TEESCHOOLS

Transferring Energy Efficiency in Mediterranean Schools

PRIORITY AXIS: Fostering Low-carbon strategies and energy efficiency in specific MED territories: cities, islands and remote areas

OBJECTIVE: 2.1 To raise capacity for better management of energy in public buildings at transnational level

DELIVERABLE NUMBER: 5.2

TITLE OF DELIVERABLE: WP5 Capitalizing TEESCHOOLS methodology: e-learning modules

WP n. 5: CAPITALISING

ACTIVITY n. 5.2.1 Report on e-learning modules

PARTNER IN CHARGE: FVMP

PARTNERS INVOLVED: ALL PARTNERS

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The e-learning modules integrates TEESCHOOOLS methodology that it has been developed during the phases of the project.

The e-learning modules has been adjusted to the MOODLE Learning Management System to be used in platforms that allow everyone to access to quality education without having to leave of workplace or home.

Professionals, researcher and other stakeholders are the target groups who the content of e-modules is addressed.

This document includes 13 modules with the following thematic:

INDEX

The normative context. Level of Implementation of EU directives. The NZEB concept. NZEB concept in the partner countries.

TITLE OF MODULE 1. THE NORMATIVE CONTEXT. LEVEL OF IMPLEMENTATION OF EU DIRECTIVES. THE NZEB CONCEPT.

- Presentation of the module

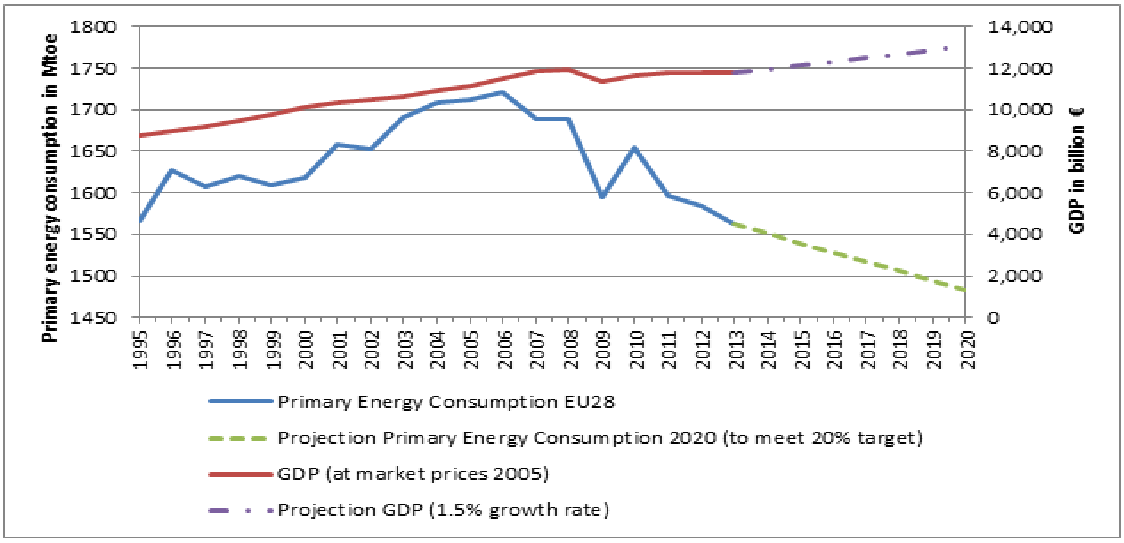
Production and usage of sustainable energy has been set as a fundamental pillar to draw a more competitive economically and environmental-friendly growth for Europe. To have at our disposal a more sustainable energy system is based mainly on taking profit of own renewable energy sources and to use energy more efficiently, permitting Europeans to reduce their energy bills, to reduce their reliance on external suppliers of oil and gas, and protecting the environment against climate change.

European Commission presented a framework for climate and energy policies in the period 2020 to 2030. This framework proposes ambitious targets for greenhouse gas emissions reduction and renewable energy as part of the Union's transition to a competitive low carbon economy. It also promotes reduced energy dependency and more affordable energy for business and consumers via a well-functioning internal market. The 2030 framework has since been complemented by a more detailed analysis of the Union's energy security, taking into account recent geopolitical events at the eastern border of the EU, together with a strategy that proposes concrete actions to reduce energy dependency in the immediate future and over the longer term

Energy efficiency has a fundamental role to play in the transition towards a more competitive, secure and sustainable energy system with an internal energy market at its core. While energy powers our societies and economies, future growth must be driven with less energy and lower costs. The EU can deliver this new paradigm. As the figure shows, well before the crisis hit in 2008, the EU had started to decouple economic growth from energy consumption through increased energy efficiency. An increasing decoupling of economic growth and energy consumption has continued since then, driven by price signals and by a comprehensive set of energy efficiency policies (see figure)[1].

Figure 1. Evolution of energy consumption and GDP in the EU 1995-2013

[1] COM(2014) 520 Final. Energy Efficiency and ints contribution to energy security and the 2030 Framework for climate and energy police.



Source: Commission services based on EUROSTAT data

The current EU energy efficiency framework is mainly formed by the following main legislation:

- The Energy Efficiency Directive 2012/27/EU (EED)[2];
- The Energy Performance of Buildings Directive 2010/31/EU (EPBD);
- Directive 2018/844/EU amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency;
- The Energy Labelling Directive 2010/30/EU and Ecodesign Directive 2009/125/EC by means of which were established product regulations laying down minimum energy performance standards and putting energy performance information on labels;

On the other hand, in Europe the building industry accounts for the largest share of greenhouse gas emissions in terms of energy end usage. It represents about 36% of Europe's national emissions. Its share in the total energy consumption is also the highest with 40%. To contribute to EU greenhouse gases reduction threshold, EU countries must implement the following measures addressed to building sector:

- EU countries making energy efficient renovations to at least 3% of buildings owned and occupied by central governments per year;
- The public sector in EU countries should purchase energy efficient buildings, products and services;
- Mandatory energy efficiency certificates accompanying the sale and rental of buildings;
- Minimum energy efficiency standards and labelling for a variety of products such as boilers, household appliances, lighting and televisions;
- The preparation of National Energy Efficiency Action Plans every three years;

[2] And its predecessors the CHP Directive (2004/8) and the Energy Services Directive (2006/32).

- The planned rollout of close to 200 million smart meters for electricity and 45 million for gas by 2020;
- Protecting the rights of consumers to receive easy and free access to data on real-time and historical energy consumption

- Learning objectives of the module

- Understand the general framework of energy efficiency policies;
- Understand the objectives of EU policies related to building sector and how this mandatory actions must be implemented by EU countries;
- Understand the status of implementation of NZEB policies at TEESCHOOLS partnership countries.

- Section 1. Energy Efficiency Directive

European Union members adopted on 2008 the 2020 climate and energy package to struggle against climate change. This plan was launched in March 2007, and after months of tough negotiations between the member countries, it was adopted by the European Parliament on December 2008. The European plan on climate change consists of a range of measures adopted by the members of the European Union to reduce greenhouse gases emissions by setting 3 key targets:

- 20% cut in greenhouse gas emissions from 1990 (Kyoto Protocol baseline year) levels by 2020;
- 20% of EU energy consumption from renewables by 2020, and;
- 20% savings of EU energy consumption by 2020.

With this 2020 climate and energy package the EU paid attention to some of the most relevant Europe common challenges resulting from increased dependence on energy imports and scarce energy resources, and the need to limit climate change impact. But it was also as a strategic driver to overcome the economic crisis and 20-20-20 target were also headline targets of the Europe 2020 strategy for smart, sustainable and inclusive growth.

Consequently, EU decided to update their energy efficiency legal framework with the Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, to firmly pursue the overall objective of the energy efficiency target of saving 20 % of the Union's primary energy consumption by 2020, and of making further energy efficiency improvements after 2020. The 2012/27/EU Directive revised the previous 2009/125/EC and 2010/30/EU Directives and repealed Directives 2004/8/EC and 2006/32/EC.

This Directive established a common framework of measures for the promotion of energy efficiency within the Union in order to ensure the achievement of the Union's 2020 20 % headline target on energy efficiency. Under the 2012/27/EU

Directive, all EU countries are required to use energy more efficiently at all stages of the energy chain, from production to final consumption.

The Energy Efficiency Directive (the "EED") entered enter into force on 4 December 2012. Member States will have mainly to transpose it by 5 June 2014.

The EED clearly defines and quantifies for the first time the EU energy efficiency target as the "Union's 2020 energy consumption of no more than 1474 Mtoe primary energy or no more than 1078 Mtoe of final energy". The EED also requires the Member States to set national indicative energy efficiency targets for 2020.

Directive 2012/27/EU sets measures for Member States addressing consumers and industry alike such as[3]:

- energy distributors or retail energy sales companies have to achieve 1.5% energy savings per year through the implementation of energy efficiency measures
- EU countries can opt to achieve the same level of savings through other means, such as improving the efficiency of heating systems, installing double glazed windows or insulating roofs
- the public sector in EU countries should purchase energy efficient buildings, products and services
- every year, governments in EU countries must carry out energy efficient renovations on at least 3% (by floor area) of the buildings they own and occupy
- energy consumers should be empowered to better manage consumption. This includes easy and free access to data on consumption through individual metering
- national incentives for SMEs to undergo energy audits
- large companies will make audits of their energy consumption to help them identify ways to reduce it
- monitoring efficiency levels in new energy generation capacities.

What refers to building industry that is the topic studied with this module, the 2012/27/EU raised the need for a increase of building stock reforbishment rate because buildings are identified as crucial to achieve EU emissions reduction.

At the same time, buildings owned by public bodies represent a considerable part or the total building stock and have high visibility in public life. The exemplary role of public administration is set in the energy efficiency directive with an annual rate of renovation of buildings to upgrade their energy performance owned and occupied by central government on Member States.

Article 5 requires that central governments of Member States renovate each year 3% of the total floor area of the buildings they own and occupy that do not meet

[3] EC website: https://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive

the minimum efficiency requirements set under the Energy Performance of Buildings Directive 2010/31/EC to at least the efficiency levels that they set in application of that Directive. Member States must establish and make publicly available an inventory of all relevant central government buildings by 31 December 2013. If a Member State renovates more than 3% of the total floor area of central government buildings, it can count this towards its obligations in any of the three previous or three following years. As an alternative to the requirement to renovate 3% of the floor space of central government buildings, Member States may take other cost-effective measures that would achieve at least an equivalent level of energy savings within their central government buildings. The amount of energy savings required under the alternative approach is cumulative, meaning that Member States are required to achieve the sum of annual energy savings over the whole period between 2014 and 2020, irrespective of the savings achieved in each individual year during that period. Member States may use estimates for establishing the required level of savings.

EED article 6 related to purchasing by public bodies, requires that central governments purchase products, services and buildings with high energy-efficiency performance defined through EU legislative acts, such as the Energy Performance of Buildings Directive. Regional and local public bodies should be encouraged to follow the exemplary role of their central governments to purchase only products, services and buildings with high energy-efficiency performance (for instance concluding long- term energy performance contracts that provide long-term energy savings).

The article 8 regarding energy audits and energy management systems, imposes two main obligations upon Member States: to promote the availability of energy audits among final customers in all sectors and to ensure that enterprises that are not SMEs carry out energy audits at least every four years.

Article 9, metering and billing information, requires that final customers for electricity, natural gas, district heating, district cooling and hot water should have a competitively priced individual meter that accurately reflects their energy consumption and provides information on the time of their energy use (with exceptions based on technical and financial grounds).

Article 14, Promotion of efficiency in heating and cooling, requires Member States to prepare a comprehensive assessment to identify the cost-effective potential of high-efficiency cogeneration and efficient district heating and cooling, taking into account climate conditions, economic feasibility and technical suitability (at the end of 2015). Based on the identified potential, Member States should take measures to implement the cost-effective potential of high-efficient cogeneration and efficient district heating and cooling. In the assessment Member States should provide information on the measures, strategies and policies that may be adopted to achieve the potential for high-efficiency cogeneration up to 2020 and 2030.

On 30 November 2016 the Commission proposed an update to the Energy Efficiency Directive, including a new 30% energy efficiency target for 2030, and measures to update the Directive to make sure the new target is met. This new regulation, the Directive 2018/844/EU of the European Parliament and of the Council of 30 May 2018 obliges Member States to set out a roadmap with measures and domestically established measurable progress indicators, with a view to the long-term 2050 goal of reducing greenhouse gas emissions in the Union by 80-95 % compared to 1990, in order to ensure a highly energy efficient and decarbonised national building stock and in order to facilitate the cost-effective transformation of existing buildings into nearly zero-energy buildings.

- Section 2. Energy Performance in Buildings Directive (EPBD)

With the purpose of laying down more concrete actions with a view to achieving the great unrealised potential for energy savings in buildings,l Member States approved the Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings.

This Directive promotes the improvement of the energy performance of buildings within the Union, taking into account outdoor climatic and local conditions, as well as indoor climate requirements and cost-effectiveness.

Going into details, EPBD article 4 states that Member States shall take the necessary measures to ensure that minimum energy performance requirements for buildings or building units are set with a view to achieving cost-optimal levels, differentiating between new and existing buildings and between different categories of buildings. Moreover, Member States shall take the necessary measures to ensure that minimum energy performance requirements are set for building elements that form part of the building envelope and that have a significant impact on the energy performance of the building envelope when they are replaced or retrofitted, with a view to achieving cost-optimal levels.

Article 6 and 7 of EPBD declared that EU members new and existing buildings (under major renovation process) would carry out the technical, environmental and economic feasibility analysis of high-efficiency alternative systems to meet the minimum energy performance requirements.

Article 8, Technical building systems, sets that Member States shall, for the purpose of optimising the energy use of technical building systems, set system requirements in respect of the overall energy performance, the proper installation, and the appropriate dimensioning, adjustment and control of the technical building systems which are installed in existing buildings. Member States may also apply these system requirements to new buildings. System requirements shall consider, at least, the following ones: heating systems, hot water systems, air-conditioning systems, large ventilation systems, and/or a combination of such systems.

Furthermore, Member States shall encourage the introduction of intelligent metering systems whenever a building is constructed or undergoes major renovation.

Article 9, concerning Nearly zero-energy buildings, specifies that all new buildings must be nearly zero-energy buildings by 31 December 2020 (public buildings by 31 December 2018). For that reason, Member States shall draw up national plans for increasing the number of nearly zero-energy buildings, including targets differentiated according to the category of building.

Article 10, Financial incentives and market barriers, EU countries shall draw up lists of national financial measures to improve the energy efficiency of buildings.

