Interreg CENTRAL EUROPE

ENERGY@SCHOOL

European Union
European Regional
Development Fund

COMMON METHODOLOGY FOR EVALUATION OF SCHOOL FACILITIES ENERGY CONSUMPTION AND FOR ASSESSMENT OF PRIORITY EE INTERVENTIONS

(MODEL DESCRIPTION)

N. DELIVERABLE D.T1.1.2 Part A
(Deliverable integrated by Part B - Excel form)

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ENERGY@SCHOOL, BRIEF PROJECT OUTLINE

The building sector has high potential for energy optimization being the most consuming one in EU. In terms of public buildings heritage, energy consumption in schools is the second highest expenditure of Municipalities total running costs. This sector offers potential remarkable achievements in terms of Energy Efficiency (EE), Renewable Energy Sources (RES) application and carbon footprint reduction and several disparities exist among Central Europe countries as for planning and implementing performances of proper sector-based strategies, action plans and managerial capacities.

With reference to the **public stock of buildings and infrastructures**, for sure educational facilities are an important opportunity to achieve substantial energy savings, as they constitute a relevant part of the overall amount of energy consumption and therefore of the expenses paid by the national budgets. Energy consumption in schools is the second most significant expense to total running costs and they account up to 70% of the thermal energy cost of Municipalities. Schools, being such an important line in energy-related budget, represent an important sector of public administration to tackle with reference to buildings' upgrade, retrofitting and renovation. Furthermore, schools are the best environment for behavior change and awareness raising of students and, indirectly, their families because they are the privileged place for the dissemination of culture and information as a whole and therefore also in the field of energy saving and efficiency. Consumption in schools can be quite variable depending on country, climate, building year of construction and type. However considering an average energy use profile, consumes can be roughly divided as follows: 47% heating; 14% lighting; 10% cooling; 9% ventilation; 7% water heating; 4% PC; 2% refrigeration; 1% cooking; 1% office equipment; 5% other. It is estimated that just by making small changes in behavior, schools could save up to 20% of their energy use (and bills). This amount can noticeably increase if energy retrofit interventions are associated to behavioral changes (e.g. around 50% with 0.5 to only 2 years payback period).
Public building sector with reference to schools is therefore one of the main issues and there is concrete need to develop energy-efficient management for schools and strategies on how to improve the energy efficiency. There is also need to raise the awareness of school staff and students, and to involve them in the energy saving activities. People have a crucial role in this process, therefore they need to be supported and provided with the best available solutions.

Main ENERGY@SCHOOL objective is to increase the capacity of the public sector to **implement Energy Smart Schools**, by application of an integrated approach that **educate and train schools**

staff and pupils to become Senior and Junior Energy Guardians (EGs) who will engage on progressive and sustainable energy efficiency of buildings and an adequate transfer of a correct attitude towards energy consumption ("energy culture"). Thanks to a commitment to high-performance schools, many school districts are discovering that smart energy choices can have lasting benefits for their students, communities, environment. The key idea is to provide concrete technical Tools and Devices and specialized trainings for School Planning Managers on financing opportunities, designing, operating & maintaining energy solutions. The innovative character lies in the active involvement of employees, experts, students, teachers, families in the process of transforming the school into an energy smart school through specific and targeted training and education activities.

The project will therefore address common barriers associated with energy smart-school management, it will develop and provide a Methodology & Approach usable and replicable within other school buildings, together with the necessary Tools, Devices & Protocols. In this way all parties involved in the energy decisions of a public school (technicians and ICT professionals, administrators, school employees Energy managers) can face in a coordinated manner the issue of Energy Efficiency by implementing effective and validated solutions.

The project will deliver:

- ⇒ 1 Common/Transferrable and 8 customized Strategies for Smart Schools,
- ⇒ 1 joint and 7 customized Energy Smart-school Management Plans,
- ⇒ 3 smart phones APPs for Energy Guardians,
- ⇒ 8 tested pilot solutions of EE & RES application in schools under direct contribution of Energy Guardians, in the form of Guidelines, Toolbox, Best Practices as reference documents and experiences to be capitalized far beyond the project end.
- ⇒ Training & education programs as adaptable & replicable models for capacity-raising and Energy Culture rooting.

ENERGY@SCHOOL expected results:

I. Optimization of energy consumption in schools,
II. Concrete and progressive increase of EE and RES use in schools not only thanks to technical application of smart solutions, but also to non-technical factors such as a better management capacity and responsible behavior toward energy use,
III. Increase of capacity of public sector to deal with increase of EE and RES use in schools thanks to strategy, action plans, tools (methods, approaches), trainings, pilot actions defined and implemented within the project,

IV. Increase in managerial and organizational competences as well as in human resources to ensure the progressive and sustainable energy efficiency and renewable energy se in public schools (trainings),

V. Creation of conditions for new job opportunities (trainings),

VI. Creation of "energy culture", thus responsible attitude towards energy use, thanks to education and raising awareness activities, as it is demonstrated that amount of saved energy can noticeably increase if energy retrofit interventions are associated to behavioral changes.

