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ENERGY EFFICIENCY IN COLD CLIMATE, DESIGN STRATEGIES: A CASE STUDY OF SHUSHA CITY IN KARABAKH REGION OF THE REPUBLIC OF AZERBAIJAN

Abstract. *To combat climate change and ensure sustainable growth, energy efficiency is essential. This academic paper examines and evaluates energy efficiency programs in cold climates, with a focus on the cities of the Republic of Azerbaijan. The study evaluates the difficulties and opportunities that these cities confront and suggests ways to improve energy efficiency while considering local climate factors and regional peculiarities. This research seeks to contribute to sustainable energy planning and policymaking in Azerbaijan and serve as a reference for other regions with comparable climatic circumstances by examining various elements of energy usage and identifying potential improvements.*

Keywords: *energy, cold climate, energy efficiency, climatic design, sustainable design.*

Introduction

The cultural and architectural history of Shusha City is well-known [2]. The city has a chilly climate that is marked by lengthy and severe winters, [2]. During the winter, the average temperature might fall below freezing, demanding a large amount of energy use for heating. Shusha's frigid environment presents difficulties for energy efficiency and necessitates specialized solutions to maximize energy use and minimize heat loss. This case study aims to analyze the energy consumption patterns, explore energy-efficient measures and technologies applicable to the city, and provide recommendations for enhancing energy efficiency in Shusha, given the context of the city's cold climate and the need to improve energy efficiency [3]. By concentrating on this case study, important insights into the difficulties and opportunities of energy efficiency in cold climate regions can be gained, which can guide the development of sustainable energy planning and policy not only in Shusha but also in other cities with comparable climatic conditions, [4].

Objectives of the Case Study: The case study's objectives are defined, with an emphasis on examining energy consumption trends in Shusha, identifying essential energy efficiency techniques and technologies appropriate to the city, and making recommendations to improve energy efficiency.

Significance of the Study: This section explains the case study's significance and relevance. It emphasizes the importance of understanding and addressing energy effi-

ciency in cold climate regions, as well as the potential impact of the findings and recommendations on sustainable energy planning and policy development in Shusha and other similar cities in the liberated cities of Azerbaijan's Karabakh region [5, 6].

2 Challenges and Opportunities

2.1 Shusha city background

The city of Shusha was founded in 1752 by Panahali Khan of Javanshir, those days ruler of Karabakh khanate. The mountain plateau, located at an altitude of 1300-1600 meters above sea level and surrounded by steep rocks on three sides, fully met these requirements, so Panahali khan built the city there. [7]

Before the occupation of the city, there were dozens of museums, several secondary and higher education institutions, schools and libraries. On May 8, 1992, the city of Shusha was occupied by the Armenian armed forces. After the occupation, the population of the city was displaced in different regions of Azerbaijan. [7]. Figures 1 to 4 show the present and past situation of buildings in Shusha.

Shusha is one of the most fascinating places in the world. The city is placed at KARABAKH region in the Republic of Azerbaijan. High mountainous areas are covered with subalpine and alpine meadows (Fig. 5)

The highest peak of Shusha is Mount Kirs (2725 m). Most of the area has a hot climate with dry summers and cold winters followed by dry cold. The average temperature ranges from −4 ° C to −1 ° C in January and 16–19 ° C in July. Annual precipitation is 700-800 mm. The soil of the city is brown and brown mountain-forest, grass-mountain-meadow type. [8]

