Program (plan) of priority activities on energy efficiency in the University within the Ukraine Higher Education (UHE) Project

LIST OF abbreviations

BMS	Building Management System
DH	District Heating
DHW	Domestic hot water
EAs	Energy Audits
EABs	Energy Audits of Buildings
EE	Energy Efficiency
E5P	Eastern Europe Energy Efficiency and Environment Partnership
EIB	European Investment Bank
IHS	Individual Heating Substation
GHG	Green House Gas
HVAC	Heating, ventilation, and air conditioning
LED	Light-Emitting Diode
MEP	Mechanical, electrical, and plumbing
MoES	Ministry of Education and Science of Ukraine
PIP	Priority Investment Programme
PVC	Polyvinyl chloride
UAH	Ukrainian Hryvnia
UHE	Ukraine Higher Education Project
VAT	Value Added Tax

Contents

1. Introduction

The European Investment Bank ("EIB") is providing financing under Finance Contract for EURO 120 million with the Government of Ukraine (represented by the Ministry of Finance) to implement Ukraine Higher Education (UHE) Project. The loan is complimented by E5P grant in the amount of EURO 10 million. The Ministry of Education and Science has primary responsibility for coordination of UHE Project implementation.

The UHE Project comprises of two phases: Phase I - pre-selected Universities identified in the loan agreement and Phase II - Universities selected through competitive process.

The objective of UHE project is to reduce the running costs of participating state higher education institutions, and to improve the quality of teaching, learning, academic research and residential facilities.

The final beneficiaries – Universities are to implement sub-projects with a view to reduce energy consumption and operating costs by implementing energy efficiency and non-energy efficiency measures.

Chernihiv National Technological University is one of the six universities (or Sub-projects) financed under EIB loan. The energy audits[1] of buildings (EABs) were conducted in 2017 by iC Consulenten Ziviltechniker GesmbH. The EABs allowed to define priority investment programme (or plan) for the energy efficiency measures to be implemented at the University. The EABs and summary audits reports[2] also serve as information source to prepare this Sub-project description, including but not limited to information on buildings conditions, descriptions of measures, energy consumption, energy savings and other parameters.

The preliminary amount of EIB funding allocated to implement the Sub-project comprising of energy efficiency (EE) and non-energy efficiency measures is EURO **5 738 964**. The Sub-project covers Chernihiv National Technological University buildings located in the city of Chernihiv.

This Sub-project description for Chernihiv National Technological University summarises the following information:

1. List and specification of buildings covered by the Sub-project;
2. Brief description of existing situation (current state) for building envelopes, heating, lighting and other systems;
3. Details on energy efficiency measures (brief description) proposed for implementation for each building;
4. Energy consumption of buildings (actual, baseline and after implementation of proposed EE measures) and energy savings estimates;
5. Estimates on reduction of greenhouse gasses (GHG) emissions which will be achieved as a result of implementation of proposed EE measures;
6. Estimates on investments needed to implement proposed EE measures, as well as basic financial indicators for the Sub-project
7. Summary information on investments to allow for comparative analysis of the Sub-project with other Universities.

More details related to points 2-7 above can be found in the energy audit reports conducted by iC Consulenten Ziviltechniker GesmbH (Austria) in 2017.

2. Buildings included in the analyses

The Sub-project for Chernihiv National Technological University covers 12 buildings. The list of buildings is presented in **Table 1** below:

[1] The energy audits were performed in accordance with the "EN 16247 – Energy audits – Part 1: General requirements" standard. Apart from performing the audits in line with the European norms, directives and standards, the energy audits were also prepared in line with the relevant Ukrainian standards, norms and regulations valid at the time of preparation.

[2] Summary Energy audit report for Chernihiv National Technological University, iC /CES 21.12.2017.

Table 1. List of buildings for Chernihiv National Technological University Sub-project [3].

№	Building	Type of building	Subtype of the building	Location	Year of construction	Number of floors	Heating area, sq.m	Heating volume, cu m
1	Educational laboratory building № 2	Real property	Faculty	95, Shevchenko st, Chernihiv region, Chernigov	1 974	3	4 232	13 726
2	Educational building № 8	Real property	Faculty	1a, Kazatska st, Chernihiv region, Chernihiv	1 970	4	3 050	9 761
3	Educational building №11	Real property	Faculty	1, Striletska st, Chernihiv region, Chernihiv	1 950	3	6 403	20 810
4	Hostel №1	Non-residential building	Faculty	99, Shevchenko st, Chernihiv region, Chernihiv	1 980	5	5 212	13 030
5	Educational laboratory building №3	Real property	Faculty	95, Shevchenko st, Chernihiv region, Chernihiv	1 978	3	3 749	9 747
6	Educational laboratory building № 4	Real property	Faculty	95, Shevchenko st, Chernihiv region, Chernihiv	1 989	9	3 125	10 103
7	Educational and administrative building №1	Real property	Faculty	95, Shevchenko st, Chernihiv region, Chernihiv	1 974	4	11 624	36 022
8	Canteen	Real property	Canteen	95, Shevchenko st, Chernihiv region, Chernihiv	1 978	2	1 680	4 956
9	Hostel №2	Real property	Hostel	1a, Kazatska st, Chernihiv region, Chernihiv	1 988	5	3 807	10 280
10	Hostel №3	Real property	Hostel	1a, Kazatska st, Chernihiv region, Chernihiv	1 969	5	4 021	11 260
11	Hostel №5	Non-residential building	Hostel	190a, Myru sq., Chernihiv region, Chernihiv	1 971	4	2 089	5 473
12	Hostel №6	Non-residential building	Hostel	14, Tsiolkovskogo st, Chernihiv region, Chernihiv	1 971	5	4 076	10 598
Total							**53 068**	**155 766**

[3] Based on energy audits of buildings (EABs) conducted in 2017 by iC Consulenten Ziviltechniker GesmbH

3. Description of the existing situation and findings

3.1. Building envelopes

3.1.1. Building walls

The outside walls of the buildings are mostly made of clay (red) bricks, plastered form inside and with a decorative layer on the outside. In general, they do not have visible surface or structural damages. In fact, the heat transfer coefficient of such walls is U=0.94÷1.22 W/m2*K (or thermal resistance R= **1,06÷0,82** m2*K/W), which does not significantly correspond to the standard value - minimum permissible heat transfer resistance R TP1 = **3,30** W/(m2*K) for the construction of new buildings and R=**2,64** W/(m2*K) for the reconstruction of existing ones. (according to the current national standard of Ukraine (DBN 2.6-31-2016 "Thermal insulation of buildings").

3.1.2. Windows and doors

The existing windows and outside doors include the following types: wooden frames with double glazing, PVC frames with double glazing, and wooden frames with single glazing. Existing windows and doors have heat transfer coefficients U=1,99÷3,16 W/m2*K (or thermal resistance R=**0,5÷0,32** m2*K/W), which does not meet the minimum requirements of Ukrainian standards, according to which the minimum allowable heat transfer resistance for windows/doors is R= **0,75/0,6** W/(m2*K) for the construction of new buildings and R=**0.6/0.48** W/(m2*K) for reconstruction of existing.

Some replacement of windows and doors happened over the past 5-7 years.

