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NATIONAL LABORATORY ASTANA

Development of energy efficient and smart building in Kazakhstan

International joint seminar on “Towards Smart Sustainable Cities – Integrated Approaches”, June 15-16, Astana, Kazakhstan

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THE INTELLIGENT SYSTEMS AND ENERGY EFFICIENCY LABORATORY

KEY RESEARCH AREAS

Energy Efficient Technologies for Buildings and Constructions

Energy efficiency research group

- aims to promote and conduct fundamental and applied research related to the efficient use of energy in the built environment.

Integration, Automation and Control of Renewable Energy Systems

The renewable power integration research group

- focuses on the development of the control algorithm that allows to manage real-time electricity demand in most optimised manner, implements an MPC-based control algorithm for "smart house" prototype installed in the premises of Nazarbayev University.

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RESEARCH FOCUS

Building energy survey

The survey includes performing air permeability test using a blower door, thermal imaging of the buildings to identify heat loss, moisture traps and leaks, electrical overheating, diagnosing engineering systems, identification of heat-conduction coefficient and thermal resistance by using different equipment. Moreover, the survey include the assessment of energy use in the existing buildings, analysis of building and utility data, real operating conditions and estimation of energy saving potential.

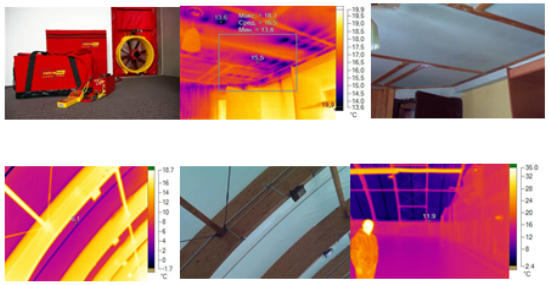

Fig.1 Building energy survey

Building energy behaviour modelling

The work include the computational simulation of a building energy consumption, life cycle costs of various energy systems, evaluation of a payback of green energy technologies such as solar panels, wind turbines, PV, heat pumps and other high efficiency appliances integrated to buildings. Prediction of annual CO2 emissions, comparing different efficiency options, prediction of the monthly and annual energy consumption. The software used TAS, IES, TRNSYS.

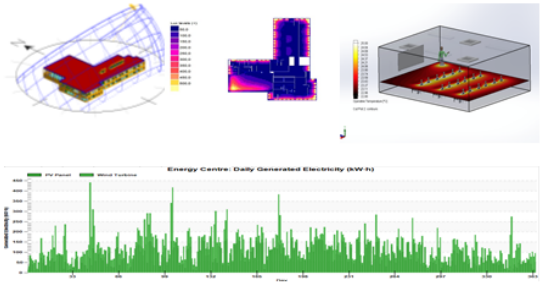

Fig.2 Energy consumption modelling

Two-dimensional heat transfer analysis

Two dimensional conduction heat-transfer analysis methodology based on the finite element method models the complicated geometries if building elements to assess the thermal bridges, estimate the surface temperatures, calculation of heat losses, optimization of insulation, analysis of window frames. Used software THERM (LBNL).

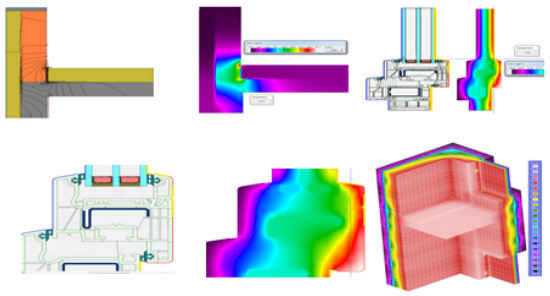

Fig.3 Heat transfer analysis

Thermal comfort measurements

The researchers perform the studies on microclimate in buildings and inspect parameters like CO2 level, radon level, air temperature, air speed, relative humidity and noise levels measurement. The necessary equipment is available at the laboratory.

Fig.4 Microclimate measurements

Studying thermal and physical properties of construction materials

The study focuses on thermal performance of insulation materials. Also includes the temperature and humidity measurements of materials, and calculations.

Fig.5 Laboratory equipment

FUNDED PROJECTS

- Study and development of technologies of renewable energy and smart grids for implementation in Kazakhstan (Ministry of Education and Science of RK, 2011-2013)
- Research on interconnected wind turbines with intelligent control (MES RK, 2011-2013)
- Hybrid energy generation with pumped hydro storage (2012-2013)
- Design of control systems of renewable power sources (Parasat, 2013)
- Integration, automation and control of renewable energy resources (MES RK, 2014-2016)
- Energy conservation and efficiency improvement in residential sector (MES RK, 2014-2016)
- Assessing the impact of ventilation systems on the concentration of radon in buildings in Kazakhstan (2016-2017)
- Development of a pilot project of energy-efficient dome-shaped dwelling with integrated renewable energy system (Shell, 2016-2017)

Shell

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NAZARBAYEV UNIVERSITY RESEARCH AND INNOVATION SYSTEM

DEVELOPMENT OF A PILOT PROJECT AT NAZARBAYEV UNIVERSITY

PROBLEM STATEMENT

- Private residential buildings in Kazakhstan are not obliged to go through the governmental expertise
- Construction of the low-rise buildings by the households is done as a rule of thumb without any significant knowledge and reference to the existing building codes and other practices and guidelines
- Majority of houses are situated in a distance from sources of thermal and electric energy
- With the development of greater range of different construction materials of overseas and local production and due to the limited and trustable information available on their properties there is a necessity to examine the existing products on the construction market
- Absence of original data on impact of renewable and green technologies on energy supply/consumption
- Development of energy efficient buildings in cold climate, tested solutions

PROJECT MOTIVATION

The Decree of the President of the Republic of Kazakhstan has assumed the concept "On the transition of the Republic of Kazakhstan to "green economy", where the main priority is the introduction of energy-saving technologies and the use of renewable energy sources.

The purpose of the project is to develop an energy-efficient building that maintains its activity autonomously through alternative energy sources: solar energy, wind and geothermal energy; the building also tests the thermal insulation properties of a polyurethane-based insulation.

Upon completion of the construction, this facility will be used as a testing laboratory that measures the thermal characteristics of a house in harsh climatic conditions and conducts evaluation of the effectiveness of renewable energy sources in various modes of operation using different digital meters.

In the future, it is anticipated for the design to be simplified and to enable the selection of precise capacities of autonomous energy sources in order to make it mobile for the possibility of erecting similar structures in remote from an urban infrastructure areas.

