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Technology Roadmap

For a sustainable low-carbon future of the Kazakhstan cement industry

Technology Roadmap: For a sustainable low-carbon future of the Kazakhstan cement industry

For the European Bank for Reconstruction and Development

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Authors:
Jelmer Hoogzaad
Jürgen Wiesmann
Inna Lissova
Michael Clark

Partner organisations:
IETA
WBCSD

Climate Focus
Sarphatikade 13
1017 WV Amsterdam,
The Netherlands

GreenStream

Whitehopleman

ENECO SOLUTIONS
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Abbreviations

AB 32	Assembly Bill 32
AF	Alternative Fuels
APCR	Allowances Price Containment Reserve
BAT	Best Available Technology
BAU	Business-As-Usual
BMU	German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety
CSI	Cement Sustainability Initiative
EBRD	European Bank for Reconstruction and Development
ECRA	European Cement Research Academy
EN	European Norm
EPC	Emissions Performance Credits
ERU	Emission Reduction Unit
ETS	Emission Trading Scheme
EU	European Union
EU ETS	European Emission Trading Scheme
EUR	European Euro
CAD	Canadian Dollar
CANACEM	Cámara Nacional del Cemento, Mexico's national chamber of cement companies
CER	Certified Emission Reduction
CO_2	Carbon Dioxide, a greenhouse gas
CSCF	Cross-Sectoral Correction Factor
CSI	Cement Sustainability Initiative
FSU	Former Soviet Union
GDP	Gross Domestic Product
GHG	Greenhouse gas
GJ	Giga Joule
HFC_{23}	Fluoroform, a greenhouse gas
IEA	International Energy Agency
IETA	International Emissions Trading Association
IFI	International Financial Institutions
IMF	International Monetary Fund
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
ISO	International Organization for Standardization
JI	Joint Implementation
Kaz ETS	Emission Trading Scheme in Kazakhstan
KCCMP	Kazakhstan Climate Change Mitigation Programme
kg	kilogram
KZT	Kazakhstan Tenge
MJ	Mega Joule
MRV	Measurement, Reporting and Verification
MWh	Megawatt-hour

Abbreviations

NAMA	Nationally Appropriate Mitigation Action
N_2O	Nitrous Oxide, a greenhouse gas
NAP	National Allocation Plan
NER	New Entrants Reserve
NO_x	Nitrogen oxides, consist of nitric oxide (NO), nitrogen dioxide (NO2) and nitrous oxide (N2O), which can cause acid rain, climate change and smog
OECD	Organisation for Economic Co-operation and Development
PETER	Partnership for Emissions Trading in the EBRD Region
PFC	Perfluorocarbons, a group of greenhouse gasses
PMR	Partnership for Market Readiness
RDF	Refuse-Derived Fuel
RE	Renewable Energy
SEMARNAT	Secretaría de Medio Ambiente y Recursos Naturales (Mexican state secretariat for environment and natural resources)
SGER	Specified Gas Emitters Regulation
SO_x	Sulphur Oxides, including SO_2 and SO_3 which can cause acid rain
t	tonne
t/d	tonnes per day
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Aid
USD	United States Dollar
WBCSD	World Business Council for Sustainable Development
WHR	Waste Heat Recovery

1. Executive Summary

1.1 Background

At the request of the Kazakhstan Association of Cement and Concrete Producers (the Association) the European Bank for Reconstruction and Development (EBRD) has taken the initiative to identify the policy and technology actions which are needed to secure a low-carbon future for the cement industry in Kazakhstan. The present document lays out a technology roadmap for low-carbon development of the cement sector in Kazakhstan. The roadmap is based on intensive consultation with experts and stakeholders, including workshops which took place on 24 November 2015 and 30 June 2016 in Astana and in which the majority of cement companies in Kazakhstan were represented. The document is accompanied by a separate Policy Roadmap which identifies the policy measures that are needed to align the regulatory framework with the Technology Scenarios.

1.2 Scenario Development

As part of the Technology Roadmap four scenarios were developed. The first is a "Business-as-Usual" (BAU) scenario that is based on the current situation and the continued application of existing policies. Without new incentives to mitigate GHG emissions cement plants would rely on existing technologies, and improvements in the carbon intensity would depend on the further spread of technologies that have already been proven commercially viable. In addition, there are three scenarios, representing a "Slow", "Medium" and "Rapid" transition to a low-carbon cement sector. They assume different levels of carbon mitigation effort from the cement companies, driven by an implicit price of carbon, while energy prices are assumed to stay at current levels. As a general rule, in the "Slow", "Medium" and "Rapid" scenarios we would expect companies to undertake mitigation actions with abatement cost of up to €10/t CO_2, €20/t CO_2, and €30/t CO_2, in the three scenarios, respectively. Relevant mitigation actions include investing in the modernisation of existing capacity, replacing outdated production lines, switching to less carbon intensive fuels, and substituting clinker with less carbon intensive materials. The quantified scenarios take into account the expected financial return of these investments, the status quo of the Kazakh cement industry, existing regulatory barriers as well as the availability of alternative raw materials and fuels.

1.2.1 Business-As-Usual (BAU) Scenario

Even under the BAU scenario there will be considerable improvement in energy efficiency as the last remaining wet kilns are being replaced by dry cement technology. This allows these modernized plants to reduce their thermal energy consumption from 7.2 GJ/t clinker to around 4 GJ/t clinker by 2030 while new plants would reach around 3.35 GJ/t clinker.

Five cement plants have been commissioned in recent years, and they are all using dry cement technology. Their performance is close to Best Available Technology (BAT) in terms of the energy efficiency per tonne of clinker, which is around 3.25 GJ/t clinker. One can expect that the bulk of the transition will be successfully completed by 2025, with wet kilns only used as standby .in case of excess demand. The resulting weighted average kiln thermal energy consumption for all cement kilns in Kazakhstan is expected to be 3.62 GJ/t of clinker. Other than the transition to dry cement technology, no major capital investments to reduce CO_2 emissions are envisaged with the BAU scenario.

Table 1: Key Performance Indicators for the BAU Scenario

Year	2011-13	2020	2025	2030
% clinker	82%	82%	82%	82%
% alternative fuels	0%	0%	0%	0%
of which biomass	0%	0%	0%	0%
GJ kiln fuel / t clinker	5.32	4.10	3.80	3.62
kg CO_2 / t cement	964	747	720	707
kg CO_2 / t clinker	1026	911	882	865

Apart from replacing the wet lines, the BAU scenario assumes little change on the other carbon reduction levers. Under the BAU scenario the kilns would continue to be fired with the current fuel mixture of predominantly coal, which has a significant cost advantage. Natural gas would only be used at one plant, which has special circumstances. There are almost no waste-derived fuels or biomass-based fuels currently used, as high-quality and price competitive alternative fuels are not yet available. It would take significant investments in waste collection, sorting, drying and logistics to make waste-derived fuels a feasible alternative.

At present, clinker substitution is already implemented at percentages that are within reach of the global averages. In the BAU scenario the clinker content of cement would be maintained around the current levels of 82% by most plants. There are barriers both in terms of available quality of substitutes, transportation costs, construction norms as well as acceptability by construction companies that need to be overcome to further increase the use of clinker substitutes.

In the BAU scenario there would be a 5% improvements in electrical efficiency by 2030, reaching an average of 114 kWh/t cement. The renewable energy share would be expected to stay at the current 12% and the emission factor for grid-based electricity including emissions associated with transmission and distribution losses would remain at 123 kg CO_2/MWh.

Under the BAU scenario the cement sector’s 2030 GHG emissions are 73% higher than its 2011-13 emissions. This is far more than the 12% increase envisioned for the overall economy in Kazakhstan’s Intended Nationally Determined Contribution (INDC).

1.2.2 Slow Scenario

Under the ”Slow” scenario, the replacement of the remaining wet kilns can be expected to proceed quicker and be fully completed by 2025. The modernized cement plants would reduce their thermal energy consumption to ~3.75 GJ/t of clinker by 2030 by more concerted optimization efforts, while the new plants would reach around 3.35 GJ/t clinker. As a result, the weighted average kiln thermal energy consumption for all cement kilns in Kazakhstan is expected to be 3.53 GJ/t of clinker. A gradual increase in clinker substitution can be expected and the overall weighted average clinker content of cement in 2030 will be 80%. The fuel mix will change slightly as pilots for alternative fuel use from municipal and industrial waste are implemented. All cement plants are expected to be burning 1% alternative fuels by 2020 and 2% by 2025. Only minor capital investments of <€1 million per cement plant are envisaged with this “Slow” scenario. Co-combusting alternative fuels at these percentages will not require any major modifications or capital investments in the plants.

In the "Slow" scenario there would be a 10% improvements in electrical efficiency by 2030, reaching an average of 108 kWh/t cement. The renewable energy share would be expected to increase by 4% to 16% and the emission factor for grid-based electricity including emissions associated with transmission and distribution losses would remain at 100 kg CO_2/MWh.

Under the "Slow" scenario the cement sector's 2030 GHG emissions are 66% higher than its 2011-13 emissions. This is far more than the 12% increase envisioned for the overall economy in Kazakhstan's INDC. The improvement versus the BAU scenario is 4%, much less than the 32% improvement envisioned in the INDC.

Table 2: Key Performance Indicators for the "Slow" Scenario

Year	2011-13	2020	2025	2030
% clinker	82%	81%	80%	80%
% alternative fuels	0%	1%	1.5%	2.0%
of which biomass	0.0%	0%	0%	0%
GJ kiln fuel / t clinker	5.32	4.06	3.68	3.53
kg CO_2 / t cement	964	736	699	680
kg CO_2 / t clinker	1026	905	869	853
CO_2 Savings vs. BAU 1000 t CO_2 per year	-/-	149	303	429

1.2.3 Medium Scenario

Under the "Medium" scenario, the bulk of the wet kilns is expected to be phased out by 2020, so that wet plants will only be operated on a stand-by basis thereafter. The modernized cement plants are expected to reduce their thermal energy consumption to approx. 3.5 GJ/t of clinker by 2030 by even more concerted optimization efforts, while the new plants are expected to reach 3.25 GJ/t clinker. As a result, the weighted average kiln thermal energy consumption for all cement kilns in Kazakhstan is expected to be 3.35 GJ/t of clinker, which is close to the Best Available Technology. In the medium scenario, we expect pilot schemes for the use for waste-derived fuels to commence before 2020 in cooperation with municipalities that are located close to the cement plants. All cement plants are expected to be burning 3% alternative fuels by 2020, 9% by 2025 and 18% by 2030. Capital investments of €5~€10 million per plant are envisaged for the necessary receiving storage and dosing systems. Cement companies would also have to modify their kilns to extend the residence time in their precalciners and install bypasses at the kiln inlet to allow the burning of lower calorific value and higher chloride content alternative fuels derived from municipal waste. These modifications of the kilns are likely to require capital investments of €5~€10 million per kiln. Total additional investments would therefore amount to €10-20 million per kiln. National standards and specifications for cement would be modified to encourage cement companies to reduce their clinker content of cement more aggressively. The overall weighted average clinker content of cement in 2030 will be 74.5%.

In the "Medium" scenario there would be a 15% improvements in electrical efficiency by 2030, reaching an average of 102 kWh/t cement. The renewable energy share would be expected to increase gradually to 20% and the emission factor for grid-based electricity, including emissions associated with transmission and distribution losses, would hence decrease to 98 kg CO_2/MWh.

Under the "Medium" scenario the cement sector's 2030 GHG emissions are 48% higher than its 2011-13 emissions. This is far more than the 12% increase envisioned for the overall economy in Kazakhstan's INDC. The improvement versus the BAU scenario is 14.2%, less than half of the 32% improvement envisioned in the INDC.

Table 3: Key Performance Indicators for the "Medium" Scenario

Year	2011-13	2020	2025	2030
% clinker	82%	80%	77%	75%
% alternative fuels	0%	3%	9%	18%
of which biomass	0.0%	1%	3%	7%
GJ kiln fuel / t clinker	5.32	3.87	3.62	3.35
kg CO_2 / t cement	964	704	658	604
kg CO_2 / t clinker	1026	879	850	810
CO_2 Savings vs. BAU 1000 t CO_2 per year	-/-	514	851	1460

1.2.4 Rapid Scenario

Under the "Rapid" scenario one can expect progress to be quicker as supportive policies are implemented with urgency and ambition. By 2020 wet kilns would be expected to be fully replaced and the modernized cement plants would eventually reduce their thermal energy consumption to BAT levels of ~3.25 GJ/t of clinker by 2030, the same as the new cement plants. At the same time supportive changes in construction norms and campaigns to change cement user attitudes towards blended cement would be implemented to prepare the ground for further clinker substitution after 2020. The modified national standards for cement would be encouraging cement companies to reduce their clinker content of cement more aggressively. The overall weighted average clinker content of cement in 2030 will be 70%.

Pilots for waste and biomass fuels would be implemented even before 2020 thus laying the groundwork for a sustained expansion of alternative fuels afterwards. All cement plants are expected to be burning 5% alternative fuels by 2020, 18% by 2025 and 30% by 2030. Capital investments of €10~€15 million per plant are envisaged for the necessary receiving storage and dosing systems. Investments would also continue to modify kilns with the installation of gasifiers and the deployment of techniques such as the oxygen enrichment of combustion to allow higher levels of alternative fuel burning. These kiln modifications would increase the capital expenditure requirements for kiln modifications to €10~€20 million per kiln. Total additional investments would therefore amount to €20-35 million per kiln. A natural gas distribution network of pipelines would be developed to encourage cement kilns in the Western and Southern regions to be fired with natural gas. By 2030 half of the kilns in Kazakhstan would be co-fired with natural gas with cement factories demanding to be connected to the gas distribution network.

Cement companies would be competing to secure sources of decarbonated raw materials such as steel and other metallurgical slags. These would have displaced 2% of the calcination CO_2 emissions of the Kazakh cement industry by 2020, 5% of the calcination CO_2 emissions by 2025 and 10% of the calcination CO_2 emissions by 2030. Cement kilns would be modified to allow the feeding of such decarbonated alternative raw materials directly to the inlet of kilns entailing additional capital expenditure of €5~€10 million per kiln.

In the "Rapid" scenario there would be a 30% improvements in electrical efficiency by 2030, reaching an average of 84 kWh/t cement. The improvement versus the "Medium" scenario would largely be due to several waste heat recovery projects for electricity production. The renewable energy share would be expected to increase gradually to 30% and the emission factor for grid-based electricity, including emissions associated with transmission and distribution losses, would hence decrease to 89 kg CO_2/MWh.

Under the "Rapid" scenario the cement sector's 2030 GHG emissions are 23% higher than its 2011-13 emissions. This about twice the 12% increase envisioned for the overall economy in Kazakhstan's INDC. The improvement versus the BAU scenario is 28.6%, close to the 32% improvement envisioned in the INDC.

