

Analysis of the energy intensity of Kazakhstan: from data compilation to decomposition analysis

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Abstract There are large gaps in energy consumption data and consequently in the estimates of CO₂ emissions from fuel combustion in Kazakhstan. This study provides the first comprehensive review of energy consumption trends in Kazakhstan, discusses several important discrepancies in energy statistics and presents an improved versions of *Energy Balances*, developed using additional data. The results indicate that Kazakhstan's energy intensity of gross domestic product (GDP) declined by 30% from 1.14 to 0.8 toe/thousand 2005USD between 2000 and 2014. To understand factors influencing this decline, the change in energy intensity of GDP was decomposed using the Logarithmic Mean Divisia Index I method. The upstream sector (mainly oil and gas) played the most important role in the observed GDP energy intensity change. Although the share of this sector in total GDP increased, causing an increase in energy intensity due to inter-sectoral structural effects, the consequences were counteracted by a twofold

decline in the sector's energy intensity, resulting in a net decrease. On the contrary, the power and heat, transport and household sectors saw an increase in energy intensity between 2000 and 2014. The results clearly demonstrate that there is an urgent need for policies and measures to be put in place in the power and heat, household and transport sectors, to support renewable energy development, increase buildings' energy efficiencies, replace inefficient stoves and improve heating systems and encourage changes in public transportation systems. Furthermore, improving energy statistics and setting appropriate sectoral energy intensity reduction targets are crucial for achieving real efficiency improvements in the economy.

Keywords Energy intensity · Decomposition · Energy statistics · Kazakhstan · Energy efficiency

Introduction

Even though Kazakhstan's energy intensity of gross domestic product (GDP)¹ fell by 30% between 2000 and 2014, the country has one of the highest energy intensities in the world. In 2014, Kazakhstan's energy intensity of GDP was calculated to be 0.37 tonnes of oil equivalent (toe)/thousand 2010USD (based on our

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¹ Energy intensity of GDP is the ratio between the total energy consumption of a country and its GDP. It provides a measure of the amount of energy required to generate 1 unit of GDP (World Energy Council 2016).

estimates),² which is 71% higher than the Organisation for Economic Cooperation and Development (OECD)'s average (0.11 toe/thousand 2010USD) and 49% higher than the world's average (0.19 toe/thousand 2010USD) (IEA 2017). Under the Paris Agreement, Kazakhstan has an ambitious nationally determined contribution (NDC) target to reduce its greenhouse gas emissions (GHG) by 15–25% by 2030 compared with 1990 levels. To meet this target, the country will need to take effective action towards energy transition because recent historical trends show a steadily increasing level of emissions over the last decade with an average annual growth rate of 3.7%. This rate will need to decrease as soon as possible for the country to meet its 2030 target.

One problem with monitoring progress is the significant uncertainty in energy consumption data. Kazakhstan's national statistics on energy are not harmonised with international standards (Eurostat 1998; IEA 2007) in terms of statistical forms, format of presentation, units and level of disaggregation (Radulov 2013; Kerimray et al. 2015a). As a result, there are significant issues with GHG inventory reporting to the United Nations Framework Convention on Climate Change (UNFCCC) and with energy balance submission of Kazakhstan to the International Energy Agency's (IEA). As an example, an inventory review report revealed that within the 2011 Energy Balance for Kazakhstan, total consumption values of coal, oil and natural gas were higher when estimated with reference approach compared with their estimate with sectoral approach³ by 19, 4 and 19%, respectively, which could lead to underestimation of GHG emissions from stationary combustion⁴ (UNFCCC 2014). As a result, CO₂ emissions calculated based on the reference and sectoral approaches vary widely from year to year, e.g. from –0.3% in 2005 to 27.3% in 2008, with discrepancies generally greater than 2.0%. Moreover, the data for total apparent energy consumption reported to the International Energy Agency and UNFCCC differ significantly, varying by up to 10% during the period

considered, except for 2002 when the difference reached 15.1% (UNFCCC 2014).

There have only been a few studies which have analysed historical trends in energy consumption in Kazakhstan: Xiong et al. (2015) and Mudarissov and Lee (2014) investigated the relationship between energy consumption and economic growth; Atakhanova and Howie (2007) estimated the country's electricity demand; and Gómez et al. (2014) identified causes of energy inefficiency in Kazakhstan in 2010 using a Long-range Energy Alternatives Planning System (LEAP) bottom-up model. Furthermore, using a TIMES-MARKAL model,⁵ Sarbassov et al. (2013) and Kerimray et al. (2015b) explored the potential for energy efficiency improvements and Kerimray et al. (2015a) also examined measures to reduce greenhouse gases emissions (Kerimray et al. 2015a; PMR Kazakhstan 2016). To date, there have been no studies which have provided an in-depth analysis of sectoral energy consumption trends or examined the effects of sectoral activities and structural shifts on energy intensity in Kazakhstan. Previous studies have not addressed the problems with current energy statistics and have mostly relied solely on energy consumption and GHG data from the UNFCCC and/or IEA (Gómez et al. 2014; Karatayev et al. 2016; Xiong et al. 2015).

Understanding the trends and drivers behind Kazakhstan's historical energy consumption and energy intensity is crucial for policy makers and the public when developing new policies for energy system transformations and climate change mitigation measures for the future. This paper presents results from in-depth data analysis and compilation along with a detailed review of energy trends and their underlying causes based on a decomposition analysis. Conducting a decomposition analysis without prior in-depth data analysis and compilation would not be practicable due to the issues with the energy statistics available (see below). As a result, improved versions of the *Energy Balances* for Kazakhstan were compiled and cross-checked with additional data provided by the Kazakhstan Electricity Grid Operating Company (KEGOC), the Ministry of Energy of the Republic of Kazakhstan (ME RK), the Information-Analytical Centre of Oil and Gas (IACOG) and the Committee of Statistics of the Republic of Kazakhstan (CSRK), as part of this study. Discrepancies and issues

² IEA reports indicate that the energy intensity of Kazakhstan in 2014 was 0.41 toe/thousand 2010USD (IEA 2017).

³ Total consumption with reference approach is calculated based on the energy supplied to a country. Sectoral approaches are based on fuel combustion statistics (IPCC 2006).

⁴ Stationary fuel combustion sources are devices that combust solid, liquid or gaseous fuel, generally for the purposes of producing electricity, generating steam or providing useful heat or energy for industrial, commercial, or institutional use, or for reducing the volume of waste by removing combustible matter (EPA 2014).

⁵ The Integrated Market allocation Energy flow optimisation model System (TIMES).

with the energy data available for Kazakhstan were highlighted. The results of this study will be useful for academics and modellers of future energy and emission scenarios to cross-check and ensure the reliability of their data. One of the aims of this study was to link sectoral energy consumption trends with economic activity data in order to determine the contributions of sectors and economic structural changes to energy intensity changes. Analysing energy consumption trends alone and neglecting economic activity trends would not provide insight into the causes underlying the trends observed. In this study, Kazakhstan's energy intensity of GDP change between 2000 and 2014 was decomposed using the Logarithmic Mean Divisia Index I (LMDI-I) method, which was initially proposed and applied by Ang (2004).

Methodology

Compilation of energy balances in the IEA format

The statistical publication *Fuel Energy Balance of Kazakhstan* produced annually by the Committee of Statistics of the Republic of Kazakhstan (CSRK) is one of the main sources of information regarding fuel and energy production, consumption, and transformation in the country for all economic sectors. Data from this publication is used to provide an inventory of the GHG emissions from the fuel combustion to the UNFCCC and the IEA. However, the energy balances reported by the CSRK do not follow the internationally used formats (Eurostat 1998; IEA 2007).

For example, the CSRK reports do not illustrate commodity flows from production to final use across sectors. The formats used mean the statistics reported are prone to double counting and the connections between sectors and uses are not immediately clear. The energy consumptions for different types of economic activity are presented in different tables, and most often, the types of economic activities have been grouped differently to the way they are in the IEA format. In addition, the way energy transformation processes are presented does not give a clear indication of fuel inputs and energy outputs. In contrast, the IEA format for illustrating energy balances offers a consistent framework for presenting data on energy use and production for all types of economic activities in a unique table (IEA 2007). The format ensures that double counting

and/or underestimated consumption of energy is minimised. The IEA format is used worldwide and allows comparable and replicable calculation of energy indicators.

