.g., gas- or coal-fired plant). The model analyses the relevant counterfactual by considering what *would have been built* at a price somewhat lower than the price at which nuclear becomes viable. This means that nuclear can displace (say) some coal-fired plant at one price point, but gas only at a higher price point.
- ***Capacity additions at different points in time.*** The relative cost of generation varies over time, notably because of changes in (relative) fuel prices. Thus even if nuclear power had constant cost, the carbon price required to make nuclear more attractive than gas-fired generation varies over the period. As the 2030 MACC shows cumulative additions over the entire period, this can result in blocks at different price points.

- ***Displacement of existing plant.*** Finally, in the power sector most of the MACC blocks show different options for investment in new capacity to meet growing demand (preserve reserve margins). However, at sufficiently high carbon prices, it becomes cheaper to construct new, low-emitting capacity than to produce electricity from existing, high-emitting plant, despite the additional investment that must be undertaken. Much of the very high-cost potential (in excess of $100/tCO2 is in this category).

In contrast to cost curve models that assume a single counterfactual for each technology, the model used here assesses abatement potential through the dynamic simulation of market conditions. The appearance of multiple blocks reflects real-world phenomena that affect abatement potential and cost. They illustrate that investments in low-carbon technologies must take into account not only the technology characteristics of the low-carbon technology itself, but also the overall market setting within which it is deployed. They also provide an illustration of the reasons that deployment of given low-carbon technologies increases as carbon prices increase – rather than enter all at one single trigger price point.

5.2. Cross-Cutting Scenario Assumptions

5.2.1. Fossil fuel markets and subsidies

In this scenario we include the following differences from the Status Quo scenario:

5.2.1.1. Reduction in natural gas flaring

In the Planned Policy scenario we assume currently enacted anti-flaring regulations are enforced and result in the gradual reduction of gas flaring. As a consequence, a large share of the currently flared gas gradually becomes available for other uses, notably electricity generation. The amount grows with the generally increasing output from the Oil & Gas sector.

5.2.2. Investment criteria and barriers

5.3. Power Generation Sector

5.3.1. Sector scenario assumptions

- **Nuclear power**. We assume that the currently planned nuclear power (Aktau plant) with a capacity of 300 MW is allowed to be considered as an abatement option.

- **Interconnectors**. We assume that there is no increase in the interconnector capacity between Kazakhstan and its neighbours.

- **Electricity wholesale prices** remain regulated, and power producers are allowed to charge electricity prices as currently proposed by the 2009 government decision[52]. Retail prices remain constant in real terms, reflecting lack of any policy drive to allow generators to recover their long-term investment costs.

Table 5.2
Maximum generation tariffs

	Tariffs by Year, KZT/kWh						
	2009	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**
Group 1	3.6	4.7	5.6	6.5	7.3	8.0	8.8
Group 2	5.9	6.5	6.9	7.9	8.3	8.5	8.7
Group 3	4.3	4.9	5.4	5.9	6.4	6.9	7.5
Group 4	3.5	3.8	4.1	4.6	5.1	5.5	6.0
Group 5	3.6	4.1	4.8	5.5	6.3	7.2	8.1
Group 6	6.3	7.3	7.7	7.9	8.1	8.2	8.3
Group 7	4.9	5.4	5.9	6.3	6.7	7.0	7.3
Group 8	4.5	5.0	5.4	6.0	6.6	7.2	7.5
Group 9	5.3	5.6	5.9	6.3	6.7	7.1	7.6
Group 10	5.7	6.7	7.1	7.4	7.8	8.2	8.6
Group 11	7.2	7.2	7.2	7.2	7.2	7.2	7.8
Group 12	5.3	5.8	6.4	7.0	7.7	8.4	8.8
Group 13	2.8	3.0	3.3	3.6	3.9	4.3	4.5

Source: AFT Bank research (May 2011), citing *Kazakhstan Government Decision, March 25, 2009 N 392 to The law of the Republic of Kazakhstan dated July 9 2004 "On Power."*

Note: The source document does not specify the year for which the prices are quoted.

- **Implicit support for renewables.** We assume that "soft" support for renewables is provided. This means that no additional cost incurred by renewables requiring remote transmissions grid connections or imposing system balancing costs resulting from intermittent generation.

- **Explicit support for renewables**. A feed-in-tariff is available to wind electricity generators, but since the policy is not firmly anchored yet, and no quantitative details of the levels of the FITs have been published, we have assumed that only a limited number of producers are able to receive this FIT.

- More transparent procurement procedures by the government improve the investment climate and reduce the hurdle rates required by investors to build new fossil fuel capacity, but the support for renewables production remains uncertain and risky.

- **Limited expansion of CHP.** CHP is limited to close its current share of heat and power generation, or around 15 GWth.

[52] Government Decision Kazakhstan, March 25, 2009 N 392 to The law of the Republic of Kazakhstan dated July 9 2004 "On Power."

- **Improved incentives for reduction of transmission and distribution losses.** The improved regulatory structure provides improved incentives for investments to reduce distribution losses, but end-user tariffs remain below the level necessary to make all the necessary investments in the T&D grid. The full technical potential for T&D upgrades is enabled, but is not necessarily profitable.

5.3.2. High-level power sector results

Like in the status quo scenario, coal continues to be the main fuel used for power generation during the period 2010-2030. In addition, significant amount of Wind capacity is built with the support from the FITs, representing 7 percent of the total production (147 TWh) in 2030. The sites that are attractive at the support level are high wind-speed sites, but as noted above such potential can be found in all of the three major transmission regions and could be made available with extensions of regional transmissions networks to reach promising areas. However, a strategic approach to transmissions planning will be required, going beyond the co-location of wind farms with existing substations. No other renewables are attractive enough, given any lack of explicit support programme for technologies other than wind.

Figure 5.2
Power Capacity, Planned Policies

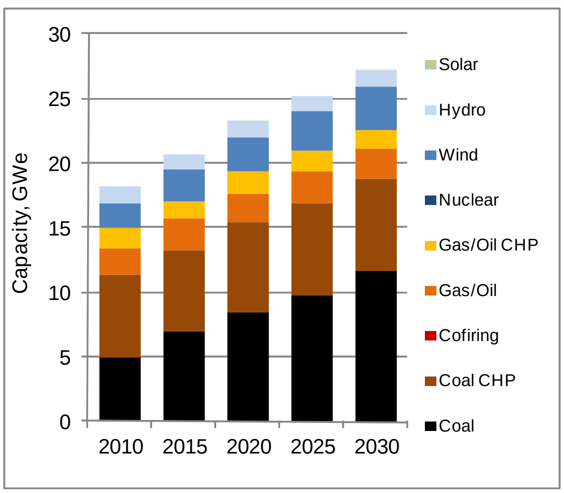


Figure 5.3
Power Generation, Planned Policies

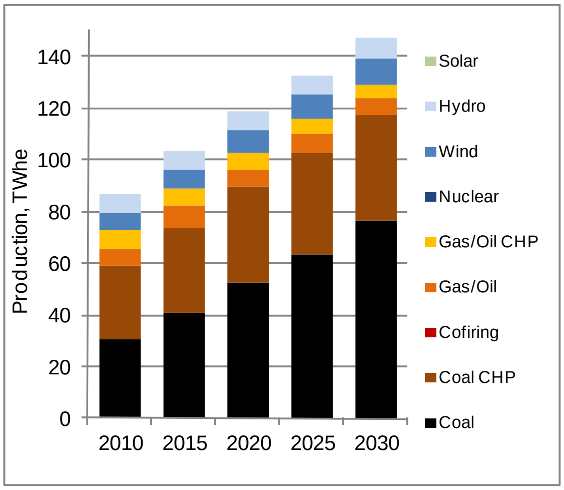
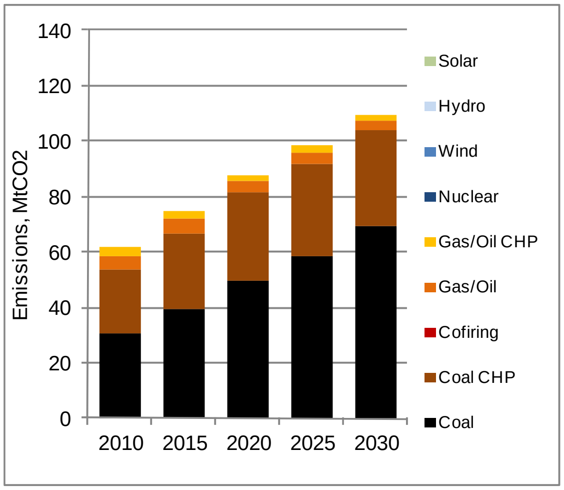


Figure 5.4
Power Emissions, Planned Policies

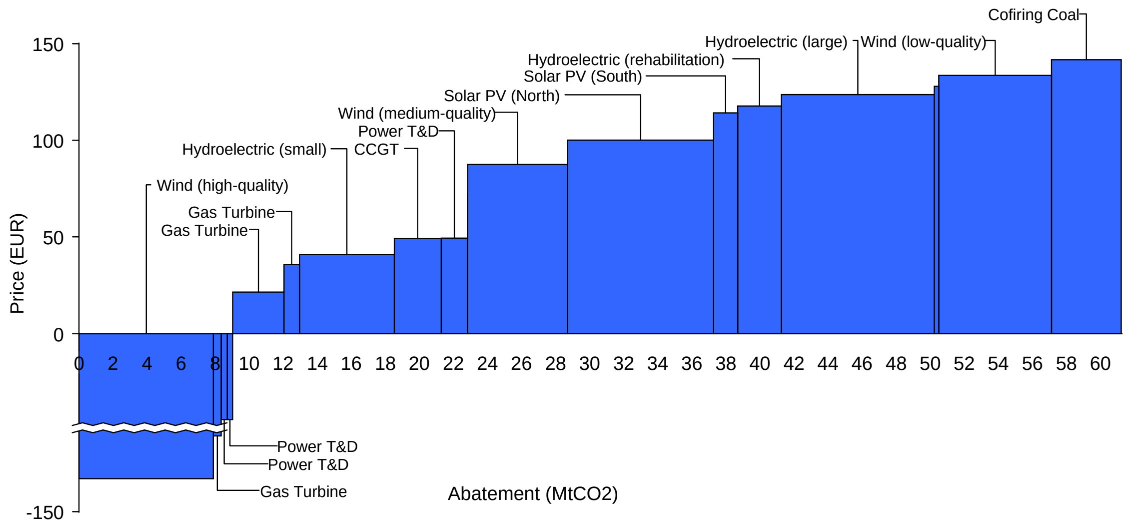


With the support for wind generation, the power sector emissions grow to 109 $MtCO_2$ in 2030, as a result of the continued reliance on coal-fired generation. Further power-generation emissions abatement cannot be realised due to persisting barriers to investment in renewables coupled with very low fossil fuel (particularly coal) prices.

5.3.3. Cost curves for the power sector

The 2030 cost curve for the Power sector is presented below..

Figure 5.5
Power MACC, Planned Policies, 2030



5.4. Heat and Buildings

5.4.1. Sector scenario assumptions

The scenario differs from the Status Quo in the effective enforcement of building standards and the implementation of information and certification schemes to reduce transaction costs.

- **Enforcement of building regulations**. Existing regulations include provisions for certification of various aspects of energy performance of buildings. These are strengthened to include certification and energy rating. These are assumed to help reduce transaction cost of energy efficiency measures, by giving building users and occupants better tools to understand the energy use characteristics of buildings, and to reduce the cost of acquiring this understanding. This serves to increase the demand for more energy efficient buildings somewhat, which in turn influences the choices of building developers. It also may help owner-occupiers to make better-informed decisions about improvements to existing buildings. Although the provisions requiring affordable housing stock may be in conflict with some efficiency requirements, we assume that efficiency standards are enforced more actively. However, we still show this with a cost on the MACC.

- **District heating regulation**. Trends towards allowing greater cost recovery continue, and heat prices are allowed to move higher. More pipes can therefore be rehabilitated, but still slowly: by 2020 up to 50 percent of the maximum technical potential upgrades and replacements may be achieved; increasing to 100 percent in 2030.

- Certification and information schemes

- Heat network operators are able to recover both their operating and long-term costs, which enables investment in more extensive network upgrade and rehabilitation. As indicated above, this enables the full rehabilitation and upgrade potential to be achieved in the heat T&D networks.
- Heat generators are also able to recover their long-run marginal costs (LRMC) and make investments in the generation equipment.
- End-users continue to pay their heating bills on the basis of their dwelling sizes, but an increasing proportion of consumers have their heat consumption metered. By 2030 over 60 percent of end users in the residential sector have their heat consumption metered and are billed according to their consumption.

End-user heat prices rise over time to reflect increasingly higher heat tariffs charged by both generators and distributing companies. See Appendix C for further details on the heat tariffs.

Figure 5.6
Heat Capacity, Planned Policies

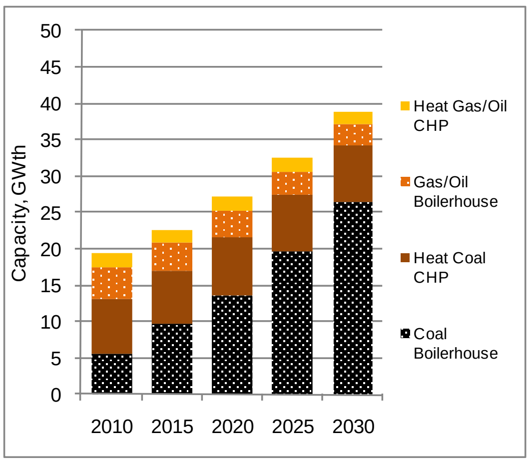
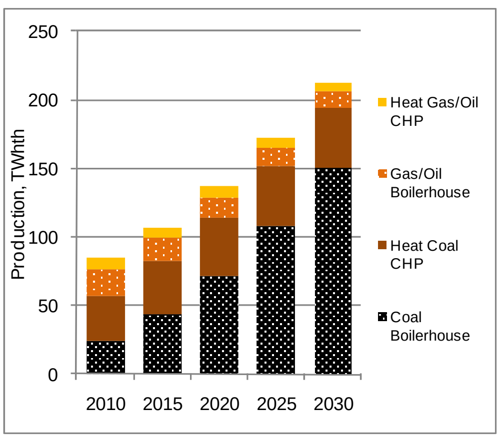


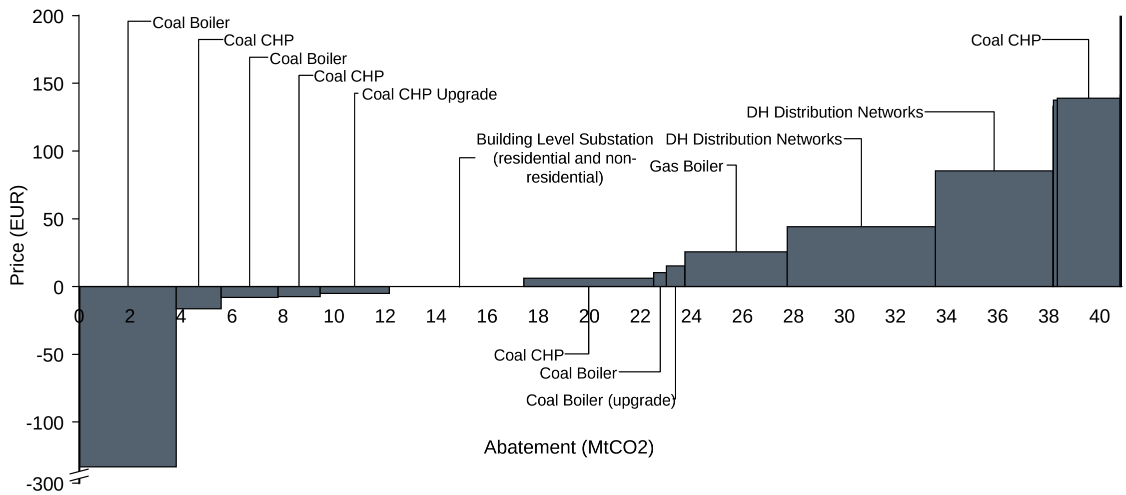
Figure 5.7
Heat Generation, Planned Policies



5.4.2. Cost curve for the heat and buildings sector

The MAC curve for the heat and buildings sector is shown below

Figure 5.8
Heat and Buildings MACC, Planned Policies, 2030



Overall, the improvements for abatement conditions in the Planned Policy scenario result in much larger abatement potential identified among profitable and unprofitable measures, coming mostly from end-users and heat distribution sectors.

In total, we have identified up to 41 MtCO2 of abatement in the heat and buildings sectors, of which 13 MtCO2 are profitable even without a carbon price.

There is also an abatement potential of 4.5 MtCO2 from the increased proportion of end-user heat consumption being metered and billed. This abatement appears on the MACC at a zero carbon price, but this does not necessarily mean that it is a profitable investment – in reality there is a cost associated with mandating heat measurement and billing. This includes the cost of the metering process itself (equipment and labour cost of collecting the data and enforcing the payments), but also the cost, which may be negative, of the inconvenience or benefit to consumers.

5.4.2.1. Heat generation

Heat generation abatement options represent almost 26 $MtCO_2$, or over 60 percent of the total heat and buildings sector abatement potential (at carbon price of up to 200 €/tCO_2) in 2030. New, more efficient, boiler and CHP capacity gradually displaces the outdated equipment, but upgrades and rehabilitations also play an important part in the emissions reduction.

There is a significant shift of heat generation towards boilers, the large majority of which continues to be fuelled by coal. As mentioned above, even though co-generation is typically considered an abatement option in itself, the uptake of CHP capacity is constrained by the developments in the power sector: additional renewable capacity means that there is less need for the power produced by CHPs, and therefore less scope to use them to provide heat. This makes boilers more attractive to serve the district heating sector.

5.4.2.2. Heat networks

The total abatement potential (at carbon price of up to 200 €/tCO_2) of the heat networks increases significantly under the Planned Policies scenario, as regulated heating companies are allowed to increase their charges in order to be able to recover their LRMC. This in turn enables them to make further investments in the upgrading and rehabilitation of the heating network.

In total, there is the potential for 10 MtCO_2 abatement from upgrading the DH network, although none of it is financially viable without further policy support. The less expensive options, or about half of the total potential would be viable at a carbon cost of 44 €/tCO_2.

