Improving Efficiency in Kazakhstan's Energy System

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Abstract Kazakhstan is one of the most energy-intensive countries in the world, almost 4 times higher than the world average and 7 times higher than the OECD average. There are various reasons for inefficiencies in Kazakhstan's energy system: administrative and economic (statistical double counting of energy flows, above normative losses and low profitability), geographic (the extremely continental climate and low population density) and technical considerations (high share of coal in generation mix, high wear on main and auxiliary equipment in energy intensive sectors, high wear on electric lines, dilapidation of housing stock, and an absence of control systems for energy savings) all contribute to the high energy intensity. This study explores energy efficiency potential by analyzing the evolution of the Kazakh energy system. All the technical inefficiencies have been taken into consideration through the explicit representation of existing inefficient technologies/chains in a TIMES-based model. Under the assumptions of a market-oriented development of the economic system, even without specific policies (Business as Usual), the model suggests significant energy efficiency improvement: 22 Mtoe (million tons of oil equivalent) by 2030 and a 40 % reduction in energy intensity of GDP by 2030. The more ambitious policy target of reducing energy intensity of GDP by 40 % by 2020 also appears easily achievable via economically viable solutions.

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1 Introduction

The high energy intensity of the Republic of Kazakhstan can be explained better by deconstructing the fuel-energy balance—as published by the Committee on Statistics of the Republic of Kazakhstan (2013) and the International Energy Agency (2013). For the present analysis, the fuel-energy balances of the Committee on Statistics were reclassified according to the IEA format, cross-checked with available information on technology and infrastructure and compiled with other local sources of information.

The total primary energy supply of Kazakhstan was 64.5 Mtoe in 2011 (million tons of oil equivalent): almost half of which was consumed by the energy sector (including losses). The International Energy Agency reported an energy intensity of GDP of 0.93 toe/thousand USD (at 2005 prices) in 2011, 3.7 times higher than the world average and 6.6 times higher than the OECD average.

As represented in Fig. 1, the ratio of total final consumption over total primary energy supply (TFC/TPES) is significantly higher in other countries, 55 % in Kazakhstan. The world average is 69 %, while the share is 64 % in the Russian Federation and 79 % in Canada (IEA 2013).

Power plants' transformation losses account for 15 Mtoe: 23 % of the country's total primary energy supply (TPES). This is explained by the fact that most power plants were inherited from Soviet Union days, and that 41 % of generating capacity have been operating for more than 30 years (ME RK 2010). Efficiency at the largest coal fired electric power plants is no more than 40 % while that at heating plants does not exceed 65–70 %. The introduction of new heating plants may increase efficiency by up to 85–90 %. Coal is the most commonly used fuel at power plants, accounting for 67 % of total generating capacity.

Another 8 % of TPES (4.8 Mtoe) is attributed to losses, most of which are heat losses (1.9 Mtoe). According to the Ministry of Energy of the Republic of Kazakhstan (ME RK 2010), between 2010 and 2011, 37 % of generated heat was lost. The country's severe climatic conditions require high consumption of heat since the average winter temperatures are −19 °C in the North and −5 °C in the South.

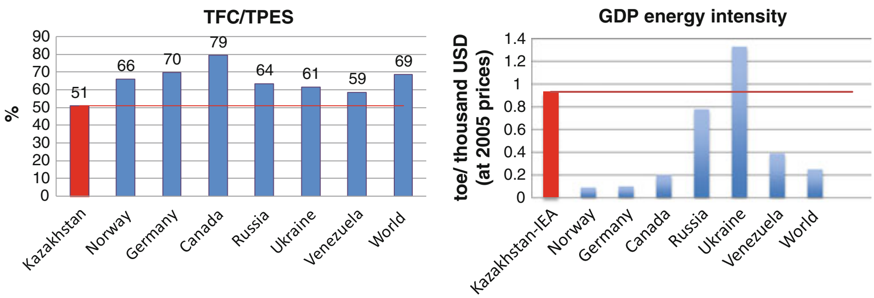

Fig. 1 Benchmarking analysis of TFC/TPES and TPES/GDP

Heating networks have deteriorated, with more than 60 % of components in use for over 20 years. Electricity losses are also high, at 9.3 % of total generation, due to long distance transmission and severe climatic conditions, and wear and tear is significant, at 50–60 %.