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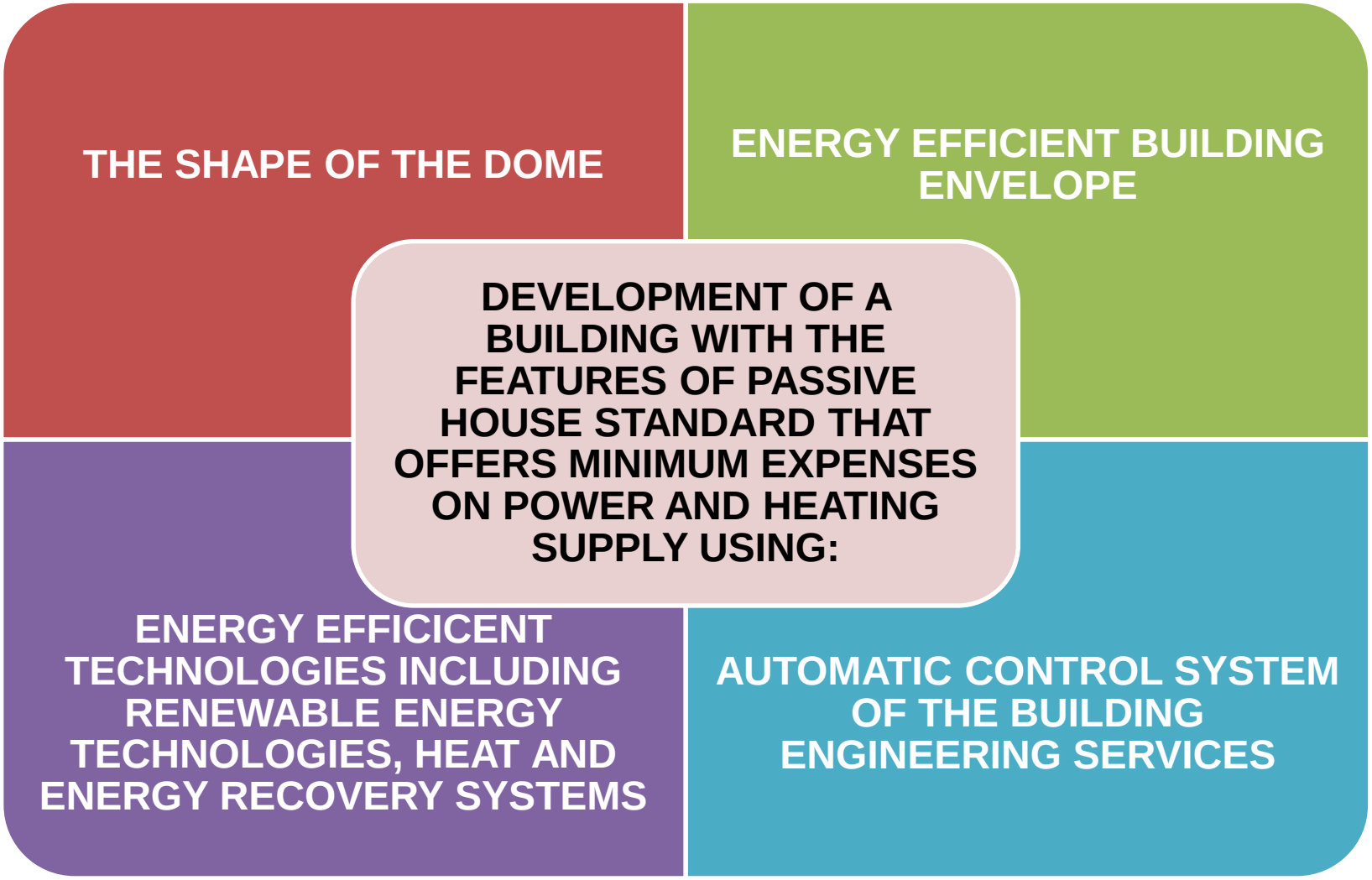
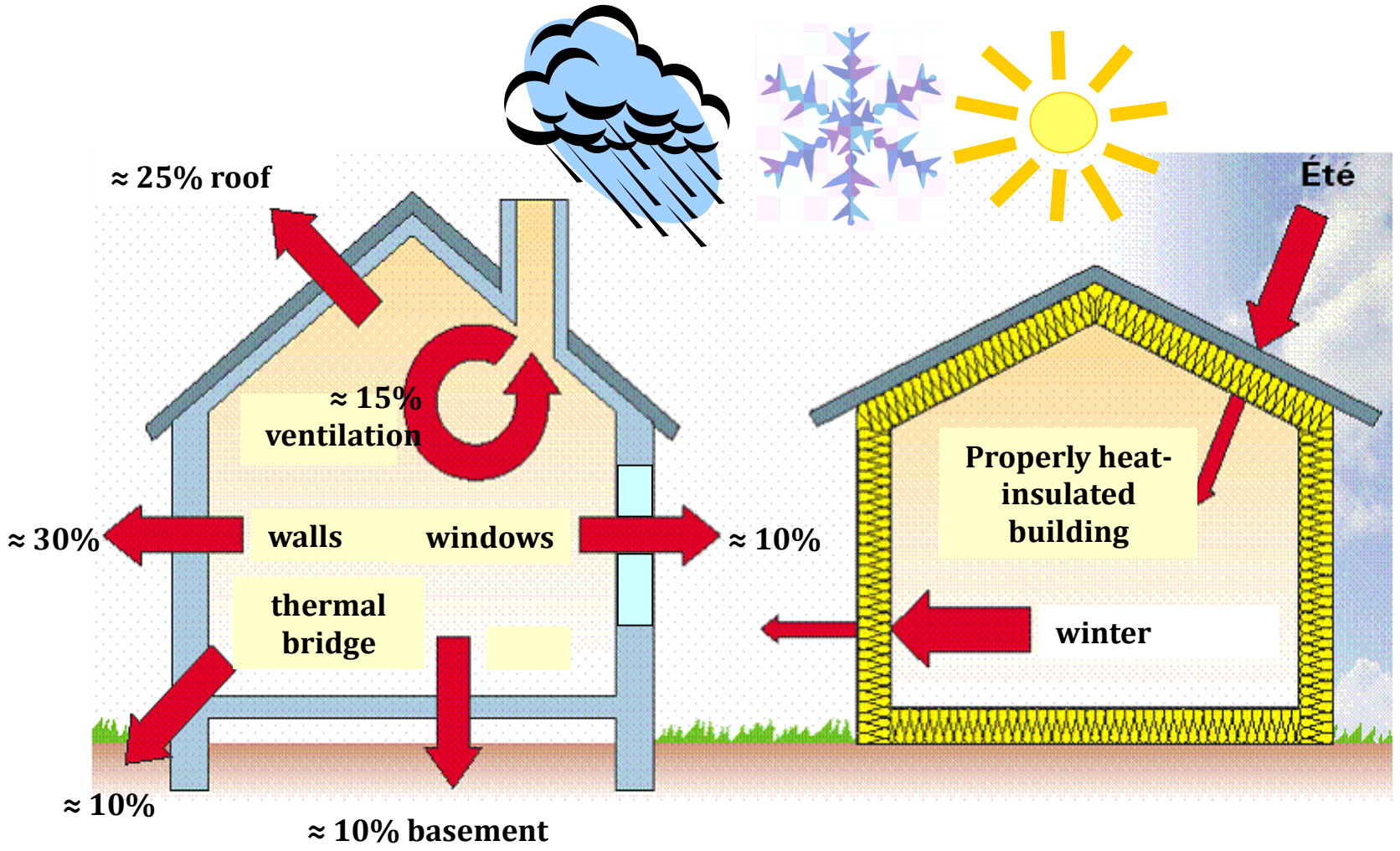
THE PROJECT CONCEPT