5.4.2.3. Building energy efficiency

Before the full abatement potential in the end-user sector can be realised, heat use must be measured and customers must face the full cost of their marginal consumption. As noted above, we have not identified the social cost associated with mandating the metering and billing. Under the planned policy scenario, however, around 60 percent of both the residential and commercial consumers are billed according to their heat consumption by 2030, leading to abatement of 4.5 MtCO_2.

We have identified further abatement options for these consumers, who now face a direct financial incentive to reduce their heat consumption by for example installing heat controls and insulation. However, given the low cost of heat generation, the heat price itself remains insufficient to motivate further reduction in heat consumption in the end-user segments at a carbon price of less than 200 €/tCO_2.

5.5. Other Major Emitting Sectors (Industry, Transport, Waste and Oil and Gas)

The Planned Policies reflected in the modelling do not involve significant changes to those modelled for the Status Quo for other major sectors. As a consequence, the emissions and abatement potential from these sectors do not change materially relative to the results reported in sections 4.5 and 4.6.

The one exception to this is the Oil and Gas sector, where additional abatement becomes feasible in the Planned Policy scenario.

The value of associated gas (AG) depends on its alternative use. Under effectively enforced regulation, and in the absence of required export infrastructure (gas processing plant and pipeline interconnection), AG may in fact have a "negative" cost, as non-use of the gas would result in penalties. A more realistic valuation under such circumstances is that the value is limited to the incremental benefit of additional re-injection. In either case, the cost of the gas is very low.

Over time, however, it seems likely that the elimination of increased flaring, as well as the more general increase in natural gas production, would lead to the development of export infrastructure. In this situation, the value of the gas depends on the price that can be fetched in export markets.

In sum, we therefore assume in this projection that the cost of AG starts at very low levels, but gradually converges to the international price of natural gas, adjusted for the cost of transport. Similarly, the full volume of currently flared AG initially is made available for domestic use, but over time also can be exported rather than used locally.

Overall, we estimate that the abatement potential (both profitable and unprofitable) in the Planned Policy scenario is about twice as high as in the Status Quo.

6. Enhanced Policy Scenarios

6.1. Enhanced Policy Scenarios: Overall Cost Curve

Summary MACCs for the overall economy under the Enhanced Policy scenario are shown below – the first figure shows the results for the Enhanced Policy scenario with carbon prices; the second figure shows the results with Capital Grants.

Figure 6.1
Full MACC, Enhanced Policy, 2030

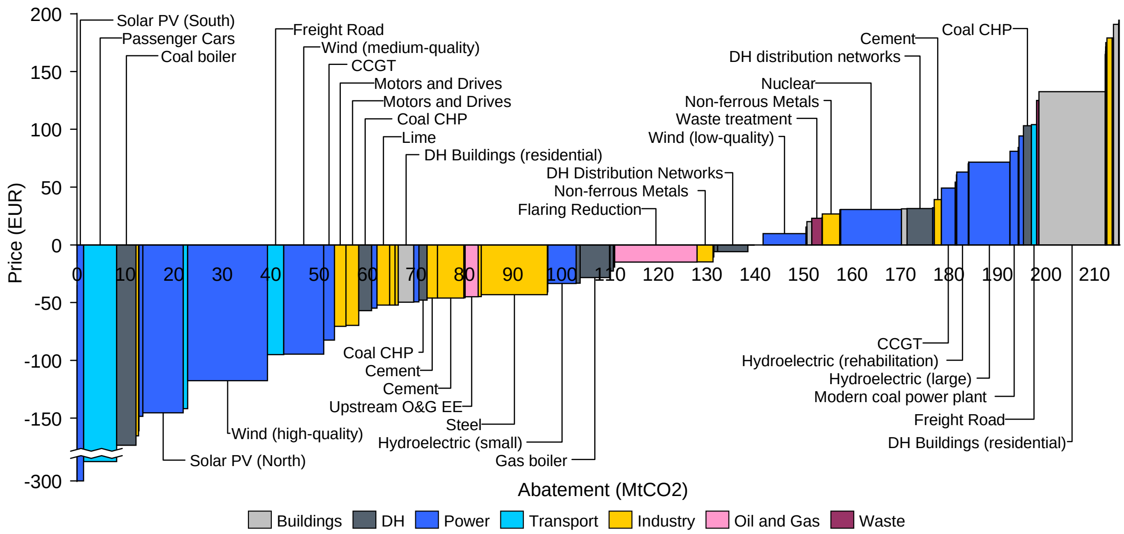
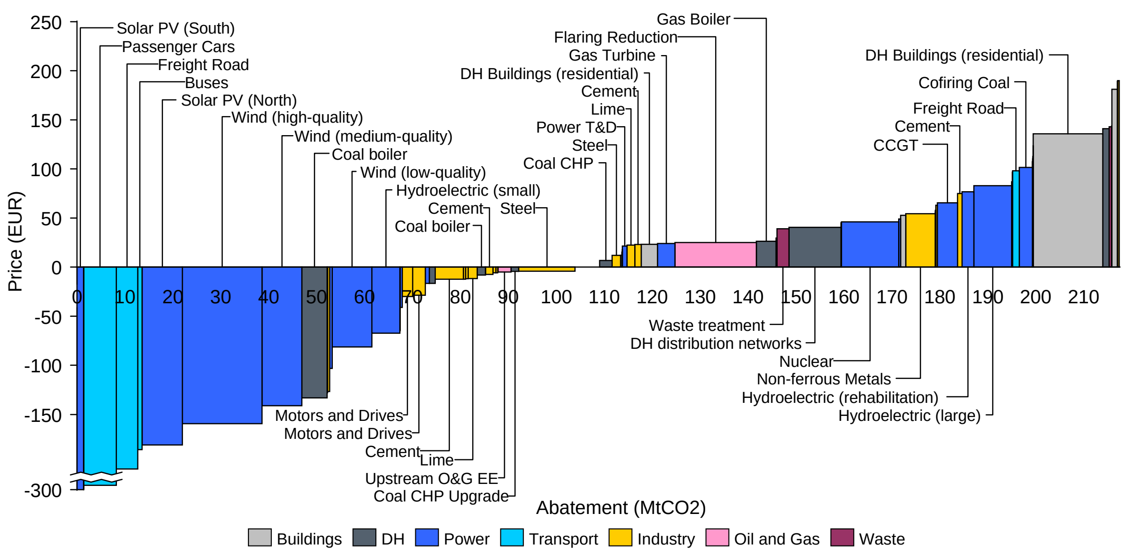


Figure 6.2
Full MACC, Enhanced Policy Capital Grants Scenario, 2030



Our analysis suggests that under Enhanced Policies, there is potential to reduce emissions in 2030 (relative to the "frozen technology" baseline) by around 140 MtCO2e through profitable investments, even without a carbon price or additional climate policies. Taking into account all measures, including those that have a positive cost, the potential abatement rises to 214 MtCO2 in 2030.

The average cost of profitable abatement measures is -€74/tCO2. Across the entire MACC up to €200/tCO2 (in real terms), the average cost per tCO2 is -€26.

Table 6.1 below summarises key aggregate economic indicators associated with the Enhanced Policy scenario. In the Enhanced Policies scenario, the incremental commercially viable investment associated with the low-carbon measures amounts to €1.1bn per year in the period 2010-2030, corresponding to almost 5 percent of total estimated gross capital formation over the period. The opex savings are €3.8bn, or over 3 percent of total estimated consumption.

The carbon revenues (defined as the volume of eligible emissions reductions evaluated at the price of carbon allowances or credits) corresponds to 5 percent of total estimated government revenues (this is for comparison only; the revenues may accrue to other parties, including firms, depending on the policy implemented). The capital grants programme would require €1 bn per year, on average, or an average of 4 percent of estimated government expenditure over the period to 2030. Finally, the price support for renewables would be €1.2 bn per year, again close to 4-5 percent of estimated government expenditure.

Table 6.1
Summary Aggregate Economic Indicators - Enhanced Policies

	Average, 2010-2030 (€bn / year)	Share, cumulative to 2030
Additional investment	€1.1bn	1.7% of gross fixed capital formation
Opex savings	€3.8bn	3.1% of estimated consumption
Carbon revenues	€1.3bn	5% of government revenue
Capital Grants	€1bn	4% of government expenditure
Renewables support	€1.2bn	4.5% of government expenditure

Notes: The percentages show the total shares in the period 2010-2030, based on a continuation of current shares of capital formation, consumption, revenues, and expenditure in GDP. Opex savings exclude avoided carbon taxes and subsidies.

6.2. Cross-Cutting Scenario Assumptions

In the low carbon policy scenario, we consider a number of extensions to the currently planned policies to make viable a range of additional abatement measures.

6.2.1. Energy Market Structure and Subsidies

- Continued low coal prices, and relatively low gas prices.

6.2.2. Carbon prices

In this scenario we assume several sectors to be exposed to a carbon price. This takes the form of including Kazakhstan in a scheme similar to the EU Emissions Trading Scheme (EU ETS), covering large emitters as planned in the current draft legislation for Kazakhstan ETS. The sectors covered in the Kazakhstan ETS would be similar to the EU ETS, including most of heavy industry and the power and heat generation sectors. These are assumed to be exposed to a carbon price of €40 /tCO2.

For sectors not included in the EU ETS-type carbon trading scheme we model the potential for credit-based emissions trading. These include the waste and coal mining sectors, gas pipelines, and agriculture, which are assumed to be exposed to a carbon price of €20 / tCO2, reflecting our assumption about primary emissions reduction credit prices under current arrangements under Joint Implementation (for which legislation is currently being drafted) and the Clean Development Mechanism.

Carbon prices have the advantage that they promote all types of abatement measure – including energy efficiency, fuel substitution, raw material substitution, as well as reduction in non-CO2 emissions and carbon capture and storage, provided these are counted towards obligations or credit opportunities under the relevant emissions trading regime – and moreover , they apply the same (marginal) incentive for each option. They therefore have the potential to achieve a given amount of emissions abatement at least cost. Another advantage is that they are scaleable, so that a large number of industries and sectors can be incorporated.

A disadvantage of carbon prices is the potential for adverse impacts on competitiveness in a situation where major competitors do not adopt similar measures.

6.2.3. Capital grants

As noted, we also model the implementation of a capital grants schemes, reducing the capex of technologies that reduce emissions if adopted.

The policy is modelled across the board in all sectors, with grants corresponding to 20 percent of the incremental capex of technologies that reduce emissions. This has an impact particularly on energy efficiency measures, but does not capture ongoing process changes or other measures where capex is a less significant aspect of abatement cost.

The scenario modelled here helps illustrate the principle of capital subsidies, but does not reflect the practical implementation difficulties that such programmes often face. Although there are many international examples of capital grants (often implemented through tax allowances or exemptions), none is nearly as comprehensive or far-reaching as the intervention modelled here. This reflects the fact that large-scale grants programmes often face significant implementation difficulties, including determining the qualifying technologies and the level of grant for different technologies; committing sufficient funding for the very substantial subsidy sums involved; and ensuring that subsidised equipment is efficiently used (notably in the power sector).

6.3. Power Generation Sector

6.3.1. Sector scenario assumptions

The discussion in section 2.1.3 noted two main reasons for the difficulties in achieving significant emissions abatement in Kazakhstan

- The uncertain investment climate that has prevailed in the Kazakhstan power sector; and
- The intrinsic higher costs of renewables, especially in the context of abundant cheap fossil fuels.

The enhanced policy scenario aims to introduce policies that focus on enabling sufficient investment to be made in new capacity, particularly renewable power capacity:

- Energy security targets for fossil fuels
- Off-take guarantees and facilitated planning permissions for renewables generation.
- Feed-in tariffs for renewable electricity

The FITs are extended to a broader range of renewable technologies in the Enhanced Policy scenario. The levels of FITs assumed for the modelling are shown below in Table 6.2.

Table 6.2
FIT Levels

FIT levels, 2010	EUR/MWh
Small hydro	62
Wind	118
Solar	256
Biomass	57

Note: The feed-in tariffs are fixed (not premia).

- Carbon pricing. Similarly to the industry sector, the Power sector is assumed to be exposed to a carbon price of €40 /tCO2.
- Capital Grants. In the carbon pricing version of this scenario, the renewable technologies receive a capital grant of 20 percent.

The above policies combine to reduce the effective hurdle rates faced by investors in making their decisions regarding investments in new power capacity. We assume that the discount rate faced by investors in fossil fuel generation is 12 percent, and in renewable generation is gradually reduced to 15 percent by 2015.

- **Maintain share of CHP.** CHP is limited to no more than its current share of heat and power generation, or around 10 GWth. This reflects the priority (in terms of planning) given to renewable power-only installations, relative to CHP expansion, which enables the maximum uptake of renewables in the power sector.

- **Improved incentives for reduction of transmission and distribution losses.** The improved regulatory structure together with end-user tariffs reflecting the full cost of generation and the long-run marginal cost of transmission and distribution infrastructure provides incentives for investments to reduce distribution losses.

6.3.2. High level power sector results

In the Enhanced Policies scenario, several policies are combined to deliver a significant shift of the current generation away from fossil fuels. Wind and hydro generation is increased as a result of feed-in-tariffs and, in the carbon price variant of this scenario, as a result of the carbon prices which make renewables more attractive relative to the fossil fuels. “Soft” policy support – notably, the availability of connections of favourable sites to the wider transmissions grid – as well as adequate assurances for investors ensure that the rate of return required by the investors is not as prohibitively high is in the status quo scenario.

By 2030, as much as one third of the power generation comes from renewable sources. New nuclear capacity could provide additional abatement. Small hydroelectric power is exploited to the maximum technical potential of 2.4 GW, but further large hydroelectric projects would be feasible if provided a similar level of support (in the Enhanced Policy scenarios only small hydro generation is offered the FIT support).

However, the main contributor to decarbonisation is wind generation, which serves 20 percent of the electricity demand in the scenario. At this level of penetration, two key implications for the wider electricity system need to be borne in mind. First, there is a need for backup capacity to manage system balancing, and penetration beyond this point the intermittency of wind generation could start posing difficulties. Balancing can be helped by interconnection, and by developing sites across the country to reduce exposure to low-wind conditions in individual regions or areas. Second, except in the North much of the high wind-speed sites are not necessarily co-located with the existing transmission and distribution infrastructure. Developing sites across the country would require extensions to regional network capacity to encompass high wind-speed areas; whereas concentration of wind farms in the north would instead require additional inter-regional transmissions capacity (notably, North-South).

Which approach is favoured by investors will depend both on the system of granting connections to individual wind farms, and on the nature of transmissions charges. The current system of uniform charges would be more likely to favour concentration on wind resources in the North, whereas a system of zonal differentiation of charges could give more weight to (potentially somewhat lower wind-speed) areas closer to sources of net demand, particularly in the South. Although the approach taken can make a big difference to the aggregate cost to investors of wind power development, and to the regional balance of generation and demand, the scenario assumes that the cost of grid connection for wind farms would be borne by the system as a whole – broadly following international practice. Nonetheless, strategic planning (rather than just incremental additions to the existing grid) will be necessary to reach the levels of wind penetration allowed here, even if for individual investors this is likely secondary to other key factors—notably, the easy availability of grid connection, the credibility of continued price support and carbon prices, and the level of FIT subsidy.

Figure 6.3
Power Capacity, Enhanced Policies

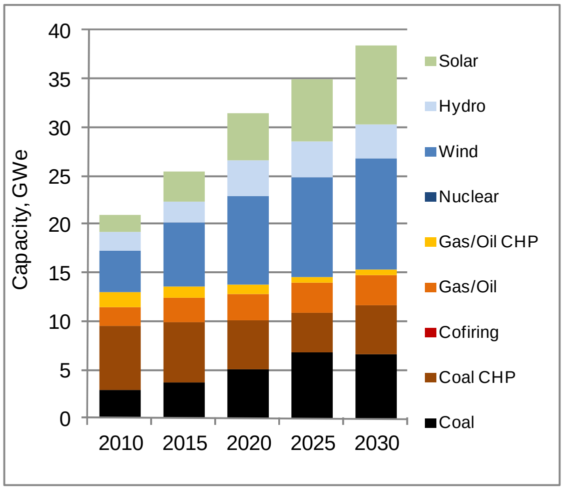


Figure 6.4
Power Generation, Enhanced Policies

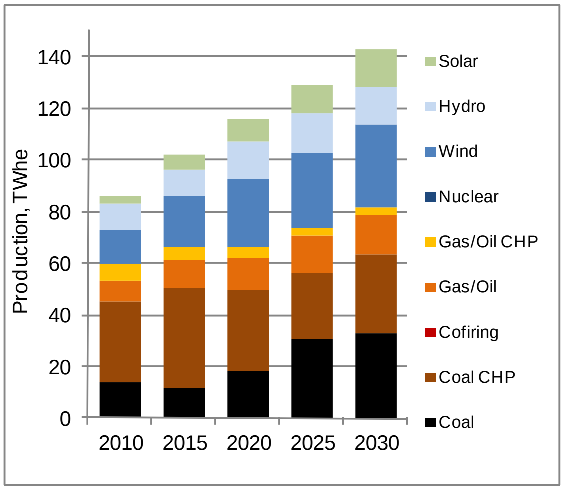
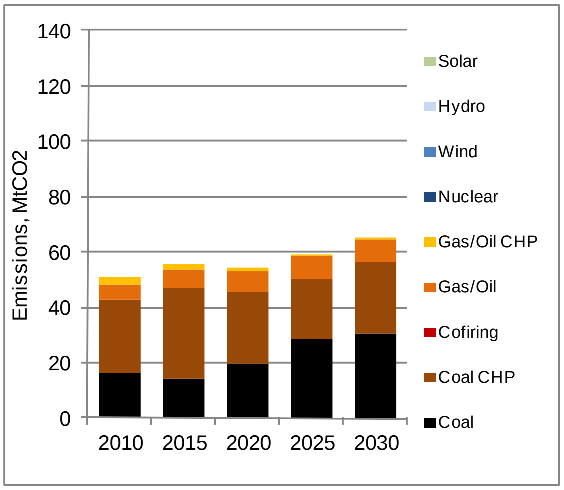


Figure 6.5
Power Emissions, Enhanced Policies



The total emissions in the Enhanced Policy scenarios increase from just over 50 $MtCO_2$ to over 60 $MtCO_2$ in 2030, representing a significant reduction in the average electricity grid emissions intensity.

As an alternative (or a complement) to imposing a carbon price on the Power sector, the modelling of the Enhanced Policies with capital grants scenario indicates that a similar generation mix can be achieved through providing substantial grants to renewable technologies.

