

Draft report

Aghali Smart Village Project



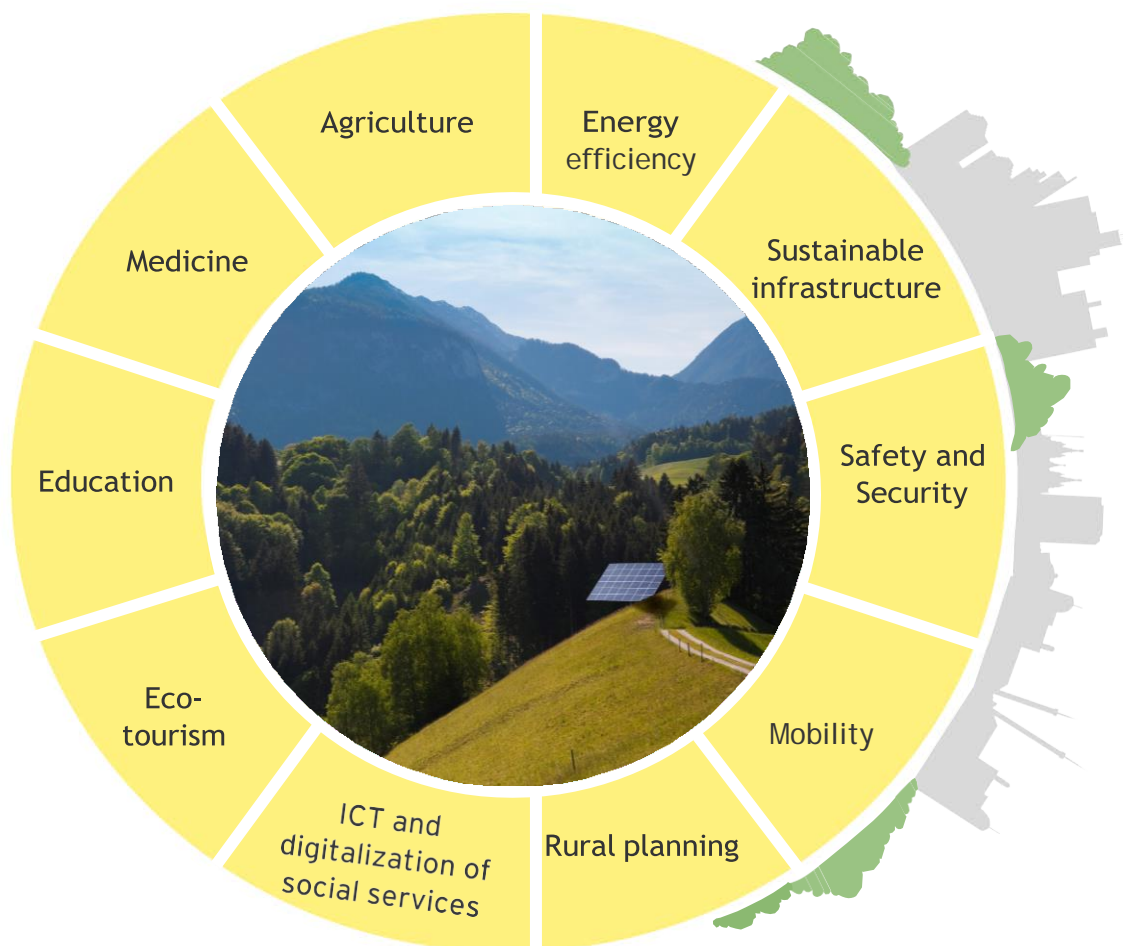
1. Background

2.1 Smart Village concept

The Smart Village concept is based on supporting rural areas and communities and developing capacities by adopting innovative and sustainable concepts and solutions. In Smart Villages, the traditional and new infrastructural systems and services are enhanced with ICT and innovative approach benefiting the rural residents and businesses operating in these areas. The smart villages' best practices entail innovations which provide a higher quality of life, better standards of living, improved public services, and sustainable use of resources by minimizing the environmental impact and providing new opportunities for rural value chains.

There is no uniform, one-fits-all solution for the Smart Village development while the integration of certain components differs case-by-case as the goals set by the governing bodies or municipalities depend on the specifics of each region, e.g. climate, location, infrastructural links, prevailing economic activity, agricultural potential etc. Alternatively, such solutions are also based on the major employment of the residents and directed to boosting the existing local businesses.

Figure 1: Smart Village strategy development basis



2.1.2 Case studies around the world

Table1: Comparable best practices of Smart Village concept		
Location	Project background	Innovations and results
Die Stanz, Austria	<ul style="list-style-type: none"> ▶ 1,850 Residents ▶ Area at 77 km² includes 130 homes, 2 churches, 7 restaurants, and social service centers, but predominantly consists of forests at 83% ▶ Duration 8 years, since 2014 	<ul style="list-style-type: none"> • 50% of goods are from local producers. • Village applied renewable energy technologies (biomass, PV, hydro and windmills) for electrification and heating and established renewable energy community
EcoVillage at Ithaca, New York, USA	<ul style="list-style-type: none"> ▶ 100 Homes, 220 Residents clustered on the site in three neighborhoods, each neighborhood is a housing cooperative ▶ Duration of construction is over nearly 20 years ▶ Residences are privately owned and contain the amenities of conventional homes. Residents also have access to extensive common facilities (open space, community gardens, play areas and a community center) ▶ Area includes homes on 61 km², 80% of the land (708 km²) used for natural areas, wildlife habitat, and two working farms 	<ul style="list-style-type: none"> • Sustainable agriculture solutions and farming cooperatives • Net-zero energy approach using renewable energy generated electricity and heating • Limited entry to the private vehicles and promotion of car sharing and carpooling. There are walking and cycling paths for residents.
Sochi, Russia	<ul style="list-style-type: none"> • Total building site area is 595,047 m² • The project planning is completed and approved in 2021 • The master plan includes: a beach area and a new marina. Called Marina City, it will be a business and innovation center for business and leisure with conference facilities, high-end hotels, vibrant nightlife, Design and Innovation Museum and a Yacht club; three different routes (The Lanes, The Boardwalk and The Green Wave) 	<ul style="list-style-type: none"> • The plan of Sochi Smart City preserves sustainable technology, digitalization and use of renewable energy sources for the business and leisure areas. • Innovative approach considers community engagement and stability in social services provision for the residents of the city.
Oberrospe village Hesse, Germany	<ul style="list-style-type: none"> ▶ 240 households ▶ The project was launched in 2007 after 2 years of planning and investment collection ▶ By 2020, 50% of all households signed up to get their energy from the community heating scheme based on using local wood energy. ▶ Total amount of investment through state and EU grants and private investors is EUR 3.7 million 	<ul style="list-style-type: none"> • Village developed renewable energy produced energy use using photovoltaic power and a combined heat and power (CHP) plant. The heating coop now purchases the waste heat from that CHP plant to provide about 50% of its heat needs. • About 700 tons of carbon emissions are saved annually.

Sources: https://enrd.ec.europa.eu/sites/default/files/enrd_publications/tq6_smart-villages_sv-green-deal-bill-slee.pdf, <https://www.smartrural21.eu/>, <https://www.unstudio.com/en/page/15292/sochi-waterfront-concept-masterplan>

2.2 Current situation

Being an energy-rich country, the Republic of Azerbaijan emerged as a major regional energy player after restoring its independence in early 1990s. Over the period of transition from the Soviet system, Azerbaijan experienced many challenges primarily because of the first Karabakh war and further occupation of the high historical and economical value region with agriculture being one of the key revenue sources. The country's territory covers an area of 86,600 sq. km.