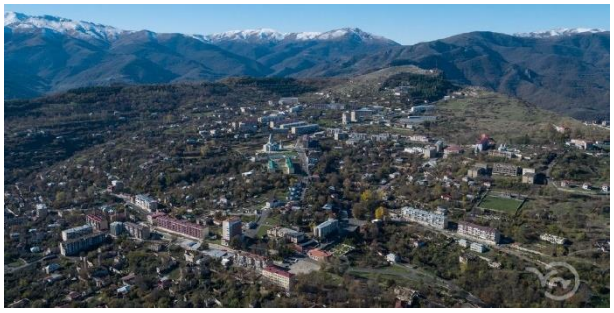


Figure 1 – Aerial view of Shusha city

Figure 2 – The house-museum of Bulbul

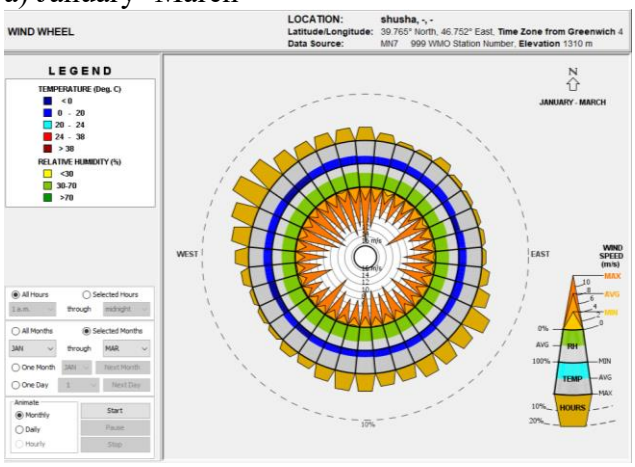
Figure 3 – Shusha historical fortress

Figure 4 – The mansion of Khurshidbanu Natavan (destroyed during the Armenian occupation)

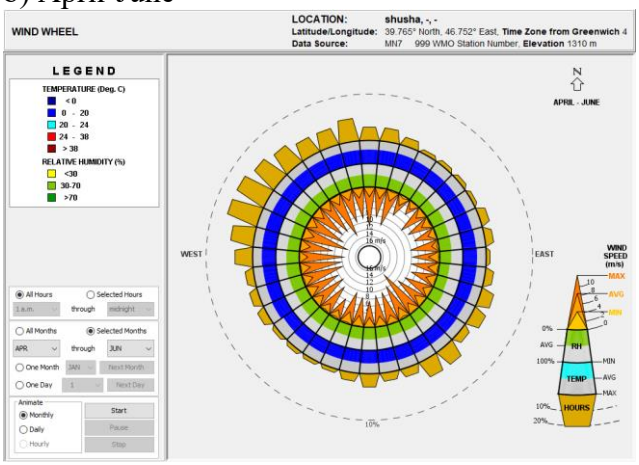
Figure 5 - Shusha city [Source: Google maps]

2.2 wind regime of Shusha

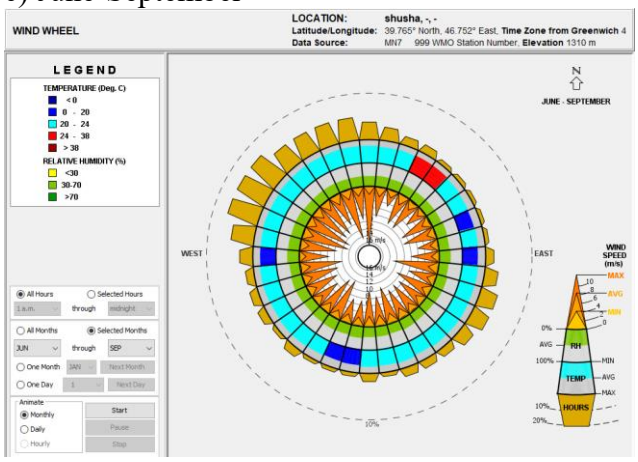
a) January -March



b) April-June



c) June-September



d) October-December

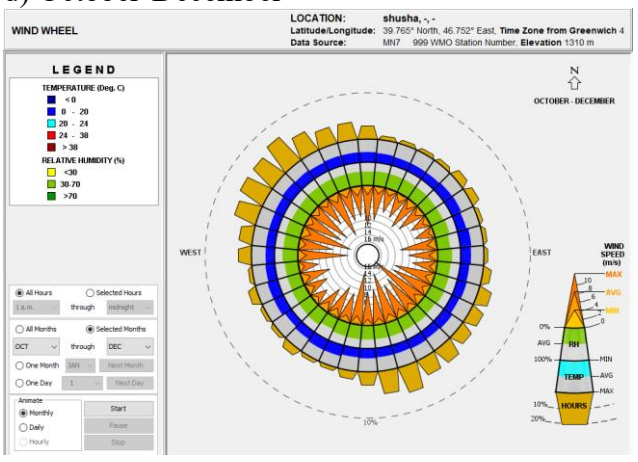


Figure 6 - wind regime of Shusha city January -March (a), April-June (b), June-September (c), October-December (d) [author's material]

Shusha, experiences a variety of wind patterns that change with the seasons. In spring and summer the prevailing winds are typically gentle to moderate mostly blowing from the south and southeast. These winds bring drier weather to the city. On the hand during fall and winter we experience winds coming from the north and northwest which bring cooler temperatures and occasional rainfall. The local landscape, with its hills and valleys can cause variations in wind patterns specific, to Shusha making its wind regime unique and influenced by microclimates (Fig. 6).

