Consulting · Engineering · Implementation

GREEN SCHOOL ENERGY MODELLING & CAPACITY BUILDING IN MONGOLIA

UNITED NATIONS ENVIRONMENTAL PROGRAMME

Green School Energy Model and Energy Efficiency Report

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ABBREVIATIONS

ASHRAE - American Society of Heating, Refrigerating, and Air - Conditioning Engineers
BSRIA - Building Services Research and Information Association
CAPEX – Capital Expenditure
CIBSE - Chartered Institution of Building Services Engineers
CO_2 - Carbon Dioxide
COP - Coefficient of Performance
dwg - From drawing
EMO - Energy Model
GDP - Green Development Policy
HVAC - Heating Ventilation and Air Conditioning
IWEC - International Weather for Energy Calculations
LED - Light emitting diode
MEGDT - Ministry of Environment, Green Development, and Tourism
NAP - National Architectural Project
PAGE - The Partnership for Action on Green Economy
2D - Two dimensional
3D - Three dimensional

UNITS

K - Kelvin
m - Meter
m^2 – meter square
s - Second
W - Watt

EXECUTIVE SUMMARY

The Government of Mongolia is committed in developing a green economy that will support in creating new jobs in a new sector, reduce poverty levels, and reduce pollution levels and environmental impact. Mongolia was the first country joining PAGE in 2013 and is leading the way in reframing its economic policies around sustainability.

In 2014, the Parliament of Mongolia approved the Green Development Policy (GDP). The objective of the GDP is the support of green development in Mongolia. The GDP has determined goals and objectives for green development up to 2030 and outlines actions to ensure these goals are achieved. The PAGE partnership in Mongolia has directly linked the development and implementation of the GDP, by providing technical support, fostering political commitment, and modelling economic, social and environmental implications of GDP targets. The partnership advances policy development and reform in specific sectors and thematic areas, such as green construction and sustainable public procurement.

The purpose of this project is to develop an energy model of a green school blueprint using computational dynamic thermal modelling. This software provides a detailed analysis of the building predicted energy consumption over a complete weather year and allows to assess potential areas of improvement. The results from this assessment could be utilized as a reference for the next green schools that will be constructed, hence the lessons learnt and recommendations highlighted in the Blue Print Green School would be disseminated and could be implemented for the new green schools to be developed. It has to be noted that model inputs are based on information provided by the different stakeholders mainly NAP and MEGDT.

Furthermore 5 day training will be undertaken enhancing the capabilities of relevant Mongolian staff related to the construction and policy sector.

1 INTRODUCTION

Energy Modelling is a method of creating a virtual replica of a building structure and simulating (virtually replicating) the energy interactions within this building in order to evaluate energy consumption and find out ways to ensure higher energy efficiency. In this process, the weather conditions that a building withstands all through the year are taken into consideration. For energy modelling between other following input information is needed:

- Details of building envelope (e.g. size, function, type, materials): here the modeller specifies the different properties of the building envelope. This information will help to understand the energy needs in the building.
- Occupancy schedules: It defines how the building is being used. Here the modeller specifies number of people in each zones and occupancy profile (people/m^2).Also the modeller specifies the time when the building is being used (like 9am to 6 pm).
- Equipment loads: It basically defines what are the different equipment being used like computers, printers, etc. Based on the equipment loads the modelling tool will analyse what will be the energy consumption in the different zones.
- Site location (e.g. climate data for the area, surrounding landscape): Here the weather data has to be defined on which the analysis will be carried out.

Building simulation helps quantify the amount of energy consumed and the energy model to be developed for the Green school will allow between others:

- Predict monthly and annual energy consumption and the resulting energy bills based on the information provided by the client
- Predict amount of CO_2 emissions of a building and device solutions to lower carbon footprints
- A detailed comparative analysis of different efficiency options (lighting, insulation, building management, etc.)
- Analyse and quantify the lifecycle payback of various energy efficiency measures.

The results within this report are based on a set of pre-agreed input information for the different spaces and systems within the school development, therefore upon the building completion, the information could be significantly different to those that are currently assessed, and as such the results detailed within this document could be impacted.

2 METHODOLGY

The purpose of this work is to develop a model of a green school blueprint using computational dynamic thermal modelling software to carry out detailed analysis of the building predicted energy consumption over a complete weather year. The main focus will be towards development of energy efficient design and use of low carbon energy technologies in order to achieve a reduction in the building energy consumption and at the same time reduce yearly running costs.

Energy Modelling of the building was carried out using dynamic energy modelling software DesignBuilder v4.7.0. It is tested ASHRAE 140 standard energy-modelling software able to perform 8,760-hour whole building simulation. The geometry of the school was generated using the drawings, system information and information available from NAP Group. Based on the 2D drawing (dwg format) a full three dimensional thermal model was created to represent the development. All design inputs were based on the agreed model inputs provided by NAP. The weather file used was the Energy Plus weather file (ASHRAE/IWEC) “Ulaanbaatar 442920 (IWEC)”.

2.1 Weather Data

The first step for creating a building model is to understand the weather conditions of the building location. This is performed by analysing the hourly weather data (for 8760 hours) of the location looking at the hourly data of dry bulb and wet bulb temperatures, humidity, solar radiation (diffused, global and direct), wind speed &direction etc. DesignBuilder has ASHRAE IWEC weather files for around 42 locations in Mongolia. Weather file “Ulaanbaatar 442920 (IWEC)” was utilized for the analysis.

Yearly weather data for Ulaanbataar, showing temperatures and solar radiation can be seen in Figure 1.

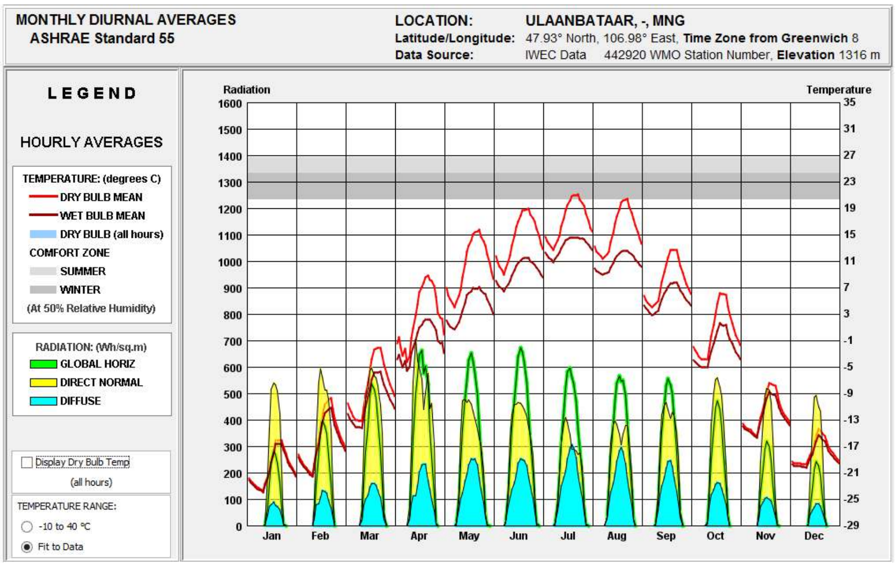


Figure 1: Yearly weather data for Ulaanbataar, Mongolia

2.2 Layout

A 3D model for the school was built in DesignBuilder based on the 2D AutoCAD drawing file provided by NAP including the plan and elevation of the building on 18th March 2016 after the inception meeting. A graphical representation of the model can be seen in

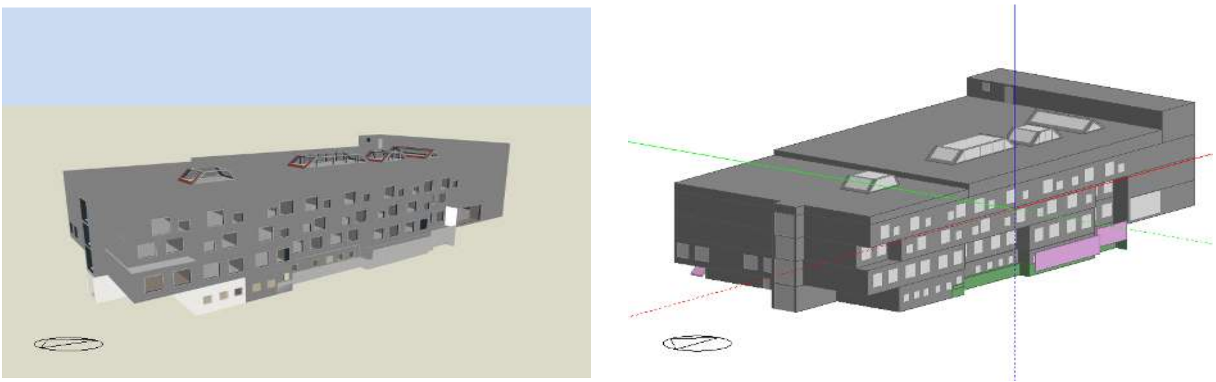


Figure 2.

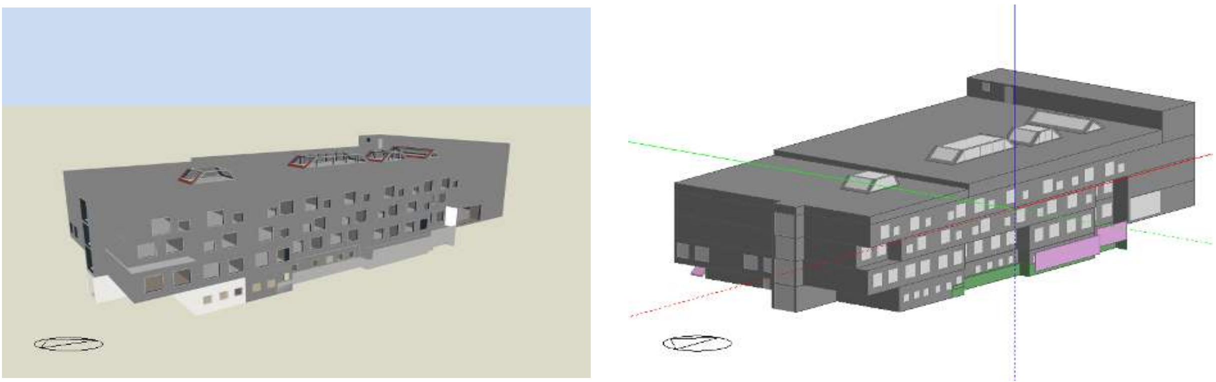


Figure 2: DesignBuilder model of the school

2.3 Zoning

The building has been zoned according to room use types and activities assigned to them based on the details provided in Annexure 1.

