The carbon footprint of shifting conventional diesel buses to electric ones in Astana, Kazakhstan

Abstract

Astana is the fastest-growing city in Kazakhstan, whose population has increased from 300,000 to 1,400,000 in just a few years. However, along with other facilities, it faces an issue with air pollution and a shortage of buses. Akimat is purchasing electric buses to solve these issues. However, this decision increases the carbon footprint of public transport as around 70% of electricity is produced from burning coal, which has the highest relative carbon emissions compared to the other fossil fuels. Moreover, despite the fact that air quality will be improved, increasing the number of electric buses in the city has a controversial impact on Kazakhstan's ambitious target to become a carbon-neutral country. In this paper, the above-mentioned decision by the government will be compared with other possible scenarios such as the use of diesel buses, electric buses powered by renewable energy, and buses that are powered using compressed natural gas. In the case of Astana, compressed natural gas buses were determined to be the optimal solution to the city's problems because this approach has good carbon-saving potential, and will almost certainly have a positive effect on air quality.

Introduction

One of the main global issues that humankind must attempt to mitigate is climate change, and in this regard over 190 countries and international organizations have joined the Paris Agreement for Climate Action. Kazakhstan has the ambitious target to produce around half of its energy from renewable sources by 2050, and completely decarbonize its economy by 2060 under the Paris Agreement (Қазақстан Республикасы Әділет министрлігі, 2023). This means that all energy produced and fuels consumed by vehicles will be greenhouse gas emission-free by that date.

Astana is one fastest-growing megalopolises in Central Asia, that accordingly has significant issues with air pollution. Also, it has faced a lack of sufficient numbers of buses, which is particularly telling as they are the only form of public transportation in the city. Akimat decided to increase the number of electric buses to both mitigate air pollution issues and solve the problem of its general shortage of buses. However, this decision has a negative impact on the carbon footprint of public transport as the electricity used to charge the buses is produced from the dirtiest form of fossil fuel, coal. Obviously, this does not particularly help Kazakhstan's attempt to achieve a carbon-neutral economy. The government increases the carbon footprint of the transport sector by improving air quality in the city. In this work, the above-mentioned problems will be described in detail, and alternative solutions will be suggested to more practically reduce carbon emissions and improve air quality.

Methodology

In this paper, secondary data was collected such as the demographics of, and public transport situation in Astana. Also, interviews were conducted with experts regarding possible future trends in the development of public transport, and how the city's growth in population and territory will affect this. Available data and strategic plans from governmental, research, and analytical organizations related to public transport were used for analysis. It is worth noting that learning about current projects relating to public transportation being implemented in other cities such as Almaty and Shymkent was helpful in terms of determining a suitable solution for the case of Astana.

Climate change influence of electric buses in Astana

Astana is the capital city of Kazakhstan, and one of the main economic cities showing a dynamic growth in population, economy, house construction, etc. Its population has grown from around 300,000 to 1,400,000 since the 2000s (БЮРО НАЦИОНАЛЬНОЙ СТАТИСТИКИ АГЕНТСТВА ПО СТРАТЕГИЧЕСКОМУ ПЛАНИРОВАНИЮ И РЕФОРМАМ РЕСПУБЛИКИ КАЗАХСТАН, 2023). Experts in urbanization assume that the territorial and population growth of Astana will

continuously accelerate, and its population could easily reach 2-2.5 million by 2030-2035 (Шашкина, 2023). Despite the fact that there are many positive factors, such as economic, increase in birth rate, increasing numbers of jobs, etc., Astana has faced a number of urban ecosystem issues, namely a shortage of energy and water supply infrastructure, significant traffic jams, air pollution, etc.

Air pollution, is one of the main issues that needs to be addressed in Astana as its levels have reached critical condition. For example, the annual average concentrations of harmful pollutants (PM10, NO_2, SO_2, and Total Suspended Particles) exceed the limits set by the WHO (World Health Organization), EU (European Union), and indeed local standards (Kerimray et al., 2018). Coal-fired power plants, vehicles, and residential heating activity have been defined as the main sources of air pollution (Agibayeva et al., 2023). Thus, there is considerable work required in converting coal-fired power plants to natural gas, and the construction of a natural gas supply infrastructure for residents that use coal for heating, should both have a profound impact on mitigating the air pollution issue. Moreover, this work would have an impact on reducing both the city's and country's carbon footprint, which will contributes to efforts to achieve net zero by 2060.

Also, a local governmental authority (Akimat) is working on the development of public transport to reduce emissions from vehicles by gradually increasing the number of electric buses. Currently, around 6800 buses are in local service, over 100 of which are powered by electricity (Аналитическая служба НПП "Атамекен", 2023). Akimat is planning to purchase around 300 electric and 200 diesel bus in 2023, and is further planning to increase the number of electric buses in the future (InformBuro, 2023). There is no doubt that increasing the number of electric buses will have a positive impact on mitigating air pollution in the city. However, this decision increases the carbon footprint of public transport as a large share of the city's electricity comes from coal-fired power stations in Kazakhstan.