2.3 Cold Climate Challenges: Cold temperature conditions pose unique issues that have a substantial impact on energy usage and efficiency in places such as Shusha [8]. Understanding these problems is critical for establishing successful ways for improving energy efficiency in cold climatic zones. (Fig. 7)

WEATHER DATA SUMMARY

LOCATION: **shusha, -, -**
Latitude/Longitude: 39.765° North, 46.752° East, **Time Zone from Greenwich** 4
Data Source: MN7 999 WMO Station Number, **Elevation** 1310 m

MONTHLY MEANS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	
Global Horiz Radiation (Avg Hourly)	231	284	315	358	386	406	412	369	353	285	230	212	Wh/sq.m
Direct Normal Radiation (Avg Hourly)	337	352	340	301	315	359	353	255	371	289	291	357	Wh/sq.m
Diffuse Radiation (Avg Hourly)	102	129	129	170	184	170	188	207	142	143	116	85	Wh/sq.m
Global Horiz Radiation (Max Hourly)	606	717	837	998	1069	1099	1100	1094	970	775	697	543	Wh/sq.m
Direct Normal Radiation (Max Hourly)	973	998	1018	1020	1017	972	966	1015	1011	995	989	958	Wh/sq.m
Diffuse Radiation (Max Hourly)	266	319	385	444	462	491	489	465	405	374	324	233	Wh/sq.m
Global Horiz Radiation (Avg Daily Total)	2200	2964	3722	4703	5487	5996	5975	4998	4347	3118	2252	1962	Wh/sq.m
Direct Normal Radiation (Avg Daily Total)	3203	3659	4000	3952	4475	5306	5133	3453	4556	3150	2832	3309	Wh/sq.m
Diffuse Radiation (Avg Daily Total)	973	1346	1534	2232	2629	2511	2725	2806	1751	1561	1139	786	Wh/sq.m
Global Horiz Illumination (Avg Hourly)	24735	30577	34101	39125	42329	44615	45485	40996	38911	31482	25208	22907	lux
Direct Normal Illumination (Avg Hourly)	30215	32257	32195	29116	29881	34910	33657	24018	35366	26739	26337	31621	lux
Dry Bulb Temperature (Avg Monthly)	-2	0	6	10	15	19	23	23	18	13	5	0	degrees C
Dew Point Temperature (Avg Monthly)	-8	-6	-3	1	5	7	9	9	7	3	0	-5	degrees C
Relative Humidity (Avg Monthly)	67	62	53	55	54	49	44	43	50	55	64	66	percent
Wind Direction (Monthly Mode)	310	300	290	300	290	290	300	310	290	320	300	160	degrees
Wind Speed (Avg Monthly)	2	3	3	3	2	2	2	2	2	1	2	2	m/s
Ground Temperature (Avg Monthly of 1 Depths)	7	5	4	5	7	11	14	17	18	17	14	11	degrees C

Figure 7 - Weather data Summary of Shusha [Source: Climate analyses used in “Climate consultant 6” program, data has been extracted using “METEONORM”]

a) Increased Heating Demand: Due to the lengthy and severe winters in Shusha City, the heating season lasts longer than usual. The rising demand for heating places a significant strain on energy infrastructure, which may increase energy costs and increase dependency on fossil fuel-based heating systems [8, 9].

b) Heat Loss and Inadequate Insulation: Buildings must have adequate insulation to reduce heat loss and increase energy efficiency [10].

c) Ice and Snow Accumulation: Shusha is one of the cold climatic areas that experiences considerable snowfall and ice formation in the winter. In cold-temperature locations, preserving energy efficiency requires effective snow and ice management measures. [11].

d) Thermal Bridging: Thermal bridging occurs when there is a direct pathway for heat transfer through materials with high thermal conductivity, such as steel or concrete. This localized heat loss reduces energy efficiency and can result in thermal discomfort, [13]. Proper building design and construction techniques that minimize thermal bridging are essential for improving energy efficiency in Shusha City.

e) Moisture and Condensation: Due to heating systems and human activity, cold climates frequently have lower external temperatures and higher inside humidity levels. This difference in temperature and humidity can cause condensation on windows, walls, and other surfaces, which can cause structural damage and moisture-related problems, including the growth of mold. Maintaining energy-efficient and healthful interior settings requires moisture control methods, including ventilation and moisture barrier installation [13].