3.1.3. Roof

In terms of thermal properties, the roofs/attic floors do not comply with the minimum requirements set out in the Ukrainian regulations. In fact, the existing value of the heat transfer coefficient of roofs of buildings is U=0.89÷1.75 W/m^2*K (or R=**1.12÷0.57** m^2*K/W) with a minimum standard value of the heat transfer resistance of the combined/attic coating R=**6.0/4.95** m^2*K/W (for the construction of new buildings) and R=**4.8/3.96** m^2*K/W (for the reconstruction of existing). The roofs also frequently have visible damages. These damages should be dealt with prior to implementing EE measures. Energy efficiency measures in terms of placing thermal insulation on the roofs/attic floors were in general not implemented before.

3.1.4. Basement

The floor slabs in the inspected buildings are, in general, in a bad condition and they have bad thermal properties. Existing floor (basement ceiling) ceilings have heat transfer coefficients U= 0.32÷0.58 W/m^2*K (or thermal resistance R= **3.13 ÷ 1.72** m2*K/W), which does not meet the minimum requirements Ukrainian standards, according to which the minimum allowable heat transfer resistance of the floor is R=**3.75** W/(m^2*K) for the construction of new buildings and R=**3.0** W/(m^2*K) for the reconstruction of existing. Namely, the thermal properties of the floor (basement ceiling) do not comply with the minimum requirements set out in the Ukrainian regulations. Energy efficiency measures in terms of placing thermal insulation on the floor were not implemented before.

3.2. Heating systems

Heating systems, in general, can be described as old and obsolete with certain improvements, which include thermal insulation of the pipes in unheated areas, heating radiators replacement. The heating systems are mostly single pipe which were installed during the construction of buildings and were not subject to reconstruction during the entire period of operation, except for minor modernization and replacement of individual emergency sections. Most radiators are cast iron radiators and (partially) smooth pipe registers requiring replacement. The thermostatic valves are not installed, therefore, maintaining the required air temperature in the building is not possible. In a number of cases the radiators are installed inside of the wall niche or located below a window sill, so issues with the air flow through the radiators can be expected.

The heating substations in the buildings are, in general, in a bad condition and should be replaced. In buildings, the temperature control of the coolant is carried out automatically. Distribution pipelines are generally in poor condition (with damage and sometimes leaks), and only a few have thermal insulation, which in most cases is insufficient in thickness and quality. In general, the equipment is old and introduction of proper operating regimes is impossible.

3.3. Ventilation and air conditioning systems

Mechanical ventilation systems were mostly installed during the original building construction and in the majority of cases are not operational. The systems have ventilation units in bad condition, if operating at all, and they are mostly equipped with old electric motors.

3.4. Lighting systems

The lighting systems in the buildings include incandescent lighting, compact fluorescent lighting, daylight lamps (fluorescent) and LED lamps. The lighting systems in most buildings are not operated at their full capacity due to energy consumption restrictions. A combination of operating the lighting system in a reduced capacity with broken or not working bulbs causes visual discomfort for the buildings occupants. At the same time electricity consumption and corresponding load are very high. The lighting standards in the premises of institutions and hostels are not maintained. Lighting control is done manually.

4. Proposed energy efficiency measures

The Energy efficiency measures included in the Sub-project should allow for a significant reduction of energy consumption in terms of heating, hot water preparation, as well as lighting and HVAC auxiliary equipment.

Thermal insulation (renovation) of the buildings' envelopes will reduce the energy consumption, but it will also increase buildings life time. At the same time this insulation will significantly decrease the inflow of air into the building. This usually creates issues related to comfort and potential impact on the performance (health) of the building occupants. To address this issue, it's proposed that each building to have a ventilation system comprising a combination of a centralized and decentralized system with heat recovery units, air trickle vents installed on the windows which will allow fresh air to enter the building.

The heating systems upgrade is considered for all buildings since the existing situation does not allow normal operations. The heating system replacement and/or renovation and installation of an individual heating substation is proposed in each building.

For the lighting systems it's envisaged to replace existing old fixtures with new LED fixtures which will significantly reduce the energy consumption and at the same time increase visual comfort buildings occupants. Whenever there are fixtures can be adapted to use LED lighting technology instead of conventional (e.g. fluorescent lamps) it is recommended to replace the lamps only.

An energy management system is recommended to be installed in all buildings to allow for energy monitoring, benchmarking, various types of analyses and corrective actions.

The energy efficiency measures are intended to reduce energy consumption and corresponding costs at the same time increasing buildings functionality and comfort (bringing indoor conditions to the standard levels).

At the same time there are certain measures which do not fit in the category of energy efficiency measures (non-EE measures), but they have an impact on building functionality, comfort, as well as ensuring the sustainability of implemented energy efficiency measures. This means that implementation of such measures is necessary under the sub-project. The final list and investment costs of non-EE measures is to be identified as a result of design documentation development for the buildings covered by the Sub-project. The list of non-energy efficiency measures for this Sub-Project may include, but is not limited, to the following:

- Roof repairs;
- Repair of windows and doors;
- Upgrade of drainage systems;
- Upgrade or installation of fire safety systems;
- Those necessary to comply with accessibility requirements in accordance with EIB Finance Contract and/or Ukrainian laws and regulations.

The summary information on the proposed EE measures in Chernihiv National Technological University buildings is provided in **Table 2** below:

Table 2 Summary information on the proposed EE and non-EE measures in the University[4]

№	Measures	Type	1	2	3	4	5	6
			Educational laboratory building № 2	Educational building № 8	Educational building №11	Hostel №1	Educational laboratory building №3	Educational laboratory building № 4
			Real property	Real property	Real property	Non-residential building	Real property	Real property
			95, Shevchenko str., Chernihiv region, Chernihiv	1a, Kozatska str., Chernihiv region, Chernihiv	1, Striletska str., Chernihiv region, Chernihiv	99, Shevchenko str., Chernihiv region, Chernihiv	95, Shevchenko str., Chernihiv region, Chernihiv	95, Shevchenko str., Chernihiv region, Chernihiv
1	Wall insulation	EE	X	X	X	X	X	X
2	Replacing existing windows	EE	X	X	X	X	X	X
3	Replacing existing doors	EE	X	X	X	X	X	X
4	Attic floor insulation	EE		X	X	X	X	X
5	Basement ceiling insulation	EE		X	X	X	X	X
6	Flat roof insulation	EE	X	X			X	X
7	Individual heating substation (IHS)	EE	X	X	X	X	X	X
8	Heating system replacement	EE	X	X	X	X	X	X

[4] Based on energy audits of buildings (EABs) conducted in 2017 by iC Consulenten Ziviltechniker GesmbH

№	Measures	Type	1	2	3	4	5	6
			Educational laboratory building № 2	Educational building № 8	Educational building №11	Hostel №1	Educational laboratory building №3	Educational laboratory building № 4
			Real property	Real property	Real property	Non-residential building	Real property	Real property
			95, Shevchenko str., Chernihiv region, Chernihiv	1a, Kozatska str., Chernihiv region, Chernihiv	1, Striletska str., Chernihiv region, Chernihiv	99, Shevchenko str., Chernihiv region, Chernihiv	95, Shevchenko str., Chernihiv region, Chernihiv	95, Shevchenko str., Chernihiv region, Chernihiv
9	Modernization of the ventilation system	EE	X	X	X	X	X	X
10	Energy monitoring system and building management system	EE	X	X	X	X	X	X
11	Replacing an existing fixture with an LED	EE	X	X	X	X	X	X
12	Heat pump	EE				X		
13	Installation of a water heating system using solar energy and a heat pump for hot water preparation	EE						
14	Rain gutters	Non-EE	X					
15	Blind area repair	Non-EE	X					
16	Roof coating replacement	Non-EE					X	
17	Sewer system repair	Non-EE						