In this study, the energy balances for Kazakhstan from the Committee of Statistics of the Republic of Kazakhstan (CSRK 2016a) have been transferred into the IEA format using the IEA guidelines for energy statistics (IEA 2007). The energy balance compilation method was followed, as described in detail by Tosato (2006), to calculate the energy balances for Kazakhstan for the period 2005–2014. The steps taken were as follows:

1. Comparison of fuels and sectors provided by the CSRK with the IEA definitions and mapping.
2. Allocation of the data from the main tables and economic activity type tables from the CSRK report to the IEA template and identification of appropriate links between fuels, sectors and uses.
3. Production of energy balances for each energy commodity in tables that reflect the supply of each energy resource and its consumption in physical units.
4. Comparison of data from the CSRK with other reliable sources, and, whenever necessary, replacement of the CSRK data in the tables with more reliable data. Investigation of the statistical differences⁶ causes and their elimination. Analysis of the efficiency of oil refineries, coke ovens, blast furnaces, gas processing plants, power generation and heat plants.
 - Replacement of data for power plants' fuel input and energy generation with data provided by KEGOC and ME RK. Data was disaggregated as necessary by type of plant, e.g. combined heat and power plants (CHP), electricity plants, heat plants, etc.; also by main activity or autoproducer.
 - Replacement of data on the production, import and export of coal, oil and gas with data provided by ME RK and IACOG.

⁶ Statistical differences are defined as deliveries to final consumption + use for transformation processes + consumption by energy industry own use + losses – domestic supply – transfers.

5. Production of unified fuel-energy balances in tables, with integration of all single fuel balances into one combined balance in energy units (oil equivalent).

The main principle behind the energy balance compilation method is to ‘close’ the balance between supply and total consumption (as applied by Tosato 2006). Importantly, in this study, data related to the supply side were untouched for most of the commodities, except in cases where data from the IACOG and ME RK were used. No assumptions were made regarding the supply side; the data were obtained from local sources and assumed to be reliable. Additional information was searched for consumption sectors, if statistical difference occurred.

In the energy balance report produced by the CSRK, bituminous coal is represented in one column, without further breakdown to coal classification (e.g. coking coal, other bituminous coal and sub-bituminous coal). In Kazakhstan, the calorific values of different coals can vary by 20–35%. Thus, in this study, bituminous coal was broken down into three categories: coking coal, other bituminous coal and sub-bituminous coal, with different calorific values. The data provided by ME RK for coal production by coal mines was used to determine the quantity of coal supplied for each category.

The statistical differences of coal were found to correspond to 2–6% of the total production of coal, depending on the year. It was originally reported that significant amounts of coal and gas were used directly by power plants and heat plants as fuel for their own purposes; these quantities were thus reallocated as fuel inputs to power plants since other sources (KEGOC, ME RK) had reported higher fuel inputs for these plants. The use of data provided by KEGOC and ME RK significantly improved fuel-energy balance: statistical differences for both coal and gas were reduced, disaggregation by power plants was improved, and the generation efficiencies of power and heat plants in the revised calculations became more consistent with expected values.

The *Energy Balances* produced by the CSRK reported losses of bituminous coal of the order of 1100–3841 kt over the period 2007–2013. According to the instructions for respondents for the CSRK’s statistical forms, these should include losses related to coal preparation, the coking industry, coal briquette production, storage and transportation and ‘non-delivery’. However, such high values of coal cannot be lost in

abovementioned processes. Therefore, the quantities of coal reported as lost were redistributed to:

- Heat plants: coal inputs were increased by taking into account heat outputs (known value) and efficiencies (around 70–80%). The efficiencies of Kazakhstan’s heat plants are reported in: ‘Concept of the Development of Fuel-energy Complex of the Republic of Kazakhstan by 2030’ (Government of the Republic of Kazakhstan 2014).
- The residential sector: quantities reallocated to the residential sector were based on the results of two surveys on household living conditions (as described below).
- The commercial and public services sector: the remainder of the lost coal was allocated to this sector to reduce statistical differences to 0. The allocated value varied between 0 (2006–2008) and a maximum of 335 thousand tons of oil equivalent (ktoe) in 2011. These amounts correspond to 0–6% of the total commercial and public sector energy consumption. For this sector, there is a lack of information required to verify energy consumption values.

The assumptions regarding the additional allocation of coal and biomass to the residential sector were based on the results of two surveys on household living conditions: the ‘Quarterly Budget Survey of Households’ and the ‘Annual Household Survey’ which cover 12,000 households in Kazakhstan (Kerimray et al. 2016). These surveys were both administered by the CSRK. Households were selected by random sampling based on data from a Population Census following the ‘Methodology for Constructing a Sample of Households on the Survey of Households Living Conditions’ (Committee of Statistics of the Republic of Kazakhstan 2015a). The households selected were considered to be representative at both the national and regional level. The surveys covered all 16 administrative regions in Kazakhstan and the number of households varied between 0.1 and 0.5% of the total in each region. Fifty-two per cent of the households surveyed were urban, and the remaining 48% were rural. The survey results show that 40% of the households surveyed use coal and 25% use firewood. Coal and biomass consumptions in the residential sector were thus estimated from data for coal and biomass expenditure (from the Household Survey) and prices. The estimates calculated indicate that in the CSRK’s energy balance, the consumption of coal and biomass

are potentially underestimated. Biomass was additionally added to the supply and residential sector end-use. Coal was added to residential sector from the statistical differences. In addition, the survey indicated that very few households used oil products (Kerimray et al. 2016). In this regard, values of oil products in the residential sector in the energy balances were allocated to the transport sector. The statistical publication: ‘Housing and Utilities Sector’ published by Committee of Statistics of the Republic of Kazakhstan (2015b) contains data for the gas supplied to the population as reported by gas supply companies. The gas consumption reported for the residential sector was higher in the ‘Housing and Utilities Sector’ publication than in CSRK’s energy balance. Due to remaining amounts of gas in the statistical differences, higher value for residential consumption (from the ‘Housing and Utilities Sector’ Publication) was taken.

Following the IEA fuel-energy balance methodology, gas which was reinjected, flared or exported under SWAP arrangements,⁷ based on data from IACOG, was not included in the energy balance (only physical flows are tracked by the National Energy Balance).

Since the questionnaire used by the CSRK for its energy balance does not have a separate category for fuels used for transport purposes, gasoline consumption reported by the non-metal industry, construction, commercial and residential sectors was reallocated to road transport. Any statistical differences related to gasoline were also allocated to road transport. This assumption is consistent with Kazakhstan’s GHG Inventory submission to the UNFCCC. The small amounts of coal (up to 55 ktoe) reported by the road transport and domestic aviation sectors were reallocated to commercial and public services, as it was assumed that it was consumed for the heating of office buildings.

It was also assumed that all coking coal produced was used in coke ovens. In addition, crude oil consumption which had been reported in the final consumption sectors was reallocated to refineries based on data supplied by the IACOG. Quantities of associated gas reported as transformed to other fuels or energy by the ‘mining and quarrying’ sector was reallocated to ‘non-specified energy transformations’ as in the IEA format this category includes gas processing. Finally, district

heating consumption reported by the transport sectors was reallocated to the commercial and public services sector.

For the years 2000–2004, the energy balances compiled by Tosato (2006) were adopted. Tosato (2006) noted statistical difference between supply and total consumption, which totalled 3.3 Mtoe in 2000 and 7.4 Mtoe in 2004. Due to the absence of disaggregated data from other sources, Tosato (2006) made assumptions about the efficiencies of transformation processes. Statistics for the primary fuels (coal, gas, oil) were balanced by modifying the input to the transformation most relevant to the fuel. The resulting efficiency for electricity and heat generation⁸ was on average 54% for the years 2000–2004 (Tosato 2006) and 55% for the years 2005–2014 (this study), which proves consistency in the energy balance compilation for the power and heat generation sector.⁹ Mainly due to the absence of relevant data, fuels were not reallocated to the final consumption sectors (households, commercial and public services, transport) by Tosato (2006), as has been done in this study. Despite these differences in assumptions, the energy balances for the year 2000–2004 compiled by Tosato (2006) are judged to be the most reliable among available sources for Kazakhstan, because the energy balances submitted to the IEA contain discrepancies which will be described in detail in ‘Comparison with data reported to the IEA and UNFCCC’. Furthermore, comparing the energy consumption of the households, commercial and public services, and transport sectors for 2000–2004 and 2005–2008, showed that there was no significant fluctuation in the numbers.

The reclassified energy balances for Kazakhstan for 2000 and 2014 are presented in Appendices 1 and 2.

Decomposition method

The decomposition analysis for the change in energy intensity of GDP of Kazakhstan for the period 2000–2014 was conducted using the LMDI-I method, which was initially proposed and applied by Ang (2004, 2015). This method is a widely used for the analysis of energy consumption, energy intensity and carbon emissions

⁷ Commodity SWAP—exchange of commodities. Under SWAP agreements, the Russian company ‘Gazprom’, supplies gas to some Northern and Southern regions of Kazakhstan and in return, gas is supplied to Russia from Western Kazakhstan.