List of Project Partners

1 Union of Municipalities of Low Romagna Region , Lead Partner – Italy
2 CertiMaC s.c.r.l. - Italy
3 City of Bydgoszcz - Poland
4 ENERGY AGENCY OF SAVINJSKA, ŠALEŠKA AND KOROŠKA REGION - Slovenia
5 City of Karlovac - Croatia
6 University of Bologna - Dept of Industrial Chemistry - Italy
7 Municipality of the CITY Szolnok with County Rank - Hungary
8 Local Government of Town Újszilvás - Hungary
9 City of Stuttgart - Germany
10 Klagenfurt - Austria
11 Graz Energy Agency - Austria
12 City municipality of Celje - Slovenia

Responsible Partner of Thematic Work Package "*Analysis phase and definition of Energy Guardians Smart-school Management Plans*" and the present document: CertiMaC – Research Laboratory -Italy

1. OVERALL APPROACH OF THE METHODOLOGY

The present document describes the evaluation criteria for Energy Efficiency assessment to be implemented on the schools inventory, necessary to define school's energy category (classification) and possible cost-effective interventions depending on costs and expected energy consumption reduction.

Starting from the need to adopt a "common methodology", a preliminary assessment on harmonised technical standards has been addressed. The starting point was the identification of a framework, recognised and already validated all around Europe despite different climate conditions, buildings typology, materials and technology implemented, etc., for calculating the energy performance of buildings. The framework chosen has constituted a starting point on which implement a calculation model easy-to-manage for Energy Managers and user-friendly for Energy Guardians.

In order to develop a model that fits with this scope some preliminary hypothesis and simplifications had to be implemented.

At this purpose, the following technical sources have been preliminarily exploited to implement the energetic model necessary to highlight the priorities in terms of Energy efficiency and Renewable Energy Sources interventions:

- ISO 13790: Energy performance of buildings - Calculation of energy use for space heating and cooling (taking account of losses and gains)
- EN 15603: Energy performance of buildings - Overall energy use and definition of energy ratings (energy use for space heating, cooling, ventilation, domestic hot water and lighting, inclusive system losses and auxiliary energy, and definition of energy ratings)
- EN 15217 - Methods for expressing energy performance and for energy certification of buildings (incl. ways of expressing requirements for regulations)
- EN 16247-1:2012 - Energy audits - Part 1: General requirements (It specifies the requirements, common methodology and deliverables for energy audits)
- EN 16247-2:2014 - Energy audits - Part 2: Buildings (It is applicable to specific energy audit requirements in buildings. It specifies the requirements, methodology and deliverables of an energy audit in a building or group of buildings, excluding individual private dwellings)

Secondarily, on the basis of the technical standards models/calculations, some simplification have been implemented in order to converge into an simplified, but adaptable and accurate model able

to evaluate different kind of structures equipped with different technical systems, situated in very different climatic conditions, etc.

The model has been designed so as to detect school's energy category (classification) and possible intervention according to energy reduction and cost analysis balancing the "cost-effective" solutions proposed. The main results are energy performance indicators, specific indexes developed ad-hoc for schools context, tables and graphs useful to describe/categorize each building school at a glance. Moreover, a list of possible measures to increase energy efficiency of the whole building has been evaluated taking into account the specific cost of each one. Such results will allow the awareness raising into Energy Guardians (junior and senior) to foster on the energy efficiency measurements and RES strategic role. Moreover, it will be possible to make comparisons between different school-facilities.

Below, a brief contents overview of the main technical standards adopted for the model development. The following paragraphs report and highlight what has been considered for the model implementation: initial hypotheses, necessary input data, calculation models and results/outputs

1.1. ISO 13790

This international standard presents a coherent set of calculation methods for the design and evaluation of thermal and energy performance of building envelope.

It provides the methods for assessment of the annual energy use for space heating and cooling of a residential or a non-residential building. It includes the calculation of:

- The heat transfer by transmission and ventilation of the building zone heated to constant internal temperature,
- The contribution of internal (e.g. people) and solar heat gains to the building heat balance,
- The annual energy needs for heating and cooling, to maintain the specified set-point temperatures in the building (latent heat not included),
- The annual energy use for heating and cooling of the building, using input from the relevant system standards.

The main inputs needed for the calculations are the envelope properties: ventilation and transmission properties of building components, heat gains from internal heat sources, solar irradiation, climate data, comfort requirements (set-point temperatures, ventilation rates), controls.

Main outputs are energy need for space heating and cooling and contribution of renewable energy sources.

The whole building is modelled as a single zone. We chose to use the "quasi-steady-state" calculation method and to calculate the building energy balance monthly.

1.2. ISO 15603

The purpose of the standard is to provide energy ratings based on primary energy, carbon dioxide emission and establish general principles for the calculation of primary energy factors and carbon emission coefficients (Annex D and E).

The assessment of the annual energy used by building comprises all the services: HVAC (heating, ventilation and air conditioning), hot water, lighting, other services (e.g. canteen, auxiliary systems, etc.)

The energy rating of buildings can be calculated or measured, depending on the purpose of the model (see *Table 1*).