Table 3 Summary information on the proposed EE measures in the University (continuation)[5]

№	Measures	Type	7	8	9	10	11	12
			Educational and administrative building №1	Canteen	Hostel №2	Hostel №3	Hostel №5	Hostel №6
			Real property	Real property	Real property	Real property	Non-residential building	Non-residential building
			95, Shevchenko str., Chernihiv region, Chernihiv	95, Shevchenko str., Chernihiv region, Chernihiv	1a, Kozatska str., Chernihiv region, Chernihiv	1a, Kozatska st, Chernihiv region, Chernihiv	190a, Myra sq., Chernihiv region, Chernihiv	14, Tsiolkovskogo str., Chernihiv region, Chernihiv
1	Wall insulation	EE	X	X	X	X	X	X
2	Replacing existing windows	EE	X	X	X	X	X	X
3	Replacing existing doors	EE	X		X	X	X	X
4	Attic floor insulation	EE			X			
5	Basement ceiling insulation	EE		X	X		X	
6	Flat roof insulation	EE	X	X	X	X	X	X
7	Individual heating substation (IHS)	EE	X	X	X	X	X	X
8	Heating system replacement	EE	X	X	X	X	X	X

[5] Based on energy audits of buildings (EABs) conducted in 2017 by iC Consulenten Ziviltechniker GesmbH

№	Measures	Type	7	8	9	10	11	12
			Educational and administrative building №1	Canteen	Hostel №2	Hostel №3	Hostel №5	Hostel №6
			Real property	Real property	Real property	Real property	Non-residential building	Non-residential building
			95, Shevchenko str., Chernihiv region, Chernihiv	95, Shevchenko str., Chernihiv region, Chernihiv	1a, Kozatska str., Chernihiv region, Chernihiv	1a, Kozatska st, Chernihiv region, Chernihiv	190a, Myra sq., Chernihiv region, Chernihiv	14, Tsiolkovskogo str., Chernihiv region, Chernihiv
9	Modernization of the ventilation system	EE	X	X	X	X	X	X
10	Energy monitoring system and building management system	EE	X	X	X	X	X	X
11	Replacing an existing fixture with an LED	EE	X	X	X	X	X	X
12	Heat pump	EE			X	X		
13	Installation of a water heating system using solar energy and a heat pump for hot water preparation	EE					X	X
14	Rain gutters	Non-EE						
15	Blind area repair	Non-EE						
16	Roof coating replacement	Non-EE						
17	Sewer system repair	Non-EE	X				X	X

4.1. Organizational and educational measures

Organizational Measures

The energy management requires for the institution to have detailed knowledge about the energy system, as well as the systems which facilitate continuous energy monitoring.

Currently available documentation for the buildings and building systems in Chernihiv National Technological University still has room for improvement:

- the layouts for the mechanical, electrical, and plumbing (MEP) systems in buildings are frequently missing and are not available for revision.
- the layouts and information presented on the layouts of buildings are sometimes insufficient and should be further improved in order to eliminate the differences compared to the actual situation of the buildings.

As a starting measure, it is recommended to prepare proper and correct documentation related to building layouts and MEP systems. Along with that, it is recommended to mark all the elements of the MEP systems in order to facilitate maintenance and occasional control of the elements. During the design phase, special attention should be paid to providing sufficient level of detail which will enable the facility management of the university to implement maintenance practices. Specifically, the developed designs should enable the facility management to use the documents in:

- Operating the building systems according to design parameters
- Monitoring the operation of building systems and detecting possible issues in the system
- Conducting repair/inspection according to appropriate schedules for the recommended systems and
- Developing checklists for maintenance/inspections used in regular maintenance/inspection intervals.

The above implementation of the measures has considerable impact on the energy savings and sustainability of Sub-project results.

Educational Measures

A change in energy user behaviour can result in a significant energy savings. Thus, it is necessary to:

- Conduct educational activities (workshops) which will increase awareness about energy and other resources use;
- Conduct constant supervision and adapt, if necessary, the educational activities to achieve impact on as many building occupants as possible;
- Provide information to the occupants of the University buildings related to consumption of energy resources in frequent common areas.

Although it is difficult to quantify the amount of energy savings the change in user behaviour has, it is possible through observation of eventual energy consumption changes.

4.2. Envelope measures

The buildings' envelope thermal insulation measures are intended to contribute to reduction of heating energy consumption in a significant manner. In addition, they will increase useful lifetime of the building. The following descriptions provide more detailed information on the envisaged energy efficiency measures related to envelopes. The buildings' envelope thermal insulation measures are aimed to bring the physical properties of building elements to the levels which meet the requirements of Ukrainian regulation[6].

4.2.1. Outside walls

The technical characteristics of the thermal insulation on outside walls are:

- Thermal insulation material: Mineral wool with a wool density of **at least 150 kg/m3**;
- Thermal conductivity of material (maximum): **0,045** W/mK.

Comments/requirements:

[6] To the standards and regulations in force at the time of energy audits of buildings. If necessary, the list of planned activities will need to be updated at the stage of project documentation development.

- Installation: after cleaning and preparation of surfaces; according to requirements of the manufacturer;
- Anchoring of thermal insulation must be done according to manufacturer requirements (to be provided by the manufacturer);
- Appropriate materials must be used (plaster, grid, etc.) according to manufacturer specification;
- Finishing: according to the requirements of the local authorities (if any) or according to the requirements of the investor.

4.2.2. Flat roofs/attic floors

The technical characteristics of thermal insulation on the flat roofs include:

- Thermal insulation material: Mineral wool;
- Thermal conductivity of material (maximum): **0,045** W/mK;
- Other items: hydro-insulation mandatory.

Installation: after cleaning and preparation of surfaces; according to requirements of the manufacturer and compliance with regulations the technology of performance of insulation.

4.2.3. Basement ceilings

The foreseen technical characteristics of thermal insulation on the floors above ground include:

- Material: depending on the fire safety regulations and possible other limitations for materials to be used in buildings;
- Thermal conductivity of material (maximum): **0,045** W/mK;
- Other items: hydro-insulation mandatory.

Installation: after cleaning and preparation of surfaces; according to requirements of the manufacturer and compliance with regulations the technology of performance of insulation.

4.2.4. Windows and doors

The technical characteristics of new windows type **4i-14Ar-4-14Ar-4i** are as follows:

- Window frame material: PVC;
- Glazing: Low-e triple glazing;
- Glass thickness: 4 mm;
- Glass filling: Argon;
- Spacing between glass panes: average 14 mm;
- Window U-value: max. **1,1** W/m2K (recent testing certificate for that type of window should be provided and must meet the requirements).

Installation: manufacturer must provide clear installation guidelines.

In order to allow infiltration of fresh outside air, it is proposed to install windows with air trickle vents in dedicated rooms. Air trickle vents are not nevertheless intended to be installed on all windows, but for some where are deemed necessary

4.3. Heating system measures

4.3.1. Installation of an individual heating substation

The heat supply temperature is regulated manually, while the flow of the heat carrier is not being changed. Normally, the pipes of the heating network are directly connected to the heating system of the building without a heat exchanger to separate the primary and the secondary circuits. Hence, the heat carrier from the DH-network flows through the entire heating system of the customer facility, which means that the heating system of the building is hydraulically linked with the DH-network. The pressure in the system and also the water quality is maintained by the DH-network.