⁸ The efficiency of electricity and heat generation was calculated by dividing the total electricity and heat production by the total fuel input for power and heat plants.

⁹ Most of the power plants and heat plants were installed while Kazakhstan was part of the Soviet Union, and there have been no significant changes in the efficiencies of electricity and heat generation.

changes by years: for example, by Sumabat et al. (2016) for an analysis of Philippine's CO₂ emissions, by Cansino et al. (2015) for an analysis of Spain's CO₂ emissions, by Torrie et al. (2016) for analyses related to Canada and by Winyuchakrit and Limmeechokchai (2016) for an analysis of the Thai industrial sector's energy intensity and CO₂ emissions. Out of all these studies, the analyses for Canada (Torrie et al. 2016) provide an example of the implementation of the method for analysing the energy intensity of whole energy systems rather than for particular sectors. For evaluating progress towards European energy efficiency targets, Reuter et al. (2017) conducted decomposition analysis with LMDI method for primary energy consumption (PEC) of all Member States of the European Union in an aggregated manner (without split to sectors in the demand side).

For the analysis of energy intensity of GDP, total energy use (total primary energy supply) (E) is divided to two components: the first comprises the energy used by sectors which contribute to GDP by producing goods and services (business economy sectors, E_B) and the second is the energy used by households (residential sector and personal transportation, E_H). From this division, the next equations follow:

$$\frac{E}{\text{GDP}} = \frac{E_B}{\text{GDP}} + \frac{E_H}{\text{GDP}} \quad (1)$$

with

$$E_B = \sum_i E_i \quad (2)$$

where i is an index which represents a sector of the economy defined in Table 1 (excluding the households sector).

From Eq. (1), the energy intensity of GDP can be divided into components for the decomposition analysis:

$$\frac{E}{\text{GDP}} = \frac{E_B}{\text{GDP}} + \frac{E_H}{\text{GDP}} = \sum_i \frac{E_i}{\text{GDP}_i} \times \frac{\text{GDP}_i}{\text{GDP}} + \frac{E_H/\text{capita}}{\text{GDP}/\text{capita}} \quad (3)$$

The following four factors can be estimated from Eq. (3), the sum of which gives the total change in energy intensity: 'inter-sectoral structural change', 'energy intensity impact', 'per capita GDP impact' and 'household energy intensity impact'.

Table 1 Definition of sectors for energy intensity of GDP decomposition analysis

Sector	Types of economic activity included in the sector
Industry	Metallurgy, chemical and petrochemical, non-metallic minerals, transport equipment, machinery, mining and quarrying (except for fuels), food and tobacco, paper, pulp and print, wood and wood products, construction, textiles and leather, rubber and plastic, furniture
Power and heat	Main activity producer electricity plants, main activity producer CHP plants, autoproducer CHP plants, main activity producer heat plants, autoproducer heat plants
Upstream	Coal mines, oil and gas extraction and associated services, coke ovens, oil refineries, blast furnaces, gas processing
Commercial and public	Water supply, sewage systems, collection and distribution of waste; post and couriers; information and telecommunications; financing and insurance; real estate; professional science and technology; administration and additional services; education; public health and social services; public administration and defence and obligatory social provision; art, entertainment and leisure; hotels and restaurants; collection, processing and distribution of water; retail, wholesale and repair of cars; retail trade except cars and the motor trade
Transport	Road transport (excluding light duty vehicles), pipeline transport, rail transport, domestic aviation, domestic navigation
Agriculture	Crop farming, cattle breeding, hunting, and services in these activities; forestry, fishing
Household	Residential sector and personal transportation (light duty vehicles)

For the decomposition analysis in this study, the various sectors of the economy were aggregated into the following six main sectors: industry, power and heat, upstream, commercial and public services, transport and households and agriculture (Table 1). Each of these sectors represents a significant share of the energy consumption according to the energy balance of Kazakhstan and collectively covers all types of economic activity in the country. This was ensured by using the statistical classification of economic activities adopted by the CSRK (2016b). The sum of the energy consumption of these 6 sectors is equal to the Total Primary Energy Supply of the country. For the power and heat and

upstream sectors, values for net consumption (total energy use minus total generation) were used.

1. Inter-sectoral structural change. This change is related to the business sector and results from changes in various sectors' contributions to total GDP.

$$\Delta\left(\frac{E}{\text{GDP}}\right)_{\text{inter-sectoral structural change}} = \sum_i L\left(\left(\frac{E_i}{\text{GDP}}\right)^{T_2}, \left(\frac{E_i}{\text{GDP}}\right)^{T_1}\right) \ln(S_i^{T_2}/S_i^{T_1}) \quad (4)$$

where E is the total energy consumption (or total primary energy supply in the energy balance), i is an index representing a sector of the economy ($i = 1, \dots, 6$), $S_i = \frac{\text{GDP}_i}{\text{GDP}}$ and represents the share of total GDP attributed to a particular sector and $\text{GDP} = \sum_i \text{GDP}_i$. The starting year (T_1) was taken to be 2000, and the ending years (T_2) were 2005, 2010 and 2014. $L(a, b)$ represents the logarithmic mean of a and b and is calculated as follows:

$$L(a, b) = \frac{a-b}{\ln\left(\frac{a}{b}\right)}, \text{ for } a \neq b \quad (5)$$

$$L(a, b) = 0 \text{ when } a = b \quad (6)$$

$$L(a, b) = \frac{a-b}{\ln\left(\frac{a}{b}\right)}, \text{ for } a \neq b \quad L(a, b) = 0 \text{ when } a = b \quad (7)$$

2. Per capita GDP impact. This factor reflects the energy intensity change per household (energy consumption of households divided by total GDP) due to a change in per capita GDP. Household energy consumption includes energy used for personal transportation (light duty vehicles).

$$\Delta\left(\frac{E}{\text{GDP}}\right)_{\text{per capita GDP impact}} = L\left(\left(\frac{E_H}{\text{GDP}}\right)^{T_2}, \left(\frac{E_H}{\text{GDP}}\right)^{T_1}\right) \ln\left(\frac{\left(\frac{\text{GDP}}{\text{capita}}\right)^{T_1}}{\left(\frac{\text{GDP}}{\text{capita}}\right)^{T_2}}\right) \quad (8)$$

3. Energy intensity impact. This factor reflects the cumulative impact of changes in the energy intensity of all sectors (other than households) on the total GDP energy intensity change.

$$\Delta\left(\frac{E}{\text{GDP}}\right)_{\text{energy intensity}} = \sum_i L\left(\left(\frac{E_i}{\text{GDP}}\right)^{T_2}, \left(\frac{E_i}{\text{GDP}}\right)^{T_1}\right) \ln(I_i^{T_2}/I_i^{T_1}) \quad (9)$$

where

$$I_i = \frac{E_i}{\text{GDP}_i} \quad (10)$$

4. Household energy intensity impact. This factor reflects the impact of changes in per capita residential energy consumption on the total GDP energy intensity change.

$$\Delta\left(\frac{E}{\text{GDP}}\right)_{\text{per capita intensity}} = L\left(\left(\frac{E_H}{\text{GDP}}\right)^{T_2}, \left(\frac{E_H}{\text{GDP}}\right)^{T_1}\right) \ln\left(\frac{\left(\frac{E_H}{\text{capita}}\right)^{T_2}}{\left(\frac{E_H}{\text{capita}}\right)^{T_1}}\right) \quad (11)$$

Value added by each of the sectors to GDP for 2000–2014 was obtained from the CSRK's statistical publication *National Accounts 2015*. For each sector, this value was converted from the national currency, tenge, in current prices to USD in 2005 using deflator values and the average currency exchange rates for 2005 reported in *National Accounts 2015*.

Results and discussion

Comparison with data reported with the IEA and UNFCCC

The main indicators from the energy balances compiled in this work and by Tosato (2006) (referred to henceforth as the NU-NLA Balance) were compared with data

reported to the UNFCCC and IEA for the years 2000–2013. Differences in the Total Primary Energy Supply (TPES) values of NU-NLA and IEA varied between 1 and 20% (depending on the year).

The problems with the accounting of energy consumption for Kazakhstan is evident in the data reported to the IEA as ‘non-specified’ sector energy consumptions which varied between 2 and 15% of TPES. Statistical differences, which additionally add uncertainty to the IEA data for Kazakhstan, varied between -7^{10} and 6% of TPES. Furthermore, significant quantities of coal were reported under ‘losses’ (1495–1705 ktoe during the period 2011–2013). For comparison, both China and Russia, which have considerably higher levels of coal production and use, reported coal losses of 0.