With the occupation of Zangilan since 29 October 1993 the region became inaccessible, forming over 8,000 sq. km security belt and leaving Nakhichevan region separated from the main part of the

country. The territories of Karabakh and the adjacent 7 districts remained isolated with constant violations of the ceasefire until it escalated to a full-scale Second Karabakh war in September 2020, resulting in peace agreement between Azerbaijan and Armenia signed on November 9, 2020 with Russia acting as a stabilizing intermediary party. With this agreement Azerbaijan returned its de facto power and issued a plan of deliberation of the territories. According to the decree "On the New Division of the Regions of the Republic of Azerbaijan" (July 7, 2021) a new division on 14 economic zones was established, where Zangilan district is a part of East Zangazur economic region.

The Government of Azerbaijan (GoA) allocated major funds for the reconstruction of the liberated territories. Over 2 billion of manats (AZN) was allocated for the infrastructural restoration projects in the region for the safe resettlement of the displaced population. The main goal of these investments is to support the return of the internally displaced people (IDPs) to their historical homeland. With a total population of over 10 million, 10% of the country's population were forcibly displaced from their areas of settlement in the early 1990s during the first Karabakh war. Despite these turbulent events of Azerbaijan's early independence period, the economy started picking up its upward trend with total gross output of agriculture rising from 726.8 mln. AZN in 1995 to 9,163.4 mln. AZN in 2021. In Azerbaijan the private farms and small household-scale agricultural activity prevails over the industrialized, enterprise type at 8,277.5 mln. AZN gross output in 2021, as opposed to 885.9 mln. AZN for agricultural enterprises in the same year (data source: stat.gov.az).

In terms of improving its energy consumption patterns Azerbaijan adopts an international approach as part of the "European Union (EU) Neighboring Countries" within EU4energy initiative program. Despite the law "On the Efficient Use of Energy Resources and Energy Efficiency" which will come into force in July 1, 2022 focused on principles of regular energy audit and accreditation of non-residential buildings, the Law establishes a baseline for similar approach for the residential buildings. One of the main targets set by a state heating energy distributor and supplier Azeristiliktechizat OJSC is to improve residential energy efficiency (EE) standards by increasing number of centralized heating network linked buildings. Currently only 15.8% of country is supplied with central heating with 25.4% in urban (predominantly Baku) and only 3.8% in rural areas (2021, Annual household survey report of The State Statistical Committee of The Republic of Azerbaijan: stat.gov.az).

2.3 Traditional village in Azerbaijan

After Azerbaijan proclaimed its independence from the USSR in 1991 the intra-economic ties collapsed, thereby causing stagnation in the agricultural sector. Introducing new type of socio-political system led to a systemic transformation and application of the reform policies, such as the Land Reform Act (1996) which established a new program of agrarian reforms shifting from the collective to individual farming. Azerbaijan completed its transition from a socialism-influenced, agriculture-led economy to an independent, modern industrialized country with the prevalence of heavy industries such as oil and gas and petrochemistry.

Azerbaijan has a high agricultural development potential due to the beneficial geographical position and other environmental factors, such as climate, soil fertility etc. Throughout history, the rural population of the country has maintained high labor productivity in this area, which indicates its readiness for further development in this sector. Despite that, more than 53% of total population still reside in urban areas. This is causing higher urban population density, thereby investments in the reconstruction of rural regions of Azerbaijan may also potentially cause lowering an overpopulation distress in urban areas and ease the infrastructural congestion issues as well.

Starting from the early 2000s, the GoA has been pursuing the goal for developing the rural areas through regional investment programs. Despite that, rural areas are considered in distress compared to the urban ones in relation to the primary needs supply and infrastructure. According to the annual report for 2021 year issued by The State Statistical Committee of the Republic of Azerbaijan (SSC) (data source: stat.gov.az):

- Only 76.7% of rural households are connected to water supply network
- 9.9% of people have no inhouse bathroom
- 86.1% use carbon-emitting timber or gas fueled oven for heating and cooking

- 97.5% are linked to the public gas network

In some distant villages people use compressed gas cylinders (48.6%) because they have no or limited access to a centralized gas network. This is highly hazardous in terms of indoor household safety and emitting environment. There is no municipal waste management system, as well as public engagement in awareness campaigns in rural areas. Deficiency of waste infrastructure and basic waste management awareness, lower education level - all these factors are causing uncontrolled waste dumping, littering, open-pit burning, which cause toxic emissions, groundwater, and soil contamination, and eventually causing high damage for public health and local ecosystem. Untreated wastewater is discharged to sewer pits or directly to the water bodies because of no central sewerage systems and insufficient number of wastewater treatment plants in rural areas.

Most of the rural population is predominantly self-employed at 43.8% (2020 year) in agriculture, due to limited employment opportunities. This is triggered by predominant gaps in education, especially for women as a sensitive social group in these areas. Lack of digitalization as well as limited health care and other public services cause barriers to social and economic mobility of rural households. Poor road infrastructure and lack of municipal support in supply system is causing low engagement of rural areas in the main sectors of the country productivity. As a result, these factors are causing high youth unemployment of rural areas and further migration of the young generation to the cities. The situation in the labor market is also complicated by the large number of IDPs. IDPs receive social support and have access to free higher education which supports their access to be active in the labor market. Additional to housing concessions, the GoA also established Social Development Fund for IDPs (SFDI) for small-scale infrastructure reconstruction within the areas of IDPs residence.

2.4 Zangilan Smart Village Project information

The implementation of smart city/smart village projects in liberated regions of Azerbaijan is a part of "The National Action Plan for 2020-2022 for the Promotion of Open Government 2020-2022", approved by the Decree of President Ilham Aliyev on February 27, 2020.

Smart City and Village concepts in Azerbaijan have specific requirements which are based on the President's decision, dated April 19, 2021. The approach for reconstruction of de-occupied territories of Karabakh and Eastern Zangazur economic zone is to apply Smart infrastructure practices throughout the region. Aghali village of Zangilan was selected as a pilot project within this reconstruction approach covering a total area of 110 hectares.

The challenging aspects for such reconstruction cases include the absence of any infrastructure, local workforce, and sparse or lacking data on climate and historical pollution. Despite those predicted challenges, the GoA decided to establish a foundation for an innovative strategy for the development of Karabakh, and East Zangazur economic region, in particular. The working group tasked with the construction of Smart Villages in the region consists of representatives of key operational sectors of municipal planning (i.e. energy, economy, agriculture, transport and high-tech and other), and the targets set for the group include the following:

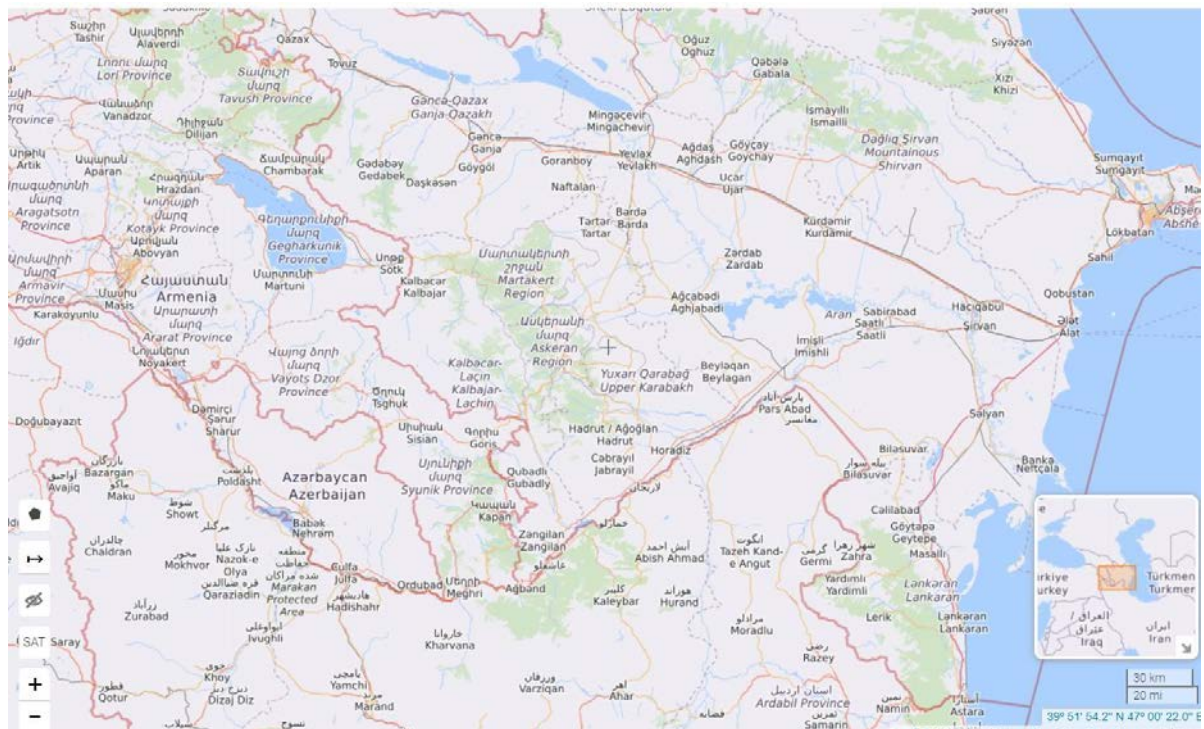
- Improve the quality, safety, and efficiency of social services
- Ensure the effective use and management of available resources for services by applying ICT;
- Boost socio-economic and agricultural productivity and efficiency
- Create new income opportunities in the overall value chain
- Improve the quality of decision-making and management

2.4.1 Zangilan Smart Village geographical location

Zangilan district is located in the south-west of the Republic of Azerbaijan on the border with Armenia and Iran, on the line of the Baku-Julfa-Nakhichevan main railways and highways and poses significant strategic importance.

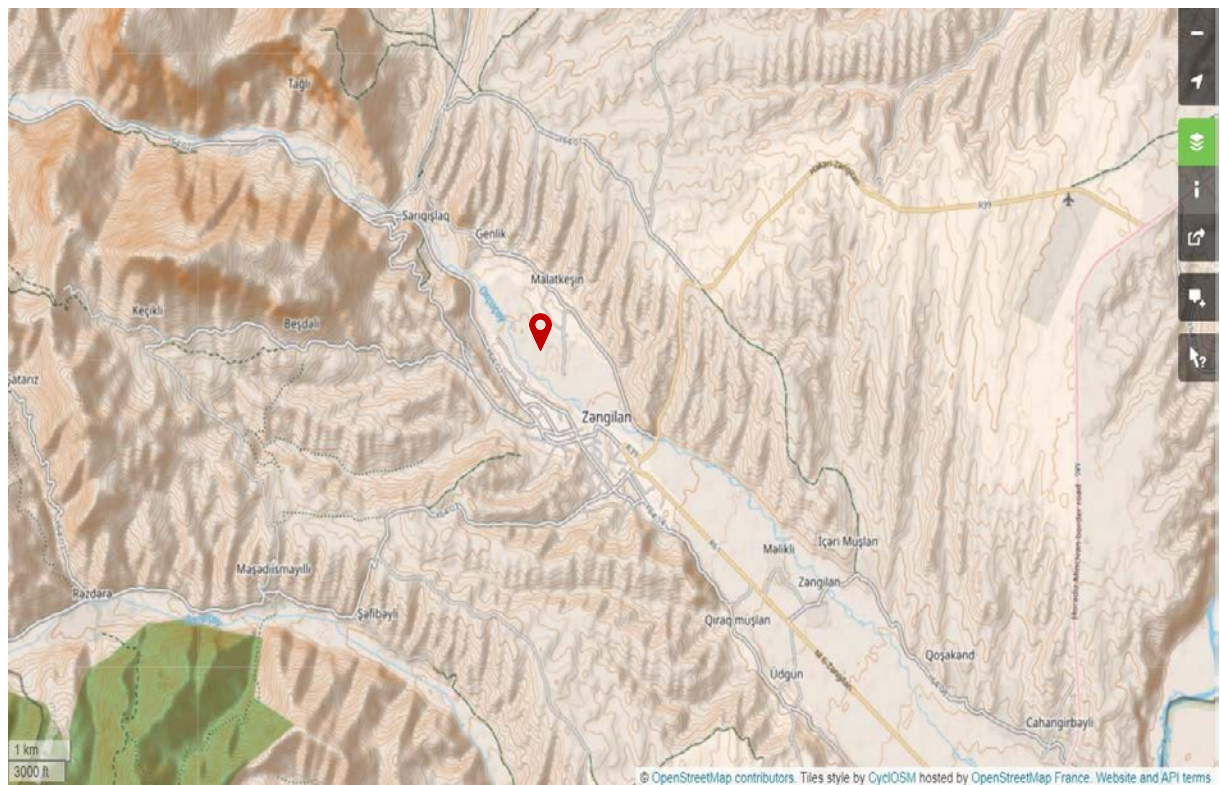
Due to its geographical location, climatic and soil characteristics, historically Zangilan boasts unique natural landscapes and diverse ecosystems. The area is located in the medium and low mountainous areas. The relief structure of the area is rugged and undulating terrain. From the north-west, the Bargushad mountain range (mountain Susen, 1,304 m) wedges into the territory of the region, descending, forming between the rivers Bazarchay and Okhchuchay a gentle plain Ag oyug (altitude 400-600 m). In the northeast, the slopes of the Karabakh mountain range, descending towards the Araz and Kura, pass into the mountain lake Geyan.

Map 1. The position of Zangilan district



Source: OpenStreetMap

Map 2. The position of Aghali village area in Zangilan district



Source: OpenStreetMap

2.4.2 Zangilan Smart Village project's infrastructure

The Company's strategy for Aghali Smart Village project in Zangilan is based on the 5 main components:

- Develop residential sector and the service infrastructure
- Create sustainable labor market in agricultural industry
- Provide innovative approach and solutions in the social services
- Establish principles of smart agriculture
- Supply the village with heat and electricity generated from the alternative energy sources

Key challenges

- The local population of Zangilan was displaced for a period of 30 years. Local population from the area are primarily from the upper-age group. The youth born outside of the area adapted in the areas of their new residence, usually Baku and environs. Since they primarily reside in urban areas it will be challenging for young generation to adapt back to rural life.
- Unexploded ordnance and munition hazards in the pasture areas surrounding the village due to the demining activities in the region.
- High level of pollution, damaging soil fertility, destruction of ecosystem and biodiversity due to the three-decade occupation, military presence and uncontrolled contamination by the occupying forces requiring environmental restoration.
- Poor economic ties in the district area with the neighboring countries while restoration and construction work in the region are in the process.

Main assets and opportunities

- As the region is of high interest for the country residents as well as foreigners after the liberation, it has a potential to develop local tourism.
- Embracing renewable energy technologies such as solar energy and hydro due its location with favorable conditions.
- Promoting synergy in economic sectors (agriculture/farming, energy production, manufacturing, social infrastructure, and other services).
- Introducing new paradigm for rural development with a high potential to promote this type of approach for the rural development at a national level.
- Successful implementation of the current project can become a good precedent for developing similar projects in the country, attracting investments to the country as well as improving environmental and social conditions in Azerbaijan.