Table 4: Key Performance Indicators for the “Rapid” Scenario

Year	2011-13	2020	2025	2030
% clinker	82%	79%	75%	70%
% alternative fuels	0%	5%	18%	30%
of which biomass	0.0%	2%	6%	12%
GJ kiln fuel / t clinker	5.32	3.59	3.34	3.25
kg CO_2 / t cement	964	663	578	500
kg CO_2 / t clinker	1,026	839	772	711
CO_2 Savings vs. BAU 1000 t CO_2 per year	-/-	978	1,900	3,043

1.3 Kazakhstan’s International Climate Policy Targets

The Intended Nationally Determined Contribution (INDC) that Kazakhstan submitted to the UNFCCC in the run-up to the 2015 Paris Climate Conference includes the following targets :

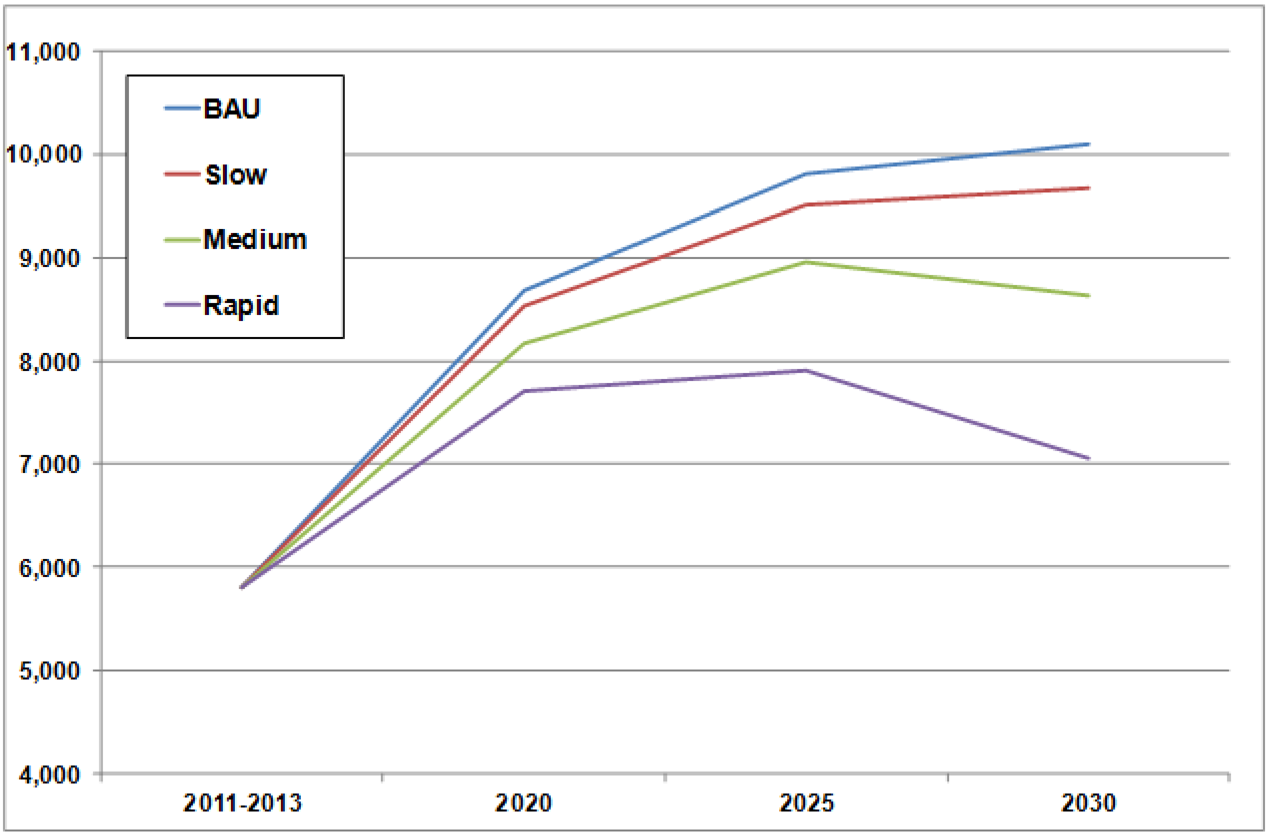
- An unconditional target of a 15% reduction in GHG emissions by 31 December 2030 compared to the base year of 1990. This amounts to a 22-34% reduction in GHG emissions by 2030 compared to BAU projected emissions.
- A conditional target of a 25% reduction in GHG emissions by 31 December 2030 compared to the base year of 1990. The additional 10% reduction is subject to Kazakhstan receiving international support in the form of climate finance, technology transfer and capacity building. The target amounts to a 32% reduction in GHG emissions by 2030 compared to BAU projected emissions.

In 2012 the cement industry accounted for 5.8 million t CO_2 or 2.2% of the total. Under the INDC Kazakhstan’s GHG emissions are allowed to increase 12% between 2012 and 2030, i.e. to 304 million t CO_2. For the cement industry a 12% increase would put the sector’s GHG emissions at approx. 6.7 million t CO_2. Given the expected production increase of approx. 90% until 2030, it is difficult for the cement sector to stay within these limits. The BAU scenario exceeds this limit by 50% and even the “Medium” and “Rapid” scenarios exceed the limit by 28% and 7%, respectively.

Kazakhstan’s INDC also states that the unconditional target amounts to a 22%-34% emission reduction compared with the BAU scenario in 2030. For the cement industry, only the “Rapid” scenario generates a comparable reduction with 30%. A major reason for this is that the BAU scenario for the cement industry already includes a significant improvement of specific GHG emissions over time. 2030 specific GHG emissions per tonne of cement in the BAU scenario are about 13% lower than average 2011-2013 emissions.

Therefore, the more ambitious “Rapid” scenario would be more aligned with the UNFCCC’s 2°C goal. Such a low-carbon pathway would demand a higher level of commitment and ambition than is implied by the introduction of the Policy Roadmap’s recommendations. It would also put Kazakhstan in a better position to mobilise the support needed from the international community to implement the Low- Carbon Roadmap, as well as other mitigation efforts under its NDC.

Figure 1: Scenarios for a sustainable low-carbon future for Kazakhstan's cement industry



2. Background

2.1 Objectives of the Assignment

At the request of the Kazakhstan Association of Cement and Concrete Producers (the Association) the European Bank for Reconstruction and Development (EBRD) has taken the initiative to identify the policy and technology actions which are needed to secure a low-carbon future for the cement industry in Kazakhstan.

The project aims to support the Association in particular, and the cement sector in Kazakhstan in general, in its policy dialogue with the government. The EBRD has mandated a consortium of Climate Focus, Greenstream, Whitehopleman and Eneco Solutions ("the Consortium") to carry out this work in close partnership with the International Emissions Trading Association (IETA) and the World Business Council for Sustainable Development (WBCSD). Both organisations have been consulted throughout the project.

This document describes a technology roadmap for low-carbon development of the cement sector in Kazakhstan. The Roadmap analyzes the existing situation with greenhouse gas emissions in the cement sector. On this basis, it develops a business-as-usual scenario for the sector's emissions through the year 2030, which is complemented by three scenarios, representing a slow, a medium and a rapid transformation of the sector towards low-carbon intensity. The scenarios are driven by sets of technology actions implemented in the periods 2016-2020, 2021-2025 and 2026-2030. For each of the scenarios the investment costs and required policy measures are listed, and the impact of changes in energy prices, carbon prices and transportation costs on the scenarios is discussed.

This Technology Roadmap complements a separate Policy Roadmap, which analyzes the existing policy framework, studies best practices from other countries and puts forward a set of sequenced policy actions to drive the sector towards low-carbon development.

2.2 Data & Methodology

The roadmap is based on intensive consultations with representatives of Kazakhstan's cement industry, relevant policy makers, technical experts and other stakeholders. The project team conducted several interviews and held two stakeholder consultation workshops in Astana on 24 November 2015 and on 30 June 2016.

The baseline for GHG emissions in Kazakhstan's cement sector is based on plant-level data for the years 2011-2013. The data included information from the GHG inventories of the plants that are participating in the Kazakhstan Emissions Trading System (ETS) as well as responses to questionnaires that were answered for 50% of the participating cement plants. The calculation of the GHG emissions followed to the extent possible the protocol developed by the Cement Sustainability Initiative (CSI) of the World Business Council for Sustainable Development (WBCSD).[1] The data set's limitations required the use of default values as well as plausible

[1] CSI. CO_2 and Energy Accounting and Reporting Standard for the Cement Industry. The Cement CO_2 and Energy Protocol. Version 3.0. May 2011.

assumptions based on the experience from other cement plants in order to fill in for unavailable data.

As part of the Technology Roadmap four scenarios were developed. These include a “Business-as-Usual” (BAU) scenario and three additional scenarios, representing a “Slow”, “Medium” and “Rapid” transition to a low-carbon cement sector. While the BAU scenario is based on the continued application of existing policies, the “Slow”, “Medium” and “Rapid” scenarios consider mitigation actions with abatement cost of up to €10/tCO_2, €20/tCO_2, and €30/tCO_2, respectively. The quantified scenarios consider the expected financial return of these investments, the existence of regulatory barriers as well as the availability of alternative raw materials and fuels.

In developing this roadmap, the project team has reviewed the Technology Roadmap developed in 2009 by the CSI in cooperation with the International Energy Agency (IEA). The roadmap lays out medium and long-term scenarios through 2050 for the energy intensity and carbon emissions of the global cement industry. Of particular relevance are the key performance indicators which constitute a point of reference and comparison for the present roadmap. To identify the most promising mitigation actions under each scenario, the project team has reviewed the five “state-of-the-art” papers and 33 technology papers that were commissioned by the WBCSD and developed by the European Cement Research Academy (ECRA).[2] The papers identify, describe and evaluate technologies that are able to increase energy efficiency and reduce GHG emissions at present as well as in the medium and long-term future. They evaluate the mitigation potential and the costs of relevant technologies as well as the potential barriers that may prevent their application. To ensure that the scenarios give a plausible view on the mitigation actions to be implemented in Kazakhstan’s cement industry, the project team conducted a large number interviews with representatives from cement companies, policy makers, technical experts and other stakeholders.

[2] European Cement Research Academy: Development of State of the Art-Techniques in Cement Manufacturing – Trying to Look Ahead (CSI/ECRA – Technology Papers).Düsseldorf, Geneva 2009. In line with the terms of reference for this project technologies 29 to 33, which are related to carbon capture and storage, are not considered.

2.3 Status of Kazakhstan's Cement Industry

Table 5: Cement companies and plants in Kazakhstan

Company	Plants	Region	Capacity in 2015 (Mt clinker / year)	Wet / Dry
Heidelberg	Vostok / Bukhtarma	East Kazakhstan	1.3	Wet
	Caspi Cement	Mangystau	1.0	Dry
Standard	Standard Cement	South Kazakhstan	1.2	Dry
Steppe	Central Asia Cement	Karagandy	0.8	Wet, On Standby
	KarCement	Karagandy	2.2	Dry
Kazakh	Sastobe Cement	South Kazakhstan	0.5	Wet
	Kazakh Cement	East Kazakhstan	1.0	Dry
Italcementi	Shymkent Cement	South Kazakhstan	1.0	Switching
Vicat	Zhambyl Cement	Zhambyl	1.1	Dry
UGC	Semey Cement	East Kazakhstan	1.1	Wet
Total			12.2	

Through 2014 the cement industry in Kazakhstan consisted of 10 cement plants that are owned by 9 cement companies (Table 5). All of the plants are privately-owned and there is significant participation of international cement companies, such as Heidelberg (Germany), VICAT (France), ItalCementi (Italy) and Steppe Cement (Malaysia). Once the acquisition of ItalCementi by Heidelberg Cement is complete[3], Heidelberg will operate three cement plants and have the largest market share of approximately 30%. Nevertheless, the cement market remains competitive, which is further enhanced by competition from cement plants in Russia and Uzbekistan that are located close to the borders of Kazakhstan as well as imports from Iran that arrive by ship via the Caspian Sea.

[3] During the week of 23 May 2016 the EU Commission allowed the takeover of Italcementi by Heidelberg Cement. See http://www.rnz.de/wirtschaft/wirtschaft-regional_artikel,-HeidelbergCement-darf-Italcementi-kaufen-_arid,194921.html#null))

Figure 2: Location of cement companies in Kazakhstan

The demand for cement is generally driven by domestic construction activity, which is closely linked to GDP growth but much more volatile. Double-digit changes in cement demand (in either direction) have been the norm over the past 15 years. In Kazakhstan construction activity is heavily driven by government initiatives, such as currently the EXPO 2017 and the Universiadi 2017. It is therefore strongly affected by changes in government revenues, oil and gas prices and international financial market conditions. In 2015 cement consumption, has reached a peak of 9.6 million tonnes.

Table 6: Kazakhstan Cement Statistics[4]

Year	Consumption	Production	Import	Export
	million t cement	million t cement	million t cement	million t cement
2000	1.29	0.85	0.24	0.01
2001	1.96	1.74	0.31	0.05
2002	2.37	2.08	0.30	0.02
2003	2.97	2.52	0.45	0.02
2004	3.84	3.00	0.85	0.01
2005	5.30	3.60	1.70	0.00
2006	6.30	4.10	2.20	0.00
2007	7.60	4.25	3.35	0.00
2008	5.50	4.00	1.70	0.00
2009	4.90	3.95	0.97	0.02
2010	5.49	5.93	0.90	0.12
2011	6.15	6.64	0.78	0.20
2012	7.20	6.22	1.20	0.21
2013	8.10	6.58	1.73	0.21
2014	8.50	7.92	1.04	0.45

Since 2001 three distinct phases for cement consumption can be distinguished.

1. Strong growth from 2001 to 2007 as the economy recovered from the long decline during the 1990s. Domestic cement consumption grew from 2 million tonnes in 2001 to 7.2 million tonnes in 2007.
2. Retrenchment in 2008 and 2009 because of an economic downturn caused by the global financial crisis. Cement consumption fell to 5 million tonnes in 2009.
3. Steady growth from 2010 to 2015. Cement consumption reached 9.6 million tonnes in 2015.

The almost five-fold demand increase has been met with the construction of new cement plants (Standard Cement, Zhambyl Cement, Kazakh Cement, Caspi Cement) and the modernization of existing ones (KarCement, Shymkent Cement). Per the 11th edition of the Global Cement Report, Kazakhstan's cement production capacity has increased from 8.8 million tonnes per year in 2010 to 14.6 million tonnes in 2014.[5] As a result, there is currently a mix of new and old plants, with very different energy efficiency levels and cost structures. Several plants are currently under construction (Kokshe Cement, BI Cement, Rudnenskyi Cement, Karatau Cement) or being expanded (Standard Cement).

Due to the large size of the country, the Kazakh cement market is focused on several centres of demand, with large geographical distances between them. Most prominent are Almaty and Astana but there are also provincial capitals, such as Karaganda, Shymkent, Aktobe, Pavlodar, Taraz or Oskemen. Thus, the cement market can be separated into five main regional markets.