Due to the missing automatic regulation of the supply flow temperature and the inability to adjust the flow rate of the heat carrier the system is working inefficiently.

Thus, the installation of an individual heating substation with automatic temperature control is one of the major energy efficiency measures. This system allows adapting the heat supply demand of the building to its current actual demand according to the outside temperature. The heat substation is the technical prerequisite for demand side management. The heat substation makes a central remote monitoring and regulation of heat supply possible.

In principle, there are two different configurations of heating substations available on the market. The two systems differ depending on the presence of a heat exchanger for hydraulic separation of the primary/secondary heating circuit.

Illustration of indirect IHS with heat exchanger for heating loop

Illustration of indirect IHS with heat exchangers for heating loop and for DHW

Apart from the higher investment costs the indirect heating substation allows to operate the building heating system hydraulically independent from the DH-network, which means that the necessary pressure regime on the secondary side is adapted to the required temperature level and the pressure losses in the building can be much lower. On the other side, the maximum supply temperature on the secondary side is lower compared to the direct heating substation due to the temperature difference between primary/secondary side of the heat exchanger.

Both systems are regulating the heat supply demand according to the ambient outside temperature via a pressure difference & volume flow controller. No relevant difference in electricity consumption is expected. An unreasonable drawback of the indirect heating substation is that the building operator is responsible for cleaning the heat exchanger which is not acceptable due to lack of specialized staff and funds of public buildings. In Ukraine, this fact is even more critical as heating networks are normally operated with untreated water which most probably leads to a lot of sediment at the heat exchanger plates and so short cleaning intervals have to be expected.

For this reason, it is foreseen to use, whenever required, direct heating substations in public buildings. Such a heating substation comprises amongst various shut off valves, check valves, filters and measuring instruments mainly a circulating pump (group), a pressure difference controller, a heat meter and an ambient temperature controller unit. The mentioned controller unit allows different operating modes e.g. enabling to operate the system with different temperature regimes for daytime hours/night-time hours respectively weekdays and weekends. The rooms in which the substation is installed should have a minimum size, have to be easily accessible and there has to be access to water and electricity supply.

4.3.3. Renovation/replacement of the heating system with hydraulic balancing

Another problem related to heating is the condition of heating pipes and radiators which are partially worn out, affected by corrosion and also have a significantly narrowed cross section area due to scaling which leads to a decrease of the heating capacity of radiators and at the same time to an increased hydraulic resistance of heating pipes. All these problems are leading to water leakages, respectively higher-pressure losses in the heating network during operation. Therefore, this measure is not necessarily a pure efficiency measure. It consists of a set of measures like:

- insulation of the heat distribution pipes,
- hydraulic balancing (installation of balancing valves),
- replacement of radiators,
- installation of thermostatic valves,
- renewal of a larger part of the heat distribution pipes of the heating pipes to descale sediments on the inner surface.

In some areas of the buildings the radiators are often installed inappropriately which in turn prevents proper air convection. Improvement of the air circulation can be easily implemented with a quite a significant impact on the emitting efficiency of the radiator.

4.4. Hot water preparation measures

- **Heat pump for hot water preparation.**

The heat pump system takes heat from the environment (heat capacity of the air) and brings the water to a higher energy level which meets the requirements of the DHW supply. An electrical booster element can be installed for the purposes of heating the hot water up to 70°C for the purpose of disinfection. University buildings such as the examined ones can have high energy consumption for hot water preparation, especially in the case of dormitories where the students

reside throughout the majority of the year, even though the occupancy regimes show decreases during academic year breaks.

- **Solar thermal system (collectors) for hot water preparation.**

Proper dimensioning of the solar thermal system (collectors) can ensure that a certain portion of the hot water load is covered with solar energy. Depending on the chosen configuration and setup of the system, the focus can be put on summer, winter or throughout the year operation. The system is actually closely tied to the operation regime of the building and therefore must meet the requirements, otherwise not enough energy can be obtained or on the other hand, the system can start to overheat if it is over dimensioned. While dimensioning the system, special care should be given to component dimensioning in order to ensure long term operation of the system (typically 20-25 years).

Due to the fact that the hostels are not fully occupied throughout the year, solar thermal systems were dimensioned to cover the majority of the summer DHW energy demand (lowest demand), but not to cause overheating of the system during the summer.

The combined solar thermal and heat pump DHW preparation system is intended to replace the current heat supply and reduce DHW preparation costs in a significant amount. The proposed DHW systems should be able to support the heating system whenever possible. In order to transfer energy from the DHW system to the heating system, a heat exchanging device should be used. For this purpose, it will be necessary to install control elements which will enable energy transfer when the specific condition for energy transfer from DHW system to heating system are met. Simulations performed within the scope of this project do not represent the final designs of solar thermal systems and the proposed systems must be examined in more detail during the design phase.

4.5. Ventilation system measures

The list of measures includes installation of air trickle vents on windows (in rooms where deemed necessary), exhaust ventilation devices which should use the existing duct spaces (where possible), as well as distributed ventilation devices with heat recovery. A combination of these technologies is deemed to ensure sufficient building ventilation, supply with fresh air and energy savings.

4.6. Lighting system measures

The technical requirements for rehabilitating and improving the lighting system are as follows:

- The existing inefficient incandescent bulbs shall be replaced with LED lamps;
- Sources of light need to have light efficiency not lower than 70 lm/W and energy consumption not higher than 20W/m2, taking into consideration the energy consumption of the switch gears and auxiliary lighting control systems.
- Additional lighting of the white board has to be done by lamps with an asymmetrical light propagation to ensure the required lighting level in the centre of the white board.

4.7. Energy management system

An effective energy management system is of utmost importance to keep the energy consumption under control and to monitor and analyse the data obtained from the system. Appropriate metering equipment is the sole basis for proper energy accounting; therefore, it is proposed to install the following metering equipment:

- Heat meter;
- Electricity sub-meter (control) meter;
- Water meter.

This equipment should be connected to an energy management/monitoring platform. Manual operation will be necessary in outstanding situations and therefore reduced to minimum. The platform should enable each University monitoring on building level, as well as on the University level, i.e. enable:

- Monitoring of the consumption of heat, electricity and water in real time in numbers and graphs;
- make a request for any meter for detail energy consumption data research;
- prevent energy losses in the engineering systems of the buildings;
- archive the energy consumption data from buildings;
- analyse consumption and to react immediately in case of emergency;
- optimize energy use beyond the working hours;
- perform energy planning (forecast of energy consumption);
- protect data.

4.8. Building management system

The building management is proposed according to the requirement of the project in order to control all the relevant energy consuming systems in the building and to meet the requirements of

the *EN 15232 – Energy Performance of buildings – Impact on building automation, controls and building management*, including the proposed:

- heating system;
- ventilation system;
- lighting system, as well as
- other available systems in the building.

The building management system is expected to ensure that:

- heating system operation is performed according to the pre-defined schedules and that the BMS controls the operation of circulating pumps, flow and return temperatures according to outside temperatures and defined setback temperatures;
- ventilation system operation is done according to CO2 sensor readings, humidity readings and that the BMS ensures that the ventilation system operates efficiently;
- lighting system operation is done according to pre-defined schedules and motion sensors which will ensure that the lighting system is not operating when there is no occupancy.