HEAT LOSSES IN BUILDINGS



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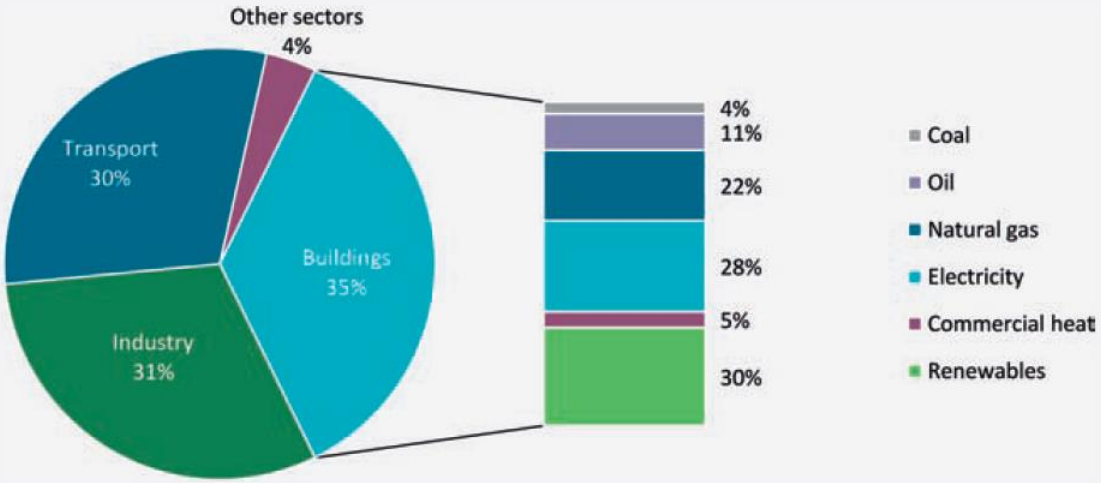
BUILDING SECTOR

Figure 1.1 Final energy consumption by sector and buildings energy mix, 2010



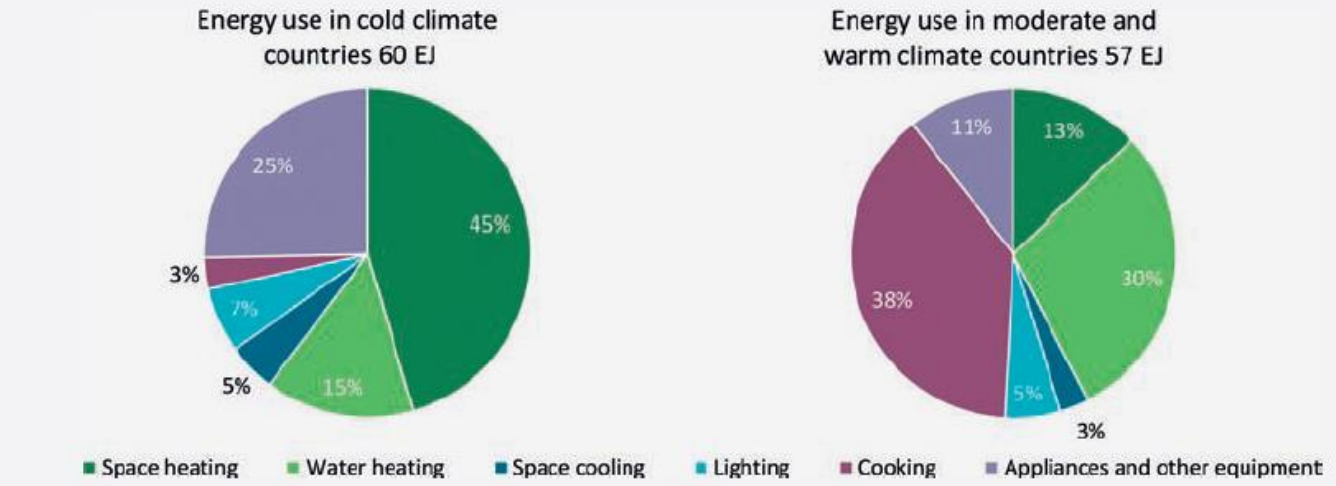
Notes: final energy consumption excludes non-energy use. Other sectors include agriculture, forestry, fishing and other non-specified.
Source: unless otherwise noted, all tables and figure in this chapter are derived from IEA data and analysis.

Key point *Buildings are a major end-use in global energy markets and need to be a strong component of any country's plan to save energy.*

Source: IEA, 2013

BUILDING ENERGY USE

Figure 1.6 Buildings end-use energy consumption, 2010



Notes: EJ = exajoule. Cold climate countries comprise OECD countries excluding Australia, Mexico, New Zealand and Israel, and non-OECD Europe and Eurasia. The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD and/or the IEA is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Key point *About 70% of buildings energy consumption is for space heating and appliances in cold climates, and for water heating and cooking in moderate and warm climates.*

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THE CONCEPT OF PASSIVE HOUSE

The Passive house – is a world leading low-energy construction standard that is designed to provide comfortable conditions for people to live with the minimal negative impact on the environment.

