Economic and Environmental Impacts of Energy Efficiency Measures in Public Buildings in Kazakhstan

By

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Submitted to

Central European University

Department of Environmental Science and Policy

In partial fulfillment of the requirements for the degree of Master of Environmental Science and Policy

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Budapest, Hungary

2020

For bibliographic and reference purposes, this thesis should be referred to as:

Baishulakova. A. 2020. *Economic and Environmental Impacts of Energy Efficiency Measures in Public Buildings in Kazakhstan*. Master thesis, Department of Environmental Sciences and Policy, Central European University, Budapest.

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Author’s declaration

No portion of the work referred to in this thesis has been submitted in support of an application for another degree or qualification of this or any other university or other institutes of learning.

Assel Baishulakova

Abstract

ABSTRACT OF THE DISSERTATION submitted by ***Assel Baishulakova***

For the degree of Master of Environmental Science and Policy and entitled: *Economic and Environmental Impacts of Energy Efficiency Measures in Public Buildings in Kazakhstan*

Month and year of submission: ***31st of July 2020***

Improving *energy efficiency is one of the most effective measures to reduce the environmental impacts* of energy use while at the same time growing economic performance. Energy efficiency is especially relevant for *Kazakhstan*, *a country* with a high carbon footprint and one of *the highest uses of energy per unit of GDP in the world*. The World Bank supports energy efficiency measures in public buildings in Kazakhstan. However, the impact of these measures on the energy use of public sector savings has not been systematically analyzed. This thesis shows that the impact of energy efficiency measures highly varies from almost negligible to very significant. The impact of energy efficiency measures on energy savings is often low because prior to applying these measures, the buildings were under-heated, but after the retrofit, the users increase heating to comfortable levels. *The impacts of energy efficiency measures depend primarily on the climate zone and how frequently the building is used (intermittent heating)*. *The impacts on simple payback of the energy efficiency measures depend on the final energy savings, initial investment capital and tariffs for energy sources*. Buildings in colder climates, more frequently used, and using coal and diesel for heating provide the highest economic payoffs to energy efficiency measures. Based on these findings, the thesis provides recommendations for which buildings to prioritize for energy efficiency measures as well as other policy and research actions.

Keywords: energy efficiency measures, climate zone, public buildings

Acknowledgments

I would like to thank my Master's degree supervisor, Prof. Dr. Aleh Cherp, for guiding my research, opening for me the exciting field to explore, helping me to frame my thesis writing, and giving me an opportunity by presenting to the exciting and highly professional people.

I am endlessly thankful to Dr. Aleksandra Novikova and Marina Olshanskaya for inspiring, sharing the interesting project, and guiding me professionally, being my mentors, and providing me with the feedbacks throughout the journey of completing my thesis. Special gratitude to Dr. Aleksandra Novikova for teaching me how to write and present my thoughts and giving me support anytime I needed it. I am also thankful to Marina Olshanskaya for inviting me to be part of this exciting project like "KEEP" and allowing me to take the project as a base of my research data.

I am expressing my gratitude to the Department of Environmental Science and Policy for giving me such an honor to study at CEU and the opportunity to discover the field I am passionate about. I am thankful to Prof. Dr. Alan Watt, for contributing to our thesis structuring and writing. Also, I would like to thank Krisztina Szabados and Tunde Veronika Szabolcs for being always there for us, MESP students, and replying to our emails promptly.

Furthermore, I am very thankful to my parents Zhanat and Gulzhakhan, and my dear friends from CEU, especially Rupal, Ananya, Tolganaya, Laura and Olzhas for giving me support anytime I needed. I also thank all my MESP classmates for being the best classmates I could ask for.

I would like to dedicate my work to my former supervisor from Nazarbayev University Prof. Dr. Natalia Barteneva, who always supported me, provided me with an opportunity to find my passion and encouraged to pursue Master of Science degree at CEU.

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List of Abbreviations

ASPO – Association for the study of the Peak Oil and Gas

CHP – Combined Heat and Power plants (cogeneration)

CO2 – Carbon Dioxide

GHG – Greenhouse Gas

GDP – Gross Domestic Product

GWh – Giga Watt Hours = Million Kilo Watt Hours

HBVs – Hydraulic balancing valves

HDD – Heating degree days

FES – Final energy savings

GHG – Greenhouse gas

IPCC - Intergovernmental Panel on Climate Change

KEEP – Kazakhstan Energy Efficiency Project

KZT – Tenge, National currency of Kazakhstan

MAC – Marginal abatement curve

NDC - Nationally Determined Contributions

OECD - Organization for Economic Cooperation and Development

SPB – Simple payback

SDG – Sustainable Developing Goals

TFC – Total Final Consumption

TRVs – Thermostatic radiator valves

UNFCCC – United Nations Framework Convention on Climate Change

1 Introduction

According to the Brundtland Commission, sustainability defines as the term describing present generation development without compensating the future generation's ability to meet their own needs (United Nations 1987). *In the context of energy, sustainability means sustainable utilization of energy resources*. Each sovereign country has the rights over its natural properties; hence they have the duty not to deplete them and consume sustainably.

Sustainable Development Goals (SDGs) were adopted in 2015 by the United Nations to bring peace and prosperity as well as end poverty across the world and protect the planet by the year 2030. Seventeen goals were created *to ensure social, economic, and environmental balance.*

Climate actions, affordable clean energy, good health and well-being, sustainable cities and communities, responsible consumption as well as decent work and economic growth can be *united via action towards energy efficiency.*

1.1 Background

Kazakhstan is a notable producer and exporter of coal (4% of the world's coal reserves), oil (1.8% of the world's oil reserves), and petroleum and natural gas. Electricity generation from *coal accounts for 75% of the total power generation*, whereas the *mining and petroleum industry is responsible for 33% of the total Gross Domestic Product (GDP)* (Karatayev and Clarke 2014). *Renewable energy also has a small and stable share in electricity generation*. Currently, coal is gradually replaced by natural gas.

Kazakhstan is one of the highest energy intensity countries in the world (0.37 tons of oil equivalent (toe)/thousand 2010USD), which is 71% higher than that in the countries of the Organization for Economic Cooperation and Development (OECD), and 41% higher than that of the world as a whole. Kazakhstan also has 50% higher greenhouse gas (GHG) emission per capita than the countries of the European Union on average (Table 1*)*.

The first law on energy savings was approved in Kazakhstan back in 1997, which was remained on the level of declarative. For the past decades, energy efficiency became a policy priority for the government, which was a preventative attempt to improve industrial competitiveness, mitigate excess energy use, and the recent increase of domestic energy prices in certain regions. *A new law on energy savings and energy efficiency was adopted in 2012 and amended in 2015. This was adopted in the country program named "Energy efficiency strategy 2020".*

Despite such differences, *Kazakhstan has shown a full commitment to a green way of development towards improving energy efficiency. In 2015, Kazakhstan ratified the Kyoto Protocol* to reduce GHG emissions by 15% by 2020 as compared to 1990*. It later signed the legally binding agreement during the Paris Conference in December 2015,* agreeing that the global temperature rises and aiming to ensure that it does not exceed 2°C above the pre-industrial level (Ministry of Energy of the Republic of Kazakhstan 2015).

Kazakhstan agreed to reduce GHG emissions to 15-25% by 2030 as compared to the base year, 1990. According to the latest National Determined Contributions (NDC) submitted by Kazakhstan, GHG reduction accounts for about 7% of what was in 1990. Under favorable conditions, stable oil prices, and a constant increase in GDP, around 30% of GHG reduction by 2030 is forecasted. *In addition, Kazakhstan set a long-term goal for a transition to a green economy by the year 2050,* aiming to increase the GDP to 3% per year, reduce GHG emission by 40%, increase the use of renewable energy stations, ensure gas-based power plants growth by 30%, as well as diversify energy-intensive economy (Strategy2050.Kz Information Agency 2020; Akorda.Kz 2020)

Kazakhstan submitted the first NDC before the COVID-19, and the oil prices dropped since then. Hence ambitious forecasting regarding GHG reduction and green economy transition shall be revised (ibid).

Table 1. The carbon footprint of Kazakhstan compared to that of the European Union, 2014

	CO2 emissions of Kazakhstan, million tons	**CO2 emissions per capita of Kazakhstan, tons**	**CO2 emissions of per capita of the European Union, tons**
Total	248.31	14.35	7.31
Of which diesel + gasoline	32.34	1.87	3.02
Of which natural gas	71.28	4.27	1.77
Of which coal	140.72	8.14	2.33
Other sources	3.98	0.23	0.19

Source: Ministry of Energy of the Republic of Kazakhstan with the support of the UNDP/GEF project (2015).

Kazakhstan will gain from energy efficiency measures. There will be economic value by decreasing electricity and heating bills, reducing GHG emissions, and contributing climate change targets. Subsequently, there will be an opportunity for co-benefits to elevate the job market in green services and technologies, contributing to health impact and social impact by shaping human perspectives towards conservation of energy and planet.

To promote *low carbon and 'green' economy*, Kazakhstan adopted the *laws* on "Energy saving and energy efficiency" and "Supporting the Use of Renewable Energy Sources.". Kazakhstan also has programs on waste management, housing, and communal services modernization, sustainable transport development, enhancement of the ecosystem conservation, and sustainable forest coverage—green economy act adoption dedicated to lead the energy-efficient technology production to reduce GHG emissions (Agency of the Republic of Kazakhstan for Construction of Housing and Communal Services 2011).

In the long term, the biggest challenge of the country is to shift from a natural resources-based economy towards a more diversified and competitive economy. The country has accepted the ambitious goals to diversify its economy by specifying the sectors of transport, pharmaceuticals, telecommunications, and petrochemicals. However, such plans have been challenging to achieve, taking the account high oil prices until 2014. Since then, significant steps have been taken to make the market more business-driven and transparent, but the situation is still facing issues with the ruling governance, laws, institutions, and existing infrastructure as well as fewer incentives for new technologies. The government set a 2050 target for the green economy transition, emphasizing the GDP increase, GHG emission decrease, and diversified energy-intensive economy.

1.2 Aims and Objectives

The current thesis advances the understanding of the status and impact of energy efficiency measures in Kazakhstan, and it was dedicated to contributing towards energy efficiency in buildings, specifically governmental and service buildings, such as hospitals, kindergartens, orphanages, and schools. They consume different energy carriers, including secondary sources, such as centrally supplied district heat and electricity and primary sources such as natural gas, oil, and coal.

The research aims to advance the understanding of factors that impact energy savings on the public sector in Kazakhstan and provide recommendations to the government of Kazakhstan on priority measures in the field of energy efficiency.

The research objectives of this thesis are:

1. Identify the factors which affect the *social, economic, and environmental impacts* of energy efficiency measures in public buildings in Kazakhstan.

2. *Estimate the influence of these factors* on financial profitability and energy savings in selected public buildings in Kazakhstan.

3. Develop *recommendations* for the selection of priority objects by the national energy efficiency program of Kazakhstan.

1.3 Kazakhstan Energy Efficiency Project

The Kazakhstan Energy Efficiency Project (***KEEP***) *challenges new low carbon innovations implications and endurance in Kazakhstan realms.* The results of the project could be used for further scaling possibilities of the given procedures in energy efficiency.

Data of the current thesis is based on the "KEEP" established by the World Bank, which has delivered energy efficiency measures to public buildings across the country from 2016 to 2019. The Ministry of Investment and Development of the Republic of Kazakhstan, together with the World Bank, officially launched the project "KEEP". It aimed to increase the energy efficiency of the state as well as to improve social facilities *for energy efficiency and conditions for creating a financing mechanism* for projects *in the field of energy-saving and energy efficiency*. The project aims to reduce energy use in *government and social buildings* such *as schools, kindergartens, hospitals, and street lighting, to demonstrate energy savings and associated social benefit*s.

The goal of the project was to *implement and demonstrate energy efficiency measures across the state and socially significant facilities*. The project delivered energy efficiency into culturally significant properties, such as schools, kindergarten, and hospitals. It produced *valuable contributions for the formation and maintenance of the State Energy Register* (World Bank 2020).

The collected data source can be applied for the future regulatory framework in energy efficiency, for the approval of the regional and sectoral energy conservation plans, and for the technical regulations on energy efficiency. *Training of specialists and promotion of high-quality energy conservation and energy audit* is a significant plus of the project. It also added its value in the development *of international cooperation* and favorable condition to establish commercial possibilities in the energy conservation field.

The World Bank Project has a long-term goal to scale the project and increase the number of buildings undergoing energy efficiency measures and support SDG. Raw data for the analysis part of the thesis was provided by the representatives of the World Bank project.

1.4 Structure of the Thesis

The next chapter contains a literature review that covers the drivers of energy efficiency, energy issues in Kazakhstan, the use of energy in buildings in Kazakhstan and worldwide. Chapter 3 contains the analytical framework and describes the sources and methods of data gathering and analysis. Chapter 4 covers the results of the thesis. The last two chapters are dedicated to Discussion and Conclusions, which include policy recommendations.

2 Literature Review

The first section ff the literature review cover *energy efficiency drivers,* which includes the adoption of the Paris Agreement and the energy scarcity theory. The second chapter explains the reason for Kazakhstan being high energy intensity country. The next section covers energy use in buildings worldwide, in the EU and in Kazakhstan. The fourth and fifth sections elaborate on energy efficiency measures in the building as well as on the current energy efficiency situation in Kazakhstan.

2.1 Energy Efficiency Drivers: the Paris Agreement, Energy Scarcity, and Others

Climate change obligation

The current concern of the energy scarcity meets the consequences of direct and indirect energy consumption, GHG emissions, and following climate change realms. The Intergovernmental Panel on Climate Change (IPCC) argues that to achieve the goals of the Paris Agreement, most of *the GHG emissions should be eliminated by mid-century*. To avoid the worst climate impacts, the UN Secretary General recently asked national leaders to come to the UN Climate Action Summit in September 2019 with the announcements of targets for net-zero emissions by 2050.

Net-zero emissions by 2050 are a very ambitious goal *that requires decarbonizing energy, transport, and the industry* as well as *reducing emissions from land use and aforestation*. Specifically, decarbonization can be reached via *three main strategies/pillars: electrification, electricity decarbonization, as well as energy efficiency* and conservation (Virta Global 2018).