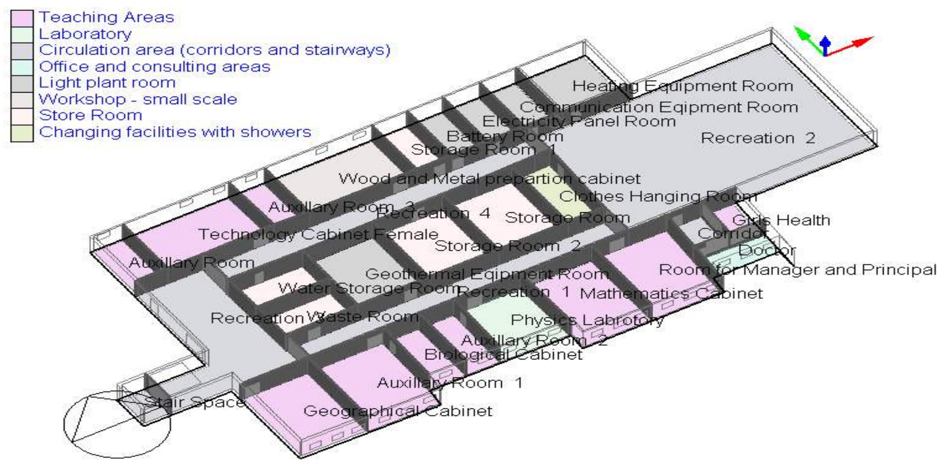


Figure 3: Basement

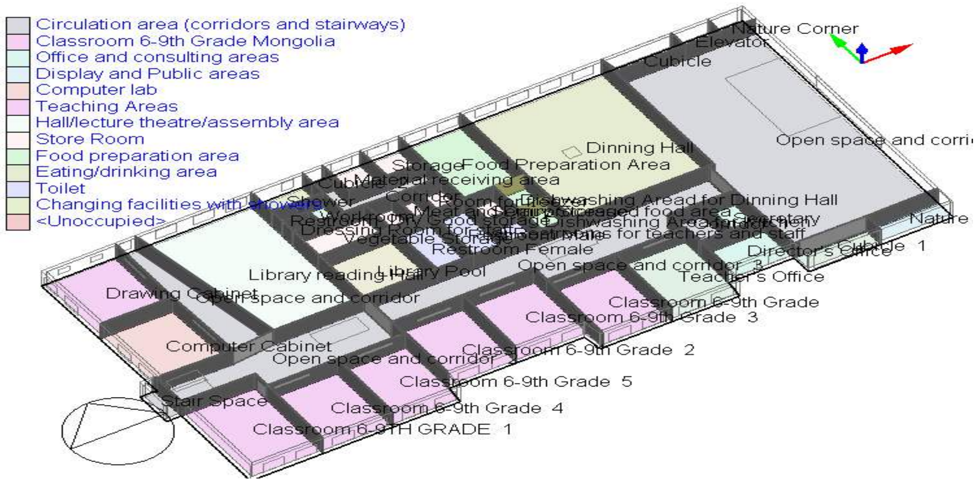


Figure 4: First floor

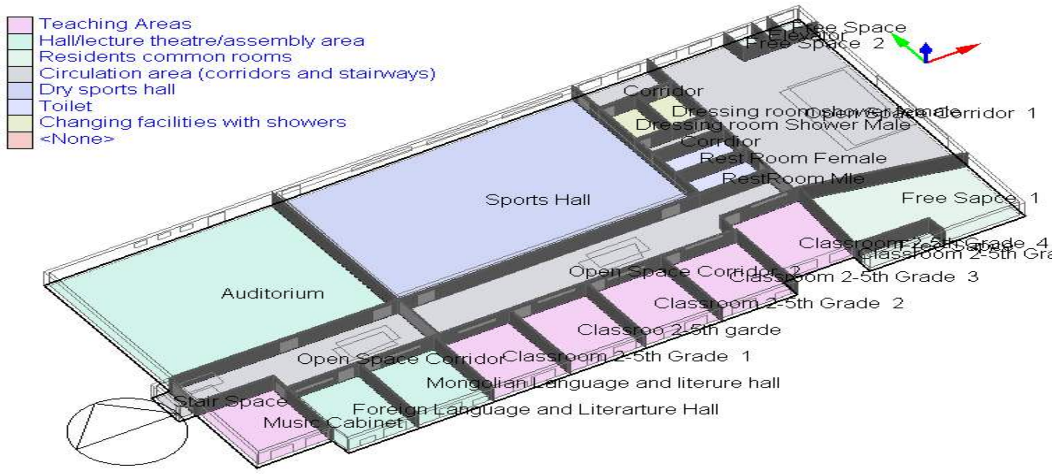


Figure 5: Second Floor

Figure 6: Third Floor

2.4 Construction Parameters

Table 1 gives the U values of the various construction elements applied to the building.

	U-Value (W/m2K)
External Doors	1.1
Internal Doors	1.5
Internal Partition (Wall 10, 11,12)	1.2,1.8,2.2
Internal Floors	1.92
Ground Floors	0.421
External Floors	0. 421
Roof	0.18

Table 1: Construction Parameters

Table 2 provides the details of the glazing and facades applied in the building.

Windows	Glass U-Value (W/m2K)	G-Value (EN 410) / Shading Coefficient	Light Transmittance (%)	Frame Factor (%)	Openable (YES/NO)	Frame U-Value (W/m2K)	Thermal Linear transmit (W/m K)	Window U value (W/m2K)
Window	1.2	0.52	67%	26.00%	YES	3.5	0.08	1.98
Glazed facades	1.2	0.52	67%	14.00%	NO	3.5	0.08	1.61

Rooflight	1.2	0.52	67%	30.00%	YES	3.5	0.08	2.18

Table 2: Glazing Properties

At the given project stage no detailed information could be provided regarding the glazing specifications an assumption had to be made. Using Pilkington glass manufacturer software, a double glass panel was modelled 6+16+6 (mm), with Argon filling and Planitherm S treatment to improve U value. The obtained thermal performance results were utilised to model the windows, rooflights and glazed facades.

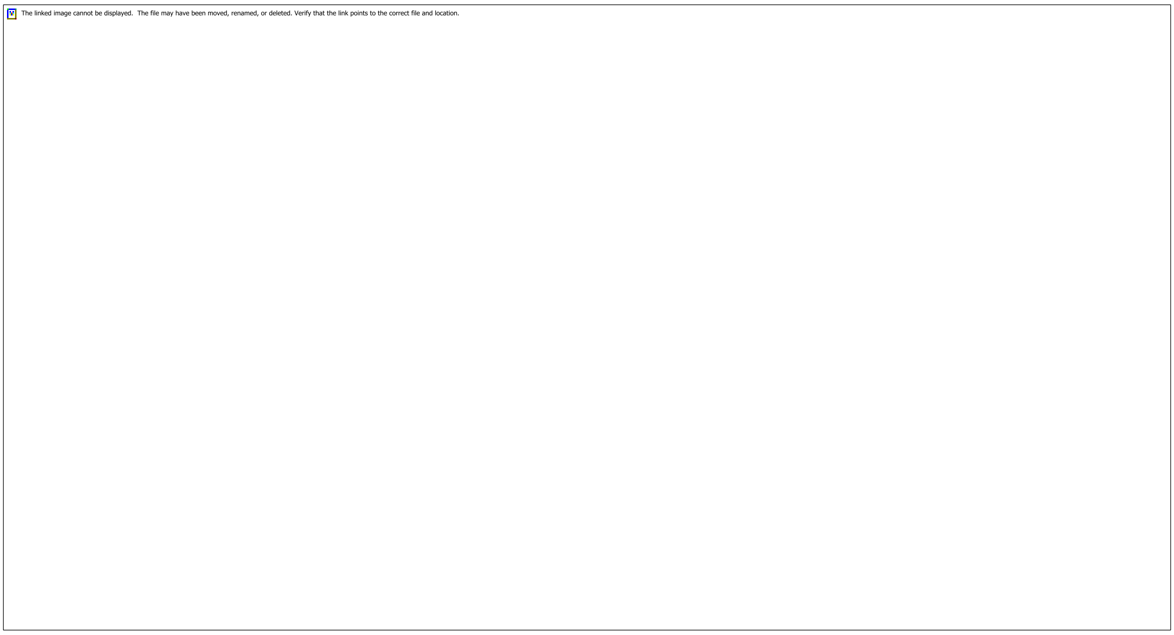


Figure 7: Pilkington Double Glass

2.5 Building Service Parameters

Table 3 describes the building service parameters applied to the building regarding permeability, ventilation and boiler specifications.

Air permeability @ 50 Pascal	9 $m^3/h/m^2$
Heating System	Coal Boiler
Mechanical Ventilation System	Heat Pump
Mechanical Ventilation System seasonal efficiency	2.5
Boiler Efficiency	80%
Ventilation heat recovery efficiency	65%
Specific fan power (supply and extract)	3 W/l/s
Specific fan power (supply)	2
Specific fan power (extract)	1

Table 3: Building Service parameters used

Based on NAP's information following considerations were taken for the heating system design were:

- The heating system operates between the 1^{th} October and 10^{th} May
- Heating system operates from Monday to Saturday (Note: Saturday the school is empty but the Auditorium, Library and Gym are open).
- The heating system is set up in a way that in cannot be switched off per zones. Thus on Saturday even if only Auditorium, Library and Gym are occupied the heating is still active for all the other areas.
- The heating is off on Sundays, the heating only gets active if temperature drops below 12^{0}C temperature.
- Between 18:00 and Midnight the set point is 12^{0}C to avoid condensation problems in the rooms.
- Between Midnight and 5am the set point is 12^{0}C to avoid condensation problems in the rooms.
- Between 5am and 8am the rooms are heated up from 12^{0}C to their respective heating set points for the rooms.

Similarly throughout the building there will use of LED lights for internal lighting without control strategy.

2.6 Heating - Set points

The HVAC Engineer from NAP provided the heating set points for the different zones (see Table 4). The following can be should be highlighted:

- A considerable percentage of the zone types are unheated (represents more than 20% of the floor area).
- The heating set point ranges typically between 16^{0}C and 20^{0}C.