[4] Global Cement Report, Volume 11th Edition

[5] Global Cement Report, Volume 11th Edition. At a clinker factor of between 80% and 85%, this corresponds to the above-mentioned 12.2 million tonnes of clinker capacity.

Table 7: Regional cement markets in Kazakhstan

Provinces included	Designated Region	Share
West Kazakhstan, Atyrau, Mangystau and Aktobe	West	16%
Kostanay, North Kazakhstan, Pavlodar, Akmola	North (incl. Astana)	22%
Karaganda	Central	8%
East Kazakhstan	East	7%
Kyzylorda, South Kazakhstan, Zhambyl, Almaty	South (incl. Almaty)	47%

Location also plays a major role with respect to proximity to the country's energy resources and sources of potential clinker substitution materials in Central, Northern and Eastern Kazakhstan. Cement companies currently rely mostly on coal as kiln fuel and benefit from being close to the coal mining areas in Karaganda and Pavlodar. Similarly, cement companies in Karaganda benefit from easy access to the blast furnace slag from the Temirtau steel mill, which they are closely located to.

Transportation costs in Kazakhstan are relatively low, even over long distances. The cost of transporting one tonne of cement is approximately USD 10 per 1000 km per tonne of cement. As a result, transportation costs for distances up to 1000 km are approximately 20% of the cement price. Therefore, the regional markets overlap and there remains effective competition between cement plants in different regions as well as from imports.

2.4 International Competitiveness

Kazakhstan is a geographically very large country covering an area of 2.7 million square km. For bulk goods such as cement long transportation distances imply that the country should be mostly self-sufficient. Due to the history of the Soviet Union, several Russian cement plants are located at the Kazakhstan border so that in the Northwestern part of the country there is strong regional competition from imports. This will only be resolved once a domestic cement plant is in this region. There are several projects in the planning stage but have not been realized, yet. Over longer term there should be demand-supply balance in the absence of any special situations, such as strong exchange rate swings, excess demand in cyclical peak years, or substantial extra costs imposed on the industry by either a carbon tax or the auctioning of emission rights.

In the past, imports have been used to cover any production shortfalls, in particular during the boom years of 2005 to 2007. In 2007 imports reached a 40% share of the Kazakh domestic cement consumption. Since then there has been a significant effort to replace imports with domestic production and pursue export opportunities. Net imports decreased from 3.35 million tonnes in 2007 to only 0.6 million tonnes in 2014.

During the first half of 2015, Kazakhstan saw a surge of cement imports from nearby Russian cement plants, which benefitted from the rouble devaluation at the end of 2014.Throughout the first eight months of 2015 the KZT traded at a value relative to the Russian rouble that was approximately 50% higher than the end of 2014. The devaluation of the KZT since then has re-established the competitive balance between Kazakhstan and Russian cement plants. The Russian cement industry is undergoing a similar modernization process as Kazakhstan's, and it should be noted that from 2010 to 2014 Russia was a net importer of cement, purchasing 2.2

million tonnes per year, or 3.5% of domestic consumption.[6] Similarly, the neighboring Central Asian republics, Turkmenistan, Uzbekistan and the Kyrgyz Republic, are neither major importers nor exporters of cement.

By contrast, Iran is a major exporter of cement and has access to the Western region of Kazakhstan via the Caspian Sea. Between 2010 and 2014, the country averaged net exports of approx. 14 million tonnes of cement, with much of this going to Middle Eastern neighbors, in particular Iraq and Afghanistan. Kazakhstan is vulnerable to imports from Iran in its Western and North-Western regions, where in the past none of the cement plants were located. The new Caspi Cement plant is located in Aktau in the Mangystau Region and has served as a way to substitute for imports from Iran and Russia.

2.5 GHG Emissions in Kazakhstan's Cement Industry

Kazakhstan is the largest emitter of greenhouse gases in Central Asia and twice as energy intensive per unit of Gross Domestic Product (GDP) as the average Organisation for Economic Co-operation and Development (OECD) economy. The Government of Kazakhstan expressed its ambition to reduce its greenhouse gas emissions, while supporting the anticipated growth in GDP.[7] The Intended Nationally Determined Contribution (INDC)[8] Kazakhstan submitted to the UNFCCC calls for an unconditional reduction of greenhouse gas emissions by 15% by 2030. This amounts to a 22% reduction in GHG emissions by 2030 compared to BAU projected emissions.[9]

The Concept for Transition of the Republic of Kazakhstan to Green Economy (the "Green Economy Concept"), approved in 2013, defines economy-wide targets for energy use and GHG emissions. On the energy efficiency of the national economy, the concept aims to reduce energy consumption per unit of GDP by 10% in 2015, 25% in 2020 and 30% in 2030 compared to the 2008 level.[10] For the power sector the concept describes a 50% share of alternative and renewable energy by 2050.

From an energy efficiency and carbon intensity perspective, Kazakhstan's cement sector is clearly in transition, as there is a mix of old inefficient plants, recently modernized plants and newly constructed plants. Consequently, from 2011 to 2013 the industry performed poorly when compared with international benchmarks as developed by the Cement Sustainability Initiative (CSI) of the World Business Council for Sustainable Development (WBCSD) and the International Energy Agency.[11] Consumption of kiln fuel at 5.5 GJ per tonne of clinker was almost 50% higher than the global average of cement plants covered by the WBCSD / IEA Study. Plants were close to the global average in the use of clinker substitutes, but almost no alternative fuels were used. In result, GHG emissions from Kazakhstan's cement plants were significantly higher than the global average.

[6] Global Cement Report, Volume 11th Edition

[7] Concept for transition of the Republic of Kazakhstan to Green Economy, Astana 2013, Approved by the President of the Republic of Kazakhstan approved on May 30, 2013 #557.

[8] http://www4.unfccc.int/submissions/INDC/Published%20Documents/Kazakhstan/1/INDC%20Kz_eng.pdf

[9] While Kazakhstan has not yet signed the 2015 Paris agreement, in contrast to 174 other countries that did so in April 2016, the country has indicated her commitment to becoming a signatory of the agreement, with a minor delay being caused by procedural issues.http://www.un.org/sustainabledevelopment/wp-content/uploads/2016/04/KazakhstanE.pdf

[10] Concept for transition of the Republic of Kazakhstan to Green Economy, Astana 2013, Approved by the President of the Republic of Kazakhstan approved on May 30, 2013 #557.

[11] WBCSD / IEA: Cement Technology Roadmap 2009. Carbon emissions reductions up to 2050

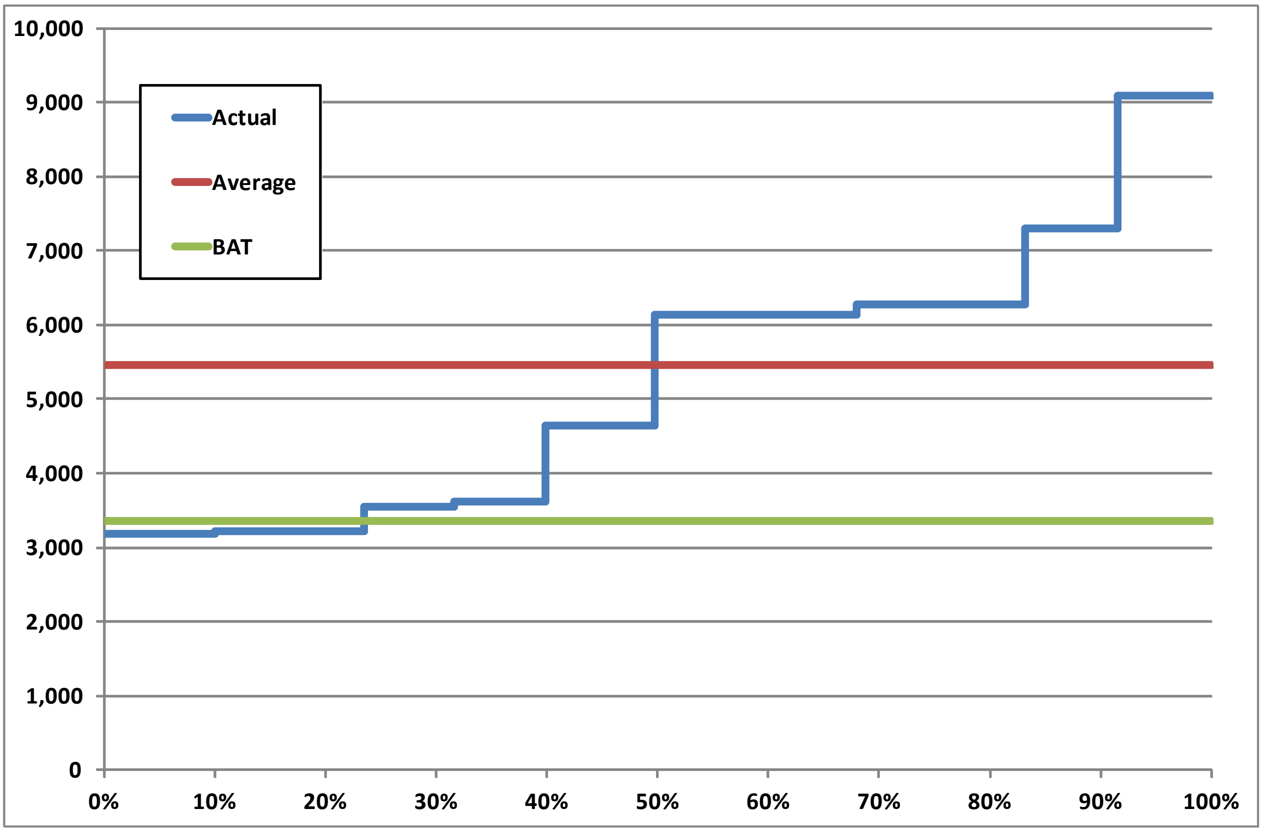
Table 8: Key Performance Indicators for Kazakhstan's Cement Industry[12]

Coverage	Kazakh Cement Industry	Global WBCSD / IEA	Global (top 10% WBCSD / IEA	Global WBCSD / IEA	Global WBCSD / IEA
Year	2011-13	2006	2006	2030	2050
% clinker	82%	79%	68%	73%	71%
% alternative fuels	0%	10%	23%	23.5%	37%
of which biomass	0%	3%	10%	N.A.	N.A.
GJ kiln fuel / t clinker	5.32	3.7	3.1	3.35	3.2
kg CO_2 / t cement[13]	964	800	N.A.	560	426
kg CO_2 / t clinker	1026		766[14]		

[12] WBCSD / IEA: Cement Technology Roadmap 2009. Carbon emissions reductions up to 2050, p.24, p.28
[13] The figures do not include indirect GHG emissions from electricity use at the cement plants.
[14] EU-ETS Benchmark for Plants producing Grey Clinker

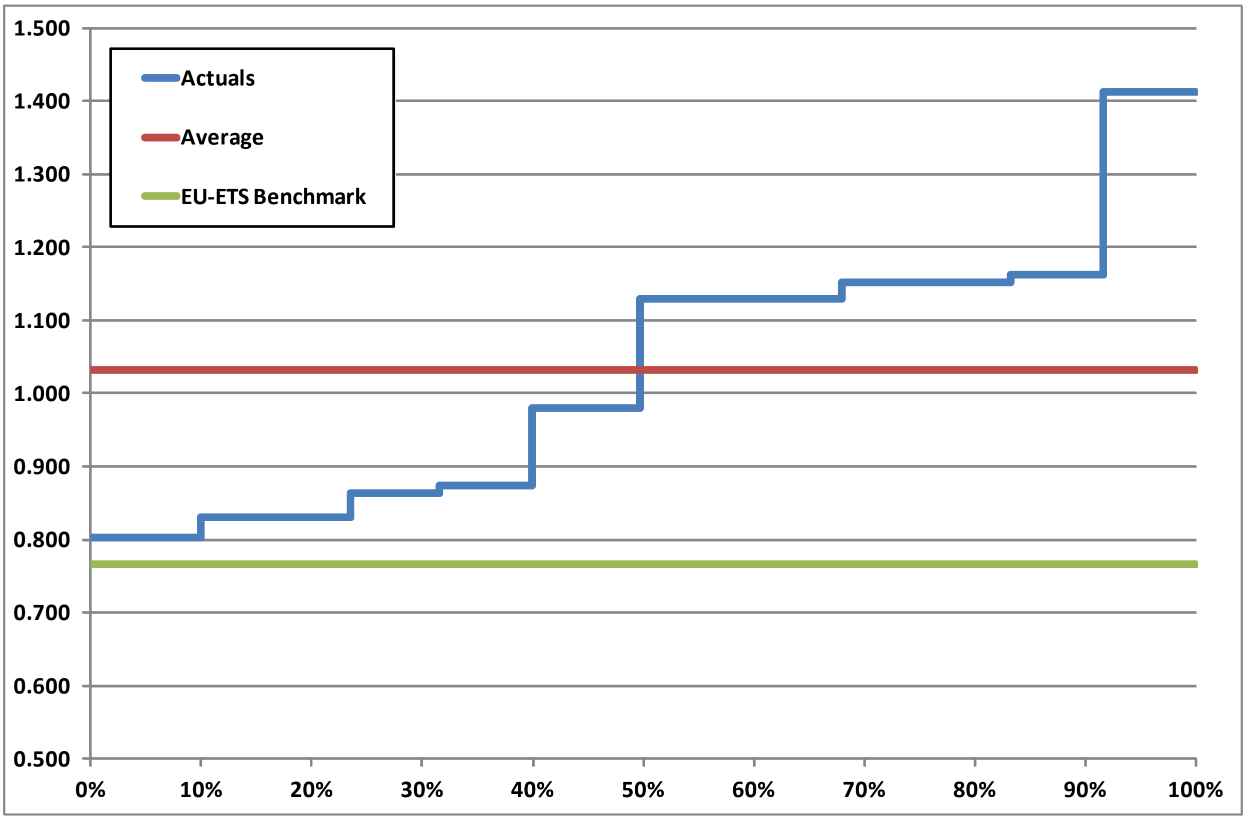
In terms of thermal energy efficiency, 40% of grey clinker production was already done at or close to Best Available Technology (BAT) levels in 2011-2013. At the same time, some very inefficient wet cement plants were still present at the time, which negatively affect the average efficiency of the sector and offer improvement opportunities for the future. For example, the Karcement plant has seen major updates by 2014 and the switch from wet-to-dry technology at the Shymkent Cement plant is being completed in 2016. In addition, there are several modern cement plants under construction or in the development stage, which will help to displace the remaining wet capacity, whose only advantage is that they are more able to tolerate alternative fuels.