Energy efficiency is thereof one of the strategies to meet the Paris Agreement, strengthening the country's capability to deal with climate impact and pursuing efforts to limit the temperature to 1.5°C. According to the marginal abatement curve (MAC) by Timilsina *et al.* (2016), energy efficiency is the cheapest strategy to deliver climate change mitigation and a decline in GHG emissions. The MAC published by Boston Consulting Group (2020) demonstrates that the energy efficiency measures do not just optimize energy consumption, but *also increases resilience to CO2 emissions* and actualizes significant *savings of the energy resources* (Burchardt *et al.* 2020). According to the International Energy Agency (2019), energy efficiency will be able to decline world's energy needs by one third in 2050 by implementing the energy efficiency measures in buildings, industrial sector as well as transportations.

<u>*Energy scarcity*</u>

There would be *far less new crude oil resources discovered compared to the level of current energy consumption*, according to the Association for the study of the Peak Oil and Gas (ASPO) founded by Cambell in 2001 (Figure 1). Although the time for "the peaks" predicted by Campbel and Laherrerre (1998) were incorrect, the proposed dogma by Hubert (1956) cannot be ignored.

Essential point (prediction) described by the ASPO (2001) is that *discoveries of the new location of oil production do ne meet the level of surged consumption and rapid development for the past decades*. To note, this can be applied only for the conventional oil locations, as data for the non-conventional and shale oil location are available. Considering the last two decades gap between new discoveries and human energy consumption has become significantly wider, this prediction is argued to be correct (Bardi 2019). Another forecasting model constructed by DNV GL energy transition outlook declared the global *oil production decline between now and 2050* (later year might be delayed due to other circumstances such as

COVID-19); by the year of 2050, conventional oil will account for about 50% of the energy source, whereas unconventional oil supply will deliver 30% of the oil worldwide.

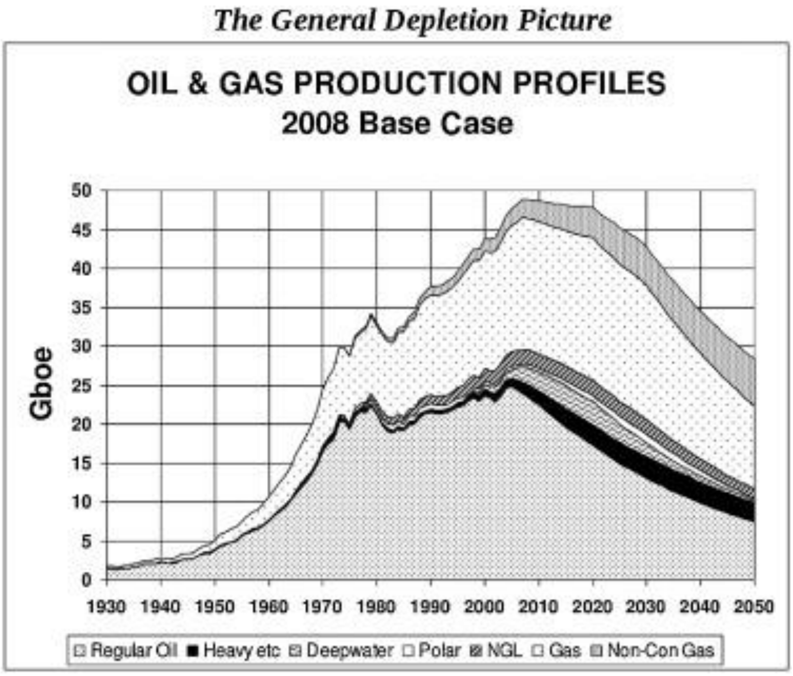

Figure 1. The general depletion of oil and gas demonstrated by the Campbell and Laherrerre

Source: Campbell and Laherrerre (2001)

Energy scarcity, in general, may *cause difficulties* in exporting oil *for oil-producing countries, including Kazakhstan, accordingly,* because the world is heavily dependent on affordable petroleum. The world's population is projected to become 9.7 billion people by 2050 (UN DESA 2020). To meet the increasing demand for energy consumption, oil-producing countries might decline the volume of oil dedicated to export. So, t*o export the same amount of oil, the afore-mentioned countries might choose a strategy on energy-saving measures*. Before the peak of conventional oil production during the period of 2000-2010, increase prices for petroleum became markedly less available for the people. *It has to be mentioned that, however, even with the help of technology and more types of oil coming to the market, the latter still cannot be supplied at such affordable prices as their predecessors.* Hence, it is hard to agree that a persistent increase in oil prices can be upheld without a negative effect on the economy and social aspects (Hallock *et al.* 2014).

Apart from the conventional oil depletion, *remaining unconventional oil is extremely difficult to extract, and expensive to produce*. It takes tremendous investment and time to start mining the new places of unconventional oil. According to Tverberg (2010), the mining process could be late if the conditional oil capacity will be far from its peak.

Kazakhstan is a significant fossil fuel producer: it is the 9th largest coal producer, the 17th in crude oil, and the 24th in natural gas production worldwide. *As a producer of a significant share of fossil fuel, considering the energy scarcity and future forecasting of the energy system perspective, Kazakhstan is directly responsible for consuming and producing energy sustainably*.

Others

From the written above, energy efficiency is driven by climate change obligation as well as the scarcity of conventional energy resources. Also, energy efficiency is stimulated by other modern circumstances:

First, it is growing quality of life, with demands for higher living standards, including a clean environment and accessible services as well as end-use technologies. Second, it is *urbanization,* which continues to grow, especially in mid-sized cities in developing countries. Next, there is a growing demand for *innovative energy services* because end-consumers are demanding more clean, convenient, and high-quality energy services. Another driver is the *diversified energy end-user,* meaning end-consumers play various roles in the energy system from consumer to producer. And finally, it is the constant improvement of the *cost and performance of the* *information and communication of the technologies*, which support the widespread application of the drivers.

2.2 Kazakhstan – an Energy-intensive Country

Kazakhstan is one of the highest energy-intensive countries in terms of energy use per unit of GDP, and *there are several major reasons for this statement.* First, the existing structure of the *economy predominates energy-intensive industries*, including extractive industries, mining and metallurgy, oil and gas sector, and coal energy. According to the International Energy Agency (IEA), *industry*, *residential buildings and commercial and services* shares are *the most energy-consuming* of total final consumption share (IEA 2019; Figure 2)

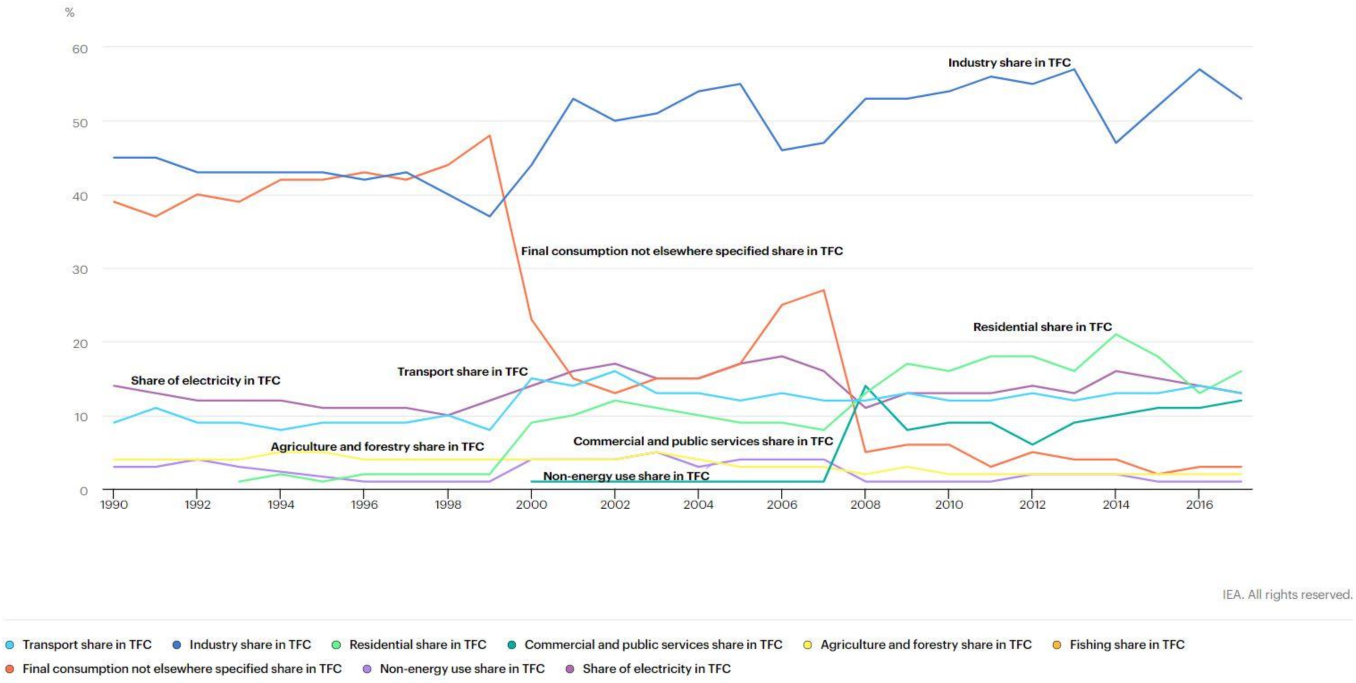

Figure 2. Energy use by sector: share of total final consumption

Source: IEA (2017).

The *industry accounts for approximately55 % of the total final energy consumption. The residential sector and public and commercial services consume about 18% and 5% of the total final energy consumption, respectively.*

<u>*Electricity consumption in Kazakhstan*</u>

Electricity generation is a load to existing thermal power plants. As a result, there is an existing problem with significant depreciation of the leading equipment and the use of *inefficient technologies* in *energy production* (Ministry of Industry and New Technologies of the Republic of Kazakhstan 2020). The general *technological backwardness*, such as d*eterioration of networks and equipment in the housing and communal services*, is associated with this *significant loss of energy, primary energy sources, and energy consumption.* For instance, more than 70-80% of the electricity is generated via power plants near coal mines (Northern Kazakhstan) but due to the deteriorated network and inefficient distribution, *energy loss accounts for about 15% or more. In 2012, energy loss estimated 7 TWh, which is equal to the total electricity use in Latvia (EBRD 2019).*

*Housing and utilities are second-ranked in terms of electricity consumption (13%) (*Table 2*)*. Services and construction account for about 10% of the total electro-energy use. *Thus, it is around 23% of the electro-energy consumptions by buildings,* which is a substantial amount to consider improving energy efficiency and applying energy conservation measures in the building sector.

Table 2. Consumption of electrical energy in various fields for 2011 in Kazakhstan

	Name of the field	% of electro-energy consumption
1	**Industry**	69,7%
2	**Housing and Utilities**	12,5%
3	**Services**	8,3%
4	**Transport**	5,5%
5	**Agriculture**	2,5%
6	**Construction**	1,5%

Source: (Tulegenov 2016)

The significant volume of electric power generation in Kazakhstan is in the Northern and Central parts of the country, and they meet the demand for electricity across these regions. The southern part lacks the full capacity to cover electricity demand. Hence, they import the energy sources, such as coal, gas, and oil from other parts of Kazakhstan as well as abroad. Western Kazakhstan has the vast reservoirs of oil and gas; hence this part of the country does not have the difficulties with energy sources shortage. However, they do not have enough power plants to supply the growing electricity demand. Thus, they import a certain amount of heat from Russia. In addition, Kazakhstan has an issue in frequency with electricity generation supply – meaning during the high peak loads for demand, the electricity sector is unable to manage regular supply. *Thus, the country needs to compensate energy supply gaps as well as maintain the frequency of the electricity.*

<u>*Coal and pollution*</u>

Coal is applied in coal-fired boilers, heating the mine facilities and air ventilation, and heavily used in industry and in thermal plants to generate *heat and electricity power*. *Coal* contributes a very high share of electricity production of Kazakhstan (around 72%) and to heat generation (about 98%) (IEA 2017). In addition to coal being the most environmentally harmful energy source, around 40% of the power generating stations use ash-coal type, highly abrasive for combustion facilities. *Coal in Kazakhstan is predominately polluting* because the generous amount of ash produced lead to high emission of sulfur and nitrogen oxide, and there are no flue gas scrubbers are installed to capture the pollutants at the power plants. A pilot project was developed in Karaganda, Central Kazakhstan, to capture coal-bed methane and coal-mine methane, which generates 1.4 MW electricity from coal-mine methane. This demonstrates, there is a potential for future improvement.

The relatively low cost of energy does not stimulate many consumers to lean towards sustainable consumption. After the Soviet Union collapsed, Kazakhstan struggle difficulties in recovering the economy, which led to *slow adaptation.* However, after foreign investments, rapid development accelerated coal production and energy consumption, which has increased the possibility for the government to subsidize the energy system. To note, Kazakhstan has one of the lowest electricity prices (for example, the electricity tariff in Kazakhstan is on average - 15 KZT per 1 KWh, whereas in Russia - 15, USA - 40, China - 40, and Europe – 90; IEA, 2018).

Climatic condition and heating in Kazakhstan

Climatic conditions are diversified because of the massive territory of the country. The northern parts and including most of central Kazakhstan have nearly *nine months of the heating season*, while the heat supply sector in the country is quite an energy-consuming (20% of total final energy consumption). To note, more than 90% of the heat is generated from coal, which makes them non-sustainable and highly carbon-intensive (Figure 3; IEA 2017).