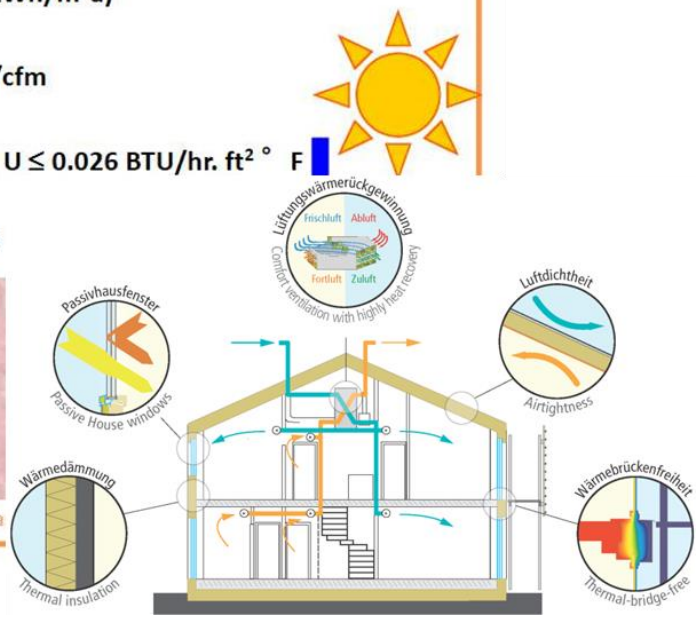
Passive house criteria as follows:

PHIUS
Passive House Institute US

Passive House Criteria

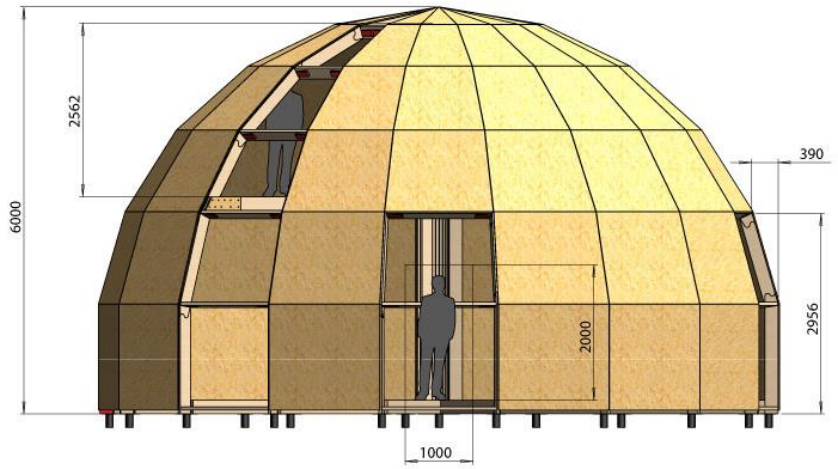
Annual Heat Demand	≤ 4.75 kBTU/ft²yr (15 kWh/m²a)
Peak Heat Load	≤ 3.17 BTU/hr.ft² (10 W/m²)
Cooling Demand	≤ 4.75 kBTU/ft²yr (15 kWh/m²a)
Peak Cooling Load	≤ 2.54 BTU/hr.ft² (8 W/m²)
Primary Energy Demand	≤ 38 kBTU/ft²yr (120 kWh/m²a)
Airtightness	≤ 0.6 ACH_{50}
Ventilation	≥75% Recovery, ≥0.76 W/cfm
Thermal Envelope*:	R ≥ 38.5 hr. ft² ° F/BTU, U ≤ 0.026 BTU/hr. ft² ° F
Thermal-bridge Free	Ψ ≤ .006 BTU/ hr. ft ° F
Windows installed*:	$U_{w\text{-}install}$ ≤ 0.15 BTU/hr. ft²
SHGC 50 – 55 %*	

*Note: Window and Thermal envelope criteria Listed are for a Central European Climate. Recommendations for these values vary In N America based on climate