Table 1 - Type of ratings, table 3 p. 17 EN 15603:2008

	Name	Input data			Utility or purpose
		Use	Climate	Building	
Calculated	Design	Standard	Standard	Design	Building permit, certificate under conditions
	Standard	Standard	Standard	Actual	Energy performance certificate, regulation
	Tailored	Depending on purpose		Actual	Optimization, validation, retrofit planning
Measured	Operational	Actual	Actual	Actual	Energy performance certificate, regulation

Energy rating calculated can be based on the real use of the building and on actual climate input data. It can be tailored on real energy consumptions, so as to optimize, validate and plan retrofit interventions on building envelope and systems.

This standard provides also a practical monitoring method in which energy consumptions are correlated with climatic variables: the energy signature method (described in Annex B). It represents the actual energy behavior of the building. It consists of a graphical representation of the power or energy consumption of a building (heating, cooling, hot water, etc.) as a function of external parameters (usually the outdoor air temperature). In an outdoor temperature-power graph, the slope of the curve represents the overall heat loss coefficient of the building. The

Energy Signature (ES) is also used to evaluate the thermal performance of building components in operational conditions, based on the assumption that in the same outdoor conditions the difference in energy performance is due to the physical characteristics of the elements under evaluation.

1.3. EN 15217

This standard specifies:

- Overall indicators to express the energy performance of the whole building, including HVAC, domestic hot ware (DHW) and lighting systems,
- Ways to express energy requirements for the design of new buildings or renovation of existing ones.

1.4. EN 16247-2

This standard specifies the requirements, common methodology and deliverables for energy audits.

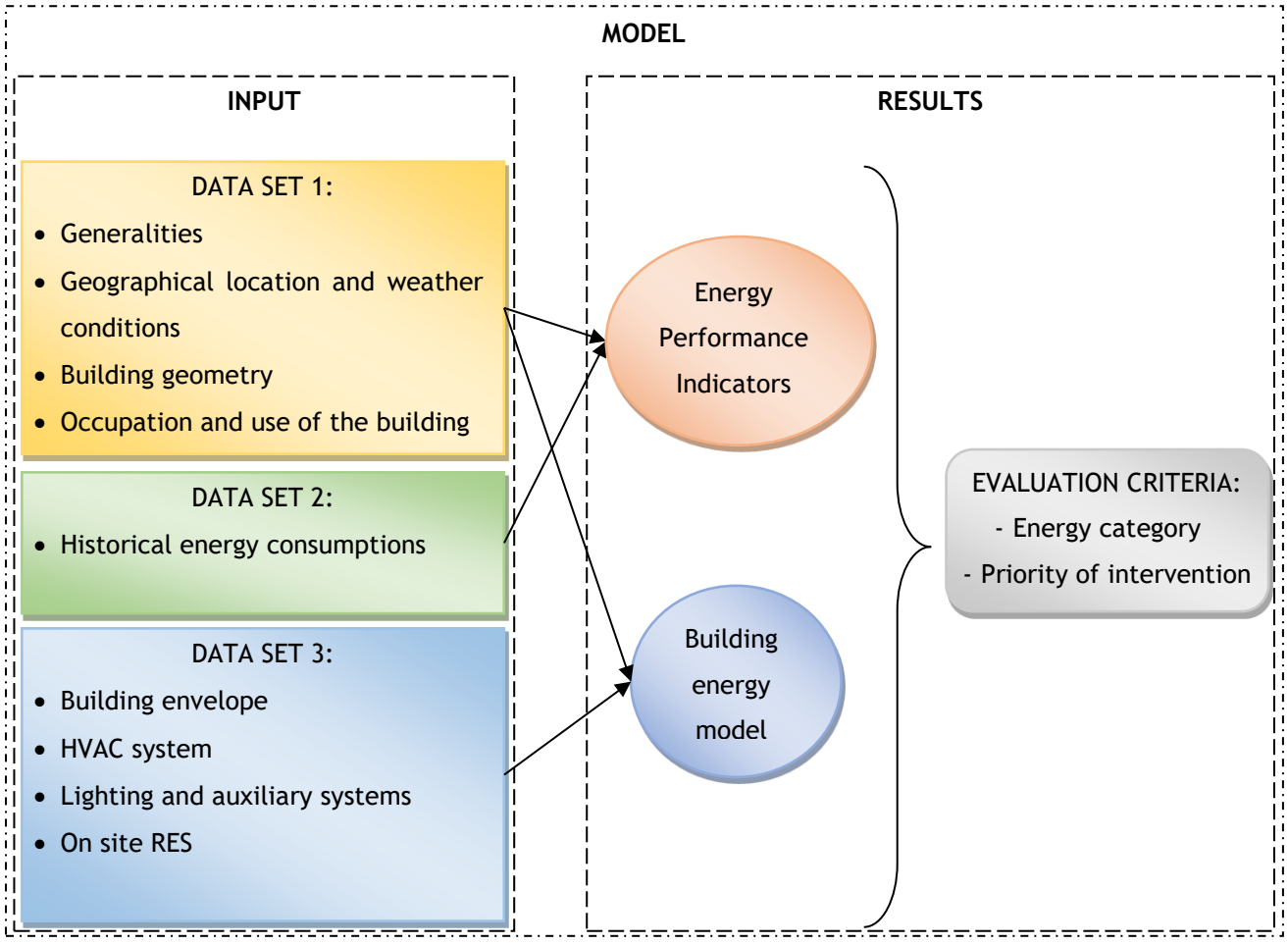
It describes which factors influence energy consumption: local climatic conditions, characteristics of the building envelope, designed indoor environment conditions, characteristics and settings of the technical building systems, activities and processes in the building, occupant behaviour and operational regime.