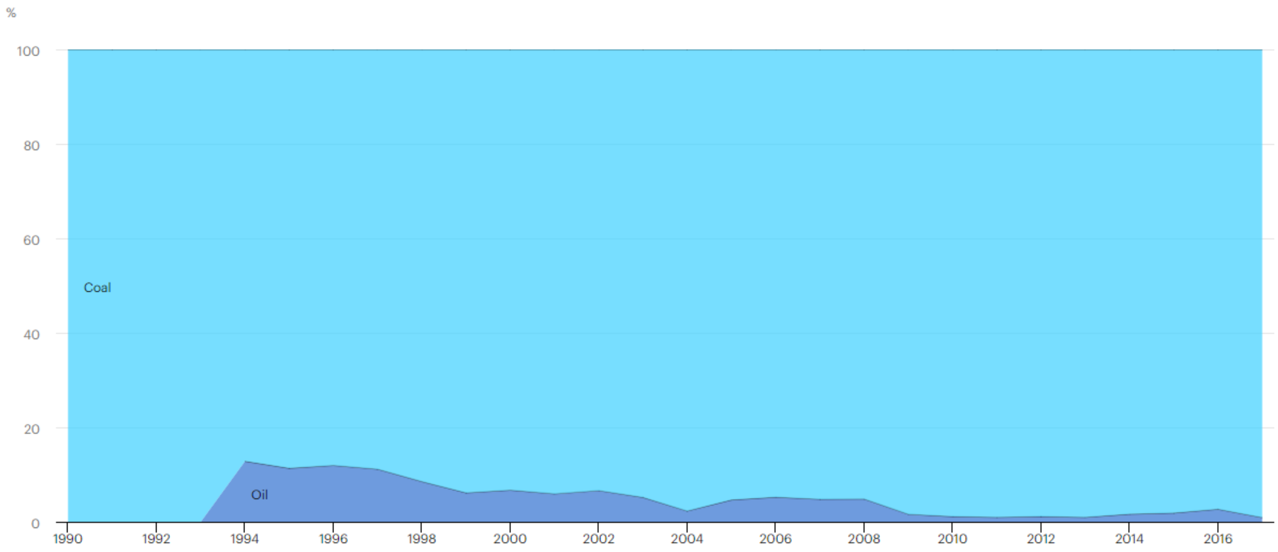

Figure 3 Heat generation by source in Kazakhstan

Source: IEA 2017

Also, there is an issue regarding the under-heating of the buildings during the heating season. For instance, every year, there are cases when consumers do not have the energy supply on an adequate level to heat their houses o comfortable level. One of the reasons is that houses are in emergency conditions, and it can consume a high amount of energy, which is costly for the consumer. This leads to an under-heating, which causes health issues for the residents of the buildings.

It shall be noticed, monitoring progress regarding the data on energy consumption is causing uncertainty because gathered information is not harmonized with international standardizations. Hence, there is a significant difference in what is reported to the United Nations Framework on GHG emissions. The same note goes to energy balance data as well as information on energy consumption by sectors.

From the overview above, Kazakhstan has four noticeable energy-intensive fields: *industry sector, residential sector, transport sector, and services and commercial sectors.* Around 80% of the electricity is generated from coal power plants, and housing services and utilities consume approximately 20%. Heating plays an important place in Kazakhstan, as the climate is known to be extremely continental and very dry, which average winter temperature -20 C (some parts of the country have nine months of winter). Around 90-95% of heat is generated from coal.

2.3 Energy Efficiency – the Key to Reducing Energy Intensity

Energy efficiency is *"the first fuel of sustainable global energy";* in other words, it is ***the key concept towards clean energy transition*** (IEA 2020). According to Grubler *et al.* (2018), energy end-use is the most inefficient field in the energy system and has enormous potential to be improved.

Energy savings covers various fields form street lighting to reducing transmission loss. However, it plays a significant role in buildings. Energy efficiency measures in buildings bring multiple benefits, such as *reducing energy bills, improving the comfort lives, or addressing the climate change emergency*. On a global level, the *energy efficiency policy area covers 35%. Hence there is a space for further scale-up* (IEA, 2020).

Energy efficiency is a multi-benefit strategy, and three benefits of the advantages are explained further: *economic effect, environmental effect, and health impact.*

Economic effects: All energy-saving measures pay off in a certain period due to saved energy consumption costs. In addition, an additional job market is created, which brings new specialists in the energy management field, generate labor income, and subsequent GDP increase with sustainable development. Further, it is increasing the competitiveness of the economy: the industrial sector is being modernized, growing encouragement for the sustainable energy sources application.

Environmental effects and resilience to future emissions: energy efficiency or energy-saving measures have a direct impact on CO_2 emission decrease (Table 3), *positive air quality impact, and subsequent health impact of the population*. Such measures set the right position for the government to chase sustainability developmental goals.

Table 3. Review of the studies which assessed the potentials for the energy efficiency and GHG mitigation in public buildings

Country, ***Reference***	**What type of buildings included (hospital, etc.)**	**What measures** **[Political, econ or technical measures, energy tax?]**	**What sort of energy efficiency?** **(window insulation, wall replacement?)**	**What is the potential of final energy consumption (FEC), GHG decrease**	**Potential Compared to what, BAU, what is the baseline**	**Baseline calculated to 2040, 2050, 2010**	**Other incentives, discount rate, etc.**
EU (5 countries) *E. Mata, et al, 2018*	Residential (complex and not homogeneous)	Energy conservation method EU Techno-economical potential* (CO2 taxes)	Thermal, thermal+	Will be elaborated below	Scenario 2020 Paris Convention	Target 2020, 2050	
France	Residential, non-residential	Energy conservation method EU Techno-economical potential* (CO2 taxes)	Thermal, thermal+ envelope, deep*(?)	FEC: R: 7% due to value cellar NR: 15% due to heating ventilation retrofit ***55% CO2 emission decrease (solar hot water, NR)***	Baseline 2009, 2010		4% Discount rate (DR) for 15-30 ys
Germany	Residential, non-residential	Energy conservation method EU Techno-economical potential* (CO2 taxes)	Thermal insulation, heating (?)	FEC: R: 23% due to on value wall ***30%-75% CO2 emission decrease (wall and***	Baseline 2009, 2012		until 2050

				biomass boilers, R)			
Spain	Residential, non-residential	Energy conservation method EU Techno-economical potential* (CO_2 taxes; package 5	Envelope renovation, efficient heating, and lightning, efficiency in existing data centers, efficient appliances, efficient district heating, cooling networks	FEC: R: 20% due to roof and wall retrofit NR: 15-5% cellar, wall. Lightning, and heat ventilation retrofit ***Up to 70% of CO_2 emission decrease (Reduced energy use, NR, R)***	Baseline 2011		R: 8,2%-5% NR: not given Until 2030, Significant job creation
Sweden	R+NR	Energy conservation method EU Techno-economical potential* (CO_2 taxes; package 5	Insulation, window replacement, ventilation recovery or heat pump, circulation pump replacement, water conservation measures, hot water recovery from waste water, controls and regulators	FEC: R: 12%-5% cellar, wall, roof, heat ventilation, lighting, solar panels NR: 25% of heat ventilation ***Up to 81% of CO_2 emission decrease (ventilation, NR)***	2011		Until 2050
UK	NR+R	Energy conservation method EU Techno-economical potential* CO_2 taxes	Insulation, draught-proofing reduced infiltration, boiler upgrade, heating controls,	FEC: R: 20% - 3% wall, cellar, roof, windows NR:12%-4% cellar, windows, roof, heat ventilation,	R: 2012, ISO standard 13790 NR: analysis of administrativ e data		3,5%, Life-time ECM

			efficient hot water production, efficient lighting, smart meters**	lightning, solar panels ***10-35% decrease in C02 emission***			
Armenia *(G.Timilsina, et al. 2016)*	Policy	Policy	Thermal insulation, replacement of energy inefficient TV set, refrigerator, air conditioning, lightbulbs				7.5%
Georgia (G. Timilsina, et al. 2016)		Policy	Thermal insulation, replacement of energy inefficient TV set, refrigerator, air conditioning, lightbulbs				7.5%
Russia	Residential (high rise apartment, individual housing Project: *hypothetical*	Technical potential Techno-economical (exporting the conserved energy sources) The policy is an additional scenario	Thermal insulation		Baseline 2003, “Thermal Protection of Buildings”	2020, 2050	

****technical potential*** is determined as the reductions in energy usage in this particular resource; **techno-economical potential** is defined as the portion of the technical potential that is cost-effective in relation to market costs using societal discount rates and given that all CO2 taxes are included in the energy prices**.** ** Reduced energy use in FEC (technical + techno-economical potential): France: 35% for public buildings; Germany: 80% for Residential, Spain: 57% for Public building (non-residential), Sweden 56% public building, UK: 42% for public building

Apart from the direct effect on economic development and the environmental issues improvement, energy efficiency brings *positive health impact* and *comfort to the local population after the retrofit of the buildings*. Below, it is illustrated the sustainable energy efficiency measures integration into school in Izrael (2015), which shows a direct link among *health economic aspects and positive learning outcomes of the students due to ensured comfort environment* (Figure 4).

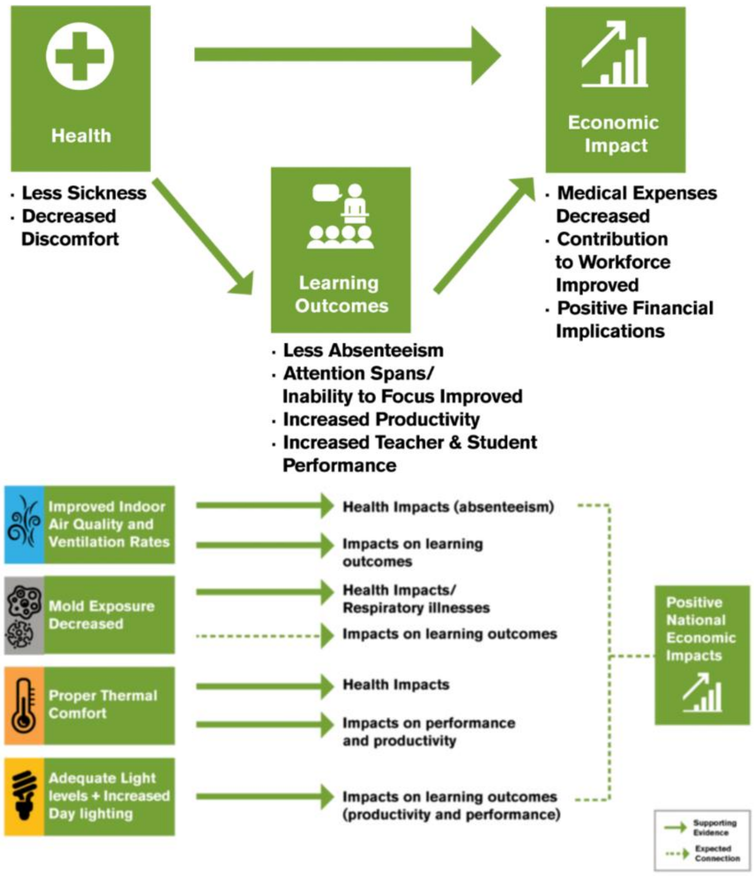

Figure 4. Summary of a positive link between health, local economic development and learning outcome in energy efficiency measures integrated schools

Source: ASU Walton Water Sustainability initiatives (2015).

2.4 Energy Use in Buildings Worldwide

Final energy consumption by buildings has grown significantly from 2820 mln tons of oil consumed (Mtoe) in 2010 to nearly 3060 Mtoe in 2018, in the respect that the fossil fuel share in it from 2010 to 2018 barely declined from 38% to 36 %, respectively. Emissions coming from the sources that are controlled by the reporting entity is called direct emissions. In contrast, emissions coming from the activities of the reporting entity but controlled by another entity is named indirect emissions. Direct emissions come from a combustion activity, whereas electricity, heat, and steam emit indirect emissions (Fernandez and Watterson 2012). Direct emissions of CO2 did not increase significantly. H*owever, indirect emission for buildings is responsible for around 28% of global energy-related CO2 emission in 2018* (Figure 5). Reducing carbon-intensive power generations is not enough to cover the growing demand for energy services. Improved energy services such as cooling/heating systems and appliances, like plug loads with the current electrification measures, can significantly contribute to reducing *the emissions related to buildings* (Figure 6).

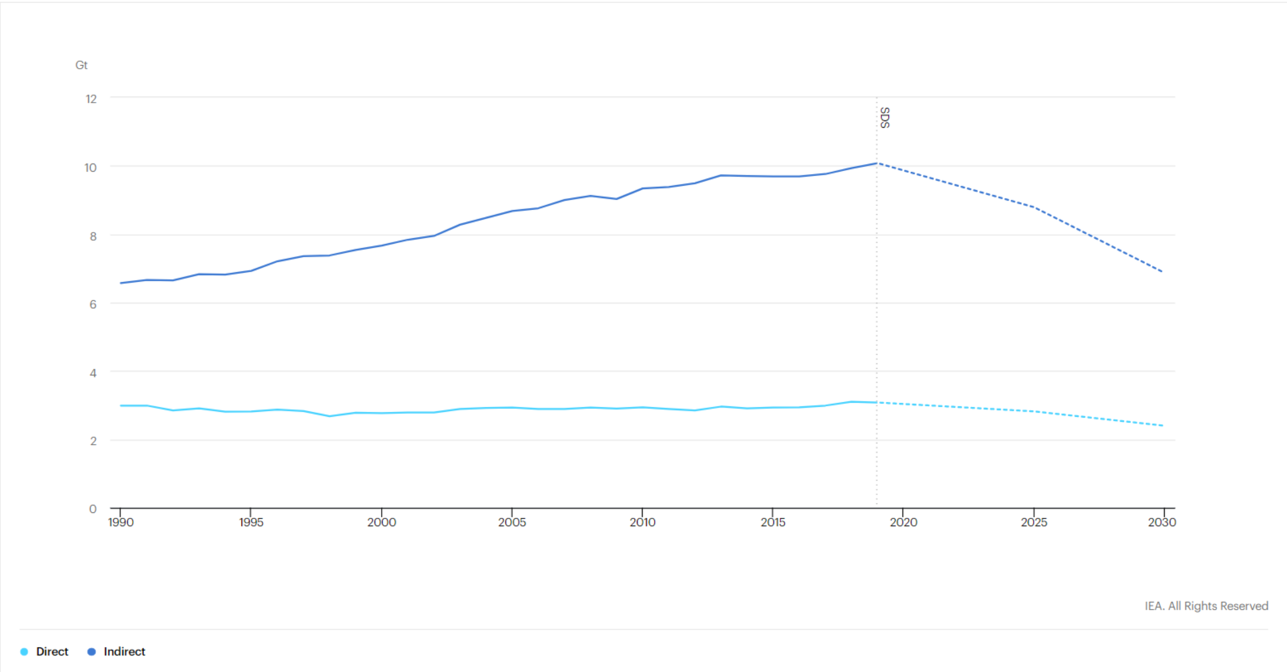

Figure 5. Direct and indirect CO2 emissions in the Sustainable Development Scenario, 2000-2030

Source: IEA (2019)

Also, a surplus of energy demand in the *building sector meets the climate change factors*, starting from 2018. Extreme heat brought a notable increase in electricity consumption for the cooling system in buildings (Dulac *et al*. 2019). Heatwave drove the highest demand for air conditioning; Spain and Portugal had almost the hottest August in history keeping the temperature of 48C; whereas Tokyo has 41C in late July, which is also the highest recorded temperature for that region. To note, in South Korea, twenty-nine people died during such hot summer days from heatstroke.