6.3.2.1. Power sector results – Capital Grants

As an alternative (or a complement) to imposing a carbon price on the Power sector, the Capital Grants scenario indicates that a similar generation mix can be achieved through providing grants to renewable technologies.

As in the Enhanced Policies scenario, capital grants motivate a transition away from fossil fuels towards renewables.

6.3.3. Cost curves for the power sector

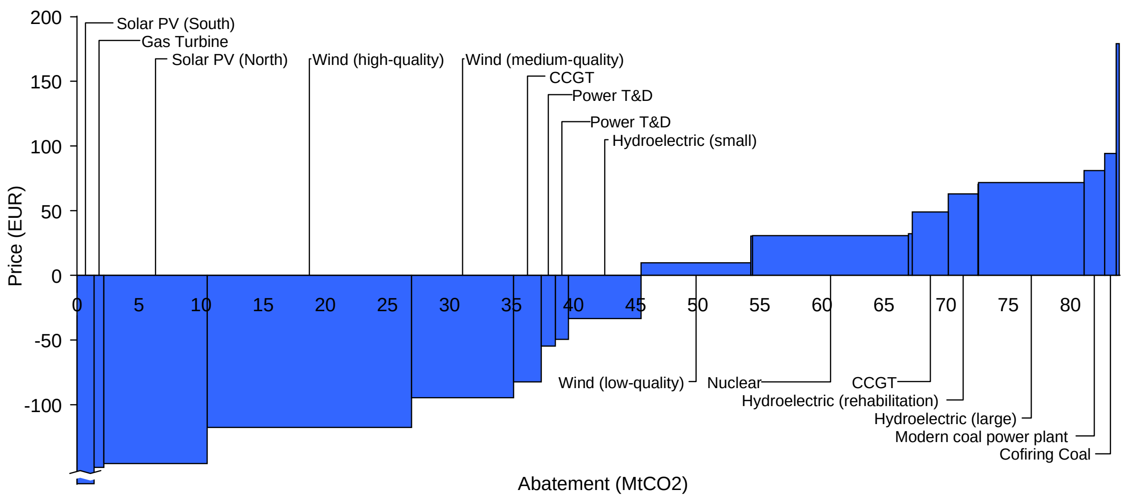
Because much of the available hydropower, solar and wind power developments are rendered financially attractive, the cost-effective portion of the MACC is significantly larger in the Enhanced Policy scenario than in either Status Quo or Planned Policy scenarios.

By 2030, a combination renewables (primarily wind and small hydro, but also Solar PV), and high-efficiency gas-fired power plants reduce emissions by 45 $MtCO_2$ compared to what the same generation would emit if produced with the current average emissions intensity.

Cost-effective investments in upgraded grid infrastructure reduce distribution losses and cut emissions by 2.3 $MtCO_2$ by 2030.

Significant abatement potential remains unprofitable even under the ambitious policies of the Enhanced Policy scenario. Particularly important is the additional potential of large hydroelectric power (together with rehabilitation of the existing capacity), as well as the somewhat speculative shift to nuclear power. More wind would also be feasible (in locations that are least easily accessible and are least favourable in terms of wind speeds) at a relatively low carbon price, but as noted this would potentially require further upgrades to the power networks to ensure sufficient grid stability. These additional options would allow additional 39 $MtCO_2$ of abatement to come forward, which are otherwise unprofitable in the Enhanced Policies scenario.

Figure 6.6
Power Sector MACC, Enhanced Policy Scenario, 2030



6.4. Heat and Buildings

6.4.1. Sector scenario assumptions

The policies are by necessity sketched on a high-level, but indicate the type of intervention (and impact on relative cost and investment attractiveness) that would be required.

6.4.1.1. District and communal heating buildings

As noted in previous sections, achieving widespread energy efficiency retrofit in communal buildings can be highly challenging. Measures have high initial cost and barriers are significant. The enhanced policy package we consider has the following key elements:

- **Consumption-based billing.** A rapid switch to metering and consumption-based billing, complete by 2015. This is an ambitious goal, going beyond the situation in many other countries with significant district heating have achieved.

- **Associations of apartment owners**. The establishment of strong associations of apartment owners. These play a pivotal role as forums to overcome the coordination problem of joint decision-making in multi-occupancy buildings. To be effective vehicles for investment decisions, they need to have budgetary responsibilities.

- **Heat prices.** Increase of heat tariffs, both as a result of carbon prices (this does not arise for the capital grants scenario) and increased heat distribution charges to fund the extensive heat generation and network investment requirements. Details of retail heat tariffs are in Appendix C.

- **Subsidised loans.** Establishment of a programme of subsidised loans to make credit available at favourable rates. To be effective, these are likely to require investment at only minimal up-front cost. Experience from other countries is that such loan programmes are likely to need government mediation.

- **"No net cost" guarantee.** To maximise impact, loans can be combined with a scheme to guarantee that loan repayments can be defrayed by reductions in energy bills. This would minimise the net impact on cash flow. It also would reduce the risk to lenders significantly. This too would require Government intermediation, with Government taking on the risk that savings will be insufficient in individual cases to defray the cost of financing. Such guarantees would require standardised retrofit packages for which savings can be easily estimated and which meet minimum standards, and also a certification scheme for installers to guarantee high performance. This standardisation in turn could help ensure replicability and returns to scale, and therefore reduce transaction costs significantly (as investors effectively choose from a menu of options).

The measures would apply both to commercial and to residential buildings.

These measures together could significantly reduce the barriers to energy efficiency in buildings heated through communal and district heating. We assume a reduction of transaction cost to 30 percent of capex, reflecting a large volume of standardised retrofit packages. We also assume much lower discount rates of 14 percent, reflecting the widespread availability of attractive financial products that eliminate the need for up-front commitments, while offering lenders low-risk investment propositions.

In the capital grants version of the enhanced policy scenario, a grant of 20 percent is offered to households or apartment owner associations for investment in energy efficiency measures such as (additional) insulation, double-glazing, or heat controls.

6.4.1.2. Individual buildings

For individually heated buildings the barriers are lower than for district heating or communal heating. Key elements of an enhanced policy package include:

- **Subsidised loans.** A subsidised loan programme on the lines indicated for buildings heated by communal / DH. The aim of this would be to minimise the impact on household cashflow, so that there is no or little up-front cost, while the cost of loan repayment is offset by lower energy bills.

- **"No net cost" guarantee and property-linked loans.** A change of legal provisions to link repayment of the loan to the occupant of the property. This would be intended to overcome the barrier posed by limited tenure, i.e., that households or other occupants are unwilling to invest in energy efficiency because of the prospect that they will not themselves benefit from lower future energy bills after they have moved, while also being unable to recoup the value of the initial investment in the sale price.

We use similar assumptions about investment criteria as for buildings heated by communal or district heating.

6.4.1.3. New buildings

The main policy option for new buildings is the enactment and effective enforcement of building regulations. As noted in preceding sections, Kazakhstan has in place regulations, and as part of an enhanced policy package they could be strengthened. In modelling terms, we include the possibility of increasing the thermal performance, but illustrate the cost on the MACC.

6.4.1.4. Network and buildings

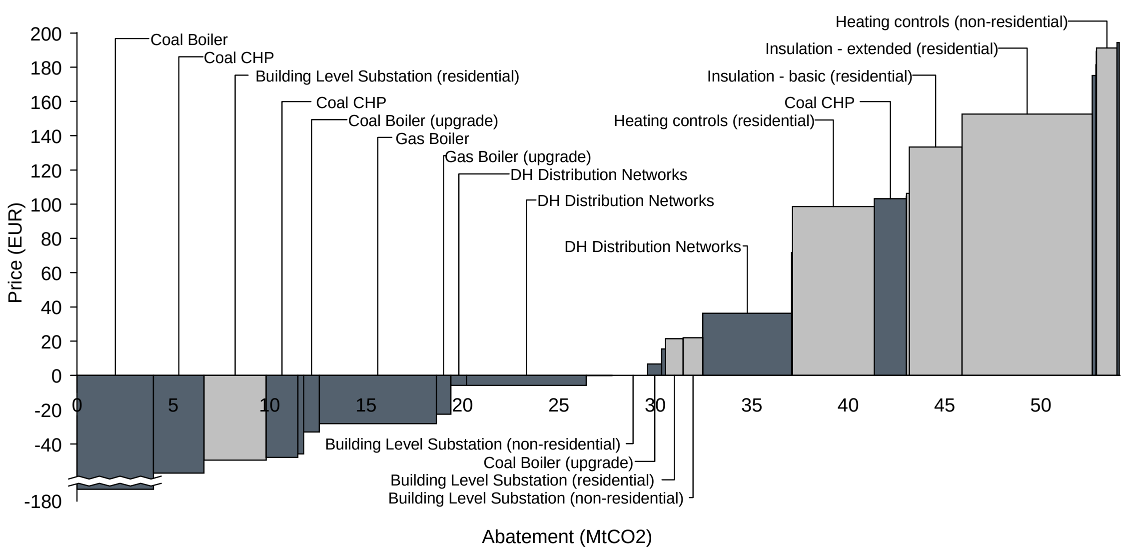
- Pace of rehabilitation: Distributor companies recoup their LRMC early on, enabling them to make extensive investments in the heating network upgrades at a much faster pace than observed in recent years. This includes replacement of existing pipes with pre-insulated pipes, additional insulation from burying the long-distance pipes underground, and preventative maintenance.

- Rapid deployment of Building-level substations at the user-end of the heat networks, enabling heat measurement, control and billing at the level of a building. This motivates distributor companies to reduce their losses further as they are no longer able to recoup the costs of the network losses through higher average heat prices.

6.4.2. Cost curves for the heat and buildings sector

The abatement cost curve for the Heat and Buildings sector is shown below.

Figure 6.7
Heat and Buildings MACC, Enhanced Policy, 2030



6.5. Industry

6.5.1. Sector scenario assumptions

As noted in the discussion in section 4.4.3.2, much of the technical GHG emissions abatement potential in industry arises through the scope to save on fuel use through more energy efficient technologies – supplemented by opportunities for fuel switching, raw material substitution and waste utilisation, the incineration or reduction of non-CO_2 GHGs, and potentially through the capture and sequestration of CO_2.

Kazakh industry in general faces fuel prices much lower than those in international energy commodity markets, which fail to provide incentives for the adoption of more efficient technologies. Higher fossil fuel prices are therefore a key driver to emissions abatement.

Additional policy interventions are available. Key options Include:

- Energy efficiency benchmarking and covenants;
- Carbon prices and related taxes;
- Capex subsidies

6.5.1.1. Energy efficiency

Several countries have promoted energy efficiency in industry through programmes to establish energy benchmarks, company reporting of performance against these benchmarks, and negotiated targets to achieve energy efficiency improvements according to a specified timetable. These often have been complemented with services to offer subsidised or free energy audits and other support.[53]

The intention of these programmes is to help disseminate information about best practice and to focus management attention on energy efficiency. This can reduce transaction costs and accelerate uptake of measures that appear financially attractive. In some cases, these have been combined with exemptions from taxes or carbon pricing linked to achievement of standards (e.g., UK Climate Change Agreements).

6.5.1.2. Energy efficiency benchmarking and other enabling policies,

As a result of energy efficiency policies, including benchmarking, the hurdle rates perceived by investors are significantly reduced – we assume that in this scenario the discount rates are reduced to 12 percent.

6.5.1.3. Carbon pricing

As discussed above, we also model a scenario with industry exposed to a carbon price. This takes the form of including Kazakh industry in a system similar to the EU Emissions Trading Scheme (EU ETS), covering most of heavy industry. These are assumed to be exposed to a carbon price of €40 / tCO_2.

[53] Prominent examples include the UK Climate Change Agreements and Dutch industrial benchmarking programme.

6.5.1.4. Capital grants

We also model a capital grants programme on the lines outlined in section 6.2.3.

6.5.1.5. Other enabling policies

In addition to intervention directly in industry sectors, we model policies to help overcome the obstacles to using waste materials for various abatement measures. With sufficient support for the use of clinker substitutes as well as waste fuels, significant additional abatement potential can be unlocked (and may become profitable), especially in the cement sector.

6.5.2. Cost curves for industry

Industry is a key driver of emissions in Kazakhstan. In 2008, direct emissions from Industry (fuel combustion and process emissions) accounted for over 41 MtCO2e, or 17 percent of total emissions. In addition to this, Industry is a significant consumer of heat and electricity, accounting for around two thirds of secondary energy demand, thus indirectly contributing to an even larger share of the total Kazakhstan emissions. In addition, Kazakhstan Industry is relatively inefficient by the international standard (see A.3.3), and therefore offers significant scope for abatement.

The Enhanced Policy MACC for Industry is shown below. The cost-effective abatement potential in 2030 increases significantly, from 15 $MtCO_2$ in the Status Quo scenario, to 35 $MtCO_2$ in the Enhanced Policy case. Most of the abatement continues to come from Metals (Steel and Non-ferrous metals) and Minerals (Cement and Lime) sectors. The profitable and unprofitable abatement potential in the key sectors is described in more detail below.

Steel. In Steel, we have identified a total abatement potential of over 14 $MtCO_2$, all of which is cost-effective in this scenario. Most of the profitable abatement is concentrated in various energy efficiency improvements of the existing BOF capacity, but additional new capacity also contributes. As discussed in section 4.5.4, the abatement costs of Steel, without a carbon price, would have been close to zero; suggesting that a smaller financial incentive (for example a carbon price lower than 40 €/tCO2e) for the sector might be sufficient to deliver much of the identified emissions reductions. Other, non-financial, barriers could, however, still prevent the full technical potential from being realised.

Non-ferrous metals. In non-ferrous metals we identify profitable abatement of around 8 MtCO2e, of which 4 MtCO2e are profitable in the Enhanced Policy scenario. Most of the profitable abatement is concentrated in investments in new capacity with modern equipment (particularly furnaces), but retrofitting various process improvement measures such as improved monitoring and heat targeting are also among the identified abatement opportunities.

Cement. In Cement, we have identified over 10 $MtCO_2$ of abatement potential, of which 7.6 $MtCO_2$ are cost-effective. With the continuing low fossil fuel prices (particularly that of "stranded" coal) in the Enhanced Policy scenario, abatement measures in Cement start off as being relatively unattractive investment opportunities, but this can be partly mitigated by the carbon price and other enabling policies for the sector – such as incentives for clinker substitution or policies that encourage waste firing. On the back of a planned expansion of the

Kazakhstan cement industry (through the State programme on accelerated industrial and innovative development 2010-2014), there is significant scope to reduce emissions through investment in modern capacity – indeed the majority (over 5 MtCO2e) of the profitable investment identified is investment in new ‘dry’ Cement capacity (compared to the current vast majority of more energy-intensive ‘wet’ capacity). Retrofitting the existing ‘wet’ cement capacity with energy efficiency measures such as improved kiln combustion, external shell cladding, or preventative maintenance, together with higher share of clinker substitution also offers scope for profitable investment in emissions reduction in the presence of the carbon price.

Lime. In Lime, we have identified 3.6 MtCO2 of abatement potential, virtually all of which is profitable in this scenario. Process emissions from limestone calcination are irreducible, so the abatement potential identified here focuses on reduction of coal combustion emissions reductions. Most of the abatement (around 2.6 MtCO2, or almost three-quarters) is concentrated in retrofitting energy efficiency measures such as improved kiln combustion, shell heat loss reduction, process improvements, including preventative maintenance. Investment in new, modern, capacity accounts for the remainder of the profitable investment identified below.

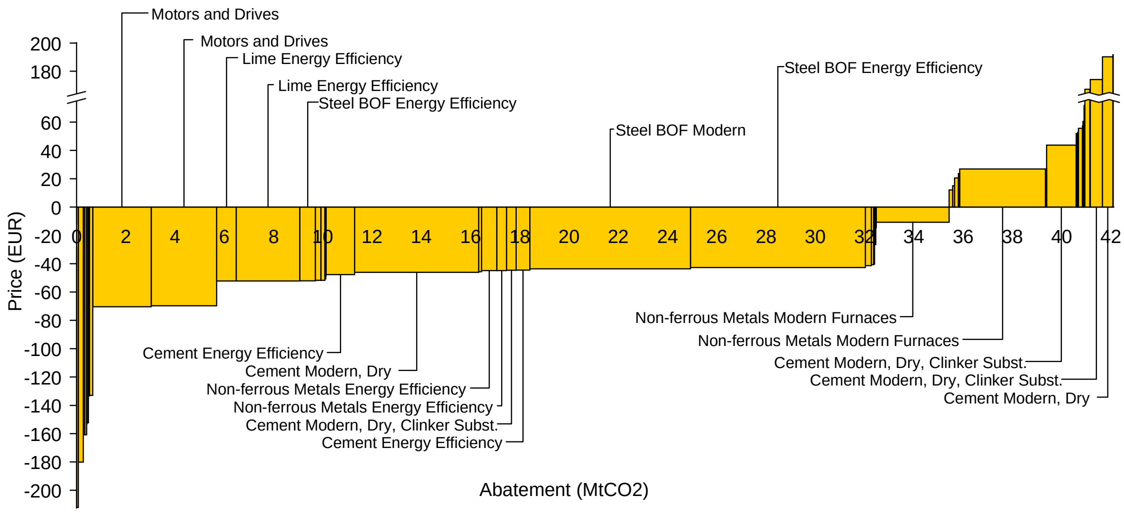
Electricity usage. The full potential of the efficiency in electricity usage has been identified as just over 5 MtCO_2, virtually all of which is a profitable option, given the relatively high electricity prices in the Enhanced Policy scenario. In this scenario we estimate that the cross-industry electricity consumption (from various motors, variable speed drives, pumps and compressors) could be reduced by as much as 12 percent. This reflects the fact that much of the existing equipment is outdated and in need of replacement, or is incorrectly sized. Investment in efficient electric devices is typically driven by a strong opex cost signal – in this case, electricity price. In the Enhanced Policies scenario, Industry faces a relatively high electricity price reflecting the fact that the sector indirectly faces the carbon price of the Power sector as well as higher cost related to improved cost-recovery of power generators and T&D companies.

Fuel switching. An alternative (or complementary) abatement option in the Industry sector would be a fuel switch from coal to gas. This would be feasible to a certain degree in many of the sectors (although less so in for example in Cement). However, given the relative costs of coal and gas, we have not identified any profitable investment opportunities from this option.

CCS. We have not included CCS in this scenario. However, our calculations do not suggest that CCS could become an attractive option except with significant additional support.

The MACC for the Enhanced Policy Scenario, with carbon prices, and the Industry sector is shown below.