Room type	Heating Air Temperature Setpoint (^{0}C)
Open space corridor	16
Library reading hall	16 - 18
Library pool	16 - 18
Kitchen and food preparation	16 - 18
Workroom	16 - 18
Music cabinet	16 - 18
Auditorium	16 - 18
Sports Hall	16 - 18
Cubicle	18 - 20
Doctor	18 - 20

Room type	Heating Air Temperature Setpoint (^{0}C)
Computer cabinet	18 - 20
Drawing cabinet	18 - 20
Restroom	18 - 20
Mongolian language and literature cabinet	18 - 20
Foreign Language and literature cabinet	18 - 20
Corner rooms	20-21
Clother hanging room	Unheated
Corridor	Unheated
Water storage room	Unheated
Waste room	Unheated

Girls Health	18 - 20	Geothermal equipment room	Unheated
Room for Manager and principal	18 - 20	Storage room	Unheated
Mathematics cabinet	18 - 20	Battery room	Unheated
Physics laboratory	18 - 20	Electricity panel room	Unheated
Auxiliary room	18 - 20	Communication equipment room	Unheated
Biological cabinet	18 - 20	Heating Equipment room	Unheated
Geography cabinet	18 - 20	Stairs	Unheated
Technology Cabinet	18 - 20	Dishwashing area	Unheated
Wood and metal preparation cabinet	18 - 20	Room for freezer	Unheated
Lobby	18 - 20	Meal and daily storage	Unheated
Nature corner	18 - 20	Dry good storage	Unheated
Dinning Hall	18 - 20	Vegetable storage	Unheated
Directors office	18 - 20	Material receiving area	Unheated
Secretary	18 - 20	Dressing room	Unheated
Teachers office	18 - 20	Elevator	Unheated
Classroom	18 - 20	Hot water	70

Table 4: Zones Heating Set Points

2.7 Activity Templates

The different activity templates for each zone in the building were provided by NAP which can be seen in Annexure 1. In some of the zones where the templates were missing ASHRAE, BSRIA or CIBSE standard values for occupancy, lighting gain and equipment gain were taken.

2.7.1 Schedules& Internal gains

A compact schedule was created in DesignBuilder for the occupancy hours of the school. The occupancy schedule was created based on the following assumptions:

- Building will be occupied from 8 am in morning to 18:10 pm in the evening from Monday to Saturday. Except for the Library, Gym and Auditorium that is occupied as well on Saturdays.
- The building will be empty from the 15thMay 15thSeptember.
- The building will be empty from the 15th December to the 15th January
- During the occupied hours building’s occupancy will be 100%, with a 75% diversification factor.

Similarly schedules for lighting, heating and equipment were also created in DesignBuilder. Some of the information for certain zones were not provided by NAP. For these cases the ASHRAE, BSRIA and CIBSE values for the zones were taken.

On the other hand the internal gain information provided for various zones were extremely high and even above any typical value seen for other schools or building of similar characteristics.

For example equipment gain for kitchen and food preparation area was 2080 W/m^2 (value provided by NAP). Hence various adjustments had to be made in order to have more realistic values for what is a typical educational building. Some of the adjusted figures were obtained from ASHRAE, BSRIA and CIBSE standards, the final model inputs for internal gains are shown in Annexure 2.

3 BASELINE ENERGY MODEL

The Green School geometry, orientation and shape already provide an indication of the building thermal dynamic. The thermal envelope totals 2836 m^2 and it can be observed from Table 5 that the South façade has a Window to Wall ratio of 30%. Furthermore a high percentage of the classrooms are located on the South side of the building being exposed to the solar gains from mid-morning to the mid-afternoon (see Figure 8), that coincides with the building occupancy periods. This will be fundamental in terms of space heating savings as the solar gains offset part of the heating needs on the other handsome overheating risks could take place on the warmer months. Nevertheless in the summer months the building will not be occupied based on the clients information.

On the other hand North facing zones such as the dining hall, library, cabinets, etc. will not benefit from the solar gains as is the case for the South façades. However the periods of occupancy of these type of areas is smaller compared to Classroom, not benefiting as much from the solar gains.

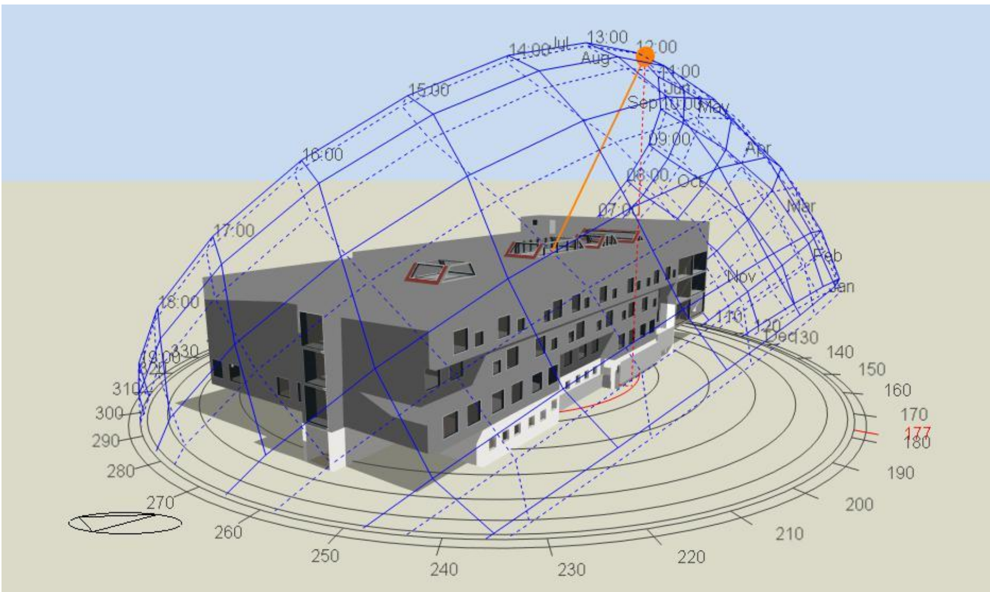


Figure 8: Green Building Sun Path Diagram

	Total	North	East	South	West
Gross Wall Area [m2]	2836	917	505	910	504
Above Ground Wall Area [m2]	2684	822	499	863	500
Window Opening Area [m2]	575	174	72	277	53

Gross Window-Wall Ratio [%]	20	19	14	30	10
Above Ground Window-Wall Ratio [%]	21	21	14	32	11

Table 5: Green School Window Ratios and Thermal Envelope Areas

3.1.1 Construction Material Specifications

The thermal elements and envelope specifications were provided by NAP. This included U values for windows, rooflights, doors, external/internal walls, roof and ground floor. The thermal elements and window data is summarised in the Table 6 below.

Thermal Element	U-Value (W/m2K)	Layer description
External Wall	0.211	See architectural drawing
Roof	0.180	
Ground Floor	0.421	
External Doors	1.1	
Internal Doors	1.5	

Windows	Glass U-Value (W/m2K)	G-Value (EN 410)	Light Transmitance (%)	Frame Factor (%)	Openable? (YES/NO)	Window U value (W/m^2K)
Window	1.2	0.52	67	26	YES	1.98
Glazed facades	1.2	0.52	67	14	NO	1.61
Rooflight	1.2	0.52	67	30	YES	2.18

Table 6: Construction material Specification

3.1.2 Seasonal Heating Efficiency & Air Permeability

The seasonal heating efficiency of the system was provided by NAP and estimated as 80% and the ground source heat pump for preheating purposes for ventilation application has a seasonal efficiency of COP 2.5.

On the other hand the air permeability of the building was defined as $9m^3/m^2.h$.

3.1.3 Ventilation

All the areas of the school will be naturally ventilated except:

- Toilet and restroom areas

- Gym
- Auditorium

3.1.4 *Energy Consumption Breakdown*

The energy model was built on the information provided a simulation completed. The obtained results show in the energy consumption breakdown that space heating represents approximately 40% of the total energy consumption followed after by equipment loads representing 29% and lighting with 18%. The low winter temperatures translate in high space heating demands, however the high building occupancies, equipment loads (sensible & latent gains) and south/east/west areas solar gains offset an important part of the space heating demands.

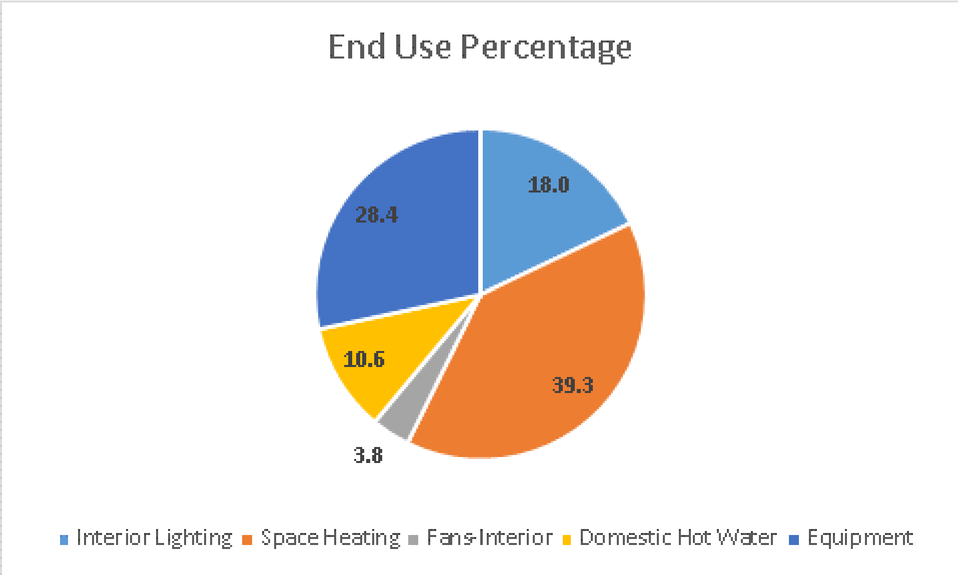


Figure 9: School Consumption Breakdown

The simulation results are highlighted in Table 7 it can be observed the values normalised by floor area for electricity are low compared to typical benchmarking values in Europe[1]. The reasons for the discrepancy are various:

- The lighting power densities for the modelled school are far lower compared to a typical school in Europe, as the lux level requirements in Europe are higher compared to Mongolian regulations. This results in lower luminance needs and results in reduced number of installed luminaires per floor area, thus reducing the energy consumption in lighting.
- The electricity benchmark data[1] is based on historical data for older traditional schools, where the lighting technologies employed are outdated and inefficient compared to nowadays. For NAP's conceptual design LED lighting technologies are proposed thus reducing electricity demand.
- The diversification factor assumed for miscellaneous loads has been defined on average on 40%. This is because equipment such as computers, laptops and other potential electric appliances will not be used on a constant basis. Furthermore the

[1] BSRIABG14 (2003),Rules of Thumb 4th Edition

amount of electronic equipment utilised in a school in Mongolia will be less compared to typical schools in Europe.

- The heating demands are much lower compared to typical energy benchmarks[1], the reasons are varied:
  - Highly insulating external walls, roofs, ground floor and windows are proposed by NAP (see section 3.1.1)
  - The heating set points for the different areas are low and many of the school zone types are untreated.
  - The space heating operation is limited between October and May.
  - High percentage of heated areas are located on the South side of the building being exposed to the solar gains from mid-morning to the mid-afternoon that coincides with the building occupancy periods. Hence minimising the heating requirements.
  - The occupancy densities and internal gains are very high based on NAP's inputs.
- The ventilation needs are very low as in the school only toilets, gym and auditorium will be ventilated. The remaining areas were defined as naturally ventilated based on NAP's inputs.