Figure 3: Thermal Energy Efficiency in Grey Clinker Production in Kazakhstan, 2011-2013



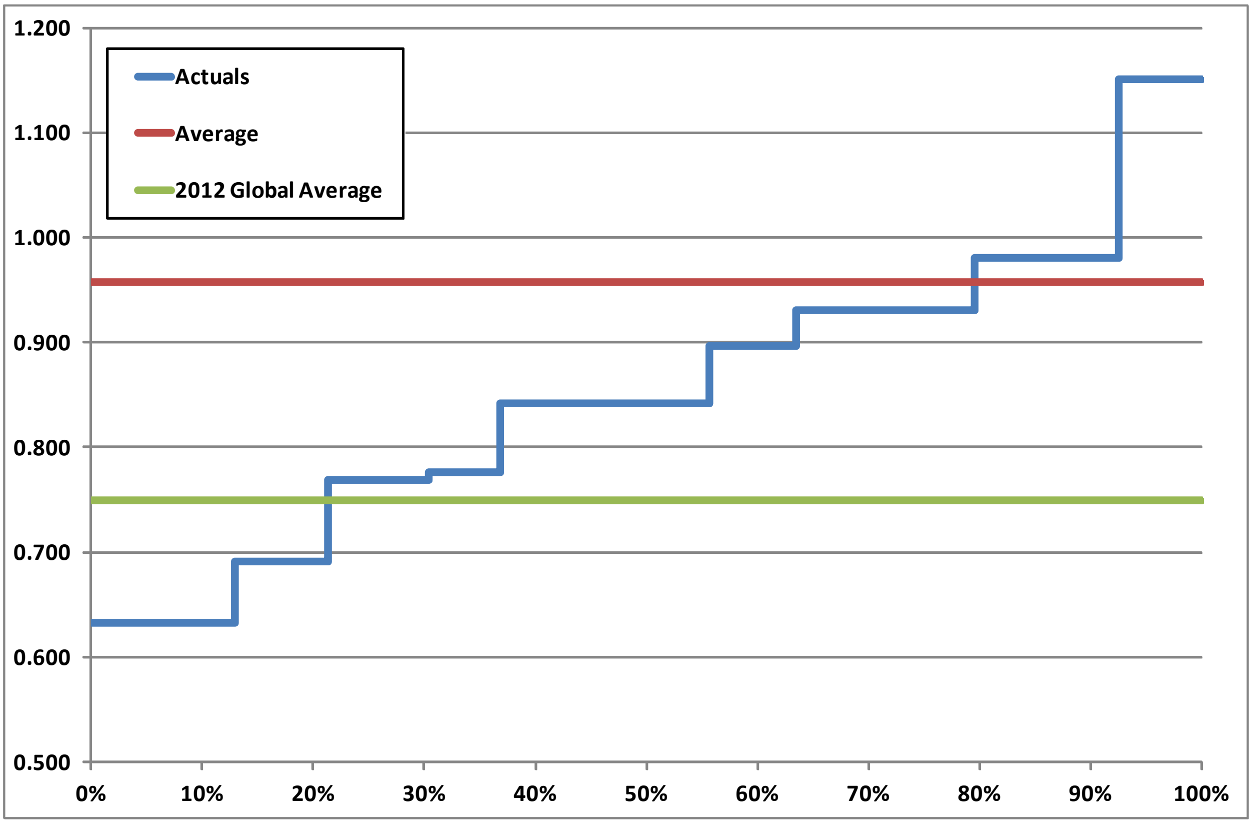
When looking at the carbon emissions per tonne of clinker all of Kazakhstan's cement plants are still significantly above the benchmark of 766 t CO_2/t clinker. The major reason for this is the carbon-intensive fuel mix. Kazakhstan cement plants still almost exclusively use coal as kiln fuel, which is more carbon-intensive than natural gas or fuel oil. There are almost no alternative waste-based or biomass fuels used and this presents an opportunity for significant future improvement.

Figure 4: Direct carbon emissions in grey clinker production in Kazakhstan, 2011-2013



A similar picture presents itself when looking at the specific carbon emissions per tonne of cement. These include emissions from the combustion of fuel, process emissions from the calcination of limestone as well as indirect emissions from the consumption of electricity. Compared with the 2012 average of worldwide cement plants as estimated by the WBCSD, average carbon emissions are indeed significantly higher. In addition to the lower energy efficiency and the more carbon-intensive fuel mix, the lesser degree of clinker substitution also plays a role.

Figure 5: Total carbon emissions in grey cement production in Kazakhstan, 2011-2013



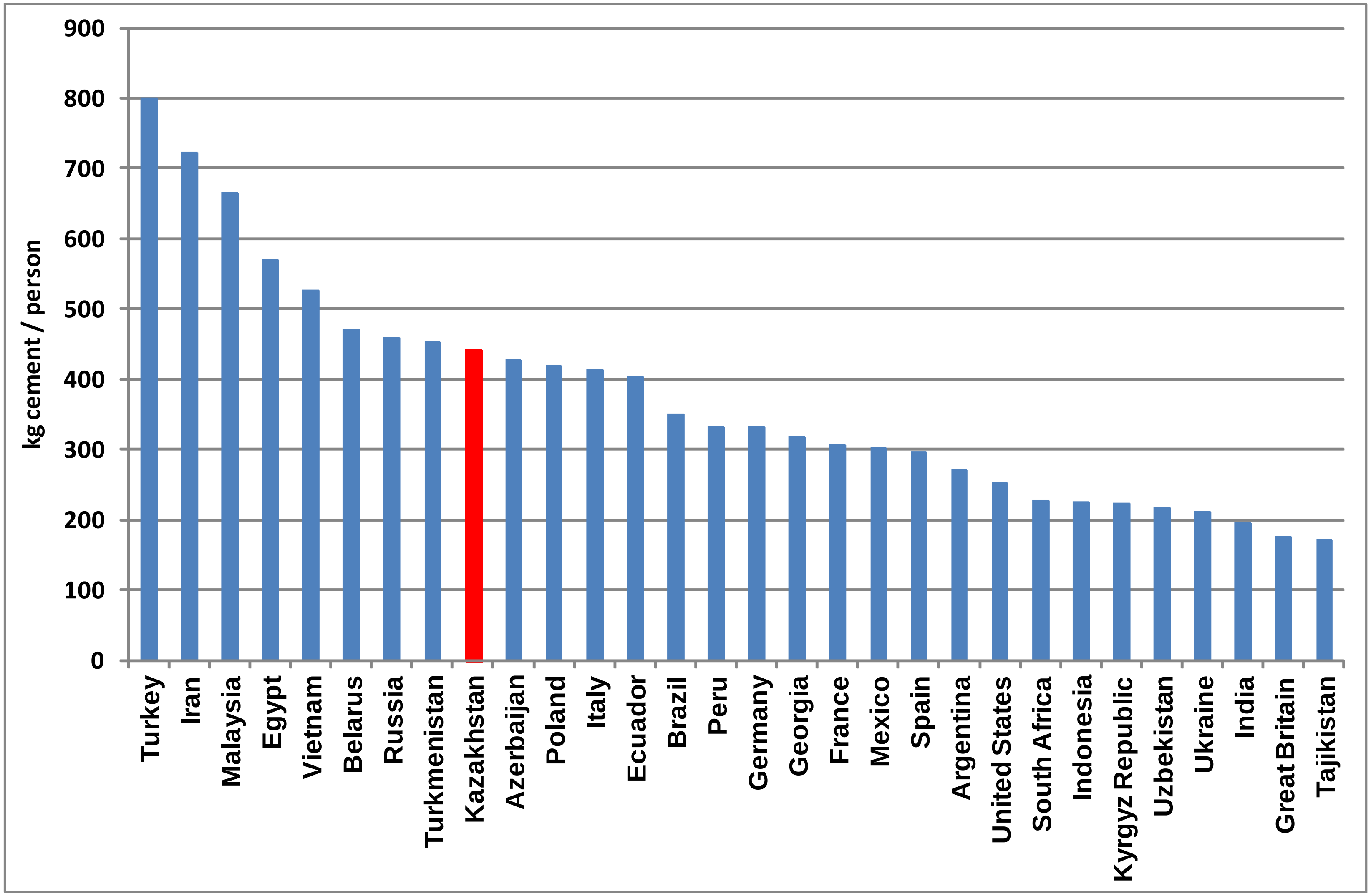
3. Analysis & Assumptions

3.1 Domestic Cement Consumption from 2015 - 2030

A key factor determining future GHG emissions of Kazakhstan's cement sector is the domestic demand for cement. Forecasting long-term cement consumption is a challenging task, and it is useful to rely on international comparisons. Average per-capita consumption of cement is around 500 kg of cement per person, however per-capita consumption varies greatly. While Saudi Arabia and China consumed more than 1500 kg per person per year between 2011 and 2014, in Pakistan and Nigeria it was less than 150 kg. During the same period, average cement consumption per capita in Kazakhstan was 442 kg per person per year. This is roughly in line with the figures for neighboring countries with similar characteristics, such as Russia (460), Turkmenistan (455), Azerbaijan (429), while Turkey (801) and Iran (724) show somewhat higher levels.

Figure 6 shows the per-capita cement consumption in selected countries. Countries with special circumstances leading to abnormally high cement consumption are not shown due to the scale of the graph. These are oil-rich Middle-Eastern countries (Saudi Arabia, the United Arab Emirates, Qatar, Bahrain, Oman and Kuwait), city states (Singapore, Macao) and China. These countries have per-capita cement consumption in excess of 1000 kg per year, due to very high levels of capital investment as a share of GDP and booming real estate sectors.

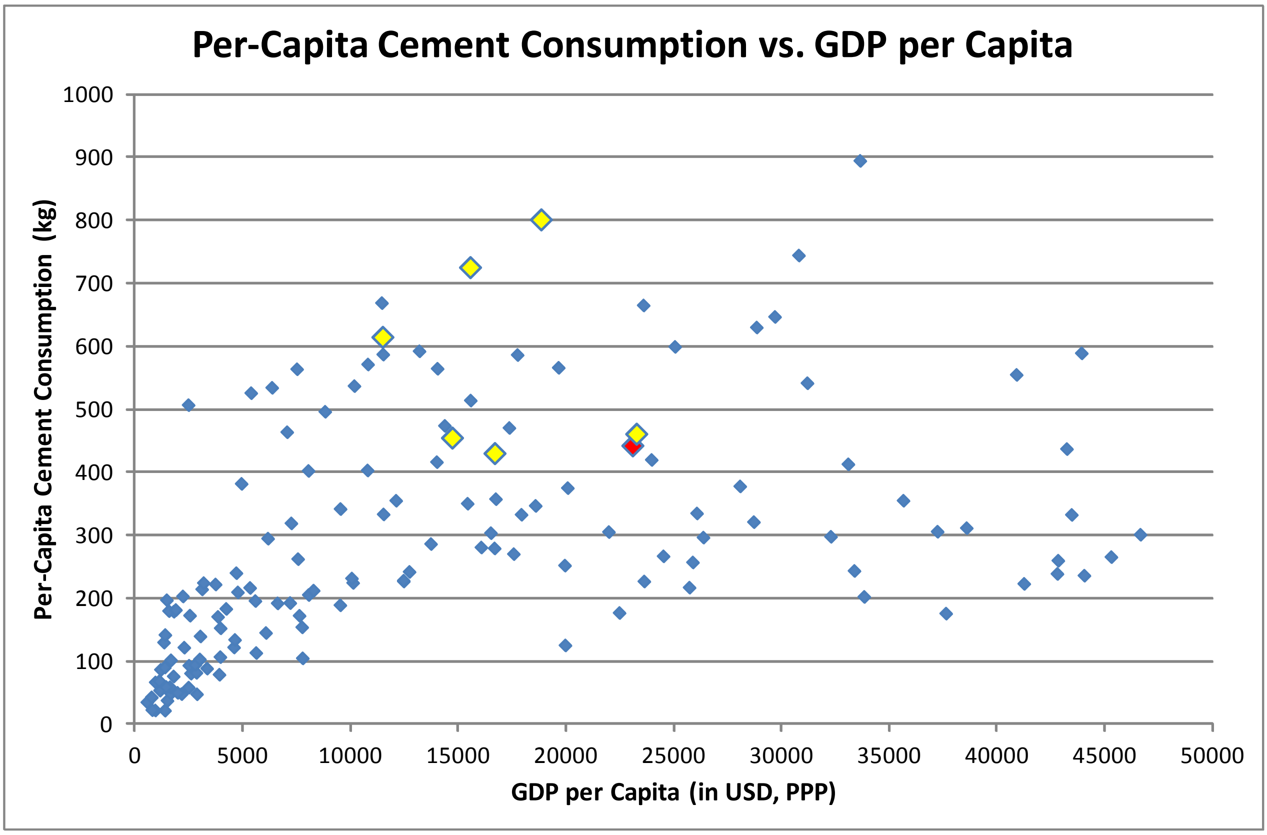
Figure 6: Per-capita Cement Consumption for various countries, average for 2011-2014[15]



[15] Source: International Cement Review / www.CemNet.com. See also Thomas Armstrong, International Cement Review. An overview of global cement sector trends. Insights from the Global Cement Report 10th Edition. Presentation at XXX Technical Congress. FICEM-APCAC. 2 September, 2013, Lima, Peru, page 8.

Cement market experts have noted that a country's per-capita consumption of cement can partly be explained by its per-capita GDP. However, Figure 7 shows that this relationship is not linear. Poor countries with a low per-capita GDP can ill afford to invest in major construction and infrastructure projects. On the other hand, highly developed countries, such as those in Western Europe or North America, typically have their infrastructure already in place and have little need for further large scale investments. The United States, Canada, Germany, France, Great Britain and Japan all had per-capita consumption below 360 kg per year.