Figure 6.8
Industry MACC, Enhanced Policy Scenario, 2030



6.6. Other Major Emitting Sectors

6.6.1. Waste

There are opportunities to reduce emissions by use of various streams of waste materials. These include energy from municipal waste incineration, capture of methane from landfill sites, biomethane production from biological wastes through anaerobic digestion or other treatments, and the combustion of other specific waste streams such as tyres and solvents. There also are opportunities to use specific waste streams such as power station fly ash and blast furnace slag for clinker substitution in cement production.

These abatement options are unlikely to become available without regulatory support that makes it more difficult to dispose of waste at traditional open dumps or landfills – thus raising the cost of disposal and reducing the cost of waste materials (or waste fuels) for other uses.

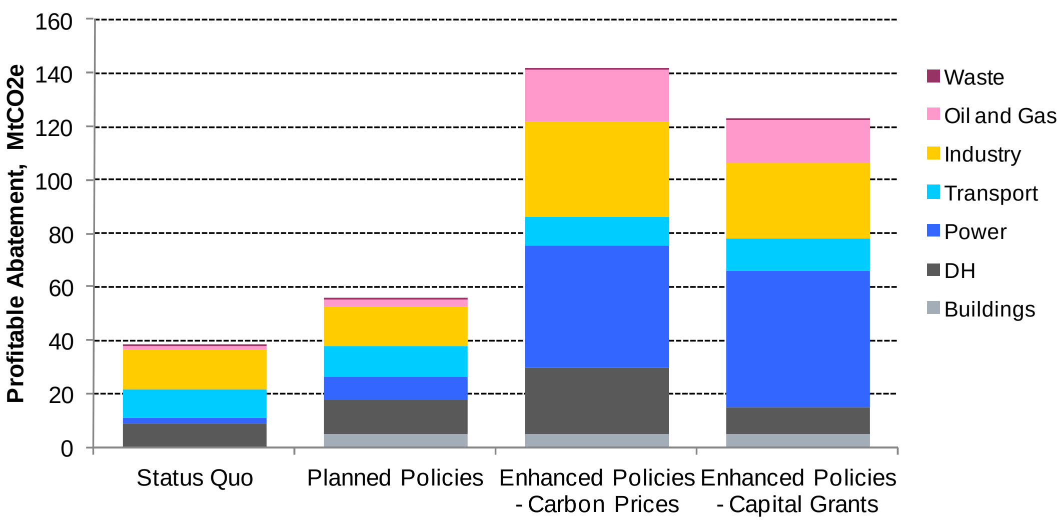
In this scenario we assume that the required regulatory and other measures are put in place, enabling the uptake of waste-related abatement. The affected sectors include power generation, the waste sector itself, and selected industrial sectors (notably, cement production). In these sectors, the combination of increased cost of traditional waste-disposal methods and the existence of either a carbon price that rewards abatement (and that imposes a cost on emissions) or a capital grant for more advanced waste treatment technologies renders some abatement from the sector financially attractive.

7. Conclusions

Our report identifies substantial technical potential for emissions reduction in Kazakhstan, relative to the "frozen" and policy Status Quo scenarios. As an emerging economy, Kazakhstan's GDP per capita is expected to continue to grow until it approaches typical European levels, and with this growth will come higher emissions. Because consumers in Kazakhstan face very low energy prices, by international standards, and because of Kazakhstan's heavy reliance on coal as an energy source, the energy intensity of Kazakhstan's economy is markedly higher than that of European economies. Significant improvements in energy efficiency are therefore technically possible.

Choice of fuel in the power sector (and others) is a major determinant of future emissions trajectory in Kazakhstan, because the power and heat sector already accounts for a very significant proportion of emissions, and because demand for electricity and heat is growing rapidly. Kazakhstan's reliance on coal across most sectors results in a significant increase in emissions over time. Limiting the use of solid fuels would therefore substantially reduce emissions. For such a scenario to be feasible, however, the government would need to significantly increase its efforts to promote the development of renewable and other low-carbon energy sources. In addition, policy-makers in Kazakhstan would need to be convinced that they would have reliable and affordable access to significant natural gas supplies.

Figure 7.1
Summary Abatement, by Scenario



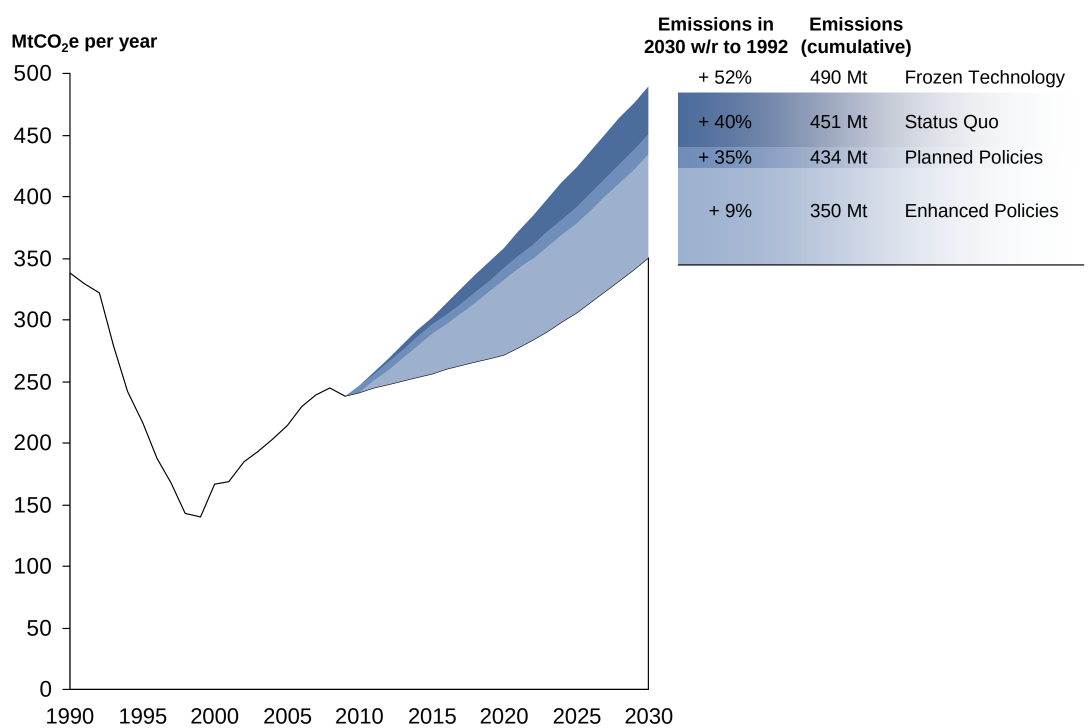
Note: The measures show the negative portion of the MACC, or abatement from measures that provide a net benefit for each tonne of CO_2e reduced. (Unprofitable measures are those on the positive portion of the MACC, where abatement imposes a real cost per tCO_2e.)

Additional abatement from the Power sector, in the Enhanced Policies – Capital Grants scenario (relative to the Carbon Prices variant) is due to the least attractive tier of wind power becoming profitable as a result of the capital subsidies. Conversely, in the capital grants scenarios, less expensive abatement in the DH sector from gas boilers heat generation equipment and additional upgrades of the heat distribution network are no longer profitable, although they were under the Carbon Prices scenario.

7.1. Emissions Pathways

Based on the investment data and policy scenarios we estimate pathways for overall emissions. If the Kazakhstan economy grew as projected over the period 2010-2030, but remained frozen at its current carbon intensity, its emissions would increase from the current level of just under 250 be to more than 350 MtCO_2e in 2020 and 490 MtCO2 in 2030. Under the Status Quo scenario, technological improvements for new and replacement equipment reduce these emissions to less than 340 MtCO_2e in 2020 and 450 MtCO_2e in 2030. The Planned Policy scenario reduces emissions further – by around 17 MtCO_2e by 2030 – primarily as a consequence of investment in renewable (wind) power, as well as some increased uptake of building insulation and heating controls energy efficiency measures. The largest policy impact is in moving to the Enhanced Policy scenario, which renders additional investment opportunities corresponding to emissions reductions of over 80 MtCO_2e commercially attractive by 2030 relative to Planned Policies. As noted above, these reductions come from a variety of sectors, with the most significant of these a large-scale shift away from solid fuels (mostly coal) in the power sector.

Figure 7.2
Emissions Pathways under Different Policy Scenarios

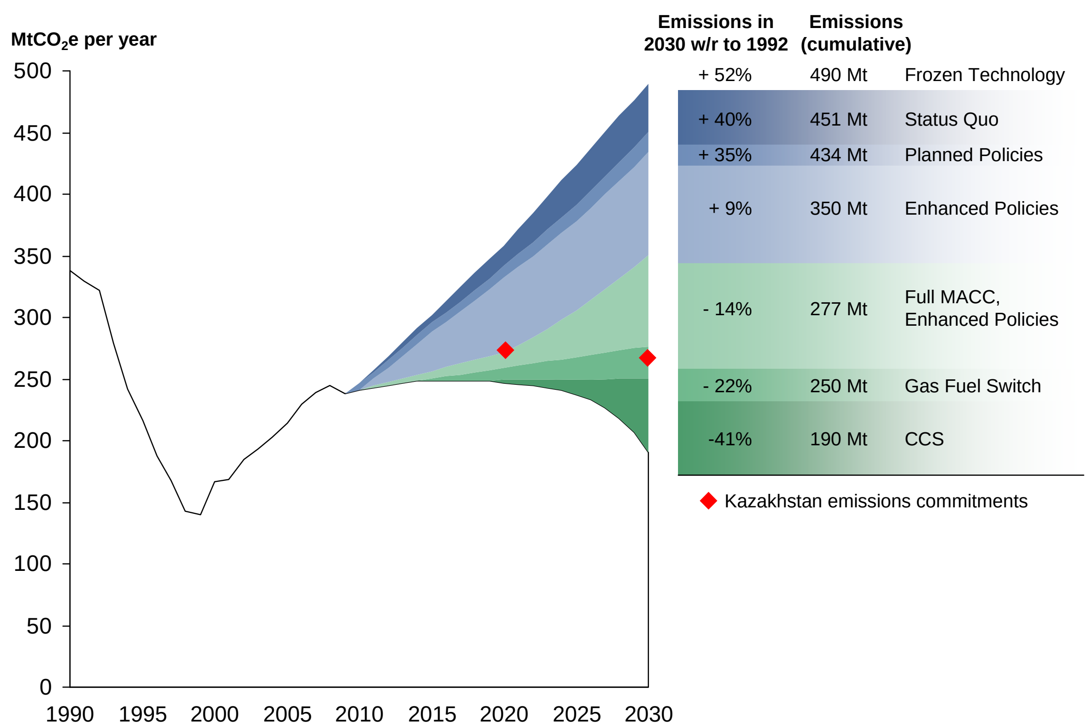


7.2. Options for Additional Emissions Reductions

The pathway under Enhanced Policies brings 2020 emissions to a level similar to the commitment adopted by Kazakhstan, at 15 percent below 1992 levels. However, with the projected continued growth across emissions-intensive sectors, emissions are on an upward trajectory even in this scenario. Additional action therefore would be required to meet 2050 commitment of a 25 percent reduction on 1992 level.

Figure 7.3 outlines aggregate emissions under three potential additional sets of measures that could contribute to such scenarios, compared to Kazakhstan emissions reduction commitments.[54] These are either more expensive or more speculative than the measures analysed above, but are presented here to indicate the developments required for more ambitious emissions cuts.

Figure 7.3
Options for Additional Emissions Reductions



The additional potential measures fall in three main categories:

- **Higher-cost measures ("Full MACC").** In addition to the measures that are profitable in the Enhanced Policy scenario, the analysis identifies a number of additional opportunities that would require further policy support to be viable—corresponding to the

54 The figure illustrates a linear pathway from the 2020 to the 2050 commitment. This study has not evaluated pathways to reach 2050 commitments. The most cost-effective pathway may involve reductions through the 2020s, or may instead be characterised by higher emissions in the 2020s followed by subsequent reductions in later decades.

"positive" portion of the Enhance Policy scenario cost curve presented above. Major remaining options include nuclear, renewable, and gas-fired power generation; reductions of emissions from oil & gas extraction; and additional building and district heating network efficiency measures. These and other measures could reduce emissions to 277 $MtCO_2$ by 2030 or 14 percent below 1992 levels, consistent with a linear trajectory to the 2050 commitment level. However, these measures would have an implied cost of carbon reduction of up to €200/tCO_2 in addition to the €40/tCO_2 carbon price included in the Enhanced Policy. The measures would require additional policy support—either in the form of higher carbon prices to the level indicated on the MACC, or through equivalent additional subsidies, regulatory requirements, etc.

- **Gas fuel switch:** Further reductions also could be achieved through increased use of natural gas. If residual coal use remaining after the higher-cost measures are implemented was phased out in favour of gas, total emissions could be brought down to 250 $MtCO_2$ by 2030. However, such large-scale fuel switching would require a major realignment of Kazakhstan's energy infrastructure, from the long-distance transport of electricity to long-distance gas transmission. In addition to this infrastructure cost of the pipelines required, incentives equivalent to an additional implied carbon cost of €40-70/$tCO_{2,}$ would be required for gas to be preferred by end-users, on top of the €40/tCO_2 already included in the Enhanced Policy scenario.

- **Carbon capture and storage.** A final set of opportunities could become available if progress were made in the commercialisation of carbon capture and storage (CCS). Kazakhstan has significant emissions from large point sources in the power, heat, and industrial sectors of sufficient size to be candidates for CCS. If the technology were to become viable and ambitiously deployed in the 2020s, emissions could be brought down further to by an additional 60 $MtCO_2$ by 2030. Cumulatively with the other higher-cost measures and gas fuel switching, total emissions could then be brought down to 190 $MtCO_2$, or 41 percent below 1992 levels.

With these measures Kazakhstan has the potential to effect deeper emissions reductions and achieve an emissions trajectory consistent with its 2050 commitment, but the analysis shows that significant policy support would be required, beyond the already ambitious policies modelled in the Enhanced Policy scenario and involving measures with rapidly increasing cost.

Appendix A. Detailed Sector Assumptions

This appendix presents the technical and cost assumptions used in the modelling of Kazakhstan MAC curves. The sections below cover the following sectors: Power (A.1), Heat and Buildings (A.2), Industry (A.3), Transportation (A.4) and Agriculture (A.5).

A.1. Power

Table A.1
Power Sector Technologies

Description	Carbon intensity	Efficiency	Availability factor	CAPEX (in 2010) €/kW		
	tCO2/MWh	%	%	New build	Upgrade	Comments
Power-only, coal plants						
Existing coal plant	1.02	32%	51%	1,500		Not built anymore.
Existing coal plant, de-mothballed	1.02	32%	75%		550	Cost of de-mothballing.
Existing coal plant, fully rehabilitated	0.96	34%	60%		80	Retrofit/rehabilitation cost.
New supercritical coal plant	0.84	39%	85%	1,800		Cost of new plant.
New supercritical coal plant running on 10% biomass	0.75	43%	85%		360	Cost of new plant.
New ultra-supercritical coal plant	0.78	42%	85%	3,000		Cost of new plant.
Power-only, gas plants						
Existing Gas turbine	0.66	36%	43%	400		Not built anymore.
Existing CCGT	0.66	36%	60%	400		Not built anymore.
New Gas turbine	0.56	43%	80%	800		Cost of new plant.
New CCGT	0.39	62%	80%	1,300		Cost of new plant.
Power-only, renewables						
Nuclear (Fission)	-	N/A	85%	3,800		Cost of new plant.
Solar Photovoltaic	-	N/A	20%	3,000		Cost of new plant.
Solar Thermal	-	N/A	28%	3,300		Cost of new plant.
Geothermal	-	N/A	85%	3,100		Cost of new plant.
Wind (High quality)	-	N/A	35%	1,300		Cost of new plant.
Wind (Medium quality)	-	N/A	28%	1,300		Cost of new plant.
Wind (Low quality)	-	N/A	28%	1,800		Cost of new plant.
Hydro, small	-	N/A	36%	2,200		Cost of new plant.
Hydro, large	-	N/A	36%	1,100		Cost of new plant.
Hydro, rehabilitation	-	N/A	36%	2,000		Retrofit/rehabilitation cost.

Notes: For CHP generation of electricity, see Table A.3 below.

A.1.1. Resource Constraints

We make the following assumptions about the availability of key resources in the power sector.

Table A.2
Power Sector Resource Constraints

Quantity	Value	Notes
Hydro, small	2.4 GW	Accounts for environmental constraints.
Hydro, large	3.3 GW	Accounts for environmental constraints.
Wind resource	16 GW	Split into three tiers with different attractiveness.
Solar resource (PV)	8 GW	Accounts for grid connection access and system stability with respect to renewables.
Nuclear	2 GW	Requires enabling policies, only in place in the Enhanced Policies scenario.

Source: various sources as discussed in the main body of the report.

A.2. Heat and Buildings

Table A.3
Heat Generation Technologies

Description	Carbon intensity	Efficiency	Availability factor	CAPEX (in 2010) €/kW		Comments
	tCO2/MWh	%	%	New build	Upgrade	
Combined Heat and Power (CHP)						
Existing coal CHP plant	0.85	39%/45%	61%	2,300		Not built anymore.
Existing gas CHP plant	0.38	62%/40%	53%	1,200		Not built anymore.
Coal CHP plant, Upgrade	0.85	39%/51%	61%		500	Retrofit/rehabilitation cost.
Gas CHP plant, Upgrade	0.38	62%/46%	70%		410	Retrofit/rehabilitation cost.
New coal CHP plant	0.85	39%/97%	70%	2,600		Cost of new plant.
New gas CHP plant	0.38	62%/88%	70%	1,300		Cost of new plant.
Heat-only Boilers (HOBs)						
Existing coal boiler	0.47	70%	31%	66		Not built anymore.
Existing gas boiler	0.47	70%	31%	66		Not built anymore.
Existing coal boiler upgrade	0.39	83%	65%		70	Retrofit/rehabilitation cost.
Existing gas boiler upgrade	0.23	90%	65%		70	Retrofit/rehabilitation cost.
New coal boiler	0.38	85%	75%	90		Cost of new plant.
New gas boiler	0.22	92%	75%	90		Cost of new plant.

Notes: For the CHP plants, two efficiencies are cited – electric efficiency (the first figure) and thermal efficiency (the second figure).