In recent years (2008–2013), the values of TPES for gas differed considerably between IEA and NU-NLA by 3138–8286 ktoe (16–48% of TPES). For this study, values for gas were provided by the IACOG and reinjection and flaring were excluded from the gas production. However, IEA values may include reinjection and flaring of gas under production. In addition, in the IEA submission, 20–73%¹¹ of gas production was noted as consumed by energy industries for their own use. In comparison, in gas-exporting countries like the Russian Federation and Norway, only 2–4% of gas produced is attributed to own use by the energy industry. Figure 1 presents a comparison of the TPES values compiled in this study and those reported to the IEA and highlights the issues with the data reported to the IEA.

It is clear that the problems with energy statistics are also evident in the CO₂ inventory submission from Kazakhstan to the UNFCCC. Firstly, as discussed earlier, there are differences in the CO₂ emissions calculated using the sectoral and reference approaches, which result from differences in the total consumption of energy across all sectors and fuel supplies. In the latest 2016 inventory submission to the UNFCCC, the difference varied between 0.7 and 12% for the years 2000–2014 (UNFCCC 2016). Secondly, the ‘other (not-specified elsewhere)’ accounts for 6–22% of total CO₂ emissions from fuel combustion, which also occurred due to the

difference in data of supplies of fuels and reported consumption. A comparison of CO₂ emissions from fuel combustion in Kazakhstan based on the data of the IEA, NU-NLA and UNFCCC is displayed in the Fig. 2. Differences in values for total CO₂ emissions from fuel combustion in Kazakhstan between NU-NLA and UNFCCC is within 1–14% depending on the year.

Energy consumption trends

The energy consumption trends in Kazakhstan are closely linked to the economic development of the country, as demonstrated in Fig. 3 below (correlation coefficient between TPES and GDP for the period 2000–2014 was 0.97). Between 2000 and 2007, the country’s economy experienced a rapid recovery mainly due to oil revenues: the average annual growth rate of GDP was 10%. TPES also grew steadily with at an average of 7% per annum in the same period. During 2008 and 2009, the growth of the economy slowed to 1–3% due to the world’s economic crisis. In 2009, TPES fell by 9% with the largest reductions in energy usage of final consumption sectors corresponding to the transport, commercial and public and industry sectors.

Because of the country’s dependency on oil exports, in 2014 Kazakhstan experienced another financial crisis due to falling oil prices and a reduction in export volumes. The country’s currency was later devalued by 82% in 2015, and the IMF (2015) revised its predictions for the GDP growth of Kazakhstan to 1.5% in 2015, 2.4% in 2016 and around 4% in 2020. The effect of this crisis on energy consumption in 2014 can be observed in the data for the industry and transport sectors.

The highest energy consumption growth during the period from 2000 to 2014 was observed in the commercial and public sector, which grew by a factor of 3.72. This was followed by the transport (factor of 2.34) and residential (factor of 2.15) sectors. Industrial energy consumption has only grown by a factor of 1.61, and consumption in the agricultural sector has remained relatively stable.

In terms of the types of fuel and energy used, coal is dominant in TPES, although its share fell from 63% in 2000 to 49% in 2014. Coal is mainly consumed by power plants (61%) and heat plants (10%) for electricity and heat generation as well as by households (8%) for domestic heating. In contrast, the share of gas increased from 17% in 2000 to 25% in 2014. In TFC sectors oil products dominate, and the share increased from 29 to

¹⁰ In some years, negative statistical differences were reported to the IEA.

¹¹ In the IEA energy balance for Kazakhstan, large amounts of gas (up to 17,900 ktoe) were reported as consumed by energy industries for their own use. If these amounts were consumed for electricity and heat generation, they should have been included in the ‘power plants’ section of the energy balances (IEA 2007).

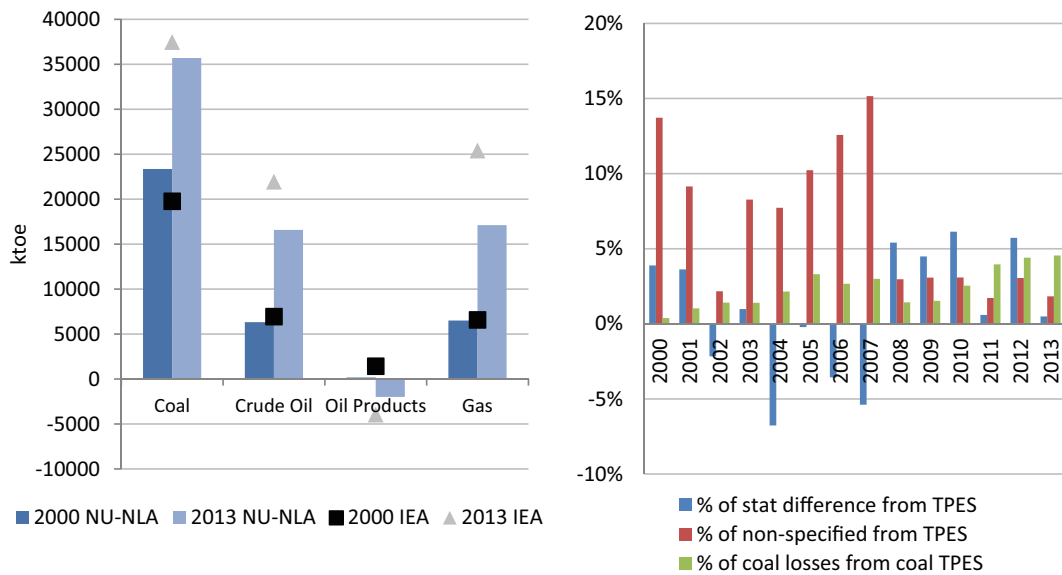


Fig. 1 Comparison of TPES values from NU-NLA and those reported to the IEA, ktoe (*left*) and issues with the data reported to the IEA (2016) (*right*)

32% between 2000 and 2014. This can mainly be attributed to the increasing demand for oil products from road transportation. Gas consumption in TFC sectors increased from 1320 ktoe in 2000 to 4960 ktoe in 2014. This is in line with the expansion of gas networks in communities located along the main pipeline in Western and Southern Kazakhstan. District heating consumption remained stable during 2005–2014 (except for 2006). An expansion of the district heating system has not been carried out because the existing system was inherited from the Soviet Union and is old and inefficient (UNDP 2013).

There are a number of significant policies and measures related to energy efficiency improvements and

climate change mitigation, which have recently been introduced in Kazakhstan. For example, the law ‘On Energy Saving and Improving Energy Efficiency’ was adopted in 2012. This law includes the creation of a State Energy Register and a requirement for mandatory energy audits to be carried out for major industrial sites and public services. Since its enactment, many industrial and buildings energy audits have been conducted and a regulatory framework has been introduced. The Government of Kazakhstan has also created a fund for the development of housing and utilities with the aim to provide credits for housing and utilities projects with a returned financing mechanism. However, to date, there is no information available regarding progress towards achieving

Fig. 2 CO₂ emissions from fuel combustion in Kazakhstan (IEA, NU-NLA, UNFCCC)

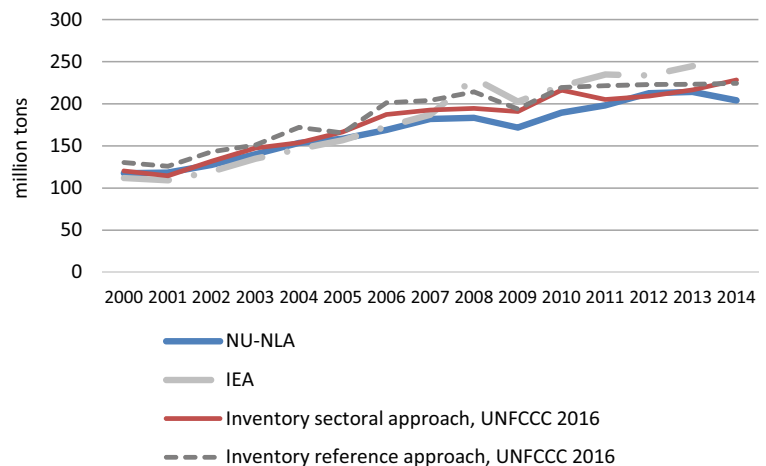
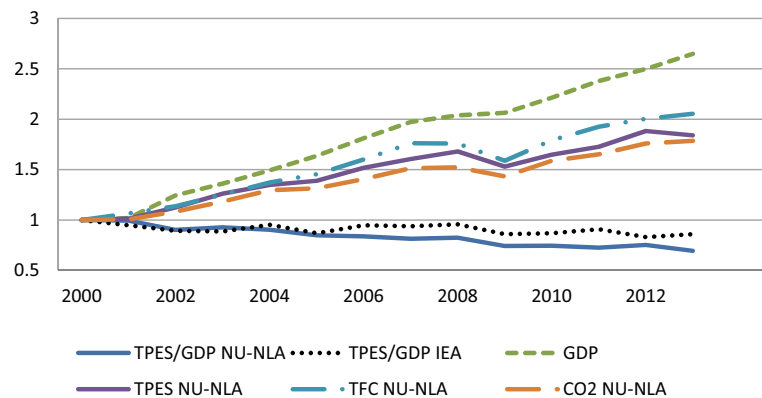