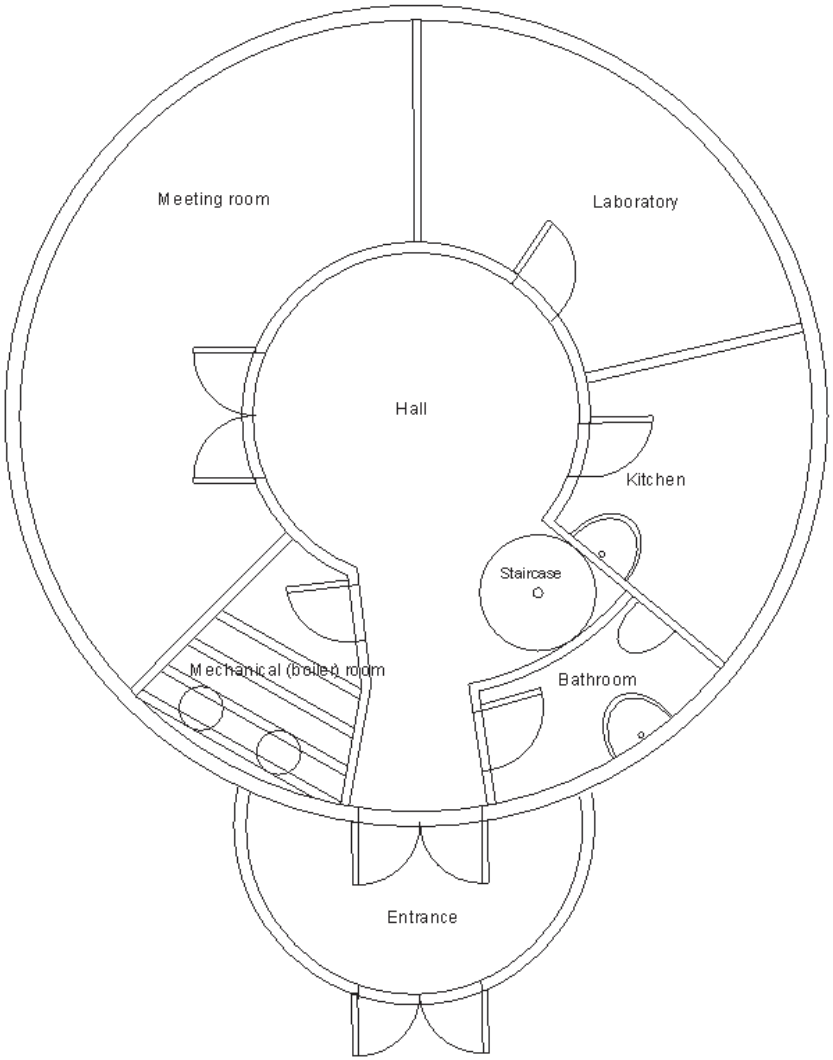


BUILDING'S PLAN AND DIMENSIONS

The main dimension of the building



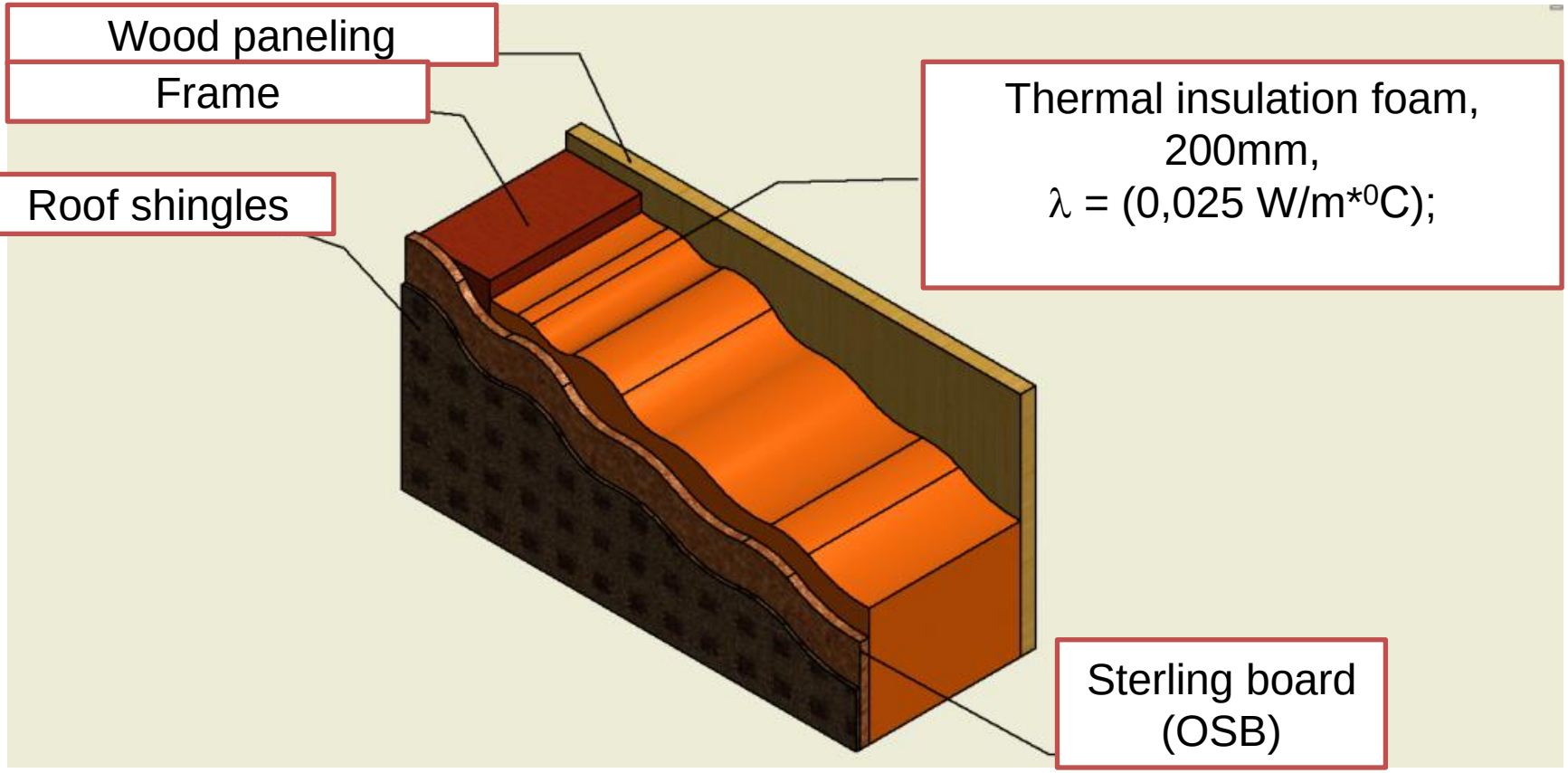
Plan



Specification

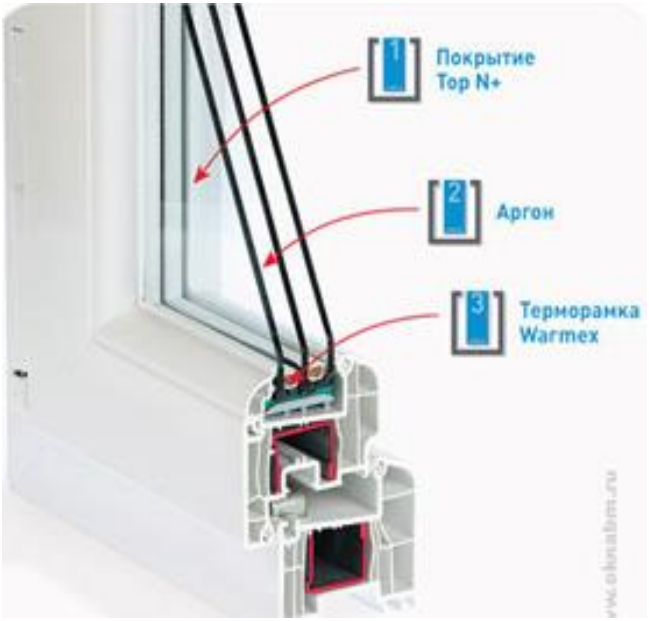
Total area, sq.m……..…115
Number of floors……..2
Number of rooms……5
Building diameter, m……10
Building height, m……6
Foundation……pile type
Utilities system……water,
power, drainage