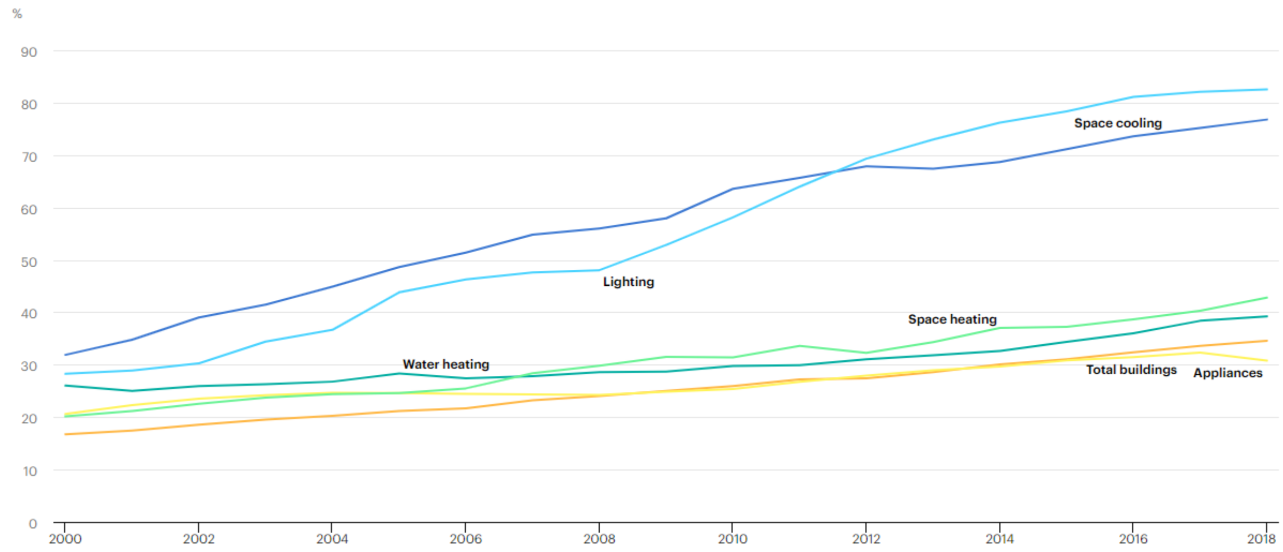

Figure 6. Final energy consumption by buildings, 2000-2018

Source*: IEA (2019).*

The building sector in the EU accounts for about 40% of the total CO2 emissions; nearly 50% of the EU's final energy consumption goes to heating and cooling. High levels of emission and energy consumption of buildings are linked to the fact that buildings are energy inefficient, and the third of them are over 50 years old. Renovated buildings may lead to a reduction of 30% of the primary energy consumption and CO2 emission by 2030. Historical buildings and buildings, in general, are highly valued in Europe and considered as part of the past heritage, which makes the government take actions towards retrofit to save the buildings as they are. It is common practice for buildings in Europe to undergo exploitation for various purposes, including for municipal purposes. Hence, actions toward energy efficiency are well accepted.

Revision of the Energy Performance of Buildings Directive (EPBD) 2010/31/EU and the Energy Efficiency Directive (EED) 2012/27/EU for better performance of the European Union operate the clean energy transition for buildings within the EU. One of the successful projects administered under the EPBD is EU Building Stock Observatory is a useful tool to keep the data on building performance and characteristics within the EU territory. Such data centers help make a model and policy specific to that region (Pohoryles et al. 2020).

2.5 Kazakhstan: Energy Use and Energy Efficiency in Buildings

Energy use increased in Kazakhstan mainly due to a non-diversified economy based on oil and gas, *low energy prices, subsequent lack of initiatives, and interests in energy efficiency*. *Energy consumption in the residential sector has grown promptly between 2000-2014, with an annual growth rate of 6.3%*. Such growth has been induced by increased income, expansion of household paces, and diffusion of household appliances (Kerimray *et al.* 2016a). Energy efficiency was encouraged via policies adopted and incorporated energy efficiency devices, such as heat measuring meters.

Coal is the most extensively used energy source (used to generate *64 % of heat*) due to its least expensive price. *The gas network was expanded remarkably* mainly due to the reason for gas supply and network pipeline expansion in the region located near the South and West Kazakhstan. The supply of *district heat remained the same* because it did not expand notably. It is generated at combined heat and power plants (CHP) (55%) and heat plants (45%) (Kerimray *et al*. 2016a).

Population growth might not be a significant factor, as it has grown only by 17% from 2000 through 2014; however, the average growth in large cities such as Nur-Sultan, Almaty, Karaganda, and Shymkent is up to 3% annually. Hence, energy efficiency plays a meaningful role in large cities, as population growth will increase the demand for municipal services and energy supply. For instance, it is forecasted that primary energy supply might increase for nearly 55% (to 34,250 GWh) in Nur-Sultan in 2050, but implementing energy efficiency measures and subsequent energy savings can slow down such considerable trend to 33% (Worldometer 2020).

In Kazakhstan, despite support from the government and some laws directed to sustainable development goals, there is *a lack of dedicated and consistent strategies towards energy efficiency in buildings*. Hence not a substantial amount of investment is in this sector. There have been pilot studies administered (ex: KEEP). However, their scale is not enough to initiate financing to a large extent but rather provide exemplary data that would bring innovative business models and references necessary to accelerate the process of clean energy transition and energy efficiency actions in the country. According to the latest changes in the law on energy conservation and energy efficiency, the following directions are stated:

1) The implementation of technical regulation in the field of energy conservation and energy efficiency.

2) The implementation of balanced tariff policy and pricing in the field of production and consumption of energy resources.

3) Stimulation of energy conservation and energy efficiency, including the use of energy-saving equipment and materials,

4) The implementation of state control over the efficient use of energy resources,

5) The promotion of economic, environmental, and social benefits of the efficient use of energy resources, improving the public educational level in this area,

6) Ensuring compliance with the legislation of the Republic of Kazakhstan on energy conservation and energy efficiency.

The buildings sector contributes around one-third of the total energy use, and it has enormous potential to reduce the negative impact on the environment. Hence this sector is a significant component in reaching environmental sustainability. According to the research (Kim and Sun 2017), *regional difference plays a major* role in the context of the green building due to the diverse climate of the country (in a given text, green building means energy efficiency, sustainable energy like solar panel penetration, and efficiency water consumption).

Kazakhstan has a constantly growing economy and population, specifically in big cities. Hence, it requires reliable energy supply as well as the provision of utilities. To note, *high energy intensity and energy loss in cities are due to outdated infrastructures,* such as district heating networks, water pipelines, and residential and public buildings (Karatayev and Clarke 2014). Despite recent initiatives to improve public transport and programs' capacity and efficiency to retool district heating and water systems, there remains a considerable need to upgrade infrastructure and meet future demand for energy and utilities.

2.6 Summary

This literature review showed the importance of reducing energy use, specifically in buildings. Energy-saving measures cover economic, environmental, and social benefits to society. In the context of Kazakhstan, reducing the energy consumption brings energy security, reduction of GHG emission, comfort living, and elevate social issues related to underheating. Also, energy efficiency measures play a significant role in an energy-intensive country like Kazakhstan to reach the goal of net-zero emissions as advised by recent reports of the IPCC and stipulated in the Paris Agreement.

3 Analytical Framework, Methodology, and Limitations

This section first explains data gathering, data analysis processes, and further data interpretations. Subsequently, it formulates the hypothesis as well as elaborates on the definitions used in the analysis. The last section interprets the limitations of the study.

3.1 Data Gathering and Data Analysis

Objects selected for the analysis in the given study include governmental buildings, kindergartens, schools, orphanages, hospitals, and street lighting infrastructure. Overall, there were five groups throughout the KEEP, which have gone through the retrofit processes:

> *Group I - 19 Buildings* in 5 regions - Pavlodar, Kyzylorda, Karaganda, East Kazakhstan region (11 kindergartens and 8 schools)
>
> *Group II - 25 objects* in 8 regions - East Kazakhstan region, Kostanay, North Kazakhstan region, Pavlodar, East Kazakhstan region, Almaty, Akmola, South Kazakhstan region (13 schools, 4 Kindergartens, 5 medical institutions, 3 objects of street lighting)
>
> *Group III - 31 objects* in 7 regions - East Kazakhstan region, Kostanay, Akmola, Pavlodar, East Kazakhstan, Almaty, South Kazakhstan. (19 schools, 4 kindergartens, 5 medical institutions / hospitals / clinics, 3 street lighting objects)
>
> *Group IV - 10 objects* in 4 regions: East Kazakhstan region, Kostanay, Akmola, South Kazakhstan region (4 schools, 2 kindergartens, 2 medical institutions/hospitals/clinics, 2 street lighting objects).

The present thesis assumed five characteristics to each object (except for the street lighting), which may impact on energy savings: *energy source, year of construction, number of stores, building type, heating degree days, and working hours of the buildings*. The number of stores was not distinct significantly from one to another, varying from one floor to four-floor buildings. The year of construction varied, but these were mostly 70 to 50 years old buildings, with the average year of construction 1970. Hence, the number of stores and year of construction were excluded from the analysis. Overall, 84 buildings were chosen, and four types of retrofit were carried out (Table 4, World Bank 2020).

Table 4. Thermal packages applied to the building during a retrofit

Thermal packages	***Package codes***	***Packages description***
Mandatory	1.1	Automated heat sub-station with or without thermostatic radiator valves (TRVs) and hydraulic balancing valves (HBVs)
Low efficiency	1.2	Exchange of windows, installation of automated heat sub-station, installation of TRVs and HBVs
Medium efficiency	1.3	Exchange of windows, installation of automated heat sub-station, installation of TRVs and HBVs, partial insulation
High efficiency	1.4	Exchange of windows, installation of automated heat sub-station, installation of TRVs and HBVs, full insulation

***No devices replacement (water heater, washer, drier, dishwasher, oven, etc.) were involved in current energy-efficient measures.*

The data was provided by KEEP. It was collected during the past three years by the different audit companies, during 2016 and 2019. Notable factors mentioned above were separated from the raw data for the further quantitative dependence analysis on energy efficiency and simple payback. For the analysis, Microsoft Excel was used. Energy efficiency percentage (*final energy savings*) was estimated by the difference in energy expenditure before retrofit and after retrofit by the following formula:

$$\text{Final Energy Savings (FES)} = \frac{\text{Energy consumption after retrofit}}{\text{Energy consumption before retrofit}} * 100\% - 100\%$$

The negative sign showed there is an energy efficiency after the retrofit, whereas positive sign demonstrated that final energy consumption increased after the retrofit.

3.2 Formulation of the Hypotheses

After energy efficiency measures, notable variables are taken for the analysis of given work, such as simple payback and factors affecting energy savings measures to identify the dependence from following components: compactness, heating degree days, intermittent heating, and energy sources. *The purpose is to identify significant factors positively affecting the final energy savings after the retrofit.*

- *Compactness* is assessing the building volume and morphology. According to the compactness valuer: over-compact or over-exposed, the building may waste or save energy. In addition, efficient space-formation may lead to the effective indoor environmental performance as well as las energy saving (Almuma 2016).
- *Heating degree days (HDD)* is the scale of measurement on how cold the days for a given period or given day, mean temperature of 40°F in a day has 25 HDD. The colder the outside temperature, the higher the measurement for degree days. As a result, a high number of HDD results in high energy use for heating or cooling the space. HDD is used to evaluate the energy consumption required to heat buildings (EIA 2020).
- *Intermittent heating* is the term used where the heating is applied for weekdays only and switched off on weekends.
- *Energy sources* used by buildings and analyzed in this study are coal, gas, oil, and district heating.
- *Final energy saving* is the measurement of Gcal used by building per year.
- *Simple payback (SPB)* represents the periodicity of time to receive net cash revenue or cost savings of a given project (retrofit on buildings) to payback the initial investment.

$$Simple\ payback = \frac{\text{Implementation cost}}{\text{Annual cost savings}} = \frac{\text{Implementation cost}}{\text{Watts saved(Final energy savings)}*\text{cost (current Tariffs)}}$$

Hence, from the formula above, *simple payback is directly depending on Investment cost, Final Energy Savings, and Tariffs.* Factors are affecting simple payback positively:

- Increasing tariffs for energy carriers
- Small capital investment (implementation cost of the energy efficiency measures)
- High energy-saving potential

Analysis conducted on the dependence of final energy savings (FES) and simple payback (SPB) on factors explained above:

- Dependence of FES on (1) Compactness, (2) Intermittent heating, and (3) HDD.
- Dependence of simple payback (SPB) on (4) Energy sources, (5) Intermittent heating and (6) HDD

Therefore, the hypotheses are:

1) There is a significant dependence of ***FES on Compactness***
2) There is a significant dependence of ***FES on Intermittent heating***
3) There is a significant dependence of ***FES on HDD***
4) There is a significant dependence of ***SPB on Energy carriers***
5) There is a significant dependence of ***SPB on Intermittent heating***
6) There is a significant dependence of ***SPB on HDD***

3.3 Interpretation and Use of the Results

Results will contribute to the realization of the energy efficiency measures in buildings in Kazakhstan. The outcome of the analysis will be taken into account by the Ministry of Energy and the World Bank for further scaling the project in public buildings. Thus, the given project would provide valuable information on formulating the strategy on local energy efficiency projects as well as using the data for later implementation.

3.4 Limitations of the Study

As mentioned above, auditing was administered by different companies. Hence *audit quality and methodology varied*. Also, *data for some factors were missing*, which decreased the number of variables in the analysis. Kazakhstan has neither unified standardization of the protocol nor the official responsible body examining reports for the buildings' energy audit, which lead to distinct types of reports submitted. Also, there is no official organization that could provide official certifications and training on unified software for the companies carrying the audit procedure.

There were issues on terms used in the energy audit report. Some words (or terms) are confusing and can be interpreted in multiple ways, representing different values. Also, there are few building codes in the country, which brings confusion for energy monitoring.

4 Results

The thesis explored public buildings, including schools, kindergartens, hospitals, and orphanages. All selected buildings were built between the late 1940s and the late 1990s, except for one hospital built in 2008. The buildings were chosen from different parts of the country. The number of floors of the buildings varied from one to five. Different energy carriers served the building*s. The building had different operating hours and locations with diverse climatic conditions. On top of that, objects possessed different levels of insulation.*

The project KEEP implemented four types of retrofit activities, which varied from types of insulation applied to buildings according to their initial energy performance. The objects fall into three groups, which had three different energy audit procedures. As research results illustrate, there was no difference among three examining audit-groups on simple payback outcome (Figure 7).