Fig. 3 Indices of GDP, TPES, total final consumption (*TFC*) and CO₂ (2000 = 1)



Kazakhstan's energy targets, and it is clear from Fig. 4 that the effect of these policies on energy consumption trends is not yet evident. Other policies, such as the 'Concept of the Republic of Kazakhstan for Transition to a Green Economy' and the carbon trading scheme which were adopted in 2013 have also been introduced. Again, the effect of these policies is yet to be seen in the energy balance analysis. The 'Energy saving—2020' programme set a target to reduce energy intensity of GDP to not less than 40% of 2008 levels by 2020. Sectoral targets have also been set, such as 'increase in energy efficiency of industry by 30% by 2020', 'reduction of specific energy consumption for electricity generation by 14%', 'increase of energy efficiency of chemical industry by 32% by 2020' etc. However, the absence of absolute values for these indicators, units of measurement and a defined base year, clearly demonstrate that the sectoral energy efficiency targets are ambiguous.

In the electricity and heat generation sector, there were no significant changes in the generation mix between 2000 and 2014, and most of the generation facilities installed during the previous century continue to operate (Fig. 5). During the period 2000–2014, electricity and heat production rose at average annual growth rates of 5 and 3%, respectively. The share of coal in electricity generation fell slightly from 77% in 2005 to 71% in 2014. In contrast, gas consumption increased by 92% between 2005 and 2014, corresponding to the share in total electricity generation increasing from 14% in 2005 to 20% in 2014. A similar trend is observed in the data for heat generation.

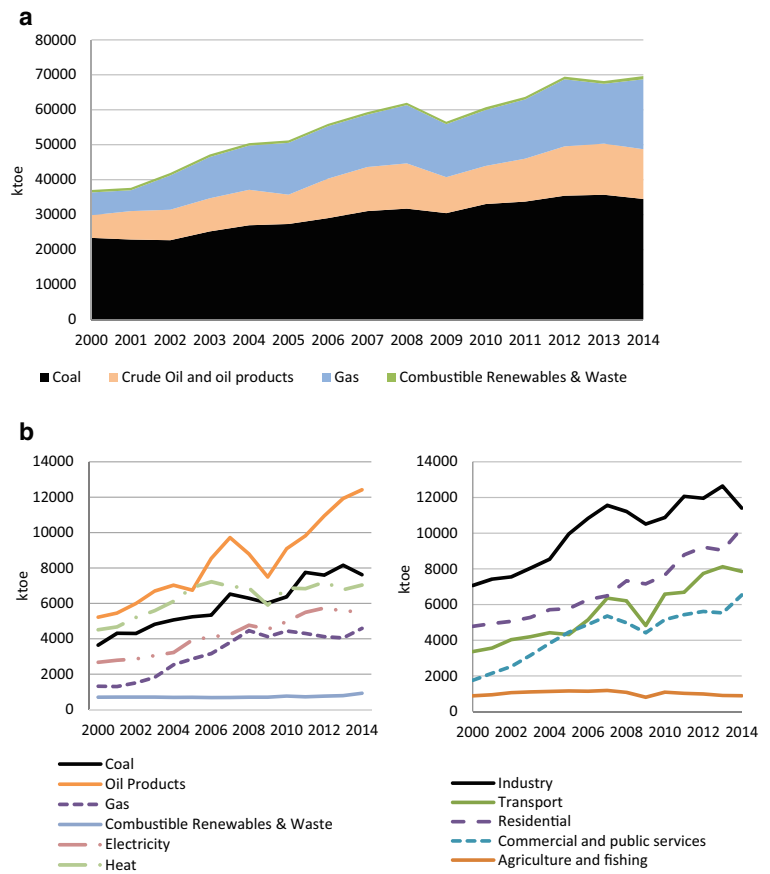
A law promoting the use of renewable energy resources was introduced in Kazakhstan in 2009. However, from Fig. 5, it can be seen that since 2009, the use of renewable energies has not increased substantially. To encourage power generation from renewables, the

Government introduced a fixed feed-in tariff. In 2014, the proportion of total electricity production which could be attributed to wind and solar was only 0.02% (Committee of Statistics of the Republic of Kazakhstan 2016a). A recent study indicated that barriers to renewable energy penetration into the energy market in Kazakhstan include the political and regulatory framework which supports fossil fuels, a lack of awareness of sustainable alternative energy generation systems, low electricity tariffs, inefficient but incumbent power technologies and a high-risk business environment (Karatayev et al. 2016).

A low level of awareness about the benefits of cleaner alternatives to coal and the negative impacts of solid fuel combustion, may also reduce the drive for switching to cleaner alternatives in Kazakhstan. A survey of public attitudes towards green energy in Kazakhstan identified insufficient knowledge of both the environmental and economic benefits of renewables as a key factor preventing their market penetration (Karatayev et al. 2016).

Benchmarking of some indicators for Kazakhstan against Germany and Canada was conducted using methods and data from the World Energy Council (2016). The results are presented in Appendix 3. The performance of various sectors in Kazakhstan in terms of the efficiency of energy use was compared with these countries in order to inform and motivate performance improvement programmes. Germany was chosen for the analysis due to the excellent energy efficiencies it achieves (ACEEE 2016), while Canada was selected because of its similarities with Kazakhstan in terms of climate, economic structure (oil and gas sector) and low population density. In addition, comparison with world averages for the indicators examined provides information about Kazakhstan's global position. The

Fig. 4 **a** Total primary energy supply by fuel. **b** Total final consumption trends by fuels (*left*) and sector (*right*)



benchmarking results show that the energy intensities of the industry, and commercial and public services in Kazakhstan are higher than Germany's by 65 and

60% and higher than Canada's by 31 and 30%, respectively. The industrial sector in Kazakhstan mainly comprises energy intensive industries such as iron and steel,

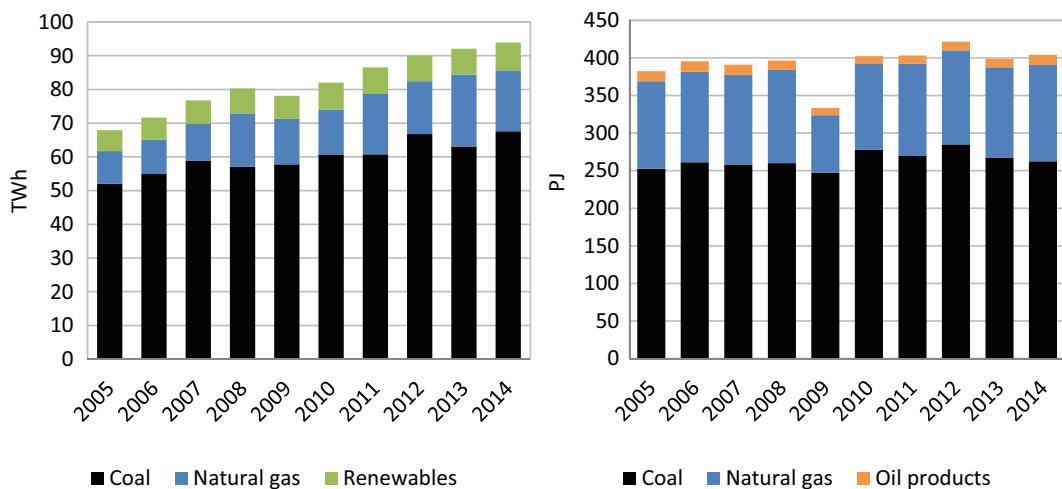


Fig. 5 Electricity (*left*) and heat generation (*right*). The graphs of electricity and heat generation show trends from 2005 to 2014. The period from 2000 to 2004 is not included in the graphs

because the energy balance data were taken from Tosato (2006) for this period and data for electricity production by fuel was not available

non-ferrous metals, mining and quarrying. Cheap energy prices, the absence of a stimulus for improving energy efficiencies as well as the absence of regulation regarding energy efficiencies (until 2012) are among the underlying causes of the poor efficiencies of Kazakhstan's industry and commercial and public services sectors. The energy intensities of the transport and agricultural sectors in Kazakhstan are 18 and 40% higher than Germany's and 95 and 476% lower than Canada's, respectively. Canada has a very high agricultural energy intensity which is nine times the world average (World Energy Council 2016). The underlying reasons for these values have not been identified and their identification is outside the scope of this study. The reason for the high energy intensity of the transport sector in Canada is that the country has a car-heavy economy, with a low use of public transport (ACEEE 2016). The energy intensities of the industry, services and agricultural sectors (except for transport) in Kazakhstan are higher than world averages by 43, 60 and 51%, respectively, which highlights the inefficient nature of these sectors in Kazakhstan.