There are significantly high rates of self-consumption in the oil and gas sector—4.6 Mtoe (7 % of TPES). Kazakhstan is a net exporter of crude oil and natural liquids: 71.3 Mtoe in 2011 (110 % of domestic TPES). Gas is also exported, at lower volumes—most recently, 10.1 Mtoe. Power plants's self-consumption account for another 2 Mtoe: 11 % of the electricity generated.

On a demand side, industry is the biggest consumer in Kazakhstan—12 Mtoe (19 % of TPES). The energy efficiency of industry in Kazakhstan is low, at 45–60 %, as equipment is old and worn out. Until recently, there were no energy efficiency policies or programmes. Also, the prices of energy commodities were too low to result in reduction of energy consumption. Industry in Kazakhstan is mainly represented by energy intensive and heavy industries.

The residential sector is the second largest consumer of energy in Kazakhstan—9.7 Mtoe. Climatic conditions force households to use 2.3 Mtoe of heat, 2 Mtoe of coal, 2 Mtoe of gas and another 1.6 Mtoe of oil products, mainly for heating purposes. The Ministry of Energy of the Republic of Kazakhstan reports that, on average, buildings consumed 270 kwh/m^2 of heat in 2010: 1.5–2 times higher than in other countries with a similar climate (ME RK 2010).

Kazakhstan has significant potential for improving its energy efficiency and reducing its GHG emissions across most sectors of its economy. The Government of Kazakhstan has already taken steps to reduce its energy consumption through the direct and indirect policies discussed in the next section. The main aim of this chapter is to investigate the energy efficiency potential of Kazakhstan, using techno-economic modeling instruments.

2 Policies and Measures in Energy Efficiency in Kazakhstan

On 12th January 2012, the Law on Energy Saving and Improving Energy Efficiency (2012) was adopted. It covers the creation of the State Energy Register, and mandatory energy audits on major industrial sites and public services. In 2014, the Government planned to establish voluntary agreements on energy saving with industrial companies. The residential sector is affected by a law promoting metering, with differentiated pricing of district heating depending on the availability of metering devices. Provision of heat, electricity and gas is prohibited to new sites unless meters are fitted, and sales and production of electricity consuming devices are prohibited unless class of efficiency is indicated. Sales and production of incandescent lamps are also now prohibited.

In 2013, the Concept of the Republic of Kazakhstan for Transition to a Green Economy (2013) was approved. It sets concrete targets for six key sectors: water resources, agriculture, energy efficiency, the power sector, air pollution and waste utilization. It aims to ensure that renewable energy and nuclear power account for half of all electricity generation by 2050. The plan is also for gas fired power plants to account for 30 % of total electricity generation by 2050. This requires investment into gas infrastructure across the Northern, Eastern and Southern regions of the country.

To realize these ambitious targets, the Energy Saving—2020 programme was adopted in 2013 (ME RK). This defines strategies to improve energy efficiency across the industry, transport and residential sectors, and electricity and heat distribution systems. The final target is to reduce energy intensity of GDP use by 40 % by 2020 (compared to 2008 levels).

3 Approaches to Modelling of Improving Energy Efficiency

3.1 Energy Efficiency Chains

The model of the Kazakh energy sector (TIMES-KZK), calibrated to the reclassified national energy balances of 2009–2012 and further broken-down by end-uses in each demand sector, makes explicit the stocks and technical characteristics of existing technologies, as well as the energy flow through the system, resulting emissions, and associated costs, thereby reproducing the present inefficiencies in Kazakhstan.

The TIMES-Kazakhstan single region model represents all steps in the energy chain: from extraction of primary resources to their supply to primary energy markets; from transformation of primary energy carriers to their transmission and distribution to the final energy sectors (residential, commercial, industry, transport, agriculture); and from the use of final energy commodities to the satisfaction of end users demand for energy services (space heating and cooling, water heating, lighting, private and public mobility, iron and steel production, etc.). This process-oriented model provides a consistent framework with which to explore various paths towards energy efficiency within the coming 15–20 years.