A.2.1. Abatement Measures in the Buildings Sector

Table A.4
Abatement Measures in the District and Communal Heating Buildings

Category	Energy / carbon savings	Cost (€)
Residential Buildings	**(relative to no measure)**	**(per dwelling)**
Building-level Substation (BLS)	20 percent	400
Individual dwelling heating controls and thermostats	15 percent	700
Insulation - basic	21 percent	1,200
Insulation - intermediate	9 percent	400
Insulation - full	16 percent	1,800
Commercial / Public Buildings	**(relative to no measure)**	**(per m2)**
Building-level Substation (BLS)	20 percent	7
Individual dwelling heating controls and thermostats	15 percent	12
Insulation - basic	21 percent	20
Insulation - intermediate	9 percent	7
Insulation - full	16 percent	31

Notes:

Basic insulation measures include simple measures such as filling wall cavities, weather stripping or door replacement, installation of double doors, sealing of baseboards or elimination of other leakages.

Intermediate insulation measures include replacement of doors and windows, adding external cladding, insulation of ceiling of roof and basement and associated ventilation measures.

Full insulation package includes, in addition to the above, residual measures such as thicker cladding, heat recovery system in air ventilation, and higher-specification windows.

A.3. Industry

A.3.1. Cement

Table A.5
Abatement Measures for Cement Sector

Measure	Description	Energy / Emissions Impact
Efficient new capacity	▪ Modern kilns using dry production processes	▪ 15 percent reduction in energy intensity (compared to average existing capacity). ▪ Emissions reduction of 6 percent compared to current average.
EE package 1	▪ Preventative maintenance ▪ Improved kiln combustion ▪ Shell heat loss reduction	▪ 10 percent reduction in energy intensity. ▪ Emissions impact depends on fuel use and clinker ratio, but is 4.5 percent for a typical, unimproved coal-fired plant.
EE package 2	▪ EE package 1 + ▪ Improved process control and automation ▪ New grate cooler ▪ Indirect firing	▪ 18 percent reduction in energy intensity. Impact on emissions depends on fuel characteristics. ▪ Emissions impact depends on fuel use and clinker ratio, but is 8 percent for a typical, unimproved coal-fired plant.
Fossil fuel substitution	▪ Switch from default fuel (coal) to other fuels with lower emissions intensity (subject to technical suitability)	▪ Emissions reduction depends on relative carbon intensity of fuels used. E.g., switch coal to gas leads to 18 percent reduction.
Waste firing	▪ Substitute fossil fuel input with waste	▪ Up to 40 percent reduction in emissions intensity
Clinker substitution	▪ Substitute up to 20 percent of clinker with alternative materials in cement blending.	▪ Reduction in energy use as well as process emissions, with up to 23 percent reduction in overall emissions intensity
Carbon capture and storage	▪ Capture up to 90 percent of CO_2 emissions.	▪ 90 percent reduction in total CO_2 emissions.

A.3.2. Detailed technology cost and performance assumptions

The tables below provide a summary of the efficiency or carbon improvement and associated capital cost (per unit of annual production capacity) for the major industrial abatement technologies included in our analysis, organised by sector.

Table A.6
Abatement Measures - Cement

Sector	Measure	Carbon savings	Cost (€/t cement)
Cement	Preventative Maintenance	1-5%	0.21
Cement	Shell heat loss reduction	5-10%	0.21
Cement	Improved kiln combustion	5-10%	0.66
Cement	Process control and automation	1-5%	0.15
Cement	New grate cooler	5-10%	5.1
Cement	Indirect firing	5-10%	7.1
Cement	Waste firing	Fuel is 40% less carbon intensive with 80% regular waste and 20% biowaste	6.2
Cement	Medium clinker substitution	10% relative to portland cement	4.1
Cement	High clinker substitution	20% relative to portland cement	6.2

Table A.7
Abatement Measures - Steel

Sector	Measure	Carbon savings	Cost (€/t steel)
Steel	Energy monitoring & management system	1-5%	0.03
Steel	Preventative maintenance	1-5%	0.01
Steel	Sinter plant heat recovery	1-5%	0.61
Steel	Coal moisture control	1-5%	0.5
Steel	Blast furnace pulverised coal injection	1-5%	5.8
Steel	Hot blast stove automation	1-5%	0.25
Steel	Heat recovery - basic oxygen furnace	1-5%	20.5

Table A.8
Abatement Measures - Oil Refining and Petrochemicals

Sector	Measure	Carbon savings	Cost (€/t output)
Oil refineries	Energy management	1-5%	0.53
Oil refineries	Fouling Mitigation	1-5%	0.88
Oil refineries	Pumps, motors and compressed air	5-10%	0.21
Oil refineries	Improved process controls	1-5%	1.10
Oil refineries	Waste heat recovery	1-5%	1.46
Oil refineries	Process Integration and change	1-5%	0.39
Petrochemicals	Energy management	1-5%	0.12
Petrochemicals	Improved distillation	1-5%	0.10
Petrochemicals	Improved drying	1-5%	0.28
Petrochemicals	Improved evaporation	1-5%	0.32
Petrochemicals	MVR	1-5%	34.4
Petrochemicals	Process control	1-5%	0.28
Petrochemicals	Process integration	1-5%	0.13
Petrochemicals	Waste heat recovery	1-5%	2.8

Table A.9
Abatement Measures - Selected Chemicals

Sector	Measure	Carbon savings	Cost (€/t output)
Ammonia	Energy management	5-10%	2.0
Ammonia	Reforming large improvements	1-5%	21
Ammonia	Reforming moderate improvements	1-5%	4.4
Ammonia	Improvement in CO2 removal	1-5%	13
Ammonia	Low pressure synthesis	1-5%	5.2
Ammonia	Hydrogen recovery	1-5%	1.7
Ammonia	Process integration	1-5%	2.6
NitricAcid	Alternative oxidation catalyst	more than 20%	13
NitricAcid	Extension of the reactor chamber	more than 20%	175
NitricAcid	Secondary catalyst - N2O decomposition in the oxidation reactor	10-20%	0.5
NitricAcid	Tertiary catalyst - Variant 2	1-5%	37
NitricAcid	Non-selective catalytic reduction of NOX and N2O (NSCR)	1-5%	26
SodaAsh	Control systems	1-5%	1.7
SodaAsh	Energy management	1-5%	1.8
SodaAsh	HEMs	1-5%	1.7
SodaAsh	High efficiency trays	1-5%	14
SodaAsh	Improved control	1-5%	2.6
SodaAsh	Waste heat recovery	1-5%	25
SodaAsh	Membrane process improvement	1-5%	3.7
SodaAsh	Electricity efficiency - other inorganics	1-5%	3.7
SodaAsh	Adjustable speed drives	1-5%	2.7

Table A.10
Abatement Measures - Minerals, Glass, Bricks, Ceramics

Sector	Measure	Carbon savings	Cost (€/t output)
Lime	Preventative Maintenance	1-5%	0.17
Lime	Process Control	1-5%	0.77
Lime	Improved kiln combustion	5-10%	0.53
Lime	Shell heat loss reduction	1-5%	0.17
Glass	Advanced burner systems	1-5%	3.1
Glass	Control	1-5%	2.1
Glass	Expert system	1-5%	2.1
Glass	External cullet	1-5%	2.7
Glass	Waste heat recovery	1-5%	6.8
Glass	Oxy trim	1-5%	1.7
Glass	Refractories and insulation	1-5%	3.1
Glass	U/S Refining	1-5%	4.1
Bricks	Improved firing and drying	55%	31
General ceramics	Improved firing and drying	25% to 40%	181

Table A.11
Abatement Measures - Selected Other Industry

Sector	Measure	Carbon savings	Cost (€/t output)
Non-ferrours metals	Monitoring and targeting	5-10%	14.3
Non-ferrours metals	Modern furnaces	more than 20%	35.8
Paper (excl. pulp)	Waste heat recovery in the pulp industry	1%	20.0
Paper (excl. pulp)	Process control and pinch analysis in the pulp industry	5%	9.5
Pulp	Process control and pinch analysis in the pulp industry	5%	9.5
Pulp	Waste heat recovery in the pulp industry	1%	0.8

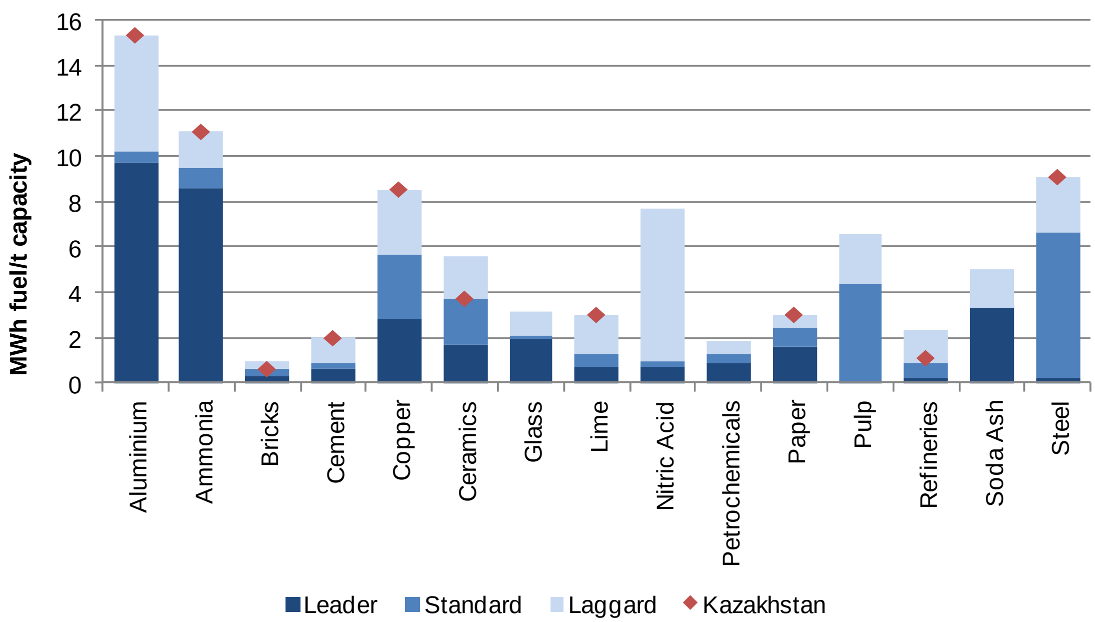
A.3.3. International Benchmarking of Industry

As shown in the main body of the report, there is considerable scope for energy efficiency improvements in Kazakh industry. In this section we present the average fossil fuel energy consumption of individual industries relative to international benchmarks, with an aim to indicate whether Kazakhstan is closer to the most inefficient plants ("Laggards"), to the most efficient ones ("Leaders"), or somewhere in between ("Standard").

In general, industrial plants in Kazakhstan have fossil fuel energy consumption close to "laggard" plants that currently operating in Europe and other developed countries, although this varies from sector to sector based on the available information.

Progressing towards state-of-art plants ("leaders"), either by upgrading current capacity or by building new, more efficient capacity, would allow Kazakhstan to significantly reduce industrial energy consumption and emissions.

Figure A.1
Industry Energy Intensity - International Benchmarks



Sources: UNFCCC, BNEF database, Kazakhstan production statistics, NERA analysis.

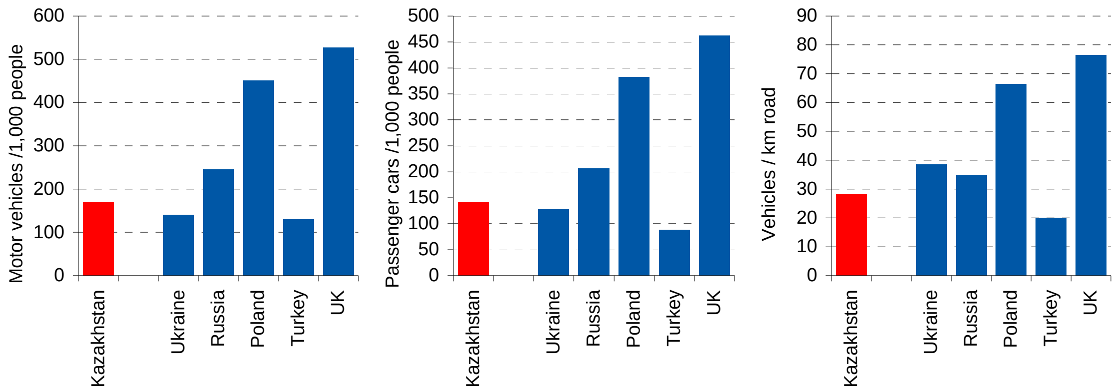
A.4. Transportation

In 2009, total freight transportation in Kazakhstan was about 264 billion tkm (tonne-kilometres) and passenger transportation almost 125 billion pkm (passenger-kilometres). Road transportation dominates passenger transportation in Kazakhstan, accounting for 88 percent of passenger kilometers travelled.

As much as 94 percent of fossil fuel consumption in Transport (excluding pipelines transport) originates in Road transport (compared to 3 percent in the Rail sector and 3 percent in civil aviation).

A.4.1. International Comparisons

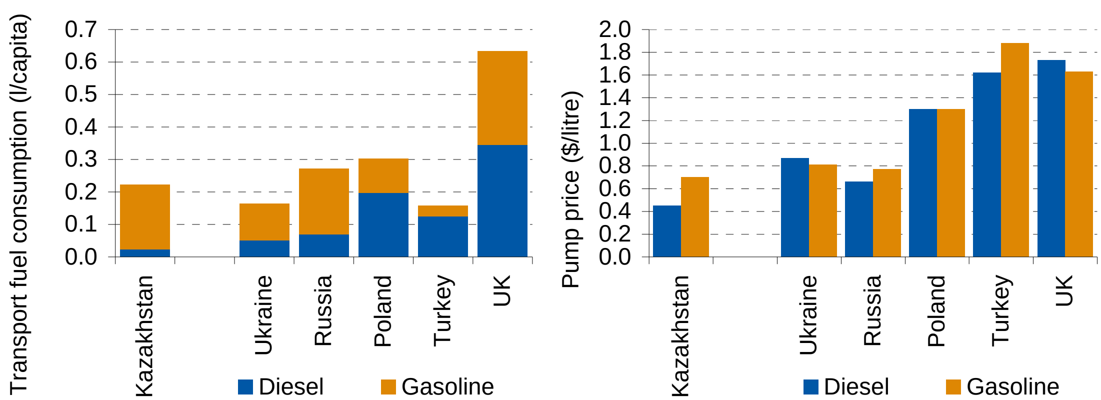
Figure A.2
Transport sector - international benchmarks (vehicles)



Source: World Bank

Vehicle penetration levels in Kazakhstan are low by international standards, as illustrated in Figure A.2 above. At around 170 vehicles per 1,000 people, the penetration rate is comparable to the rate in Ukraine and Russia, but just around 35 percent of that in Poland or the UK.

Figure A.3
Transport sector - International Comparison of Fuel Consumption per Capita and of Fuel prices



Source: World Bank. Data are for 2007 (fuel consumption) and 2006 (fuel prices).

Motor fuel prices in Kazakhstan are low by international standards – significantly lower than fuel prices in other Eastern European countries such as Russia or Ukraine, and even lower than fuel prices in the UK or Poland. In fact, both the diesel and gasoline prices are the lowest among the benchmarked countries. Fuel consumption per capita, particularly that of diesel, is low by international standards, despite the low prices – reflecting lower GDP/capita.

A.4.2. Detailed cost and performance assumptions

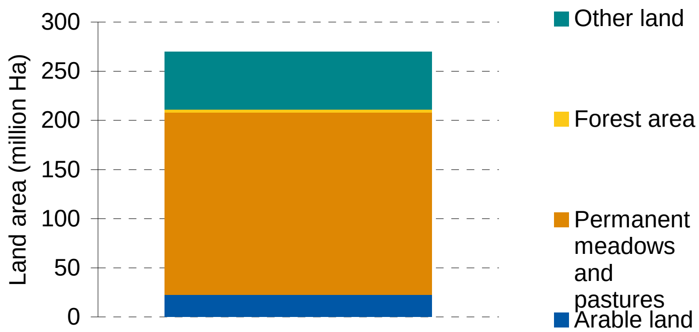
Table A.12
Abatement measures in Transport sector

Category	Indicative energy or carbon savings	Indicative costs (2010 €)	
Standard vehicles	**Fuel cost savings relative to a standard gasoline car in 2010**	**Costs per vehicle relative to a standard gasoline car in 2010**	**Costs per vehicle relative to a standard gasoline car in 2020**
Gasoline car	N/A	N/A	N/A
Diesel car	34 percent	-1,000	-1,000
Electric car	76 percent	8,700	5,000
LPG car	44 percent	1,100	1,100
CNG car	-19 percent	3,100	2,900
Non-plug-in Hybrid	42 percent	8,000	7,100
Plug-in Hybrid	55 percent	12,800	9,400
Modern vehicles		**Costs per vehicle relative to a modern gasoline car in 2010**	**Costs per vehicle relative to a modern gasoline car in 2020**
Next generation gasoline car	17 percent	N/A	N/A
Next generation diesel car	45 percent	-600	-500
Next generation electric car	78 percent	12,800	8,800
Next generation LPG car	53 percent	1,100	1,100
Next generation CNG car	0 percent	3,100	2,900
Next generation hybrid car (non-plug-in)	51 percent	13,500	9,400
Next generation hybrid car (plug-in)	61 percent	20,200	14,900
Ultra-modern vehicles		**Costs per vehicle relative to an ultra-modern gasoline car in 2010**	**Costs per vehicle relative to an ultra-modern gasoline car in 2020**
Post-2020 gasoline car	28 percent	N/A	N/A
Post-2020 diesel car	51 percent	-	-
Post-2020 electric car	79 percent	16,700	11,800
Post-2020 hybrid car (non-plug-in)	56 percent	18,900	13,600
Post-2020 hybrid car (plug-in)	65 percent	27,200	20,500

A.5. Agriculture, Forestry and Land Use

Agriculture in Kazakhstan represents a large share of GDP – over 6 percent in 2009 – which is more than in more developed countries. Among its most important agricultural products are grain (in 2008 Kazakhstan was the 13th largest producer of wheat in the world), cotton and livestock. Around 8 percent of Kazakhstan's land is arable and another 69 percent of the land area is permanent meadows and pastures. Forests represent a relatively small share of the country's land area.

Figure A.4
Land Use in Kazakhstan



Source: FAO. Data are for 2007.

Notes: Other land includes built-up and related land, barren land, other wooded land.