This standard suggests to include some modelling or calculations to determine the current energy use profile and the energy efficiency improvement opportunities, depending on the scope and thoroughness of the energy audit.

Furthermore, it provides some examples of energy performance indicators, of energy consumption breakdown (using breakdown pie-charts) and of energy signature method.

2. LOGICAL FRAMEWORK

Starting from these hypothesis and the European standards, a calculation model, that allows to analyze energy consumptions and energy performances of a school-facility, has been develpoed. The logical framework of the calculation model is shown in *Picture 8Errore. L'origine riferimento non è stata trovata.*.



Picture 8 - Model logical framework

The model described in this report has been implemented on an excel spreadsheet divided as follows:

- Input data have been reported in 3 different sheets called “DataSet1”, “DataSet2” and “DataSet3”,
- The results have been reported in the “Results” sheet

- The model is developed in 2 further sheets called “Envelope”, reporting the calculations relating to the envelope heat loss, and “Systems Load” reporting the calculations relating to the technical systems and real energy consumption.
- 2 further spreadsheets have been implemented for a quick and effective comparison of consumption before and after the intervention, with the implementation of interventions for the improvement of energy performance.

2.1. INPUT

The input data are divided into three main categories:

- Data set 1: generalities (geographical location and weather conditions, geometry and typical occupation of the building examined);
- Data set 2: Energy consumptions collection;
- Data set 3: Physical data of the building envelope and technical equipment description

Data are collected through a compilation form (ref. D.T1.1.1-Checklist) for each school-facility.

2.1.1. DATA SET 1

The first group (DS1) describes the school generalities, its location and its user profile. More in detail, it contains information about the:

- type of school (primary or secondary school),
- actual climate conditions (average monthly temperatures and average horizontal solar irradiation),
- building geometry (heated floor area, number of floors, exterior wall area, area allocated to classrooms/offices, etc …)
- management criteria (e.g. how the school is used): monthly days of use, opening hours. For this purpose and in order to simplify the data set, users profile are referred to last school year before the analysis period (for Energy@School purposes: from August 2015 until July 2016).

DS1 plays a key role, together with DS2 (described below), in the estimation of Energy performance indicators and, together with DS3, in the implementation of the “building model” according to the necessity to elaborate performance characteristics concerning climate and boundary conditions, envelope features (wall, roof, etc thermal performances) and technical systems efficiency.

2.1.2. DATA SET 2

The second group (DS2) highlights the school historical consumptions in order to lay the basis for a subsequent and more thorough energetic analysis leading toward Energy Audit. For “common

methodology" purposes, the historical consumptions play a pivotal role in the evaluation of Energy Performance indicators.

More in detail, it contains information about each energy carrier[1] used within the building.

Monthly consumptions of the last three school-years are collected:

- electrical energy,
- natural gas,
- fuel oil/Diesel,
- GPL,
- biomass (pellet),
- heat from district heating and cold from district cooling.
- energy produced and consumed by renewable energy technologies (photovoltaic systems, solar thermal collectors, geothermal energy).

2.1.3. DATA SET 3

DS3, together with DS1 (described above) is preparatory to the implementation of the "building model" according to the necessity, as already discussed, to elaborate performance characteristics concerning climate and boundary conditions, envelope features (wall, roof, etc thermal performances) and technical systems efficiency.

DS3 is specifically addressed on the physical characteristics of the building envelope and on the technical systems and equipment of the school-facility (i.e. heat supply systems, ventilation, lighting, etc.).

2.2. RESULTS

The model is provided with a sheet "Results". It contains the outputs of the model that are divided into three main groups.

2.2.1. Energy Model Outputs

Data set 1 plus Data set 3 are forced and elaborated into the energy model framework in order to estimate the whole performance of the building considering both envelope and technical systems contributions/effects. The performances of each partition/sub-system are calculated according to the international standards previously described (ISO 13790, EN 15603 and EN 15217) and the

[1] Energy carrier definition: substance or phenomenon that can be used to produce mechanical work or heat or to operate chemical or physical processes [ISO 13600:1997].

global Energy demand for the heated area and distribution of heat losses through the envelope are calculated.
Moreover, the model estimates HVAC systems performances, lighting and auxiliary systems electric energy demand and canteen energy/fuel consumptions.
Furthermore, the total consumption distribution for each energy carrier split for each final-use, is evaluated and showed into synthetic and visual pie charts.