	Baseline	Baseline	Baseline	Baseline
	Electricity [kWh]	Heating [kWh]	Electricity [kWh/m2]	Heating [kWh/m2]
Heating	0	104,470	0.00	14.33
Interior Lighting	47,683	0	6.54	0.00
Interior Equipment	75,347	0	10.34	0.00
Fans	9,957	0	1.37	0.00
Hot Water Systems	0	28,187	0.00	3.87
Total End Uses	132,987	132,657	18.25	18.20

Table 7: Baseline energy consumption and normalised energy intensity

4 ENERGY EFFICIENCY& TECHNOLOGY

4.1 Introduction

Energy efficiency in buildings combines energy-efficient constructions, HVAC, appliances, and lighting with commercially available and feasible renewable energy systems, such as solar water heating and solar electricity. The concept of energy efficiency is to reduce building energy consumption and as cost-effectively as possible, and then meet the reduced load with on-site renewable energy systems whenever feasible. Optimizing energy efficiency in buildings requires considering all the variables, details, and interactions that affect energy use such as:

- Appliances
- Insulation and air sealing
- Lighting and daylighting
- Space heating and cooling
- Water heating
- Constructions (walls, roofs, floors, windows, doors, and skylights)

In addition the occupant behaviour, site conditions, and climate must also be taken into account for designing an energy efficient building. New technologies and use of control systems can help increasing energy efficiency in buildings. Technologies which help reduce energy consumption in buildings between others are:

4.2 Lighting controls

The use of timers, daylighting and presence detection controls integrated in the operation of lighting systems allow occupants to have appropriate lighting levels, minimizing glare, balancing surface brightness, and enhancing the surrounding architecture. When electric lighting controls are properly implemented energy will be saved. The lighting controls will help reduce energy by:

- Reducing lighting energy consumption by dimming lights for the areas with daylight access or turning them off when the zones are not occupied
- Reducing the number of hours per year that the lights will be on
- Reducing internal heat gains by cutting down lighting use when it is not needed
- Allowing occupants to use controls to lower light levels and save energy

Some of the different lighting controls include:

4.2.1 *Presence detectors (PIR)*

Presence detectors use a switch and automate it with a sensor which tells the switch to turn the lights off when it detects the absence of people. They are ideal for intermittently occupied spaces with an unpredictable occupancy profile. PIR detectors serve three basic functions:

- To automatically turn lights on when a room becomes occupied,
- To keep the lights on without interruption while the controlled space is occupied
- To turn the lights off within a preset time period after the space has been vacated.

Passive infrared sensors (PIR) get activated by the movement of a heat-emitting body through their field of view. However it must be noted that PIR sensors cannot "see" through opaque walls, partitions, or windows so occupants must be in direct line-of-site of the sensor.

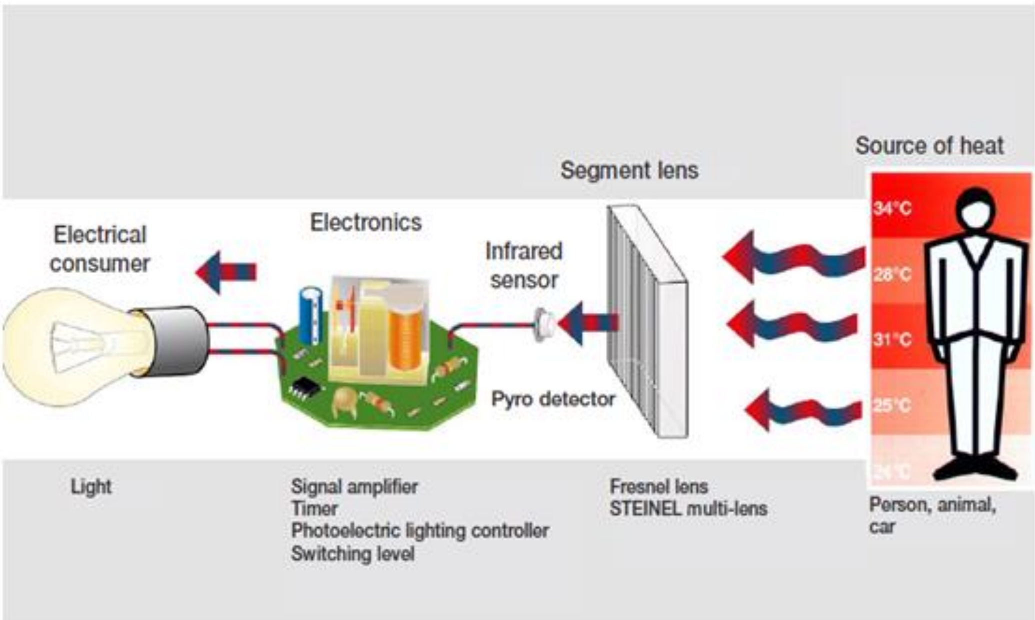


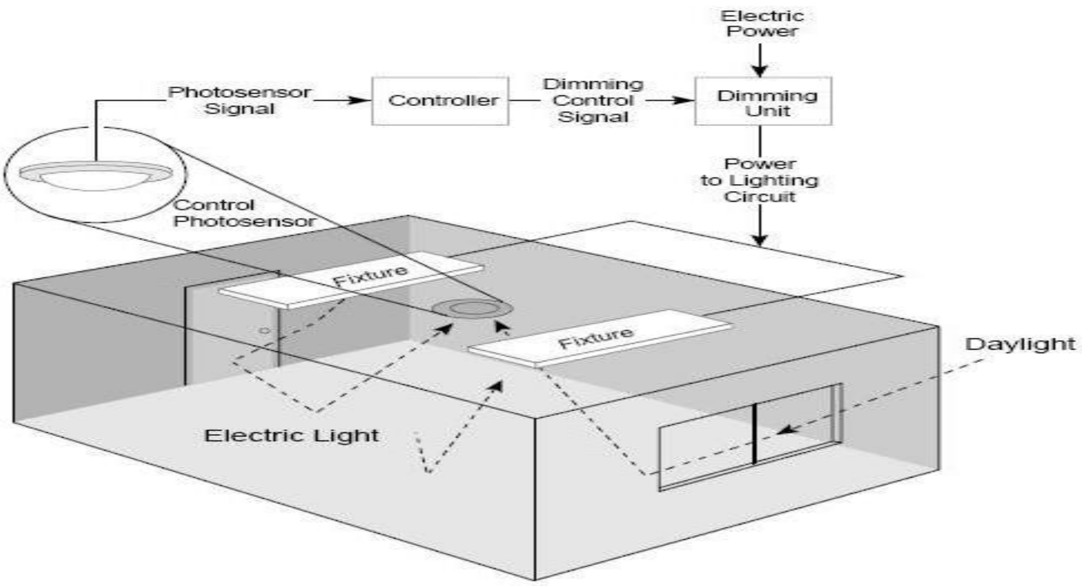
Figure 10: PIR Sensor[2]

4.2.2 *Daylight Dimmers*

Daylight dimmers are typically mounted on a ceiling, wall or a fixture and measure the amount of illumination at the task surface in the space or at the daylight aperture, with this information the dimming ballast adjusts the light output from the electric lighting system to maintain the desired level of illumination. An effective daylight harvesting control system saves energy while being virtually unnoticed by occupants. Hence with a daylight harvesting control system, electric lighting is increased or decreased in direct proportion to the amount of natural light available. This results in a minimum maintained illumination level in the controlled space. Daylight harvesting controls can be effective in virtually any type of facility where the lights operate much of the time and where a significant quantity of daylight is available through windows or skylights. Spaces with skylights, and corridors and open cubicles near windows with task lighting are particularly good candidates for daylight controls. If the entire space is uniformly skylighted, energy savings can accrue on the entire lighting load. More commonly, they apply only to the perimeter zone of a vertically glazed installation.

Working Principle:
Automatic daylight harvesting control systems are comprised:

a. Electric Lighting System: It consists of lamps, ballasts, wiring to the fixtures, number of fixtures per circuit, and fixture placement and spacing.
b. Photo sensor: These device automatically measures light level entering the space or at the task surface. Once the light threshold is reached it signals the controller (light levels are increasing or decreasing).
c. Controller: It consists of a control unit, such as a dimmable ballast or low-voltage relay, which receives the photosensor signal as an input and issues a command to connected dimming or switching controls to adjust light output accordingly.
d. Dimming controls: These devices receive the command signal from the controller as an input and as an output adjust the light output of the controlled electric lighting system by dimming.



[2]Image source- PIR Sensor From Steinel Professional (https://pirtechnology.wordpress.com/2011/09/09/hello-world/)

Figure 11: Daylighting control system[3]

4.2.3 *Timers*

All building lights are on either a movement sensor or an automatic timer. The movement sensor will turn off lights when it does not sense movement. Sometimes working at a desk is not enough movement and the system will shut off, but will come back on the next time it senses movement. These lights can be turned off manually as well. The automatic timer will shut off the lights at a particular specified times. The system is set up with a warning that will blink once then shut off five minutes later. If you need the lights to stay on longer pressing of the override button will clear the will override the system for two hours. You can do this as many times as needed.

4.3 Building Management

A building management system (BMS), also known as a building automation system (BAS), is a computer based control system installed in buildings that controls and monitors the building’s mechanical and electrical equipment such as ventilation, lighting, power systems, fire systems, and security systems. A building management system controls Illumination (lighting) control electric power control, heating, ventilation and air-conditioning (HVAC), access control, fire alarm system, lifts, elevators etc.

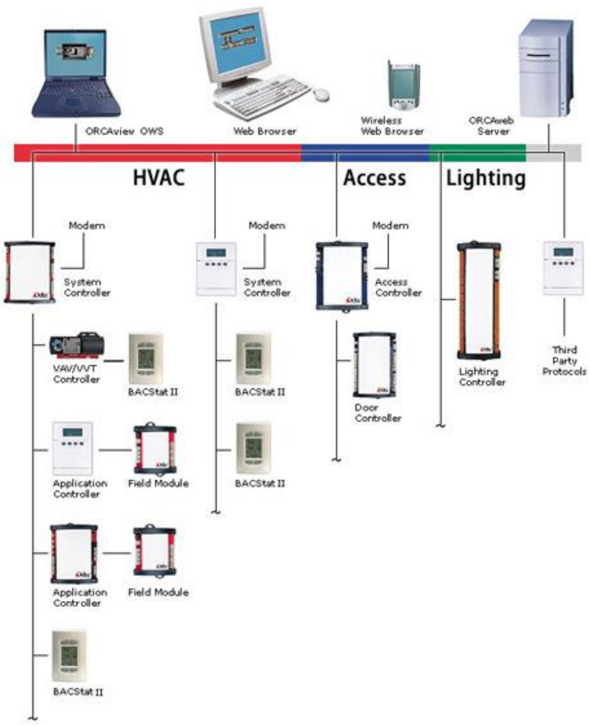


Figure 12: Building Management System[4]

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[3]Image Source: Lawrence Berkeley National Laboratory

[4]www.rosemechanical.com

4.4 Electronic Thermostatic Radiator Valves

The thermostatic radiator valves (TRVs) are devices fitted for radiators and are used to control the temperature within the room. They have the potential to significantly reduce the energy used by the heating system by limiting the temperatures within each room, and prevent overheating. TRVs allow heating the rooms more efficiently and allow having different heating zones throughout the building, despite only one centralised boiler is currently providing heat. Furthermore nowadays with the technology advancements the heating can be switched on and off when required in a remote way.