Article 11, Energy performance certificates, sets that Member States shall lay down the necessary measures to establish a system of certification of the energy performance of buildings. The energy performance certificate shall include the energy performance of a building and reference values such as minimum energy performance requirements in order to make it possible for owners or tenants of the building or building unit to compare and assess its energy performance. The energy performance certificate shall include recommendations for the cost-optimal or cost-effective improvement of the energy performance of a building or building unit, unless there is no reasonable potential for such improvement compared to the energy performance requirements in force.

In this line, article 12 obliges Member States to issue an energy performance certificate when a buildings or building units which are constructed, sold or rented out to a new tenant. Public authority building must also haver at public disposal the energ certificate.

Article 14 and 15 , Inspection of heating and air-conditioning systems, declares that EU countries must establish inspection schemes for heating and air conditioning systems.

New Directive 2018/844/EU also update EPBD establishing new rules such as follows:

- Smarter buildings by means of encouraging more automation and control systems to make them operate more efficiently. And the obligation to rate the smart readiness of buildings with an indicator that will measure building's capacity to use new technologies and electronic systems to adapt to the needs of the consumer, optimise its operation and interact with the grid;
- Electromobility in buildings to ensure the deployment of e-mobility infrastructure such as e-charging points in new and buildings undergoing major renovation;
- Increase in financing instruments and technical support by mobilising public and private financing and investment for renovation activities,

and strengthening long-term building renovation strategies to achieve highly efficient and decarbonised building stock towards nearly zero-energy buildings (NZEB), in particular by an increase in deep renovations;
- Struggle against energy poverty and reduce the household energy bills through renovation and improved energy performance of older buildings.

Section 3. Nearly Zero-Energy Buildings (NZEB)

Buildings are considered as central for the EU's energy efficiency policy, and all energy regulations framework is pushing for catalysing the energy performance of buildings and the transition to nearly zero- energy buildings (NZEB) that shall become the norm for any new building in the EU from 2021 on.

The main rule that is affecting NZEB is the Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings.

The EPBD Directive 2010/31/EU defined 'nearly zero-energy building' as follows: *'nearly zero-energy building' means a building that has a very high energy performance, as determined in accordance with Annex I. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby;*

The article 9 of EPBD obliged Member States to:

a) by 31 December 2020, all new buildings are nearly zero-energy buildings; and;
b) after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings.

The referred article also compelled Member States to draw up national plans for increasing the number of nearly zero-energy buildings. These national plans might include targets differentiated according to the category of building and invited Member States to develop policies and take measures such as the setting of targets in order to stimulate the transformation of buildings that are refurbished into nearly zero-energy buildings.

Briefly, the national plans should include, at least, the following elements:

I. Definition of NZEBs, its detailed application in practice is the responsibility of the Member States;
II. The energy performance of a 'nearly zero-energy' building reflecting their national, regional or local conditions, and including a numerical indicator of primary energy use expressed in kWh/m 2 per year. Primary energy factors used for the determination of the primary energy use may be based

on national or regional yearly average values and may take into account relevant European standards;

III. Intermediate targets for improving the energy performance of new buildings, by 2015, with a view to preparing the implementation of expected deadlines;

IV. Information on the policies and financial or other measures for the promotion of nearly zero-energy buildings, including details of national requirements and measures concerning the use of energy from renewable sources in new buildings and existing buildings undergoing major renovation.

V. Member States might decide not to apply those requirements in specific and justifiable cases where the cost-benefit analysis over the economic lifecycle of the building in question is negative.

The framework definition of NZEB in the EPBD does not differentiate between new and existing buildings.

On 2016, the European Commission published the Recommendation (EU) 2016/1318 of 29 July 2016 on guidelines for the promotion of nearly zero-energy buildings and best practices to ensure that, by 2020, all new buildings are nearly zero-energy buildings. The referred document provides an overview of the EU expectations and vision for NZEB. This recommendations provided a the following ranges for the different EU climatic zones:

<u>Mediterranean</u>

- Offices: 20-30 kWh/(m2.y) of net primary energy with, typically, 80-90 kWh/(m2.y) of primary energy use covered by 60 kWh/(m2.y) of on-site renewable sources;
- New single family house: 0-15 kWh/m2.y) of net primary energy with, typically, 50-65 kWh/(m2.y) of primary energy use covered by 50 kWh/(m2.y) of on-site renewable sources;

<u>Oceanic:</u>

- Offices: 40-55 kWh/(m2.y) of net primary energy with, typically, 85-100 kWh/(m2.y) of primary energy use covered by 45 kWh/(m2.y) of on-site renewable sources;
- New single family house: 15-30 kWh/(m2.y) of net primary energy with, typically, 50-65 kWh/(m2.y) of primary energy use covered by 35 kWh/(m2.y) of on-site renewable sources;

<u>Continental:</u>

- Offices: 40-55 kWh/(m2.y) of net primary energy with, typically, 85-100 kWh/(m2.y) of primary energy use covered by 45 kWh/(m2.y) of on-site renewable sources;
- New single family house: 20-40 kWh/(m2.y) of net primary energy with, typically, 50-70 kWh/(m2.y) of primary energy use covered by 30 kWh/(m2.y) of on-site renewable sources;

<u>Nordic:</u>

- Offices: 55-70 kWh/(m2.y) of net primary energy with, typically, 85-100 kWh/(m2.y) of primary energy use covered by 30 kWh/(m2.y) of on-site renewable sources;
- New single family house: 40-65 kWh/(m2.y) of net primary energy with, typically, 65-90 kWh/(m2.y) of primary energy use covered by 25 kWh/(m2.y) of on-site renewable sources.

The state-of-art of NZEB at TEESCHOOLS project member states is shown at the following section:

1. Italy.
   Italian National law considering nZEB is the Legislative Decree 102/2014 (with consequent modifications and additions) and the Interministerial Decree 26 June 2015 that establishes minimum requirements for buildings about envelope, systems and nZEB.

   Italy defines a nZEB as a building with very high energy performance in which the energy requirement (very low or almost zero) is covered by a significant part of energy from renewable sources, produced locally.

   A nearly zero energy building (nZEB), both for new and existing building, must meet the following technical requirements:

   a) minimum requirements established by the Ministerial Decree of 26 June 2015 "Minimum building requirements"
   b) the obligations of integrating renewable sources are respected in compliance with the minimum principles set out in Annex 3, paragraph 1, letter c) of Legislative Decree 3 March 2011, n. 28.

   From 2021, all new buildings or buildings subject to a major first-level renovation will have to be nZEB. In the same cases public buildings will give the example, responding to the NZEB requirements already from 2019.
   Some regions have even been more ambitious. For new buildings, in Lombardy the date was brought forward to 2016 and, in Emilia Romagna, to 2017 for public buildings and to 2019 for others.

   Regarding the numerical indicator for energy demand will be defined on the basis of the definition and of the minimum energy performance requirements which, for the year 2020, will be validated on the basis of the results of the cost-optimal method, it will also be possible to establish a range for primary energy consumption expressed in kWh/m²/y, differing according to building type, location and use.

Regarding the share of renewable energy sources at nZEB, the obligation to include renewable energy sources in new buildings and buildings undergoing major renovations is equal to 50% of the expected consumption for hot water and to 50% of total consumption for heating, cooling and hot water. This latter share is to be increased to 35% from the beginning of 2014 and to 50% from the beginning of 2017.

2. Greece.

   Regulation on the Energy Performance of Buildings (KENAK) (including public buildings & schools) replaced the previously existing regulation which had been in force since 1979. Full implementation of KENAK started in January 2011 for all types of buildings & building uses, and for both new buildings and existing buildings undergoing major renovations. Finally, Directive 2010/31/EU on buildings energy efficiency, was transposed into national legislation on 19 February 2013 (Law 4122/2013).

   The Law 4122/2013 mainly defines:

   - the methodology to calculate the Energy Efficiency (EE) of a building;
   - the minimum requirements of energy performance;
   - the type and content of emergency study of energy efficiency;
   - the procedure and frequency of energy efficiency audit;
   - the type and the content of the energy performance certificate and the procedure to issue it, and;
   - the energy audit procedure.

   In the following table is compiled the minimum energy efficiency requirements of building components[4]:

[4] Living Prospects Ltd. (2017). Energy Efficiency State of the Art in Greek Schools. TEESCHOOLS Valencia project meeting presentation.

Minimum requirements according to new regulation on the Energy Performance of Buildings **(KENAK)**		**U-value (W/m².K)**			
		Climate zone			
		A	B	C	D
Heating degree days (18° C)		800-900	1100-1400	1700-2100	>2200
Roofs	U_{V_D}	0.50	0.45	0.40	0.35
External walls*	U_{V_W}	0.60	0.50	0.45	0.40
External floors	U_{V_DL}	0.50	0.45	0.40	0.35
Floor over ground	U_{V_G}	1.20	0.90	0.75	0.70
External walls in contact with the ground	U_{V_WE}	1.50	1.00	0.80	0.70
Openings*	U_{V_F}	3.20	3.00	2.80	2.60
Glass facades	U_{V_GF}	2.20	2.00	1.80	1.80
Minimum requirements according to the Thermal Insulation Regulation **(Old regulation)**		**U-value (W/m².K)**			
		Climate zone			
		A	B	C	
Roofs	U_{V_D}	0.50	0.50	0.50	
External walls	U_{V_W}	0.70	0.70	0.70	
Floor over ground	U_{V_G}	3.00	1.90	0.70	
External walls in contact with the ground	U_{V_WE}	3.00	1.90	0.70	

Such as in Spain, only the basic definition has been decided and the details about more minimum requirements concerning the envelope characteristics, the energy systems, the contribution of Renewable energy sources etc. are still to be defined in the next future by the Greek government. Up to date, a building to be NZEB it must be in energy class A, if its new and in energy class B+ if its renovated. The energy class refers to the national energy performance certification classification. T

3. Spain.
   Spain has a not yet official nearly zero-energy buildings (NZEB) definition in the national legislation. This is under development and a new update of Spanish Technical Building Code (CTE) defining NZEB was expected to be officially approved by the end of 2018. Meanwhile, there is only a draft proposal of a new CTE DB HE published at July 2018 but pending to be approved.

New CTE DB HE draft proposal contains the following requirements for NZEB[5], as show here below green shaded:

LIMITS TRANSMITTANCES					
Transmittances *U (W/m2K)*	CTE 2006	CTE 2013[1]	CTE 2013[2]	NZEB[3] *(Pending to be approved)*	Technical Limits
Facade Walls	0,95	0,75	0,29	0,2	0,1
Roofs	0,59	0,5	0,23	0,2	0,1
Building envelope	0,65	0,5	0,36	0,25	0,15
Windows (casement + frame)	4,4 - 3,5 Depending on orientation and % size hole)	3,1	1,6-2,05	1,4-2,1 (Depending on Solar Capture parameter)	0,8

1: 2.3 CTE DB-HE1 2013 table, limits values C2 zone
2: E Appendix CTE-2013 - Values thermal envelopment residential uses
3: Maybe in the future NZEB regulation won't be transmittances limit values

Moreover, new CTE proposes for Mediterranean part of Spain the following NZEB requirementes for a non-residential buildings (single-family dwelling):

- Primary energy consumption between 158-190 kWh/m2 year.
- Renewable energy sources (produced on-site) supply 105 kWh/m2 year.

4. Croatia.
Croatian criteria for nearly Zero Energy Building (NZEB) are defined in Technical regulation on energy economy and heat retention in buildings (Official Gazette 128/15).
NZEB means a building that has a very high energy performance, as determined in accordance with Technical regulation on energy economy and heat retention in buildings (Official Gazette 128/15).The nearly zero or very low amount of energy required should be covered to a very significant extent (min 30%) by energy from renewable sources, including energy from renewable sources produced on-site or nearby.

As may be observed in the following table, the maximum primary energy demand for educational institutions for NZEB label are 55 kWh/m2 and year.

[5] Consorci de la Ribera (2017). NZEB Spanish regulations. TEESCHOOLS Split project meeting presentation.

REQUIREMENTS FOR NEW BUILDINGS AND nZEB	Q''H,nd [kWh/(m²·a)]						E_{prim} [kWh/(m²·a)]			
	NEW BUILDING AND nZEB						NEW		nZEB	
TYPE OF BUILDING	mainland, θmm ≤ 3 °C			coastal, θmm > 3 °C			mainland,	coastal,	mainland,	coastal,
	f0 ≤ 0,20	0,21 < f0 < 1,05	f0 ≥ 1,05	f0 ≤ 0,20	0,21 < f0 < 1,05	f0 ≥ 1,05	θmm ≤ 3 °C	θmm > 3 °C	θmm ≤ 3 °C	θmm > 3 °C
Multi residential building	40,50	32,39 + 40,58·f0	75,00	24,84	19,86 + 24,89·f0	45,99	120	90	80	50
Family House	40,50	32,39 + 40,58·f0	75,00	24,84	17,16 + 38,42·f0	57,5	115	70	45	35
Office building	16,94	8,82 + 40,58·f0	51,48	16,19	11,21 + 24,89·f0	37,34	70	70	35	25
Educational institution	11,98	3,86 + 40,58·f0	46,48	9,95	4,97 + 24,91·f0	31,13	65	60	55	55
Hospital	18,72	10,61 + 40,58·f0	53,21	46,44	41,46 + 24,89·f0	67,6	300	300	250	250
Hotel and restaurant	35,48	27,37 + 40,58·f0	69,98	11,50	6,52 + 24,89·f0	32,65	130	80	90	70
Sports hall	96,39	88,28 + 40,58·f0	130,89	37,64	32,66 + 24,91·f0	58,82	400	170	210	150
Store	48,91	40,79 + 40,58·f0	83,40	13,90	8,92 + 24,91·f0	35,06	450	260	170	150
Non residential buildings	40,50	32,39 + 40,58·f0	75,00	24,84	19,86 + 24,89·f0	45,99	150	100	/	/

5. Cyprus.
   Republic of Cyprys defines NZEB such a building that has a very high energy performance, determined in accordance with the methodology for the calculations of the energy efficiency. The nearly zero, or very low amount of energy required, should -to a very significant extent (min 25%) - be covered by energy from renewable sources, including renewable energy produced on-site or near.'

   The Regulation on the Energy Performance of Buildings (Requirements and technical characteristics that must be met by a nearly zero-energy building) Decree of 2014 (RAA 366/2014) sets out the requirements that must be met by a building in order to be classified as NZEB. RAA 366/2014 was adopted on 1 August 2014, specifying the maximum permissible primary energy consumption and the minimum share of renewable energy sources in energy consumption. It also laid down more stringent requirements regarding thermal insulation levels compared to the minimum energy performance requirements currently in force for new buildings. As regards office buildings, there is a maximum permissible installed power in place to meet lighting needs[6].

   At the image below may be observed the different requirements for NZEB at Cyprus legislation[7]:

[6] Ministry of Energy, Commerce, Industry and Tourism (2017). 2nd National plan for increasing the number of nearly zero-energy buildings.