2.2.2. Real consumptions Outputs.

Tables, graphs and histograms display the results obtained thanks to the analysis of real consumptions distribution:

- histograms show user's profile and average monthly consumptions for each energy carrier and allow the users to identify at a glance the most critics months, the absolute value (maximum/minimum) of consumptions in each season and accordingly to the EG awareness about the building management, they will foster the opening of a discussion into the working group devoted to energy efficiency matters,
- energy signature method (EN 15603:2008), is used as an indirect empirical tool to assess the overall energy behavior of the school-facility at a glance. Plotting fossil fuels (natural gas, GPL and fuel oil) monthly consumptions for heating versus average external temperature provides useful information on the building energy performance and allows a fast detection of critical issues, such as: the internal temperature set point, the under/over size of the heat generator/s installed, the degree of the insulation of the envelope as is, etc.
- the combination of generalities (DS1) and actual consumptions (DS2) provides also Energy Performance Indicators. These indicators, developed ad hoc in order to address the most critical issues into schools environment, are strategic to identify the energy categories and to compare the schools selected all around Central Europe Area.

2.2.3. Evaluation Criteria

In the third group the "evaluation criteria" have been gathered, which will be useful for Energy Guardians and Energy Managers as an operational tool to assess school buildings' energy efficiency interventions/improvements. Here the main possible improvement interventions are proposed: they are evaluated taking into account the cost of intervention and the potential reduction in energy use / fuel consumption.

3. MODEL DEVELOPMENT

3.1. BUILDING ENERGY MODEL

According to the technical standards borrowed (ISO 13790, EN 15603 and EN 15217), a brief description of the calculation criteria and hypotheses are reported below, distinguishing between envelope and technical systems. More in details:

3.1.1. ENVELOPE

The model here described allows to make an estimation of the energy demand of a building in winter (heating) period.

The model approximately quantifies dispersions, taking into account the different contributions (calculated according to the model described in ISO 13790):

- Loss through the building envelope (opaque and transparent, taking also into account the detrimental effects caused by the presence of heat bridges),
- Loss due to ventilation (calculated estimating a standard and constant hourly air exchange equal to n = 0,3 vol/h,
- Internal contributions (depending on the number of students and the auxiliaries turned-on)
- Contribution of the sun in terms of Solar Irradiation.

For every construction system different building / wall types have been hypothesized, each of which has been associated to a thermal transmittance value and a heat bridge correction factor. However, the model gives to the users the opportunity to input a specific trasmittance value, if they know it.

To show an example, below you can find a table with the estimated transmittance values of a perimeter wall.

Table 2 - Estimated trasmittance value for an external wall

	External wall	U [W/m^{2}K]
1	Traditional fired-clay brick m	1,75
2	Cavity wall	1,15
3	Concrete hollow blocks	0,95
4	Fired-clay hollow blocks	0,9
5	Prefab wall (sandwich)	0,7
6	Prefab wall (concrete)	2,8
7	Other: (add U value)	

Also, four different levels of wall insulation have been hypothesized, to which thermal resistance values have been associated, as shown in *Table 3*.

The thermal transmittance of insulation materials are characterised by their λ-values. For instance, λ-value of 0.038 W/m/K is used as standard for the insulation within the model as reference value balancing among the several commercial solutions available onto the market (e.g. Mineral Wool – 0.044, Expanded or Extruded Polystyrene – 0.032).

In Data Set 3 the user has the possibility to choose one of the four insulation level proposed.

Table 3 - Levels of insulation and thermal resistance

	s [m]	R [m^{2}K/W]
No insulation	0	0
Low [2-5 cm]	0,03	0,78947368
Medium [5-10 cm]	0,08	2,10526316
High [>10 cm]	0,12	3,15789474

At this point, following the calculation method described in ISO 13790, it is possible to calculate the dispersion coefficient H [W/K] of perimeter walls. Following the same procedure for the roof, the floor and the windows one can make an estimate of the loss due to transmission through the whole building envelope.

The model allows the evaluation of the free heating up from the sun (e.g. solar gains). The sun heating on the horizontal surface of the roof has been evaluated (no heating from the sun has been calculated on the vertical walls). The estimate of the energy demand in winter must therefore be considered as a conservation calculation due to the absence of internal gains and partially of the solar gains.

The energy demand of the heated area/volume is calculated on a mothly basis, taking into account a monthly average external temperature (based on the geographic localization – DS1

– the monthly average external temperature are evaluated) and a constant internal temperature (conventionally established at 20 °C as comfort set point value) and hypothesizing a continuous operation of the heat generating system throughout the heating period (24h/day).

3.1.2. TECHNICAL SYSTEMS

The systems responsible of the energy consumptions (utilizers) inside the school building are:

- Heating system
- Domestic Hot Water production
- Cooling system
- Ventilation system
- Canteen
- Lighting
- Auxiliary systems (PC, laboratories, etc.)