Figure 13: Honeywell Electronic TRV

4.5 Insulation

Building's heating loads can be reduced through proper insulation and air sealing techniques. These techniques will also make the buildings more comfortable. Insulation materials are of different types such as fiberglass, rock and slag wool, cellulose, natural fibers, rigid foam boards and sleek foils. Bulky insulation materials resist conductive and to a lesser degree convective heat flow in a building cavity. Rigid foam boards trap air or another gas to resist conductive heat flow. Highly reflective foils in radiant barriers and reflective insulation systems reflect radiant heat away from living spaces, making them particularly useful in cooling climates.

For cold places like Mongolia it is frequently beneficial to use bulk insulation like glass wool or rock wool batts, or loose-fill cellulose. Keeping the heat in is the main goal and good bulk insulation will help keep the heat inside the building.

4.6 Glazing

For continental and cold climates like Mongolia selection of a proper window is of critical importance thus well insulating windows should be installed. Typically a double glass window with thermal break framing has a 4 to 6 times higher U value compared to a well insulated wall. Doors and windows represent between 10 to 30% of the envelope heating losses in a typical building. Thus to be effective, a low U-value windows to reduce conductive heat transfer are need and south-facing windows should have high solar G values or heat gain coefficient (SHGC) to maximize solar heat gain during the winter (but manging overheating risks too). Similarly windows should have high light transmittance (LT) for good visible light transfer to maximise daylight.

5 IMPLEMENTED ENERGY EFFICIENCYMEASURES

The planned Green School by NAP does already have efficient systems proposed in their conceptual design such as: LED lights, high performance thermal elements with low U Values for roofs external walls and windows. In section 3 the baseline model was simulated based on NAPs provided information.

Nevertheless additional energy efficiency measures have been identified and analysed and individual energy models for each of the scenarios simulated. This allowed estimating the potential energy savings for each of the proposed actions and a cost benefit analysis of the energy management opportunities (EMO).

5.1 EMO 1: Energy Modelling and Lighting controls

In the energy model artificial light use has been linked with natural light levels using sensors and smart control systems to minimise energy use. It has to be noted that the daylight dimming controls have been implemented for the perimeter areas (typically between 5 to 8m meter zones from the window to the inside of the room) where daylight access is granted. This included following areas in the School:

- For the Ground Floor 8 perimeter zones have been modelled with linear daylight dimmers:
    - Auxiliary room
    - Geographical cabinet
    - Girls health
    - Mathematics cabinet
    - Physics laboratory
    - Mathematics cabinet
    - Room for manager & principal
    - Classrooms
- For the First Floor 16 perimeter zones have been modelled with linear daylight dimmers:
    - Classrooms
    - Computer cabinet
    - Cubicle
    - Dining hall
    - Directors office
    - Drawing cabinet
    - Nature corners
    - Open space perimeter areas
    - Teaching office
- For the Second Floor 14 perimeter zones have been modelled with linear daylight dimmers:
    - Classrooms
    - Foreign language and literature hall
    - Mongolian languag and literature hall
    - Music cabinet
    - Open space perimeter areas
- For the Third Floor 11 perimeter zones have been modelled with linear daylight dimmers:
    - Classrooms
    - Chemical laboratory
    - Free space areas

5.1.1 Energy Consumption Breakdown

The comparison of the baseline model with the improved energy model with daylighting controls shows that:

- Implementation of linear of daylight dimmers achieves yearly savings of 6,608kWh in electricity lighting, representing a lighting consumption reduction of almost 14% and overall electricity consumption saving of 5%. The parasitic loads of the daylight dimmer can be considered as neglectable compared to the overall savings.
  In Figure 14 an example is shown for the 3rd floor for one of the Classrooms with daylight access on a random day at the end of January. The comparison clearly shows the lighting electricity consumption reduction (for that single day the energy saving represents approximately 30%). Obviously the energy saving is variable depending on the day conditions as this will affect the entering daylight intensity in the room.

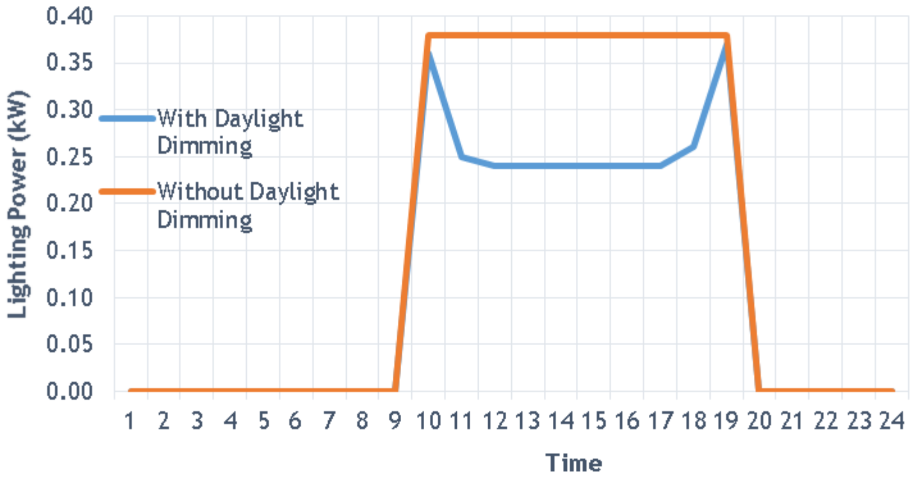

Figure 14: Lighting Load (28th January) - Classroom Grade 10-12th

- For a 14% yearly lighting electricity saving and at daily use electricity tariff of 0.0643 USD/kWh (information provided by MEGDT), this translates in a yearly cost saving of USD 424.
- The additional capital cost of implementing in a new building with daylight dimmers for suitable LED lights has been estimated as an additional cost of 740 dollar on top of the existing lighting design representing a payback of less than 2 years. (Please note the contracted peak power demand saving has been considered as neglectable).
-

	Baseline	EMO 1
	Electricity [kWh]	Electricity [kWh]
Interior Lighting	47,683	41,075
Interior Equipment	75,347	75,347
Fans	9,957	9,957
Total End Uses	132,987	126,379

Table 8: Baseline and improved model energy consumption with implemented daylighting dimmers

5.2 EMO 2: Energy Modelling and High Efficiency Coal Boiler

The boiler proposed by NAP runs on coal, not an environmentally friendly option. Thus other solutions have been assessed such as:

- Natural gas boilers: unfortunately in the location no gas infrastructure is currently available.
- Biomass boilers: as occurred for the natural gas no biomass suppliers are available close to the school area and in Ulaanbaatar biomass resources are scarce.

Unfortunately coal seems to be the most feasible alternative as already proposed by NAP. The fact that Mongolia has abundant coal reserves at low cost makes this fuel very cost effective and the most economical alternative. However it is not the best choice from environmental point of view.

In order to minimise the environmental impact it would be suggested to employ high efficiency coal boilers. The currently proposed boiler for the conceptual design has a seasonal efficiency of 80% and this could be improved with higher specification coal boilers.

5.2.1 Energy Consumption Breakdown

The baseline model space heating and hot water consumption totals 132,657kWh on a yearly basis (see Table 14). Implementing for example a higher efficiency boiler as an example the Stalmark Max boiler instead of the proposed boiler and taking a seasonal efficiency of 86% following can be concluded:

- The cost of the current unit proposed for the conceptual design was not provided yet. Nevertheless assuming a higher specification system and additional cost of 10-15% was assumed (e.g. the Stalmark unit, see product description in Table 15). This results in an additional cost of USD1,537 compared to a conventional standard boiler.
- The yearly savings with the more efficient unit would be of 7,959kWh in energy terms representing 1.2 tonnes of coal savings per year compared to the standard unit with an yearly energy cost saving of USD63 (at a coal price in Mongolia of 50USD/tonne, information provided by MEGDT). This would represent payback close to 25years, assuming the boiler has a technical lifetime of 25-35 years. Thus from the financial point of view the investment is not as attractive. On the other hand in terms of energy and environmental impact it as very positive impact reduce the carbon footprint and energy consumption.
  Therefore the energy savings achieved with a higher efficiency boiler would reach 6% compared to a standard unit, however the very low prices of coal unfortunately do not allow a rapid return of the investment.

	Baseline
	Heating [kWh]
Heating	104,470
Hot Water Systems	28,187
Total End Uses	132,657

Table 9: Baseline energy consumption with conventional boiler

5.3 EMO 3: Zone Heating System (BMS) or Radiator Thermostat Timer

The heating system operates between the 1st October to the 10th May from Monday to Saturday (Note: Saturday the school is empty but the Auditorium, Library and Gym are open).The heating system in the conceptual design is set up in a way that in cannot be switched off per zones. Thus on Saturday even if only Auditorium, Library and Gym are occupied the space heating is still active for the remaining zones. Therefore 2 solutions are proposed:

- Implementing a zoning layout with independent temperature sensor controlled through a building management system.
- Implementing independent electronic or remotely controlled thermostatic radiator valves with timers in each of the rooms.

5.3.1 Energy Consumption Breakdown

The comparison of the baseline energy model against the thermal model zoned heating system shows that:

Building management system:

- The savings in terms of heating after the implementation of the BMS could potentially represent 4,412kWh per year (see Table 11). This presents a reduction of almost 4.2% in space heating requirements (overall yearly fuel saving of 3.3%). In terms of energy this represents savings of 0.7tonne coal per year and a yearly saving of USD35 at a coal price of 50USD/tonne (information provided by MEGDT). Again as with EMO 2 considerable energy savings can be achieved however the very low costs of coal reduces the yearly cash returns significantly.
- The cost estimation of a BMS system is difficult to assess as it depends on the system design and layout, controlled variable, number of devices employed, number of sensors, manufacturers etc. and more importantly the number of measuring devices and variables measured. BSRIA has a rules of thumb guideline providing cost information on a floor area basis[5] Currently 5,800m^2 of the building is conditioned and the BMS cost would be of USD $145,000. Obviously the BMS will mostly only control the heating variables, hence a much lower investment cost would be expected. The installation cost and layout still keep the CAPEX very high so unfortunately it is not viable for a typical lifetime of a BMS system. For bigger developments the BMS could potentially be more attractive however not in this scenario especially with the low coal prices. Nevertheless it has to be noted that in energy terms the implementation of a BMS system would contribute to with a savings of 4.2% in space heating energy.