5. Energy consumption

5.1. Metered (actual) energy consumption

The buildings included in the Sub-project use three different sources of energy for the purposes of heating, hot water preparation, cooking, lighting and powering electrical devices.

The final energy consumption of the university amounts to 9 046 809 kWh/year. The structure of energy consumption is as follows:

- District Heating: 7 715 457 kWh/year;
- Electricity: 1 331 352 kWh/year.

The heating energy is provided by the district heating system and supplied from central boiler room, depending on the location of buildings.

The hot water preparation is conducted using the following sources: district heating and electrical energy. The natural gas is not used in the buildings.

The electrical energy is used for lighting and hot water supply (educational building No. 11) and the power supply of various equipment in buildings (HVAC equipment, appliances and other electrical devices).

5.2. Calculated characteristics (baseline consumption) of audited buildings

As presented in the energy audits for each building, the most often case is that the buildings were underheated, i.e. indoor temperature was lower than specified by the standard (e.g. 20°C). This leads to the situation there actual metered heating energy consumption cannot be used as the baseline. Thus, it was recommended to use the calculated figures according to the standard as the baseline. The calculated figures, i.e. the considered baseline is therefore significantly higher than the metered consumption since the heating requirement (indoor temperature) is much higher.

The following **Table 3** presents the figures for metered heating energy consumption, as well as the figures for the calculated baseline.

Table 3. Metered and calculated (baseline) heating energy consumption per building and per sq.m.[7]

#	Building	Actual (measured), kWh/a		Baseline, kWh/a		After implementation (estimated), kWh/a	
		Thermal Energy Consumption - Heating	Sq.m	Thermal Energy Consumption - Heating	Sq.m	Thermal Energy Consumption - Heating	Sq.m
1	Educational laboratory building № 2	462 827	109	960 806	227	317 132	75
2	Educational building № 8	510 568	167	686 419	225	219 914	72
3	Educational building №11	1 127 474	176	1 615 450	252	520 044	81
4	Hostel №1	493 242	95	627 276	120	152 048	29
5	Educational laboratory building №3	491 599	131	794 709	212	191 053	51
6	Educational laboratory building № 4	488 371	156	844 525	270	122 949	39
7	Educational and administrative building №1	1 161 031	100	2 342 256	202	708 805	61
8	Canteen	184 316	110	356 006	212	73 488	44
9	Hostel №2	464 497	122	654 759	172	131 986	35
10	Hostel №3	437 851	109	588 749	146	133 274	33
11	Hostel №5	375 128	180	494 570	237	152 267	73
12	Hostel №6	518 213	127	769 706	189	310 296	76
Total		**6 715 117**	**132**	**10 735 231**	**205**	**3 033 256**	**56**

[7] Based on energy audits of buildings (EABs) conducted in 2017 by iC Consulenten Ziviltechniker GesmbH

The figures presented in the table 3 above show that total metered heating energy consumption (including covering the heating as well as ventilation losses) of all considered buildings amounts to **6 715 117** kWh/a, while the calculated baseline points out that the actual heating consumption should be **10 735 231** kWh/a. The difference between the two consumption figures in certain buildings can reach substantial amounts.

The table 3 shows that almost all buildings covered by the Sub-project have a metered consumption for heating more than 100 kWh/m2year. The average specific indicator of the measured heat energy consumption for heating for all buildings is **132** kW*h/m^2. The average specific indicator of the basic energy consumption for heating (including heating and compensation for heating the air for the ventilation system) is **205** kW*h/m^2. The difference between the average specific indicator of the basic and actual energy consumption for heating is on average 73 kW*h/m^2 that is 36%, which means that the indoor climate standards will be significantly maintained in buildings.

Opposed to the specific metered heating energy consumption, the baseline specific heating energy consumption shows a situation which is considered to be more realistic when the conditions and properties of the building envelopes and HVAC systems are taken into consideration. Since buildings covered by the Sub-project do not have insulated envelopes, this number is much more realistic.

5.3. Metered vs baseline energy consumption

The metered consumption is in most cases significantly lower *(show range)* than the baseline calculated heating energy consumption. The main reasons for this difference are:

- lower indoor temperature as compared to required (norms) level;
- lower air exchange (improper ventilation), including complete sealing of windows in order to prevent infiltration and drafts;
- manual regulation of the heating systems;
- energy budget restrictions.

5.4. Energy consumption after implementation of proposed energy efficiency measures

The situation after implementation of proposed energy efficiency measures shows a significant reduction in both energy consumption and related energy costs. The main targets of the proposed energy efficiency measures are thermal energy used for heating and hot water preparation, as well as electricity used for lighting and powering other auxiliary devices such as HVAC system equipment.

As presented in the energy audits for each separate building, the most often case is that the buildings were underheated in the existing situation, i.e. heated to a temperature lower than specified by the standard (e.g. 20°C). In the situation after renovation, the main assumption is that the building will be heated to the standard temperature of 20°C in order to maintain thermal comfort.

The figures point out that the total heating energy consumption after implementation of energy efficiency measures (including covering the heating as well as ventilation losses) of all considered buildings amounts to **3 033 256** kWh/a, which is a reduction of 72% compared to the baseline and a reduction of 55% compared to the real (metered) consumption.

After implementation of EE measures, the average specific heating energy consumption (including covering the heating as well as ventilation losses) after implementation of energy efficiency measures drops to **56** kWh/m²a. The specific energy consumption after the implementation of energy efficiency measures will average **44** kW*h/m². Specific electricity consumption will increase after the introduction of energy efficiency measures for additional costs of electric energy by ventilation systems and heat pumps.

Data on the consumption of thermal energy for heating, hot water and electricity after the implementation of the proposed energy efficiency measures are shown in **Table 4** below:

Table 4. Energy consumption indicators before and after the implementation of energy efficiency measures [8].

#	Building	Actual (measured), kWh/a				Baseline, kWh/a				After implementation (estimated), kWh/a			
		Heating	HW	Electricity	Total	Heating	HW	Electricity	Total	Heating	HW	Electricity	Total
1	Educational laboratory building № 2	462 827	8 374	35 985	507 186	960 806	8 374	45 851	1015 031	317 132	8 374	60 003	385 509
2	Educational building № 8	510 568	6 762	50 741	568 071	686 419	6 762	79 479	772 660	219 914	6 762	100 584	327 260
3	Educational building №11	1127 474	4 038	80 262	1211 774	1615 450	4 038	102 341	1721 829	520 044	4 038	103 546	627 628
4	Hostel №1	493 242	390 471	243 299	1127 012	627 276	390 471	296 448	1314 195	152 048	390 471	354 689	897 208
5	Educational laboratory building №3	491 599	4 187	13 133	508 919	794 709	4 187	40 604	839 500	191 053	4 187	51 530	246 770
6	Educational laboratory building № 4	488 371	7 850	111 294	607 515	844 525	7 850	165 171	1017 546	122 949	7 850	172 564	303 363
7	Educational and administrative building №1	1161 031	18 998	137 560	1317 589	2342 256	18 998	239 576	2600 830	708 805	18 998	172 902	900 705
8	Canteen	184 316	40 232	59 781	284 329	356 006	40 232	63 906	460 144	73 488	40 232	65 485	179 205

[8] Based on energy audits of buildings (EABs) conducted in 2017 by iC Consulenten Ziviltechniker GesmbH

#	Building	Actual (measured), kWh/a				Baseline, kWh/a				After implementation (estimated), kWh/a			
		Heating	HW	Electricity	Total	Heating	HW	Electricity	Total	Heating	HW	Electricity	Total
9	Hostel №2	464 497	161 624	178 814	804 935	654 759	162 210	253 252	1070 221	131 986	162 210	274 916	569 112
10	Hostel №3	437 851	121 156	159 059	718 066	588 749	121 156	242 309	952 214	133 274	121 156	266 975	521 405
11	Hostel №5	375 128	143 963	90 318	609 409	494 570	167 390	114 246	776 206	152 267	167 390	166 697	486 354
12	Hostel №6	518 213	92 685	171 106	782 004	769 706	92 685	219 520	1081 911	310 296	92 685	241 135	644 116
Total		**6715117**	**1000340**	**1331352**	**9046809**	**10735231**	**1024353**	**1862703**	**13622287**	**3033256**	**1024353**	**2031026**	**6088635**

6. Assessment of investments and savings

The investment costs for each building are based on estimates provided in corresponding energy audit reports. The costs for each measure within a package of measures have been taken according to market prices of the proposed products, materials and labour costs related to implementation of specific energy efficiency measures at the time of the energy audit report preparation.