Simplifications have been adopted for every system mentioned above, and they are reported in the spreadsheed called “Systems loads”. For example, for the heating system, the main systems that generate and distribute heat have been chosen, to which efficiency and therefore energy consumption have been associated, established on the basis of criteria given by regulations and on the basis of the average performance analysed, ensured by the technologies currently available on the market. A request was made to fill in the heating period and the utilization profile of the heating system; in case it is not specified by the user, the heating period is identified as the months in which the external temperatures fall below a certain value (e.g. 12°C) with the aim of distinguish the heating period against the whole solar year.

3.1.3. MODEL IMPLEMENTATION AND OUTPUTS

The energy model, reconstructed according to the above mentioned standards and assumptions, allows to estimate the energy demand of the systems that are responsible for the energy or fuel consumptions and the allocation of consumptions for every energy carrier. For example, the power carrier might be used by the following systems:

- Heating system
- Domestic Hot Water production

- Cooling system
- Ventilation system
- Canteen
- Lighting
- Auxiliary systems (PC, laboratories, etc.)

The model makes an estimate of each systems consumption and therefore the distribution of electric power consumptions is determined with respect to the total amount estimated. The results obtained are visible through pie charts. The results of this part of the model are eventually used to estimate the reduction of energy consumption of every energy utilizer following the interventions of energy requalification.

The following energy audit phase will lead to a further model fine-tuning, which foresees the use of load/utilization adjustment factors, through which it is possible to obtain a match of the energy model with the real building consumption.

3.2. ACTUAL MEASURED CONSUMPTIONS ANALYSIS

In this part of the model, analysis of real consumptions were made, according to the technical standards (EN 15603 and EN 16247). Below, a brief description of the method used.

3.2.1. ENERGY PERFORMANCE INDICATORS (EnPIs)

As reported in EN 16247-1, an Energy Performance Indicator is a qualitative value or measure of energy performance. It represents the consumption of an energy carrier or of overall energy related to an adjustment factor[2]. Adjustment factors are the consumption drivers (independent variables) that affect energy consumptions. These indicators allow us to compare consumptions of different school-facilities.

The factors chosen for the school-facilities inventory are shown in *Table 4Table 1*.

Table 4 - Adjustment factors

[2] Adjustment factor definition: Quantifiable parameter affecting energy consumption: weather conditions, behaviour related parameters (indoor temperature, light level) working hours, etc. [EN 16247-2]

Adjustment factor	Heated volume of school-facility	Total floor heated area	Total classrooms area	Number of students	Number of days
u.m.	m^3	m^2	m^2	Student	day

Energy Performance Indicators are calculated by dividing measured annual consumption of an energy carrier by an adjustment factor. For each energy carrier the EnPIs shown in *Table 5* were calculated. For each EnPI, the unit of measurement (u.m.) depends on the u.m. of energy carrier analyzed (e.g. Sm^3 for natural gas or kWh for electrical energy).

Table 5 - Energy Performance Indicators

EnPI	Consumption per volume	Consumption per heated area	Consumption per classrooms area	Consumption per number of students	Consumption per number of days
	u.m./m^3	u.m./m^2	u.m./m^2	u.m./student	u.m./day

The indicators are useful to compare the analysed school building with other buildings and benchmark of reference and contribute to create a common methodology also during a comparison phase. They are also the basis on which the identification of energy categories is grounded.
Once the yearly consumption of energy carriers used is collected, it is possible to calculate also the kg CO_2 equivalent produced [3] (kg CO_2 equiv) and the tons equivalent oil[4] (toe). This is useful to compare and sum up among them the consumption components deriving from different energy sources and not comparable by nature (e.g. electrical and thermal kWh), with the aim of obtaining the school's global consumptions.
This is the reason why it is necessary to use conversion factors.
Regulations EN 15603 reports in Table E.1, annex E, the only European reference with respect to the conversion factors of primary energy and kg CO_2. The source of the values reported in the Regulations (*Picture 9)* is a study conducted by ETH in Zurich in 1996.

[3] A **carbon dioxide equivalent or CO2 equivalent**, abbreviated as **CO2-eq** is a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential (GWP), by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential.

[4] **Tonne(s) of oil equivalent**, abbreviated as **toe**, is a normalized unit of energy. By convention it is equivalent to the approximate amount of energy that can be extracted from one tonne of crude oil. It is a standardized unit, assigned a net calorific value of 41 868 kilojoules/kg and may be used to compare the energy from different sources. (http://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary)

	Primary energy factors f_p		CO_2 production coefficient K
	Non-renewable	Total	kg/MWh
Fuel oil	1,35	1,35	330
Gas	1,36	1,36	277
Anthracite	1,19	1,19	394
Lignite	1,40	1,40	433
Coke	1,53	1,53	467
Wood shavings	0,06	1,06	4
Log	0,09	1,09	14
Beech log	0,07	1,07	13
Fir log	0,10	1,10	20
Electricity from hydraulic power plant	0,50	1,50	7
Electricity from nuclear power plant	2,80	2,80	16
Electricity from coal power plant	4,05	4,05	1340
Electricity Mix UCPTE	3,14	3,31	617

Picture 9 - Primary energy factors and CO2 production coefficients - Table E.1 Annex E, EN 15603

In the last 20 years the European energy mix has surely changed, because the share of energy produced from renewable sources has increased and the performance/efficiency of traditional energy production systems has improved.