Thermostatic radiator valve with timer:

- The cost of the BMS is too high to be viable. However the implementation of individual thermostatic radiator valves with timer functions could be the cheaper alternative (see Figure 15). It would fulfil a similar function to the BMS and would be programmed to switch the radiators off during the weekends and regulate the radiator output depending on the space temperature. Identically to the BMS the space heating reduction would be of 4.2% (overall fuel saving of 3.3%) equivalent to yearly savings of 4,412kWh per year (see Table 11).
- The cost of implementing 69 units would be of USD 1,594 (please note it has been assumed one TRV per room and not per radiator.) At a yearly saving of USD35 the payback is of 40 years hence not an attractive investment from the financial point of

[5] BSRIA (2011), Rules of thumb guidelines for building services

view. Again as for the BMS option in terms of energy it would achieve 4.2% savings on space heating (overall space heating and hot water saving of 3.3%), however the very low coal fuel costs do not make the investment attractive as the cost savings are considerably small.

	Area [m2]
Total Building Area	7289
Net Conditioned Building Area	5806
Unconditioned Building Area	1483

Table 10: Conditioned building Area

	Baseline	EMO 3
	Heating [kWh]	Heating [kWh]
Heating	104,470	100,058

Table 11: Baseline and improved model energy consumption with zone heating system

5.4 EMO 4: Ground Floor Insulation

The ground floor insulation in the NAP conceptual design has a U value of 0.421W/m^{2}K. The thermal resistance could be increased by improving the thickness of the proposed polystyrene XPS insulation.

5.4.1 Energy Consumption Breakdown

The baseline model has been remodelled with an improvement of the ground floor insulation from the conceptual design of0.421W/m^{2}K to 0.250W/m^{2}K. This represents an increase of the insulation thickness for the given construction. This would have following impacts:

- Space heating demand reduction from 104,470 to 98,825kWhrepresenting an energy saving of 5.4%.
- This would involve an energy saving of 5,645kWh equivalent to 0.9tonnes of coal representing USD45 cost saving per year.
- The upgrade of the insulation thickness for the ground floor from 64mm to 120mm has an additional material cost of USD 7,860 for a total ground floor area of 1,400m^2 (it has been assumed the installation costs would not vary as just thicker panel would need to be installed instead).
  The improvement of the insulation would achieve in savings on space heating of 5.4% (overall fuel saving of 4.2%) and corresponding emission reductions. However the investment is not financially attractive as the low prices of coal do not generate sufficient energy cost returns to recover the additional investment.

	Baseline	EMO 4
	Heating [kWh]	Heating [kWh]
Heating	104,470	98,825

Table 12: Baseline and improved model energy consumption with improved ground floor insulation

6 OTHER ENERGY EFFICIENCY MEASURES

The proposed EMOs have been simulated in the energy model and compared against the baseline energy model with a description (see section 5). Nevertheless there are other measures that are not possible to be modelled because of their unpredictable use in the building but that are highly recommendable and would be recommended to be included in the school design:

- Lighting PIR (presence detectors): presence detectors are highly recommendable especially for areas with variable occupancy habits for example for a classroom or office. Thus if lights are left on this will cause high energy wastage. Taking this into consideration the PIRs could be installed in locations such as: toilet areas, teacher rooms, plant room, dress rooms, corridors (not stair case areas though), cloth rooms, cubicles, storage rooms, free areas, technical rooms, battery room, geothermal room, communication room, etc.
  There are certain areas where PIR devices are not advisable because of the activities developed in the space and usage habits as they could create discomfort or annoyance such as library, classrooms, offices, laboratory, rest rooms, foreign language and literature kitchen and food areas, etc. This includes stair case areas as well because of safety reasons.
  For clarity this does not disregard the implementation of daylight dimmers for any perimeter area exposed to daylight access, as lighting controls can include PIR and daylight dimmers together.
- Lighting Zones: review the zoning of electrical layouts and favour the amount of zones (if appropriate) to allow lights to be turned on or off when certain areas of a room are not occupied.
- Timers: the occupancy schedules for this type of buildings are typically consistent over the school months and implementation of timers could contribute to the building energy efficiency.
- Openable windows: as the building has high occupancy ratios with considerable internal gains in addition to the strong solar gains especially on the South façade it would be suggested to consider the implementation of openable windows. Therefore it is recommended to use window types with high opening areas, such as slide or casement windows (obviously safety aspects would need to be taken into consideration as well by the architect).

7 RECOMMENDATIONS

First of all it has to be mentioned that the current building features provided by NAP do already show a high specification building, involving between others:

- High insulating thermal elements with well insulated walls, windows and roof.
- Low permeability building $9m^3/m^2h$ @ 50Pa.
- Furthermore LED systems have been proposed as well by NAP hence having high efficient lighting systems.
- Ventilation heat recovery.

Therefore improving the building further is highly challenging. On the other hand the energy assessment undertaken, involved various energy improvement measures as shown in Table 13. In terms of energy the actions proposed are technically viable and show acceptable energy savings with the corresponding environmental benefit. However the business case for 4 of the 5 identified measures is not, due to very low prices of coal in Mongolia. For space heating and hot water applications where the fuel employed is coal the financial attractiveness is challenging as the yearly cash returns are minimal against the capital investment required for the improvement measures. This can be clearly compared against the daylight dimmer lighting option where an electricity saving is achieved, as electricity is comparatively more costly and the cash returns are higher favoring financial viability.

From the identified measures following is concluded:

- EMO 1 is the most attractive measure from the techno-economic point of view with the implementation of daylight dimmers in the zones with daylight access and would be highly recommended.
- EMOs 2, 3 and 4 are not viable in cost terms with the extreme case of the BMS system. In financial terms these EMOs are not favorable.
- The “other” measures suggested in section 6 would be highly recommendable.

However from the point of view of energy savings and carbon emission reductions we can observe that all the proposed EMOs have emission savings between 1.7 to 15.3 tonnes in CO_2 and energy savings range between 3.3 to 5%.

EMO	Improvement measure	Energy Saving (kWh)	Emission Savings (tonnes CO_2)	Electricity/ Fuel Saving (%)	Fuel	Additional Cost for Upgrade (USD)	Yearly Cost Saving (USD)	Simple Payback (years)
1	Implementation Daylight Dimmers	6,608	15.3	5.0	Electricity	740	424	1.7
2	High Efficiency Boiler upgrade	7,959	3.1	6.0	Coal	1,537	63	24.4
3	BMS Implementation (heating side)	4,412	1.7	3.3	Coal	145,000	35	4142.9
3	Electronic Thermostatic Valve TRV	4,412	1.7	3.3	Coal	1,594	35	45.5
4	Ground Insulation improvement	5,645	2.2	4.2	Coal	7860	45	174.7

Table 13: Summary Energy Efficiency Measures[6]

[6]Grid Electricity Carbon Factor for Mongolia: Ecometrica, Electricity emission factor for grid electricity
Coal Carbon Factor: UK Part L2A 2013

A remark regarding the coal prices, the current regulation through subsidies make coal very cost competitive. However any potential change of the prices or level of subsidization could have a crucial impact on the operating costs of the schools. Therefore to mitigate the impact the schools built in the coming years should be efficient to reduce such a risk.

As a final note the development of a green school has the advantage of being able to contribute in the reduction of the operating energy costs of the building. On the other hand the initial CAPEX implications need to be considered carefully as well. The development of high efficient school is possible however the potential budget constraints or financial resources available have to be taken into account. This is especially relevant if a replication of such a green school and investment has to be repeated for 1500 additional schools, as has been planned by the Mongolian government. Therefore the development of a green school is “technically” possible but the financial constraints will define to what extent this is sustainable in cost terms and to what extent the efficiency measures are implemented. Thus the economics will influence the green design.

8 ANNEXURES

8.1 Annexure 1

Room Type	Occupancy Diversification Factor	Ocupancy Period (weekday)	Ocupancy Period (weekend)	Occupancy rate (m2/pers)	Lighting Gain (W/m2)	Miscellanous Diversification Factor	Equipment/Miscellanous Gain (W/m2)	Heating type (if applicable)	Ventilation type (if applicable)	Ventilation Heat Recovery (YES/NO)	Natural Ventilation (YES/NO)
BASEMENT FLOOR											
1.Recreation	**0.75**	**8am - 18:10pm**	**8am - 18:10pm**	**3**	**11**	**0.4**	**19**	**Radiator**	**By window**		**YES**
2.Clothes hanging room	**0.75**	**8am - 18:10pm**	**Closed**	**0**	**2.6**	**0.4**	**6.6**	**Unheated**	**No vent**		**NO**
3.Cubicle	**0.75**	**8am - 18:10pm**	**Closed**	**0**	**20**	**0.4**	**0**	**Unheated**	**No vent**		**NO**
4.Doctor	**0.75**	**8am - 18:10pm**	**Closed**	**4.5**	**6.5**	**0.4**	**25**	**Radiator**	**By window**		**YES**
5. Girl’s health	**0.75**	**8am - 18:10pm**	**Closed**	**6**	**6.5**	**0.4**	**25**	**Unheated**	**No vent**		**NO**
6. Corridor	**0.75**	**8am - 18:10pm**	**Closed**	**0**	**7**	**0.4**	**0**	**Unheated**	**No vent**		**NO**
7. Room for manager and principal	**0.75**	**8am - 18:10pm**	**8am - 18:10pm**	**5.8**	**20**	**0.4**	**25**	**Radiator**	**By window**		**YES**
8. Mathematics cabinet	**0.75**	**8am - 18:10pm**	**Closed**	**1.96**	**11**	**0.4**	**20**	**Radiator**	**By window**		**YES**
9. Physics laboratory	**0.75**	**8am - 18:10pm**	**Closed**	**1.47**	**11**	**0.4**	**25**	**Radiator**	**By window**		**YES**
10.Auxilary room	**0.75**	**8am - 18:10pm**	**Closed**	**4.3**	**5**	**0.4**	**25**	**Radiator**	**By window**		**YES**