Figure 7: Per-Capita Cement Consumption versus GDP per capita[16]

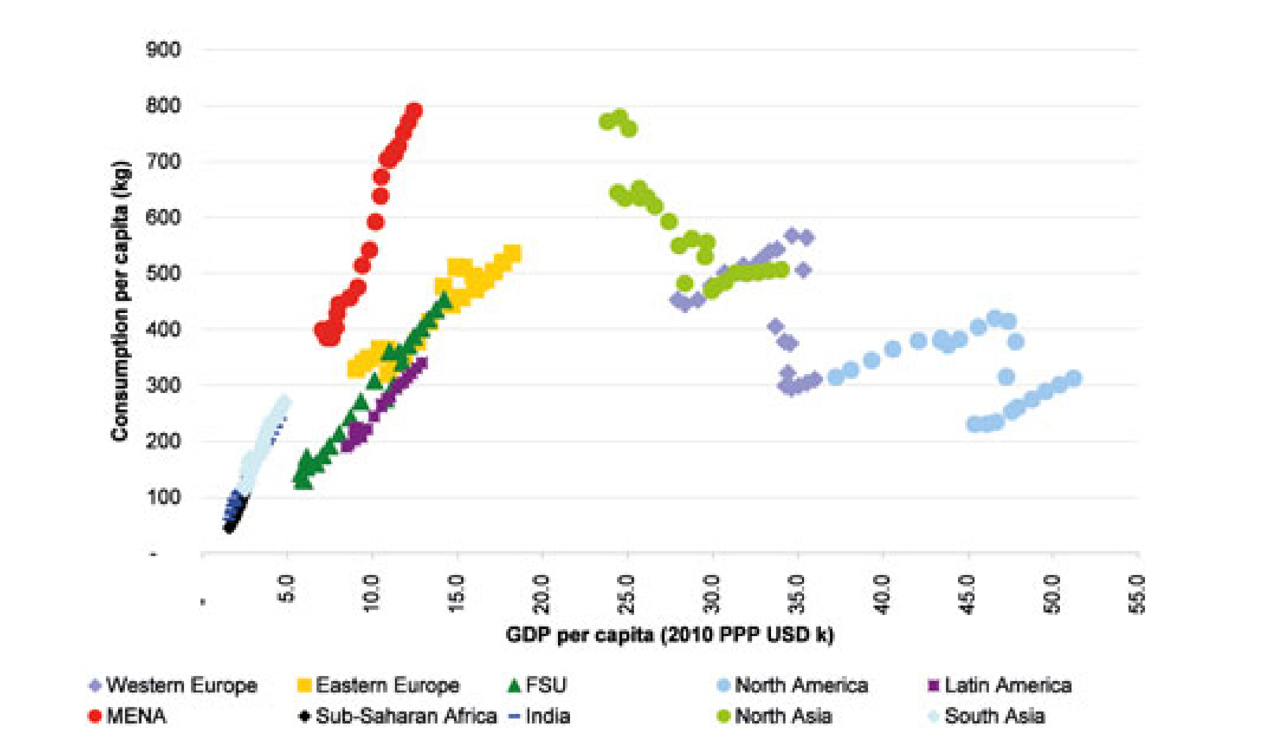


By contrast, emerging economies with a per-capita GDP of USD 15,000-40,000 have a much higher per-capita cement consumption. With a per-capita GDP of approximately USD 23,092 on a PPP basis Kazakhstan is within the range, as are Russia (23,293), Turkmenistan (14,762), Azerbaijan (16,710) as well as Turkey (18,884) and Iran (15,573). In Figure 7 Kazakhstan is highlighted in red colour while the five comparison countries and Mongolia are highlighted in yellow. Kazakhstan's GDP per capita can be expected to grow at an average rate of around 4% over the next decade, in line with the experience between 2005 and 2015. Thus, the per-capita GDP of Kazakhstan will remain within the range of peak cement consumption for most of the period 2016-2030.

When determining the level of peak per-capita cement consumption, it is also important to note the impact of the countries' economic structure. Fast growing countries with high fixed-capital investment rates will have a higher cement consumption, even if per-capita GDPs are similar. This effect is partly captured in Figure 8, which shows that countries of the former Soviet Union (FSU) and Latin America have a lower cement consumption than the oil-rich countries of the Middle East & North Africa. Similarly, North Asian countries have higher investment and cement consumption rates than Western Europe or North America.

[16] Per-capita GDP data on a PPP basis is provided by the World Bank. Please see http://www.tradingeconomics.com/kazakhstan/gdp-per-capita-ppp. Percapita cement consumption is provided by the International Cement Review / www.CemNet.com.

Figure 8: Per-Capita Cement Consumption in Regions of the World



For Eastern European, Central Asian and Latin American countries Figure 8 suggests a peak cement consumption of between 600 and 700 kg cement per person. [17] Emma Davidson postulates that "the relationship between GDP and cement consumption, plotted by multiple sources and years, shows a general inclination towards a cement consumption of 600 kg per capita or less in countries with per-capita GDPs in excess of USD 25,000."[18] Even if this level is exceeded in a given year by a particular country, consumption levels typically fall back over time. Therefore, the scenarios are based on cement consumption reaching an average level of 600 kg / capita between 2020 and 2030. In Kazakhstan, such a relatively high level of demand also reflects that there continues to be pent-up demand due to a significant period when construction investment was neglected. From 1996 to 2000 Kazakhstan cement consumption had dropped to less than 1.5 million tonnes, i.e. less than 15% of the 8.25 million tonnes reached in 1990. Even though short-term cyclical variations of up to 30% in either direction would not be surprising, the medium-term per capita consumption can be expected to be around 600 kg per year. With population expected to continue to grow at a rate of around 1% per year, cement consumption would be expected to reach 12.9 million tonnes in 2030, up from the 9.6 million tonnes reached in 2015, which constituted a peak in the period since Kazakhstan's independence. The forecast of around 12 million tonnes of domestic cement consumption is also in line with the cement capacity that is being put into place. Once the cement plants currently under construction are completed, cement capacity will likely reach 15.5 million tonnes of cement in 2018, of which more than 12 million tonnes will be produced using the dry cement process. To the extent that the most efficient plants are allowed to operate, this will mean that the wet plants will likely move towards standby. With the increased use of clinker substitutes in blended cement, the cement production capacity will further increase over time even if the clinker capacity remains unchanged, resulting in a situation where supply will tend to outstrip demand. While several further cement plants remain in the planning stage, it is therefore not clear that they will actually be commissioned.

[17] http://www.cemnet.com/Articles/story/153619/global-cement-2014-outlook.html.
http://www.worldcement.com/publications/preview/WorldCement/WorldCement-January-2015-Preview.pdf

[18] Emma Davidson. Cement consumption versus Gross Domestic Product. Global Cement Magazine, June 2014, p.8-14.

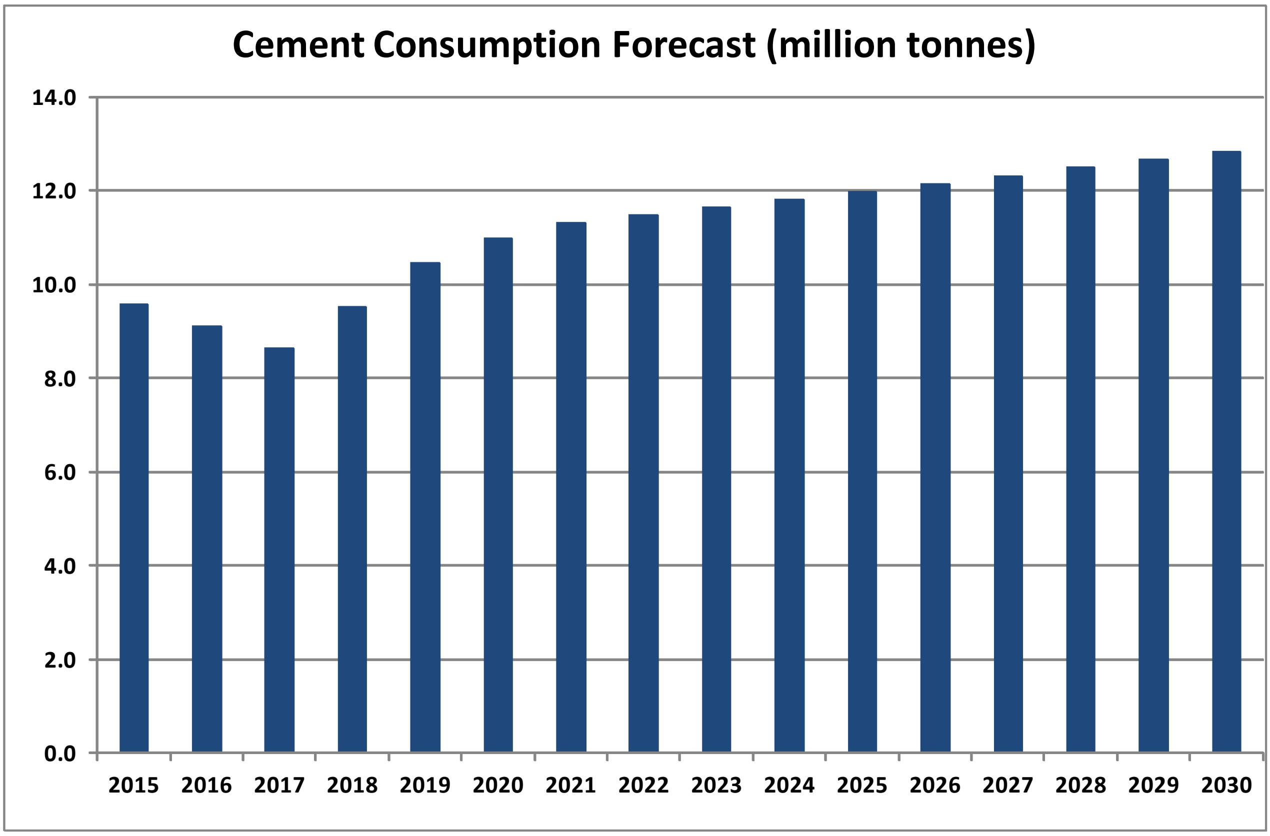
The near-term outlook is less favourable as Kazakhstan's economic growth slowed to 1% in 2015 and is expected by the International Monetary Fund (IMF) and the Asian Development Bank to stagnate in 2016 and 2017. These levels of GDP growth are typically associated with reductions in domestic cement consumption. For example, 2009 cement consumption was 35% lower than the 2007 peak as GDP growth slowed to 3% in 2008 and 1% in 2009 after seven years during which average GDP growth was in the double-digits.

Table 9: Kazakhstan Cement Consumption Forecast for 2016-2030

	Kazakhstan Cement Consumption		GDP	Population	
	million tonnes	% change	% change	million	% change
2015	9.6	10.3%	1.0%	17.4	0.6%
2016	9.1	-5.0%	0.7%	17.6	1.4%
2017	8.7	-5.0%	1.0%	17.9	1.4%
2018	9.5	10.0%	7.0%	18.1	1.4%
2019	10.5	10.0%	7.0%	18.4	1.4%
2020	11.0	5.0%	5.0%	18.7	1.4%
2021	11.3	3.1%	5.0%	18.9	1.4%
2022	11.5	1.4%	5.0%	19.2	1.4%
2023	11.7	1.4%	5.0%	19.4	1.4%
2024	11.8	1.4%	5.0%	19.7	1.4%
2025	12.0	1.4%	5.0%	20.0	1.4%
2026	12.2	1.4%	4.0%	20.3	1.4%
2027	12.3	1.4%	4.0%	20.6	1.4%
2028	12.5	1.4%	4.0%	20.8	1.4%
2029	12.7	1.4%	4.0%	21.1	1.4%
2030	12.9	1.4%	4.0%	21.4	1.4%

The forecast results are illustrated in Figure 9.

Figure 9: Kazakhstan Cement Consumption Forecast, 2015-2030



3.2 Carbon Reduction Levers

There are three categories of relevant GHG mitigation actions for the Kazakhstan cement sector that should be considered in order to set the sector on a path towards low-carbon cement production. The categories are Energy Efficiency, Clinker Substitution and Alternative Fuels and Raw Materials.

3.2.1 Thermal Energy Efficiency

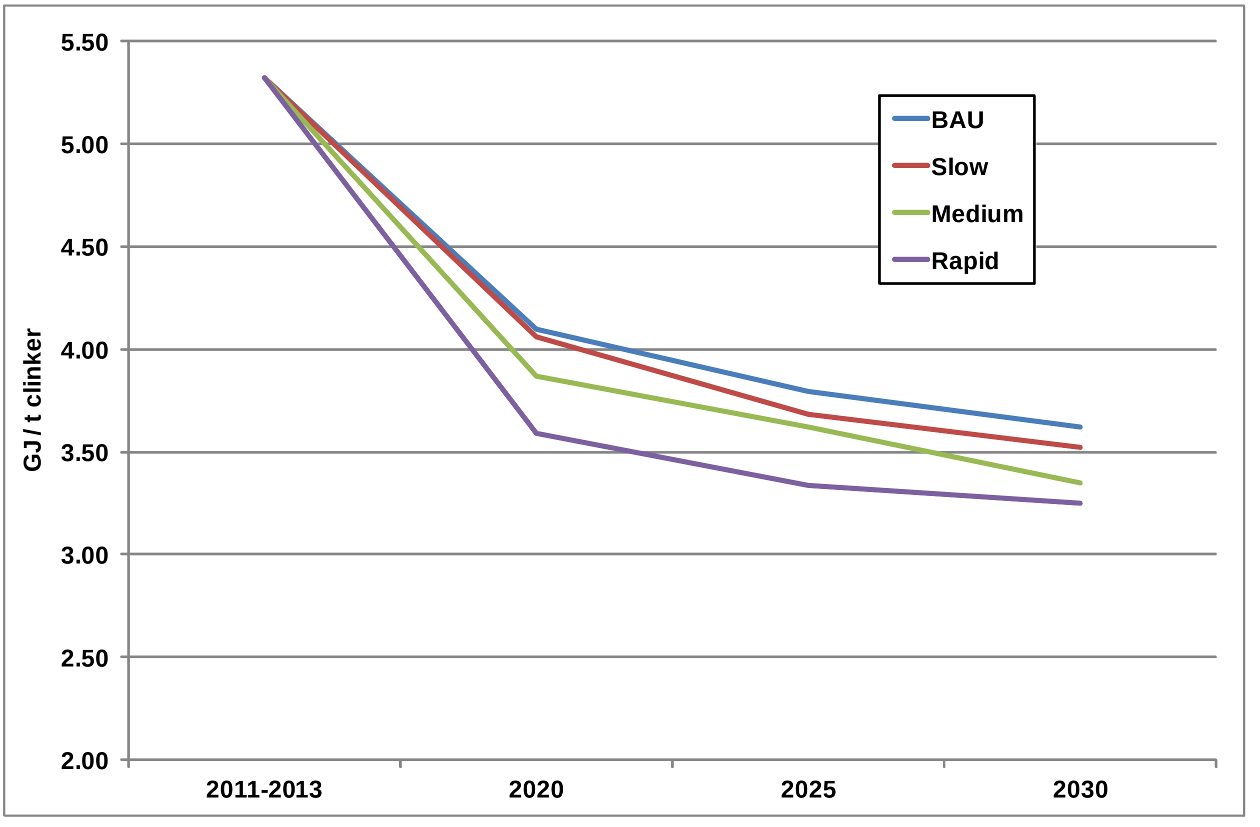
The thermal efficiency of the kilns derives, to a large extent, from the fuel input and the resulting combustion emissions. When Kazakhstan was still part of the Soviet Union, the prevailing cement technology were wet kilns. In recent years, new kilns have been constructed (Caspi, Standard Cement, Kazakh Cement, Zhambyl, Khantau) and some old ones have been renovated (KarCement, Shymkent). This has already significantly improved the average thermal efficiency. In the period 2011-2013, the average specific energy consumption of the new dry kilns at 3.6 GJ / t clinker was only about half the energy consumption of the old wet killns at 7.2 GJ / t clinker.