After accurate researching, it has therefore been decided to use the values reported in Circular 18th December 2014 issued by MiSE (Italian Ministry of Economic Development) shown in *Table 6* as conversion factors.

The first factor shown in the table is the Low Heating Value, which allows to transform the volumes and masses of fuel in thermal energy. Starting from energy consumption and through the use of the conversion factors contained in the table, it is possible to calculate the kg CO_2 equiv and toe.

Table 6 - Lower Heating Value, Co2 production coefficients, toe conversion factor

ENERGY CARRIER	u.m.	LHV (Lower Heating Value)		CO_2 equivalent		Conversion factor toe*	
Electricity	kWhe		-	0.4332	kg_CO_2/kWh	0,187 x 10^-3	Toe/kWh
Natural gas	Sm^3	9.6	kWh/Sm^3	0.1998	kg_CO_2/kWh	8.250 x 10 ^-7	Toe/Sm^3
Diesel/Fuel oil	t	11.76	kWh/kg	0.2642	kg_CO_2/kWh	LHV (kcal/kg) x 10^-4	Toe/t
GPL	t	12.8	kWh/kg	0.2254	kg_CO_2/kWh	LHV (kcal/kg) x 10^-4	Toe/t
Pellet	t	4.6	kWh/kg	0	kg_CO_2/kWh	LHV (kcal/kg) x 10^-4	Toe/t
District heating	kWh_t		-	0.36	kg_CO_2/kWh	860/0,9 x 10^-7	Toe/kWh_t
District cooling	kWh_f		-	0.1688	kg_CO_2/kWh	(1/ EER) x 0,187 x 10^-3	Toe/kWh_f

4. EVALUATION CRITERIA

4.1. SCHOOL'S ENERGY CLASSIFICATION

The criteria of energy classification adopted for the analysis of school buildings are based on a confrontation principle connected to the sample of schools analysed in the project. In practice, the classification has been set starting from the EnPI calculated on the basis of the real consumptions calculated in toe and kg CO_2 equivalent normalizing such EnPI according to a specific parameter climate related. This parameter is a "standard Degree Day" evaluated as follow:

$$DD = \sum_{e=1}^{n} (T_i - T_e) \quad for\ T_e < T_i$$

Where:

- DD = degree day indicator
- Ti = internal reference temperature assumed as setpoint able to guarantee indoor comfort (e.g. 20 °C),
- Te = external monthly average temperature evaluated in each territory
- n = conventional number of days assumed as "heating period".

In this way, it is possible to compare schools starting from a common criterion taking into account homogeneous energy quantities climate related, but at the same time taking into account the specific features of each of them.

According to this approach, it has been chosen to build up a "scale" of normalised energy performances (Measured energy rating) of school buildings identifying 5 different categories. Data were collected in all the schools and the highest EnPI were chosen (less efficient buildings), which were awarded one star, and the lowest indexes (more efficient buildings) to which 5 stars were awarded. The interval between the two indexes is divided into 5 sub-intervals each of which is assigned a category (corresponding to a different number of stars).

In this way no "absolute classification" is obtained, as it is the case with energy classification, but rather a classification relating to the sample of the analysed schools. Nevertheless, considering the high number of structures taken into account (more than 70) in 7 different countries (Italy, Slovenia, Croatia, Hungary, Poland, Germany and Austria), each of them having different climate characteristics, architecture specifications and management strategies with respect to the envelope/system energy solutions used, it's possible to assume

this classification representative of the whole (specific) existing building stock along Central Europe. So, we believe that the classification described might have a much broader importance and create a benchmark for the other countries in the Central Europe area.

Table 7 - School's energy classification based on EnPI

EnPI	*	**	***	****	*****
	Low performance				High performance
toe/m^2/DD					
toe/student/DD					
toe/day/DD					

4.2. PRIORITY OF INTERVENTIONS

The interventions proposed have been hypothesized and selected on the basis of the state-of-the-art situation and market practice typically used today, both in the field of energy efficient solutions (requalification of envelope and system) and of renewable energy sources implementation (photovoltaic systems, thermal solar, etc.), as well as regulation and automation (e.g. BACS).

On the other hand, the criteria according to which an intervention is defined as a "priority" instead of another, have been chosen starting from the analysis of the "status quo" of the building-system conditions, taking into account its physical features, the utilization profiles the year of installation of its components, and the relevance/weight of the different consumption items.

On the basis of the critical points observed analysing the data reported in Data set 3, some standard interventions have therefore been identified. They are listed in the following paragraph.

For every intervention the reduction in consumption has been calculated and the costs of

Retrofit external walls with the addition of an insulation layer

- Retrofit roof with the addition of an insulation layer
- Replace windows with more efficient ones
- Install solar shading systems

Assumptions:

The thickness and insulation of the roof, floor and wall insulation influences the buildings heat exchange with the external environment and thereby its heating and/or cooling energy demand. In this analysis, due to the very huge number of possible case studies, simplified and discrete scenarios are considered.