Regarding the statistics published by the Ministry of Energy of the Republic of Kazakhstan (2023), overall 5.1 billion kWh of electricity is generated from renewable sources, namely wind and solar energy, but this represents only 4.5% of the total electricity produced. Approximately 70% and 20% of electricity comes from the combustion of coal and natural gas, respectively. Coal is the dirtiest fossil fuel worldwide, where combusting 1 kg of coal produces more than 2 kg of carbon dioxide, which is the main greenhouse gas that contributes a climate change. The average efficiency of modern coal-fired power plants is around 30%, which means that only 30% of the total energy can be converted into electricity. The conversion efficiency of coal-fired power plants in Kazakhstan is supposed to be lower due to the depreciation of the power plants' condition and poor coal quality. The Ministry of Energy of the Republic of Kazakhstan assessed all power plants to define their depreciation at the end of 2022, which on average is 66% (Forbes Kazakhstan, 2023). Also, most of the coal-fired power plants use coal from the Kazakh Ekibastuz coal basin, which further reduces the conversion efficiency of coal into electricity due to its high ash content. These factors inevitably result in reduced production efficiency of electricity and increased greenhouse gas emissions from coal combustion.

It is beneficial to use electric buses if electricity is produced from renewable energy sources. In the current case of Astana, such usage would have a controversial effect on the work being done by the government in terms of decarbonization and climate resilience. The number of buses that are in service for the residents in Astana needs to be doubled in the next decade because of the city's rapid growth. However, despite the fact that increasing the number of electric buses will have a positive effect on air pollution, it will greatly increase the country's carbon footprint in terms of the environment.

Two birds with one stone: reducing the air pollution and carbon footprint due to public transport

The new buses need to be purchased due to the rapid growth in population and city territory. In the next ten years, it was assumed that around 15,000 busses need to be in service for the city residents. In the case of Astana, four different possible scenarios were considered: 1- diesel buses, 2- electric buses

working on electricity from coal, 3- electric buses working on electricity from renewable sources, and 4- compressed natural gas buses.

In general, it is beneficial to purchase diesel buses in terms of capital investment and applicability. Astana has all the necessary diesel fuel infrastructure, and the average cost of a standard diesel bus is lower at around 50% that of an electric buses, but the operating cost of the former is higher than the latter on average worldwide (Laizāns et al., 2016). Moreover, diesel buses are not a good option in the current situation with the current levels of air pollution in Astana. Finally, diesel buses' carbon footprint is quite high because diesel is produced from oil and buses generate around 2.7 kg CO_2 per litre of diesel in the use phase (Gabriel et al., 2021).

Currently, Akimat is gradually increasing the number of electric buses it runs, and this seems to have the potential for significant mitigation of air pollution. Also, electric buses are easier to operate than diesel buses and could reduce expenses with regard to fuel and maintenance. However, the majority of electricity is generated from the dirtiest fuel, namely coal, and will thus have the highest potential to cause global warming compared to other scenarios. This can be solved in itself by shifting electricity production from coal to renewable energy sources, but there are other significant issues with the development of carbon-neutral infrastructure and technologies that would still have to be addressed. The proportion of electricity produced from renewable sources is lower than 5% in Kazakhstan, and is increasing annually by only around 1%. This means that Kazakhstan needs more time and resources to develop renewable energy to any significant extent. In the current case of Astana, and indeed other cities in Kazakhstan, it is simply not possible to create a public transport system powered mostly via renewable energy sources.

In the last scenario, compressed natural gas buses are considered, and it is the most highly recommended for Astana as air pollution can be mitigated and the carbon footprint reduced. Compressed natural gas buses, in their lifespan, have around 50% less global warming potential than standard diesel buses (Gabriel et al., 2021). Also, Kazakhstan is doing extensive work in developing its natural gas industry. For example, a small number of natural gas processing plants are under construction in the west of Kazakhstan (Eurasian Research Institute). There is the gasification programme in Astana, and this could be used to switch from diesel buses to compressed natural gas ones. One national company, "QazaqGaz", has already started a few large projects switching diesel buses to compressed natural gas in Almaty and Shymkent (Bus World Central Asia, 2023). It is worth noting that the carbon-saving potential and economics of such were assessed, and it is also considered to be a more sustainable solution to mitigating urban air pollution. Astana can learn these implementing projects and adopt them.

Compressed natural gas buses can be implemented in other central Asian countries to reduce the global warming potential of public transport and mitigate air pollution in cities. To the best of my knowledge, in Uzbekistan, compressed natural gas is already used as a main vehicle fuel. Kazakhstan and Uzbekistan have the potential to create a hub and promote other Central Asian countries' shift from diesel buses to ones running on compressed natural gas.

Table 1. Scenario comparison in terms of air pollution, global warming potential, economics, and applicability.

	Air pollution	Global warming potential	Economics	Applicability
Diesel buses				
Electric buses working on electricity from coal				

Electric buses running on electricity from renewable sources				
Compressed natural gas buses				

Good	Satisfactory	Poor

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