11.Cubicle	0.75	8am - 18:10pm	8am - 18:10pm	0	5	0.4	0	Radiator	By window		YES
12.Biological cabinet	0.75	8am - 18:10pm	Closed	1.96	11	0.4	20	Radiator	By window		YES
13.Geography cabinet	0.75	8am - 18:10pm	Closed	1.96	11	0.4	20	Radiator	By window		YES
14.Technology cabinet (woman)	0.75	8am - 18:10pm	Closed	2.2	12	0.4	170	Radiator	By window		YES
15.Auxilary room	0.75	8am - 18:10pm	Closed	8	5	0.4	74	Radiator	By window		YES
16.Wood and metal preparation cabinet	0.75	8am - 18:10pm	Closed	4.53	12	0.4	93	Radiator	By window		YES
17.auxilary room	0.75	8am - 18:10pm	Closed	2.2	4.9	0.4	25	Radiator	By window		YES
18.Water tank room	0.75	8am - 18:10pm	8am - 18:10pm	0	0.9	0.4	0	Unheated	No vent		NO
19.Waste room	0.75	8am - 18:10pm	Closed	0	0.9	0.4	0	Unheated	No vent		NO
20.Geothermal equipment room	0.75	8am - 18:10pm	Closed	0	1.3	0.4	0	Unheated	No vent		NO
21.Storage	0.75	8am - 18:10pm	Closed	0	1.3	0.4	5	Unheated	No vent		NO
22.Storage	0.75	8am - 18:10pm	Closed	0	1.3	0.4	5	Unheated	No vent		NO
23.Storage	0.75	8am - 18:10pm	Closed	0	0.4	0.4	5	Radiator	By window		YES
24.Battery room		8am - 18:10pm	8am - 18:10pm	0	0.4		0	Radiator	By window		YES
25.Electrical panel room	0.75	8am - 18:10pm	8am - 18:10pm	0	1	0.4	0	Radiator	By window		YES
26.Communication room	0.75	8am - 18:10pm	8am - 18:10pm	0	1	0.4	34	Radiator	By window		YES

27.Heating plant room	0.75	8am - 18:10pm	8am - 18:10pm	0	2	0.4	250	Radiator	By window		YES
28.Stair area	0.75	8am - 18:10pm	8am - 18:10pm	0	0	0.4	0	Unheated	No vent		NO
29.Staircase	0.75	8am - 18:10pm	8am - 18:10pm	0	0	0.4	0	Unheated	No vent		NO
30.Staircase	0.75	8am - 18:10pm	8am - 18:10pm	0	0	0.4	0	Radiator	By window		YES
31.Staircase	0.75	8am - 18:10pm	8am - 18:10pm	0	0	0.4	0	Unheated	No vent		NO
1st floor											
1.Cubicle	0.75	8am - 18:10pm	8am - 18:10pm	0	9	0.4	0	Unheated	No vent		NO
2.Lobby	0.75	8am - 18:10pm	8am - 18:10pm	1.6	4	0.4	73	Radiator	By window		YES
3.Life natural corner	0.75	8am - 18:10pm	8am - 18:10pm	0	17	0.4	0	Radiator	By window		YES
4.Cubicle	0.75	8am - 18:10pm	8am - 18:10pm	0	9	0.4	0	Unheated	No vent		NO
5.Life natural corner	0.75	8am - 18:10pm	8am - 18:10pm	0	17	0.4	0	Radiator	By window		YES
6.Receration, corridor	0.75	8am - 18:10pm	8am - 18:10pm	1.6	2	0.4	0	Unheated	No vent		NO
7.Lunch hall	0.75	8am - 18:10pm	Closed	2.2	5	0.4	9.9	Radiator	By window		YES
8.Director's room	0.75	8am - 18:10pm	8am - 18:10pm	3.4	9	0.4	50	Radiator	By window		YES
9.Secretary	0.75	8am - 18:10pm	8am - 18:10pm	5.1	5	0.4	6	Unheated	No vent		NO
10.Corridor	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4		Unheated	No vent		NO
11.Teachers' room	0.75	8am - 18:10pm	Closed	4.7	10	0.4	25	Radiator	By window		YES

12.Classroom (6-9th grade)	0.75	8am - 18:10pm	Closed	1.95	11	0.4	20	Radiator	By window		YES
13.Classroom (6-9th grade)	0.75	8am - 18:10pm	Closed	1.95	11	0.4	20	Radiator	By window		YES
14.Classroom (6-9th grade)	0.75	8am - 18:10pm	Closed	1.95	11	0.4	20	Radiator	By window		YES
15.Classroom (6-9th grade)	0.75	8am - 18:10pm	Closed	1.95	11	0.4	20	Radiator	By window		YES
16.Classroom (6-9th grade)	0.75	8am - 18:10pm	Closed	1.95	11	0.4	20	Radiator	By window		YES
17.Classroom (6-9th grade)	0.75	8am - 18:10pm	Closed	1.95	11	0.4	29	Radiator	By window		YES
18.Computer cabinet	0.75	8am - 18:10pm	Closed	3.6	9	0.4	100	Radiator	By window		YES
19.Drawing cabinet	0.75	8am - 18:10pm	Closed	1.8	11	0.4	20	Radiator	By window		YES
20.Library, reading hall	0.75	8am - 18:10pm	8am - 18:10pm	1.9	6	0.4	13	Radiator	Exhaust		NO
21.Library resource	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Unheated	No vent		NO
22.Kitchen and food preparation	0.75	8am - 18:10pm	Closed	0	9	0.4	100	Radiator	Exhaust		NO
23.Dish washing area of lunch hall	0.75	8am - 18:10pm	Closed	0	7.5	0.4	32	Radiator	Exhaust		NO
24.Dishwashing area of kitchen	0.75	8am - 18:10pm	Closed	0	7.5	0.4	0	Unheated	No vent		NO
25.Semi-processed food storage	0.75	8am - 18:10pm	Closed	0	10	0.4	15	Unheated	No vent		NO
26.Room for storage	0.75	8am - 18:10pm	Closed	0	2	0.4	0	Unheated	No vent		NO
27.Meat and dairy storage	0.75	8am - 18:10pm	Closed	0	2	0.4	100	Unheated	No vent		NO

28.Dry goods storage	0.75	8am - 18:10pm	Closed	0	2	0.4		Unheated	No vent		NO
29.Vegetable storage	0.75	8am - 18:10pm	Closed	0	1	0.4	0	Unheated	No vent		NO
30.Storage	0.75	8am - 18:10pm	Closed	0	1	0.4	0	Radiator	By window		YES
31.Material receiving area	0.75	8am - 18:10pm	Closed	0	4	0.4	0	Radiator	By window		YES
32.Dressing room for staff	0.75	8am - 18:10pm	Closed	0.7	3	0.4	0	Unheated	No vent		NO
33.Restroom	0.75	8am - 18:10pm	Closed	0	15	0.4	15	Unheated	No vent		NO
34.Shower	0.75	8am - 18:10pm	Closed	0	4	0.4	0	Unheated	No vent		NO
35.Office room	0.75	8am - 18:10pm	Closed	0	4	0.4	85	Radiator	By window		YES
36.Cubicle	0.75	8am - 18:10pm	Closed	0	9	0.4	0	Radiator	By window		YES
37.Corridor	0.75	8am - 18:10pm	Closed	0	4	0.4	20	Unheated	No vent		NO
38.Restroom (woman)	0.75	8am - 18:10pm	8am - 18:10pm	0	7	0.4	15	Unheated	Exhaust		NO
39.Toilet (man)	0.75	8am - 18:10pm	8am - 18:10pm	0	7	0.4	15	Unheated	Exhaust		NO
40.Restroom for teacher and staff	0.75	8am - 18:10pm	8am - 18:10pm	0	15	0.4	15	Unheated	No vent		NO
41.Lift			Closed	0		0.4	0	Unheated			NO
42.Stair area	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Radiator	By window		YES
43.Staircase	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Unheated	No vent		NO
44.Stair area	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Radiator	By window		YES

45.Staircase	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Unheated			NO
2nd floor											
1.Pecreation, corridor	0.75	8am - 18:10pm	8am - 18:10pm	1.96	5	0.4	4.7	Radiator	By window		YES
2.Classroom (2-5th grade)	0.75	8am - 18:10pm	Closed	1.8	12	0.4	20	Radiator	By window		YES
3.Classroom (2-5th grade)	0.75	8am - 18:10pm	Closed	1.96	12	0.4	20	Radiator	By window		YES
4.Classroom (2-5th grade)	0.75	8am - 18:10pm	Closed	1.96	12	0.4	20	Radiator	By window		YES
5.Classroom (2-5th grade)	0.75	8am - 18:10pm	Closed	1.96	12	0.4	20	Radiator	By window		YES
6.Classroom (2-5th grade)	0.75	8am - 18:10pm	Closed	1.96	12	0.4	20	Radiator	By window		YES
7.Mongolian language and literature cabinet	0.75	8am - 18:10pm	Closed	1.96	12	0.4	20	Radiator	By window		YES
8.Foreign language and literature cabinet	0.75	8am - 18:10pm	Closed	1.96	11	0.4	19	Radiator	By window		YES
9.Music cabinet	0.75	8am - 18:10pm	Closed	1.8	12	0.4	20	Radiator	By window		YES
10.Arts hall	0.75	8am - 18:10pm	Closed	0.8	5.2	0.4	5	Radiator	By window		YES
11.Sport hall	0.75	8am - 18:10pm	8am - 18:10pm	0 0	10	0.4	9	Radiator	Supply/ exhaust	YES	NO NO
12.Dressing room, Shower (woman)	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Unheated	Exhaust		NO
13.Dressing room, Shower (man)	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Unheated	Exhaust		NO
14.Corridor	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Radiator	By window		YES

15.Corridor	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Unheated	No vent		NO
16.Restroom (woman)	0.75	8am - 18:10pm	8am - 18:10pm	0	1.8	0.4	5	Unheated	Exhaust		NO
17.Restroom (man)	0.75	8am - 18:10pm	8am - 18:10pm	0	1.8	0.4	5	Unheated	Exhaust		NO
18.Free area	0.75	8am - 18:10pm	8am - 18:10pm	0	5	0.4	0	Unheated	No vent		NO
19.Free area	0.75	8am - 18:10pm	8am - 18:10pm	0	5	0.4	0	Unheated	No vent		NO
20.Free area	0.75	8am - 18:10pm	8am - 18:10pm	0	5	0.4	0	Unheated	No vent		NO
21.Free area	0.75	8am - 18:10pm	8am - 18:10pm	0	5	0.4	0	Unheated	No vent		NO
22.Lift			Closed	0	0	0.4	0	Unheated			NO
23.Stair area	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Unheated	No vent		NO
24.Staircase	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Unheated	No vent		NO
25.Stair area	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Radiator	By window		YES
26.Staircase	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Unheated	No vent		NO
3rd floor											
1.Recreation, corridor	0.75	8am - 18:10pm	8am - 18:10pm	1.5	5	0.4	4.7	Radiator	By window		YES
2.Classroom (6-9th grade)	0.75	8am - 18:10pm	Closed	2	11	0.4	19	Radiator	By window		YES
3.Classroom (6-9th grade)	0.75	8am - 18:10pm	Closed	2	11	0.4	19	Radiator	By window		YES
4.Classroom (6-9th grade)	0.75	8am - 18:10pm	Closed	1.96	11	0.4	19	Radiator	By window		YES