2.4.2.1 Dwellings

Zangilan Aghali Smart Village Project is the first Smart village project in the country. The planned residential area of the village is 119 ha with 200 residential and 4 administrative dwellings, as well as two educational facilities - a school and a kindergarten. There are three types of residential houses to be constructed for 1000 residents:

Table 2: Types of buildings in the Aghali Smart Village			
Type of the dwelling	Design	Number of dwellings	Capacity, people per dwelling
<i>Residential</i>			
Type 1	Detached one story houses	80	4
Type 2	Detached one story houses	80	5
Type 3	Detached two story houses	40	6-7
<i>Educational</i>			
School	Two story building with underground level	1	360

Kindergarten	One story building with underground level	1	60
Public			
Municipal/administrative	Two story building	4	40

Based the expected number of residents, proposed dwellings are considered sufficient. Moreover, positioning of the residential houses considering solar orientation can provide additional environmental benefits by reducing energy demand for heating and cooling.

Building envelope materials

The construction materials used for outer shell of the buildings are considered energy efficient and have appropriate insulation level. The main material used for the dwellings walls is Thermoblock. The envelope solutions are the same for both residential and public buildings type. Thermal characteristics of the materials are obtained from the project owner and are given in Table 3.

Table 3: Building envelope specifics			
Structure	Thickness, mm	R value, W/(m ² · °C)	U-value, W/(m ² · °C)
Walls	0.33	3.99	0.25
Floor	0.31	2.94	0.34
Ceiling	0.43	2.98	0.34
Window	0.02	0.44	2.28
Door	0.03	0.82	1.21

Energy and water needs

The energy and water consumption specifics for each type of the dwelling is given in the Table 4 that are also certified by the relevant governmental entity, the State Agency on Construction Safety Control under the jurisdiction of the Ministry of Emergency Situations of Azerbaijan.

Table 4: Energy and water consumption by each type of the buildings given per building type				
Building type	Energy needs for space heating, kWh/season	Electricity needs, kWh/year	Cold water needs, m ³ per day	Hot water needs, m ³ per day
Residential building Type 1	7,777.62	1,794.38	350.0	150.0
Residential building Type 2	9,520.73	1,955.70	437.5	187.5
Residential building Type 3	11,075.58	2,323.20	262.5	612.5
School	104,415.15	18,082.50	2,880.0	1,260.0
Kindergarten	88,586.71	78,002.94	4,200.0	2,100.0
Administrative building 1	27,895.58	26,920.56	915.0	475.0
Administrative building 2	27,895.58	26,920.56	369.0	287.0
Administrative building 3	27,895.58	26,920.56	369.0	287.0
Administrative building 4	27,895.58	26,920.56	388.0	522.0

Space heating technologies include using electrode boilers “Krepish Gradient” for 200 houses. The manufacturer claims that compared to traditional electric heaters (TEHs), these units produce the same amount of thermal energy by consuming on average 50% less electricity. At the same time,

traditional stove firewood/pellets will be also installed to guarantee additional method of space heating and cooking that is more traditional for local residents. This method also implies that residents can consider electricity economy when needed, particularly during the cold winter days.

The water needs will be met by the artesian wells. Hot water for residential buildings will be provided through the solar thermal technologies installed at each house.

Table below demonstrates the solutions and key characteristics of the technologies used for meeting residents' energy and water needs.

<i>Table 5: Solutions used in the project.</i>		
<i>No</i>	<i>Infrastructure Components and Facilities</i>	<i>Description</i>
<i>1. Economic Infrastructure</i>		
<i>1.1 Energy</i>		
<i>1.1.1</i>	HES (636 kW)	Archimedes Plant consisting of 3 generators with installed capacity of each 212 kW. Annual production capacity is 5.5 million kWh.
<i>1.1.2</i>	Solar power plant with installed capacity of 325 kW	The most modern 455 W photovoltaic panels.
<i>1.1.3</i>	Solar collectors (200 units installed capacity of 400 kW)	Evacuated tubes solar collector from INCI Systems manufacturer.
<i>1.1.4</i>	Gradient electric boiler (200 pieces)	Based on reports obtained from the manufacturer's test results, and compared to traditional electric heaters (TEHs), this unit produces the same amount of thermal energy by consuming an average of 50% less electricity.
<i>1.1.5</i>	Wood stove	Stove that meets the needs of the kitchen and heating. Operates on firewood/pellets.
<i>1.1.6</i>	Smart distribution network	240 subscribers in the village will be equipped with smart meters. Smart meters wirelessly transmit information on energy consumption, external interference and accidents to data collectors installed on 11 transformers located in rural areas, and data from data collectors is sent to the dispatch center. An additional advantage of the meter is that operating and maintenance costs are very low and eliminates the need for additional manpower to collect information on subscribers' energy consumption. The device provides the necessary database for various analyzes, protecting information on energy consumption for up to 10 years.
<i>1.1.7</i>	Electric charging stations for cars	The village waste will be transported by electric garbage truck and the truck will be filled at the electric charging station. Given the fact that in the near future, traditional vehicles will be replaced by electric cars, the importance of these points will increase sharply.
<i>1.2 Road</i>		
<i>1.2.1</i>	Bicycle paths	13.6 km of bicycle roads planned to be built in the village. This solution has a positive impact on the environment and ecology, but also reduces health costs as a result of its benefits to human health. The United Nations HEAT (Health and

		Economic Assessment Tool) software has been calculated to reduce cycling deaths and its economic impact. In addition, research has shown that riding a bicycle instead of a car for 10 km a day will prevent the emission of 720 kg of greenhouse gases per year.
1.3 Telecommunications		
1.3.1	Information and Dispatch Center	It is designed to monitor, collect and process data from power plants, in general, the network, as well as information received from surveillance cameras and meteorological observation stations. If necessary, it will be possible to intervene in the operation of power sources, pumps, switches and other devices by direct interference. The center is of great importance in ensuring the efficient use of the power grid and other systems, making better decisions by analyzing the data and preventing the occurrence of potential accidents, including failures, and minimizing the effects of system failures.
1.3.2	Automatic meteorological observation station	The most important of these elements, the meteorological observation station, is a tool that helps the rural population to plan their daily and economic activities by providing real-time and accurate data on weather information. Thanks to the accurate information provided by this station, statistical analysis can be carried out and future-oriented agricultural planning can be carried out. This, in turn, will boost economic development with increased productivity.
1.4 Water Supply, Dam, Canal and Sewage System		
1.4.1	Smart home (purified) drinking water supply network	Due to the installed smart water meters, information on water consumption, interference and leaks is immediately sent wirelessly to the data center via light meters. The device provides the necessary database for various analyzes, protecting information on energy consumption for up to 10 years.
1.4.2	An artificial lake for irrigation, entertainment and electricity	Due to the recreational areas to be developed around the lake, the opportunity to engage in canoeing, kayaking and other sports activities, in particular, will increase the opportunities for tourist activities. The water collected in the lake will be a necessary source of water for the operation of the hydropower plant. In addition, lake water will be used to irrigate the surrounding fields. Due to the contact of water with air, the amount of oxygen will increase and contribute to the biodiversity of the lake.
1.4.3	Pressure pools for water supply	Efficient use of relief
1.4.4	Water canals and lines within the village for irrigation	The relief-adapted irrigation system is designed to be used without the need for additional power sources
1.4.5	Sewage network	The relief-oriented sewage system is designed to be used without the need for additional power sources.
1.4.6	Wastewater treatment plants	Wastewater treatment will provide 63,875 cubic meters of technical water per year, which could be used to irrigate the common green areas of the village.