[7] Cyprus Energy Agency – CEA (2017). Cyprus state of the art. TEESCHOOLS Split project meeting presentation.

State of the art of nZEB regulation

	Minimum Energy Efficiency Requirements					nZEB
	21.12.2007 - 31.12.2010	01.01.2010 - 10.12.2013	11.12.2013 - 29.10.2015	30.10.2015 - 31.12.2016	01.01.2017 - 31.12.2020	On going from 01.08.2014
	Decree 568/2007	Decree 446/2009	Decree 432/2013	Decree 359/2015	Decree 119/2016	Decree 366/2014
Ranking - Class	-	≥ B	≥ B	≥ B	≥ B	A
U value - Walls	≤ 0.85 W/m².K	≤ 0.85 W/m².K	≤ 0.72 W/m².K	≤ 0.72 W/m².K	≤ 0.40 W/m².K	≤ 0.4W/m².K
U value – Horizontal structural elements	≤ 0.75 W/m².K	≤ 0.75 W/m².K	≤ 0.63 W/m².K	≤ 0.63 W/m².K	≤ 0.40 W/m².K	≤ 0.4W/m².K
U value of a ground (over non - heated spaces)	≤ 2.0 W/m².K	≤ 2.0 W/m².K	≤ 2.0 W/m².K	≤ 2.0 W/m².K	-	-
U value of the windows	≤ 3.8 W/m².K	≤ 3.8 W/m².K	≤ 3.23 W/m².K	≤ 3.23 W/m².K	≤ 2.90 W/m².K	≤ 2.25 W/m².K
U value – Mean (Walls & Windows)	-	1.3 W/m².K	≤ 1.3 W/m².K	≤ 1.3 W/m².K	≤ 1.3 W/m².K	-
Maximum consumption of primary energy	-	-	-			100 kWh/m².year 125 kWh/m².year
Maximum energy demand for heating	-	-	-			15 kWh/m².year
Maximum window shading coefficient	-	-	0.63	0.63	0.63	0.63
Maximum power of lighting installations at office buildings					10 W / m²	10 W / m²
Share of RES in primary energy consumption	-	Solar Thermal & PVs Providence	Solar Thermal & PVs Providence	Solar Thermal & PVs Providence	25% (Detached) 3% (Apartments) 7% (Non Resid.)	25%

Interreg Mediterranean TEESCHOOLS
Project co-financed by the European Regional Development Fund

The maximum primary energy consumption in non-residential buildings is 125 kWh/m2 and year. At least 25% of total primary energy consumption comes from renewable energy sources. Maximum mean installed lighting power for office buildings is 10 W/m2.

6. Bosnia and Herzegovina.
   Bosnia and Herzegovina has not yet an official Nearly Zero Energy Buildings (NZEB) definition in the national legislation.

   The organisation of the energy sector in Bosnia and Herzegovina (BiH) is complex and the competencies in the sector are divided between the state, two entities of BiH (Federation of BiH and Republika Srpska) and Brcko District of BiH. The energy sector is of strategic importance for BiH's competitiveness and economic and social development. The adoption of countrywide energy strategy and a legal framework in compliance with the Energy Community Treaty (EnCT)[8], has been recognized as a priority under a policy guidance of the Economic Reform Program (ERP) for BiH 2019-2021[9].

   With the aim to move forward with energy sector reforms, BiH adopted a countrywide sector strategy, namely Framework Energy Strategy until

[8] „Official Gazette BiH – International Contracts“, number 09/06.
[9] Council of Ministers of BiH adopted ERP BIH 2019-2021 at its 165. Session (30/01/2019).

2035 in August 2018[10]. This document represents the strategic framework which allows for, among others, a harmonized countrywide approach in transposition, implementation and enforcement of the relevant EU energy *acquis* necessary to ensure that BiH makes credible and measurable progress in meeting its commitments under EnCT. Commitments imply adoption of core EU energy legislation, keeping the pace with EU developments and continiously aligning its regulatory frameworks in energy and other sectors. BiH is lagging in the transposition and implementation of adapted EU legislation and regulations.

According to the EnCT Report, the reform of the renewable energy sector has to be speeded up in Bosnia and Herzegovina. Although, certain progress has been achieved with the adoption of the state-level Energy Efficiency Action Plan, additional measures remain to be adopted in order for BiH to be compliant with the energy efficiency *acquis*.

Future commitments stemming out from different contractual obligations[11] that BiH has signed, pose the challenge for the relevant institutions in the energy sector in BiH due to the complexity of the tasks ahead and the timeline for their completition. One of the obligations represents the development of the Integrated National Energy and Climate plan (NECP 2021-2030). BiH has already started preparing NECP with the deadline for draft completion set to the end of 2020.

- Conclusión of the module

Sustainable energy production and use has been identified as a fundamental pillar to draw a more competitive economically and environmental-friendly growth for Europe. For that reason, the Europe 2020 strategy that is the EU's agenda for growth and jobs for the current decade, emphasises smart, sustainable and inclusive growth as a way to overcome the structural weaknesses in Europe's economy, improve its competitiveness and productivity and underpin a sustainable social market economy.

The Europe 2020 Strategy agreed 5 headline targets to meet by 2020 related to employment, research and innovation, climate change and energy, education, and for combating poverty.

[10] „Official Gazette BiH“, number 70/18.

[11] BiH, as a Contracting party of EnCT is obliged to develop an Integrated National Energy and Climate Plan (NECP), that should cover the period from 2021 to 2030, including a perspective until 2050m which ensures the achievement of the objectives and targets of the Energy Union in line with the 2015 Paris Agreement on climate change, United Nations Framework Convention on Climate Change (UNFCCC) and Energy Community obligations. According to the decisions from the EnCT Ministerial Council from November 2018, at the end of 2019 within the Energy Community, through the adaption of the new Energy Efficiency Directive, Renewable Energy Directive and Governance Regulation once they are in force in EU, a 2030 energy and climate targets should be established.

The climate change and energy target is aiming to reduce greenhouse gas emissions by at least 20% compared to 1990 levels, to increase the share of renewable energy sources in our final energy consumption to 20%, and a 20% increase in energy efficiency.

With the purpose of reaching 20-20-20 objectives, EU has deployed a wide range of policies and directives among which is worth noting what refers to building sector the 2012/27/EU Energy Efficiency Directive and the 2010/31/EU Energy Performance of Buildings Directive. Those directives set the roadmap to foster investment in the renovation of public and private buildings.

A great potential to reduce EU energy consumption are linked with NZEB. Nearly zero-energy buildings (NZEB) construction, emanated from this European regulations, is the challenge of Member States because all new buildings must be NZEB after 31 December 2019, and all new buildings occupied and owned by public authorities must be NZEB nowadays.

But Member States National Plans regarding NZEB progress at different speed.

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- EU, Directive 2018/844. European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency. Official Journal of the European Union (2018).

- ECOFYS (2014). Overview of Member States information on NZEBs. Working version of the progress report - final report. Groezinger Jan, et al.

- Self assessment

1. What are the main EU regulations supporting energy efficiency of buildings:

    Possible answers

    2012/27/EU, Energy Efficiency Directive

    2010/31/EU, EPBD and ins update 2018/844/EU.

    Both of them

2. Building energy efficiency regulations in Europe are willing to:

    Possible answers

    Build energy.efficient buildings.

    To renovate existing buildings towards low-energy consuming standard.

    Both of them

3. Buildings energy performance label is ranking buildings in a scale of:

Possible answers

A to C

A to G

None of them

4. Energy Efficiency Directive 2012/27/EU set the following measure:

    Possible answers

    EU members must renovate every year at least 3% of the buildings own by central government.

    Energy performance certificates.

    Both of them

5. All new public buildings must be NZEB from:

    Possible answers

    31st December 2018 on.

    31st December 2020.

    None of them

6. All new private buildings must achieve a NZEB level from:

    Possible answers

    31st December 2018 on.

    31st December 2020 on.

    None of them

7. New 2018/844/EU Directive establishes that:

    Possible answers

    New buildings must consider electromobility needs.

Concerning existing buildings deep renovation, Member States must increase in financing instruments and technical support.

Both of them

8. Member States NZEB National Plans must include:

Possible answers

Definition of NZEB at every country.

Are not compulsory.

Both of them

9. NZEB maximum primary energy consumption in non-residential buildings are:

Possible answers

May be different depending on their national/regional/local conditions.

Are among 20-30 kWh/m2 and year for every member state for offices.

Both of them

10. NZEB definition at national level must consider:

Possible answers

Must include a mimimum rate of renewable energy sources (produced on-site) supply for NZEB.

Share of renewable energy sources in primary energy consumption must be of 25%.

Both of them

Bioclimatic architecture of schools

E-MODULE: BIOCLIMATIC ARCHITECTURE OF SCHOOLS

MODULE PRESENTATION

The module aims to illustrate and deepen what is meant by "bioclimatic architecture design". The many issues related to the interaction between environment and building will be examined and will be defined the general principles for a correct design approach to the enhancement of site resources and their effective implementation in architecture.

Every anthropic settlement in the territory causes an alteration of the natural flows of light, heat, soil permeability and water regime, ventilation and microclimate. The adoption of correct methodologies of design and construction approach, aimed at the exploitation of these resources allows to obtain sustainable buildings, environmentally compatible and whose impact on energy resources is minimal or neraly zero. The basis of this methodology is the use of renewable sources to reduce the use of exhaustible fossil fuels.

From this arises an inseparable bond between the environment and the building that generates architectures and spaces different from time to time depending on the site in which one operates and which needs particular attention when evaluating the real conditions, according to the place, the seasonal regimes and many other local conditions.

The application of bioclimatic architecture to school buildings is even more important because school building is a place that requires particular conditions of comfort (thermal, luminous and acoustic) and psycho-physical well-being to improve students' concentration qualities. Schools represent a strategic sector for the development of pilot experiences in the environmental sector, energy efficiency and the use of renewable sources.

The purpose of the e-module is to clarify the principles of the bioclimatic approach and to present existing solutions of particular importance linked to school buildings in the Mediterranean area. Schools are places of residence from the first years of life until adolescence and therefore through correct information, they can intervene on the growth of environmental awareness of future citizens, as well as influence their psychophysical well-being.

The design elements that we want to introduce to the user concern the following aspects:

• to reduce consumption with energy conservation measures

• to use the energy resources naturally available and convert them with technological systems into energy forms that can be used directly (i.d. heat and electricity)

• to improve the thermo-hygrometric, lighting and health conditions of the classrooms

• to improve acoustic comfort

• to protect facades from solar radiation

Bioclimatic design is not a standard, but must be adapted to specific needs, location, type of user and everything concerning the use of the building. With the term "Mediterranean bioclimatic school", therefore, not only a geographical place is delimited but also a set of peculiarities made by climate, culture, colors, customs, materials and everything that defines what the buildings is the Mediterranean architectural style par excellence .

Even the current regulations on nZEB, defined in the various countries of the European Community, explain how the designer should highlight the results of the assessment of the technical, environmental and economic feasibility for the use of alternative high-efficiency systems including, purely by way of example , renewable energy supply systems, cogeneration, district heating and cooling, heat pumps and intelligent measurement systems. To be able to obtain these results it is no longer enough to rely on the systems, it is known to everyone that the orientation of the building, the orientation of the facades, the correct position of the glass surfaces and a good insulation of the surfaces are decisive to achieve specific objectives of energy improvement: these systems are the basis of bioclimatic architecture.

The module aims to give rules and schemes in the design of bioclimatic architecture which is particularly complex especially for the relationships that link the numerous variables, for the quality and quantity of the problems to be solved.

EDUCATIONAL OBJECTIVES

1. TO LEARN ABOUT BIOCLIMATIC ARCHITECTURE

2. TO EVALUATE ELEMENTS TO BE STUDIED

3. TO KNOW REAL CASES

1. TO LEARN ABOUT BIOCLIMATIC ARCHITECTURE

The concept of bioclimatic architecture was first defined by the architect Victor Olgyay, when in 1963 he published the results of his studies in the book “Design with Climate: Bioclimatic Approach to Architectural Regionalism”. The essence of bioclimatic design is to create a favourable microclimate both inside the building and outdoors through the application of architectural techniques. The studies produced comprehensive theoretical information about designing of the human-friendly spatial environment in different climatic regions and a design method, which employed a bioclimatic chart and determined comfort zones. According to Olgyay, the design process of bioclimatic architecture is linear and consists of four successive stages .

Later a number of other researchers undertook the further study of the bioclimatic design concept, among them B. Givoni in 1969 and S. Szokolay in 1986. The works produced by these authors shared a common feature as they all focused on the principles for determining comfort zones based on the average monthly climate data (wind, humidity and temperature), using psychrometric charts as a methodological aid in designing. In 1971, C. Mahoney took a slightly different approach proposing a design methodology that followed three stages of design elaboration (the idea-sketching phase, development of the design and detail drawings). The method was based on a successive climate analysis. There were altogether six charts, where the first four of them were intended for the input of climate data to make a comparison with the comfort zone, and the last two were used for reading the recommended design principles as regards the layout, orientation and shape of the building respecting the local climate conditions.

These studies formed an important basis for development of climate-appropriate and environmentally-balanced architectural design.

Traditional architectural typologies could play a crucial role in the environmental architectural contemporary framework, due to many attempts developed in last decades to adopt passive house model and bioclimatic criteria in the Mediterranean areas. According to climate responsive approach, the interactive and adaptive relationship between building, site, and climate consider a basic rule to reduce the environmental impact and improving energy efficiency in buildings. In recent decades this concept has extended to the preservation of the cultural identity of the places. High level of adaptive, sustainable and functional performances could be deduced from the traditional residential buildings as the case of Aleppo proves. The traditional Arab house in Aleppo is based on series of adaptive and sustainable-oriented principles derived from the integration of active and interactive design approaches. The old city of Aleppo (included in the UNESCO List of World Heritage Sites) is considered one of the largest historical cities in the world, in terms of its population number (110,000 people before the war). The damage to cultural and historical heritage by the war asserts the peculiarity of the city in the Eastern Mediterranean area. It is very important a study carry out on Aleppo, considering the bioclimatic approach as a key element to reorient the future construction process of the Syrian city to achieve the objectives of global sustainability and identify design criteria's for the development of the residential buildings. The study also aims to analyse the mutations which appeared through evolution process of residential buildings and identify the invariant elements and the main trajectories of modification established in the past, confirming their compatibility with the future development of Aleppo.

Nowadays, many initiatives have been developed to create a contemporary environmental framework for achieving sustainable buildings design, where the quantitative aspects in the residential buildings overwhelmed the qualitative aspects because of the population growth and city development. In addition, the use of modern building materials and new construction technologies have led to a radical change in architectural principles, articulated through the abandonment of local traditional architecture elements, instead of employing them to serve local architecture and environmental circumstances. The historical experiences (in terms of adapting to the current environment) have a wealth of knowledge derived from the past experiments, worthy of consideration to develop innovative solutions that fit with contemporary architecture and maintain the cultural identity of places.