Table 10: Cement companies and plants in Kazakhstan

Company	Plants	Capacity in 2015 (Mt cement / year)	Wet / Dry	Greenfield / Renovated
Heidelberg	Vostok / Bukhtarma	1.3	Wet	
	Caspi Cement	1.0	Dry	Greenfield
Standard	Standard Cement	1.2	Dry	Greenfield
Steppe	Central Asia Cement	1.0	Wet	
	KarCement	1.0	Dry	Renovated
Kazakh	Sastobe Cement	0.5	Wet	
	Kazakh Cement	1.0	Dry	Greenfield
Italcementi	Shymkent Cement	1.0	Dry	Renovated
Vicat	Zhambyl Cement	1.1	Dry	Greenfield
UGC	Semey Cement	1.1	Wet	

Several more cement plants are currently under construction, in Khantau, Kokshe and Sofievka. In addition to Standard cement plant is being expanded. All investment in new capacity will clearly be in dry lines to save energy costs. Over time, it is expected that domestic consumption can be fully satisfied with new and modernized plants utilizing the dry cement process, so that the remaining wet plants will either be renovated or put on stand-by to cover excess demand. The gradual phase-out of wet cement technology and general efficiency improvements are expected to occur at various speeds in each of the four scenarios. This is reflected in the substantial improvements of the thermal efficiency in all four scenarios compared with the 2011-2013 baseline. In the "Rapid" scenario the BAT level of 3.25 GJ / t clinker is approached by 2025. In the "Medium" scenario this takes until 2030.

Figure 10: Scenarios for Specific Energy Use in Kazakhstan's Grey Clinker Production, 2011-2030



3.2.2 Clinker Substitution

Most of the carbon emissions from cement production are generated in the kilns where the clinker is produced. This is true for emissions from the combustion of kiln fuel as well as for process emissions from the calcinations of limestone. By replacing clinker with other materials, so-called clinker substitutes, the carbon emissions from cement production can thus be significantly reduced.

There is significant potential for clinker substitution in Kazakhstan, as potential clinker substitutes, such as metallurgic and phosphoric slags, fly ash, pozzolanas or limestone, are available in large quantities. The most important supplier of granulated blast-furnace slag is the Arcelor-Mittal steel mill in Temirtau. Fly ash from coal-fired power plants can also be used.

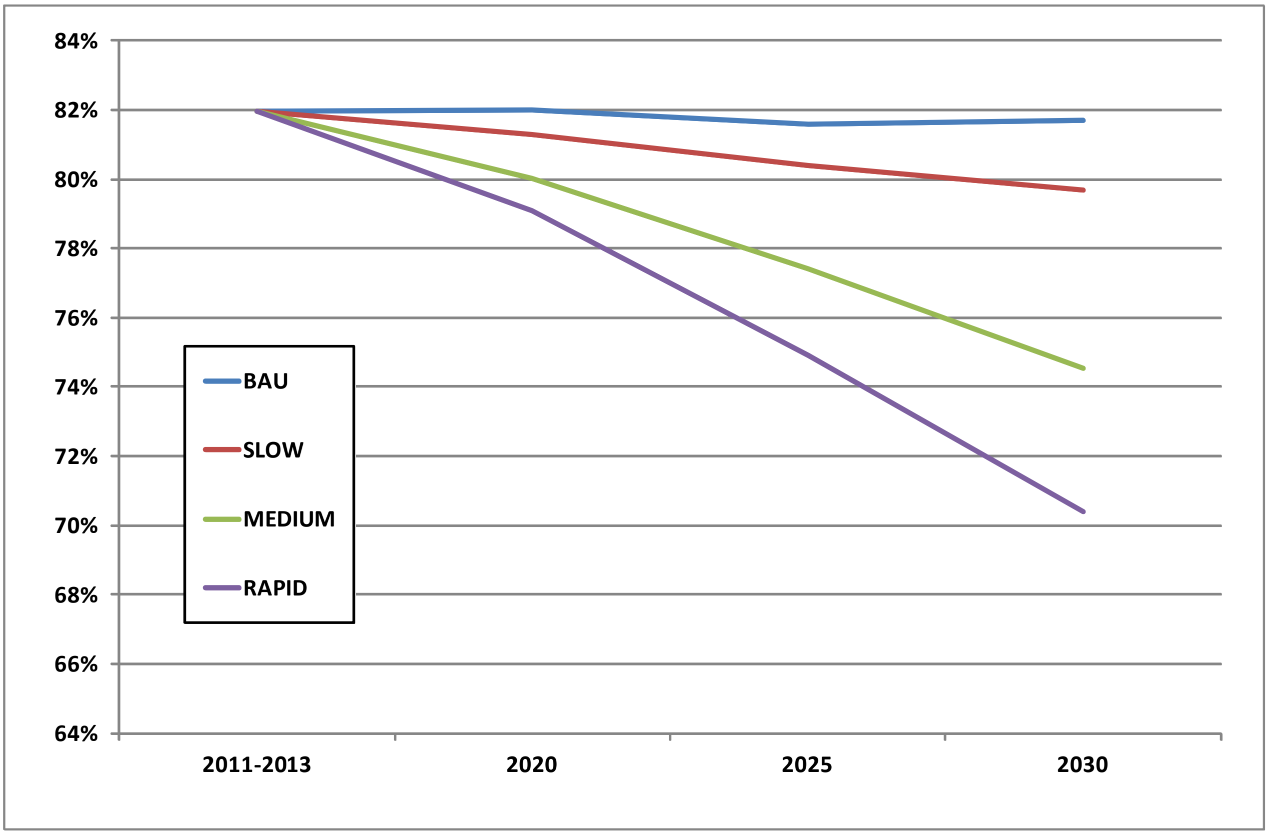
Table 11: Annual Requirements of Clinker Substitutes in 2030

Material	BAU	Slow	Medium	Rapid	Shares
	tonnes/year	tonnes/year	tonnes/year	tonnes/year	tonnes/year
Granulated Blast Furnace Slag	979,605	1,126,363	1,488,624	1,821,969	60%
Other Metallurgic and Phosphoric slags	244,901	281,591	372,156	455,492	15%
Fly Ash	408,169	469,318	620,260	759,154	25%
Total	**1,632,676**	**1,877,272**	**2,481,040**	**3,036,615**	**100%**

In the 2011-2013 period Kazakhstan cement plants already replaced around 18% of the clinker with substitutes, especially granulated blast-furnace slag and phosphoric slag. Cement companies are very interested in further increasing the use of clinker substitutes. A key barrier has been that the standards for road construction that do not allow the use of additives as well as the attitudes of construction companies that appear to prefer unblended cement for many applications. [19] A further challenge is that the sources of clinker substitutes are concentrated in a few locations, which favours cement plants in the vicinity but results in long transportation distances for other plants. The relevant clinker substitutes will therefore vary by cement plant with metallurgical slags, phosphoric slag and fly ash to provide the bulk of the material. Some plants may even choose to import additives, such as granulated blast-furnace slag from Russia.

Given the interest of the cement plants the degree of clinker substitution depends mostly on the acceptance of blended cement and the availability of high-quality substitutes. Under the BAU scenario there would likely not be any material change in the share of clinker in the cement from the current 82%. However, under the "Slow", "Medium" and "Rapid" scenarios the share of clinker is expected to decrease gradually to 80%, 75% and 70% by 2030.

Figure 11: Scenarios for Share of Clinker in Kazakhstan's Grey Cement Production, 2011-2030



3.2.3 Changing the fuel mix

Alternative Fuels

The use of alternative fuels presents a major opportunity to reduce carbon emissions in Kazakhstan's cement industry. Waste-derived fuels, especially those with a high biomass content are less carbon-intensive than coal. The biomass fraction of refuse-derived fuel is considered as carbon-neutral under greenhouse gas protocols, such as the European Union Emissions Trading Scheme (EU-ETS), and can therefore be used by cement plant operators to reduce their overall

[19] Interviews with representatives from undisclosed cement companies in Kazakhstan.

reported CO_2 emissions.[20] This is not the case under the Kazakhstan ETS. However, for the purposes of this report, the biomass fraction of refuse-derived fuels is considered as carbon neutral with an emission factor of zero in line with the treatment under the EU-ETS.

Table 12: Carbon Emission Factors for Various Fuels

Hard Coal	Natural Gas	Heavy Fuel Oil	Alternative Fuels (average)	Renewable Biomass
96.1	56.1	77.4	44.2	0

From a technical point of view cement plants can increase their share of alternative fuels up to two-thirds. However, in Kazakhstan there is currently almost no use of alternative fuels in cement plants, beyond the occasional combustion of old tires. More than 90% of the kiln fuel used is coal, with the remainder being natural gas. Several companies have reported an interest in the use of alternative fuels, ranging from municipal waste to sunflower husk, sewage sludge and contaminated oil sands, but all these initiatives are in the very early stages. Experiments with oil sludge and sewer sludge have so far yielded disappointing results. Cotton stalk and rice husk were found too expensive at current energy and carbon price levels.

For alternative fuels to provide a substantial share of kiln fuel the key variables of availability, the quality and the price of the alternative fuels need to be addressed. According to cement industry stakeholders, the utilisation of waste-derived fuels is feasible only if waste management, including the collection, sorting, drying and transportation of the waste is improved, providing a consistent, reliable and high-quality source of waste-derived fuel.[21] There are no cemet plants close to Astan and Almaty, but several that are close to Shymkent, with a population of almost 900,000. Most cement plants are near medium-sized cities of between 100,000 and 500,000 inhabitants, such as Karaganda, Aktau, Semey, Oskemen and Taraz.[22] Such cities can be expected to provide the necessary municipal waste and sewage sludge. The government can support this by requiring best practices for waste management and by putting restrictions on the landfilling of wastes.

In the BAU scenarios, no increase in the use of alternative fuels is expected. This is different in the “Slow”, “Medium” and “Rapid” scenarios where the share of alternative fuels in 2030 gradually increases to 2%, 18% and 30%, respectively. The material for the refuse-derived waste is expected to come from three main sources, municipal solid waste, especially the paper and plastic fractions, sewage sludge and waste from processing industries. The biomass content is expected to increase over time in line with the experience from other countries and reach 40% in 2030. This is similar to the percentage used in the WBCSD / IEA Roadmap and is the global average in the latest CSI data for 2013.[23]

Table 13: Alternative Fuel Requirements in 2030

Alternative Fuel	BAU	Slow	Medium	Rapid
	tonnes/year	tonnes/year	tonnes/year	tonnes/year
Industrial Waste	0	0	101,017	160,834
Tyres	0	10,419	20,881	19,460
Municipal Solid Waste	0	29,692	93,162	173,640
Agricultural Waste	0	76	94,062	140,330

[20] Reductions of indirect GHG emissions associated with electricity use are at present not credited under the Kazakhstan ETS.
[21] Interviews with representatives from undisclosed cement companies in Kazakhstan.
[22] The population figgures are based on the 2016 census. See http://www.citypopulation.de/Kazakhstan.html.
[23] Philip Kerton (CPK Consultancy): Looking at the right numbers. In International Cement Review, December 2015.

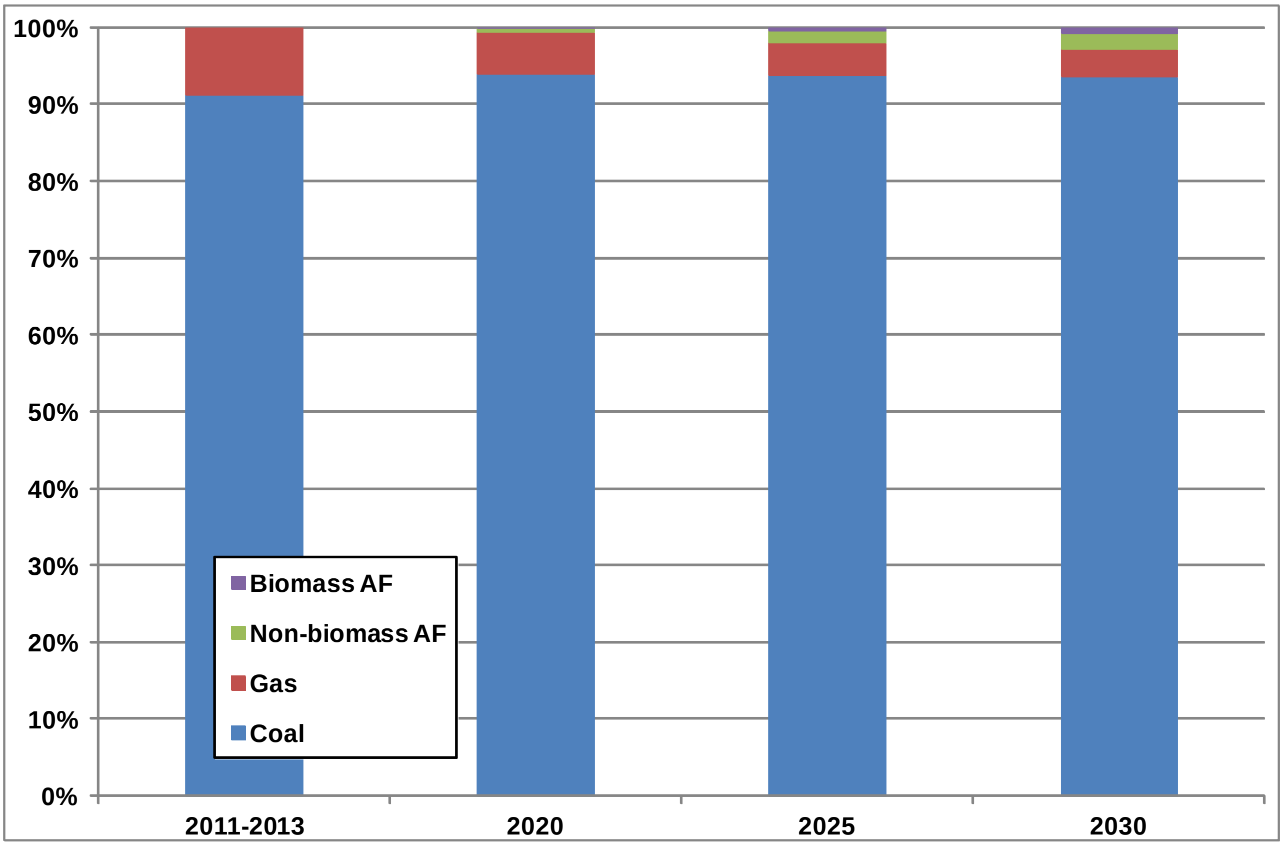
Table 14: Alternative Fuel Quality Characteristics

Alternative Fuel	Calorific Value (GJ/t)	Biomass Content (%)
Industrial Waste	22	0%
Tyres	29	27%
Municipal Solid Waste	13	50%
Agricultural Waste	15	100%

Fuel Switch to Natural Gas

Coal is the predominant fossil fuel (>90%) used to fire Kazakh cement kilns. Between 2011 and 2013 significant amounts of natural gas were used at only two cement plants. One of them is in the process of switching back to coal, since at current energy and carbon prices natural gas is not competitive with coal. Natural gas is a good alternative to coal because it is only about half as carbon-intensive and presents a significant opportunity to reduce carbon emissions associated with cement production. In theory, Kazakhstan is well-positioned for this, as the country is home to a very significant oil and gas industry[24]. Availability of natural gas differs by region, as the major oil and gas fields, the Pre-Caspian Basin and the Mangistau-Usturt Basin are in the Western and Northwestern part of the country along the Caspian Sea. Natural gas is available through a pipeline network in the Western and Southern regions of the country. There gas is better able to compete against coal due to the longer transportation distances outside the coal basin in the North-East.