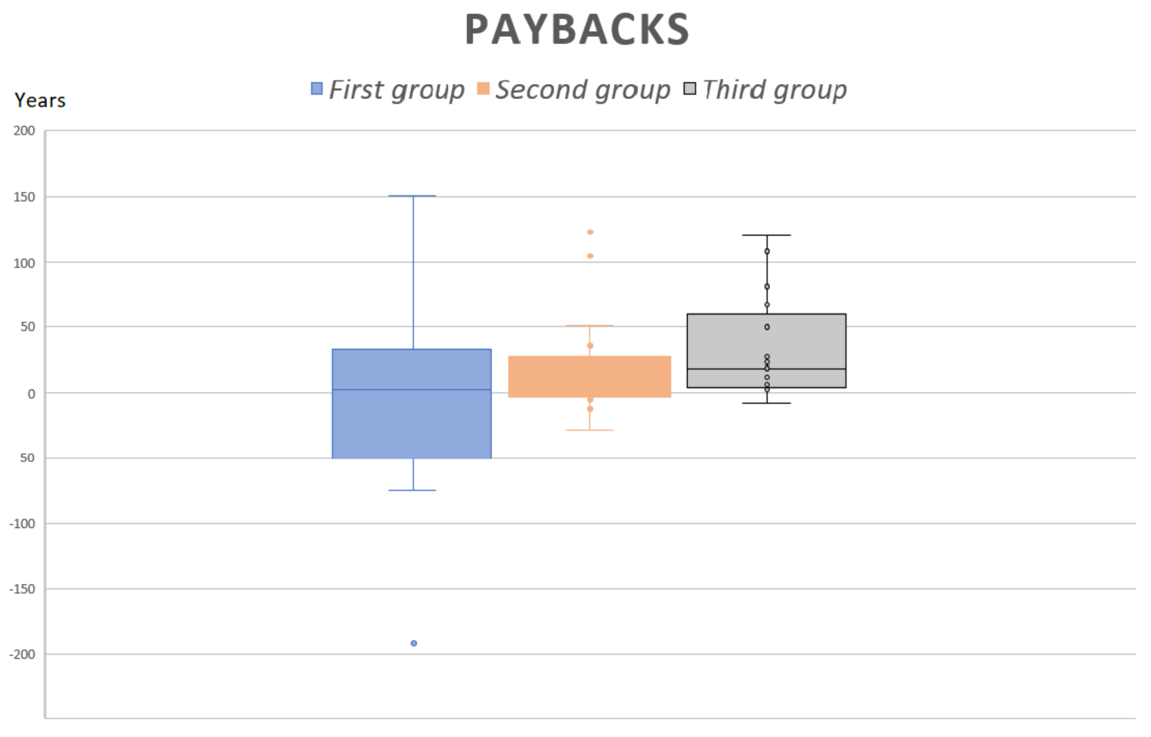

Figure 7. Dependence of simple payback (in years) on three examining energy-audit groups

The "Simple Payback (SPB)" of a building retrofit is a crucial financial indicator based on which one decides whether the renovation will be implemented. Hence the thesis evaluates factors, which may impact SPB. These include final energy savings, energy carrier prices (tariffs), and capital investments required. The first section will be covering the factors, which presumably affects final energy savings: intermitted heating (working periodicity of the building), heating degree days, and compactness. The second section introduces the SPB dependence on the three mentioned factors, type of energy sources used for heating, and initial capital investment.

4.1 Factors Impacting Final Energy Savings

4.1.1 Intermitted Heating

There was a positive result between FES and buildings operating at nights and weekends ((FES for such buildings were in the range from 70% to 78%), compared to those buildings which do not run after working hours or during the weekends (FES were in the range from 7% to 72%) (Figure 8). Buildings using energy at night and on weekends had significantly better final energy savings because it allows the building to undergo full exploitation. Hence, *energy efficiency measures show a significantly positive result of full-time working buildings compared to the buildings with intermittent heating with reduced final energy use.*

Because district heating systems do not have an intermittent heating regime anyway, district heating was excluded from the analysis (Figure 8) to show the capacity of an intermittent heating factor on FES. Since buildings having other sources of energy often had both characteristics, intermittent heating or full time working with no periodicity, it was decided to test all the objects except for those using district heating. As a rule, buildings operating with district hearting either do not have an energy management system to switch on and off the heat manually or by having the system do not exploit the system properly. The system can be controlled by the responsible people (owner of the building or staff). However, the system requires additional learning or training.

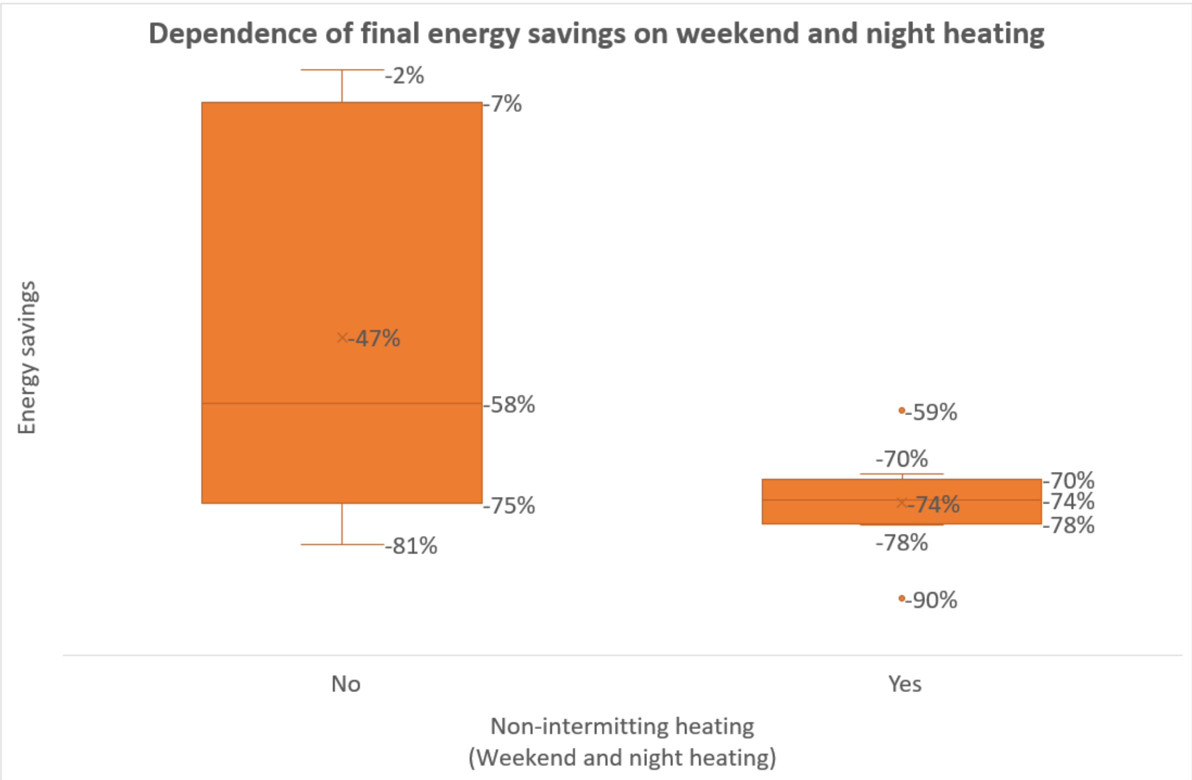

*Figure 8. Dependence of final energy savings on weekend and night heating *no means building was not using energy on weekends and night times*

4.1.2 Climate Zone

There is a significant dependence of FES on HDD. Colder regions, with HDD within the range from 4000 to 7000, benefit from higher FES after the retrofit as compared to regions with lower HDD (Figure 9). Colder regions mostly include North, Central, and some of the Eastern parts of Kazakhstan. They are known to have the longest period of winter (from 6 to 9 months of heating season) and, the longest heating seasons, subsequently. For instance, Astana starts its heating seasons end of October and ends in early May.

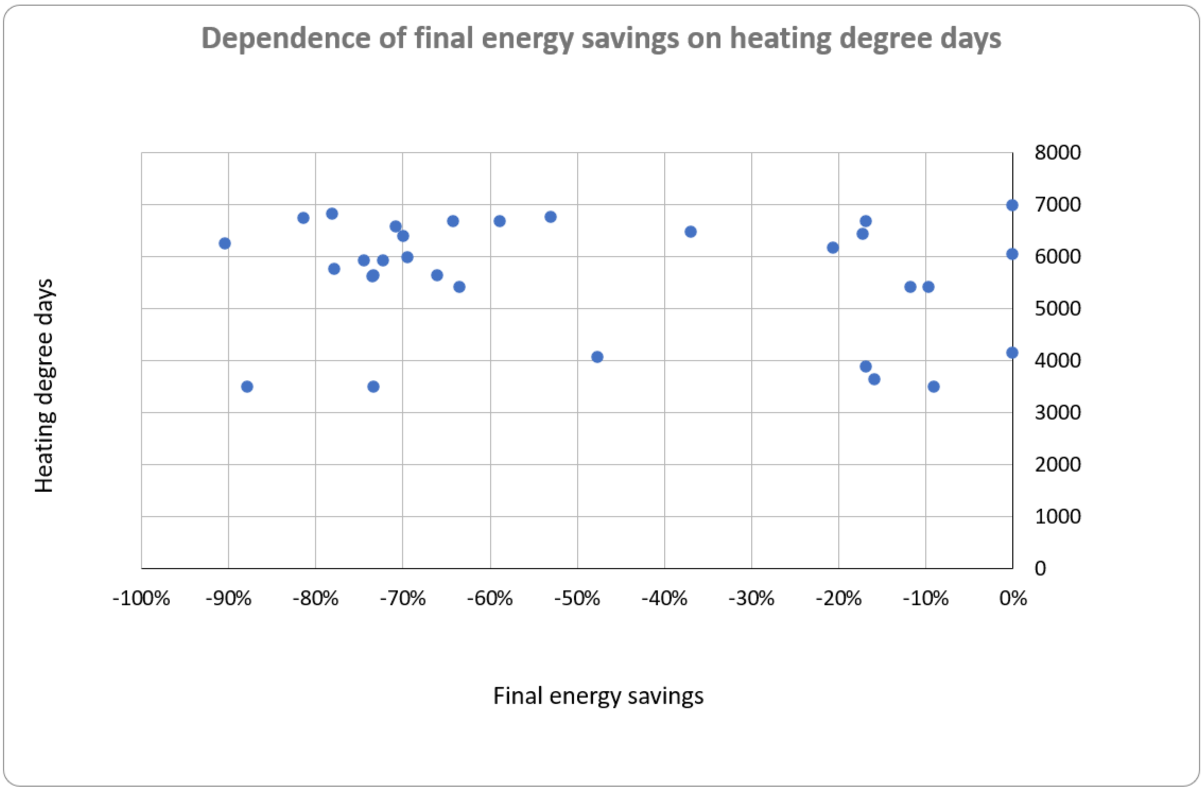

Figure 9. Dependence of final energy savings on heating degree days

4.1.3 Building Compactness

There is a *mild correlation between compactness of the building and the FES after the energy efficiency measures* applied (Figure 10); buildings, which have compactness measure from 0,45 to 0,60, benefit from better FES. By looking at general features of the buildings' shape, mostly rectangular or square, and the floor level, from one to four, it can be said that buildings are standard in shape and not large in volume. However, further studies are needed to confirm the significance of the compactness factor.

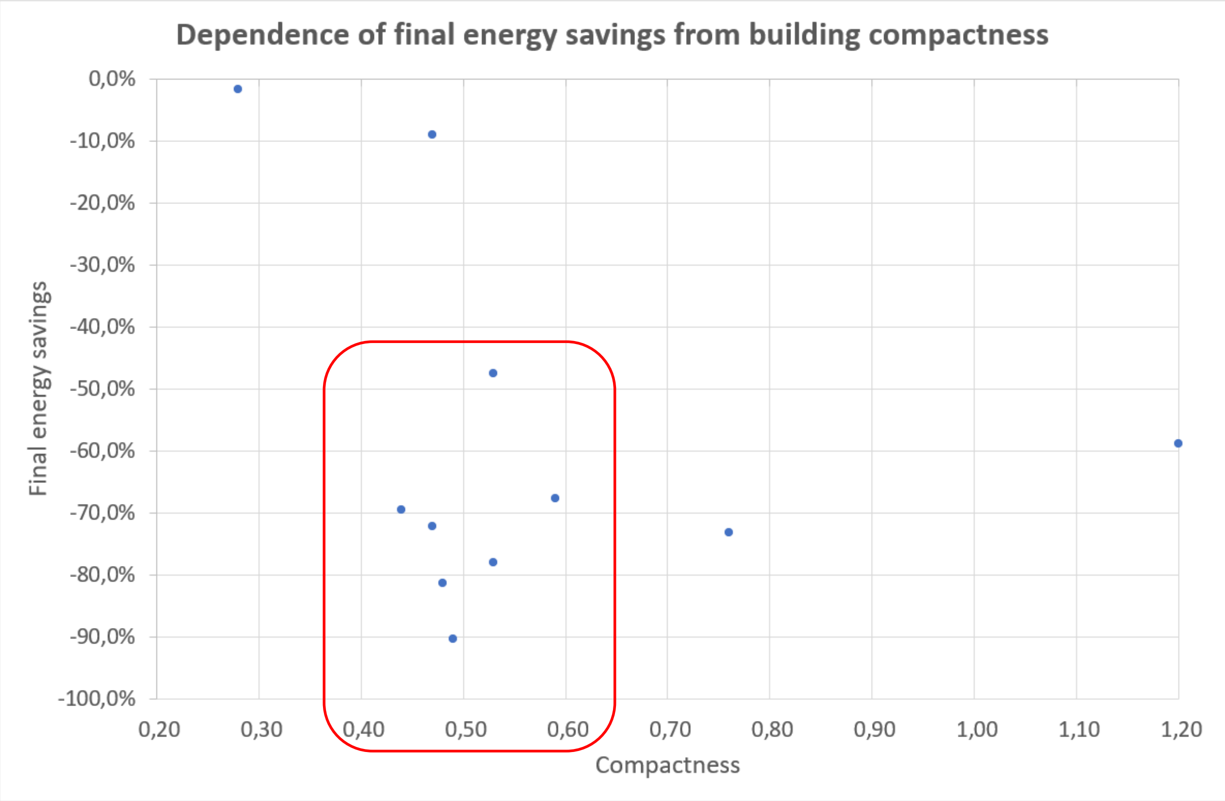

Figure 10. Dependence of final energy savings on building compactness

4.1.4 Type of Energy Carriers

The research concluded that the level of final energy savings achieved during retrofits did not depend on the type of energy carrier used for space heating (Figure 11**Ошибка! Источник ссылки не найден.**). Both significant and not significant energy savings were observed in buildings heated with all energy carriers (district heat, coal, natural gas, and diesel). The exception was buildings heated with natural gas, which showed comparatively good energy savings. However, there were not sufficient data to confirm the outcome for natural gas.