2.4 Opportunities for Energy Efficiency: Despite the challenges, there are various opportunities to enhance energy efficiency in Shusha City's cold climate:

a) Efficient Heating Systems: Upgrading to more energy-efficient heating systems, such as condensing boilers or heat pumps, can significantly reduce energy consumption, (Figure 8). These systems utilize advanced technologies to extract and utilize heat more efficiently, resulting in lower energy costs and reduced greenhouse gas emissions [14].

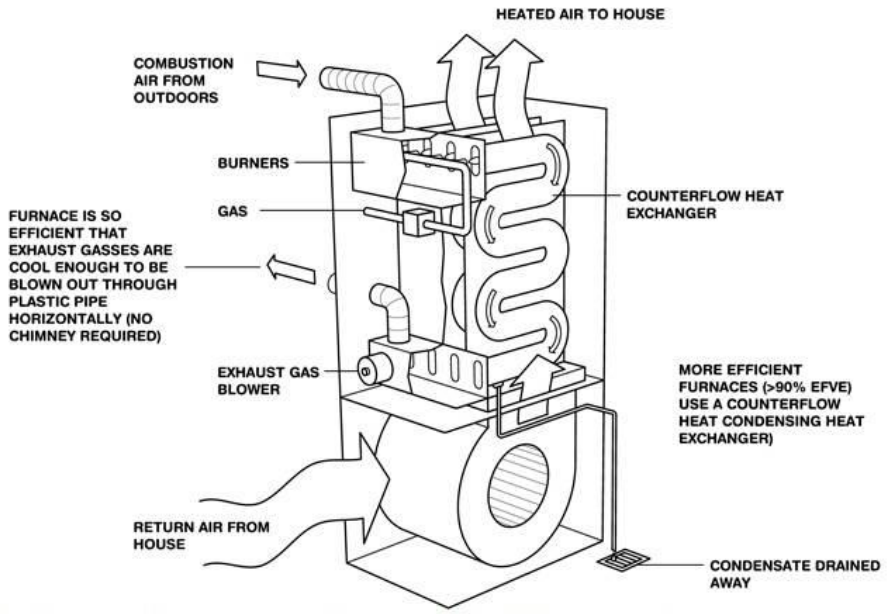


Figure 8 - Using efficient appliances (with low energy consumption), [Source: Climate Consultant 6.0].

Building Envelope Improvements: Enhancing insulation and sealing air leaks in buildings can minimize heat loss and improve energy efficiency. Proper insulation of roofs, walls, and windows, along with the installation of weather stripping and caulking, can create a more thermally efficient building envelope, (Fig.9) [15].