Figure 12: "Slow" Scenario for Fuel Mix in Kazakhstan's Cement Industry



[24] Global Cement Report 2012.

At present, low coal prices are a major barrier for companies wishing to switch to natural gas. It is therefore expected that coal will remain the predominant kiln fuel through 2030 unless there are significant incentives for cement companies to switch to firing their kilns with natural gas. Therefore we would not expect an increase in the use of natural gas in the BAU, “Slow” and “Medium” scenarios. Only in the “Rapid” scenario, with costs of carbon up to €30 / t CO_2 we would expect to see cement plants in the Western and Southern regions gradually increase their natural gas usage to about 50% of fossil fuel input.

Figure 13: “Medium” Scenario for Fuel Mix in Kazakhstan’s Cement Industry

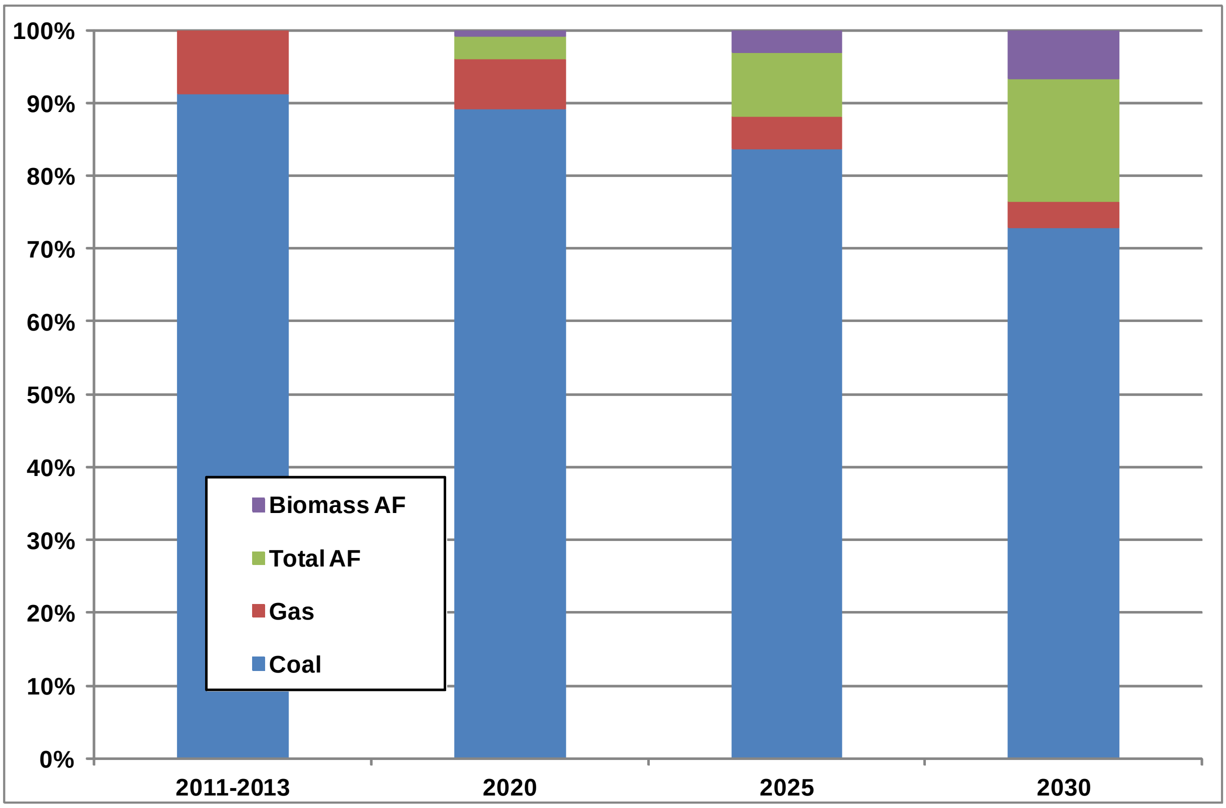
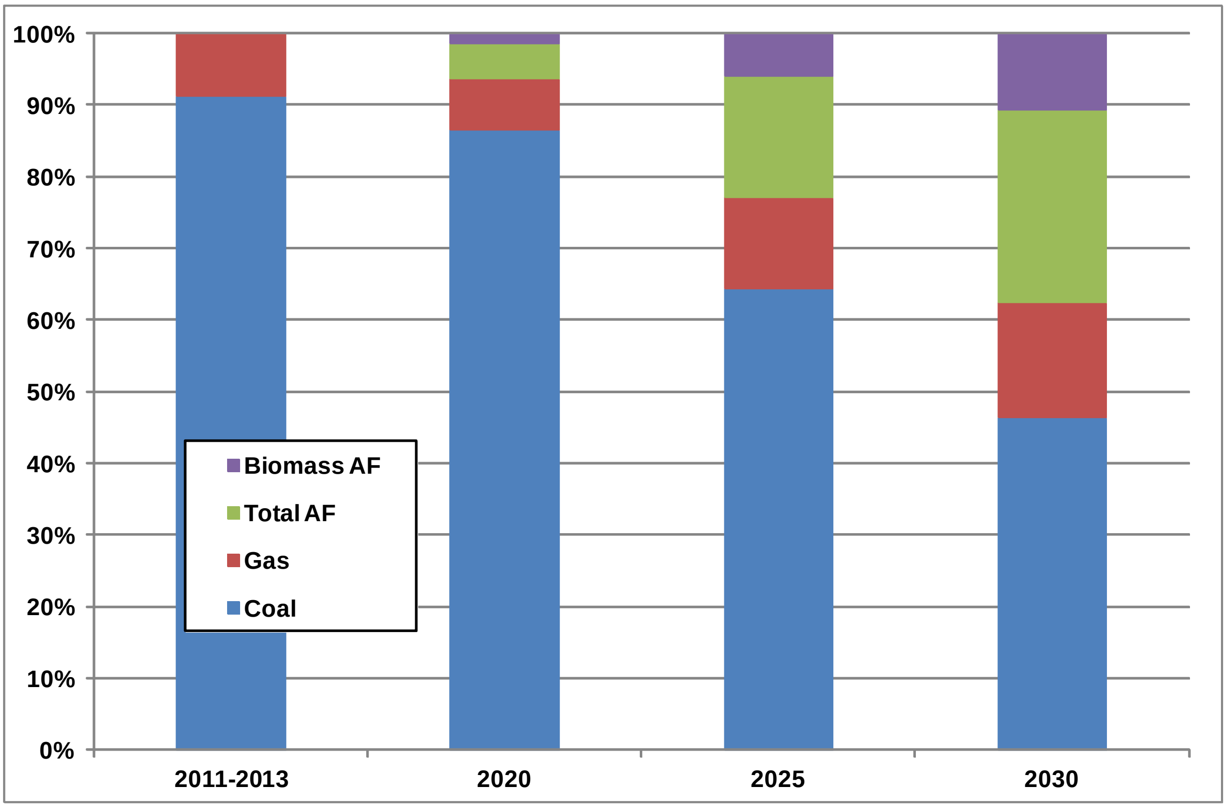


Figure 14: "Rapid" Scenario for Fuel Mix in Kazakhstan's Cement Industry



3.2.4 Electric Energy Efficiency

Indirect emissions from electrical power consumption for the various cement production processes (grinding, etc.) contribute approximately 10% of overall emissions from the cement sector. These emissions are "indirect" because GHGs are emitted at thermal power plants instead of at the cement plants themselves. For this reason, such emissions are not included in the cement sector's GHG inventory under the Kazakh ETS. Nevertheless, these emissions are driven by the activity of the cement plants, and improvements in electrical efficiency at the cement plants are one way to contribute to the achievement of Kazakhstan's climate targets.

All scenarios include gradual improvements in electrical efficiency. While in the BAU scenario this improvement only amounts to 2% by 2030, improvements are 5%, 10% and 15% in the "Slow", "Medium" and "Rapid" scenarios.

The "Medium" and "Rapid" scenarios also assume that the share of renewable power will increase as there is good potential for wind and solar projects as long as government support in the form of preferential grid access and feed-in tariffs can be provided. Large-scale hydro power projects currently provide around 10% of the power supply. To significantly increase this share with the help of smaller-scale projects will likely take until after 2025 as regulatory changes have to be implemented and private sector capacity needs to be built. By 2030 renewables could reach a share of 20% in the "Medium" scenario and 30% in the "Rapid" scenario. The latter would be consistent with the 2030 target for renewable energy consumption under the Concept of development of fuel-power complex of the Republic of Kazakhstan until 2030.[25] Under the Rapid scenario one can also expect to see the first installations of waste heat recovery projects for electricity production from 2025, in particular for large scale plants with a capacity of 6000 to 8000

[25] Carbon Limits. Support to Kazakhstan's Intended Nationally Determined Contribution. Guidance for submission of Kazakhstan's first NDC.

tonnes of clinker per day. Waste heat recovery (WHR) projects are too small for delivering heat to district heating networks and inefficient compared with Combined Heat and Power plants. Therefore WHR is only considered for power generation.

3.2.5 Alternative Raw Materials

Using alternative raw materials replacing limestone is a technology to reduce the calcination emissions in the clinker production process. Under the “Rapid” scenario cement companies would be competing to secure sources of decarbonated raw materials such as steel and other metallurgical slags. These would displace 2% of the limestone used in the Kazakh cement industry by 2020, 5% by 2025 and 10% by 2030. Cement kilns would be modified to allow the feeding of such decarbonated alternative raw materials directly to the inlet of kilns.

4. Scenarios

4.1 Scenario Definitions

The BAU scenario is the scenario that would occur in the absence of new more ambitious actions towards a low-carbon economy. The scenario presumes that there are no major changes to the existing domestic and international policy framework and relative prices for cement, energy, and clinker substitutes remain the same. In this scenario, certain improvements to the energy and carbon intensity of the Kazakhstan cement industry would still occur. For example, the transition from wet to dry cement kilns has been under way for several years. Several new dry plants have been constructed and several other old plants have been converted (KarCement, Shymkent Cement). It is therefore reasonable to expect that all new cement plants would be constructed with dry technology and that existing wet cement plants will be gradually retired.

In addition to the BAU scenario three scenarios have been developed which assume different speeds at which low-carbon technologies are adopted. Table 15 shows the sequencing of the mitigation actions that would be taken under the "Slow", "Medium" and "Rapid" scenarios in response to progressively higher levels policy support, both in form of carbon pricing and regulatory support.

Table 15: Scenarios for the transition towards low-carbon cement production

	Business-as-Usual	Slow Transition	Medium Transition	Rapid Transition
2016-2020	• Replace some wet kilns • No alternative fuels • Increase in clinker substitution at new plants • Constant share of renewable energy (RE) in power production	• Replace some wet kilns • No alternative fuels • Increase in clinker substitution at new plants • Constant share of RE in power production	• Replace remaining wet kilns • Operate some wet kilns as stand-by • Pilots for use of alternative fuels, waste • Gradual increase in clinker substitution at all plants • Slow increase in RE share in power production	• Fully replace wet kilns • Operational energy efficiency improvements for renovated plants • Pilots on alternative fuels, waste and biomass • Gradual increase in clinker substitution at all plants • Slow increase in RE share in power production
2021-2025	• Replace remaining wet kilns • Operate some wet kilns as stand-by • No alternative fuels • No increase in clinker substitution • Constant share of RE in power production	• Replace remaining wet kilns • Operate some wet kilns as stand-by • Small operational energy efficiency improvements for renovated plants • Pilots for use of alternative fuels (waste) • Gradual increase in clinker substitution • Slow increase in RE share in power production	• Fully replace wet kilns • Some operational energy efficiency improvements for renovated plants • Increased use of waste fuel • Pilots for biomass fuel • Gradual increase in clinker substitution at all plants • Slow increase in RE share in power production	• Further operational energy efficiency improvements for renovated plants • Increased use of alternative fuels; waste and biomass • Pilots for Waste Heat Recovery (WHR) • Fast increase in clinker substitution due to new markets (road construction) • Fast increase in RE share in power production
2026-2030	• Fully replace wet kilns • No WHR • No alternative fuels • No increase in clinker substitution • Constant share of RE in power production	• Fully replace wet kilns • Some operational energy efficiency improvements for renovated plants • No WHR • Gradual increase in clinker substitution • Pilots for use of alternative fuels (waste) • No use of biomass fuels • Slow increase in RE share in power production	• Further operational energy efficiency improvements for renovated plants • Pilots for WHR • Increased use of waste and biomass • Fast increase in clinker substitution due to new markets (road construction) and new sources • Fast increase in RE share in power production	• Further operational energy efficiency improvements for renovated plants • Several WHR projects • Fast increase in use of waste and biomass • Fast increase in clinker substitution due to new markets (road construction) • Fast increase in RE share in power production

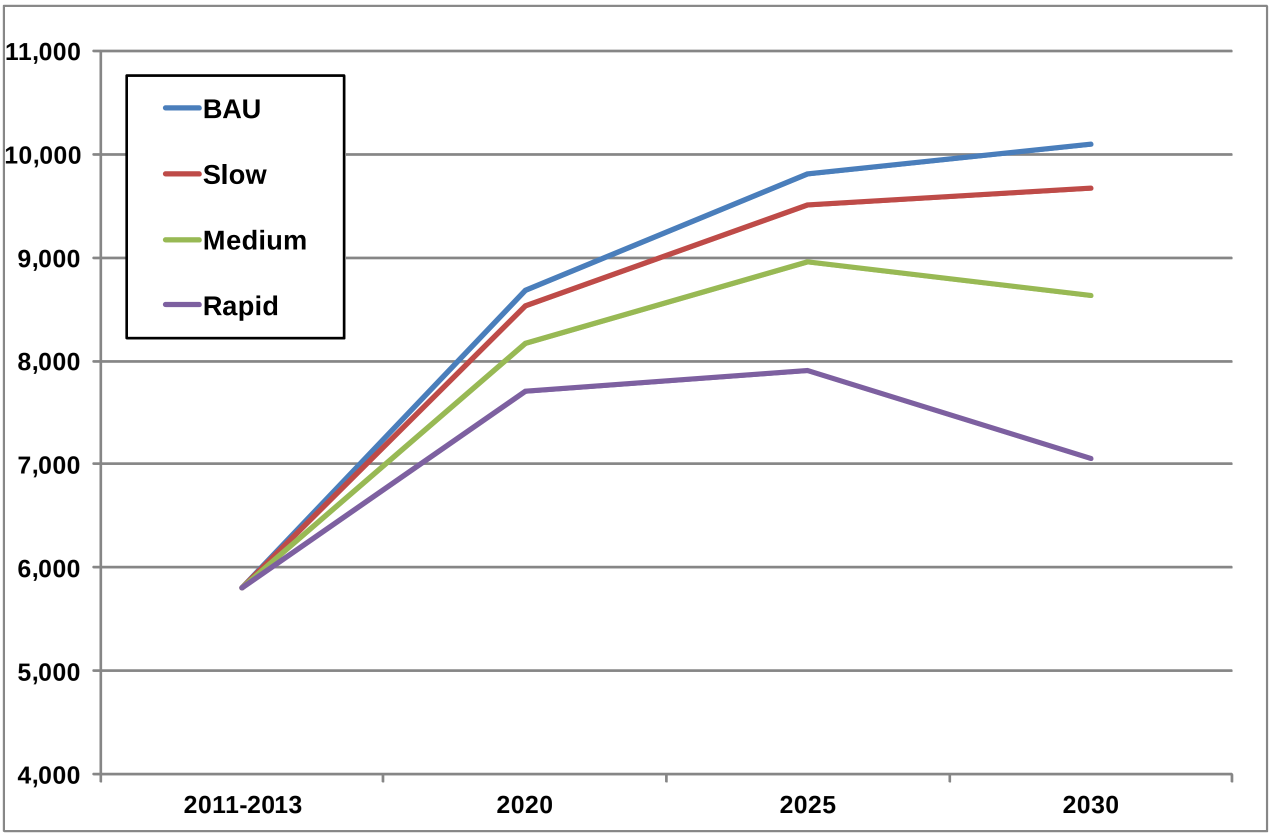
4.2 Performance of Scenarios against Kazakhstan's Climate Policy Targets

The Intended Nationally Determined Contribution (INDC) that Kazakhstan submitted to the UNFCCC in the run-up to the 2015 Paris Climate Conference includes the following targets[26]:

- An unconditional target of a 15% reduction in GHG emissions by 31 December 2030 compared to the base year of 1990. This amounts to a 22-34% reduction in GHG emissions by 2030 compared to BAU projected emissions.
- A conditional target of a 25% reduction in GHG emissions by 31 December 2030 compared to the base year of 1990. The additional 10% reduction is subject to Kazakhstan receiving international support in the form of climate finance, technology transfer and capacity building. The target amounts to a 32% reduction in GHG emissions by 2030 compared to BAU projected emissions.