1.5 Waste Management		
1.5.1	Waste management, sorting and transportation	Garbage bins installed for waste sorting will be transported to the destination by an environmentally friendly electric garbage truck.
2. Social Infrastructure		
2.1 Accommodation		
2.1.1	200 energy efficient dwellings (80/80/40)	Thermoblocks were used in the construction of the outer walls of the houses in the Smart village project, and energy-efficient insulation materials were used in the construction of the ceilings and floors. These solutions allow buildings to become more energy efficient than traditional buildings. Thus, it results in a reduction of energy used for space heating.
2.2 Education		
2.2.1	A fully equipped energy efficient school for 360 students	Thermoblocks were used in the construction of the outer walls of the houses in the Smart village project, and energy-efficient insulation materials were used in the construction of the ceilings and floors. These solutions allow buildings to become more energy efficient than traditional buildings. Thus, it results in a reduction of energy used for space heating. Opportunity to organize online teaching.
2.2.2	60-bed local fully equipped energy-efficient kindergarten	Thermoblocks were used in the construction of the outer walls of the houses in the Smart village project, and energy-efficient insulation materials were used in the construction of the ceilings and floors. These solutions allow buildings to become more energy efficient than traditional buildings. Thus, it results in a reduction of energy used for space heating.
2.3 Organization of administrative and other services		
2.3.1	4 energy efficient office buildings	Thermoblocks were used in the construction of the outer walls of the houses in the Smart village project, and energy-efficient insulation materials were used in the construction of the ceilings and floors. These solutions allow buildings to become more energy efficient than traditional buildings. Thus, it results in a reduction of energy used for space heating.
2.4 Tourism, Entertainment, Recreation and Sports		
2.4.1	Construction of recreation and active recreation areas around the artificial lake	Effective leisure and development of tourism business.
2.4.2	Construction of a fountain and a park in the center of the village	Effective leisure, holding mass events Attracting tourists.
2.4.3	Landscape-recreation	Improving the well-being of residents and attracting tourists.

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4.1 Renewable energy technologies

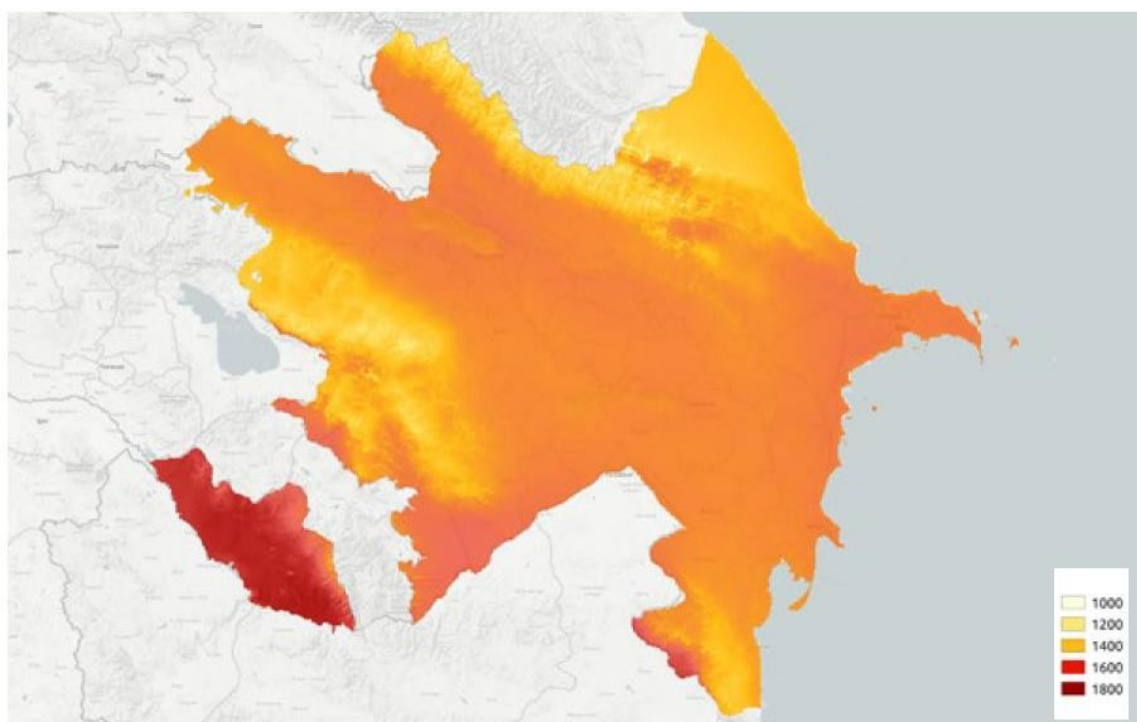
4.2.1 Hydropower

Hydropower has traditionally maintained a solid position in the country's energy mix. While hydropower is subject to seasonal fluctuations, however, its substantial share in the country's electricity system offers a strong basis for supporting the integration of future solar and wind power generation capacity (data source: [Renewables Readiness Assessment: Republic of Azerbaijan \(irena.org\)](https://www.irena.org/publications/2019/05/renewables-readiness-assessment-republic-of-azerbaijan)). The data on hydro power plant energy output has been provided by Company and the energy production of installed capacity of 636 kW is estimated as 5,553,200 kWh/year.

4.2.2 Photovoltaic

According to the International Renewable Energy Agency (IRENA) Azerbaijan has moderate level of solar days, thereby has high solar power potential. Azerbaijan Ministry of Energy states that the country has a technical potential to generate solar energy at around 23,000 MW. The country annual solar radiation hours range from 2,400 to 3,200. Its solar intensity estimated values equally range from 1,500 kWh/m² to 2,000 kWh/m² (data source: [iea.org](https://www.iea.org/)). According to the Company data Energy yield of power plant with capacity 325 kW was calculated and estimated at 444 197 kWh/year.

Map 3. Annual global horizontal solar irradiation (GHI in kWh/m²)



Source: IRENA

Zangilan has a high potential for harvesting solar energy due to its climatic conditions. Within the project photovoltaic power plant is considered for the energy balance to provide the electricity to the main grid and local communities.

The projected panels have the following features are given in Table 8.

Table 8: Features of the projected panels	
PV panels model	PV panels TT455-144PM-HC 455 Wp
Installed capacity, kW	325
Number of panels	716
PV panel area, m ²	2.18
A - total PV panels area, m ²	1,558.5
r - module efficiency	20%
PR - performance ratio, coefficient for losses (default value is 0.8)	0.8
H - annual average irradiation on tilted panels. It is assumed there are no shadings on site of solar power plant, kWh/m ² .ann.	1,755

The general recognized method is used to estimate the solar energy yield of the given PV power plant

$$E = A \times r \times H \times PR$$

It was assumed that the panels would be placed by their tilted angle (39 degrees) and is the same as longitude of Zangilan area. According to the Global Solar Atlas (data source:

globalsolaratlas.info/map) the Global tilted irradiation at the optimum angle is 1,755.0

kWh/m²/year.

4.2.3 Solar thermal for hot water supply

According to the project documentation, the evacuated solar thermal collectors are presumed to be used in hot water supply for the residential buildings. The manufacturer of the evacuated solar thermal collectors is INCI systems (data source: [incisolar.com.tr](http://eng.incisolar.com.tr/)). To calculate the equivalent energy output of the technology the characteristics and absorbent collectors' area were considered (Table 9).

Table 9: Characteristics of the thermal collector absorbent capacity			
Type	Capacity, litres	Collector absorbent area, m ²	Number of each type of collectors
Type 1	240	3.6	80
Type 2	300	4.5	80
Type 3	360	5.4	40

Source: <http://eng.incisolar.com.tr/>

The methodology used for estimation of solar thermal energy output of 400 kW installed capacity is based on daily solar radiation at tilted angle of 39 degrees for each month obtained from NASA, efficiency of the collectors, number of collectors and the collector absorbent surface (obtained from INCI). The following formula is applied:

$$E = \text{daily solar radiation} \times \text{number of days in a month} \times \text{number of collectors} \times \text{efficiency} \times \text{collector absorbent area}$$

4.4.1 Space heating

The entry data are consistent of assumptions used for space heating energy estimation of the dwellings by analyzing the existing meteo-data of external temperature in this region and the national building code standards. Zangilan district is in the south-western part of Azerbaijan and the climate here is relatively mild. The estimated heating period here is for 175 days with average outside temperature of 7 degrees Celsius in winter.