Using the number of tractors per hectare of arable land as a proxy for the level of agricultural modernisation, Kazakhstan's agricultural sector is still relatively under-developed. The country has only 18 tractors per hectare of arable land, compared to 33 in Russia, 104 in Ukraine and 728 in the UK. The use of fertiliser is also very low, and both of these factors contribute to a relatively low value added per worker in the sector. This is illustrated below in Table A.13.

Around 42 percent of Kazakhstan's population still lives in rural areas, which is a relatively higher share by international standards. Further migration of rural population to urban areas is expected – and higher proportion of urban population.

Table A.13
Agriculture - International Benchmarks

Agriculture benchmarks	Kazakhstan	Ukraine	Russia	Poland	Turkey	UK
Fertiliser consumption (kg / ha arable land)	54	327	141	2,126	1,000	2,546
Tractors per ha arable land	18	104	33	1,243	474	728
Agriculture value added per worker (constant 2000$)	1,870	2,019	3,043	2,620	3,153	27,173
Rural population (per 100 population)	44	32	27	39	32	10

Source: World Bank. Data are for 2007.

Appendix B. Transaction Costs, Discount Rates, and Payback Assumptions

B.1. Project Transaction Costs

B.1.1. Households and small/medium firms: background and sources

The "energy efficiency gap"

- A very large literature has documented how households and firms leave low carbon (particularly, energy efficiency) investments untapped that appear to have with rates of return in excess of 30 percent, as calculated by comparing initial capex against assumed future savings on energy expenditure
- It also is documented (albeit more anecdotally) that many firms apply very stringent payback criteria to energy efficiency investments (e.g., 3-4 year payback). Comparing results from models (e.g., UK ENUSIM model of industry energy use), it is clear that uptake is limited to measures with very high rates of return (when evaluated at capex + energy savings).
- Quantitative estimates of these findings, often referred to as the "energy efficiency gap" (although applicable also to small-scale renewables, see below) are often expressed as a discount rate or rate of return – which emerges as a "residual" in modelled or estimated relationships between capex, opex, and other engineering-economic factors. By far the largest body of data on transaction costs are in this format. [55]

There is little agreement about the relative importance of the factors that may explain the energy efficiency gap.

- A large number of explanations have been advanced, with little agreement on what accounts for the observed situation. The main categories of explanation are the following:
  - *Transaction costs (e.g., "hassle", cost of time spent, additional staff, costs of contracting, etc.)*
  - *Poor performance of equipment, or high variability in performance (e.g., [CRA])*
  - *High discount time preference rates of individuals. (e.g., Frederick et al. 2002)*
  - *Misaligned incentives, within organisations (E.g., Sorrel et al., 2005)*
  - *Opportunity costs, either of credit in the presence of credit market imperfections, or management / leisure time.*
  - *Option value associated with and irreversible investments under uncertainty, which in some models have suggested hurdle rates four times higher than the cost of capital.*

---

[55] See NERA's previous note on discount rates for sample references of estimates of the magnitude of costs, typically expressed as rates of return / discount rates.

  - *Consumer / manager irrationality.*

- There is little agreement in the literature about which of the above factors is the most important, or that any of the factors suffices to account for observed behaviour.

The "bottom-up" approach to estimating transaction costs has met with limited success

- One approach to explaining the observed behaviour has been to supplement standard costs with bottom-up estimates of transaction costs.
- This is unusual in the academic literature, although there are some isolated examples. It has been more common in the applied or policy-related literature. The below table summarises some of the more extensive recent efforts, spanning both the household and non-domestic sectors, and between them span the large majority of key small/medium-sized renewables and energy efficiency measures.

Table B.1
Examples of Sources on Bottom-Up Estimates of Transaction Costs Faced by Households and Small/Medium Firms

Source	Method	Measures	Extent of transaction cost
Ecofys (2009)	Literature review, expert interviews/survey, and judgement	Energy efficiency: Measures in household sector	5-10 percent, rising to 35-100 percent for individual measures.
Enviros (2006)	Literature review, expert interviews / survey, and judgement	Energy efficiency measures: across industry, commercial, and public sectors.	Larger measures typically around 5 percnet, rising to 20 percent or more for smaller or more complex measures.
Element Energy (2008)	Stated preference survey	Renewables: for small and micro generation of heat and electricity	Focus on the largest measures, with estimates in the region of 20-40 percent
Enviros (2008a, 2008b)	Interviews, expert judgement	Renewables: Heat generation, covering all sectors	1-5 percent for key measures, depending on measure and scale of measure. Negligible for large measures.
Björkqvist and Wene	Survey, desk-based judgement		25-30%, based on assumptions about time use
Sathaye et al. (2004)	Survey, desk-based judgement		[25-30%, based on assumptions about time use]

- The purpose of these studies has typically been to augment models to better understand and model household and firm behaviour. However, this cannot be said to have been a success in bridging the gap between technological assumptions and observed behaviour. None of the above studies has resulted in estimates that correspond to the magnitude implied by observed behaviour.
- Some of the key difficulties include:
  - *The lack of data and need for subjective judgement in defining costs*
  - *The specificity and idiosyncracy of relevant costs, and therefore necessary incompleteness of bottom-up estimates.*
  - *The bias introduced by focussing on issues that are more readily quantified*
  - *The likelihood that many factors other than transaction costs (see above list) are important.*
- Our assessment is that these are likely inherent in the methodology. Bottom-up estimates do not succeed in spanning the full range of relevant costs and other factors.
- The implication for this study is that the more limited estimates available from bottom-up assessments should be supplemented with the much wider data on hurdle rates.

Our approach makes joint use of additions to capex, discount rates, and payback criteria, and is informed by the wider literature on discount rates and "payback" criteria

B.1.2. Large-scale projects

- Different considerations arise with large, capital-intensive projects that are at the core of a firm's business. Here it may be more feasible to itemise transaction costs, although the problems of idiosyncracy and boundaries between transaction costs and other factors (standard capex, risk premia, cost of financing) remain.
- Evidence is often anecdotal. Examples of sources consulted in the course of developing our estimates include:
  - Interviews have suggested that, for example, 10 percent was a reasonable indicative figure for large, capital intensive projects in Ukraine.
  - CDM and JI project documents.
    - For example, estimates of costs for an individual windfarm itemised capex and transaction costs separately, but included interest during construction as a transaction cost. Removing the interest payments, a reasonable estimate of pure transaction costs (site surveys, consulting, contracting, etc.) is 10-15 percent of capex (depending on financing terms).
  - Interviews with industrial stakeholders in Turkey, Kazakhstan, and Ukraine
    - For example, one interviewee noted the higher up-front cost required for investments in industrial capacity in Kazakhstan compared to China or some western countries (citing $200/t instead of $150/t). This datum is a composite of

factors: greater delays (higher interest rate payments, higher interest rate, higher risk); higher capex because of more vertical integration (e.g., need to invest in auxiliary or transport infrastructure); as well as more traditional transaction costs (administrative requirements, more difficult contracting, etc.)

        - It is clear that there are diverging practices for defining “capex”. For example, some stakeholders did not agree with the distinction, considering land costs and contracting part and parcel of capex; or considering overheads or staff costs as costs to be covered by the hurdle rate criteria used in investment appraisal, rather than as individual line items.

    - Project Team JI and investment advisory experience.

        - E.g., comparisons of client experience of estimates of total project costs vs. published engineering cost estimates for key technologies in the power sector. (However, here too conventions for the boundaries between “capex” and other project costs are nearly never well defined)

- The data arising from these sources is complex and subject to interpretation. We have centered on a 10 percent addition to transaction costs as a reasonable central estimate.
- An important observation is that key barriers (likelihood of getting permits, quality of available local contractors, small supplier markets, requirements for political connections) are factors that are crucial to whether projects can realistically go ahead, but not items that can be readily monetised. Rather than affecting cost, they affect whether projects are viable propositions.

B.1.3. Background: Overview of McKinsey assumptions

McKinsey’s assumptions can be summarised as follows:

- Costs are expressed as a share of capex for project transaction costs. For a given lifetime, this is arithmetically equivalent to expressing costs as a premium on the discount rate.
- 30%: for household (energy efficiency, waste). Based on two “bottom-up” studies (e.g., time required to find out about energy efficient washing machines).
- 10% for large measures (energy efficiency, renewables). Based broadly on interviews with Bashinform, EBRD bankers, and Global Carbon, and supplemented by McKinsey judgement.
- 15% for mid-sized (energy efficiency, renewables, waste). No particular source cited, but “per-project” nature of cost is rationale for higher number than for large projects.
- Additional assumptions:
    - 3% for transport. This is extrapolated from the household number, by comparing vehicle capex to appliance capex.
    - 12% for nuclear, CCS. Given lack of (recent) investment history in these, these are speculative.

B.2. Summary of Estimates

We summarise our assumptions for key sectors overleaf.

The following are explanations of columns three to five:

- Transaction costs, expressed as an addition to up-front cost in terms of a share of the capex.
- Discount rate and payback period: these are the terms used in the formula to levelise costs.[56] For new investments, the equipment lifetime is used. For retrofit, a more stringent requirement may be applied.

[56] Costs are levelised by calculating the stream of annual payments would be required over the payback period to generate a present value equivalent to the capex + transaction costs, when future payments are discounted at the discount rate.

Table B.2
Summary of Barriers Estimates

Category	Examples of abatement measures	Transaction costs (% of capex)	Discount rate (%)	Payback period[57] (years)	Notes / motivation
Power and Utilities					
Power utilities: conventional technologies	▪ New coal plant New gas plant	10%	18%	20	This incorporates a country risk premium
Power utilities: renewables	▪ Wind power ▪ Biomass ▪ Hydroelectric	10%	20-25%	20	▪ Higher hurdle rates for investment in technologies with less mature supply chain ▪ Smaller additional premium for technologies with proven track record of investment (e.g., Kazakhstan wind); but higher premiums for biomass power, which faces significant supply chain issues, or nuclear power.
Power utilities: nuclear	▪ Nuclear Power	10%	25-30%	20	▪
Heat utilities: conventional technologies	▪ New coal Heat-Only Boiler (HOB) ▪ New coal or gas –fired CHP	10%	25%	20	▪ This incorporates a country risk premium.
Utilities: power	▪ Power transmission and distribution	30%	20-25%	20	▪ Lower hurdle rates for utilities where cost-recovery of investments is possible.
Utilities: heat distribution	▪ DH networks rehabilitation and upgrades	30%	20-25%	20	▪ Lower hurdle rates for utilities where cost-recovery of investments is possible.
Experimental / end-of-pipe	▪ CCS	10%	28%	20	▪ Measures whose sole or main motivation is abatement are more risky and more difficult to implement than ones that affect energy use or cost.
Households					
Building-level heat controls	▪ Modern building-level substations (BLS)	40%	20-25%	15	▪ Shorter payback periods motivated by shorter tenure and / or rental and leasing agreements. ▪ Overall hurdle rate consistent with range of published studies. ▪ Transaction costs reflect weak resident associations and high

[57] For retrofit measures. New capacity is evaluated at 20 years or the equipment lifetime, whichever is the smallest.

Category	Examples of abatement measures	**Transaction costs** (% of capex)	**Discount rate** (%)	**Payback period**[57] (years)	Notes / motivation
					bargaining and coordination costs.
Dwelling-level heat controls in communal / multiple occupancy buildings (apartment and office blocks)	▪ Radiator heat controls ▪ Thermostats	40%	20-25%	15	▪ Shorter payback periods motivated by shorter tenure. ▪ Overall hurdle rate consistent with range of published studies. ▪ Transaction costs reflect weak resident associations and high bargaining and coordination costs.
General Household-scale / small business, insulation measures	▪ House insulation (wall, floors, loft) ▪ Window double/triple-glazing	30%	20-25%	15	▪ Shorter payback periods motivated by shorter tenure and / or rental and leasing agreements. ▪ Overall hurdle rate consistent with range of published studies.
Communal / multiple occupancy buildings insulation measures	▪ Building fabric of apartment and office blocks ▪ External cladding	40%	20-25%	15	▪ Additional transaction costs arise from common action problem (e.g., landlord/tenant split, condominium associations).
Passenger transport - private	▪ Passenger vehicles	30%	20-25%	15	▪ Shorter payback periods motivated by shorter useful lifetime of vehicles
Passenger transport – public	▪ Buses ▪ Electric buses	15%	20-25%	10	▪ Lower transaction costs motivated by economies of scale.
Industry, Fugitives, Waste					
New industrial production capacity	▪ New Cement capacity ▪ New Steel capacity	15%	15%	15	▪ Lower transaction costs reflect established supply chains and well-known planning requirements.
Waste	▪ Industrial waste firing	15%	20%	15	▪ Waste-based measures start from a low base (lack of collection and infrastructure), and often face significant regulatory hurdles
Waste (landfill) management	▪ Landfill gas capture	15%	30-35%	15	▪ Waste-based measures start from a low base (lack of collection and infrastructure), and often face significant regulatory hurdles ▪ Reflects current low share of legally operating landfills.
Wastewater treatment (municipal and industrial)	▪ Mechanical and biological treatment ▪ Anaerobic digestion	30%	20-25%	15	▪ Waste-based measures start from a low base (lack of collection and infrastructure), and often face significant regulatory hurdles
Waste heat capture	▪ Waste heat recovery in Paper and Pulp industries	15%	15%	15	▪ Lower hurdle rates for energy intensive industry for which energy is a key part of operating cost.
Energy intensive industry	▪ Process improvements	15%	15%	15	▪ Lower hurdle rates for energy intensive industry for which

Category	Examples of abatement measures	Transaction costs (% of capex)	Discount rate (%)	Payback period[57] (years)	Notes / motivation
	▪ Energy management systems				energy is a key part of operating cost.
Electricity energy efficiency	▪ More efficient motors (pumps, variable speed drives, compressors) ▪ Adequately sized motors	15%	15%	15	▪ Lower hurdle rates for energy intensive industry for which energy is a key part of operating cost.
Chemical processes	Nitric acid catalysts	15%	15%	15	▪ Lower hurdle rates for energy intensive industry for which energy is a key part of operating cost.
Coal Mining	Coal mine methane	15%	30-35%	15	▪ Measures that are unproven are likely to face additional hurdles.
Gas distribution	Gas leakage prevention	30%	20-25%	15	▪ Lower hurdle rates for established technology and processes.
Freight transport					
Freight road transport	▪ Efficient vehicles, improved maintenance ▪ Improved vehicle fleet management	15%	15%	15	▪ Lower hurdle rates for commercial vehicles for which fuel cost and opportunity cost of maintenance time is key part of operating cost.
Agriculture and Forestry					
Agriculture – crops	▪ Low-tillage; ▪ Precision fertiliser application; ▪ Ionophores ▪ Crop rotation	30%	20-25%	15	▪ Measures are often dispersed and require changes to practices of cultural importance in sensitive industry.
Agriculture – land use	▪ Land conversion ▪ Pasture management	30%	20-25%	15	▪ Extensive coordination with often dispersed land rights. ▪ Additionally, land-rights often poorly delineated
Agriculture – livestock	▪ Improved manure management ▪ Improved livestock diet	30%	20-25%	15	▪ Dispersed measures ▪ Efficient use of animal waste complicated in the absence of sufficient on-site energy demand (e.g. seasonality issues).
Forestry	▪ Afforestation / reforestation ▪ Degraded forest restoration	30%	20-25%	15	▪ Extensive coordination with often dispersed land rights.

Box 2
Comparison of Assumptions to Project Finance Criteria

We have compared the above assumptions to alternative formulations of investment criteria, notably project finance. To take an example, consider project finance for a wind farm investment with the following features

2) 80% debt, 20% equity stake
3) 12% cost of capital
4) 10-year debt maturity, one-year grace period
5) 20 year investment lifetime
6) 25% return on equity
7) DSCR of 1.2

In many configurations, the binding constraint is the DSCR, which requires revenue in individual years to be relatively high – on a par with revenue streams that would result in an effective IRR of 20 percent if sustained throughout the equipment lifetime. We have assumed similar or higher “equivalent” rates for Kazakhstan, where investment in key renewables does not appear to be going ahead at IRRs below this level.

Appendix C. Energy Price Assumptions

In this appendix, the fuel price assumptions are presented – below in Table C.1, and in graphical form in Figure C.2, Figure C.3 and Figure C.4 below.

Table C.1
Fuel Price Assumptions - by Year and Scenario

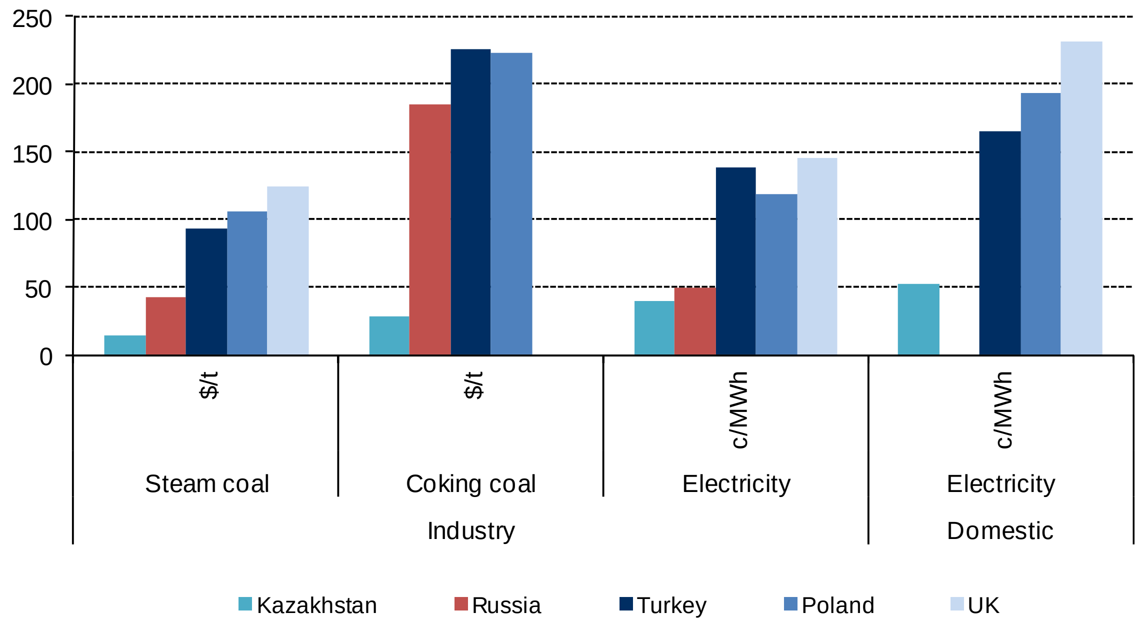
			2010	2020	2020	2020	2030	2030	2030
Sector	**Fuel**	**Unit**	**All**	**SQ**	**PP**	**EP**	**SQ**	**PP**	**EP**
Power	Coal price	€/tonne	9	9	9	9	9	9	9
	Gas price	€/MWh	8	29	29	29	41	41	41
	Biomass price	€/MWh	15	18	18	18	21	21	21
	Mazut price	€/tonne	148	168	168	168	191	191	191
	Electricity pric	€/MWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	Heat price	€/MWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Industry	Coal price	€/tonne	22	22	22	22	22	22	22
	Gas price	€/MWh	8	29	29	29	41	41	41
	Biomass price	€/MWh	15	18	18	18	21	21	21
	Mazut price	€/tonne	148	168	168	168	191	191	191
	Electricity pric	€/MWh	33	33	33	77	33	33	71
	Heat price	€/MWh	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Commercial / Residential	Coal price	€/tonne	22	22	22	22	22	22	22
	Gas price	€/MWh	14	26	26	26	27	27	27
	Biomass price	€/MWh	31	47	47	47	57	57	57
	Mazut price	€/tonne	267	288	288	288	285	285	285
	Electricity pric	€/MWh	41	41	41	80	41	41	75
	Heat price	€/MWh	11	11	17	33	11	16	33

Fuel prices in Kazakhstan are among the lowest in the world, and significantly lower than those facing major benchmarking countries, such as Russia and Ukraine.