For instance, in case of a wall with no or low insulation (current situation), a 8 cm layer of insulation is added (retrofitted solution) considering an intermediate level of refurbishment. For the roof insulation can be added from above. An extra layer of insulation may be added on the inside or on the outside of the walls, the latter being more efficient, but generally also more costly. These solutions can improve the whole performance of the building.

For windows replacement, choosing a low-ε-coated double or triple glazed window will often be the best choice. In this analysis windows are replaced with a window with U_w = 1,5 W/m^{2}K.

More shading can lower sun effect during summer time, lowering air conditioning energy consumptions up to 10%.

4.2.1. RETROFIT OF THE HEAT GENERATING SYSTEM AND ITS REGULATION AND DOMESTIC HOT WATER PRODUCTION SYSTEM

- Replace heat generator with a more efficient one
- Install thermostatic valves
- Replace electrical boilers with heat pumps

Assumptions:

For the analysis when heating supply is an old gas boiler, possibilities to improve and replace this system are:

- New high efficiency gas boiler
- New condensing gas boiler

The technical characteristics of each of the above replacement technologies are primarily efficiencies which represent the best available technologies today.

For Domestic Hot Water, old electric boilers can be replaced with more efficient heat pumps.

Thermostat controllers prevent the heating system from continuing to heat when internal temperatures have reached the comfort zone. It is estimated a thermal energy reduction for heating system of 2-5%.

4.2.2. RETROFIT OF THE LIGHTING AND REGULATION SYSTEM

- Replace lights with LED
- Install Energy Saving Switches and Presence Sensors

Assumptions:

The efficient lighting systems considered are new light LED lamps of 25 W.

Energy consumed by the electrical lighting system can be saved by installing better light emitting technology, better control systems (occupancy and daylight dependent dimming).

4.2.3. INSTALLATION OF SMART METERING AND/OR DI BUILDING AUTOMATION SYSTEMS

- Install smart metering
- Install building automation system (automatic centralized control of a building's heating, ventilation and air conditioning, lighting…)

Assumptions:

A building energy management system (BEMS) may be used for several purposes, but energy-wise a BEMS system can reduce heating distribution system losses (e.g. by closing down the system, when there is no heating need or reducing the temperatures to what is precisely required) and can reduce lighting and electrical equipment consumptions. Depending on the technology installed, overall consumptions can be reduced up to 10-50%.

Besides, a smart metering system can provide a continuous overview of the state of the system and thereby contribute to locating any malfunctioning.

4.2.4. INSTALLATION OF RES SYSTEMS

- Install a photovoltaic system
- Install a solar thermal system

Assumptions:

Electrical energy produced with PV system with a standard assumed area and efficiency: 1100 kWh/kW_p

Thermal energy produced with solar collector systems with a standard assumed area and efficiency: 400 kWh/m^2

The installation of a 20 kW_{peak} photovoltaic system has been hypothesized in case the consumption of electric power exceeds 25000 kWh/year.

4.2.5. CHANGE END-USER BEHAVIOUR: CONTROL DEVICES STAND-BY (MONITORS, PCS, LABORATORY EQUIPMENT, LIGHTS, ETC.)

Assumptions:

To a greater awareness of users, it follows a more careful and controlled use of technologies such as lighting, cold and heat generation systems, electronic equipment. It is plausible to consider a reduction of approximately 2-5% of the electrical consumption of the building according to a behavioral change.

4.3. COSTS OF INTERVENTIONS

In order to define a reference framework on which defining theoretical costs of interventions, a deep research on the state-of-the-art has been implemented through the major European network devoted to Buildings science (e.g. BPIE papers, ECTP platform documents), but anyone define standard costs for intervention at European Level. So, in order to implement a baseline in terms of costs of interventions, the following table has been assumed as reference for model implementation (values reported are referred to “Maximum costs” provided into DGR 610/2016 - Annex 2). This assumption is clearly a simplification into the wide range of possibilities and technologies costs available all around Europe, but it fix a starting point to implement the present Common Methodology. Moreover, choosing the maximum costs, a cautionary assumption has been implemented though aware that in some of the Countries involved into the Project, these costs could be result overestimated.

Table 8 - Costs of interventions

	Unit cost of intervention	
Retrofit of external walls with insulation	100	€/m2
Retrofit of roof with insulation	200	€/m2
Replacement windows	450	€/m2
Installation solar shading systems	150	€/m2
Replacement of heat generator with a more efficient one	160	€/kW
Installation of thermostatic valves	70	€/valve
Replacement of lights with LED	25	€/lamp
Installation of Energy Saving Switches and Presence Sensors	250	€/point
Installation of smart metering	5000	€
Installation of a photovoltaic system	1600	€/kWp
Installation of a solar thermal system	600	€/m2
Replacement of an electrical boilers with heat pumps	1500	€/kW
Installation of building automation system (automatic centralized control of a building's heating, ventilation and air conditioning, lighting…)	25	€/m2
Change in end-user behaviour: control devices stand-by (monitors, PCs, laboratory equipment, lights, etc.)	0	€