According to Kazakhstan's latest GHG inventory total GHG emissions[27] in 2012 were 260 million t CO_2 or 27% below 1990 levels. The cement industry accounted for 5.8 million t CO_2 or 2.2% of the total. Under the INDC Kazakhstan's GHG emissions are allowed to increase 12% between 2012 and 2030, i.e. to 304 million t CO_2. For the cement industry, a 12% increase would put the sector's GHG emissions at approx. 6.7 million t CO_2. Given the expected production increase of approx. 90% until 2030, it is difficult for the cement sector to stay within these limits. The BAU scenario exceeds this limit by 50% and even the "Medium" and "Rapid" scenarios exceed the limit by 28% and 7%, respectively.

Figure 15: Scenarios for GHG Emissions in Kazakhstan's Cement Industry



[26] http://www4.unfccc.int/submissions/INDC/Published%20Documents/Kazakhstan/1/INDC%20Kz_eng.pdf

[27] Including all sectors: energy, industrial processes, agriculture, LULUCF (land use, land use chance and forestry), waste.

Table 16: GHG Emissions from the Cement Sector in Kazakhstan, 2011-2030

Scenario	2011-2013	2020	2025	2030	Increase 2030 over 2012	Savings vs. BAU 2016-30
	1000 t CO_2	1000 t CO_2	1000 t CO_2	1000 t CO_2	%	1000 t CO_2
BAU	5,800	8,577	9,703	10,010	73%	
Slow	5,800	8,437	9,418	9,616	66%	3,545
Medium	5,800	8,082	8,876	8,586	48%	11,204
Rapid	5,800	7,656	7,861	7,146	20%	23,516

Kazakhstan's INDC also states that the unconditional target amounts to a 22%-34% emission reduction compared with the BAU scenario in 2030. By comparison, the improvement of GHG emissions in the cement industry versus the BAU scenario is relatively small, i.e. 4% for the "Slow" scenario and 14% for the "Medium" scenario. Only the "Rapid" scenario generates a comparable reduction with 30%. A major reason for this is that the BAU scenario for the cement industry already includes a significant improvement of specific GHG emissions over time. 2030 specific GHG emissions per tonne of cement in the BAU scenario are about 13% lower than average 2011-2013 emissions.

When compared with the BAU scenario the "Medium" and "Rapid" scenarios provide very significant aggregate improvements over the course of the 2016 to 2030 period. As shown in Table 16, they are generating 11 million tCO_2 and 23.5 million tCO_2 in GHG emission reductions, respectively. The savings in the "Rapid" scenario would thus provide 2.3% of the aggregate savings required under the INDC. This is in line with the 2.2% share the cement industry contributed to total GHG emissions in Kazakhstan in 2012.

4.3 Performance of Scenarios against WBCSD / IEA Roadmap

Kazakhstan's Key Performance indicators for energy efficiency and carbon intensity from 2011 to 2013 compared unfavourable with the global average as identified by the WBCSD / IEA study. Nevertheless, over the coming 15 years the sector can catch up with regards to several indicators. In the Medium and the Rapid scenario, the figures for thermal efficiency are expected to lie close to the global 2030 average. The situation is similar for the use of clinker substitutes where Kazakhstan has already been using such materials in significant quantities but has room to further increase the volume. The situation is difficult for the fuel mix, as waste-derived or biomass-based fuels are currently not available and significant efforts are required to overcome barriers to their use. In result, Kazakhstan is expected to fall far short in terms of the carbon intensity of final cement products.

Table 17: Key Performance Indicators for the Cement Sector in Kazakhstan, 2011-2030

Coverage	Kazakhstan						Global Average		
Scenario	History	BAU	Slow	Medium	Rapid		WBCSD / IEA		
Year	2011-2013	2030	2030	2030	2030	2050	2006	2030	2050
% clinker	82%	82%	80%	75%	70%	67%	79%	73%	71%
% alternative fuels, incl. biomass	0%	0%	2%	18%	30%	40%	10%	23.5%	37%
% biomass	0%	0%	0%	7%	12%	16%	3%	N.A.	N.A.
GJ kiln fuel / t clinker	5.32	3.62	3.53	3.35	3.25	3.20	3.7	3.35	3.2
kg CO_2 / t cement	841	707	680	604	468	457	800	560	420*
kg CO_2 / t clinker	1026	865	853	810	690	678	-/-	-/-	-/-

4.4 Performance of Scenarios against EU ETS Benchmarks

The benchmarks which were imposed by the European Commission were 766 kg CO_2 per tonne of grey cement clinker and 987 kg CO_2 per tonne of white cement clinker. Grey cement plants in Kazakhstan will have difficulty reaching the EU-ETS benchmark, mostly due to the fuel mix, which is more heavily weighted towards coal in all three scenarios.

Table 18: Comparing the scenarios with the EU-ETS Benchmark for Grey Clinker Production

Coverage	Actual	BAU	Slow	Medium	Rapid	EU-ETS Benchmark
Year	2011-13	2030	2030	2030	2030	
kg CO_2 / t clinker	1026	865	853	810	711	766

For white cement plants GHG emissions per tonne of clinker were already significantly lower than the benchmark, even though the white cement plant was still using a wet cement production process. This was largely due to the exclusive use of natural gas at the kilns of the company,

4.5 Performance of Scenarios against Energy Efficiency Targets and EU BAT benchmarks

The Green Economy Concept, approved in 2013, sets economy-wide targets for energy efficiency and aims to reduce energy consumption per unit of GDP by 10% in 2015, 25% in 2020 and 30% in 2030 compared to the 2008 baseline level.[28] A comparison with the energy efficiency

[28] Concept for transition of the Republic of Kazakhstan to Green Economy, Astana 2013, Approved by the President of the Republic of Kazakhstan approved on May 30, 2013 #557.

improvements under the four scenarios is made more difficult because the base years are different. Compared to 2011-2013, the improvement required by the Concept is around 25%, which is exceeded in all the scenarios, even the BAU. In the “Rapid” scenario the energy consumption per tonne of clinker is slightly better than BAT, while the “Slow” and “Medium” scenario fall slightly short.

Table 19: Comparing the scenarios with the BAT standard for Energy Efficiency in Grey Clinker Production

Coverage	Kazakh Cement Industry	BAU	Slow	Medium	Rapid	EU BAT
Year	2011-13	2030	2030	2030	2030	
Units	GJ/t clinker	GJ/t clinker	GJ/t clinker	GJ/t clinker	GJ/t clinker	GJ/t clinker
Thermal Efficiency	5.32	3.62	3.53	3.35	3.25	3.35

4.6 Performance of Scenarios versus Kazakhstan’s National Allocation Plan

The draft National Allocation Plan (NAP) for the 2016-20 envisioned an annual allocation of 5.9 million tonnes of CO_2 for the Kazakhstan cement sector. It also set aside a New Entrants Reserve (NER) of almost 22 million t CO_2 for companies that are starting up production and were not previously covered by the Kazakhstan ETS.

Table 20: Draft Phase III allocation of allowances in the Kazakhstan ETS, 2016-2020[29]

Sector	Number of participating companies	Allocation for 2016-2020 (tonne CO_2)	Allocation per year (tonne CO_2)
Energy	52	471,225,485	94,245,097
Oil, gas and coal extraction	44	83,355,877	16,671,175
Industry	43	191,932,522	38,386,504
… of which cement	**9**	**29,625,664**	**5,925,133**
Total allocation	139	746,513,884	149,302,777
New Entrants Reserve		21,946,508	4,389,502

When comparing with the expected 2020 emissions under the four scenarios, the allocation for the cement sector will be insufficient to cover all the GHG of the cement sector. On the other hand, for at least the “Medium” and the “Rapid” scenario the allocation will be sufficient to cover all existing cement plants. New plants would have to rely on the NER to obtain their allocation or purchase quotas from other ETS-participants. New cement plants could need a very significant share of the available NER, as under each scenario they would claim more than 25% of the available annual NER quotas. That is a substantial share considering that the cement industry makes up 4% of the total allocation in the NAP for 2016 to 2020.

[29] National Allocation Plan for 2016-2020, submitted on 3 November 2015 for approval by the parliament.

Table 21: GHG Emissions by Kazakhstan's Cement Industry, 2011-2020

	2011-13	2020		
	Total	**By Existing Cement Plants**	**By New Entrants**	**Total**
	t CO_2	t CO_2	t CO_2	t CO_2
BAU	5,716,320	6,144,503	1,329,787	7,474,290
Slow	5,716,320	6,063,862	1,299,831	7,363,693
Medium	5,716,320	5,273,027	1,554,557	6,827,585
Rapid	5,716,320	4,190,808	2,473,519	6,664,327

5. Cement Plant of the Future

The cement plants currently operating in Kazakhstan are of very similar size. All the grey cement plants produce around 1 million tonnes of clinker per year, or 3000-4000 tpd. Exceptions are the two Steppe Cement plants, Karcement and Central Asia Cement, which are located closely together in Karaganda. Similarly, Standard Cement is in the process of doubling its capacity. Most of the plants currently in operation are either new or already modernized. Once the plants currently under construction are commissioned, their total capacity will be sufficient to meet the expected cement demand until 2030. Consequently, it can be expected that the two size classes will remain representative until at least that time.

Over the years to 2030 it is expected that the cement plants in Kazakhstan will evolve into two size classes of 3,000 to 4,000 tonnes per day (t/d) of clinker (3,750 to 5,000 t/d of cement) and 6,000 to 8,000 t/d of clinker (7,500 to 10,000 t/d of cement). The larger size class of cement factories will operate two kilns or a single high capacity kiln. Long kilns will be largely phased out and replaced by dry process kilns with suspension preheaters and precalciners. As a result, such reference cement plants for the future are expected to perform close to current best practices.

Table 22: Cement Plant of the Future: Key Performance Indicators

Key Performance Indicators	Unit	Current best practice	Performance Indicators of Kazakhstan cement installations	
			2011-13	Suggested for 2030
Clinker substitution	% clinker/t cement	<65%	82%	70%
Thermal energy consumption*	kJ/kg clinker	<3,350	5,340	3,250
Electrical energy consumption	kWh/t cement	<80	120	85
Alternative fuels (AF)**	% (thermal)	65-70%	0%	30%
Alternative raw materials (AR)**	% (kg/kg raw meal)	100% (small scale industrial)	0%	7%
CKD/BPD	% (of clinker)	0%	1%	0%
Specific CO_2 emissions	kg CO_2/t clinker	766 (EU ETS)	1026	711
Specific CO_2 emissions[30]	kg CO_2/t cement		841	500

Table 23 shows the technologies that would be applied in the reference plants. It can be seen that the technologies are largely the same for the two size classes. Waste Heat Recovery is an exception as economies of scale make such systems more economically viable for large cement plants.

[30] The figures exclude indirect emissions from the consumption of electricity at the cement plants.

Table 23: Cement Plant of the Future: Technologies

Processing Group	Processing Machinery / Inventories	Medium Sized Plants (3000-4000 tpd clinker)	Large-Sized Plants (6000-8000 tpd clinker)
Raw Material Crushing & Storage	Crushing Systems Raw Material Storage Systems	Hammer crusher (1) for limestone. Jaw or roll crusher for secondary materials. 7 days storage for crushed limestone (~35,000t). 15 days storage for secondary materials (~15,000t).	Hammer crusher (1) for limestone. Jaw or roll crusher for secondary materials. 7 days storage for crushed limestone (~70,000t). 15 days storage for secondary materials (~30,000t).
Raw Material Preparation & Storage	Raw Material Grinding Systems Raw Material Storage Systems	Vertical roller mill Controlled flow silo	Vertical roller mill(s) Controlled flow silo(s)
Clinker Production & Storage	Pyro processing Systems Clinker Storage Systems	Kilns with suspension preheaters and precalciners 20 days covered storage (~70,000t)	Kilns with suspension preheaters and precalciners 20 days covered storage (~140,000t)
Fuel Preparation	Coal Grinding Systems Raw Coal Storage Systems AFR Processing Platforms and Storage	Vertical roller mill Blending stockyard with 50 days capacity (~18,000t) Multiple facilities dependent of AF being used.	Vertical roller mill(s) Blending stockyard with 50 days capacity (~36,000t) Multiple facilities dependent of AF being used.
Cement Grinding and Storage	Cement Grinding Systems Cement Storage Systems	Vertical roller mills or Ball mills with roll presses for pregrinding Silos with 6 days capacity (~20,000t)	Vertical roller mills or Ball mills with roll presses for pregrinding Silos with 6 days capacity (~40,000t)
Packing & Dispatch	Packing Systems Dispatch Systems	Rotopacking machines Palletising, shrink-wrapping and automatic truck loading systems	Rotopacking machines Palletising, shrink-wrapping and automatic truck loading systems
Thermal Heat Recovery	Thermal Heat Recovery Systems		Steam Rankine cycle waste heat recovery systems