Energy efficiency improvements (EEI) are virtual commodities of the model, representing energy not consumed whenever an existing technology is substituted with something better, at extra cost (Sarbassov et al. 2013). Equations 1 and 2 make explicit the efficiency gaps (EG) between an existing reference technology (ET) and the new ones (NT) available for the same energy sector/service (j), as well as the virtual savings due to the use of more efficient technologies (Q(NT)). Alternative options (NT) are included in a technology repository and characterized by an additional attribute representing the efficiency gap. Per each unit of output of the new technology (i), $EG_{i,j}$ units of improvements (units of losses avoided) are generated.

$$EG_{i,j} = \left(EFF(NT_i)_j - EFF(ET)_j\right) \quad (1)$$

$$EEI_{i,j} = EG_{i,j} * Q(NT_i)_j \quad (2)$$

EG efficiency gap
NT new technology
ET reference technology
EFF energy efficiency of the technology, which can be expressed as a ratio between energy output of the technology to its input
EEI energy efficiency improvement
Q savings
i indicator for a generic new technology
j energy service

EEI index must be intended as an approximate measure of efficiency improvement due to the chain of commodities and technologies before and after the system point where each measure applies. In terms of primary energy supply equivalent, the amount of avoided losses is greater; in terms of final energy consumption it is slightly lower.

In particular, new-generation electricity consumption meters are explicitly described through investment costs (US$2 at prices of 2000 per GJ per activity) and savings potential (up to 4 % of the unnecessary electricity consumption, based on authors estimation), while the installation of heat meters (with automatic regulation of the radiator temperature) could reduce the consumption by about 35 % (Sarbassov et al. 2013) with reference to the present situation, at a cost of about US$25 at prices of 2000 per GJ per activity.

The main technical causes for inefficiencies have been taken into consideration in current analysis, through the explicit representation of existing inefficient technologies and chains, as well as of some more efficient alternatives for the future development of the Kazakh system. To reduce tampering, which causes the above normative losses, the possible installation of meters has been considered. Thus, the model is able to track improvements in electricity, heat and natural gas transmission/transport and distribution, as well as in the oil, coal and gas transformation and uses.

The development of demand toward 2030 is driven by assumed population, and GDP (a medium variant projection by the Committee on Statistics of the Republic of Kazakhstan). From 2009 to 2030, the population is predicted to grow by 30 % (at 1.25 % pa), while GDP is assumed to rise at an annual rate of 6 % pa until 2020, followed by 5 % pa later on (300 % growth by 2030).

3.2 Internalising Energy Policy Instruments

Energy efficiency improvements result from investments into upgrading, affecting primary energy supply and resulting emissions. Through tracking technologies and energy flow, analysts can determine improvements in efficiency across the system, checking where specific measures bring cost-effective changes.

Standards and carbon taxes are often considered in order to reduce consumption across energy systems, and such regulatory-based and market approaches are usually combined in a multi-policy instrument, aiming to enhance additive energy and carbon reducing effects. Moreover, the explicit modelling of existing and new technological options allows for the use of subsidies (directly stimulating energy efficiency improvements), by applying an incentive per unit of loss avoided. Such a new instrument, generally called energy efficiency feed in tariffs—EEFiTs, has not been used for the scenarios presented in this paper, but it is fully embedded in the last version of the Kazakhstan model.

The present study aims to test two alternative approaches across the entire system: targeting energy intensity of GDP (a regulatory-based approach), and testing a CO_2 tax (a market-based approach).

4 Scenarios and Results

Two scenarios were run for this study, to quantify the potential for energy efficiency improvements in the Kazakhstan's system, subject to two types of energy measures. The first envisages reducing energy intensity of GDP by 40 % by 2020 (compared to the 2008 level) as set in the Energy Saving-2020 programme (ME RK 2013). The second offers an incentive of US$20 (at 2000 prices) per ton of CO_2 equivalent reduced starting from 2020 (CO_2TAX). The results, presented in Fig. 2, show the strong impact of energy intensity on reducing TPES (which is the denominator of the indicator, the reduction is due largely to improved efficiency in the coal chain), and the relevant impact of CO_2 taxation on emissions and the penetration of natural gas.

The Business as Usual (BaU) scenario doubles TPES by 2030, with coal remaining the dominant fuel (57 % of TPES). Assuming rigid GDP growth[1] (inelastic energy service demand), the target for GDP energy intensity would lower TPES by more than 22 Mtoe both in 2020 as well as in 2030, almost halving the coal supply compared to BaU. The overall efficiency of the system (the amount of energy consumed per unit of energy supplied) will reach 72 %: comparable to the levels in

[1]Domestic GDP is strongly tied to oil and gas export volumes. In the present analysis, all the scenarios share the same assumptions about export increases, which are consistent with the assumed GDP growth rate.