The measures have been separated into energy efficiency measures (ones that generate energy savings) and non-energy efficiency measures (which do not generate energy savings, but they contribute to sustainability of the proposed energy efficiency measures or increase general building functionality/operating conditions).

The investment amounts have been split in the same way, into energy efficiency investment costs and non-energy efficiency investment costs. Since the non-energy efficiency measures do not contribute to the overall saving potential of the proposed packages, they have not been included in the financial analysis of investment packages (provided in **Section 7** below).

The following **Table 5** shows the Sub-project investment details costs.

Table 5. Sub-project investments details (measures and buildings)[9].

№	Building	Type	1	2	3	4	5	6
			Educational laboratory building № 2	Educational building № 8	Educational building №11	Hostel №1	Educational laboratory building №3	Educational laboratory building № 4
			Real property	Real property	Real property	Non-residential building	Real property	Real property
			95, Shevchenko str., Chernihiv region, Chernihiv	1a, Kozatska str., Chernihiv region, Chernihiv	1, Striletska str., Chernihiv region, Chernihiv	99, Shevchenko str., Chernihiv region, Chernihiv	95, Shevchenko str., Chernihiv region, Chernihiv	95, Shevchenko str., Chernihiv region, Chernihiv
1	Wall insulation	EE	73 530	65 475	163 035	115 155	109 395	114 930
2	Replacing existing windows	EE	67 080	35 582	97 540	9 460	65 000	104 738
3	Replacing existing doors	EE	3 740	1 716	1 631	1 463	1 747	2 354
4	Attic floor insulation	EE		21 272	63 640	34 500	26 310	10 859
5	Insulation of the ceiling in the basement.	EE		3 240	16 428	34 500[10]	26 310	7 200
6	Flat roof insulation	EE	97 185	23 095			6 270	20 405
7	Individual heating substation (IHS)	EE	16 000	16 000	24 500	20 000	17 000	17 500
8	Replacing the heating system	EE	77 280	66 280	128 060	113 980	87 300	91 940
9	Modernization of the ventilation system	EE	75 600	76 630	89 270	24 780	62 340	77 720
10	Energy monitoring system and building management system	EE	29 000	27 200	32 000	30 300	28 200	27 500
11	Replacing an existing fixture with an LED	EE	35 350	30 700	45 450	48 000	33 650	55 200

[9] Based on energy audits of buildings (EABs) conducted in 2017 by iC Consulenten Ziviltechniker GesmbH
[10] Not included in the University's priority investment plan.

№	Building	Type	1	2	3	4	5	6
			Educational laboratory building № 2	Educational building № 8	Educational building №11	Hostel №1	Educational laboratory building №3	Educational laboratory building № 4
			Real property	Real property	Real property	Non-residential building	Real property	Real property
			95, Shevchenko str., Chernihiv region, Chernihiv	1a, Kozatska str., Chernihiv region, Chernihiv	1, Striletska str., Chernihiv region, Chernihiv	99, Shevchenko str., Chernihiv region, Chernihiv	95, Shevchenko str., Chernihiv region, Chernihiv	95, Shevchenko str., Chernihiv region, Chernihiv
12	Heat pump, installation of water heating system due to solar energy and heat pump [11]	EE				93 858		
13	Rain gutters	Non-EE	2 250					
14	Pavement repairment	Non-EE	6 750					
15	Roof Covering Replacement	Non-EE					17 540	
16	Reconstruction of the hot water system	Non-EE						
Total, EURO			**483 765**	**367 190**	**661 554**	**525 996**	**481 062**	**530 346**

[11] Not included in the University's priority investment plan.

Table 5. Sub-project investments details (measures and buildings), continuation [12].

№	Building	Type	7	8	9	10	11	12
			Educational and administrative building №1	Canteen	Hostel №2	Hostel №3	Hostel №5	Hostel №6
			Real property	Real property	Real property	Real property	Non-residential building	Non-residential building
			95, Shevchenko str., Chernihiv region, Chernihiv	95, Shevchenko str., Chernihiv region, Chernihiv	1a, Kozatska str., Chernihiv region, Chernihiv	1a, Kozatska str., Chernihiv region, Chernihiv	190a, Myru sq., Chernigiv region, Chernigiv	14, Tsiolkovskogo str., Chernigiv region, Chernigiv
1	Wall insulation	EE	221 535	41 760	92 835	98 685	43 110	83 385
2	Replacing existing windows	EE	277 940	16 770	53 391	68 024	37 440	78 260
3	Replacing existing doors	EE	2 420		997	521	1 870	1 100
4	Attic floor insulation	EE			22 225			
5	Insulation of the ceiling in the basement.	EE		2 550	37 135		5 820	
6	Flat roof insulation	EE	228 195	50 545	27 335	51 838	29 315	53 625
7	Individual heating substation (IHS)	EE	20 000	12 000	16 000	16 300	16 000	16 000
8	Replacing the heating system	EE	230 000	25 960	69 200	80 440	44 700	81 120
9	Modernization of the ventilation system	EE	113 000	15 600	32 870	13 250	4 500	4 500
10	Energy monitoring system and building management system	EE	35 800	25 500	28 200	28 700	25 900	28 800
11	Replacing an existing fixture with an LED	EE	80 750	16 300	40 100	43 950	26 000	51 700
12	Heat pump, installation of water heating system due to solar energy and heat pump [13]	EE			71 286	27 027	41 286	34 514

[12] Based on energy audits of buildings (EABs) conducted in 2017 by iC Consulenten Ziviltechniker GesmbH
[13] Not included in the University's priority investment plan.