In this regard, a conscious and responsible approach of Aleppo post-war should consider the traditional buildings, on the one hand, to preserve the complex cultural identity of the city. On the other hand, to propose new design solutions derived from the conceptual design of the traditional typologies, through balancing the relationship between local materials, building techniques, and climate conditions. When we speak about the traditional buildings (courtyard house) of Aleppo, we enter the lives of a community that lived in simplicity and in harmony with its surrounding. This paragraph discusses the historical evolution of residential buildings in Aleppo city to comprehend the formation and mutations processes in this city. Where the relationship between architecture and nature formed a pivotal force in the architectural design of the courtyard house, thus, this bioclimatic typology could adapt and survive for a long time.

The first rule of bioclimatic architecture is to take advantage of local bioclimatic conditions with the benefit of the natural and built environment. That approach should always be based on multidisciplinary in-depth research of individual circumstances: from the specifics of the ecosystem through cultural factors up to the economic analysis. In final effect safe and comfortable building which is created does not harm the environment but contributes to its health and enriched biodiversity.

Basic elements of bioclimatic design are passive solar systems which are incorporated onto buildings and utlilise environmental sources (for example, sun, air, wind, vegetation, water, soil, sky) for heating, cooling and lighting the buildings. Bioclimatic design takes into account the local climate and includes the following principles:

Heat protection of the buildings in winter as well as in summer, using appropriate techniques which are applied to the external envelope of the building, especially by adequate insulation and air tightness of the building and its openings.
Use of solar energy for heating buildings in the winter season and for daylighting all year round. This is achieved by the appropriate orientation of the buildings and especially their openings (preferably towards the south), by the layout of interior spaces according to their heating requirements, and by passive solar systems which collect solar radiation and act as “natural” heating as well as lighting systems.
Protection of the buildings from the summer sun, primarily by shading but also by the appropriate treatment of the building envelope (i.e. use of reflective colours and surfaces).
Removal of the heat which accumulates in summer in the building to the surrounding environment using by natural means (passive cooling systems and techniques), such as natural ventilation, mostly during nighttime.
Ensuring insolation combined with solar control for daylighting of buildings, in order to provide sufficient and evenly distributed light in interior spaces.
Improvement of the microclimate around buildings, through the bioclimatic design of exterior spaces and in general, of the built environment, adhering to all of the above principles.

To satisfy contemporary anticipations the built environment needs to ensure suitable temperature range, adequate humidity and air exchange, good acoustic parameters as well as correctly designed lighting. Overall visual comfort expectations should be also met. In numerous cases these are lighting and indoor climate requirements that tend to bring about some serious issues. In standard buildings, in spite of many criticism, the plant air conditioning systems are most frequently used in purpose to regulate temperature and humidity. However, in bioclimatic premises the application of renewable materials and energy sources is promoted, while the usage of plant systems is considerably reduced in favor of methods described further in the text. One of the key elements of proper bioclimatic design is maximum usage of daylight to ensure adequate illumination of interiors. Reduction, or in some cases even elimination of electricity consumption for artificial lighting, leads to significant savings, both for the consumers and the environment.
Natural lighting should be carefully controlled to avoid glare effect and overheating, but correctly designed, is an important factor of the user comfort. Finally, appropriate daylighting has positive influence on the human perception of the built environment, which should not be underestimated. Thermal comfort in bioclimatic buildings can be achieved in many ways. Some of the most efficient systems are based on radiating floors and ceilings. Unlike high-tech edifices in eighties and nineties years of XX century which were operating in the narrow range of so-called optimal temperature and humidity parameters, bioclimatic structures allow for some customization and more individual adjustment of

thermal settings. The most advanced and simultaneously the most economical solutions are hybrid systems. Correct oxygen content is another necessary factor of the comfortable indoor microclimate. This parameter is often underestimated, which should not happen as the permanent lack of oxygen in rooms where people spend a couple of hours a day may result with symptoms like drowsiness, tiredness, delayed responsiveness and less effective functioning of the brain. Prolonged exposure to hypoxic conditions may also lead to some pathological changes in human organism, particularly at the level of the body's biochemistry. Therefore the amount of oxygen in the built environment should be carefully controlled. However, the level of oxygen in the building interiors can be relatively easily increased by properly designed ventilation as well as by the introduction of greater amount of green plants into the edifice. Some very interesting examples of how such systems work in practice can be observed in already existing regional architecture. Analysis of traditional solutions that were used in purpose to provide the building adaptation to the climate helps to choose some everlasting methods but also to develop new bioclimatic strategies.

2. TO EVALUATE ELEMENTS TO BE STUDIED

Energy efficient buildings can be defined as buildings that are designed to provide a significant reduction of the energy needs for heating and cooling, independently of the energy and of the equipments that will be chosen to heat or cool the building.

To achieve this we wil study specific elements:

1. shape
2. orientation
3. solar protection
4. passive solar systems
5. insulation of walls
6. performing glazing and windows
7. ventilation
8. heat recovery
9. lighting

Bioclimatic architecture concept: 1. reduce the demand of energy implementing energy saving measures, 2. use sunstainable renewable sources instead of fossil fuels, 3.use fossil energy as efficiently as possible.

Bioclimatic architecture takes into account climate and environmental conditions to reach thermal comfort and air quality indoor high performances. Bioclimatic design takes into account the local climate to make the best possible use of solar energy and other environmental sources, rather than working against them.

1. SHAPE: The shape of the building has to be compact to reduce the surfaces in contact with the exterior.

2. ORIENTATION: The desirable orientation of buildings is the direction which performs the best throughout the year in relation to human comfort conditions. Those situations can be evaluated with the use of the Bioclimatic Chart. The building and especially its openings are given an appropriate orientation (preferably towards the south). Interior spaces are laid out according to their heating requirements. In order to qualify the shape, a "shape coefficient" C_f is defined as follows: C_f=S/V. Where S is the envelope surface of the building, i.e. the external skin surfaces, and V is the inner volume of the building.
3. SOLAR PROTECTION: Inside buildings, occupants benefit from a view outside and from the maximum available daylight, without ever being subjected to discomfort due to direct solar radiation or excessive contrasts in light levels. And, nowadays, we know that visual comfort, thermal comfort or air quality can have a direct impact on occupants' well-being, health and productivity. In bioclimatic architecture the cooling strategy is a response to the need for summer comfort: shading from solar radiation and heat gain, minimising internal heat sources, dissipating excess heat and cooling down naturally. Shading the building - and, in particular, its apertures - from direct sun in order to limit direct gain means basically erecting screens, externally if possible, to shade it. These screens can be permanent, mobile or seasonal (plants). Furthermore, in order to prevent solid vertical walls from heating up the building, sufficient insulation should be used to prevent the accumulation of heat. In a hot climate, allowing heat to enter through walls and roofs heated by the sun should particularly be avoided. This can be achieved by increasing their insulation or their inertia, by having reflective surfaces facing the sun or else by reducing the hot air entering the building. Vegetation can effectively be used to reduce the exposure of windows to the sun. Plants need to be carefully chosen taking into account their size and type as this choice influences the shape of the shade that they case in summer and in winter as well. Buildings can provide a fixed screen for neighbouring ones. They can play a positive role if protection from the sun is sought: this is the case in traditional Mediterranean towns where the narrowness of the streets and the height of the buildings significantly reduces direct sunshine and provides welcome shade.
4. PASSIVE SOLAR SYSTEMS: Basic elements of bioclimatic design are passive solar systems which are incorporated onto buildings and utlilise environmental sources (for example, sun, air, wind, vegetation, water, soil, sky) for heating, cooling and lighting the buildings. The sun can provide a substantial portion of winter heating energy through elements such as equatorial-facing windows and greenhouses, and other passive solar techniques which use spaces to collect, store, and transfer solar heat. There are four inter-related components in passive solar buildings, which work together to make the buildings efficient utilisers of energy: 1 Collection and absorption of the maximum amount of solar radiation during the day 2 Storage of the heat collected from the suns radiation during the day 3 Release of this heat into the interior of the building during the night

4 Insulation of the whole building to retain as much of the heat as possible inside the building.

It is possible to formulate a number of general rules for the design of passive solar buildings, according to three common building configurations: In multi-storey buildings, the following design guidelines should be followed:

- The ground floor should be used for cattle and livestock.
- The first floor should be used for rooms that are used mainly during the winter.
- The second floor should be used for rooms that are used mainly during the summer.

For single-storey buildings, the following design guidelines should be followed:

- The north-facing side should be used for storerooms and other little used areas, to create a buffer zone.
- The south-facing side should contain the most commonly used rooms, including the living room, the kitchen, and the bedrooms.
- The east-facing side of the building should contain rooms that are used mainly in the morning.
- The west-facing side should contain rooms that are used mainly in the evening.

For individual rooms, where possible, the following design guidelines should be followed:

- Glaze the south-facing walls
- Reduce as much as possible the window area on the east and west facing walls
- Avoid glazing on the north-facing side.

5. INSULATION OF WALLS: Appropriate techniques are applied to the external envelope and its openings to protect the building from solar heat in winter as well as in summer; passive solar systems collect solar radiation, acting as “free” heating and lighting systems; the building is protected from the summer sun, primarily by shading but also by the appropriate treatment of the building envelope (i.e. use of reflective colours and surfaces). Well installed insulation ensures energy efficiency in every part of the building envelope including ground decks, roofs lofts, walls and facades. It is also well suited for pipes and boilers to reduce the energy loss of a building’s technical installations. Insulation is as relevant in cold regions as in hot ones. In cold/cool regions, insulation keeps a building warm and limits the need for energy for heating whereas in hot/warm regions the same insulation systems keep the heat out and reduce the need for air conditioning. An exterior wall is well insulated when its thermal resistance (R value) is high, meaning the heat losses through it are small (reduced U value). Insulation is a key component of the wall to achieve a high R value (or a low U value) for the complete wall. The thermal resistance R of the installed insulation products has to be as high

as possible. To limit the thickness of the insulation within acceptable dimensions, it is recommened improveing the thermal conductivity of its materials (lower lambda value) thus allowing increased thermal resistance within the same space.

6. PERFORMING GLAZING AND WINDOWS: Buildings experienced significant amount of heat gain or loss through window and this will affect the thermal comfort of buildings′ occupants. Building without window is able to save energy, but it is not recommended due to the benefits of natural light on visual comfort and the biological effect of natural light on humans. Hence, window design plays important role in building architect. One of the essential parts of window is the glazing. Selecting a window glazing is complicated when energy saving and daylighting aspects of a building are considered concurrently. Optimization techniques offer a balance solution for the contradictions in selecting a window glazing of energy-efficient building. Natural light enhances productivity in the workplace and helps uphold a healthy environment. It is just as important that glass materials and design endorse energy efficiency. Designers use high-performance double-glazed glass, which is laminated or coated, to moderate interior temperatures by controlling heat loss and gain.The coating filters the heat-producing aspects of solar rays. The use of such glass in bioclimatic buildings is used comprehensively in tropical climates as well as the Middle East. In hot climates, solar control glass can be used to minimize solar heat gain and help control glare. The design and placement of glass, known as fenestration, in specific areas of the building crafts the best environment for energy efficiency. In temperate regions, it can be used to equalize solar control with high levels of natural light. In more serene climates, designers employ operable windows as a cost-saving substitute to air-conditioning. Solar control glass can be an eye-catching characteristic of a building whilst at the same time diminishing, or even eradicating the need for an air-conditioning system, reducing running costs of the building and saving energy. Solar control glass can be particular for any situation where unwarranted solar heat gain is likely to be a bother (e.g. Large façades, glass walkways, atria and conservatories).
7. VENTILATION: Ventilation is the intended and controlled ingress and egress of air through buildings, delivering fresh air, and exhausting stale air through purpose-built ventilators in combination with the designed heating system and humidity control, and the fabric of the building itself. If you do not insulate properly and ventilate too little, you can risk warm humid air condensing on cold, poorly insulated surfaces which will create moisture that allows for moulds and fungi to grow. A controlled ventilation strategy will satisfy the fresh air requirements of an airtight building. Natural ventilation has the potential to considerably improve the energy efficiency of a building by saving on fan electrical energy, cooling and heating. The main mechanism behind natural ventilation is natural or free convection. This principle in air and fluid movement relies on pressure differences as a result of a temperature gradient. The driving force of the movement is buoyancy, where the differences in density of the air will

result in a vertical distribution. Air that is heated becomes less dense and therefore rises. It is then replaced by cooler surrounding air, which is subsequently also heated and will rise as well. While this process goes on, a continuous flow of air is created. This mechanism produces the two driving forces for natural ventilation on a building scale, which are wind-driven and buoyancy-driven ventilation.

10. LIGHTING: Daylight can be considered as one of the most important principles of sustainable architecture. In vernacular architecture, natural lighting was the main source of light available and was largely achieved through the central courtyard. Using a daylight controller system increases space natural light quality and decreases building lighting consumption by 60%. It also affects building thermal behavior, because most of them operate as shading. The light shelf is one of the passive systems for controlling daylight, mostly used with shading and installed in the upper half of the windows above eye level. In bioclimatic design, solatubes or light cones are often used to help sunlight enter the rooms but illuminate them without bringing too much solar gains in summer. This can lead to better visual comfort but, at the same time, to an electric lighting savings of up to 30-40%.

3. TO LEARN REAL CASES

Abst ract

PRIMARY SCHOOL (Marinella di Bruino, TO - ITALY)

Information about city

Bruino (Bruin in Piedmont) is an Italian municipality of 8586 inhabitants in pronince of Turin in Piedmont. Located about 20 kilometers west of the capital, it stands on the right bank of the Sangone torrent, near the homonymous valley.

Climate and Temperature data

Below the climate zone assigned by the 412/93 Decree.

Degrees Day	**2834**
Climate zone (according to italian law)	E
Altitude	320 m
Surface	5,57 km^2
Inhabitans	8586
Coordinates	45’01’N7’28E
Density	1.541,47 inh/Km^2

Information about heating and cooling operational period

The operational period of the Italian heating system is defined by a national law. The Italian Decree 412/93, it divides Italy into 6 different climatic zones ranging from A (the hottest) to F (the coldest) depending on the degrees day.

Each climatic zone is divided in range of Degrees Day (DD): the degrees day of a location is the unit of measurement that estimates the energy requirements to maintain a comfortable internal climate in buildings. It represents the sum, extended to each day of a conventional annual heating period, of the average daily temperature you need to reach 20°C. Higher is the DD value, cooler is the zone.