5.Classroom (6-9th grade)	0.75	8am - 18:10pm	Closed	1.96	11	0.4	19	Radiator	By window		YES
6.Classroom (6-9th grade)	0.75	8am - 18:10pm	Closed	1.96	11	0.4	19	Radiator	By window		YES
7.Classroom (10-12th grade)	0.75	8am - 18:10pm	Closed	1.96	11	0.4	19	Radiator	By window		YES
8.Classroom (10-12th grade)	0.75	8am - 18:10pm	Closed	1.96	11	0.4	19	Radiator	By window		YES
9.Classroom (10-12th grade)	0.75	8am - 18:10pm	Closed	1.96	11	0.4	19	Radiator	By window		YES
10.Classroom (10-12th grade)	0.75	8am - 18:10pm	Closed	1.96	11	0.4	19	Radiator	By window		YES
11.Chemical laboratory	0.75	8am - 18:10pm	Closed	2.3	12	0.4	16	Radiator	By window		YES
12.Sport hall	0.75	8am - 18:10pm	8am - 18:10pm	0	10	0.4	4.7	Radiator	By window		YES
13.Teachers' room	0.75	8am - 18:10pm	Closed	6	10	0.4	15	Radiator	By window		YES
14.Restroom (woman)	0.75	8am - 18:10pm	8am - 18:10pm	0	1.2	0.4	5	Unheated	No vent		NO
15.Restroom (man)	0.75	8am - 18:10pm	8am - 18:10pm	0	1.2	0.4	5	Unheated	No vent		NO
16.Restroom for teacher and staff	0.75	8am - 18:10pm	Closed	0	4	0.4	5	Unheated	No vent		NO
17.Free area	0.75	8am - 18:10pm	8am - 18:10pm	0	5	0.4	0	Unheated	No vent		NO
18.Free area	0.75	8am - 18:10pm	8am - 18:10pm	0	5	0.4	0	Unheated	No vent		NO
19.Free area	0.75	8am - 18:10pm	8am - 18:10pm	0	5	0.4	0	Unheated	No vent		NO
20.Free area	0.75	8am - 18:10pm	8am - 18:10pm	0	5	0.4	0	Unheated	No vent		NO
21.Lift			Closed	0	0	0.4	0	Unheated	No vent		NO

22.Stair area	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Unheated	No vent		NO
23.Staircase	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Unheated	No vent		NO
24.Stair area	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Radiator	By window		YES
25.Staircase	0.75	8am - 18:10pm	8am - 18:10pm	0	4	0.4	0	Unheated	No vent		NO
26.Technical room	0.75	8am - 18:10pm	8am - 18:10pm	0	1.2	0.4	100	Unheated	No vent		NO

8.2 Annexure2

Dane techniczne kotłów typu STALMARK MAX																		
MODEL KOTŁA	J.m.	60	70	80	90	100	120	140	150	160	180	200	220	250	300	350	400	480
Moc nominalna	kW	60	70	80	90	100	120	140	150	160	180	200	220	250	300	350	400	480
Zakres mocy	kW	20-60	23-70	27-80	30-90	33-100	40-120	47-140	50-150	53-160	60-180	67-200	73-220	83-250	100-300	116-350	133-400	160-480
Powierzchnia grzewcza	m^2	6	7	8	9	10	11	13	14	15	17	19	21	24	29	35	39	48
Pow. ogrzewanych pomieszczeń	m^2	600	700	800	900	1000	1100	1300	1400	1500	1700	1900	2200	2500	3000	3500	3900	4800
Max dop. ciśnienie robocze	MPa	0,15																
Wymagany ciąg spalin	Pa	30-40																
Wymiary komory paleniska awaryjnego* szer/gl/ wys	mm	400/ 200/ 310	400/ 200/ 310	400/ 200/ 310	400/ 200/ 310	600/ 350/ 405	600/ 530/ 405	750/ 530/ 405	750/ 530/ 405	750/ 530/ 405	750/ 530/ 405	920/ 530/ 405	1048/ 530/ 405	1048/ 530/ 405	1100/ 530/ 405	1100/ 530/ 405	1353/ 530/ 405	1446/ 530/ 405
Wym. otworu załadunkowego szer / wys	mm	398/ 356	398/ 356	398/ 356	398/ 356	398/ 356	398/ 356	398/ 356	398/ 514	398/ 514	398/ 514	398/ 514	398/ 514	398/ 514	398/ 514	398/ 514	398/ 514	398/ 514
Zasyp paliwa kosza	l	230	250	270	290	310	340	370	400	440	480	520	580	640	680	740	800	940
Temperatura wody na zasilaniu [min/max.]	oc	55/90																
Masa kotła	kg	1220	1300	1360	1510	1760	1900	2040	2150	2300	2580	2840	2900	3340	3700	4200	4800	5520
Pojemność wodna kotła	l	210	240	280	310	340	450	520	580	680	770	830	960	1150	1300	1500	1700	2200
Min wysokość komina	m	7	7,5	7,5	8	8	8	8	9	9	9	10	10	10	10	12	12	12
prawność kotła	%	~86 - 89																
Wymiary czopucha	ø /mm	246				296											366	
Średnica zasilania i powrotu	in	2"				3"										Króciec śr. 150 mm		
Zasilanie elektryczne	V/Hz	230/50													400/50			
Pobór mocy sterownika	W	7																
Pobór mocy wentylatora	W	100				370											2x 370 (3 fazy)	
Pobór mocy silnika	W	180				370											370 (3 fazy)	

Table 14: Coal Boiler Stalmark Max technical specification

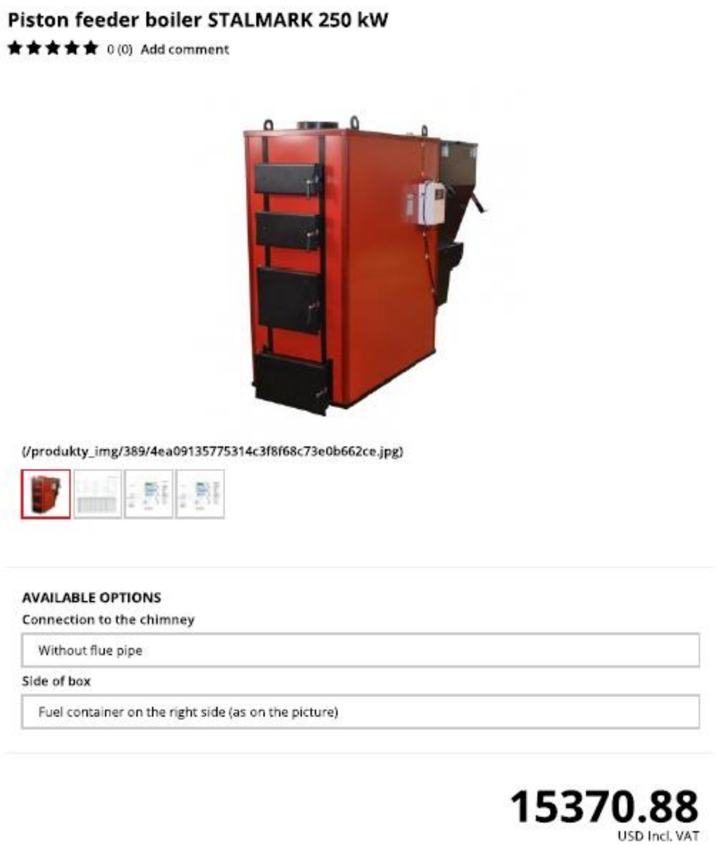

Table 15: Boiler cost Stalmark

Example Thermostatic valve

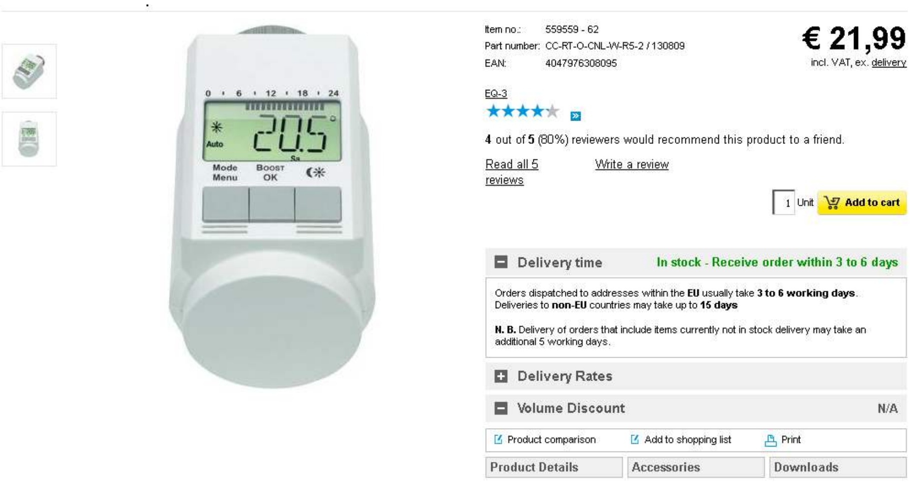

Figure 15: Example Thermostatic Valve eQ-3

Technical data

Category	Elelcronic TRV
Operating voltage	2 x AA battery (1.5 V)
Operation type	electronical
Switching cycle	24 h mode
No. of daily switching programs	7
Temperature settings	5 up to 29.5 °C
Frost protection	Yes
Hysteresis	0.5 °C
Colour	White
Thermostat dimensions (L x W x H)	90 mm x 58 mm x 71.5 mm mm
Content	1 pc(s)
Min. temperature setting	5 °C
Max. temperature setting	29.5 °C

Highlights & details

- LCD
- 7 different time settings per day
- Built-in heat booster

Description

Save up to 30 % on heating bills.
This thermostatic radiator valve operates timer-based, allowing you to pre-set your room temperature preferences for the entire week. The built-in thermostat controls the water flowing through the radiator via the radiator valve, setting the room temperature in the process. The TVR comes with presets - means it is ready for immediate use. To adapt the room temperature to your preferences, the TVR features 3 different timer programs (each with 7 available time settings per day) as well as a 1-week 7-day program menu that allows you to personalise the temperature presets for each day of the week. The built-in heat booster button enables you to raise the room temperature rapidly to comfort level by overriding the TVR presets if required. The device also detects temperature drops caused by open windows. Fitting the TVR is easy and straightforward - no need for specialist tools. Also doesn't require any draining of radiators or alterations to the central heating system.
The TVR is compatible with Heimeier, Danfoss RA-, RAV-, RAVL (adapter required), MNG, Honeywell-Braukmann, Oventrop A/AV6, Schlösser, Comap D 805, Valf Sanayii and Watts radiator valves.

Features

- Automatic frost protection
- Detects rapid drops in temperature
- Detects open windows
- Heat booster
- Child proof
- Easy installation
- Valve protection
- Comes with presets. Ready for immediate use.