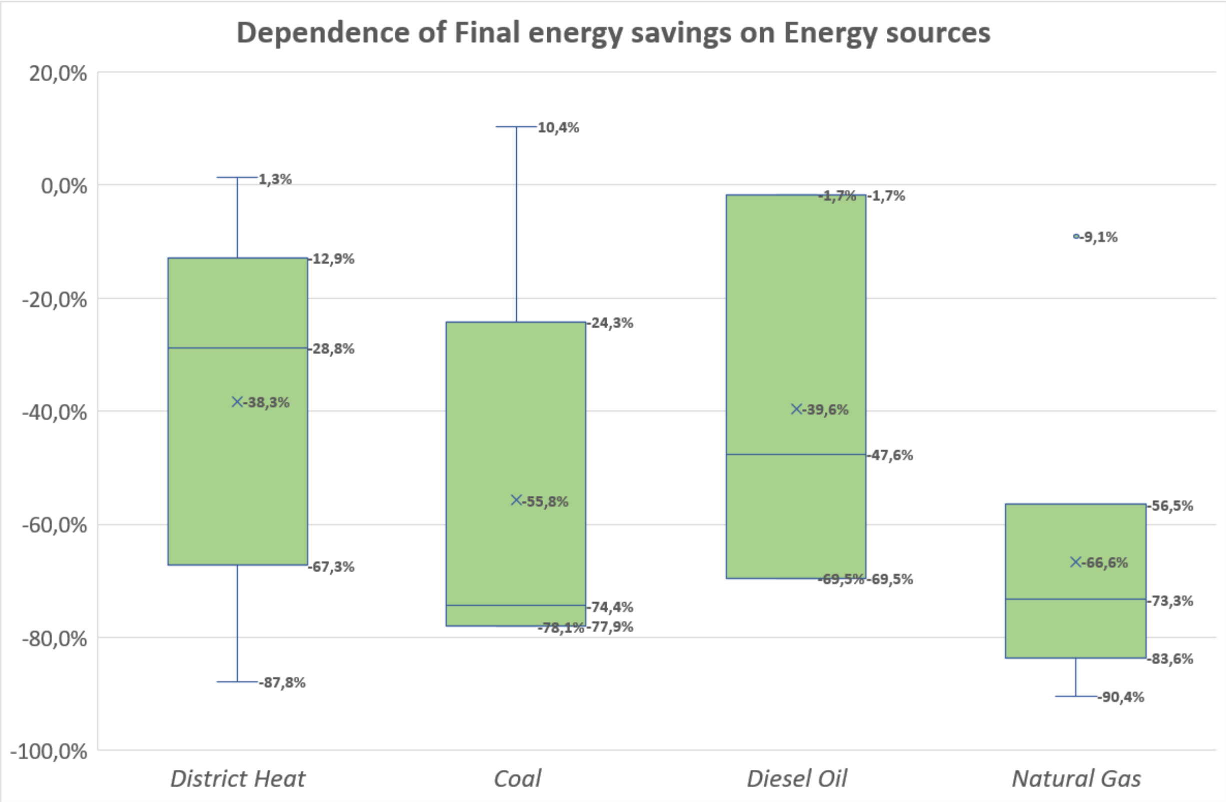

Figure 11. Dependence of final energy savings on energy carriers

4.2 Factors Impacting Simple payback

4.2.1 Compactness, Intermittent heating, and HDD

There was *no dependence of SPB on the compactness of the building (*Figure 12*) as it was seen for FES.* It was a mild dependence for FES (Figure 10); thus, this factor might need further research to verify the outcome.

There was no dependence of SPB on buildings periodicity of the heating at night and on weekends (Figure 13), which showed the opposite outcome for positive FES dependence on intermittent heating (Figure 8).

There was a positive outcome toward of SPB dependence on intermittent heating of buildings (Figure 14). *SPB benefits from buildings located in the regions with HDD from 4000 to 7000,* which coincides with the results obtained from the analysis for FES dependence on HDD (*Figure 9*).

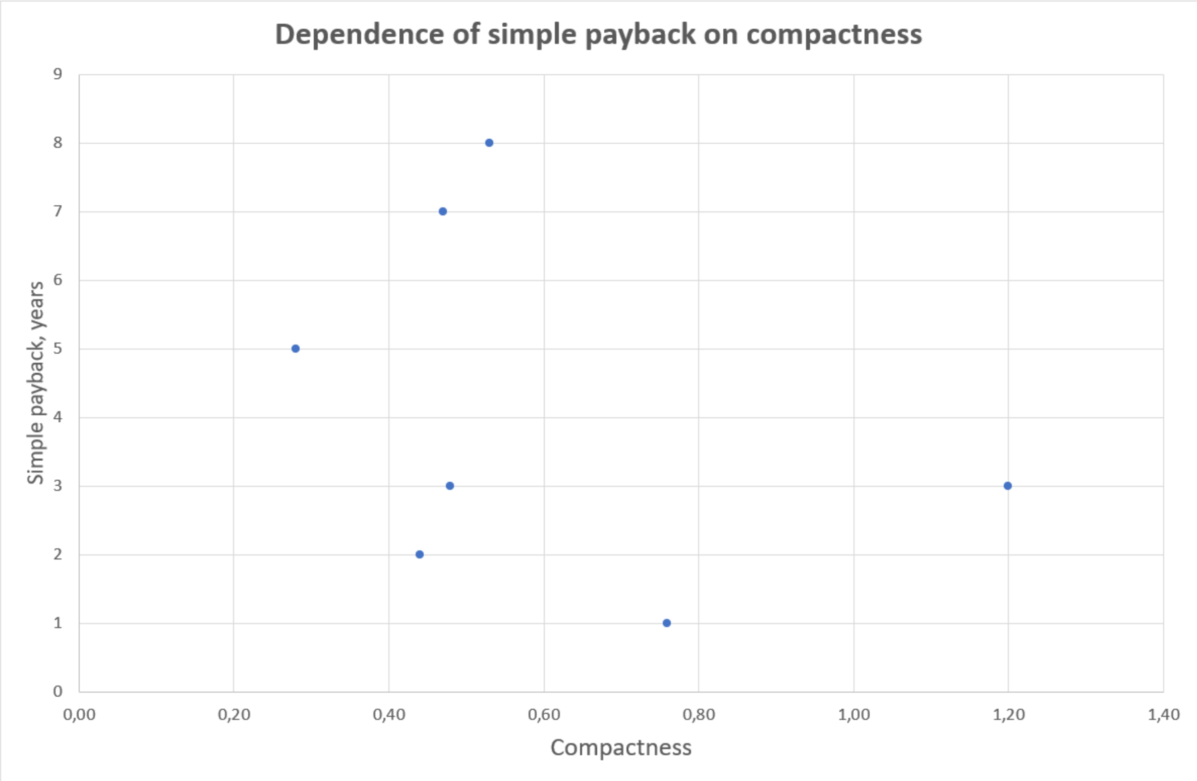

Figure 12. Dependence of simple payback on compactness

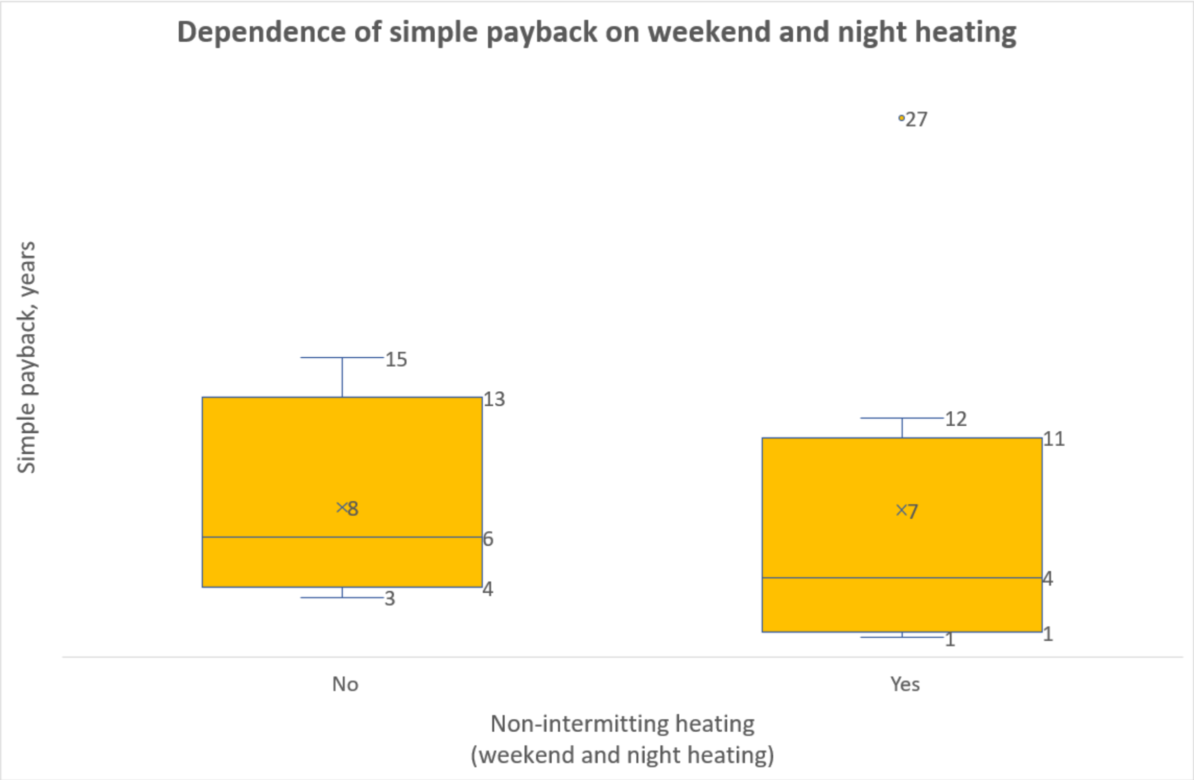

Figure 13. Dependence of simple payback on weekend and night heating

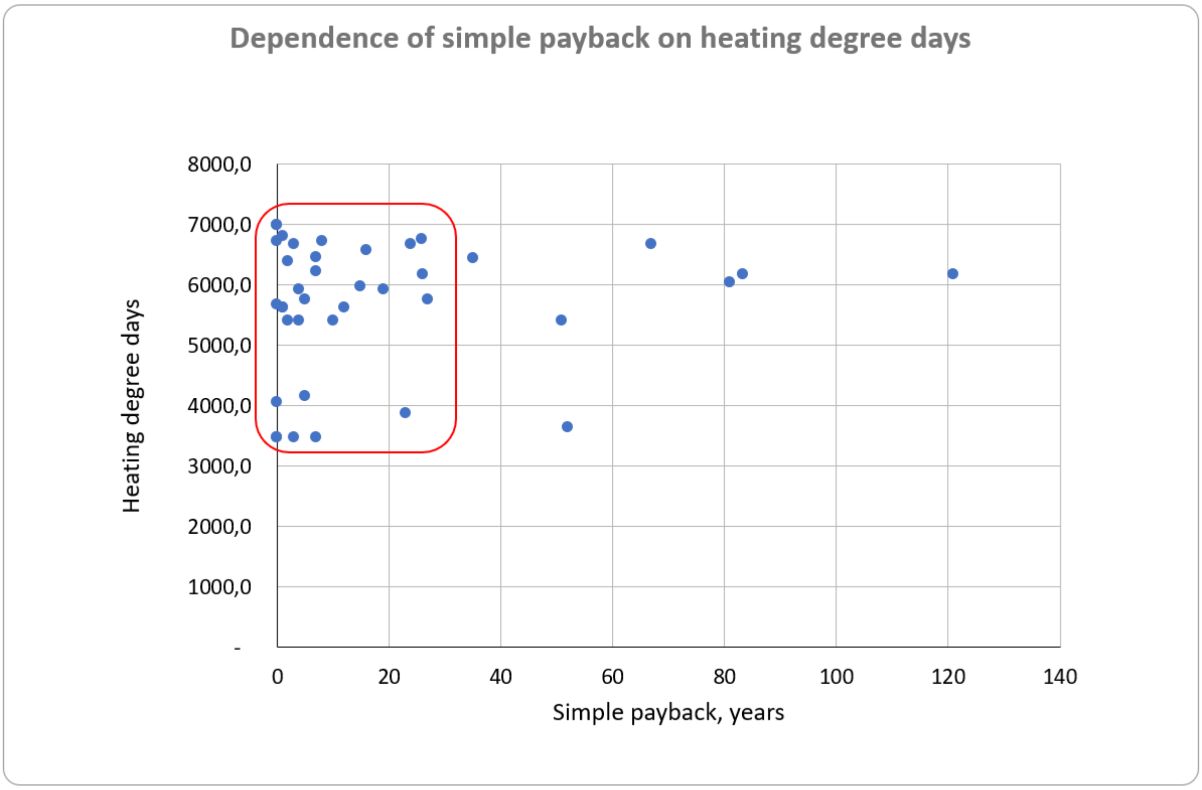

Figure 14. Dependence of simple payback on heating degree days

4.2.2 Types of Energy Carriers

Furthermore, the analysis of *SPB dependence on the energy sources* showed that SPB is the highest in buildings using coal and diesel compared to those connected to district heating and natural gas (Figure 15). A significant part of buildings using coal is located in the central and northern regions, where the heating season is twice longer compared to the southern part. Since district heating showed a wide range of SPB, for the demonstration, it was excluded from **Ошибка! Источник ссылки не найден.**, where coal and diesel showed the most favorable SPB values. To note, variables for *district heating* and *natural gas are scattered*, and further analysis is needed to confirm the outcome.