Climatic Zone	Degrees-Day	Period	Number of hours
A	Municipality DD ≤ 600	1° december - 15 march	6 hours for day
B	600 < Municipality DD≤ 900	1° december - 31 march	8 hours for day
C	900 < Municipality DD GG ≤ 1.400	15 november - 31 march	10 hours for day
D	1.400 < Municipality DD ≤ 2.100	1° november - 15 april	12 hours for day
E	2.100 < Municipality DD ≤ 3.000	15 october - 15 april	14 hours for day
F	Municipality DD > 3.000	All the year if necessary	No limit

MARINELLA DI BRUINO SCHOOL GENERAL INFORMATION

The "Marinella Primary School" of Bruino (Turin) was built in '70s. The school building have two floors and it has a centralized heating system, placed on the groundfloor. The building is used both during the day for school activities and during evening time for additional activities such as dance classes and other sports activities.

Type of school	**Primary school (6-10 years old)**
Number of pupils/classrooms	19 (total 93)
Number of other people that work in it	91
Use profile	Morning and afternoon (Monday-Friday) only morning on Saturday.
Urban context	Downtown
Classrooms	5
Rooms	offices
	gym
	laboratories
	hygienic services
	Multiporpose room

GENERAL DESCRIPTION ABOUT ENERGY ISSUES

The main source of heat dispersion was due to poor **insulation of the roof**. Thanks to the insulation of the roof it was possible to achieve environmental comfort (20°C), with an important saving of primary energy. It were used panels of glass wool to obtain the mandatory minimum requirements.

The existing wooden windows with simple glass were replaced with PVC thermal break **windows** equipped with low emissivity glass. The final U value for windows is less than 1.3 W / m^{2}K

SHORT DESCRIPTION OF THE RENOVATION AND ITS PURPOSE

The most important aim of the project was to reduce primary energy consumption and polluting emissions. The building needed an important refurbishment focused mainly on energy efficiency.

Another improvement action was made on the envelope: it was installed an **external walls insulation** with 14 cm panels of graphite EPS; the intervention reduces thermal bridges and improves the summer thermal comfort performance with significant energy advantages even in winter.

ENERGY CONSERVATION AND RENEWABLE ENERGY MEASURES

Efficient energy supply: Replacement of a methane boiler with an **air-water heat pump**; installation of programmable **thermostatic valves**; installation of a **remote management system.**

Renewables: installation of a **photovoltaic system** grid-connected (250 Wp modules; 12,75 kW; 15500 kWh/y**).**

SAVINGS: Energy classification **nZEB** according to Piedmont Region standards.

CONCLUSION

The module described the idea of bioclimatic architecture from its genesis and showed how basic methods of adapting architecture to the local climate originated in vernacular building evolved from simple to more complex systems. We can learn how indigenous solutions, developed in different regions of the world, gained support by the application of cutting-edge technologies and how contemporary knowledge transfer increases the awareness of the available possibilities. That allows to choose strategies most appropriate to the climate and ecosystem which is especially helpful in the regions that did not develop their own suitable vernacular examples. The research revealed how basic passive methods were successfully hybridized with the most advanced technologies to provide comfortable indoor microclimate and optimal building performance. The analysis of biological and climatic parameters is of fundamental importance and must be carried out for each location which excludes the practice of copying some techniques and producing dwellings without complete checking their potential environmental impact. Finally the research results with the conclusion that contemporary bioclimatic architecture can be defined as one that is based on traditional systems of adapting dwellings to the

climate but combines them creatively with advanced research, design and technological methods. This approach results with developing innovative systems designed specifically for the location needs. The main goal is the architectural environment, which is comfortable for the user and maximally integrated with the ecosystem in purpose to retain its natural harmony and continuity.

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SELF ASSESSMENT TEST

1. Who was the first to define the concept of bioclimatic architecture?
   a) Victor Olgyay
   b) Le Corbusier
   c) Renzo Piano
2. Bioclimatic design takes into account the local climate
   a) Yes
   b) No
   c) It depends on the type of climate
3. Do bioclimatic principles affect a better quality of life?
   a) No
   b) Just in Mediterranean zone
   c) Yes
4. To satisfy contemporary anticipations the built environment needs to ensure all these elements:
   a) adequate humidity and air exchange, good acoustic parameters as well as correctly designed lighting
   b) suitable temperature range, good acoustic parameters as well as correctly designed lighting
   c) suitable temperature range, adequate humidity and air exchange, good acoustic parameters as well as correctly designed lighting
5. Has sustainable architecture made a positive impact on the environment and the pollution?
   a) Absolutely not
   b) Yes
   c) Not always
6. Green building has many positive effects on the environment. What are the most significant environmental benefits?
   a) reduction of greenhouse gas emissions and less consumption of un-renewable fuels
   b) just reduction of greenhaouse emission
   c) No benefit is expected
7. The best solution for building shape is
   a) Compact

   b) Elongated
   c) With many indentations
8. What does bioclimatic architecture provide for renewable energy sources?
   a) A large use
   b) A limited use
   c) No use
9. What is ventilation?
   a) the intended and controlled of air through buildings
   b) the intended and controlled ingress and egress of air through buildings
   c) it coincides with the wind
10. Daylight can be considered as one of the most important principles of sustainable architecture?
   a) No
   b) Yes
   c) Just in Mediterranean zone

1. Int

Energy audits in schools

TITLE OF MODULE 3. ENERGY AUDITS IN SCHOOLS.

- Presentation of the module

Energy efficiency is key pillar to improving Europe's energy competitiveness and supply security. Additionally, Europe’s building industry accounts for the largest share of greenhouse gas emissions in terms of energy end usage, representing about 36% of Europe’s total emissions.

As a consequence, European Union has deployed a broad legislative framework, tackled in module 1, to meet the target to cut energy use by 20% by 2020. The most relevant regulation is the Energy Efficiency Directive 2012/27/EU.

The 8th article of 2012/27/EU directive rules that Member States shall promote the availability to all final customers of high quality energy audits based on the following minimum guidelines (Annex VI of 2012/27/EU):

a. Energy audits must be based on up-to-date, measured, traceable operational data on energy consumption and load profiles;
b. It must comprise a detailed review of the energy consumption profile of buildings or groups of buildings, industrial operations or installations, including transportation;
c. They should address, whenever possible, life-cycle cost analysis (LCCA) instead of Simple Payback Periods (SPP) in order to take account of long-term savings, residual values of long-term investments and discount rates;
d. They should be proportionate, and sufficiently representative to permit the drawing of a reliable picture of overall energy performance and the reliable identification of the most significant opportunities for improvement.
e. Energy audits should allow detailed and validated calculations for the proposed measures so as to provide clear information on potential savings.
f. The data used in energy audits should be storable for historical analysis and tracking performance.

On the other hand, an energy audit may be defined as a systematic inspection of energy use and energy consumption of a site, building, system or organisation with the objectives of establishing energy flows, identifying the potential for energy efficiency improvements and reporting them to the energy user.

So that, it is clear that an energy audit results must be the ground, the basis from which any energy efficiency action must based on. In the case of TEESCHOOLS project, the project software or tool developed to simplify the energy audits procedure of Mediterranean school buildings must be checked and the results obtained compared with standard energy audits outcomes.

The standard audits will have to follow a common protocol, defined on TEESCHOOLS project deliverable 3.2.3 ‘Report on selection of a common technical protocol', based on the European standard EN 16247-1:2012 Energy Audits General Requirements.

As a consequence, the present module is laying down on both TEESCHOOLS project common practices and procedures agreed during the energy audits in the pilot schools and EN 16247-1:2012.

- Learning objectives of the module

- Understand project common energy audits protocol carried out at pilot schools.
- Acquiring and applying knowledge about European standard EN 16247-1:2012 Energy Audits General Requirements.

- Section 1. Energy audits introduction.

Directive 2012/27/EU defines 'energy audit' such a systematic procedure with the purpose of obtaining adequate knowledge of the existing energy consumption profile of a building or group of buildings, an industrial or commercial operation or installation or a private or public service, identifying and quantifying cost-effective energy savings opportunities, and reporting the findings;

Furthermore, energy audits offer many benefits to both small and large energy consumers[12]:

- Energy audits should identify the greatest opportunities for energy savings. Therefore they offer the opportunity to reduce the energy costs of an organisation. This improves profitability and enhances competitiveness;
- Energy audits can identify potential for improvement in business and production processes and thereby contribute to improved productivity;
- Energy audits can help organisations reduce the environmental impact of their activities;
- Energy audits can help some organisations to fulfil obligations under their national with respect to emissions to air and pollution control;
- Energy audits can also help improve employee satisfaction and project a positive image to customers and the wider community.

[12] Joint Research Centre (2015). Survey of energy audits and energy management systems in the Member States. http://publications.jrc.ec.europa.eu/repository/bitstream/JRC95432/survey%20of%20energy%20audits%20and%20energy%20management%20systems%20in%20the%20member%20states_pub.pdf

EN 16247-1:2012 energy audit technical standards settles the requirements for energy audits and corresponding obligations within the energy auditing process. It recognises that there are differences in approach to energy auditing in terms of scope, aims and thoroughness, but seeks to harmonise common aspects of energy auditing in order to bring more clarity and transparency to the market for energy auditing services. EN 16247-1:2012 standard applies to commercial, industrial, residential and public-sector organisations, excluding individual private dwellings.

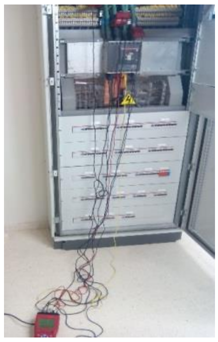
EN 16247 technical standard is composed by five parts, each of these concerns a specific sector (, general energy audit issues, buildings, industrial processes and transportation). The first part, EN 16247-1 covers the general requirements common to all energy audits. Specific energy audit requirements will complete the general requirements in separate parts dedicated to energy audits for buildings, industrial processes and transportation. Most relevant terms and definitions contained are as follows:

- Energy Audit: systematic inspection and analysis of energy use and energy consumption of a site, building, system or organisation with the objective of identifying energy flows and the potential for energy efficiency improvements and reporting them;
- Energy auditor: individual, group of people or body carrying out an energy audit;
- Adjustment Factor: quantifiable parameter affecting energy consumption production throughput, etc;
- Audited Object: building, equipment, system, process, vehicle or service which is the subject of the energy audit;
- Energy Consumption: quantity of energy applied;
- Energy Efficiency: ratio or other quantitative relationship between an output of performance, service, goods or energy, and an input of energy;
- Energy Performance Indicator: quantitative value or measure of energy performance, as defined by the organisation;
- Energy Efficiency Improvement Measure: amount of saved energy determined by measuring and/or estimating consumption before and after implementation of one or more energy efficiency improvement measures, whilst ensuring normalisation for factors that affect energy consumption;
- Building: construction as a whole, including its envelope and all technical building systems, for which energy may be used to condition the indoor

climate, to provide domestic hot water and illumination and other services related to the use of the building and the activities performed within the building;

- System Boundary: boundary that includes within it all areas associated with the audited object (both inside and outside the audited object) where energy is consumed or produced;
- Building Services: the services provided by the technical building systems and by appliances to condition the indoor environment (thermal comfort, air quality, visual and acoustic quality) and other services related to the use of the building;
- Technical Building System: technical equipment for heating, cooling, ventilation, domestic hot water, lighting and on-site energy production.





Section 2. TEESCHOOLS energy audits protocol

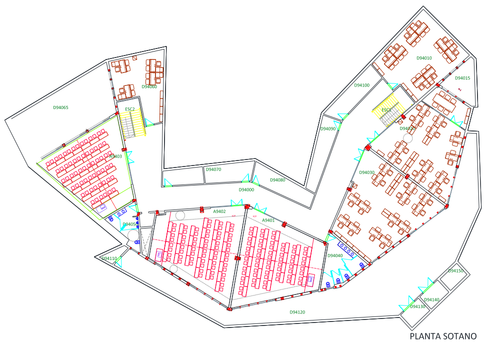
Standard audits implemented within TEESCHOOLS project activities are based on EN 16247-2:2014 standards related to buildings energy audits. EN 16247-2:2014 identifies the main steps for the completion of a building energy audit as shown below:

1) <u>Preliminary Contact</u>: Energy auditor shall identify all parties/organizations and their roles in ownership, management, use, operation and maintenance of the building and their respective impacts and interests on energy use and consumption. During this phase it is very important defining the energy boundaries of energy audit in terms of:
    a. which buildings from a list of buildings or parts of a building;
    b. which energy services;
    c. which technical building systems;
    d. which areas and systems outside the building;
    e. which energy performance indicators could be used as appropriate to the audit.

2) Start Up Meeting: During the start-up meeting, energy auditor shall agree with the organization on:
    a. timing of site visits;
    b. level of occupant engagement;
    c. areas of restricted access; d) potential health hazards and risks.

   The energy auditor shall obtain from the organization:
    a. set-points and operational limits of indoor environmental conditions (such as temperatures, air flows, illuminance, noise) and any seasonal variations;
    b. occupancy patterns for the different range of activities within the building;
    c. comments from occupants on operational performance of the building and the level of the building service;
    d. The energy certificates if available;
    e. whether any building occupant awareness or motivation programmes have been implemented.

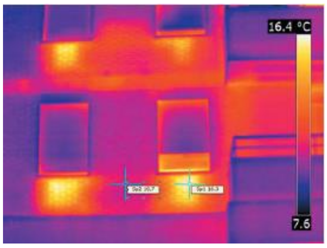
3) Data collection: During this step the energy auditor shall collect data about:



    a. energy carriers, present and available;
    b. energy related data as:
        i. delivered, produced and exported energy, for each energy carrier (for example identify the energy streams for a CHP unit, or for photovoltaic systems where production is used locally or exported);
        ii. energy consumption data (or readings with related time and date) of any available meters or counters (e.g. heat meter, domestic hot water meter, fuel meter, burner hour counter);
        iii. data from individual metering, if it is available;

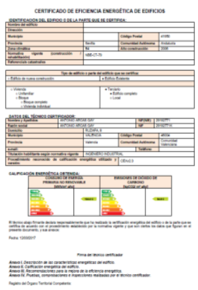
   iv. short-interval (e.g. hourly) energy demand / load curve, if available;
   v. relevant related measurements;
c. adjustment factors affecting energy consumption:
   i. climatic data from the local building automation and control system (BACS), if available (e.g. temperature, degree-days, hygrometry, lighting) ;
   ii. occupancy patterns;
d. information on important changes in the past 3 years related to building envelope or plants.

This phase foresees the Review of the available data and the Preliminary data analysis. The final result is a preliminary list of efficiency improvement actions that is called “Opportunity list”.



4) Fieldwork: The energy auditor or working team shall inspect the audited object to define each significant energy aspect and service that affects on energy consumption and/or improvements.

5) Analysis: This phase foreseen the energy performance indicators calculation or building specific baseline. The energy auditor shall identify and shall model energy efficiency improvement opportunities and evaluate them in terms of economic advantages.