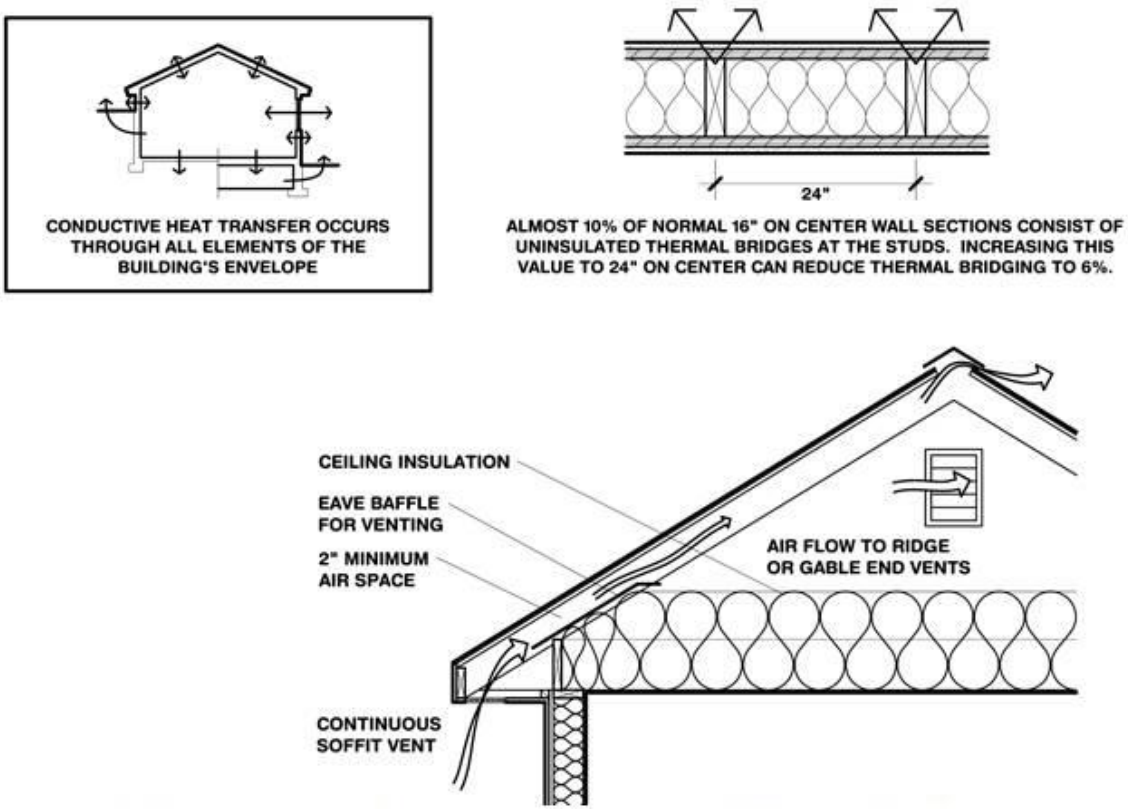


Figure 9 - Extra insulation might prove cost effective, and will increase occupant comfort by keeping indoor temperatures more uniform, [Source: Climate Consultant 6.0].

b) Energy-Efficient Lighting: Replacing traditional lighting fixtures with energy-efficient alternatives, such as LED lights, can lead to significant energy savings. LED lights consume less electricity, have longer lifespans, and provide better quality lighting [16].

c) Renewable Energy Integration: Exploring the potential for renewable energy sources, such as solar (table 2, 3) and wind power, [Diagram 1] can contribute to energy diversification and reduce reliance on fossil fuels [17]. Shusha City's geographical location and available land area may offer opportunities for solar panel installations and small-scale wind turbines.

Table 2: optimal solar panel tilt angles by season is 31.4° from horizontal. [18]

Spring		31.4°
Summer		16.4°
Fall		31.4°
Winter		46.4°

Table 3: optimal Solar panel tilt angles by month. [18]

January	February	March	April	May	June	July	August	September	October	November	December
41.4°	36.4°	31.4°	26.4°	21.4°	16.4°	21.4°	26.4°	31.4°	36.4°	41.4°	46.4°

d) Smart Building Technologies: By automatically altering heating and cooling settings based on occupancy and the weather outside, smart building solutions like energy management systems and smart thermostats can reduce energy consumption [19].

3 Energy Efficiency Measures in Shusha City: To improve energy efficiency in Shusha City's cold climate, various measures can be implemented. This section explores key energy efficiency measures and technologies applicable to the city.

3.1 Recommendations for Enhancing Energy Efficiency in Shusha City: To enhance energy efficiency in Shusha City's cold climate, the following recommendations are proposed:

3.2 Policy and Regulatory Framework: Create and put into effect energy efficiency laws and policies that are tailored to Shusha City's chilly climate. These regulations should cover the building codes, norms, and rules that support energy-efficient building techniques and retrofitting existing structures [20]. To ensure compliance with energy efficiency standards, set energy performance goals and specifications for both new and renovated buildings.

3.3 Building Codes and Standards: Building regulations should be updated and strengthened to include requirements particular to areas with cold climates. In order to enhance the energy efficiency of buildings in Shusha, these rules should cover insulation, air sealing, window performance, and other pertinent issues. To achieve successful application and enforcement of the codes, collaboration between neighborhood stakeholders, architects, builders, and engineers is required [21].

3.4 Financial Incentives and Support Mechanisms: Introduce financial incentives, subsidies, and other support systems to promote investments in energy efficiency in Shusha City. Offer grants, low-interest loans, or tax breaks to encourage the adoption of efficient heating systems, the installation of renewable energy sources, and energy-efficient renovations. For easier access to finance options for energy efficiency projects, form relationships with financial institutions and energy service providers [22, 23].