BUILDING ENVELOPE STRUCTURE



TRANSLUSCENT BUILDING ENVELOPE

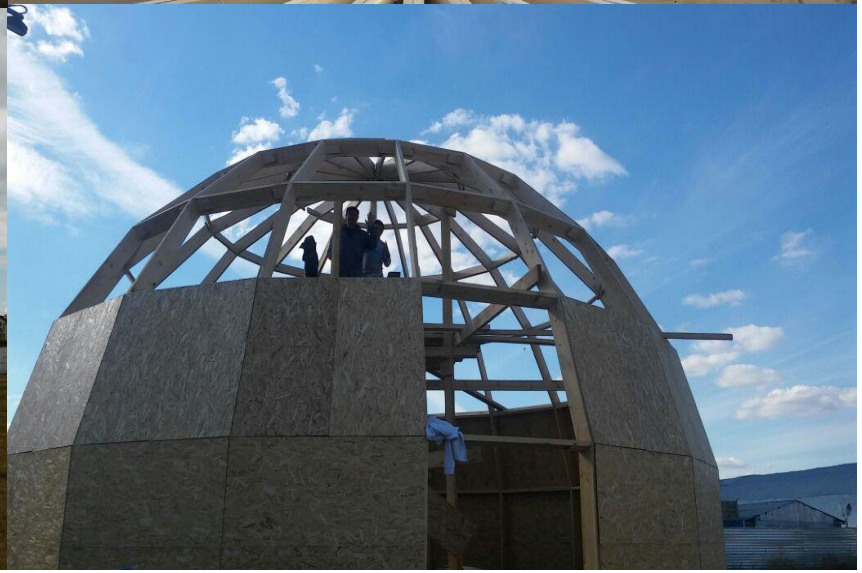
Energy efficient window



Roller blinds

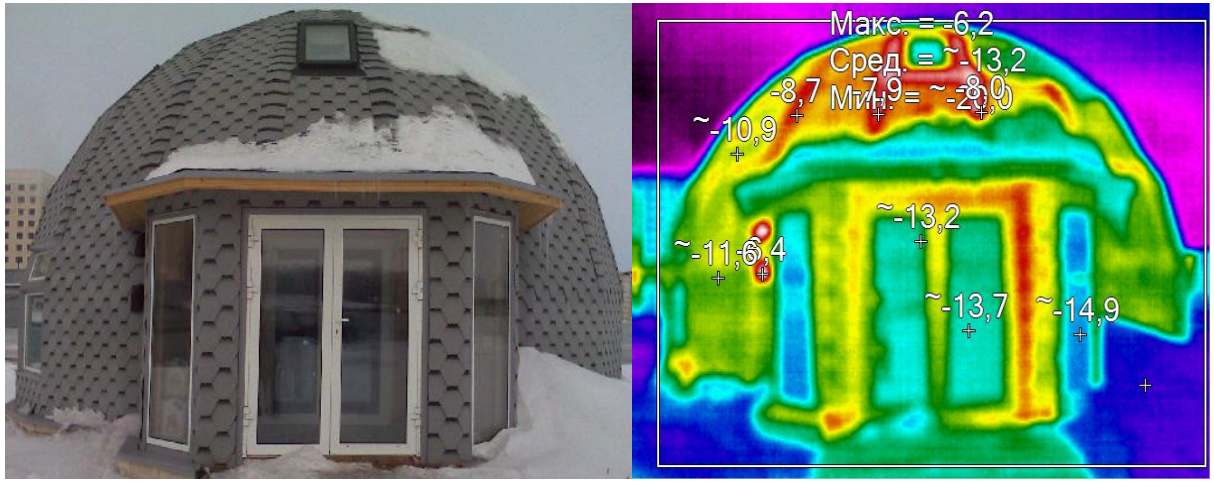
- Argon-filled triple-pane window 40mm (4M1-16Ar-И4), reduced thermal resistance coefficient R~0,4;
- Availability of energy-saving internal low-emission I-glass of the brand Top-N (heat remains inside due to reflection of infrared radiation back into the room);
- Filling the internal chambers of the insulating glass with inert gas argon (Argon (Ar) increases the reflective heat-shielding function of the energy-saving glass)

CONSTRUCTION PHASE

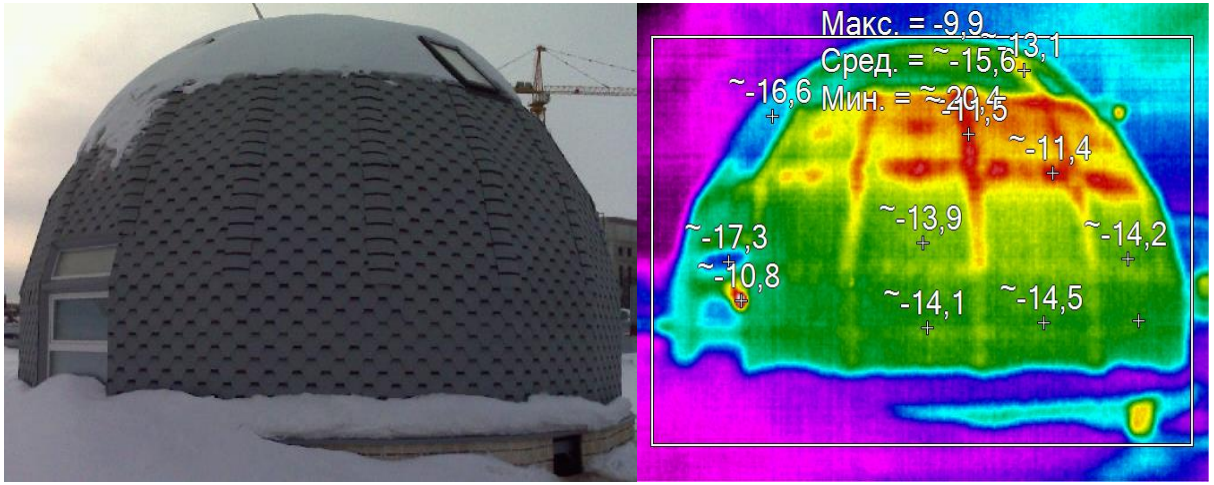


CONSTRUCTION PHASE

IR THERMAL IMAGING OF THE DOME HOUSE



Point of measurement	Temperature	Outside temperature
P0	-8,7°C	-13,0°C
P1	-7,9°C	
P2	-8,0°C	
P3	-6,4°C	
P4	-11,6°C	
P5	-13,7°C	
P6	-14,9°C	
P7	-10,9°C	



Point of measurement	Temperature	Outside temperature
P0	-17,3°C	-13,0°C
P1	-10,8°C	
P2	-11,5°C	
P3	-11,4°C	
P4	-14,2°C	
P5	-14,5°C	
P6	-16,6°C	
P7	-14,1°C	
P8	-13,1°C	