- Conclusión of the modul

2012/27/EU directive, 8th article, establishes that Member States shall promote the availability to all final customers of high quality energy audits based on the following minimum guidelines and contents gathered at Annex VI of the same directive paper.

Project partnership decided to follow a common protocol by using the European standards EN 16247-1:2012 at pilot schools energy consumption investigation.

An energy audit is the ground to establish in order to know the current status of the analysed installations and, secondly, to totally and necessarily define the improvements to implement in buildings/facilities and action planning.

Energy efficiency goes further than an energy audit, as after defining the energy saving options, its real savings must be monitored and verified. This follow up plan will be useful also to define comparision energy ratios and building users behavior patterns, to compare results from different schools, according to their building typology, geographical area, activity time, and other parameter that may affect energy consumption.

- Self assesment

1. European Energy efficiency Directive is the:

   Possible answers

   2018/2001/EU

   2012/27/EU

   2009/28/EC

2. European standard energy audit protocol requirements followed at TEESCHOOLS project is:

   Possible answers

   AS/NZS 3598:2014

   ISO 14001

   EN 16247-1:2012

3. It’s recommended that energy audits must address:

Possible answers

simple payback periods to analysis the proposed investments.

life-cycle cost analysis to take into account not only the investment cost of actions.

Economical analysis is not really important in that case.

4. Energy audits benefits are

Possible answers

just related with energy savings.

considering mainly business environmental impact reduction.

embracing energy saving opportunities, improvement of production processesand reduction of environmental impact.

5. EN 16247-1:2012 general requirements applies to:

Possible answers

Individual private dwellings

Commercial, industrial, residential, public buildings but not to individual private dwellings.

Public buildings and facilities.

6. EN 16247-2:2014 is dealing with building energy audits. Which are its main steps?

Possible answers

Preliminary contact, start-up meeting, data collection, fieldwork and analysis of data.

Preliminary contact, data collection on the spot and data analysis.

None of the answers

7. When a school energy audit is being carried out is important:

Possible answers

To set the energy audit boundaries.

To identify all organizations and their roles in building owhership.

Both of them

8. During a school energy audit is important:

Possible answers

To know school year calendar.

To know school weekly timetable.

Both of them

9. School community patterns of behauviour

Possible answers

Are not affecting building energy audit results.

Must be addressed with awareness-raising actions

Both of them

10. The energy audit report must include:

Possible answers

A list of potential energy saving actions.

An analysis of energy data collected.

Both of them

Calculation and monitoring tools. Webtool TEESCHOOLS

E-MODULE: CALCULATION AND MONITORING TOOLS. WEBTOOL TEESCHOOLS

MODULE PRESENTATION

The module aims to illustrate the use of the web tool for assessing the energy efficiency of school buildings. The tool is currently applicable to 7 European countries: Bosnia – Herzegovina, Croatia, Cyprus, France, Greece, Italy, Spain.

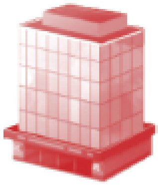
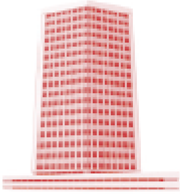
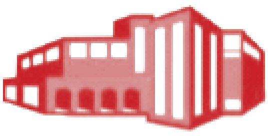
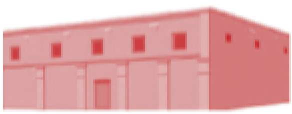
Reducing energy should be a priority for all organisations; it saves money, is socially responsible and helps everyone in the fight against climate change. One of the simplest ways to do this is to use energy more efficiently.

From the emotional to the architectural value, buildings occupy a key place in our lives and society as a whole. Yet, the energy performance of our buildings is generally so poor that the levels of energy consumed in buildings place the sector among the most significant CO_2 emissions sources in Europe. While new buildings can be constructed with high performance levels, it is the older buildings, representing the vast majority of the building stock, which are predominantly of low energy performance and subsequently in need of renovation work. With their potential to deliver high energy and CO2 savings as well as many societal benefits, energy efficient buildings can have a pivotal role in a sustainable future. Energy performance evaluation and its methodology are being developed in order to benchmark and classify the energy performance. Energy benchmarking is the way to communicate on building efficiency and carbon gas emission to building owners. This energy classification method enables building owners or publics to obtain information on the performance of a building.

Achieving the energy savings in buildings is a complex process. Policy making in this field requires a meaningful understanding of several characteristics of the building stock. Reducing the energy demand requires the deployment of effective policies which in turn makes it necessary to understand what affects people's decision making processes, the key characteristics of the building stock, the impact of current policies etc.

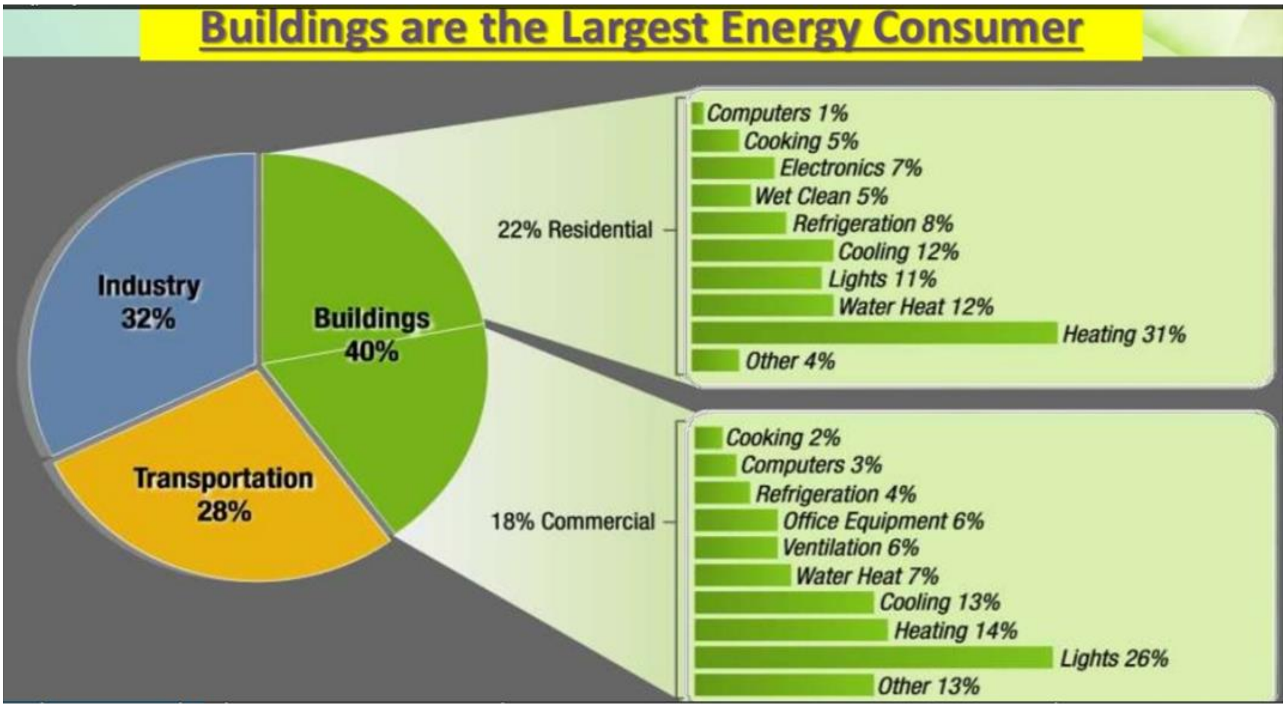
Non-residential buildings account for 25% of the total stock in Europe and comprise a more complex and heterogeneous sector compared to the residential sector. The retail and wholesale buildings comprise the largest portion of the non-residential stock while office buildings are the second biggest category with a floor space corresponding to one quarter of the total non-residential floor space. Variations in usage pattern (e.g. warehouse versus schools), energy intensity (e.g. surgery rooms in hospitals versus to storage rooms in retail), and construction techniques (e.g. supermarket versus office buildings) are some of the factors adding to the complexity of the sector.

Source: BPIE survey

	Wholesale & retail 28%	Detached shops, shopping centres, department stores, large and small retail, food and non food shops, bakeries, car sales and maintenance, hair dresser, laundry, service stations (in gas stations), fair and congress buildings and other wholesale and retail.
	Offices 23%	Offices in private companies and offices in all state, municipal and other administrative buildings, post-offices.
	Educational 17%	Primary and secondary schools, high schools and universities, research laboratories, professional training activities and others.
	Hotels & restaurants 11%	Hotels, restaurants, pubs and cafés, canteens or cafeterias in businesses, catering and others.
	Hospitals 7%	Public and private hospitals, medical care, homes for handicapped, day nursery and others.
	Sport facilities 4%	Sport halls, swimming pools, gyms etc.
	Other 11%	Warehousing, transportation and garage buildings, agricultural (farms, greenhouses) buildings, garden buildings.

The schools buildings, like all the other buildings, consume energy for space heating, for the production of hot domestic water, for lighting and for other services.

As you can see in the image, buildings represent the largest energy consumer: around 40% of total consumption derives from the use of buildings and most of this consumption is due to heating, cooling and lighting.



Sometimes the types of energy used aren't the most appropriate for the product service, other times the system for the production and the energy distribution have low performances or the energy use doesn't take place in the best way (high heat losses, overheating).

In all these cases there is a greater use of resources than necessary, with negative effects both on the users comfort and on the waste of money.

To help stakeholders interested in school buildings, a web tool has been developed with the aim of simplifying the analysis of the actual state of a school building and the implementation of energy improvement actions.

The web tool (http://www.improveyourschool.enea.it/) allows knowing the energy quality of the schools building, evaluated with respect to the average value of the national school consumption. It also allows to identify the easier interventions and the lower costs to improve the energy quality and to evaluate the opportunity of carrying out , through more deepen energy audits, more complex analysis.

The evaluation of energy quality of the school building takes place through the comparison with a representative sample of similar schools. The examples used for the comparison were originated from a series of complex energy audits performed in different European countries (TEESCHOOLS project partners).

The EU 2030 climate and energy framework sets three key targets for the year 2030: at least 40% reduction in greenhouse gas (GHG) emissions (from 1990 levels), a 27% cut in energy consumption through improved energy efficiency and a 27 % increase in the use of renewable energy. In this framework renovation of buildings emerges as an urgent issue, but there is lack of knowledge on performance/cost characteristics of advanced component and systems for efficient renovation of buildings. Moreover, while incentives are given to private sector, public sector faces severe limitations of budget.
TEESCHOOLS project aims at providing an integrated set of user-friendly but scientifically sound tools to support Public Authorities to approach Nearly-Zero Energy Building (nZEB) renovation in Mediterranean Schools.
The set of the user-friendly tools contains:

1. a simplified energy and environmental audit tool composed of two modules:
   a) Energy profile module of the building: It calculates the energy index of the school building and estimates its energy performance
   b) Renovation Options module: it calculates the potential energy and CO_2 savings of the school building and helps in selecting the most promising renovation options
2. A database of innovative best practices for renovation of school buildings in the Mediterranean area
3. A list of available financing opportunities in Mediterranean area.

For further information on the TEESCHOOLS project and other activities (trainings, e-learnings, capitalization etc.) visit https://teeschools.interreg-med.eu/.

EDUCATIONAL OBJECTIVES

1. TO LEARN ABOUT SCHOOL BUILDINGS CONSUMPTION

2. TO CALCULATE CONSUMPTION

3. TO EVALUATE IMPROVEMENT OPTIONS

1. TO LEARN ABOUT SCHOOL BUILDINGS CONSUMPTION

Benchmarking is the first step that needs to be done to determine the energy performance of buildings to improve energy efficiency in the buildings.

Improving energy efficiency in schools does not mean compromising the comfort of staff and students. In many cases, implementing some simple energy saving measures actually improves conditions, as well as saving money.

In addition to economic benefits, there are social and environmental advantages to reducing energy consumption, such as preserving fossil fuels and minimising impact on the environment. This is increasingly important to the reputation of schools, as students, teachers and parents become increasingly aware of climate change. Moreover, actions taken to become energy efficient provide an excellent opportunity for practical learning and real-life application for students.

How can you benefit from energy efficiency?

- The school manager will benefit from reduced costs and enhanced learning environments
- Staff and students will have improved comfort conditions which can boost productivity and morale
- Students can learn about and experience 'real world' activities when exploring energy efficiency in Maths, English, Science and Citizenship classes
- Parents and the wider community could reduce their own energy use as a result of pupil action and awareness
- The environment will benefit from reductions in energy use and carbon emissions which will enhance school image.

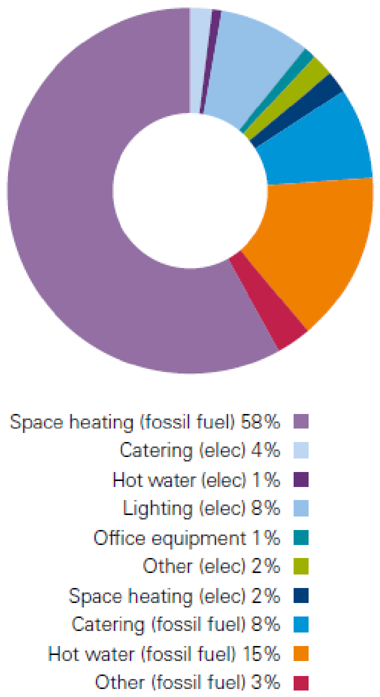
Schools are, first and foremost, places for opening up to the world, to the acquisition of knowledge and for socialisation.

Energy consumption in schools can vary depending on the age of the buildings, their state of repair, occupancy hours and the amount and type of electrical equipment installed.

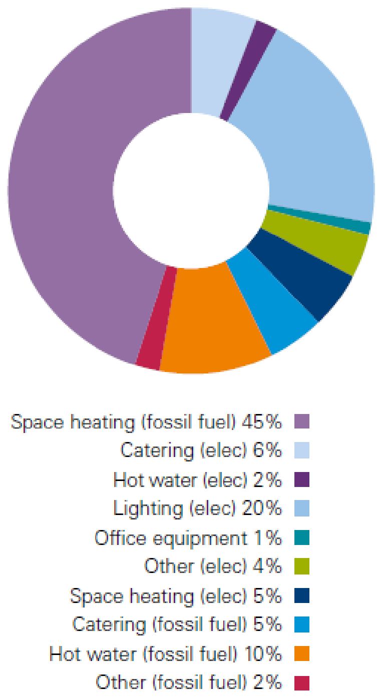
Generally, secondary schools will have higher energy costs than primary schools. This can be explained by secondary schools' longer hours and larger number of students, as well as more widespread use of electrical equipment in ICT, science, sports and crafts lessons.

However, areas of energy waste are often the same regardless of school size or level. The charts detail where the biggest savings can be made. They are divided into energy use and energy cost and comparing them could help school managers decide which areas to prioritise.