For energy generation this implies a strong incentive to continue meeting Kazakhstan's growing electricity and heat needs from coal, and a disincentive to switch to either gas or renewables. For consumers, this means little motivation to save energy or to use it more efficiently.

The international benchmarks of energy prices are shown below in Figure C.1.

Figure C.1
Fuel Prices in Kazakhstan - International Benchmarks



Source: EIA. Data are for 2008.

Figure C.2
Fuel Price Assumptions - Status Quo

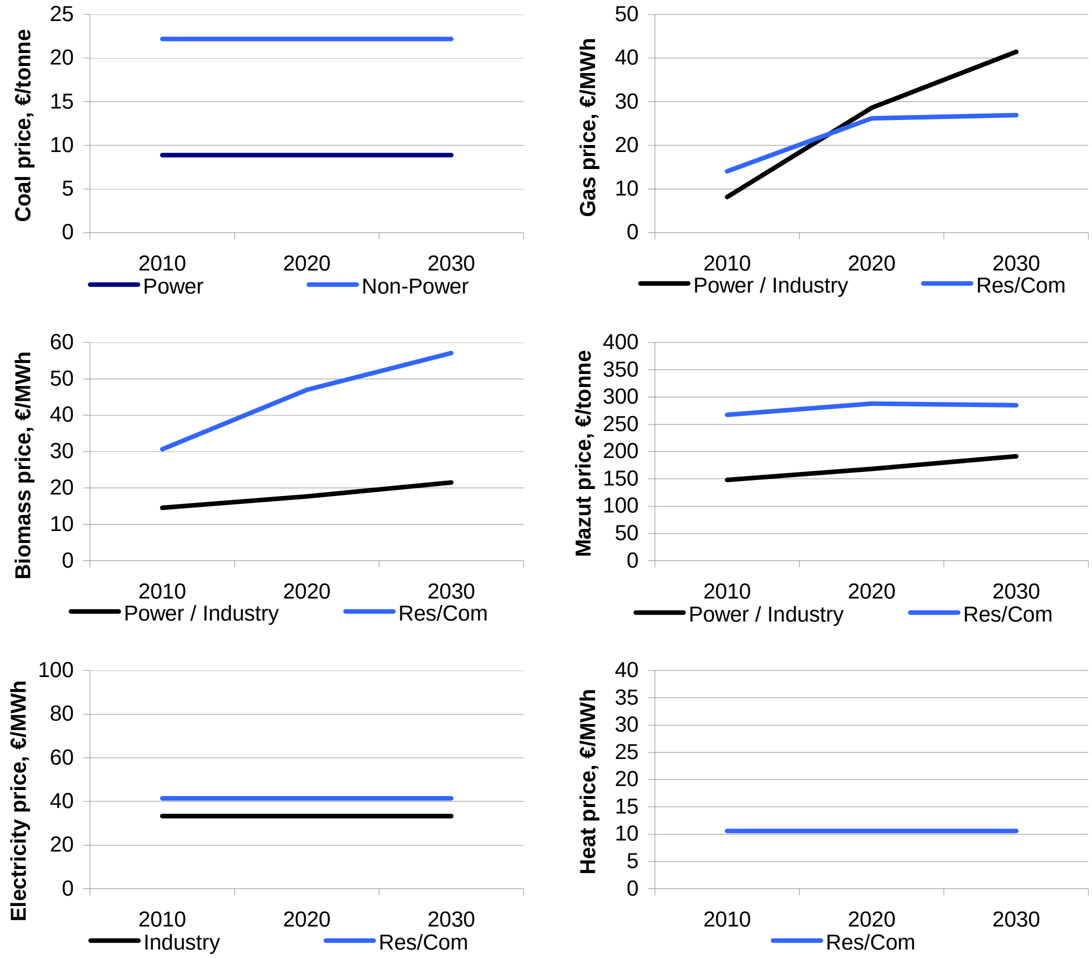


Figure C.3
Fuel Price Assumptions - Planned Policies

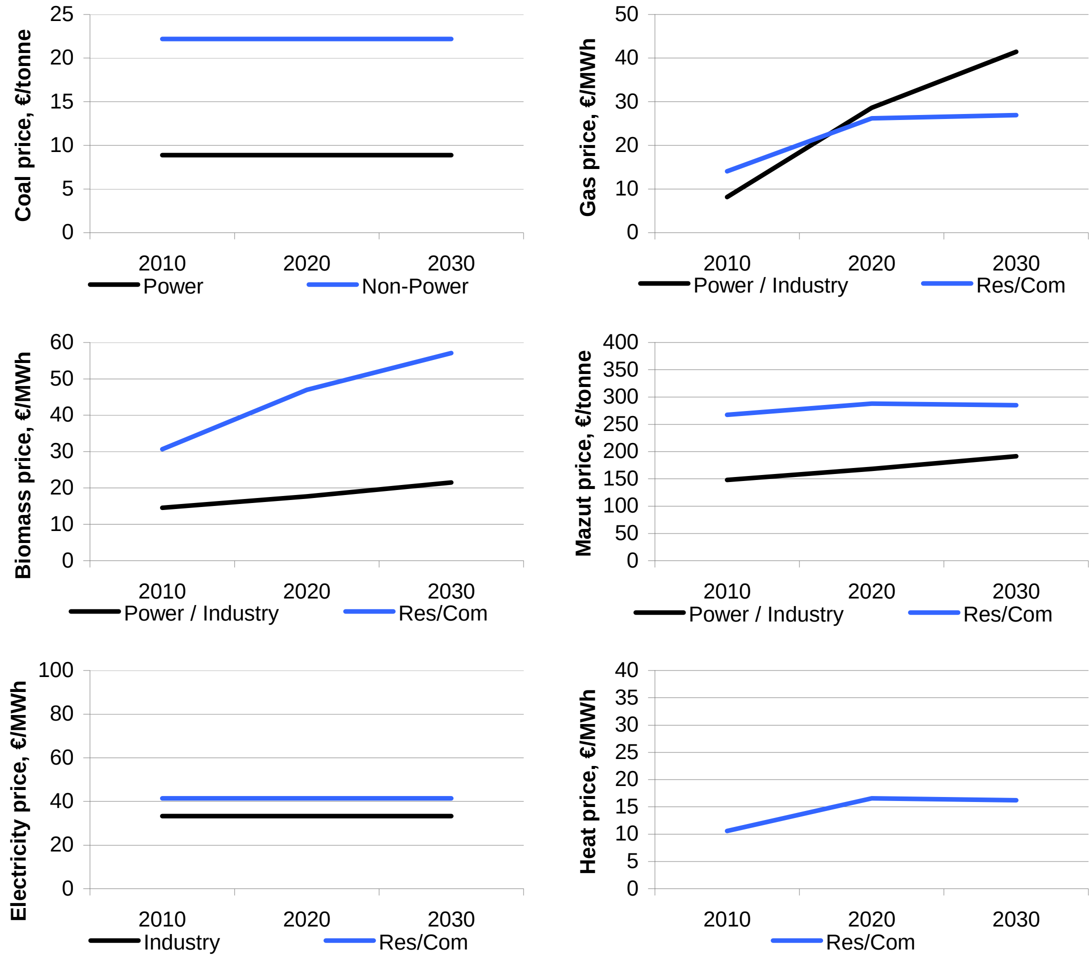
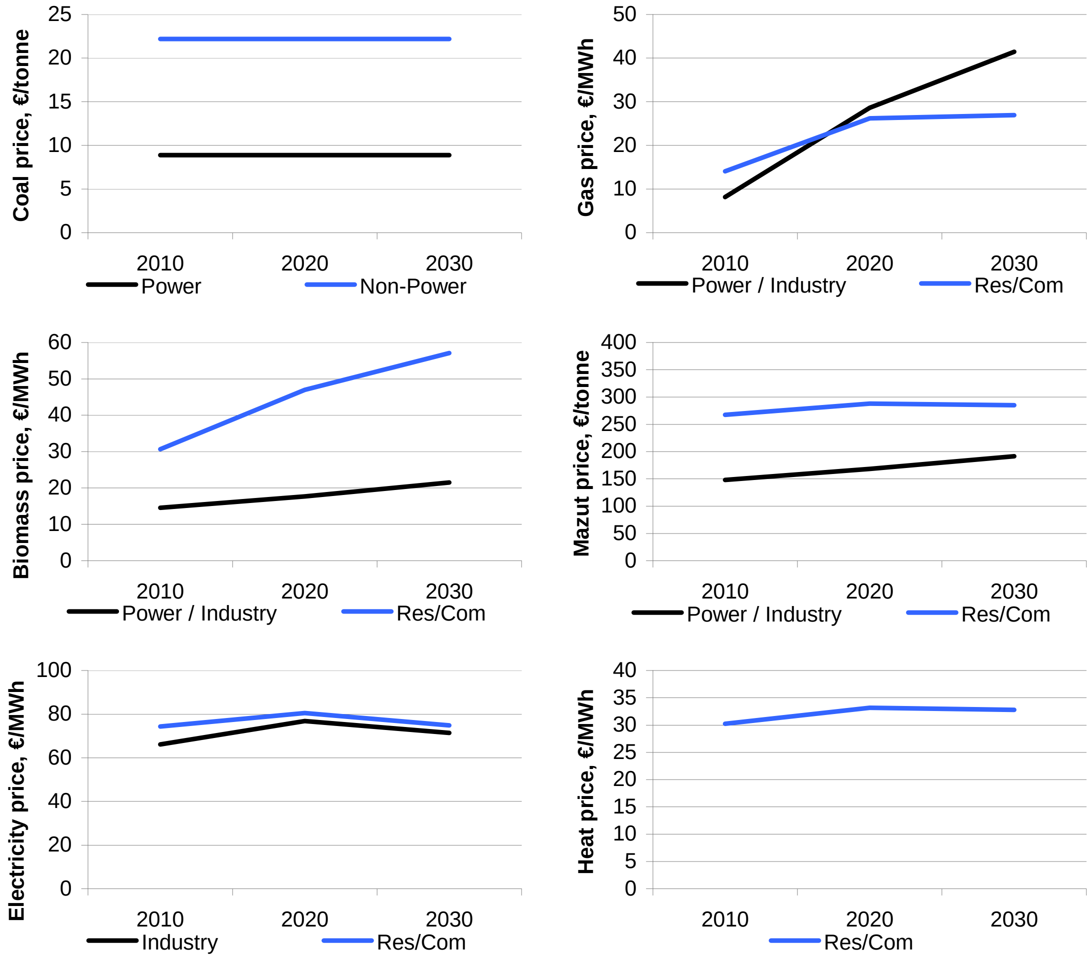


Figure C.4
Fuel Price Assumptions - Enhanced Policies



Appendix D. MAC Curve Data

This appendix provides the underlying data for the full MAC curves presented in the main body of the report.

Table D.1
Full MACC, Status Quo Policy, 2030

Sector	Description	Abatement (MtCO2)	Price (EUR)
District Heating	Gas/oil CHP rehabilitation - de-mothballing of existing, non-functional capacity	0.04	-300
Transport	Passenger Road transport (increased fuel efficiency, hybrid and electric vehicles)	6.82	-289
Power	CCGT Power (Upgraded existing plants)	1.04	-170
District Heating	New coal heat-only boiler, serving District Heating networks	5.28	-136
Industry	Oil refineries (energy management, improved process controls, pumps / motors / compressed air, waste heat recovery)	0.40	-125
Transport	Public transport (modernised buses)	0.92	-119
Industry	Ceramics (improved drying and firing)	0.06	-114
Industry	Ceramics (improved drying and firing)	0.07	-114
Transport	Freight Road transport (increased fuel efficiency, preventative maintenance)	3.26	-90
Waste	Municipal and Industrial wastewater treatment (flaring, waste treatment, anaerobic digestion), and Landfill Gas management (composting, waste treatment, energy generation).	0.04	-65
Power	Power Transmission and Distribution (improved monitoring, control and fault detection, reduced losses)	0.37	-44
Power	Power Transmission and Distribution (improved monitoring, control and fault detection, reduced losses)	0.30	-44
Industry	Efficient use of electricity in Industry - modern motors, variable speed drives, pumps, compressors.	1.64	-23
Industry	Efficient use of electricity in Industry - modern motors, variable speed drives, pumps, compressors.	1.63	-22
District Heating	New coal Combined Heat and Power (CHP), serving District Heating networks	1.06	-18
Industry	Steel (process improvements including coal moisture control, heat recovery, energy monitoring and management, hot blast stove automation)	1.85	-12
Industry	Steel (process improvements including coal moisture control, heat recovery, energy monitoring and management, hot blast stove automation)	0.59	-12
Industry	Lime (shell heat loss reduction, improved kiln combustion, process control)	0.45	-12
Industry	Lime (shell heat loss reduction, improved kiln combustion, process control)	1.94	-11
District Heating	New coal heat-only boiler, serving District Heating networks	0.76	-9
Industry	Cement (high clinker substitution, fuel switching and waste firing, kiln modernisation, process improvements)	1.18	-8
Industry	Cement (high clinker substitution, fuel switching and waste firing, kiln modernisation, process improvements)	4.30	-8
Industry	Ammonia (energy management, hydrogen recovery, low pressure synthesis, process improvements)	0.03	-6
O&G	Energy Efficiency measures in upstream Oil and Gas production: efficient pumps, motors, turbines, heaters and drives, measures to	1.35	-5

Sector	Description	Abatement (MtCO2)	Price (EUR)
	avoid pipeline fouling, and process controls including optimised pressure maintenance		
District Heating	Upgrade of coal Combined Heat and Power (CHP), serving District Heating networks	1.60	-5
Industry	Non-ferrous metals production: improved monitoring and targeting (copper), modern furnaces.	0.27	-3
Industry	Non-ferrous metals production: improved monitoring and targeting (copper), modern furnaces.	0.42	-3
District Heating	Upgrade of gas/oil heat-only boiler, serving District Heating networks	0.24	-
District Heating	Upgrade of coal Combined Heat and Power (CHP), serving District Heating networks	1.12	5
Industry	Steel (process improvements including coal moisture control, heat recovery, energy monitoring and management, hot blast stove automation)	11.43	7
District Heating	New coal Combined Heat and Power (CHP), serving District Heating networks	5.38	10
District Heating	Upgrade of gas/oil heat-only boiler, serving District Heating networks	0.91	12
Industry	Cement (high clinker substitution, fuel switching and waste firing, kiln modernisation, process improvements)	2.13	13
Transport	Passenger Road transport (increased fuel efficiency, hybrid and electric vehicles)	0.08	13
Industry	Bricks (improved drying and firing)	0.10	14
Industry	Ammonia (energy management, hydrogen recovery, low pressure synthesis, process improvements)	0.08	14
District Heating	Upgrade of coal heat-only boiler, serving District Heating networks	0.45	21
Industry	Efficient use of electricity in Industry - modern motors, variable speed drives, pumps, compressors.	1.64	23
Power	CCGT Power (Upgraded existing plants)	2.58	25
O&G	Reduction of natural gas flaring in Oil extraction industry	8.50	25
District Heating	New gas/oil heat-only boiler, serving District Heating networks	4.69	26
Industry	Lime (shell heat loss reduction, improved kiln combustion, process control)	1.71	29
Power	CCGT Power (Existing plants)	0.90	36
Waste	Municipal and Industrial wastewater treatment (flaring, waste treatment, anaerobic digestion), and Landfill Gas management (composting, waste treatment, energy generation).	2.45	39
Power	Power Transmission and Distribution (improved monitoring, control and fault detection, reduced losses)	0.43	40
Power	Hydroelectric power (small)	6.17	41
Transport	Freight Road transport (increased fuel efficiency, preventative maintenance)	0.58	68
Industry	Paper (waste heat recovery, process control and pinch analysis)	0.08	70
Industry	Non-ferrous metals production: improved monitoring and targeting (copper), modern furnaces.	6.34	71