3.5 Collaboration and Partnerships for Energy Efficiency: Encourage cooperation and collaborations between governmental entities, local governments, companies, institutes of higher learning, and community-based organizations to collaboratively address Shusha City's energy efficiency concerns. Promote research, development, and innovation in energy-efficient techniques and technology. Encourage public-private collaborations so that large-scale energy efficiency projects can take advantage of available financing, resources, and knowledge [22].

Shusha City can significantly advance energy efficiency, lower energy consumption, and support sustainable development by putting these proposals into practice. These actions not only help citizens and companies cut costs, but they also have beneficial socioeconomic and environmental effects, raising the standard of living in Shusha City.

4 Impacts and Benefits of Energy Efficiency Measures: The implementation of energy efficiency measures in Shusha City can have several positive impacts and benefits. This section highlights some of the key impacts and benefits associated with energy efficiency initiatives in the city:

4.1 Reduced Energy Consumption: One of the primary benefits of energy efficiency measures is the reduction in energy consumption. By improving the thermal performance of buildings, upgrading heating systems, and integrating renewable energy sources, Shusha City can significantly decrease its energy demand [10, 15]. This reduction in energy consumption translates into lower utility bills for residents and businesses, freeing up financial resources for other purposes.

4.2 Cost Savings: Energy efficiency measures can lead to substantial cost savings for both individuals and the city. By implementing building envelope improvements, such as insulation and efficient windows, heating costs can be significantly reduced [11, 21, 24]. Upgrading to energy-efficient heating systems and appliances can also result in long-term cost savings through reduced fuel or electricity consumption [10, 15]. These savings contribute to the economic well-being of residents and businesses in Shusha City.

4.3 Environmental Benefits: Reduced greenhouse gas emissions and climate change mitigation are made possible by energy efficiency techniques [19]. Shusha City can lessen its carbon footprint and support national and international efforts to mitigate climate change by reducing its energy consumption. As more fossil fuels are replaced with renewable energy sources, such as solar photovoltaic systems, energy generation becomes cleaner and more sustainable [17].

4.4 Improved Comfort and Indoor Air Quality: The comfort and wellbeing of inhabitants in Shusha City can be improved with the use of energy efficiency techniques. High-performance windows, efficient insulation, and air sealing all contribute to stable indoor temperatures by minimizing drafts and cold spots. This improves the quality of life and the working environment, particularly during the difficult winter months. Additionally, effective ventilation and energy-efficient heating systems help to improve interior air quality, enhancing inhabitants' health and comfort.

4.5 Job Creation and Local Economy: Shusha City's adoption of energy-saving measures has the potential to encourage job growth and strengthen the local economy [24]. Building retrofitting, installing energy-saving equipment, and creating renewable energy projects all demand specialized labor and knowledge [20, 21]. This offers local companies, contractors, and service providers the chance to participate in energy-efficiency projects, which will boost the city's economy and create more jobs.

4.6 Resilience to Energy Price Volatility: Measures to improve energy efficiency can make Shusha City more resilient to changes in energy prices. The city becomes less reliant on outside energy sources and more self-sufficient by reducing en-

ergy use and integrating renewable energy systems [17]. This makes Shusha City's future energy more reliable and safer by reducing the effects of fluctuating energy prices and potential supply disruptions.

Conclusion

In conclusion, the liberation of Shusha City from Armenian forces after 30 years of occupation offers a special chance to concentrate on energy efficiency and sustainable growth. The findings in Shusha emphasize the significance of giving energy efficiency measures priority when rehabilitating and revitalizing the city. In conclusion, Shusha City's energy efficiency initiatives have had a positive impact on the environment through reduced energy use, cost savings, enhanced comfort and indoor air quality, the creation of jobs, and increased resilience to fluctuations in energy prices. These advantages contribute to the city's and its citizens' general sustainability, economic prosperity, and well-being. Shusha City can build an energy-efficient and sustainable future by putting energy efficiency first.

The implementation of energy efficiency measures in Shusha City can bring about numerous benefits and positive impacts. The liberation of Shusha City opens new prospects for energy efficiency in the post-conflict period. As the city undergoes reconstruction and development, energy efficiency should be integrated into urban planning and infrastructure projects. This includes incorporating energy-efficient design principles in new buildings, retrofitting existing structures to improve insulation and heating systems, and exploring renewable energy options for power generation.