Schools – percentage of energy use



Schools – percentage of energy cost



Most school buildings in Europe are old, dilapidated and poorly insulated. Heating systems too are old and often cannot be regulated. Ventilation systems, if any, are inefficient. Outdoor spaces and playgrounds are often restricted and of poor quality.

Then in all Europe school buildings are in urgent need of fundamental rehabilitation. Sustainable and cost-efficient refurbishment of a school or school buildings provides a real opportunity for making pupils, teachers and parents aware of energy efficiency as well as comfort and the quality of indoor and outdoor environments. School buildings, their technical equipment and operation can be used as a showcase for the pupils and their families: a showcase that, once experienced, can influence their attitudes and lead them to behave in a more responsible and public-spirited way.

School buildings have a relatively low occupancy rate, which is very different from that of other public buildings. They are, most of the time, occupied between four and five days per week, from Monday to Friday, from 8 a.m. till 4 p.m. Some premises, such as the library, canteen, study rooms and childcare rooms have even lower rates of occupation, in the order of a few hours per day. School buildings are used for about 30 weeks or 200 days a year, with relatively long periods during which they are unoccupied and, in general, few activities take place during weekends and evenings, other than partial occupation of sports halls, gyms or some cultural spaces.

There is no predefined model of a school. Some schools have a very large footprint and are very spread out, with one- or two-storey buildings. Other schools use multi-storey buildings. Yet others operate with a mixture of old and prefabricated «container»-type buildings.
According to the construction period, the construction methods and materials used are different:

- Buildings with heavy masonry facades and structure. The facades, mainly of masonry construction, are punctuated with relatively large openings;
- Buildings with load-bearing structural frame (concrete or steel) and non-load-bearing infill facade components;
- Buildings with a load-bearing structural frame and a non-load-bearing facade that completely hides the structural frame;
- Complexes of prefabricated or container buildings.

Europe's school building stock is relatively old, often dilapidated and has poor energy performance. Article 4 of the European Commission's proposal for an Energy Efficiency Directive (June 2011) provides that, from 1 January 2014, 3% of public buildings or buildings belonging to public bodies should be refurbished every year, with the objective of energy efficiency. Currently, the same percentage is refurbished annually, but energy efficiency improvement is only included in a half of those cases (1.5% of the rate of energy-related refurbishment). This type of infrastructure should be renovated with a high standard of insulation to the envelope and roof, installing double glazing and replacing inefficient or obsolete heating systems. However, there remains a major problem to be dealt with: the ventilation and air quality of school premises.
All these elements contribute to the achievement of the nZEB class.
According to the European Conference on Sustainable Refurbishment of Buildings (2012), the building sector represents 25 billion m² of constructed surface area in Europe. 40% of this stock, which was erected before 1960, requires major refurbishment.

The environmental impacts of the construction sector are substantial:

- 40% of natural resources exploited
- 40% of total energy consumption
- 35% of waste produced
- 40% of greenhouse gas emissions (GWP)
- 15% of water consumption.

If renovating school buildings is, above all, an undertaking based upon improving occupant comfort (teachers and pupils) and on the energy performance of buildings and their equipment, with the goal of ensuring effective learning and energy efficiency, this undertaking, in order to also be considered sustainable, must be based on the three aspects of sustainable development and be committed to a systematic approach, as defined by the Rio Declaration (1997) and the 27 principles proposed in application of the definition of sustainable development.

Sustainable design of a refurbishment project entails attention to the contexts within which the buildings are located, in order to enrich or protect both the building and its environment through a variety of interrelationships. This type of design will cause the building or buildings subject to refurbishment to:

- be enriched by the opportunities offered by all the contexts within which it is located (social, environmental and economic: this involves the contexts of climate (orientation, solar gain, ventilation, shading etc.); geology (land, soils, altitude etc.), hydrology (resources, treatment, distribution, conservation etc.), plants (trees, crops etc.), institutions (ways of living together), infrastructure (utilities etc.), technology (technologies, materials etc.), policy (social mix, operational mix etc.) and heritage (buildings, landscapes etc.).
- be protected against local threats: this involves protection from cold, heat, rain, noise, pollution and flood risk, but also from insecurity, lack of drinking water, serving only a single generation or a single function, lack of public transport, harmful materials etc.
- enrich its environment with sustainable improvements: constructing a building which, if it must be removed, will not have caused any detriment to its environment, is not sufficient for a sustainable building. Thus, the architecture must locate itself within a triple perspective: the past it inherits, the present it constructs and the future it transmits.
- protect the immediate environment from nuisance it may cause: this involves atmospheric and hydrological pollution connected with manufacture of component materials, production of waste (domestic, demolition etc.), noise nuisance etc., additional traffic, soil sealing etc.

Following European undertakings in the light of the Kyoto Protocol, the European Union Parliament and Council adopted, in 2002, The European Directive 2002/91/CE (EPBD) on energy performance and indoor climatic conditions of buildings assesses the energy performance of buildings such as:

"*The amount of energy actually consumed or estimated to meet the different needs associated with a standardised use of the building, which may include, inter alia, heating, hot water heating, cooling, ventilation and lighting for non-residential buildings). This amount shall be reflected in one or more numeric indicators which have been calculated, taking into account insulation, technical and installation characteristics, design and positioning in relation to climatic aspects, solar exposure and influence of neighbouring structures, own-energy generation6 and other factors, including indoor climate, that influence the energy demand.*"

The Directive requires each member state to define in local or regional law:

- A calculation method for energy performance of buildings
- Minimum requirements with regard to the energy performance of new buildings and existing buildings subject to major refurbishment
- Certification schemes for building energy performance
- Requirements with regard to regular inspection of boilers and air conditioning systems.

In compliance with the Directive, an energy performance certificate must also be issued at each key point of a building's life cycle: construction, sale and rental.

The period of validity of the certificate is 10 years and it must be displayed in public buildings. Obviously, energy certification covers all types of buildings with any intended use, including school buildings.

For sustainable construction, responsible and public-spirited choice of materials or construction products means taking

the following into account for their whole service life:

- A technical and/or physical performance audit
- **An environmental audit**
- **An energy audit**
- A health audit (workers and occupants)
- An economic audit

Carrying out these five audits is not easy, mainly because of the lack of objective and quantifiable data for the environmental and health audits.

The purpose of the TEESCHOOLS project is mainly to create an easy-to-use tool for the subjects interested in the school buildings (principals, energy, managers, mayors, cost decision-makers...) so that they can carry out a quick energy and environmental check and understand which improvements solutions can be more energetically, environmentally and economically advantageous.

2. TO CALCULATE CONSUMPTION

The web tool allows knowing the energy quality of the schools building, evaluated with respect to the average value of the national school consumption.

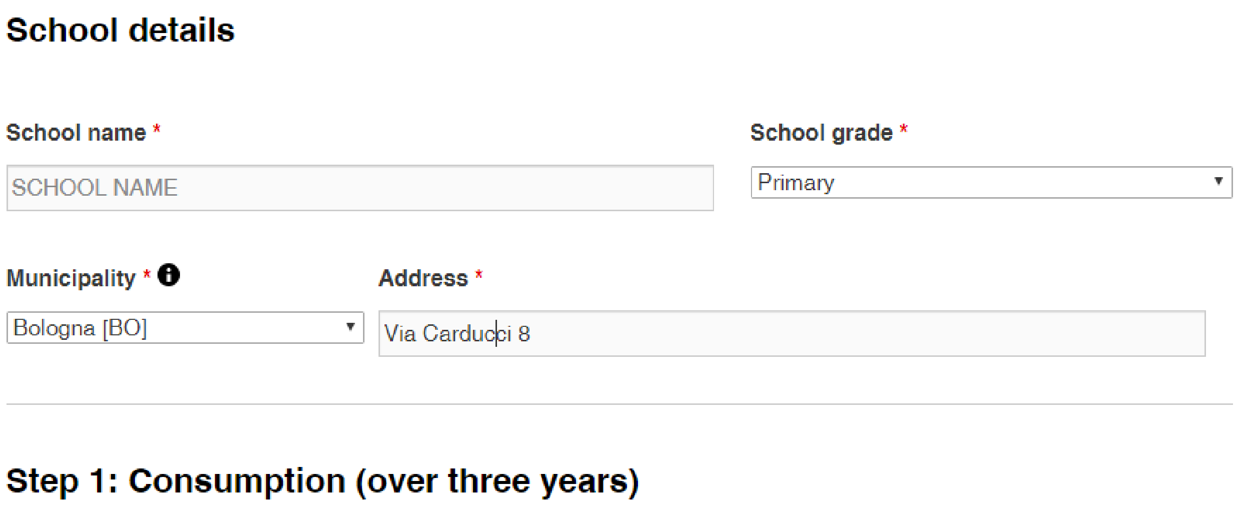
It also allows to identify the easier interventions and the lower costs to improve the energy quality and to evaluate the opportunity of carrying out , through more deepen energy audits, more complex analysis.

The webtool allows stakeholders to carry out a simplified assessment of energy consumption and, with a second step, allows to verify possible energy improvement actions. At the end, carbonfoot print assessments are also returned both of the current state of the school building and of the post intervention improvement actions.

To calculate the current consumption of the school building, it is necessary to find important data: electricity and thermal bills, surfaces, volumes, locations, construction types of the enclosure and of the heating and cooling systems.

The specific normalized consumption are called **energy normalized indicators for heating ENI_R** and **energy normalized indicators for electricity ENI_E**. The indicators are drawn by the ratio between the annual middle consumption and the area of the floor, normalized in comparison to the operating time of the school.

At the beginning the format ask for general information:



To determine the energy indicators the single phases below indicated must be follow:

1. consumption evaluation
2. gross heated volume, gross area of the floors and dispersing surface of buildings collection
3. degrees days (k_d) of the city in which is located the school
4. heating consumption normalization factor, depending on the shape of the buildings
5. the operating time normalization factor fh
6. normalized energy indicators calculation

STEP 1 - CONSUMPTION EVALUATION

The energy consumption for heating per year detected by the bills relating to the previous 3 years the energy evaluation will be collected. The fuel consumption of three years is added together and divided by obtaining the annual average fuel consumption.

The same will be done for electricity. The data of annual consumption of fuel and electricity should be registered in specific tables as shown below:

Type	Year (0)	Year (-1)	Year (-2)	Average	
Natural gas [m^3]	0	0	0	0.00 m^3	x 9.59 = 0.00 kWh_t
Diesel fuel [l]	0	0	0	0.00 l	x 11.86 = 0.00 kWh_t
Fuel Oil [l]	0	0	0	0.00 l	x 11.40 = 0.00 kWh_t
LPG [Kg]	0	0	0	0.00 l	x 12.79 = 0.00 kWh_t
Firewood [Kg]	0	0	0	0.00 kg	x 4.77 = 0.00 kWh_t
Coal [Kg]	0	0	0	0.00 kg	x 8.15 = 0.00 kWh_t
Electric Energy for heating [kWh]	0	0	0	0.00 kWh	kWh_t

Thermal consumption

Contract ID	Year (0)	Year (-1)	Year (-2)	Average
Electric Contract 1	kWh	kWh	kWh	0.00 kWh
Electric Contract 2	kWh	kWh	kWh	0.00 kWh
Electric Contract 2	kWh	kWh	kWh	0.00 kWh

Electric consumption

STEP 2 - GROSS HEATED VOLUME, GROSS AREA OF THE FLOORS AND DISPERSING SURFACE OF BUILDINGS COLLECTION

The gross heated volume (V)

It is obtained from the drawings, if they are available, or the building is measured from the outside. In the gross heated volume, the external walls must be included and the not heated parts of the buildings must be excluded (undergrounds, attics, stores, garage...).

If the school building consists of several buildings, V will be the sum of the volumes of the individual building.

Step 2: Volumes and surfaces

Gross heated volume [m³] *

Dispersing surface [m²] *

Gross floor area [m²] *

The gross floor Area (Ap)

The area of the floors is obtained from the drawings of buildings or, if these are not available, with direct measures of the area.

The floor areas include internal walls that separate different rooms. If the school consists several buildings Ap will be the sum of the areas of the individual buildings.

The dispersing surface (S)

The dispersing surface is obtained from the sum of the individual surface of the gross heated volume V (walls, roofs, ground floor slabs).

Is not considered as a dispersing surface all walls or slabs that are connected to other heated buildings. If the school consists of several buildings S will be the sum of the dispersing surfaces of the individual buildings.

PHASE 3 - DEGREES DAYS (DAYS (KD) OF THE CITY IN WHICH IS LOCATED THE SCHOOL

To compare heating consumptions, it is necessary to consider the climatic differences in the country and the city in which the school buildings are located. According to this issue, consumption is released from climatic differences through the use of degrees day (k_D). K_D is obtained as the sum of the positive differences between the internal comfort temperature (20 °C) and the outdoor daily average temperature.

The summation is extended to all the heating days of the winter season.

After entering this data, the degree days and the shape normalization factor are automatically calculated.

The specific consumption of schools buildings, must be normalized with a factor depending on shape. It is expressed by the ratio between the buildings dispersing surface and its heated volume (S/V).

The normalization factor Fe is obtained from the following value:

V = A m^3

S = B m^2

S/V = B/A m^2/m^3

STEP 3 - THE OPERATING TIME NORMALIZATION FACTOR Fh -

The normalization factor Fh depends on the operating time of the school buildings.

The factor Fh, found according to the type of school, will be multiplied by the heating consumption and the electricity consumption of the school buildings.

Step 3: Operating time factor

Time normalizazion factor *

h/day ▾

RESULTS - NORMALIZED ENERGY INDICATORS CALCULATION

Calculate two normalized indicators NEIh e NEIe, copying the previously identified data into specific schemes.

NORMALIZED ENERGY INDEX FOR HEATING

NEIh = **185.15** Wht/m³ x DD x year

Heating rating:

Below average

Not good, you **NEED** to improve
Check how by clicking NEXT.

NORMALIZED ENERGY INDEX FOR ELECTRICITY

NEIe = 270.77 kWhe/m² x year

Electricity rating:

Below average

Not good, you **NEED** to improve
Check how by clicking NEXT.

If the NEI value is "above average", to the school building is associated an average consumption and it is advisable to propose improvement actions.
If the NEI value is "average", the school building has efficient systems and good management than no improvement actions is obliged But it is advisable to propose improvement actions to reach the nZEB class.
If the NEI value is "below average", it is necessary identify deep interventions to improve school building energy efficiency.

The second module of webtool calculates the potential energy savings of your building and helps in selection the most promising renovation action.

The module allows you to choose different improvement actions for the building both for the building envelope and for the energy systems:

- Glazing
- Roof

- Walls
- Floor
- Heat generator
- Lights

and through a few data such as surfaces, performance or power returns the results about saving.