Table 10: Heating energy estimation of the dwellings based on the entry data	
Region	Zangilan
Internal temperature in accordance with building code	$t_{int} = 20\text{ }^{\circ}\text{C}$
External temperature	$t_{ext} = -7\text{ }^{\circ}\text{C}$
Average external temperature for heating period	$t_{ave} = 7\text{ }^{\circ}\text{C}$
Number of heating days	175 days
Heating degree days	2275 $^{\circ}\text{C} \times \text{days}$

The required by standards heat transfer resistance coefficients of building structures are obtained and shown in Table 11. Results of interpolation calculations for the table 6 are given in Table 11.

Table 11: Heat transfer resistance				
$D_d, \text{ }^{\circ}\text{C} \times \text{days}$	Required heat transfer resistance $R, (\text{m}^2 \times \text{ }^{\circ}\text{C})/W$			
	Walls	Ceiling	Floor	Windows and doors
2,275	2.20	3.34	2.92	0.32

Heat transfer resistance value of the accepted envelope structures has been calculated based on the

Company data on construction materials both for traditional and energy-efficient scenarios. Materials used for the dwellings in traditional scenario and calculated heat transfer resistance values for the traditional scenario are shown in Table 12.

<i>Table 12: Traditional Scenario</i>					
<i>Structure</i>	<i>Materials</i>	<i>Material thickness, m</i>	<i>Thermal conductivity $W/(m \times ^\circ C)$</i>	<i>R-value, $W/(m^2 \times ^\circ C)$</i>	<i>U-value, $W/(m^2 \times ^\circ C)$</i>
<i>Wall</i>	<i>Outer plaster</i>	<i>0.02</i>	<i>0.14</i>	<i>1.00</i>	<i>1.00</i>
	<i>Limestone</i>	<i>0.4</i>	<i>0.6</i>		
	<i>Inner plaster</i>	<i>0.02</i>	<i>0.58</i>		
<i>Ceiling</i>	<i>Plaster</i>	<i>0.005</i>	<i>0.14</i>	<i>0.35</i>	<i>2.84</i>
	<i>Reinforced concrete</i>	<i>0.2</i>	<i>1.69</i>		
<i>Floor</i>	<i>Laminate</i>	<i>0.006</i>	<i>0.14</i>	<i>0.79</i>	<i>1.26</i>
	<i>PET foil</i>	<i>0.003</i>	<i>0.17</i>		
	<i>Plywood</i>	<i>0.091</i>	<i>0.58</i>		
	<i>Reinforced concrete</i>	<i>0.15</i>	<i>1.69</i>		

	PVC membrane	0.002	0.17		
	Gravel	0.1	0.21		

For the second scenario of energy efficient buildings, used materials and calculated heat transfer resistance values are shown in Table 13. The energy efficient materials in this case include the use of Thermoblock instead of the traditional Limestone for walls, additional layer of mineral wool for ceilings, and Sundolitt Expanded Polystyrene (EPS) Floor insulation boards. All these materials are considered as cost effective in a long-term perspective and permanent solutions to meet EE in buildings. The use of materials in standard traditional scenario, may cause consumers to consider a cost saving by spending less, however in the long-term effect the necessary reconstruction works will cause higher expenses.

Table 13: Energy Efficient Scenario					
Structure	Materials	Material thickness, m	Thermal conductivity W/(m·°C)	R-value, W/(m²·°C)	U-value, W/(m²·°C)
Wall	Outer plaster	0.02	0.14	3.99	0.25
	Thermoblock	0.29	0.0797		
	Inner plaster	0.02	0.58		
Ceiling	Plaster	0.005	0.14	3.06	0.33
	Reinforced concrete	0.2	1.69		
	Mineral wool "ТЕХНОАКУСТИК ТУ 5762-010-74182181-2012"	0.1	0.037		
Floor	Laminate	0.006	0.14	2.94	0.34
	PET foil	0.003	0.17		
	Plywood	0.091	0.58		
	Reinforced concrete	0.15	1.69		
	EPS	0.075	0.035		
	PVC membrane	0.002	0.17		
	Gravel	0.1	0.21		

The heat transfer coefficients for the external doors and windows for both scenarios had been taken as:

$$R_{\text{door}} = 0.44 \text{ W/(m}^2\text{x}^\circ\text{C)}$$

$$R_{\text{windows}} = 0.83 \text{ W/(m}^2\text{x}^\circ\text{C)}$$

As it could be observed, heat transfer resistance values for wall, ceiling and floor in traditional scenario fails to meet the building code requirement $R_{\text{req}} \geq R_{\text{limestone accepted}}$. Whereas the heat transfer values for the envelope structures of the energy-efficient scenario comply with the main requirement $R_{\text{req}} \leq R_{\text{therm accepted}}$. Moreover, the value for the wall is almost twice as high than required by the standard.

Table 14: Heat transfer resistance for 2 scenarios

Envelope structure	Heat transfer resistance required by the building code	Heat transfer resistance for Traditional scenario	Heat transfer resistance for Energy efficient scenario
Wall	2.20	1.00	3.99
Ceiling	3.34	0.35	3.06
Floor	2.92	0.79	2.94

The demand of space heating energy during the heating season has been calculated for all residential, educational, and administrative buildings for both traditional and energy-efficient scenarios. Further, the difference between both scenarios has been taken as the point for estimation of emissions and gas savings. The outcomes of testing are summarized in Table 15.

Table 15: Outcomes of testing for 2 scenarios

	Traditional scenario	Energy-efficient scenario	Difference	
Type of the dwelling	<u>Heating energy demand,</u> <u>kWh/season</u> Energy consumption per kWh per m ²	<u>kWh/season</u> <u>kWh/m²</u>	Difference between scenario 1 and 2	%
Residential building Type 1 (80)	<u>3,200,92.38</u> 370.48	<u>619,466.02</u> 71.70	<u>2,581,463.36</u> 298.78	81%
Residential building Type 2 (80)	<u>3,850,881.53</u> 368.01	<u>755,555.91</u> 72.21	<u>3,095,325.62</u> 295.81	80%
Residential building Type 3 (40)	<u>2,004,341.42</u> 265.39	<u>414,494.74</u> 54.88	<u>1,589,846.68</u> 210.51	79%
School (1)	<u>522,117.43</u> 193.09	<u>107,432.36</u> 39.73	<u>414,685.08</u> 153.36	79%
Kindergarten (1)	<u>470,531.82</u> 445.33	<u>76,689.60</u> 72.58	<u>393,842.22</u> 372.74	84%
Administrative building 1 (1)	<u>147,057.53</u> 204.25	<u>32,863.66</u> 45.64	<u>114,193.87</u> 158.60	78%
Administrative building 1 (1)	<u>147,057.53</u> 204.25	<u>32,863.66</u> 45.64	<u>114,193.87</u> 158.60	78%
Administrative building 1 (1)	<u>147,057.53</u> 204.25	<u>32,863.66</u> 45.64	<u>114,193.87</u> 158.60	78%
Administrative building 1 (1)	<u>147,057.53</u> 204.25	<u>32,863.66</u> 45.64	<u>114,193.87</u> 158.60	78%
Total for the project	<u>10,637,031.7</u> 319.46	<u>2,105,093.66</u> 63.22	<u>8,531,938.43</u> 256.24	79%

*Energy consumption per kWh per m² is shown as kWh based on heated area of the buildings.

The space heating energy saving potential is estimated at the level of 79%.