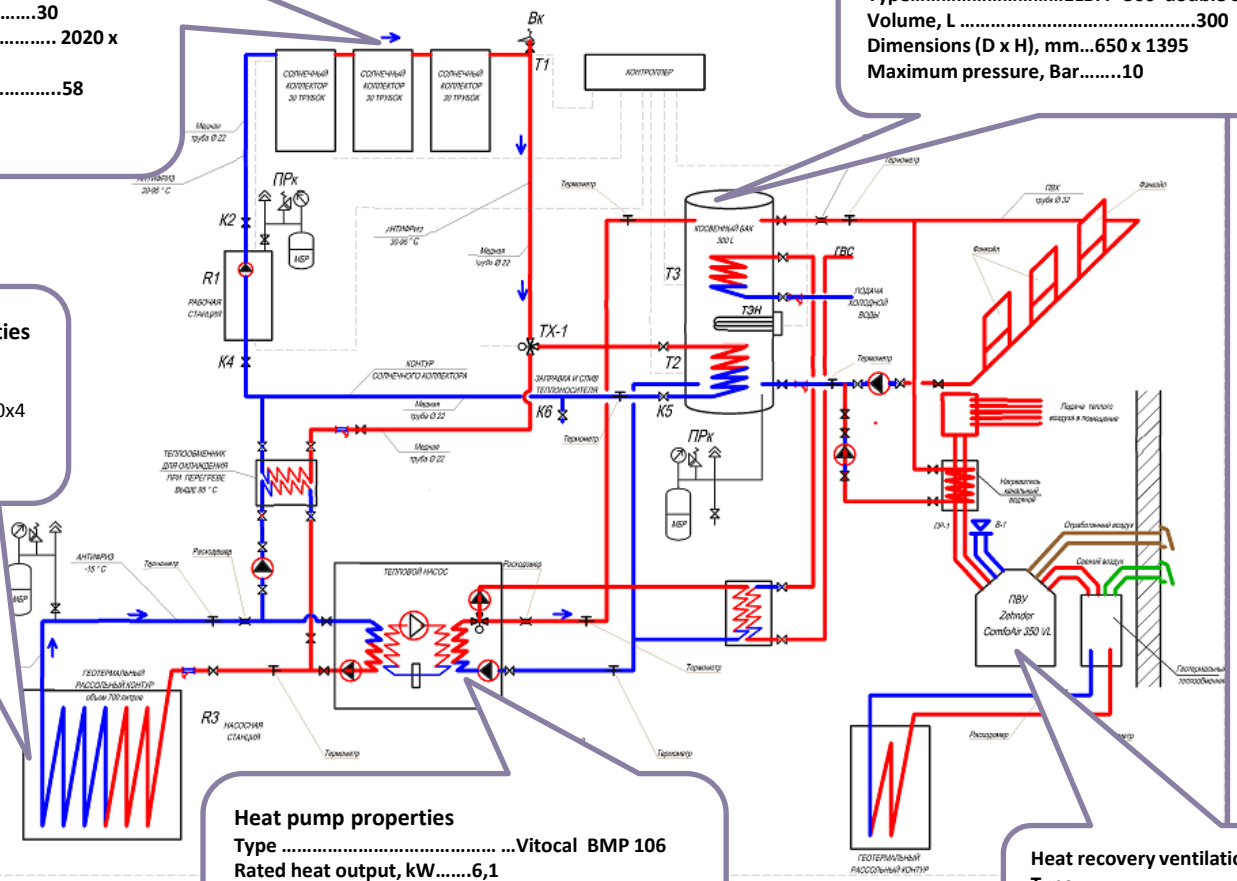
THE USE OF RENEWABLE ENERGY FOR HEAT SUPPLY

Heat supply scheme

Solar thermal collector specification
Type of vacuum collector……SR-30
Number of vacuum tubes, units……30
Collector dimensions, mm…… 2020 x 2420 x 2355 x 123
Diameter of tubes, mm……58
Daily output (50°C), L…..280-300
Maximum pressure, Bar….5,8

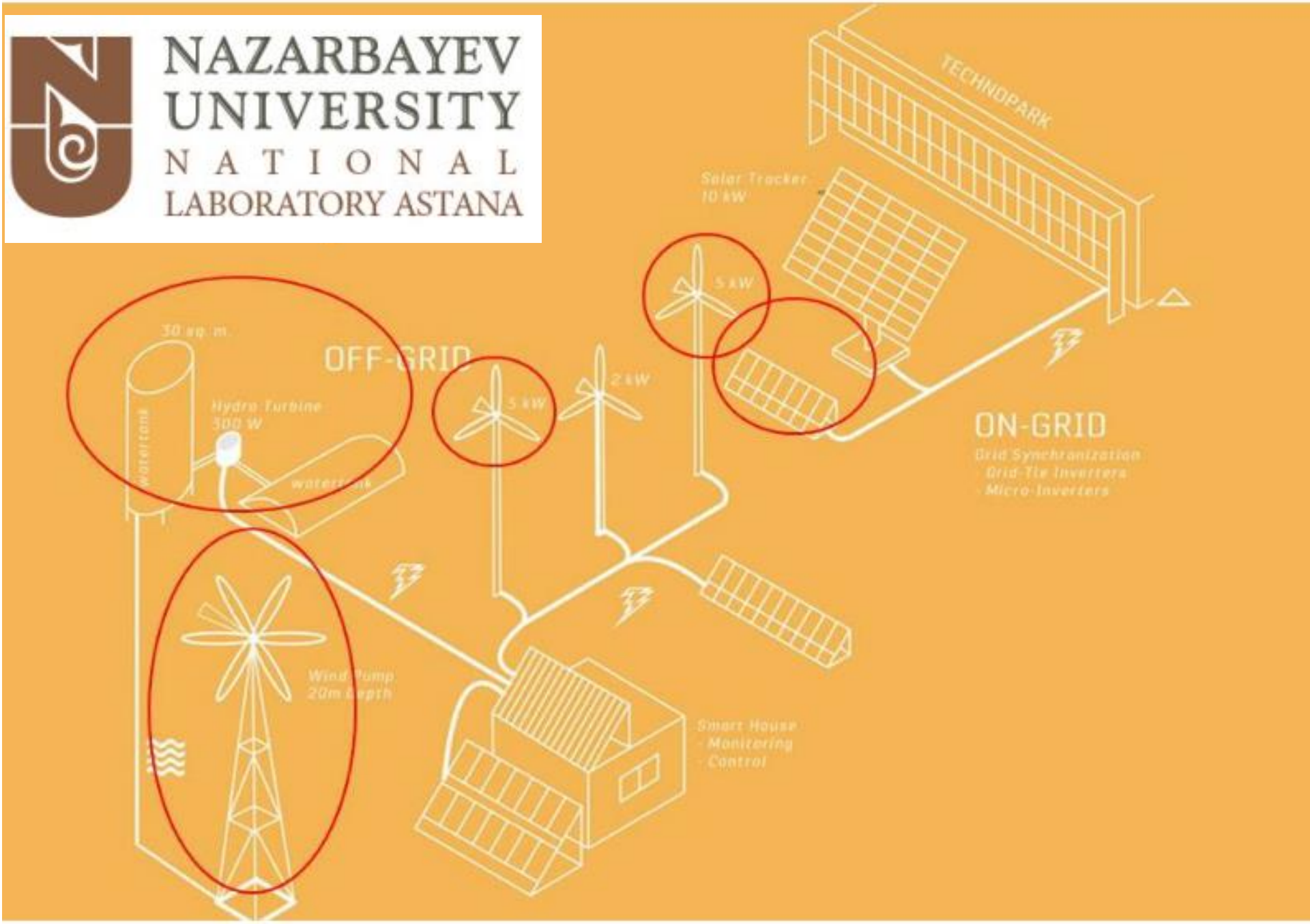
Water tank properties
Type……ELBI P-300 double circuit
Volume, L ……300
Dimensions (D x H), mm…650 x 1395
Maximum pressure, Bar……10