It can also be seen from Appendix 3 that electricity use by households per capita in Kazakhstan is still low compared with Germany and Canada. Power generation in Kazakhstan is inefficient compared with other countries due to the prevalence of old coal fired power stations. Renewable energies (including large and small hydro) account for only 9% of power generation in Kazakhstan, with solar and wind providing only 0.02%.

Results of decomposition of energy intensity of GDP

Kazakhstan's energy intensity of GDP¹² declined by 30% from 1.14 to 0.80 toe/thousand 2005USD between 2000 and 2014, a total of 0.34 toe/thousand 2005USD. To understand the reasons for this change, the energy intensity of GDP was decomposed as per the four factors detailed in 'Decomposition method' (Fig. 6). The highest reduction during the period 2000–2014 was due to cumulative (non-household) energy intensity change (−0.18 toe/thousand 2005USD), followed by inter-sectoral structural change (−0.13 toe/thousand 2005USD) and changes in GDP per capita (−0.14 toe/thousand 2005USD). In contrast, the energy intensity of

households increased by 0.11 toe/thousand 2005USD during this period.

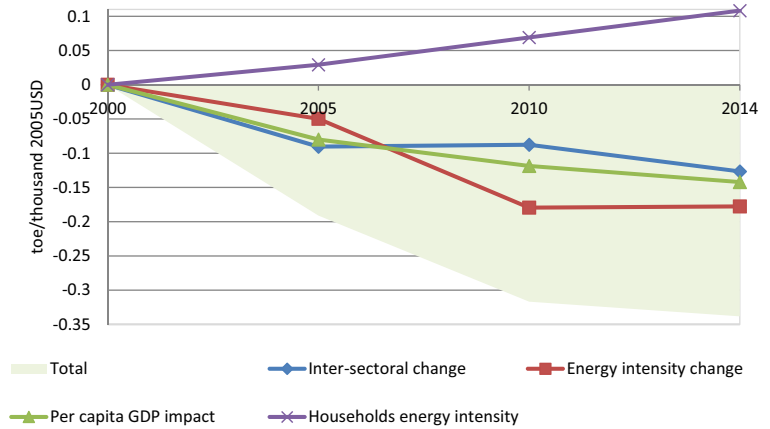
In Fig. 6, the changes in energy intensity of GDP are presented for certain years during which oil prices remained more or less stable. Year-by-year analysis of the changes in the energy intensity component demonstrated that these components fluctuated strongly in years when oil prices fell dramatically (2003 and 2008). The results clearly indicate the limitations of using monetary measures (GDP) to calculate energy efficiency indicators; it is difficult to differentiate between price changes and real energy efficiency improvements.

Figure 7 shows the contribution of inter-sectoral structural changes and energy intensity changes by sector. Inter-sectoral structural changes were mostly related to the upstream and power and heat sectors. The largest reduction in GDP share corresponded to the power and heat generation sector. This occurred due to relatively slow growth of the value added by this sector, since domestic electricity price increases were slower than export commodity price increases. In contrast, the share of GDP corresponding to the upstream sector increased from 12% in 2000 to 17% in 2014, which contributed to the increase in energy intensity of GDP of 0.08 toe/thousand 2005USD during that period. The upstream sector (including oil and gas) has contributed the most to the observed energy intensity change, leading to a reduction of 0.19 toe/thousand 2005USD in total energy intensity of GDP. The decline in the energy intensity of the upstream sector between 2000 and 2014 can be attributed to the large increase in value added by the sector (from a combination of increased production and high oil prices) as well as lower energy consumption per unit of product. Thus, fluctuations in oil prices can affect GDP structure as well as the energy intensity of GDP. The energy intensity of GDP of the upstream sector increased between 2010 and 2014 by 11%, which may be partially due to the reduction in oil prices in 2014.

The efficiency improvements in the upstream sector can also be clearly seen in the *Energy Balances*: the proportion of energy used for own purposes of the production values (oil, gas, coal) declined from 6% in 2000 to 3.6% in 2014. In contrast to the upstream sector, the power and heat, transport, and commercial and public services sectors gave rise to increases in energy intensity of GDP of 0.03, 0.01 and 0.02 toe/thousand 2005USD, respectively. With regards power and heat and transport, this may have been due to the relatively

¹² GDP was calculated as a sum of sectoral value added and converted to USD using 2005 prices. Taxes and subsidies were not accounted for.

Fig. 6 Changes in energy intensity of GDP related to the four main factors considered



slow increase in the value added by these sectors, since they are oriented towards the domestic market. Particularly in the power and heat sector, this is coupled with an absence of technological improvement; 50% of the country’s generating capacity is from stations which have been in operation for more than 30 years (Ismagulova et al. 2012). Changes in GDP per capita reduced energy intensity of GDP by 0.14 toe/thousand 2005USD. Between 2000 and 2014, GDP per capita in Kazakhstan increased considerably, by a factor of 2.28.

The energy intensity increase arising from households may be attributable to a number of factors. The energy consumption in the households sector including personal transportation increased considerably, by a factor of 2.19. There are several reasons for this, including an increase in household incomes, an increase in living area per person and a higher demand for heating. In addition, the number of light duty vehicles per 100 people increased from 7.3 in 2003 to 22 in 2014, according to CSRK data. The increase in the population has affected the total energy consumption of the

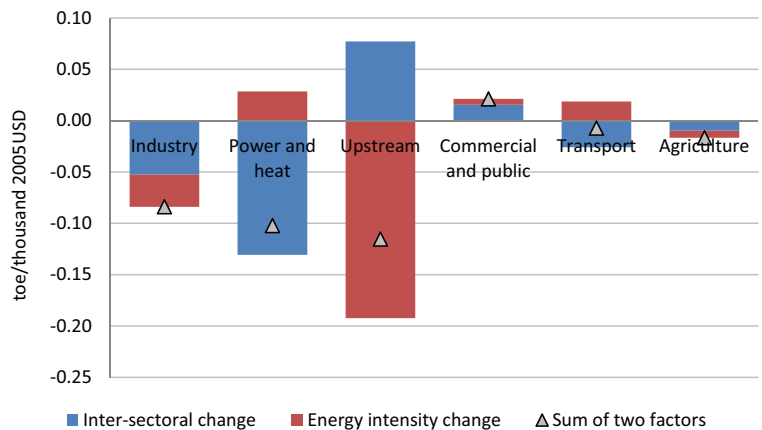
households sector to a much lesser extent, since the corresponding indicator increased by only 17% between 2000 and 2014. Comparison of residential energy consumption per capita in Kazakhstan with the OECD average (IEA 2016) shows that in 2000, residential energy consumption per capita was 53% lower in Kazakhstan compared with OECD average, but by 2013, it had almost reached the OECD average. However, the severe climate and as a result the long heating season, coupled with poor insulation of buildings and inefficient stoves, has led to elevated energy consumption by households in Kazakhstan.

Appendices 4, 5 and 6 present data for value added by sector, energy consumption by sector and energy intensity by sector for the period 2000–2014.

Policy implications

There is an urgent need for Kazakhstan to move towards harmonisation of its energy statistics with

Fig. 7 Contribution of inter-sectoral change and energy intensity change by sectors, toe/thousand 2005USD (2000–2014)



internationally recognised standards in order to better monitor and plan energy system transformations and climate change mitigation measures. Changes should be made not only in the questionnaires, instructions and reporting formats used but also stricter penalties should be introduced for providing incorrect data and for poor control over the data provided by companies.

There is also an urgent need for new policies and measures to reduce energy consumption for heating. These policies should promote energy efficiency improvements for buildings and stoves and the use of cleaner and more efficient fuels. In addition, the energy intensity of personal transportation could be reduced by stimulating public transport, providing an efficient transport infrastructure, improving fuel quality and promoting the use of more efficient vehicles.

Decomposition of Kazakhstan's energy intensity of GDP clearly demonstrated that the energy intensity of GDP is not the best indicator of efficiency improvements. Despite the overall reduction in the energy intensity of GDP between 2000 and 2014, most sectoral energy intensities decreased only slightly and some even increased, with the exception of the upstream sector. Moreover, changes in oil price contributed to fluctuations in energy intensity changes, making it impossible to track real energy efficiency improvements. Recent government programmes promoting energy efficiency still rely on measures of energy intensity of GDP and lack clearly defined sectoral indicators. Because of the inhomogeneity of the physical output, it is also a challenge to estimate energy intensities per unit of physical output for the overall economy. Thus, clearly defined sectoral energy intensity reduction targets based on best practice are crucial for planning and monitoring efficiency improvements in the economy.