4.4.2 Energy consumption of the project

Project's energy consumption is estimated considering the following:

- ▶ Demand for space heating
- ▶ Power demand for appliances, including energy demand for hot water supply of administrative buildings
- ▶ Demand for hot water supply for residential buildings
- ▶ Energy demand for energy generating technologies operational use, smart solution, waste treatment facility, street lighting and water pump

- Estimation of energy output of solar thermal collectors used for domestic hot water supply are given for the monthly basis per annum in Table 17.

The solar collectors will be used to cover hot water energy needs for residential buildings. Hot water supply for non-residential buildings will employ an electrical boiler. The amount of hot water and energy required for water heating for both residential and administrative buildings is presented in Table 16.

<i>Table 16: Energy consumption of the project by building type</i>		
	<i>Residential</i>	<i>Non-residential</i>
<i>Amount of hot water required in a year</i>	<i>13,687.5</i>	<i>1,1310.52</i>
<i>Energy required to heat the water, kWh/year</i>	<i>746,242.5</i>	<i>71,449.28</i>

There is a slight difference between EY and Company calculation approach of solar thermal collectors' performance. Both approaches include the parameter of absorbent area of solar collectors:

- EY uses the data on absorbent area given in INCI Solar Systems catalogue
- The Company data used for calculation instead included the number of tubes integrated into a solar collector, the diameter, and length of the tubes.

The difference in absorbent area parameter affects the total energy output of the solar collectors consequently. According to EY calculations the required energy for hot water heating is estimated as 746,242.5 kWh/year, and the installed 400 kW of evacuated solar thermal technologies estimated to produce 1,334,489.47 kWh/year. Thus, there is an extra potential occurring to harvest solar energy which is equivalent of 587,246.97 kWh/year as of the difference between the total energy output of the hot water supply system and the energy required to heat the water for the residential buildings.

The results of solar energy estimation by month are given in Table 17.

<i>Table 17: Estimation of energy output for domestic hot water supply</i>					
<i>Months</i>	<i>Daily solar radiation at tilted angle of 39 degrees, kWh/m²/d</i>	<i>Number of days in a month</i>	<i>Collector type1 kWh/month</i>	<i>Collector type2 kWh/month</i>	<i>Collector type3 kWh/month</i>
January	3.27	31	27,734.83	34,668.54	20,801.12
February	3.78	28	28,957.82	36,197.28	21,718.37
March	4.19	31	35,537.90	44,422.38	26,653.43
April	4.5	30	36,936.00	46,170.00	27,702.00
May	4.95	31	41,983.92	52,479.90	31,487.94
June	5.58	30	45,800.64	57,250.80	34,350.48
July	5.68	31	48,175.49	60,219.36	36,131.62
August	5.48	31	46,479.17	58,098.96	34,859.38
September	5.22	30	42,845.76	53,557.20	32,134.32
October	4.44	31	37,658.30	47,072.88	28,243.73
November	3.54	30	29,056.32	36,320.40	21,792.24
December	2.79	31	23,663.66	29,579.58	17,747.75
<i>Total energy produced by each type of collectors, kWh/year</i>			444,829.82	556,037.28	333,622.37
<i>Total energy output by the system, kWh/year</i>					1,334,489.47

The total energy consumption by different systems of the project is evaluated and given in Table 18. The demand for space heating includes values both for residential and non-residential buildings and estimated as 1,789,516.67 kWh/year and 315,576.61 kWh/year respectively. As it can be observed the space heating energy demand of residential buildings is significant and makes up 85% of total energy required for heating, i. e. 2,105,093.28 kWh/year.

The electricity demand of 668,151.36 kWh/year includes electricity consumption for residential and non-residential buildings, 392,934.40 kWh/year and 203,767.68 kWh/year respectively. The power demand also includes 71,449.28 kWh/year of energy required for hot water heating in administrative buildings.

Beside the energy use in buildings, the other systems of the project that affect the total energy consumption are also considered. The main systems and their energy demand per year are as follows:

- Waste treatment facility - 45,990 kWh/year
- Water pump - 36,500 kWh/year
- Street lighting - 105,256.95 kWh/year
- Hydro plant - 18,125 kWh/year
- Smart systems - 87,561.75 kWh/year.

The total energy demand required by the systems is 293,433.7 kWh/year.

Savings of 746,242.50 kWh/year of energy will be sustained by the supply of hot water for residential buildings with the use of solar thermal collectors.

Table 18: Energy consumption of the project by systems

	<i>Demand for space heating</i>	<i>Electricity (power) demand for appliances</i>	<i>Demand for hot water supply for residential buildings (200)</i>	<i>Demand by energy generating technologies, waste treatment facility, water pump, smart system and street lighting</i>
Energy, kWh/year	2,105,093.28	668,151.36	746,242.50	293,433.7

It is assumed, that energy for hot water heating for residential houses from solar thermal will stay in the system and will not be returned to the grid consequently. Thus, the calculation of potential energy that could be fed into the network includes electrical energy obtained from PV and Hydro plants only.

Considering this, it is estimated that out of 5,997,397 kWh/year generated by PVs and hydro plant, 3,066,678.34 kWh/year will be consumed for project needs mentioned above, while 2,930,718.79 kWh/year can be transferred to the central grid and used for other purposes by other residential areas as well.

<i>Total electricity generated by alternative sources, kWh</i>	<i>Total electricity used in the project, kWh</i>	<i>Total electricity surplus transferred to the central grid, kWh</i>
5,997,397.12	3,066,678.34	2,930,718.79

4.3. Avoided CO₂ emissions

The energy sector is the major source of CO₂ emissions, primarily associated with the oil and gas products combustion within the electricity and heat energy generation process. The responsibility for CO₂ emissions is distributed across the sectors, with the residential sector's global indirect GHG footprint at approximately 15% of total emissions.

In case of Azerbaijan, the default emissions factors provided by the WRI and IPCC were applied based on a national average factor considering a representative sample of energy facilities. According to the WRI GHG Protocol and IPCC Assessment Reports selected as the reference methodologies for the carbon emissions calculations in the project scope, the indirect Scope 2 carbon emissions cover the use of purchased electricity, heat, or steam.

Within this report calculations, the CO₂ emissions were calculated using the electricity emission factor for Azerbaijan defined at 0.46 kg/kWh (irena.org). Smart Village project implementation allows carbon emissions avoidance mainly due to following:

- Carbon emissions avoided due to insulation of the dwellings
- Carbon emissions avoided due to generation of the energy from alternative sources, i.e., hydro plant, PVs and solar thermal

Based on the calculated reduction in the energy demand for heating (see Table 15), reduction of 3924.69 tCO₂e is estimated to be achieved for the project.

Table 19: Avoided carbon emissions due to reduced energy demand for heating

	<i>Reduced energy demand for heating, kWh/season</i>	<i>Total amount of avoided carbon emissions, tCO₂e</i>
Total for the project	8,531,938.43	3,924.69

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Additional CO₂ reduction at 1,754 tons of CO₂e is estimated to be achieved from using alternative sources for electricity generation required for meeting the project needs (see Table 20). In the Smart Village, electricity will be generated by solar and hydro plant with the predicted capacity at 5,997,397.12 kWh. The required energy for village needs is lower at 3,066,678.34 kWh, that brings electricity surplus of 2,930,718.79 kWh/year. On the other hand, 746,242.5 kWh/year would be required to supply hot water for 200 residential houses with similar characteristics in a traditional village which means that 307 tCO₂e will be avoided.. The surplus electricity will be transmitted through the main grid to other villages in the region. Therefore, the amount of carbon emissions avoided as a result of redundant alternative energy usage equals to additional 1,348 tCO₂e avoidance.