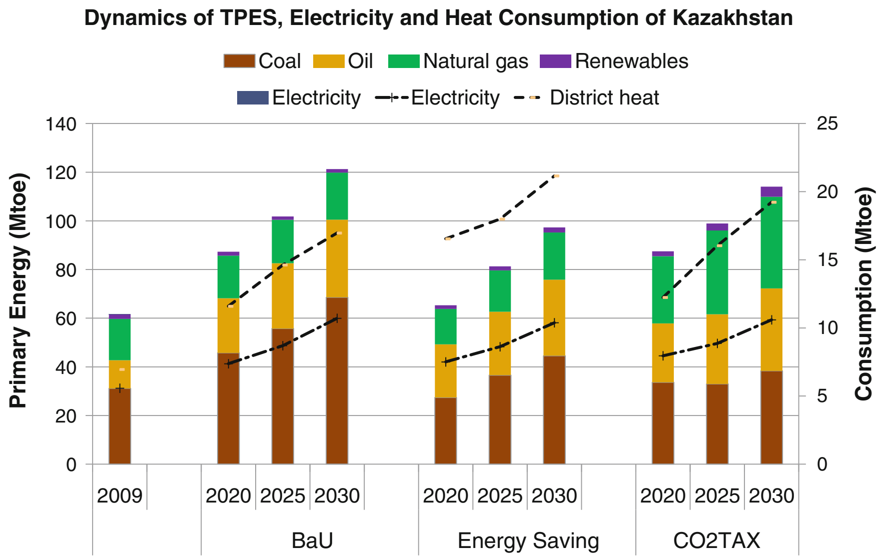

Fig. 2 Dynamics of TPES, electricity and heat consumption

Norway and Germany. The impact of CO_2 taxation[2] on TPES is less evident. The total supply in 2020 would be almost the same as in the BaU case, with reduction by 2030 to around 7 Mtoe.

In terms of reducing emissions, regulatory-based measures are much less effective than taxation-based measures. The dynamic of CO_2 in the former case is very similar to the BaU dynamic, while the latter produces an evident reduction in emissions (more than 25 %). Such a reduction is mainly due to the strong penetration of natural gas (from 19.5 Mtoe to 37.5 Mtoe in TPES) in the generation and final consumption sectors, and to the significant improvement of the efficiency of natural gas-fired stations, as shown in Figs. 3 and 4. Reducing the growth of CO_2 emissions in Kazakhstan—from the average annual 12–8 %—would require significant change in the configuration of the energy system and the involvement of gas. Currently, most of the gas extracted is reinjected; therefore, issues on gas production, processing and transportation should be resolved, to provide additional gas to the domestic market.

Figure 3 shows that even in the BaU case, energy savings may reach 10 Mtoe by 2020 and 22 Mtoe by 2030—mainly through more efficient coal transformation and electricity end-use sectors. This scenario reduces energy intensity of GDP by 18 % by 2020 and by 40 % by 2030 (compared to current levels). Meanwhile, the

[2]Such an approach simulates policies and measures already announced, for instance in the Concept of the Republic of Kazakhstan for Transition to a Green Economy (2013), and (more in general) aims to stimulate a market-based renovation and improvement of those technologies which become competitive at a low CO_2 price.

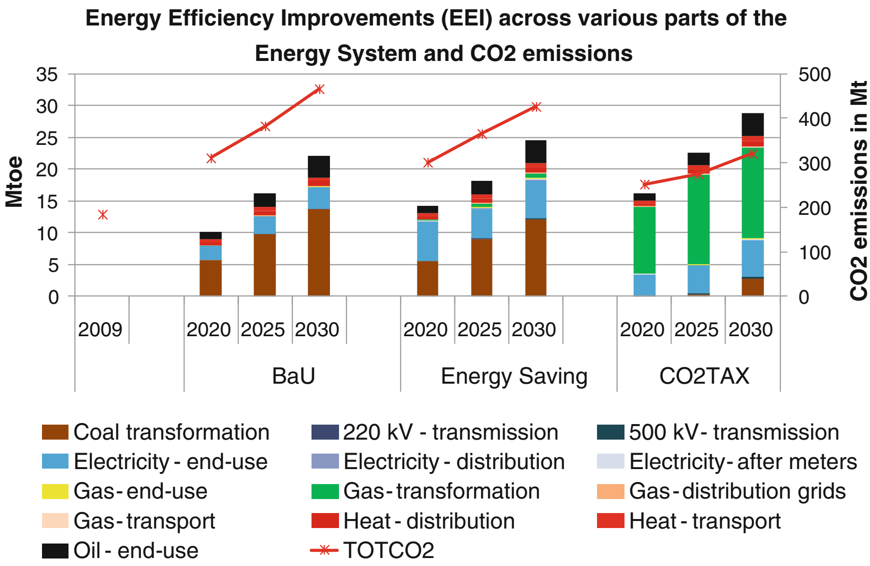

Fig. 3 Energy efficiency improvements across various parts of the energy system and CO_2 emissions