№	Building	Type	7	8	9	10	11	12
			Educational and administrative building №1	Canteen	Hostel №2	Hostel №3	Hostel №5	Hostel №6
			Real property	Real property	Real property	Real property	Non-residential building	Non-residential building
			95, Shevchenko str., Chernihiv region, Chernihiv	95, Shevchenko str., Chernihiv region, Chernihiv	1a, Kozatska str., Chernihiv region, Chernihiv	1a, Kozatska str., Chernihiv region, Chernihiv	190a, Myru sq., Chernigiv region, Chernigiv	14, Tsiolkovskogo str., Chernigiv region, Chernigiv
13	Rain gutters	Non-EE						
14	Pavement repairment	Non-EE						
15	Roof Covering Replacement	Non-EE						
16	Reconstruction of the hot water system	Non-EE	3 000				4 500	5 700
Total, EURO			**1 212 640**	**206 985**	**491 574**	**428 735**	**280 441**	**438 704**

The investment amounts do not include value added tax (VAT). All investments include costs for all stages of project implementation, including:

- designs (architectural, civil, mechanical and electrical) are estimated at approx. 5.5% of the overall sub-project value;
- sub-project management and FIDIC are estimated at approx. 3% of the overall sub-project value;
- construction technical supervision at approx. 1.5% of the overall sub-project value.
- construction (incl. materials, works, system installations, commissioning, verification, testing, as well as all other related costs) at approx. 90% of the overall sub-project value;

The information on Sub-project savings in KWh and in monetary terms is summarised in **Table 6 below.**

Table 6. Sub-project savings in KWh and monetary terms per year [14].

#	Building	Savings as compared to baseline, kWh/a				Savings as compared to baseline, EURO				Savings as compared to baseline, %	
		Thermal Energy - Heating	Thermal Energy - HW	Electricity	Total	Thermal Energy - Heating	Thermal Energy - HW [15]	Electricity [16]	Total	Energy Resources	EURO
1	Educational laboratory building № 2	643 674		-14 152	629 522	22 593		-1 056	21 537	32%	58%
2	Educational building № 8	466 505		-21 105	445 400	19 547		-1 574	17 972	30%	51%
3	Educational building №11	1 095 406		-1 205	1 094 201	54 787		-90	54 697	33%	62%
4	Hostel №1	475 228		-58 241	416 987	16 681	13 706	-1 747	28 639	18%	64%
5	Educational laboratory building №3	603 656		-10 926	592 730	21 188		-815	20 373	36%	66%
6	Educational laboratory building № 4	721 576		-7 393	714 183	25 327		-552	24 776	38%	59%
7	Educational and administrative building №1	1 633 451		66 674	1 700 125	57 334		4 974	62 308	34%	62%

[14] Based on energy audits of buildings (EABs) conducted in 2017 by iC Consulenten Ziviltechniker GesmbH
[15] Additional cost savings through the use of heat pumps and a solar system.
[16] Negative values for additional costs of electric energy by ventilation systems and heat pumps

#	Building	Savings as compared to baseline, kWh/a				Savings as compared to baseline, EURO				Savings as compared to baseline, %	
		Thermal Energy - Heating	Thermal Energy - HW	Electricity	Total	Thermal Energy - Heating	Thermal Energy - HW [15]	Electricity [16]	Total	Energy Resources	EURO
8	Canteen	282 518		-1 579	280 939	9 916		-118	9 799	33%	52%
9	Hostel №2	522 773		-21 664	501 109	19 965	6 195	-650	25 510	27%	66%
10	Hostel №3	455 475		-24 666	430 809	17 395	4 627	-740	21 282	26%	62%
11	Hostel №5	342 303		-52 451	289 852	13 073	6 393	-1 574	17 892	20%	62%
12	Hostel №6	459 410		-21 615	437 795	14 876	3 001	-648	17 228	23%	50%
Total		**7 701 975**		**-168 323**	**7 533 652**	**292 681**	**33 921**	**-4 590**	**322 012**	**29%**	**59%**

7. Economic and financial analyses

The proposed Sub-project was analysed to obtain the simple payback period for the investment envisioned for each building.

As presented in the chapter above, the total investment in the proposed packages of energy efficiency measures amounts to EURO 6 108 992 (VAT exclusive), this includes energy efficiency measures in the amount of EURO 6 069 252 (VAT exclusive) and non-energy efficiency measures in the amount of EURO 39 740 (VAT exclusive). The total savings resulting from the implementation of the Sub-project are equal to EURO 322 012 per year. The Sub-project simple payback period is 19 years, and for the buildings it's ranging from 17 to 22 years.

The details on investments and payback are provided in **Table 7** below.

Table 7 Sub-project investments and payback.[17]

#	Building	Investments[18], EURO (excl. VAT)	Savings, EURO	Payback, years
1	Educational laboratory building № 2	483 765	21 537	23
2	Educational building № 8	367 190	17 972	20
3	Educational building №11	661 554	54 697	12
4	Hostel №1	525 996	28 639	18
5	Educational laboratory building №3	481 062	20 373	24
6	Educational laboratory building № 4	530 346	24 776	21
7	Educational and administrative building №1	1 212 640	62 308	20
8	Canteen	206 985	9 799	21
9	Hostel №2	491 574	25 510	19
10	Hostel №3	428 735	21 282	20
11	Hostel №5	280 441	17 892	16
12	Hostel №6	438 704	17 228	26
Total		**6 108 992**	**322 012**	**19**

The structure of EE investments is as follows:

- Thermal insulation of building envelopes is EURO 3 053 411 (50% of total);
- HVAC systems is EURO 2 240 720 (37% of total);
- Lighting systems is EURO 507 150 (8% of total);
- DHW systems is EURO 267 971 (4% of total).

The average specific investment cost for Chernihiv National Technological University amounts to 114/m² of heated area of buildings.

Details regarding unit costs and reduction of energy consumption of buildings included in the Sub-project are provided in **table 8.**

[17] Based on energy audits of buildings (EABs) conducted in 2017 by iC Consulenten Ziviltechniker GesmbH

[18] **Note**: The total investment of energy efficiency measures will decrease from **6 069 252** to **5 801 281** euros (excluding VAT) if the project does not provide the implementation of the EE measures "Installing a water heating system using solar energy and a heat pump for preparing hot water" and "Installing a heat pump".

Table 8. Investments and energy consumption of buildings included in the subproject [19]

#	Building	Investments, EURO (excl. VAT)	Investment per m2 EURO (excluding VAT)	Energy consumption per m2 (baseline)	Energy consumption per m2 (after implementation)
1	Educational laboratory building № 2	483765	114	240	91
2	Educational building № 8	367190	120	253	107
3	Educational building №11	661554	103	269	98
4	Hostel №1	525996	101	252	172
5	Educational laboratory building №3	481062	128	224	66
6	Educational laboratory building № 4	530346	170	326	97
7	Educational and administrative building №1	1212640	104	224	77
8	Canteen	206985	123	274	107
9	Hostel №2	491574	129	281	149
10	Hostel №3	428735	107	237	130
11	Hostel №5	280441	134	372	233
12	Hostel №6	438704	108	265	158
Total		**6108992**	**115**	**257**	**115**

8. Assessment of GHG emission reductions

The reduction in GHG (CO2) emissions was calculated using as a basis energy savings (projected energy consumption versus baseline) resulting from implementation of EE measures. The estimated GHG emissions reductions for the Sub-project are provided in **Table 9** below.