It is crucial for Shusha City to take advantage of the momentum and global attention that its emancipation has brought about to obtain money and assistance for energy efficiency projects. Strategic planning, interaction with international players, and effective dissemination of the city's potential are all ways to do this.

In conclusion, the liberation of Shusha City offers a special chance to emphasize energy conservation and sustainable growth. Shusha City can set the road for a resilient, energy-efficient, and sustainable future by tackling the issues, maximizing the advantages, and utilizing foreign assistance. Incorporating energy-saving techniques into the rehabilitation process will benefit the city and its citizens while also showcasing Shusha as a regional leader in sustainable development.

In summary as conclusion to have more energy efficient building in Shusha climate it is recommended to use:

1- Solar glazing admits direct sunlight into a space for passive heating in winter

2- Provide double pane high performance glazing (LOW-E) on west, north, and east, but clear on south for maximum passive solar gain

3- Heat gain from lights, people and equipment greatly reduces, heating needs so keep keep home tight, well insulated.

4- Sunny wind-protected outdoor spaces to extend living areas in cool weather

5- Organise floorplan so winter sun penetrates into day-time.

6- Window overhangs or operated sunshades can reduce or eliminate air conditioning.

7- Keep buildings small (right-sized) to reduce heating and cooing energy.

8- Using high mass interior surfaces to store winter passive heat and summer night “coolth”.

9- Extra insulation might prove cost efective, and will increase occupant conmfort by keeping indoor temperatures more uniform.

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ЭНЕРГОЭФФЕКТИВНОСТЬ В ХОЛОДНОМ КЛИМАТЕ, СТРАТЕГИИ ПРОЕКТИРОВАНИЯ: НА ПРИМЕРЕ ГОРОДА ШУША КАРАБАХСКОГО РЕГИОНА АЗЕРБАЙДЖАНСКОЙ РЕСПУБЛИКИ

Аннотация. *Для борьбы с изменением климата и обеспечения устойчивого роста большое значение имеет энергоэффективность. В данной статье рассматриваются и оцениваются программы повышения энергоэффективности в условиях холодного климата, с особым уклоном на города Азербайджанской Республики. Исследование оценивает сложности и возможности, с которыми сталкиваются эти города, и предлагает пути повышения энергоэффективности с учетом местных климатических факторов и региональных особенностей. Это исследование направлено на содействие устойчивому планированию и разработке политики в области энергетики в Азербайджане, а также служит ориентиром для других регионов с сопоставимыми климатическими условиями путем изучения различных аспектов использования энергии и выявления потенциальных улучшений.*

Ключевые слова: *энергия, холодный климат, энергоэффективность, климатический дизайн, устойчивый дизайн.*

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СУЫҚ КЛИМАТТАҒЫ ЭНЕРГЕТИКАЛЫҚ ТИІМДІЛІК, ЖОБАЛАУ СТРАТЕГИЯЛАРЫ: ӘЗЕРБАЙЖАН РЕСПУБЛИКАСЫ, ҚАРАБАҚ ОБЛЫСЫ, ШУША ҚАЛАСЫНЫҢ ҮЛГІСІ

Аңдатпа. *Климаттың өзгеруімен күресу және тұрақты өсуге қол жеткізу үшін энергия тиімділігі маңызды. Бұл мақалада Әзербайжан Республикасының қалаларына ерекше назар аудара отырып, суық климаттық аймақтардағы энергия тиімділігі бағдарламалары қарастырылады және бағаланады. Зерттеу осы қалалардың қиындықтары мен мүмкіндіктерін бағалайды және жергілікті климаттық факторлар мен аймақтық ерекшеліктерді ескере отырып, энергия тиімділігін арттыру жолдарын ұсынады. Бұл зерттеу Әзірбайжандағы тұрақты энергияны жоспарлау мен саясатты дамытуға үлес қосуды мақсат етеді, сонымен қатар энергияны пайдаланудың әртүрлі аспектілерін зерттеу және әлеуетті жақсартуларды анықтау арқылы салыстырмалы климаттық жағдайлары бар басқа аймақтар үшін нұсқаулық ретінде қызмет етеді.*

Түйін сөздер: *энергия, суық климат, энергия тиімділігі, климаттық дизайн, тұрақты дизайн.*