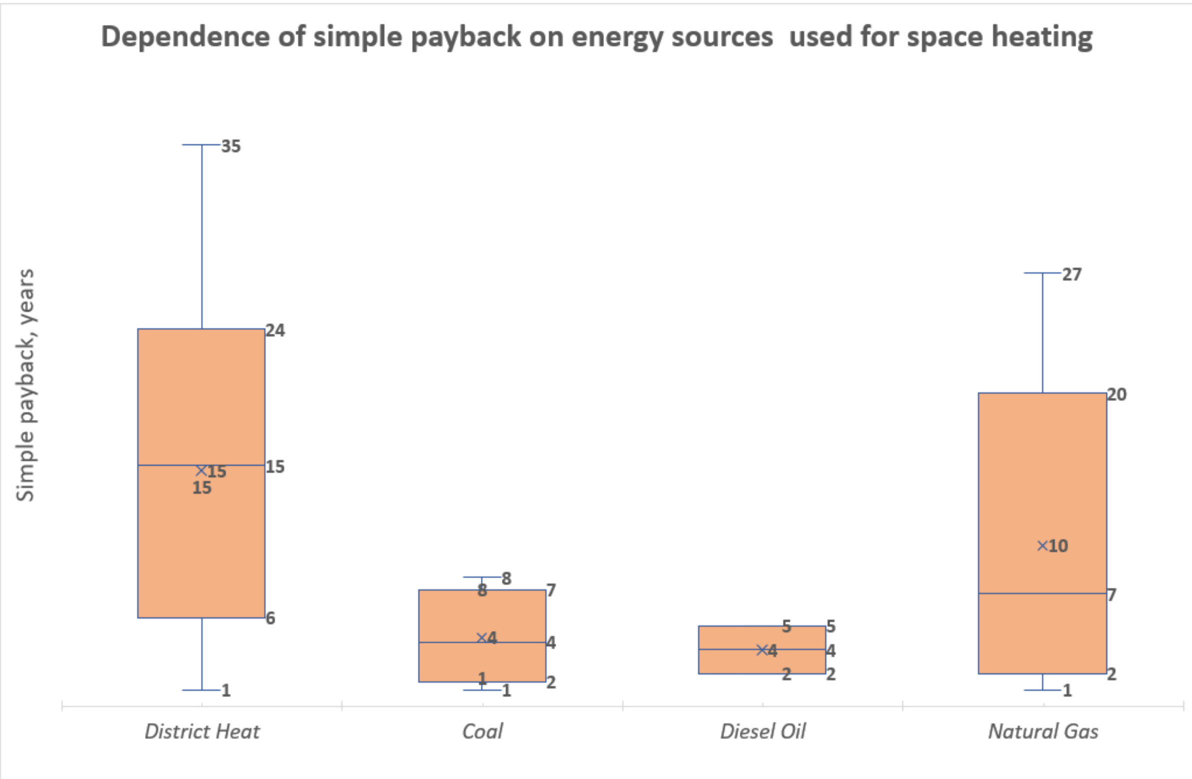

Figure 15. Dependence of simple payback on energy sources used for space heating

4.2.3 Level of Capital Expenditure

There is a direct correlation between SPB and the level of capital investment (Figure 16). Objects having investment requirement from 0 to 30,000 KZT per m^2 demonstrate favorable payback from 0 to 25 years (highlighted red box in Figure 16).

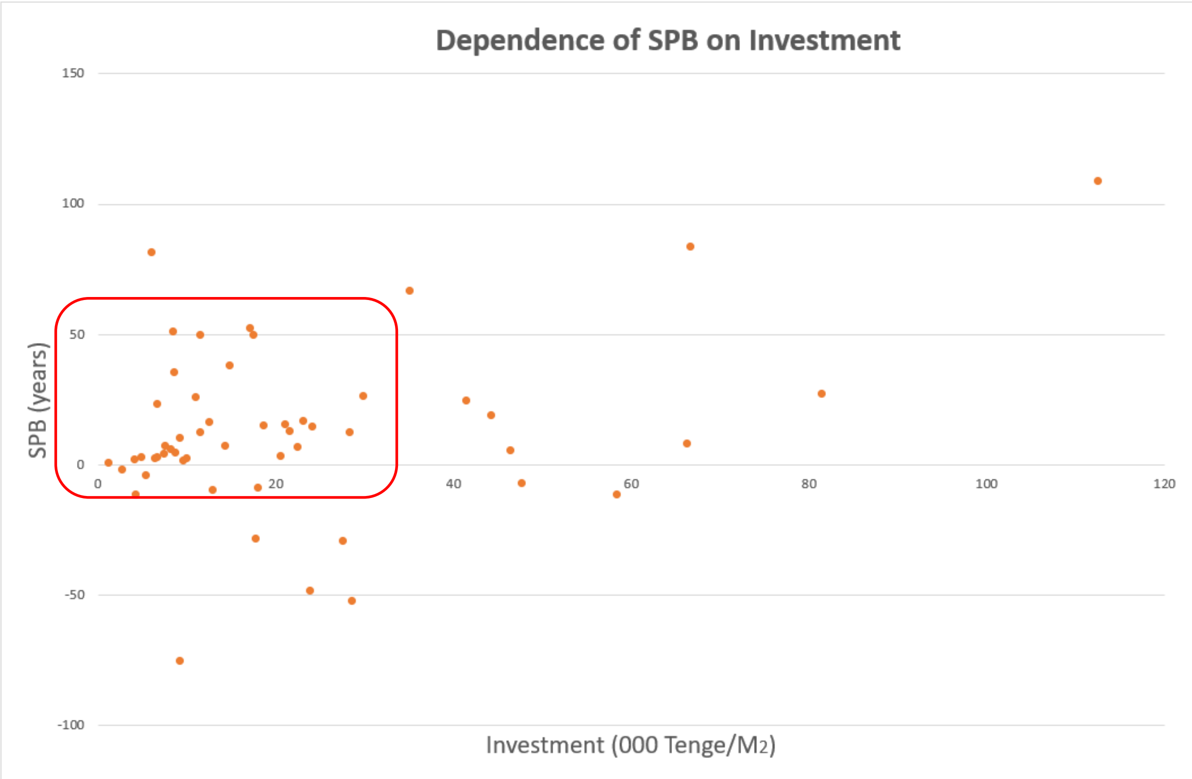

Figure 16. SPB dependence on the level of capital investment

To conclude the analyses above, the number of hypotheses is confirmed. There is a significant dependence of FES on intermittent heating and HDD, and mild correlation with the compactness of the building. Furthermore, there is a strong dependence of the SPB on HDD (similar outcomes as for FES), the type of energy sources that construction uses, and the initial investment capital. In contrast, there is no dependence of SPB on intermittent heating as well as on compactness. Overall, variables of SPB (years) is scattered due to various factors affecting the values (Figure 17).

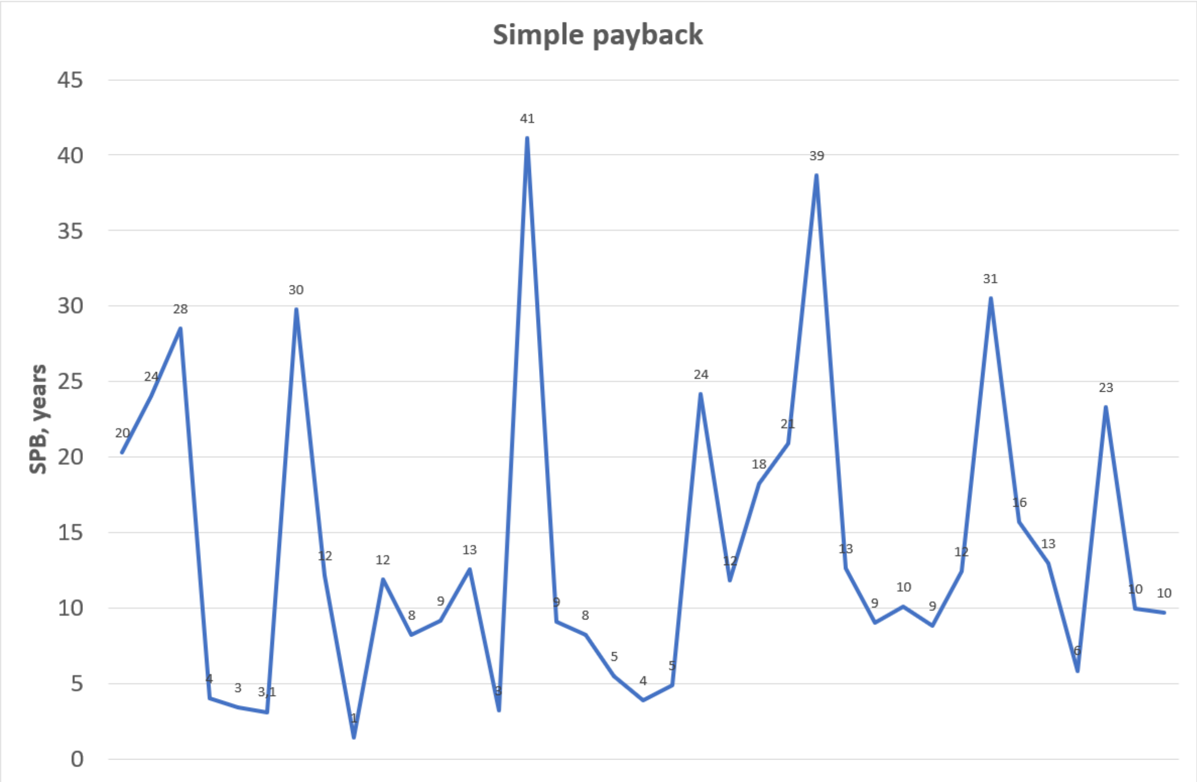

Figure 17. Overall SPB outcome

5 Discussion

5.1 Analysis of the Compared Variables

Energy efficiency measures require significant investment. There are several indicators of financial analysis using which one can conclude on its effectiveness; these include simple payback, discounted payback, a discounted rate of return, profitability index, internal rate of return, and others. In the given study, the simple payback of the investment allocated to the energy efficiency project in Kazakhstan is assessed (Gorshkov et al. 2018). The main reason for simple payback to be chosen is that it is the simplest way to evaluate and compare objects to provide feedback as recommendations.

Simple payback is dependent on FES, tariffs, initial investment cost, and energy source. To note, tariffs were not assessed directly in the dependence analysis. Instead, energy sources are taken as a significant factor affecting the tariffs. It is because the tariffs directly depend on the type of energy source used. Overall, the given study assessed factors impacting FES and SPB.

Dependence of FES on Intermittent Heating, Heating Degree Days and Compactness

There is a significant *dependence of FES on the intermittent heating of the buildings (*Figure 8***Ошибка! Источник ссылки не найден.****)*. For the positive outcome of the energy-saving measures, a building should be under full exploitation. Hence, it is the reason for building operating full time showing positive final energy savings.

Kazakhstan has the phenomena of high demand for the heating season due to its dry and continental climate. The wintertime in the regions of central and northern parts are notably characterized by temperature-dependent energy demand. From the analysis above (*Figure 9*), *final energy savings from heating degree days in the condition of 5000 to 7000* showed *the* *highest final energy savings after the retrofit.* This shows a relation that the colder regions have higher final energy savings.

There was mild dependence of FES on the compactness of the building. Different geometric properties affect the energy performance of the buildings, such as size, compactness, and shape. The compactness of the building is one of the main features explaining the energy demand of the building. Compactness explains the efficient use of building envelope enclosing a particularly heated area (Parasonis, Keizikas, and Kalibatiene 2012). Buildings with smaller external areas experience deceased energy loss. According to Hegger *et al.* (2008), buildings with rectangular and square shapes perform the highest final energy conservation. Most of the buildings in the project were not large (from one floor to four-floor buildings), square, or rectangular shapes. Hence, compactness, specifically the buildings with a square or rectangular shape and with a one to the four-floor area, most probably plays an influential role in final energy saving after the retrofit.

Dependence of SPB on Intermittent Heating, Heating Degree Days and Compactness

Simple payback showed favorable values in the condition of heating degree days from 4000 to 7000, which is the same outcome as for FES dependence on HDD. However, there was only mild dependence on the periodicity of the building operation, buildings operating full time have slightly better outcomes than the structures working only on weekdays; this outcome coincides with the results obtained for FES. Compactness did not show any correlation.

From this analysis, it can be observed that the factors which significantly impact FES, also impact or slightly impact SPB value too, namely HDD in the range from 4000 to 7000, and periodicity of the building operation (full time exploited buildings).

Dependence analysis of SPB on Tariffs and Investment

Buildings in Kazakhstan uses various energy sources, and they have different prices, accordingly. District heating showed a heterogeneous outcome because variables were scattered, whereas coal and diesel showed the most favorable outcome for SPB (Figure 15). *There is no unified tariff system in the country (*Figure 18*)*, and different prices for energy and heat generation are standard in Kazakhstan due to the various primary energy sources used with distinct prices for each of them.