[19] Based on energy audits of buildings (EABs) conducted in 2017 by iC Consulenten Ziviltechniker GesmbH

Table 9. GHG emissions reductions for the Sub-project [20]

#	Building	Baseline emissions, kgCO2/a				Emissions after implementation of measures (estimated), kgCO2/a				Emission reductions (estimated) by reducing consumption, kgCO2/a			
		Thermal Energy - Heating	Thermal Energy - HW	Electricity	Total	Thermal Energy - Heating	Thermal Energy - HW	Electricity	Total	Thermal Energy - Heating	Thermal Energy - HW	Electricity	Total
1	Educational laboratory building № 2	278 634	2 428	41 082	**322 145**	91 968	2 428	53 763	**148 159**	186 665	0	-12 680	**173 985**
2	Educational building № 8	199 062	1 961	71 213	**272 236**	63 775	1 961	90 123	**155 859**	135 286	0	-18 910	**116 376**
3	Educational building №11	468 481	3 618	91 698	**563 796**	150 813	1 171	92 777	**244 761**	317 668	2 447	-1 080	**319 035**
4	Hostel №1	181 910	113 237	265 617	**560 764**	44 094	113 237	317 801	**475 132**	137 816	0	-52 184	**85 632**
5	Educational laboratory building №3	230 466	1 214	36 381	**268 061**	55 405	1 214	46 171	**102 790**	175 060	0	-9 790	**165 271**
6	Educational laboratory building № 4	244 912	2 277	147 993	**395 182**	35 655	2 277	154 617	**192 549**	209 257	0	-6 624	**202 633**
7	Educational and administrative building №1	679 254	5 509	214 660	**899 424**	205 553	5 509	154 920	**365 983**	473 701	0	59 740	**533 441**
8	Canteen	103 242	11 667	57 260	**172 169**	21 312	11 667	58 675	**91 653**	81 930	0	-1 415	**80 515**
9	Hostel №2	189 880	47 041	226 914	**463 835**	38 276	47 041	246 325	**331 642**	151 604	0	-19 411	**132 193**
10	Hostel №3	170 737	35 135	217 109	**422 981**	38 649	35 135	239 210	**312 994**	132 088	0	-22 101	**109 987**
11	Hostel №5	143 425	48 543	102 364	**294 333**	44 157	48 543	149 361	**242 061**	99 268	0	-46 996	**52 272**
12	Hostel №6	223 215	26 879	196 690	**446 783**	89 986	26 879	216 057	**332 921**	133 229	0	-19 367	**113 862**
Total		**3113217**	**299 509**	**1668982**	**5081708**	**879 644**	**297 062**	**1819799**	**2996506**	**2233573**	**2 447**	**-150 817**	**2085202**

[20] Based on energy audits of buildings (EABs) conducted in 2017 by iC Consulenten Ziviltechniker GesmbH

9. Sub-project summary information

The Sub-project information for Chernihiv National Technological University summarized in **Table 10** below.

Table 10. Chernihiv National Technological University Sub-project summary information [21]

Indicator	Description/Value
EABs conducted, year	2017
Number of buildings	12 (7 educational buildings, 4 hostels and 1 canteen)
Buildings heated area	53 068 м2
Baseline Energy Consumption, kWh/year	13 622 287
Metered Energy Consumption	The metered consumption is in most cases significantly lower (1.3-2 times) than the baseline calculated heating energy consumption
Reduction in Energy Consumption, kWh/a	7 533 652:
Reduction in energy consumption, kWh/a	• District heating – (7 701 975) • Natural gas – • Electricity – (-168 323)
Estimated Energy Consumption post EE modernization, kWh/a	6 088 635
Measures proposed for implementation	**Energy efficient measures:** • Insulation of walls • Replacement of existing windows • Replacement of existing doors • Insulation of attic floors • Basement ceiling insulation • Attic floor insulation • Individual heating substation (IHS) • Heating system replacing • Modernization of the ventilation system • Energy monitoring system and building management system • Replacing an existing fixtures with LED • Heat pump • Solar thermal and heat storage system placement **Technical measures:** • Rain gutters • Pavement repair • Roof cover replacement • Sewer system repair •
Estimated Investment[22] (ex. VAT), EURO	6 069 252[23] euro (without VAT)- including measures using solar systems and heat pumps
Estimated Investment Breakdown (ex. VAT), EURO	• Thermal protection of building envelopes – 3 053 411 Euro (50%); • HVAC systems – 2 240 720 Euro (37%); • Lighting systems – 507 150 Euro (8%) • DHW systems – 267 971 Euro (4%)

[21] Based on energy audits of buildings (EABs) conducted in 2017 by iC Consulenten Ziviltechniker GesmbH
[22] Including costs of designs (architectural, civil, mechanical and electrical), project management, construction (incl. materials, works, system installations, commissioning, verification, testing, as well as all other related costs) and construction supervision).
[23] Energy efficient measures costs.

Indicator	Description/Value
Estimated cost of non-EE measures (ex. VAT), EURO	39 740[24]
Estimated Annual Savings (ex. VAT), EURO	322 012
Simple Payback for the Sub-project, years	19
GHG emissions reduction, CO2 t/year	2 085 (compared to baseline)

10. List of assumptions used

10.1 Tariffs

The following average tariffs (in EURO per KWh) were used for calculations during energy audits (2017).[25]

Resource	Basic	After the implementation of the measures
Educational buildings		
Heat Energy (Educational building №1,2,3,4, canteen)	0,0351	0,0351
Hot water	0,0351	0,0351
Electricity	0,0746	0,0746
Educational building 8 (heat energy)	0,0419	0,0419
Educational building 11 (heat energy)	0,05	0,05
Hostels		
Heat Energy (Hostel №1)	0,0351	0,0351
Hot water (Hostel №1)	0,0351	0,0351
Electricity	0,0300	0,03
Heat Energy (Hostel №2,3,5)	0,0382	0,0382
Heat Energy (Hostel №6)	0,0324	0,0324

10.2 CO2 emission factors

The following CO2 emission factors (kg CO2 per KWh) were used for calculations.[26]

Resource	Basic	After the implementation of the measures

[24] Determined based on energy audit data. The list of activities and financing can be determined only after the development of design estimates.
[25] Based on energy audits of buildings (EABs) conducted in 2017 by iC Consulenten Ziviltechniker GesmbH
[27] [28] Based on energy audits of buildings (EABs) conducted in 2017 by iC Consulenten Ziviltechniker GesmbH

Heat Energy	0,290	0,290
Hot water	0,290	0,290
Electricity	0,896	0,896

10.3 The cost of the main activities adopted for the calculation of investments [27]

№	Measure	Unit	Cost, UAH			
			Works	Materials	Other *	Total
1	Wall insulation	Euro/m²	15,8	22,5	6,7	45
2	Replacing existing windows	Euro/m²	26	91	13	130
3	Replacing existing doors	Euro/m²	22	77	11	110
4	Attic floor insulation	Euro/m²	10,5	15	4,5	30
5	Basement ceiling insulation	Euro/m²	9	18	3	30
6	Replacing conventional lamps with LED	Euro/lamp	1,2	6,4	0,4	8
	Replacing an existing fixtures with LED	Euro/fixture	7,5	40	2,5	50
7	Flat roof insulation	Euro/m²	19,3	27,5	8,3	55
8	Individual heating substation (IHS) <2000m²	Euro/unit	3 575	8 580	2 145	14 300
	Individual heating substation (IHS) >2000m²	Euro/unit	4 000	9 600	2 400	16 000
	Individual heating substation (IHS) >5000m²	Euro/unit	5 000	12 000	3 000	20 000
9	Heating system replacing Heating system pipelines isolation Heating system balancing	Euro/m² heating area	7	12	1	20
10	Modernization of the ventilation system	Euro/unit	Depends on the building size, configuration, use, number and type of ventilation units. The approx. cost varies from 3600 to 160000 per building.			
11	Solar thermal and heat pump system	Euro/m²	135	247,5	67,5	450
12	Energy monitoring system and building management system	Euro/building	Depends on the building size, configuration, use, number and type of meters, sensors and transmission devices. The approx. cost varies from 24800 to 41000 per building.			