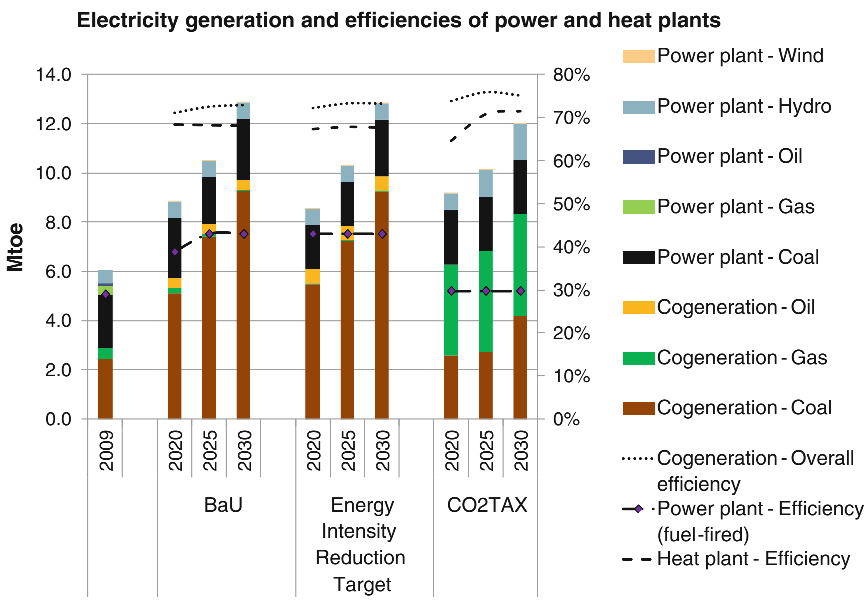

Fig. 4 Electricity generation and efficiency of power and heat plants

TFC/TPES indicator rises to 62 % by 2030. This means that most energy efficiency improvements are economically feasible and can be easily achieved once administrative and regulatory barriers are eliminated.

For all considered scenarios, most improvements are due to higher efficiency of generation (mainly coal-based in the BaU and in the Energy Intensity Reduction Target scenario, and mainly gas-based in the CO_2TAX case). Also, improvements are evident in the substitution of old electrical appliances with more efficient options, and new vehicles for the transport sector.

By 2030, the efficiency of CHP plants will rise by 9 % (maximum) while that of heat plants rise by 7 %. Figure 4 also demonstrates that CHP plants prevail in the new capacity-mix, rather than fuel fired pure electricity plants—mainly because climatic conditions force high demand for heating (as well as increasing levels of housing stock per capita). This is consistent with the recent Energy Saving Law, which aims to increase the use of cogeneration plants.

In absolute terms, the effects of the two efficiency-oriented alternative measures are hardly distinguishable in the demand side, as the total final consumption is almost the same over the three scenarios (slight reductions of 5 and 6 Mtoe compared to the BaU case for 2030), although the share of resources shifts, with natural gas partially replacing coal for heating.

5 Conclusions

The BaU case suggests significant energy efficiency improvement, meaning some significant cost-effective improvement (in particular regarding generation) can be gained, even without a specific energy policy to reduce (eliminate) market barriers (low priority of energy issues, incomplete markets for energy efficiency, distortionary fiscal and regulatory policies, and insufficient, or inaccurate information).

More than 50 % of energy efficiency improvement in the BaU case can be obtained by replacing old, coal-fired stations with modern coal plants. The efficiency of the energy system (TFC/TPES) increases from the current level of 55–62 % in the BaU scenario and to 72 % in the Energy Intensity Reduction Target scenario, by 2030, reaching the current level of Norway and Germany.

The reduction of energy intensity of GDP by 40 % by 2020 (compared to the 2008 level) can be achieved with economically viable options and without significant structural changes to the energy system: using timely technology updates and no market barriers. On the contrary, reduction of CO_2 would require significant efforts to increase the share of gas in the fuel mix.

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