Sector	Description	Abatement (MtCO2)	Price (EUR)
Power	Wind (High-quality sites)	11.23	74
Power	CCGT Power (New plants)	3.60	76
District Heating	New gas/oil heat-only boiler, serving District Heating networks	0.09	82
Industry	Oil refineries (energy management, improved process controls, pumps / motors / compressed air, waste heat recovery)	0.45	84
Buildings	Residential District Heating buildings: installation or retrofit of Building Level Substations and metering devices, heat controls, and energy efficiency measures (insulation, external cladding)	0.53	93
District Heating	District Heating networks upgrades: replacement with pre-insulated pipes or retrofitted insulation, burying of pipes underground, leakage reduction	1.64	98
Power	Wind (Medium-quality sites)	5.82	104
Industry	Cement (high clinker substitution, fuel switching and waste firing, kiln modernisation, process improvements)	1.54	107
Industry	Bricks (improved drying and firing)	0.04	119
Industry	Ammonia (energy management, hydrogen recovery, low pressure synthesis, process improvements)	0.03	137
Transport	Passenger Road transport (increased fuel efficiency, hybrid and electric vehicles)	0.15	141
Waste	Municipal and Industrial wastewater treatment (flaring, waste treatment, anaerobic digestion), and Landfill Gas management (composting, waste treatment, energy generation).	0.48	143
Power	Hydroelectric power (rehabilitation of currently non-functioning capacity)	2.58	143
Buildings	Commercial / Public District Heating buildings: installation or retrofit of Building Level Substations and metering devices, heat controls, and energy efficiency measures (insulation, external cladding)	1.06	147
Power	Solar PV power generation (Northern regions)	8.56	154
District Heating	Upgrade of gas/oil heat-only boiler, serving District Heating networks	0.09	155
Power	Hydroelectric power (large)	8.97	158
District Heating	District Heating networks upgrades: replacement with pre-insulated pipes or retrofitted insulation, burying of pipes underground, leakage reduction	0.65	166
Power	Coal power generation - Biomass co-firing	3.95	171
Transport	Freight Road transport (increased fuel efficiency, preventative maintenance)	0.30	171
Power	Wind (Low-quality sites)	6.44	174
Power	Coal Power (New plants)	0.18	179
Industry	Cement (high clinker substitution, fuel switching and waste firing, kiln modernisation, process improvements)	0.32	190
Industry	Oil refineries (energy management, improved process controls, pumps / motors / compressed air, waste heat recovery)	0.02	200

Table D.2
Full MACC, Planned Policies Scenario, 2030

Sector	Description	Abatement (tCO2)	Price (EUR)
District Heating	Gas/oil CHP rehabilitation - de-mothballing of existing, non-functional capacity	0.04	-300
Transport	Passenger Road transport (increased fuel efficiency, hybrid and electric vehicles)	6.82	-289
District Heating	New coal heat-only boiler, serving District Heating networks	3.78	-133
Power	Wind (High-quality sites)	7.90	-133
Industry	Oil refineries (energy management, improved process controls, pumps / motors / compressed air, waste heat recovery)	0.40	-125
Transport	Public transport (modernised buses)	0.92	-119
Industry	Ceramics (improved drying and firing)	0.06	-114
Industry	Ceramics (improved drying and firing)	0.07	-114
Power	CCGT Power (Upgraded existing plants)	0.45	-111
Transport	Freight Road transport (increased fuel efficiency, preventative maintenance)	3.26	-90
Waste	Municipal and Industrial wastewater treatment (flaring, waste treatment, anaerobic digestion), and Landfill Gas management (composting, waste treatment, energy generation).	0.04	-65
Power	Power Transmission and Distribution (improved monitoring, control and fault detection, reduced losses)	0.37	-44
Power	Power Transmission and Distribution (improved monitoring, control and fault detection, reduced losses)	0.30	-44
Industry	Efficient use of electricity in Industry - modern motors, variable speed drives, pumps, compressors.	1.64	-23
Industry	Efficient use of electricity in Industry - modern motors, variable speed drives, pumps, compressors.	1.63	-22
District Heating	New coal Combined Heat and Power (CHP), serving District Heating networks	1.76	-16
Industry	Steel (process improvements including coal moisture control, heat recovery, energy monitoring and management, hot blast stove automation)	1.85	-12
Industry	Steel (process improvements including coal moisture control, heat recovery, energy monitoring and management, hot blast stove automation)	0.59	-12
Industry	Lime (shell heat loss reduction, improved kiln combustion, process control)	0.45	-12
Industry	Lime (shell heat loss reduction, improved kiln combustion, process control)	1.94	-11
District Heating	New coal heat-only boiler, serving District Heating networks	2.23	-8
Industry	Cement (high clinker substitution, fuel switching and waste firing, kiln modernisation, process improvements)	1.18	-8
Industry	Cement (high clinker substitution, fuel switching and waste firing, kiln modernisation, process improvements)	4.30	-8
District Heating	New coal Combined Heat and Power (CHP), serving District Heating networks	1.65	-8

Sector	Description	Abatement (tCO_2)	Price (EUR)
Industry	Ammonia (energy management, hydrogen recovery, low pressure synthesis, process improvements)	0.03	-6
District Heating	Upgrade of coal Combined Heat and Power (CHP), serving District Heating networks	2.70	-5
O&G	Energy Efficiency measures in upstream Oil and Gas production: efficient pumps, motors, turbines, heaters and drives, measures to avoid pipeline fouling, and process controls including optimised pressure maintenance	2.70	-5
Industry	Non-ferrous metals production: improved monitoring and targeting (copper), modern furnaces.	0.27	-3
Industry	Non-ferrous metals production: improved monitoring and targeting (copper), modern furnaces.	0.42	-3
District Heating	Upgrade of gas/oil heat-only boiler, serving District Heating networks	0.79	-
Buildings	Commercial / Public District Heating buildings: installation or retrofit of Building Level Substations and metering devices, heat controls, and energy efficiency measures (insulation, external cladding)	1.32	-
Buildings	Residential District Heating buildings: installation or retrofit of Building Level Substations and metering devices, heat controls, and energy efficiency measures (insulation, external cladding)	3.18	-
District Heating	New coal Combined Heat and Power (CHP), serving District Heating networks	5.08	6
Industry	Steel (process improvements including coal moisture control, heat recovery, energy monitoring and management, hot blast stove automation)	11.43	7
District Heating	New coal heat-only boiler, serving District Heating networks	0.49	10
Industry	Cement (high clinker substitution, fuel switching and waste firing, kiln modernisation, process improvements)	2.13	13
Transport	Passenger Road transport (increased fuel efficiency, hybrid and electric vehicles)	0.08	13
Industry	Bricks (improved drying and firing)	0.10	14
Industry	Ammonia (energy management, hydrogen recovery, low pressure synthesis, process improvements)	0.08	14
District Heating	Upgrade of coal heat-only boiler, serving District Heating networks	0.74	15
Industry	Efficient use of electricity in Industry - modern motors, variable speed drives, pumps, compressors.	1.82	21
Power	CCGT Power (Upgraded existing plants)	3.03	22
O&G	Reduction of natural gas flaring in Oil extraction industry	17.00	25
District Heating	New gas/oil heat-only boiler, serving District Heating networks	4.00	26
Industry	Lime (shell heat loss reduction, improved kiln combustion, process control)	1.71	29
Power	CCGT Power (Existing plants)	0.90	36
Waste	Municipal and Industrial wastewater treatment (flaring, waste treatment, anaerobic digestion), and Landfill Gas management (composting, waste treatment, energy generation).	2.45	39
Power	Hydroelectric power (small)	5.58	41
Power	CCGT Power (New plants)	2.74	49

Sector	Description	Abatement (tCO2)	Price (EUR)
Power	Power Transmission and Distribution (improved monitoring, control and fault detection, reduced losses)	1.54	49
District Heating	District Heating networks upgrades: replacement with pre-insulated pipes or retrofitted insulation, burying of pipes underground, leakage reduction	10.38	62
Transport	Freight Road transport (increased fuel efficiency, preventative maintenance)	0.58	68
Industry	Paper (waste heat recovery, process control and pinch analysis)	0.08	70
Industry	Non-ferrous metals production: improved monitoring and targeting (copper), modern furnaces.	6.34	71
Power	Wind (High-quality sites)	0.01	73
Industry	Oil refineries (energy management, improved process controls, pumps / motors / compressed air, waste heat recovery)	0.45	84
Power	Wind (Medium-quality sites)	5.88	87
Power	Solar PV power generation (Northern regions)	8.56	100
Industry	Cement (high clinker substitution, fuel switching and waste firing, kiln modernisation, process improvements)	1.54	107
Power	Solar PV power generation (Southern regions)	1.42	114
Power	Hydroelectric power (rehabilitation of currently non-functioning capacity)	2.57	118
Industry	Bricks (improved drying and firing)	0.04	119
Power	Hydroelectric power (large)	8.97	124
Power	Coal Power (New plants)	0.27	128
District Heating	New coal heat-only boiler, serving District Heating networks	0.02	133
Power	Wind (Low-quality sites)	6.63	133
Industry	Ammonia (energy management, hydrogen recovery, low pressure synthesis, process improvements)	0.03	137
District Heating	Upgrade of gas/oil heat-only boiler, serving District Heating networks	0.15	138
District Heating	New coal Combined Heat and Power (CHP), serving District Heating networks	2.46	139
District Heating	New gas/oil heat-only boiler, serving District Heating networks	0.01	140
Transport	Passenger Road transport (increased fuel efficiency, hybrid and electric vehicles)	0.15	141
Power	Coal power generation - Biomass co-firing	4.09	142
Waste	Municipal and Industrial wastewater treatment (flaring, waste treatment, anaerobic digestion), and Landfill Gas management (composting, waste treatment, energy generation).	0.48	143
Transport	Freight Road transport (increased fuel efficiency, preventative maintenance)	0.30	171
Industry	Cement (high clinker substitution, fuel switching and waste firing, kiln modernisation, process improvements)	0.32	190
District Heating	District Heating networks upgrades: replacement with pre-insulated pipes or retrofitted insulation, burying of pipes underground, leakage reduction	0.03	193
Industry	Oil refineries (energy management, improved process controls,	0.02	200

Sector	Description	Abatement (tCO2)	Price (EUR)
	pumps / motors / compressed air, waste heat recovery)		
District Heating	Upgrade of gas/oil heat-only boiler, serving District Heating networks	0.04	200

Table D.3
Full MACC, Enhanced Policies Scenario, 2030

Sector	Description	Abatement (tCO2)	Price (EUR)
Power	Solar PV power generation (Southern regions)	1.38	-300
Transport	Passenger Road transport (increased fuel efficiency, hybrid and electric vehicles)	6.84	-283
District Heating	New coal heat-only boiler, serving District Heating networks	3.96	-173
Industry	Oil refineries (energy management, improved process controls, pumps / motors / compressed air, waste heat recovery)	0.52	-165
Industry	Ceramics (improved drying and firing)	0.06	-161
Industry	Ceramics (improved drying and firing)	0.07	-161
Power	CCGT Power (Upgraded existing plants)	0.79	-148
Power	Solar PV power generation (Northern regions)	8.32	-145
Transport	Public transport (modernised buses)	0.92	-142
Power	Wind (High-quality sites)	16.46	-118
Transport	Freight Road transport (increased fuel efficiency, preventative maintenance)	3.37	-95
Power	Wind (Medium-quality sites)	8.22	-95
Power	CCGT Power (New plants)	2.22	-82
Industry	Efficient use of electricity in Industry - modern motors, variable speed drives, pumps, compressors.	2.37	-70
Industry	Efficient use of electricity in Industry - modern motors, variable speed drives, pumps, compressors.	2.66	-70
District Heating	New coal Combined Heat and Power (CHP), serving District Heating networks	2.63	-57
Power	Power Transmission and Distribution (improved monitoring, control and fault detection, reduced losses)	1.14	-55
Industry	Lime (shell heat loss reduction, improved kiln combustion, process control)	2.58	-52
Industry	Lime (shell heat loss reduction, improved kiln combustion, process control)	1.18	-52
Industry	Steel (process improvements including coal moisture control, heat recovery, energy monitoring and management, hot blast stove automation)	0.64	-52
Buildings	Residential District Heating buildings: installation or retrofit of Building Level Substations and metering devices, heat controls, and energy efficiency measures (insulation, external cladding)	3.21	-50
Power	Power Transmission and Distribution (improved monitoring, control and fault detection, reduced losses)	1.06	-49
Industry	Ammonia (energy management, hydrogen recovery, low pressure synthesis, process improvements)	0.01	-49
District Heating	New coal Combined Heat and Power (CHP), serving District Heating networks	1.65	-48
Industry	Cement (high clinker substitution, fuel switching and waste firing, kiln modernisation, process improvements)	2.15	-46

Sector	Description	Abatement (tCO2)	Price (EUR)
Industry	Cement (high clinker substitution, fuel switching and waste firing, kiln modernisation, process improvements)	5.43	-46
District Heating	New gas/oil heat-only boiler, serving District Heating networks	0.31	-46
O&G	Energy Efficiency measures in upstream Oil and Gas production: efficient pumps, motors, turbines, heaters and drives, measures to avoid pipeline fouling, and process controls including optimised pressure maintenance	2.70	-45
Industry	Non-ferrous metals production: improved monitoring and targeting (copper), modern furnaces.	0.62	-45
Industry	Steel (process improvements including coal moisture control, heat recovery, energy monitoring and management, hot blast stove automation)	13.62	-43
Industry	Ammonia (energy management, hydrogen recovery, low pressure synthesis, process improvements)	0.10	-41
Power	Hydroelectric power (small)	5.85	-33
District Heating	Upgrade of coal heat-only boiler, serving District Heating networks	0.80	-33
Industry	Paper (waste heat recovery, process control and pinch analysis)	0.02	-29
District Heating	New gas/oil heat-only boiler, serving District Heating networks	6.07	-28
Industry	Bricks (improved drying and firing)	0.05	-26
Industry	Bricks (improved drying and firing)	0.01	-26
District Heating	Upgrade of gas/oil heat-only boiler, serving District Heating networks	0.75	-23
Waste	Municipal and Industrial wastewater treatment (flaring, waste treatment, anaerobic digestion), and Landfill Gas management (composting, waste treatment, energy generation).	0.23	-19
O&G	Reduction of natural gas flaring in Oil extraction industry	17.00	-15
Industry	Non-ferrous metals production: improved monitoring and targeting (copper), modern furnaces.	3.34	-15
Waste	Municipal and Industrial wastewater treatment (flaring, waste treatment, anaerobic digestion), and Landfill Gas management (composting, waste treatment, energy generation).	0.14	-10
District Heating	District Heating networks upgrades: replacement with pre-insulated pipes or retrofitted insulation, burying of pipes underground, leakage reduction	0.81	-6
District Heating	District Heating networks upgrades: replacement with pre-insulated pipes or retrofitted insulation, burying of pipes underground, leakage reduction	6.22	-6
Buildings	Commercial / Public District Heating buildings: installation or retrofit of Building Level Substations and metering devices, heat controls, and energy efficiency measures (insulation, external cladding)	1.32	-0
District Heating	Upgrade of coal Combined Heat and Power (CHP), serving District Heating networks	1.85	-
Power	Wind (Low-quality sites)	8.84	10
District Heating	New gas/oil heat-only boiler, serving District Heating networks	0.20	15
Buildings	Residential District Heating buildings: installation or retrofit of Building Level Substations and metering devices, heat controls, and energy efficiency measures (insulation, external cladding)	0.96	20

Sector	Description	Abatement (tCO2)	Price (EUR)
Waste	Municipal and Industrial wastewater treatment (flaring, waste treatment, anaerobic digestion), and Landfill Gas management (composting, waste treatment, energy generation).	2.10	23
Industry	Paper (waste heat recovery, process control and pinch analysis)	0.06	24
Industry	Non-ferrous metals production: improved monitoring and targeting (copper), modern furnaces.	3.62	27
Industry	Efficient use of electricity in Industry - modern motors, variable speed drives, pumps, compressors.	0.05	27
Power	Power Transmission and Distribution (improved monitoring, control and fault detection, reduced losses)	0.14	30
Power	Nuclear power	12.54	31
Buildings	Commercial / Public District Heating buildings: installation or retrofit of Building Level Substations and metering devices, heat controls, and energy efficiency measures (insulation, external cladding)	1.15	31
District Heating	District Heating networks upgrades: replacement with pre-insulated pipes or retrofitted insulation, burying of pipes underground, leakage reduction	5.31	31
Power	Solar PV power generation	0.33	32
Industry	Cement (high clinker substitution, fuel switching and waste firing, kiln modernisation, process improvements)	1.45	39
Power	CCGT Power (New plants)	2.88	49
Industry	Oil refineries (energy management, improved process controls, pumps / motors / compressed air, waste heat recovery)	0.26	54
District Heating	New coal Combined Heat and Power (CHP), serving District Heating networks	0.01	56
Industry	Bricks (improved drying and firing)	0.04	60
Power	Hydroelectric power (rehabilitation of currently non-functioning capacity)	2.41	63
Power	CCGT Power (Existing plants)	0.03	70
Industry	Ammonia (energy management, hydrogen recovery, low pressure synthesis, process improvements)	0.03	72
Power	Hydroelectric power (large)	8.50	72
District Heating	New gas/oil heat-only boiler, serving District Heating networks	0.05	72
Power	Coal Power (New plants)	1.66	81
Transport	Passenger Road transport (increased fuel efficiency, hybrid and electric vehicles)	0.16	84
Power	Coal power generation - Biomass co-firing	0.93	94
District Heating	New coal Combined Heat and Power (CHP), serving District Heating networks	1.67	103
Transport	Freight Road transport (increased fuel efficiency, preventative maintenance)	1.05	104
District Heating	New gas/oil heat-only boiler, serving District Heating networks	0.02	104
Waste	Municipal and Industrial wastewater treatment (flaring, waste treatment, anaerobic digestion), and Landfill Gas management (composting, waste treatment, energy generation).	0.50	125

Sector	Description	Abatement (tCO2)	Price (EUR)
Buildings	Residential District Heating buildings: installation or retrofit of Building Level Substations and metering devices, heat controls, and energy efficiency measures (insulation, external cladding)	13.67	133
District Heating	District Heating networks upgrades: replacement with pre-insulated pipes or retrofitted insulation, burying of pipes underground, leakage reduction	0.06	165
Industry	Bricks (improved drying and firing)	0.01	167
Transport	Passenger Road transport (increased fuel efficiency, hybrid and electric vehicles)	0.04	171
District Heating	Upgrade of gas/oil heat-only boiler, serving District Heating networks	0.20	175
Industry	Cement (high clinker substitution, fuel switching and waste firing, kiln modernisation, process improvements)	1.13	179
Power	CCGT Power (New plants)	0.25	179
District Heating	New coal Combined Heat and Power (CHP), serving District Heating networks	0.01	189
Buildings	Commercial / Public District Heating buildings: installation or retrofit of Building Level Substations and metering devices, heat controls, and energy efficiency measures (insulation, external cladding)	1.06	191
Industry	Lime (shell heat loss reduction, improved kiln combustion, process control)	0.01	192
District Heating	New coal Combined Heat and Power (CHP), serving District Heating networks	0.12	194

NERA Economic Consulting
15 Stratford Place
London W1C 1BE
United Kingdom
Tel: +44 20 7659 8500
Fax: +44 20 7659 8501
www.nera.com

NERA UK Limited, registered in England and Wales, No 3974527
Registered Office: 15 Stratford Place, London W1C 1BE