A low level of awareness about the benefits of cleaner alternatives to coal and the negative impacts of solid fuel combustion has also reduced the drive towards the use of cleaner alternatives in Kazakhstan. In this regard, it is recommended that information and awareness campaigns on the benefits of cleaner fuels and technologies should accompany any future intervention programmes.

To meet its NDC target, Kazakhstan will need to limit future growth of its energy consumption, which will be difficult to achieve without effective support programmes for clean technologies.

Conclusions

It is believed that this is the first study to examine energy consumption trends in Kazakhstan for the period 2000–2014. In this paper, discrepancies in energy statistics have been reported and factors influencing the change of energy intensity of GDP have been quantified. In addition, the energy balances for Kazakhstan were reconstructed. It was highlighted that there are large discrepancies and issues related to energy consumption data and consequently the data regarding CO₂ emissions from fuel combustion reported by Kazakhstan to the IEA (2016) and UNFCCC (2016). Allocation of consumed energy to 'not-specified'/'other'/'statistical differences' introduces uncertainties which affect the monitoring of energy consumption and CO₂ emission trends. In this study, an attempt was made to reduce uncertainties in values for energy intensity of GDP (TPES) by using the energy balance approach, which aims to match supply with total consumption. Additional sources of information to those used by the CSRK were employed in this study, but a number of assumptions and simplifications were still required due to a lack of information for some sectors (commercial and public sector, transport, and energy transformation processes).

The extension of gas pipeline networks to local communities has had an effect on energy usages: between 2000 and 2014 the TPES of gas increased by a factor of 2.15, and gas is replacing coal across almost all sectors of the economy (except agriculture and transport). However, coal continues to dominate in TPES (49% in 2014) and remains the main source of fuel for electricity (71%) and heat generation (65%) in the country.

Kazakhstan has introduced a number of policies and measures domestically over the last 5–7 years to promote penetration of renewable energies and to improve energy efficiencies. However, energy consumption trend analysis has shown that changes in the energy mix are slow: renewable energy penetration is still low and there were no significant energy intensity reductions for any sectors between 2010 and 2014 (except for power and heat). Benchmarking analysis indicated that the energy intensities of industry and services in 2014 were significantly higher than those in developed countries like Germany and Canada and even the world average. Future studies incorporating detailed decomposition analysis at the sub-sectoral level is required to understand the trends and drivers for energy consumption in those sectors.

Kazakhstan is an exporter of oil and gas; this sector plays an important role in the country's economy. As in the case of Canada (Torrie et al. 2016), the oil and gas sector has played an important role in energy intensity of GDP changes as it accounts for a large portion of GDP and energy consumption and has a relatively high energy intensity. It was found that the upstream sector (mainly oil and gas) has played the most important role in energy intensity of GDP changes during the period examined; the portion of total GDP related to this sector increased, which resulted in an increase in energy intensity due to inter-sectoral structural effect. However, these effects were offset by a twofold decline in the sector's energy intensity, resulting in a net decrease.

The power and heat generation sector is the most energy intensive sector in Kazakhstan. This sector made a positive contribution to energy intensity of GDP in terms of energy intensity change, and a negative contribution to inter-sectoral structural changes. The increase in the sector's energy intensity may be due to old and inefficient coal-fired generation plants coupled with a relatively slow increase in its value added to GDP. The overall efficiency of power generation in Kazakhstan is 33%, which is significantly lower than in Germany and Canada and is even below the world average. However, this indicator does not take into account heat generation, and there are large numbers of CHP plants in Kazakhstan. It is clear that technological improvements in the power and heat generation sector could contribute significantly to reductions in the energy intensity of GDP.

Households and personal transportation made a negative contribution to energy intensity of GDP changes due to the GDP per capita factor but positively due to household energy intensity changes. Electricity

consumption by households in Kazakhstan is still much lower than in Germany and Canada. However, due to the high demand for heating, there is a high level of consumption of other energy commodities like gas, coal and district heating. In 2013, the total residential energy consumption in Kazakhstan almost reached average OECD levels. It was found that household and personal transportation energy consumption increased by a factor of 2.1 between 2000 and 2014.

Future research is needed to analyse sectoral and sub-sectoral energy intensity trends in Kazakhstan, to examine physical energy intensity indicators and differentiate between price changes and real energy efficiency improvements.

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Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Appendix I. Reclassified energy balances of Kazakhstan

Table 2 Energy balance of Kazakhstan for the year 2000

Kazakhstan, 2000 (ktoe)	Coal	Crude oil	Oil products	Gas	Hydro	Combustible renewables and waste	Electricity	Heat	Total
Production	33,704	35,645	0	7548	699	0	0	0	77,596
Imports	702	1020	967	3504	0	267	0	0	6460
Exports	-11,313	-29,598	-830	-4337	0	-4	0	0	-46,082
International aviation bunkers	0	-55	-26	0	0	0	0	0	-81
Stock changes	270	-689	52	-211	-2	0	0	0	-580

Table 2 (continued)

Kazakhstan, 2000 (ktoe)	Coal	Crude oil	Oil products	Gas	Hydro	Combustible renewables and waste	Electricity	Heat	Total
Total primary energy supply	23,363	6323	163	6504	0	696	263	0	37,313
Transfers			-45	0		0	0	0	-45
Statistical differences	1	0	0	0	0	0	0	0	1
Main activity producer electricity plants	-5526		0	-237		0	2173	0	-3590
Autoproducer electricity plants				-435			145		-290
Main activity producer CHP plants	-6881		-100	-618		0	1466	2858	-3275
Autoproducer CHP plants	-2200			-641			486	1000	-1355
Main activity producer heat plants	-1975		-200	-1146		0	0	2629	-692
Oil refineries	0	-5909	5248	0		0	0	0	-661
Coal transformation	-2800		0						-2800
Non-specified (transformation)	0		1230	-832					398
Energy industry own use	-341	-74	-1067	-1075		0	-1241	-794	-4592
Losses	0	-263	-8	-200		0	-617	-1179	-2267
Final consumption	3642	77	5220	1320	0	696	2675	4515	18,145
Industry	2407	1	1079	192	0	1	1726	1660	7065
Iron and steel	2004	0	336	0		0	798	552	3690
Chemical and petrochemical	19	0	7	114		0	90	53	284
Non-ferrous metals	96	0	167	0		0	515	697	1475
Non-metallic minerals	153	0	22	50		0	22	33	280
Transport equipment									0
Machinery	41	0	124	3		0	238	111	517
Mining and quarrying									0
Food and tobacco	69	0	117	20		0	47	183	435
Paper, pulp and print	0	0	3	0		0	2	4	9
Construction	15	1	161	5		0	14	28	223
Textile and leather	3	0	4	0		0	0	0	6
Non-specified (industry)	7	0	140	0		0	0	0	147
Transport	100	1	2673	455	0	1	63	71	3364
Road	0	0	2351	4		0			2409
Domestic aviation	0	0	14	0		0	1	1	17
Rail	34	0	197	0		0	42	45	319
Pipeline transport	11	1	109	451		0	20	25	617
Domestic navigation	0	0	2	0		0	0	0	2
Non-specified (transport)									0
Other	1064	4	1348	641	0	694	887	2783	7421
Residential	484	3	270	606		685	630	2106	4784
Commercial and public services	476	0	629	31		3	190	482	1756
Agriculture/forestry	158	0	450	4		6	67	195	880
Non-energy use	71	71	120	33	0	1	0	0	295
Non-energy use industry/transformation/energy	71	71	120	33		1	0	0	295