Vertical heat exchanger properties
Number of wells, units……4
Depth, m……40
Length of the heat exchanger,m……40x4
Well filler - salt brine



Heat pump properties
Type …… …Vitocal BMP 106
Rated heat output, kW…….6,1
Rated cooling capacity, kW……..4,7
Max.power consumption……1,4
Dimensions, mm…… 720 x 600 x 1145
Working pressure, Bar……4

Heat recovery ventilation properties
Type ……ComfortAir 350 Luxe
Flow rate, m3/h……50-350
Dimensions, mm…… 800 x 625 x 572
Pressure, Bar……0-0,00225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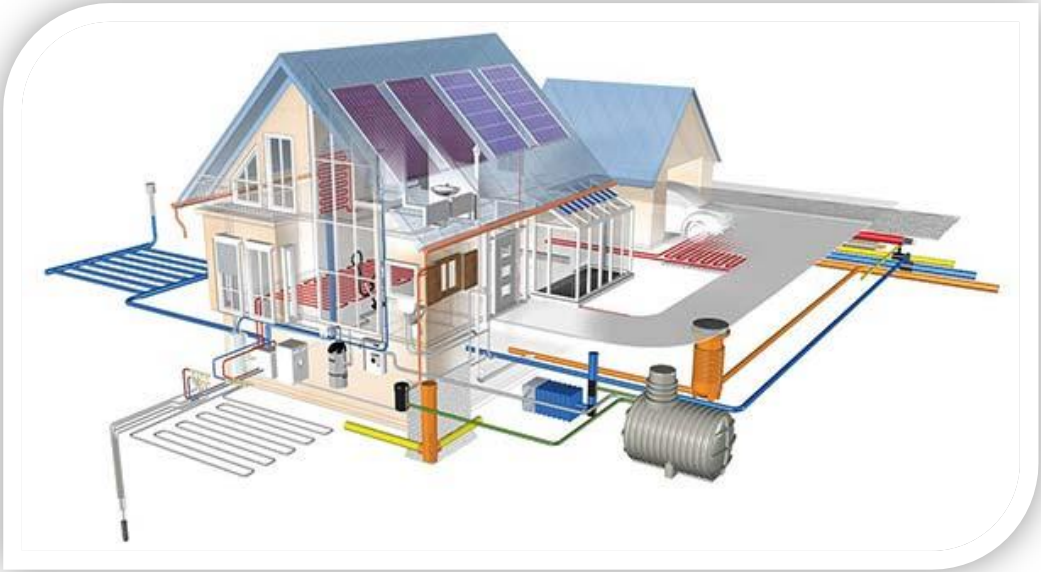
TECHNOPARK
Solar Tracker
10 kW
5 kW
30 sq. m.
OFF-GRID
Hydro Turbine
300 W
5 kW
2 kW
ON-GRID
Grid Synchronization
Grid-Tie Inverters
Micro-Inverters
Wind Pump
20m Depth
Smart House
Monitoring
Control

AUTOMATIC CONTROL SYSTEM OF ENGINEERING SERVICES

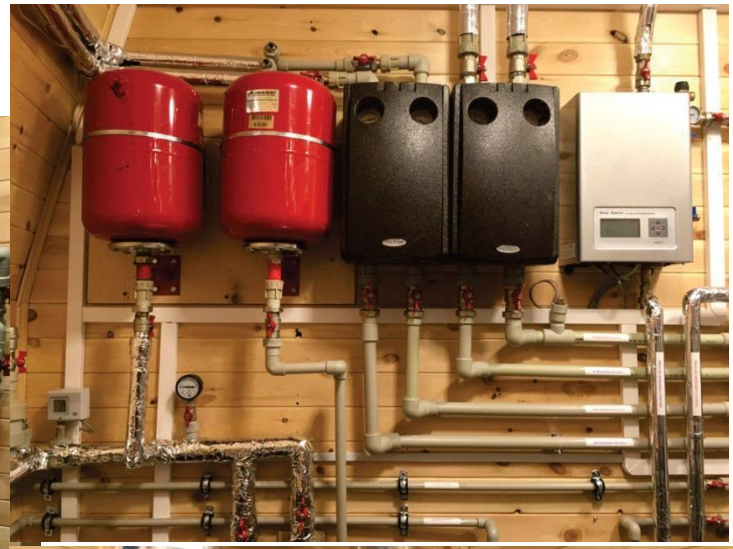
EFFECTIVE ENGINEERING SYSTEM

AUTOMATIC CONTROL SYSTEM OF ENGINEERING SERVICES



- ENERGY EFFICIENT HEATING AND WATER SUPPLY
- ENERGY EFFICIENT VENTILATION AND AIR CONDITIONING
- ENERGY EFFICIENT POWER SUPPLY
- WATER SUPPLY AND WATER DISPOSAL

INTERIOR DESIGN



LOOKING TO THE FUTURE

The plan is to develop a new facility which will support innovation in not only energy efficiency but at smart homes, new materials and new building techniques and bring together companies, research partners and local government to extend understanding of building performance.