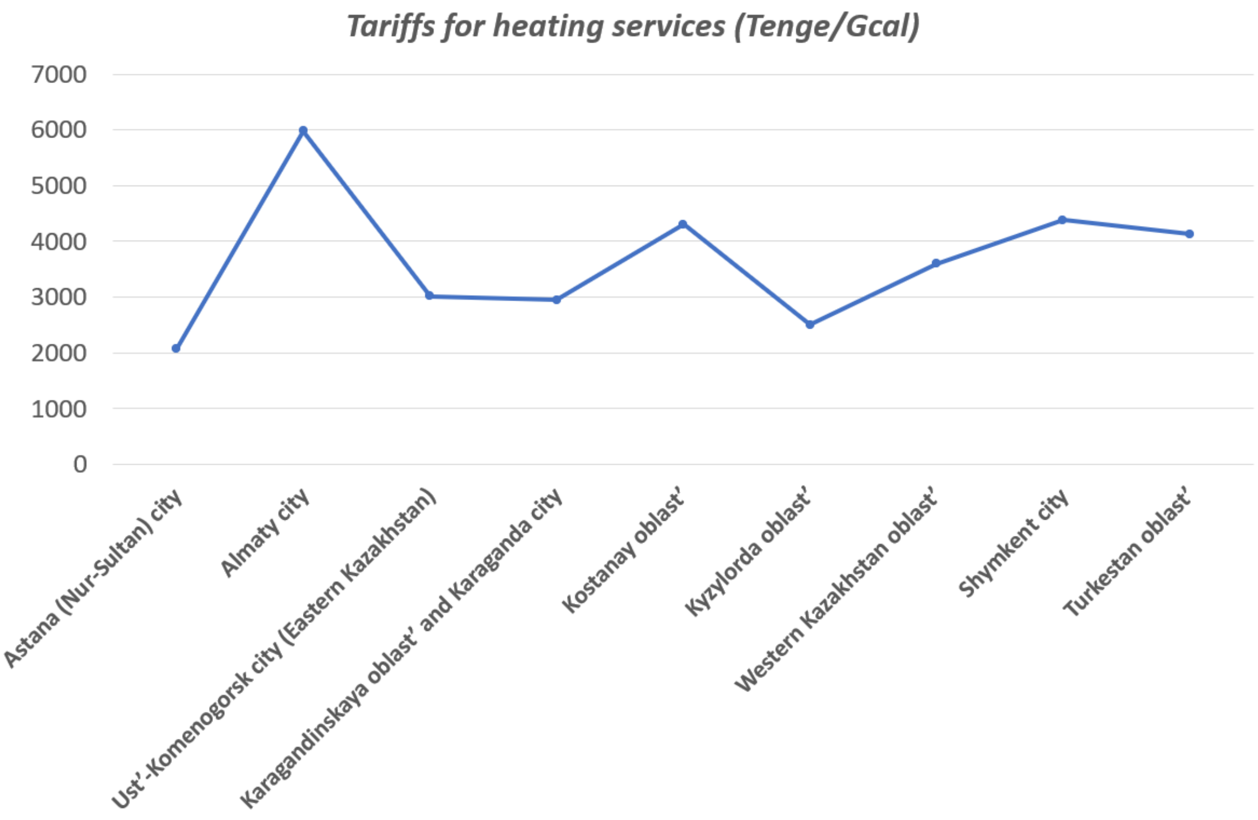

Figure 18. Tariffs for heating services in Kazakhstan

Source: Bogayeva 2018

Additionally, the district heating system requires major remodeling as it has the issue of high energy loss. Even with the presence of energy management systems[1] in the buildings using

[1] Energy management system is the manual control of the heat supply

district heating, responsible people do not apply the system correctly, and buildings are not switched off when a building is not exploited, for instance, during weekends. This is one of the reasons for district heating, showing scattered variables in Figure 15. The current level makes it significantly *hard to convey energy efficiency on existing buildings with the existing district heating systems.*

Furthermore, there is a factor of underheating in buildings. Some buildings could exploit a building on a comfortable level without underheating, only after the energy efficiency measures. Such cases substantially decrease the chances to observe the final energy savings after the retrofit.

Dependence of SPB on initial capital investment showed (Figure 16) that the highest concentration of lowest simple payback in years correlates with the low value of investment from 0 to 30.000 KZT per m^2.

Conclusion

In conclusion, simple payback is positively affected by high final energy savings, low investments, and high tariffs. The analysis showed, there are positive energy savings after the retrofit. Critically impacting factors on FES are HDD in the range from 4000 to 7000 and full exploitation of buildings. SPB shows a positive dependence on HDD, with the highest values achieved in regions with HDD from 4000 to 7000. Compactness showed a mild correlation with FES, which means building with rectangular and square shapes and floor number from one to four would benefit FES. There is a good SPB (ranging from 0 to 20 years) with the investments in a range of 0 to 30.000 KZT per m^2. However, overall, SPB did not show good outcomes due to low tariffs for energy (low prices for energy sources). It is because each region has different access to energy sources, and there are no unified energy prices for the heating supply across the country. Hence, to obtain good value for SPB, significant impacting factors must be present.

5.2 Recommendations

Recommendations can be given for two periods: before and after energy efficiency measures applied. After analyzing the data gathered and discovering the quality of the energy audit, *there are recommendations for buildings and objects before they undergo energy efficiency measures for building selection:*

The selection of the buildings should undergo specific multi-level criteria. Considering the deflation level in the country, buildings shall be selected taking account of payback feasibility. *The first step is to go via general selection via the database of* the building. *The second step is to estimate the necessity for renovation* and roughly the potential of the energy savings. The *third* one is to *produce a detailed audit and retrofit plan*. Hence, retrofit shall be carried out only in those who have enough capacity for energy efficiency measures with adequate payback (up to 10 years only) and potential positive final energy savings.

To avoid troublesome objects and increase the energy efficiency measures outcome, buildings are proposed to possess the following criteria:

- The exploitation of the building
- Heating degree days in the range of 4000 to 7000 or more
- The building must not be in the emergency condition to undergo energy efficiency measures
- Compactness (not the major impacting factor)

Further*, there are recommendations for the buildings after the retrofit processes:*

It shall be ensured that the buildings undergo a full regime of exploitation. Responsible bodies of the building or sub-contractors shall show involvement and ensure to run the good-quality energy-management, energy-monitoring system and submit adequate-quality energy reports. Personnel needs to have a training session on how to use automated energy monitoring systems correctly because it regulates the heating energy expenditure. Also, it should be *obligatory for buildings to have an energy passport after renovation*.

After a comprehensive reading of the gathered data, there are other issues identified, and recommendations are proposed:

Development of a General National Building Data Base or a National Energy Register would help to provide the information on buildings across the country. This is to select the focus group of buildings, by looking at the general criteria such as final energy consumption and availability of minimum thermal protection.

There is no unified system of energy audit procedures. Hence, it is difficult to analyze data from the audit reports. Reports have different terms for one concept, and vice versa, there could be mixed meanings for one word used in several energy audit documents conducted by various organizations. Hence, there should be a unified *form for audit reports with methodology, terminology, and results*. Audit companies should have a centralized system of energy savings calculation. It is recommended to have *regular official certifications of energy audit organizations to sustain the quality of the work of the employee and the organization*.

In addition, *building energy efficiency codes (standards) in Kazakhstan are not* synchronized, and such a set of codes leads to confusion. Hence it is advised to have *one unified system of building codes for the country*.

Kazakhstan has legislation in energy efficiency and energy conservation. However, it does not sufficiently stimulate the companies involving in energy and heat production to invest or to be part of the energy-efficient and energy-saving projects, as they are responsible for a large share of energy loss. Because Kazakhstan is rich with fossil fuels, energy prices cannot be high. Subsequently, tariffs for energy carriers and subsequent secondary sources such as heat and electricity are low. Payback of the energy efficiency measures is directly affected by high prices for tariffs. *It is recommended to imply the restructuring of the tariffs system and increase the prices to stimulate energy efficiency. It would stimulate a healthy payback environment for energy efficiency measures and drive energy generating companies to invest in energy-saving projects.* It would involve elimination or restructuring the subsidiary system for energy and heat distribution (Hafner and Tagliapietra, 2016). Besides, high prices for energy and heat is the main tool to influence consumer's behavior to lean on efficient energy usage.

5.3 Recommendations on Future Steps

Energy efficiency in households

The government has a challenging task to incentivize energy efficiency improvement, and the project KEEP analyzed in this thesis adheres to this mission by analyzing the energy efficiency in public buildings. Hence, the next step to implement such measures in the residential sector, which is responsible for 30% of the energy consumption (Table 2). Inefficient use of resources leads to economic losses estimated at USD4-8bln per year and may grow to USD14bln by 2030.

Hence, it is essential to consider *gradual energy efficiency application in existing residential buildings* and *to implement immediate energy efficiency measures on buildings which are planning to be built* and *on buildings facing harsh winters (North and Central Kazakhstan).* The Ministry of Investment and Development of the Republic of Kazakhstan declared to annul over 180 building codes developed during the Soviet Union at the end of 2017. Buildings in Kazakhstan was panned to be built following European standards and comply with recent energy efficiency measure from 2020, which will increase the cost of new housing properties. However, due to the COVID-19 and national economic constraints, such plans might be delayed.

Furthermore, any retrofit process involving household/owner of the properties have additional constraints to overcome. During the realization of the energy efficiency measures, people’s behavior factor, and possible financial constraints of the owner, who is responsible for covering or partially covering the energy efficiency measures, shall be considered.

Heat delivery points and plants facilities

There is enormous potential for energy efficiency by investing the heat-generating points. For instance, investing in district heat-generating points, which is mostly generated from coal, has the potential to reduce GHG emission and subsequent pollution. As known, pipes and transmission networks are outdated, which lead to heat loss during transmissions as well as the waste of primary energy source. In addition to the inefficient transmission pipes, there are outdated power and heat plant facilities, which do not meet current emissions standards in the country. To note, standards are less strict compared to the OECD countries and China. For example, coal-fired power plants in Kazakhstan emit solid particles, which level is substantial times above the EU limits. Thus, it is crucial to adopt more stringent standards for emissions of sulfur dioxide (SO_2) and nitrogen oxide (NO_x), and particular matter from the power plants considering the fact that energy demand is actively increasing. Coal, as a primary source for heating in households (around 30%), is dynamically increasing up to 70% in rural areas.

Hence, it is recommended to consider the gradual replacement of heat transmission pipes to reduce loss and stimulate a decrease in primary energy consumption. Second, it is recommended to introduce modern facilities on the plant stations for a long-term benefit to reduce GHG emissions as well as reduce energy loss. Also, it is highly advised to consider the standards regarding emissions from plant stations.

Domestic low carbon technologies

A lack of technologies hampers energy efficiency. Low carbon technologies diffusion into society is necessary to achieve the energy demand for the future on an adequate scale with sustained balance for present and future generations. Examples are the supply chain for energy technologies such as insulation, thermostat, efficient windows, and lightning. The northern part of Kazakhstan has the most extended heating season, around nine months of winter, which is the focus for energy efficiency to improve the heating system and transmission loss. *Presumably, North Kazakhstan could be the place for pilot projects to produce and test low carbon technologies.*

*Low carbon innovations on a large-scale follow the existing socio-technical system*s. At the same time, low-carbon innovations diffusion *happens on existing barriers and active resistance; for example, the absence of incentives in cities with cheap energy supply or outdated facilities, where innovation diffusion is difficult*. *Low carbon innovations and low carbon actions are expensive, and significant policies are driven by public concerns*, such as sustainability and climate change, rather than economic development. Hence, multi-dimensional support is needed, such as *policy support, the creation of incentives, calling investors, and social pressure* (Geels, Schwanen, Sorrell, Jenkins & Sovacool, 2018).

It is recommended to start low carbon innovations in places where it is highly deeded, for example northern and central Kazakhstan. This would include including new technologies as well as social behavior and organizational arrangements.

6 Conclusion

Kazakhstan is an energy resource-rich country, and the economy is highly dependent on fossil fuels and mineral resources. The country is recognized to be energy-intensive due to low prices of energy resources as well as outdated technologies and facilities in the energy sector. Kazakhstan set long-term goals to reduce GHG emission by 40% by 2050 as compared to 1990.

The current thesis provides an advanced understanding of the status of energy efficiency in the buildings sector of Kazakhstan. The data for the analysis of the thesis is taken from the project KEEP, which was initiated by the Government of Kazakhstan and the World Bank. The analysis is dedicated to contributing to the improvement of energy efficiency in buildings, specifically socially important buildings such as hospitals, kindergartens, orphanages, and schools. They have different energy supply sources, including centralized district heating, natural gas, coal, and diesel. Also, objects were selected from different parts of the country to diversify the climatic conditions.

The analysis presented in this thesis identified some factors which should be taken into account when one plans energy efficiency measures in Kazakh buildings:

1. *Energy savings are significant*, if the buildings are located in a *cold climate* (5000-7000 HDD), undergo *full exploitation after the retrofit* (i.e. do not have intermittent heating) and *have adequate compactness* (including the shape and the outside envelope of the building).
2. *Simple payback of the retrofit is very much affected by tariffs of* energy, as well as by *initial capital investment*. One of the biggest challenges to implement energy efficiency and energy conservation measures is that the incentives for such activities are not enough, and one of the stimuli could be to increase energy tariffs.

Following the analysis implemented the thesis provides recommendations to stimulate energy efficiency measures in the country. First, high-quality audit services and unified reporting system (online platform) of energy audits would increase the chances to implement high-quality energy-saving measures. Second, the availability of the energy passport for buildings as well as multi-level audits of the buildings would help understand which buildings should be retrofitted first. And last, buildings must be under full control of the contractor and frequently convey energy management system, which would help increase awareness of energy efficiency and increase/support final energy savings.

Hence, the impacts of energy efficiency measures are affected by climate zone and how frequently the building is used (exploitation). Based on the findings of this research, the thesis contributes to energy efficiency measures implemented in Kazakhstan by giving recommendations and pointed at the areas for further improvement. It provides recommendations on energy audit procedures, prioritizes buildings to undergo energy efficiency measures as well as on other policy actions.

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8 Appendices

Министерство национальной экономики
Республики Казахстан
Комитет по статистике

Energy balance of Kazakhstan 2014
(data of Committee on statistics)

thousand tones of oil equivalent

SUPPLY AND CONSUMPTION	Coal	Crude Oil	Oil Products	Gas	Hydro	Biomass	Electricity	Heat	TOTAL
Indigenous production	49 944	83 737	0	31 044	711	19	0	0	165 456
Import	771	987	1 723	4 582	0	2	52	0	8 117
Export	-13 752	-67 004	-12 061	-11 534	0	0	-251	0	-104 601
International bunkers	0	0	59	0	0	0	0	0	59
Withdrawal from stock	-131	428	-763	-9	0	2	0	0	-473
Total Primary Energy Supply	36 833	18 148	-11 041	24 083	711	23	-199	0	68 558
Total Final Consumption	10 202	15 428	-11 855	15 036	707	15	-1 018	-911	27 604
Energy use	10 427,8	141,3	5 480,5	3 755,0	3,6	29,4	1 131,2	18,2	20 986,9
Enterprises	7 708,6	141,3	282,7	729,7	1,1	2,6	130,5	16,0	9 012,4
Agriculture	63,6	0,0	0,2	0,7	0,0	0,5	0,2	0,0	65,2
Industry	7 449,1	0,0	207,3	541,1	1,1	0,6	101,8	12,0	8 313,0
Iron&steel	5 460,8	0,0	178,0	235,4	0,0	0,0	41,9	0,0	5 916,1
non ferrous	1 250,5	0,0	2,4	0,0	0,0	0,0	32,1	0,0	1 285,1
non metallic minerals	17,3	0,0	0,9	0,3	0,0	0,0	21,3	0,0	39,8
chemical, petroch. & plastic	3,5	0,0	4,0	72,5	0,0	0,1	0,1	0,0	80,1
machinery	11,0	0,0	0,0	3,2	0,0	0,0	0,4	0,0	14,6
paper&pulp	0,0	0,0	0,6	14,2	0,0	0,0	0,0	9,6	24,4