Appendix 2

Table 3 Energy balance of Kazakhstan for the year 2014

Kazakhstan, 2014 (ktoe)	Coal	Crude oil	Oil products	Gas	Hydro	Combustible renewables and waste	Electricity	Heat	Total
Production	46,999	81,660	0	25,751	721	845	0	0	155,977
Imports	14,642	27,220	29,458	30,413	0	295	2811	0	104,839
Exports	-26,919	-92,454	-31,326	-35,756	0	-210	-3010	0	-189,675
Stock changes	-227	423	-741	-429	0	3	0	0	-970
Total primary energy supply	34,496	16,849	-2610	19,978	721	934	-199	0	70,170
Transfers	0	0	0	0	0	0	0	0	0
Statistical differences	-1	0	-10	1	0	5	0	0	-5
Main activity producer electricity plants	-8322	0	0	-632	-708	0	4023	0	-5640
Autoproducer electricity plants	0	0	0	-2024	0	0	762	0	-1262
Main activity producer CHP plants	-9744	-9	-64	-1501	-14	-11	2495	3841	-5007
Autoproducer CHP plants	-2895	0	-34	-1090	0	-1	806	1575	-1639
Main activity producer heat plants	-3226	0	-400	-2171	0	0	0	4233	-1564
Autoproducer heat plants	0	0	0	-499	0	0	0	0	-499
Oil refineries	0	-15,907	13,591	-42	0	0	0	0	-2357
Coal transformation	-2501	0	0	0	0	0	0	0	-2501
Non-specified (transformation)	0	0	2763	-4953	0	0	0	0	-2190
Energy industry own use	-159	-194	-864	-2040	0	0	-1613	-725	-5594
Losses	-31	-607	-43	-436	0	0	-751	-1885	-3753
Final consumption	7617	132	12,421	4591	0	926	5524	7039	38,250
Industry	3275	0	2323	858	0	15	3066	1869	11,406
Iron and steel	2173	0	536	57	0	0	890	470	4126
Chemical and petrochemical	7	0	16	171	0	1	291	147	632
Non-ferrous metals	233	0	99	0	0	0	990	772	2094
Non-metallic minerals	684	0	71	178	0	12	113	42	1100
Transport equipment	1	0	3	4	0	0	4	7	18
Machinery	26	0	33	17	0	0	43	51	170
Mining and quarrying	79	0	573	301	0	0	570	148	1672
Food and tobacco	35	0	79	74	0	1	91	170	450
Paper, pulp and print	0	0	4	2	0	0	6	4	16
Wood and wood products	0	0	1	0	0	0	1	2	5
Construction	31	0	900	39	0	1	42	41	1054
Textile and leather	1	0	4	7	0	0	9	8	30
Non-specified (industry)	4	0	6	6	0	0	14	8	38
Transport	16	9	7484	267	0	0	71	8	7855
Road	0	0	7065	14	0	0	0	0	7086
Domestic aviation	0	0	90	0	0	0	0	0	91
Rail	9	0	313	1	0	0	57	0	380
Pipeline transport	0	9	12	252	0	0	14	8	295
Domestic navigation	0	0	4	0	0	0	0	0	4
Non-specified (transport)	0	0	0	0	0	0	0	0	0
Other	4123	5	2085	3416	0	912	2387	5162	18,089
Residential	2881	1	324	2722	0	869	1003	2484	10,284
Commercial and public services	1093	4	901	619	0	40	1320	2569	6539
Agriculture/forestry	128	0	571	16	0	2	64	104	885
Fishing	0	0	0	0	0	0	1	0	2
Non-specified (other)	28	1	288	59	0	1	0	4	380
Non-energy use	202	118	529	50	0	0	0	0	899
	202	118	529	50	0	0	0	0	899

Table 3 (continued)

Kazakhstan, 2014 (ktoe)	Coal	Crude oil	Oil products	Gas	Hydro	Combustible renewables and waste	Electricity	Heat	Total
Non-energy use industry/transformation/energy									
Elect. output in GWh	67,007	0	13	18,603	8389	0	0	0	94,022
Elect. output-main activity producer electricity plants	35,700	0	0	2833	8231	0	0	0	46,773
Elect. output-autoproducer electricity plants	0	0	0	8856	0	0	0	0	8856
Elec output-main activity producer CHP plants	25,299	0	13	3545	158	0	0	0	29,015
Elect. output-autoproducer CHP plants	6008	0	0	3369	0	0	0	0	9377
Heat output-main activity producer CHP plants	136,280	0	277	24,246	0	0	0	0	160,803
Heat output-autoproducer CHP plants	47,014	0	21	18,908	0	0	0	0	65,942
Heat output-main activity producer heat plant	79,172	0	13,008	85,059	0	0	0	0	177,239
Heat output-autoproducer heat plants	0	0	0	0	0	0	0	0	0
Heat output in TJ	262,465	0	13,306	128,212	0	0	0	0	403,984

Appendix 3

Table 4 Energy efficiency indicators benchmarking in 2014

Sector	Definition	Unit	Kazakhstan	Germany	Canada	World
Industry	Ratio between the final energy consumption of industry and the value added measured in constant purchasing power parities (ppp).	kilogrammes of oil equivalent (koe)/\$2005ppp	0.203	0.070	0.14	0.12
Commercial and public	Ratio between the final energy consumption of the sector and the value added measured in constant purchasing power parities (ppp).	koe/\$2005ppp	0.040	0.016	0.028	0.016
Transport	Ratio of the energy consumption of transport to overall GDP.	koe/\$2005ppp	0.023	0.019	0.045	0.028
Agriculture	Ratio between the final energy consumption of the sector and the value added measured in constant purchasing power parities.	koe/\$2005ppp	0.056	0.034	0.325	0.036
Households	Ratio between the electricity consumption of households and the number of inhabitants.	kWh/capita	669	1586	4384	739
Power	The total net electricity production divided by the energy inputs.	%	33%	42%	58.8%	41.5%
Share of renewable energy in the power generation	Electricity produced from hydro, geothermal, solar, marine and wind energy divided by the total electricity production.	%	9%	28%	61.9%	22.8%
Share of wind and solar in power production	Electricity produced from wind and solar energy divided by the total electricity production.	%	0.02%	14.8%	1.8%	3.8%
Primary energy intensity	Ratio between the total energy consumption of a country and its GDP.	koe/\$2005ppp	0.22	0.10	0.19	0.15

Appendix 4

Table 5 Value added by sectors, mln USD 2005

Sector	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Industry	8272	8983	9425	9995	10,686	11,861	14,141	15,058	14,677	13,880	16,148	16,286	16,776	16,820	16,461
Power and heat	1067	1133	1241	1319	1227	1116	1138	1200	1192	1310	1385	1439	1485	1515	1596
Upstream	4068	4199	4895	5350	6497	8517	9618	9743	12,768	12,478	13,817	13,898	13,987	13,338	14,955
Commercial and public	13,043	15,518	17,437	19,444	22,485	24,055	26,696	31,075	30,930	32,851	33,648	35,911	39,254	43,028	44,373
Transport	3490	3835	4382	5111	5235	5583	5893	6222	6081	5963	6197	5820	6571	7145	5803
Agriculture	2829	3456	3474	3735	3710	3639	3477	3900	3782	4425	3483	4233	3809	4233	4254
Households	0	110	111	65	83	78	71	73	59	59	58	55	53	40	103
Total GDP	32,769	37,235	40,854	44,954	49,838	54,772	60,964	67,270	69,489	70,967	74,678	77,642	81,936	86,119	87,443

Appendix 5

Table 6 Energy consumption by sectors (ktoe)

Sector	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Industry	7360	7748	7961	9025	9823	10,696	11,521	12,341	12,316	11,600	12,018	12,994	12,842	13,331	12,369
Power and heat	9202	8691	10,104	11,197	11,567	12,184	13,298	13,509	14,062	13,449	15,074	14,914	15,831	15,518	15,648
Upstream	9922	9793	11,195	13,118	13,790	13,248	14,306	14,381	16,899	14,599	13,687	14,553	18,046	15,865	16,097
Commercial and public	1756	2154	2531	3154	3832	4452	4888	5359	4982	4422	5161	5434	5615	5889	6841
Transport	3364	3561	4030	4197	4422	4317	5145	6361	6206	4826	6585	6690	7706	8122	7871
Agriculture	880	941	1064	1101	1125	1158	1137	1180	1077	805	1089	1022	985	901	885
Households	4784	4935	5064	5283	5713	5772	6283	6492	7332	7163	7661	8790	9222	9045	10,286
Total	37,268	37,823	41,950	47,076	50,273	51,826	56,578	59,623	62,875	56,864	61,275	64,397	70,248	68,671	69,998

Appendix 6

Table 7 Energy intensity by sectors in toe/thousand 2005 USD

Sector	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Industry	0.89	0.86	0.84	0.90	0.92	0.90	0.81	0.82	0.87	0.84	0.74	0.80	0.77	0.79	0.75
Power and heat	8.62	7.67	8.14	8.49	9.43	10.92	11.68	11.26	12.35	10.27	10.89	10.36	10.66	10.24	9.80
Upstream	2.44	2.33	2.29	2.45	2.12	1.56	1.49	1.48	1.76	1.17	0.99	1.05	1.29	1.19	1.08
Commercial and public	0.13	0.14	0.15	0.16	0.17	0.19	0.18	0.17	0.19	0.13	0.15	0.15	0.14	0.14	0.15
Transport	0.96	0.93	0.92	0.82	0.84	0.77	0.87	1.02	1.05	0.81	1.06	1.15	1.17	1.14	1.36
Agriculture	0.31	0.27	0.31	0.29	0.30	0.32	0.33	0.30	0.31	0.18	0.31	0.24	0.26	0.21	0.21

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