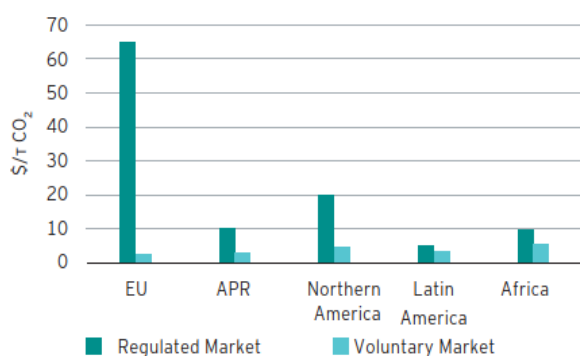
Table 20: Avoided carbon emissions due to alternative energy generation and consumption

<i>Energy consumption by purposes</i>	<i>Energy consumption, kWh/year</i>	<i>Total amount of avoided carbon emissions, tCO₂e</i>
<i>Electricity for space heating</i>	<i>2,105,093.28</i>	<i>968.34</i>
<i>Electricity for household appliances</i>	<i>668,151.36</i>	<i>307.35</i>
<i>Energy demand for hot water supply to 200 residential buildings</i>	<i>746,242.50</i>	<i>343.27</i>
<i>Electricity consumption by public systems, i.e., waste treatment facility, water pump, smart systems and street lightning</i>	<i>293,433.7</i>	<i>134.98</i>
<i>Alternative electricity surplus transferred to the grid ¹</i>	<i>2,930,718.79</i>	<i>1,348.13</i>
Total amount of avoided carbon dioxide, tCO₂e	3,102.07	

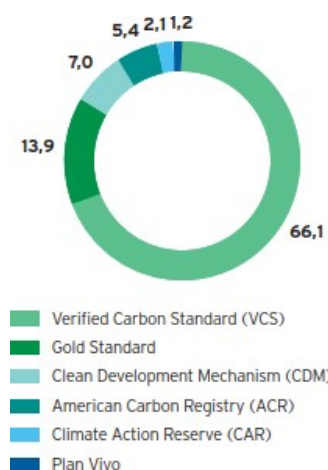
The avoided CO₂ has a potential for verification at emission trading systems (ETS), enabling the carbon emissions monetization and additional value creation for the project. Energy saving projects like the Aghali Smart Village fall within the scope of the international carbon (emission) trading schemes (ETS).

¹ Calculated as a difference between total energy generated by PVs and hydro plant minus energy for space heating, power demand of the buildings, street lighting, operational energy needs for waste treatment facility, water pump, smart systems, hydroplant needs considering that energy generated by solar thermal remain in a close system.

Comparison of the carbon prices at the Regulated and Voluntary Markets



Source: The World Bank, ICAP, Ecosystem Marketplace



Share of ETS mechanisms in the total amount of traded carbon

Source: Ecosystem Marketplace

Being a signatory to the Kyoto Protocol, Azerbaijan can be involved in voluntary carbon trading schemes enabling monetization potential for the country from the avoided carbon emissions. ETS present a new, emerging market for Azerbaijan entering it with an exemplary rural carbon solution based on a post-conflict rural development. Depending on the region and specifics of an ETS, the average pricing for 1 metric t of CO₂ vary from 3 USD to 30 USD. Given its a first ETS possibility in rural energy efficiency carbon saving, Azerbaijan could consider applying for a voluntary ETS mechanism at an initial stage, with a further view of expanding its experience to other international ETS schemes.

There are several international ETS mechanisms with the energy efficiency scope which can be explored and applied to the Aghali Smart Village project:

- ▶ American Carbon Registry
- ▶ Gold Standard
- ▶ Verified Carbon Standard (VCS)
- ▶ Clean Development Mechanism
- ▶ Joint Implementation Mechanism

The voluntary adoption of ETS will lower overall country's distress factor and demonstrate Azerbaijan's carbon reduction commitments by the Paris Climate Agreement, since Azerbaijan has a great share of economy, benefiting from the rich fossil fuel production, petrochemicals refining, and other types of heavy industry. The selected region is on recently de-occupied territories with no existing industrial operation, and sparse data on its historical industrial pollution. This brings high potential to adopt strategy for sustainable initiatives in operation and attracting investors interest in sustainable development and green projects in this region. The voluntary adoption of ETS in the region opens up pathways to provide further support in transition to the other neighboring countries. This will cause straightening of binding connections within the region and with the CIS countries.

4.4 Natural gas savings and monetary effect due to reduced energy demand for heating

Estimated 79% reduction in energy demand for heating due to insulation of the dwellings implies that amount of natural gas otherwise used for generation of the electricity required to heat the traditional houses is also saved. Considering that natural gas combustion to generate the electricity prevails in Azerbaijan, the total estimated savings in energy for space heating in gas equivalent are **1,962,346 m³**. According to the Center for Economic and Social Development (CESD) and last available data of

State Statistical Committee of Azerbaijan Republic, in average around 0.23 m³ of natural gas is consumed by combined cycled gas turbine for generation of 1 kWh of energy in Azerbaijan.

Table 21: Total savings in energy for space heating

	<i>Electric energy saved, kWh/season</i>	<i>Savings in gas equivalent, m³</i>	<i>Monetary effect, AZN</i>
Total for the project	8,531,938	1,962,346	1,660,145

To calculate the monetary effect from this saving, two scenarios of gas pricing were used:

- Monetary effect scenario 1: The price calculation was carried out for the case, when saved gas volume is calculated based on the export price point. An average gas export price in Azerbaijan provided by the National Customs Committee was 497.95 USD per 1,000 m³ in January 2022. Following this assumption, the total monetary effect from the gas savings in space heating accounts for **1,660,145 AZN**, with 347,968 AZN from this amount being saved as a result of building insulation. The USD-AZN currency conversion rate is taken as 1.7 AZN per USD.
- Monetary effect scenario 2: In case the domestic gas market tariffs are applied, the monetary effect will be around 5.7 times lower at approximately **219 thousand AZN**.

Additionally, consumption of alternative energy sources, i.e., both for project needs and transmitted to the grid for further consumption, implies that 1,551,037 m³ otherwise used for generation of the required electricity is also saved. Similarly, monetary effect of the savings given in the Table 22 can also deviate based on the gas tariffs considered. **Therefore, if domestic gas market tariffs are taken, monetary effect will be around 230 thousand AZN.**

Table 22: Savings due to alternative energy sources

<i>Electricity generated by alternative sources, kWh</i>	<i>Savings in gas equivalent, m³</i>	<i>Monetary effect, AZN</i>
<i>Energy for space heating</i>	<i>484,171</i>	<i>409,609.05</i>
<i>Energy for household appliances</i>	<i>153,675</i>	<i>130,008.89</i>
<i>Energy demand for hot water supply</i>	<i>171,636</i>	<i>145,203.87</i>
<i>Electricity consumption for public systems</i>	<i>67,490</i>	<i>57,096.33</i>
<i>Total alternative electricity surplus transferred to the grid</i>	<i>674,065</i>	<i>570,259.26</i>
Total savings	1,551,037	1,312,177

4.6 Social effects of the project

Social aspects of the Smart Village in Zangilan district include both direct and indirect outcomes. The project will benefit the village and the impact area residents, including the rural and urban settlements of East Zangazur and Karabakh region.

- Direct impacts:
 - Better living conditions for the people residing in this region
 - Improved public health, access to clean water and sanitation
 - Access to high quality education with the application of higher technologies

- Access to medical services with mobile type of medical treatment
- Higher employment rate in sustainable agriculture
- Local population awareness on the greener solutions
- As an intangible benefit, a better sense of local and cultural connectivity and sense of community belonging
- Connectivity with the other regions of the country, better transport network
- Controlled treatment of municipal solid waste
- Indirect impacts:
 - Benchmark for transition to new business models, alternative operations, or new, emerging product/services in rural development within the country
 - Connections with the neighboring countries and big market players within the region
 - Better household savings as an indirect effect of lower energy bills for the households
 - New opportunities for developing eco- and rural tourism

Opportunities for engagement of private investors for new businesses in the region