Selecting one or more improvements, you will get the estimated energy and CO_2 savings, and the impact (in percentage) of the selected improvement on the total savings.

Elements	U_{old} [W/m²K]	U_{new} [W/m²K]	Area [m²]	Energy Saving [kWh]	% Contribution
Glazing	single glass + woo	Good Insulation	12	2,810	13.0 %
Roof	Bricks + concrete r	Insulation	25	2,388	11.1 %
Walls	Solid masonry wall	Best Insulation	45	5,075	23.5 %
Floor	Bricks + concrete s	Insulation	45	3,883	18.0 %

What systems do you want to change?

η_{old} and P_{old} = the efficiency and the installed power before the renovation
η_{new} and P_{new} = the efficiency and the installed power after the renovation
hh/y = the working hours per year

Elements	Old	New		Energy Saving [kWh]	% Saved
Heat Generator	η_{old}[%] 89	η_{new}[%] 98		1,378	6.4 %
Lights	P_{old}[kW] 16	P_{new}[kW] 9	hh/y 865	6,055	28.0 %

The results will be returned both in energy and environmental terms.

As an example, potential savings in CO_2e* are compared to the distance covered by a school bus carrying 45 students.

RESULTS

The table below shows the potential CO_2e* savings associated to the type of energy sourches used for the heating system. As an example, potential savings in CO_2e* are compared to the distance covered by a school bus carrying 45 students.

Total THERMAL Energy Saved: 15,534 [kWh]

Fuel Carbon Footprint	kg CO_2e*	km Schoolbus
Methane gas	4,117	915
Diesel	4,753	1,056
Fuel Oil	4,903	1,090
L P G	4,722	1,049
Firewood	6,524	1,450
Coal	5,918	1,315
Electric energy	6,555	1,457

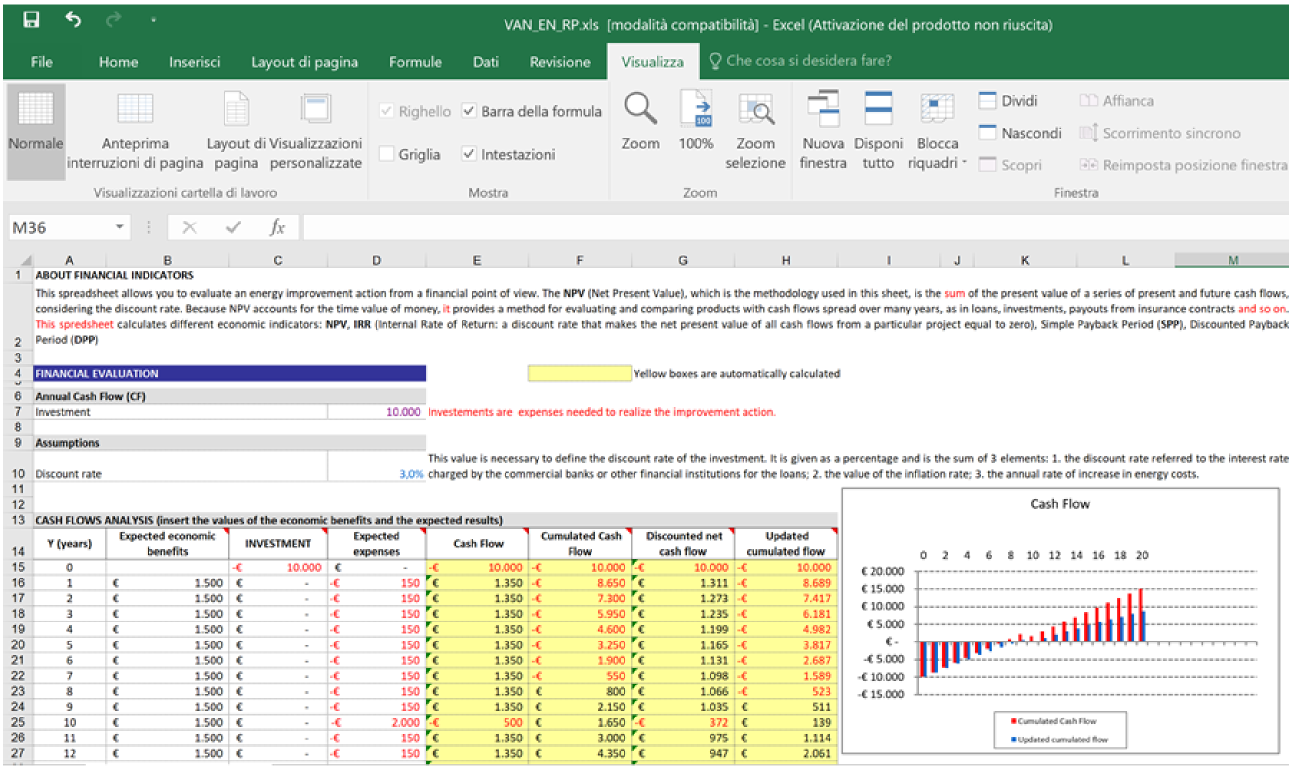
Total ELECTRIC Energy Saved: 6,055 [kWh]

Fuel Carbon Footprint	kg CO_2e*	km Schoolbus
Electric energy	2,555	568

*Emissions are all expressed in kg of CO_2e (equivalent) calculated according to IPCC method.

1. Check a simple financial analisys in this excel worksheet for your renovation plan
2. Several examples of Best Practices have been implemented in Mediterranean countries. Check it on this BAT page

At the end it is possibile to download a calculation excel with a simple financial analisys for renovation plan.



ABOUT FINANCIAL INDICATORS

This spreadsheet allows you to evaluate an energy improvement action from a financial point of view. The **NPV** (Net Present Value), which is the methodology used in this sheet, is the sum of the present value of a series of present and future cash flows, considering the discount rate. Because NPV accounts for the time value of money, it provides a method for evaluating and comparing products with cash flows spread over many years, as in loans, investments, payouts from insurance contracts and so on. This spredsheet calculates different economic indicators: **NPV**, **IRR** (Internal Rate of Return: a discount rate that makes the net present value of all cash flows from a particular project equal to zero), Simple Payback Period (**SPP**), Discounted Payback Period (**DPP**)

FINANCIAL EVALUATION

Yellow boxes are automatically calculated

Annual Cash Flow (CF)

Investment 10.000 Investements are expenses needed to realize the improvement action.

Assumptions

Discount rate 3,0% This value is necessary to define the discount rate of the investment. It is given as a percentage and is the sum of 3 elements: 1. the discount rate referred to the interest rate charged by the commercial banks or other financial institutions for the loans; 2. the value of the inflation rate; 3. the annual rate of increase in energy costs.

CASH FLOWS ANALYSIS (insert the values of the economic benefits and the expected results)

Y (years)	Expected economic benefits	INVESTMENT	Expected expenses	Cash Flow	Cumulated Cash Flow	Discounted net cash flow	Updated cumulated flow
0		-€ 10.000	€ -	-€ 10.000	-€ 10.000	-€ 10.000	-€ 10.000
1	€ 1.500	€ -	-€ 150	€ 1.350	-€ 8.650	€ 1.311	-€ 8.689
2	€ 1.500	€ -	-€ 150	€ 1.350	-€ 7.300	€ 1.273	-€ 7.417
3	€ 1.500	€ -	-€ 150	€ 1.350	-€ 5.950	€ 1.235	-€ 6.181
4	€ 1.500	€ -	-€ 150	€ 1.350	-€ 4.600	€ 1.199	-€ 4.982
5	€ 1.500	€ -	-€ 150	€ 1.350	-€ 3.250	€ 1.165	-€ 3.817
6	€ 1.500	€ -	-€ 150	€ 1.350	-€ 1.900	€ 1.131	-€ 2.687
7	€ 1.500	€ -	-€ 150	€ 1.350	-€ 550	€ 1.098	-€ 1.589
8	€ 1.500	€ -	-€ 150	€ 1.350	€ 800	€ 1.066	-€ 523
9	€ 1.500	€ -	-€ 150	€ 1.350	€ 2.150	€ 1.035	€ 511
10	€ 1.500	€ -	-€ 2.000	-€ 500	€ 1.650	-€ 372	€ 139
11	€ 1.500	€ -	-€ 150	€ 1.350	€ 3.000	€ 975	€ 1.114
12	€ 1.500	€ -	-€ 150	€ 1.350	€ 4.350	€ 947	€ 2.061

3. TO EVALUATE IMPROVEMENT ACTIONS

In the context of sustainable refurbishment of school buildings, optimising or installing efficient building services means providing a suitable response to occupants' needs, improving building services, reducing the number of items of equipment or systems and facilitating their regulation and daily use. This also means ensuring that they consume little energy and produce little pollution.

By building services, we mean ventilation, heating, cooling, sanitary hot water and artificial lighting.

By equipment, we mean heating equipment (boilers etc.), pipework, distribution equipment and heaters or heating units.

By management system, we mean regulatory equipment (thermostats, valves, sensors etc.).

It is not possible to optimise all the building services without first having optimised the building envelope.

Optimising the envelope and building services enables, on the one hand, reduction of fossil fuel consumption and, on the other hand, noticeable improvement to the comfort of school users while, at the same time, considerably reducing operation and maintenance costs.

We shall, thus, take as our initial premise that, before optimising a school's building services, it is first necessary to:

- Reduce heating, cooling and artificial lighting requirements by optimising the volume, spatial layout and external envelope of the buildings;
- Make maximum use of natural or existing sources of heating, cooling and lighting;
- Integrate and make maximum use of renewable energy sources.

Three technical aspects need to be addressed as priorities in school building refurbishment, both for improving teaching and learning comfort, and for reducing energy costs and environmental impact. These are:

- The heating system and its regulation;
- The ventilation installation and its regulation;
- The artificial lighting installation and its control.

Regulation and adjustment of services plays an overriding role with regard to both comfort levels and energy saving.

The tool aims to verify the energy quality of school buildings and to identify improvement actions to reach best energy conditions and to reduce energy managing costs. A good management plan can help to solve problems related to energy waste and can anticipate problems that if identified late make the expenses grow enormously.

A good plan can include:

- Designation of an activity manager
- Preventive maintenance program
- Periodic evaluation of the contractual conditions of energy supplies
- Evaluation of electrical and thermal systems for safety and compliance with energy legislation

CONCLUSION

To better understand the use of webtool we provide a tutorial that explains the steps to be taken.

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- TEESCHOOLS VIDEO TUTORIAL

SELF ASSESSMENT TEST

1. Which are the technical aspects to avaluate to refurbish a building?
   d) Heating, ventilation and lighting
   e) Heating and hot domestic water
   f) Heating
2 Which are aspect to to avaluate to refurbish a building according to the envelope?
   a) Walls
   b) windows
   c) Walls, windows, roof
3. Is it important to aveluate CO_2 emission for building refurbishment ?
   a) Yes
   b) No
   c) It is your choice
4. Is the webtool used for?
   a) Office
   b) Hospitals
   c) School buildings
5. Can you use the webtool to evaluate carbonfoot print?
   d) No
   e) Just for hospitals
   f) Yes
6. The evaluation of electrical and thermal is usefull for refurbishment?
   a) Yes
   b) No
   c) It is your choice
7. Is the webtool used for?
   a) Energy evaluation
   B) Environmental evaluation
   c) Energy and environmental evaluation
8. Achieving the energy savings in buildings is a complex process?
   a) Yes
   b) No
   c) No for school buildings
9. The environmental impacts of the construction sector are:
   a) 40% of total energy consumption
   b) 50% of total energy consumption
   c) 60% of total energy consumption
10. Used energy for cooking in building is about
   a) 20%
   b) 8%
   c) 2%

Calculation and monitoring tools. Carbon footprint

Carbon Footprint in building sector, calculation and monitoring tools.

Presentation of the module

After a brief description of the European context concerning the greenhouse gas emissions in the building sector, this module will introduce the Life Cycle Assessment methodology, describing its phases an in particular the Carbon Footprint indicator, the approach employed to asses it and the calculation processes.

This module wants to provide students with some basic concepts that will help the understanding of the Carbon Footprint indicator and the Life Cycle Assessment methodology.

Educational objectives

- The European context concerning the building sector greenhouse gas emissions
- The Life Cycle Assessment methodology
- What Carbon Footprint means
- Information on simplified Carbon Footprint tools

Section 1 – Background and EU policies

The building sector is characterized by an inhomogeneous variety of building types utilizing a large number of technologies for heating, cooling, and lighting, and a wide range of building materials and building techniques. The use of energy has grown in the time doubling between 1971 and 2010 driven by population increase and economic growth (IEA et al. 2013). Nevertheless, technologies and good practices to move from this business as usual scenario to a more sustainable one already exist. These include the policies and technologies capable of making new buildings more energy efficient than current.

As stated in the Energy-efficient buildings for low-carbon cities (ICCG Reflection No. 47/March 2016), around one-third of global greenhouse gas (GHG) emissions derive from buildings, this value could double by 2050 if no action is taken (UNEP, 2015). Buildings account for more than 40% of global energy use; nevertheless, adopting existing best practices and technologies may significantly reduce energy use and consequently GHG emissions. Energy efficiency technologies are cost-effective with paying back periods within the building lifetime; this can have a direct advantage reducing energy use and emissions. On 9 July 2018, the new Directive 2018/844/EU has introduced a revision of previous target with the aim at accelerating the renovation of existing buildings, the final goal is to have a decarbonised building stock by 2050.

There are plenty of methods available to decrease energy consumption and to reduce CO_2 emissions produced by the building that comprehend all the buildings life cycle from design, to building and operational phases. Reductions in GHG emissions can be achieved by increasing the amount of electricity generated from low-carbon technologies, retrofitting existing buildings, and by constructing new buildings to be nearly zero energy buildings (nZEB).

Europe states need common and long-term strategy to remove barriers that prevent diffusion of mass nearly zero energy building renovation activities, increases energy efficiency, reduces carbon footprint of building stock while improving the growth of local jobs. School buildings in particular, being 20% of the surface of all non-residential buildings in Europe, have a high impact on the annual costs of all communities because of their energy costs (heat, cold and electricity).

Section 2 – Carbon Footprint

To evaluate Nations' progress in reaching Europeans goals in greenhouse gas emissions reducing one of the proposed instrument is the Carbon Footprint, based on the Life Cycle Assessment methodology, in the following sections definitions, approach and calculation method will be presented.

– **What is Life Cycle Assessment**

LCA methodology is a holistic procedure for compiling an inventory (inputs and outputs of materials and energy) of the whole life cycle of a product or service system with a specific function and then for assessing the related environmental impacts. The life cycle includes raw-material production, manufacture, distribution, use and disposal including the direct and indirect emissions related to all the investigated phases.

LCA allows quantifying the environmental performance of a system/product/process avoiding shifting of burdens on different life cycle phases or locations.

The methodology includes four main phases (Figure below).

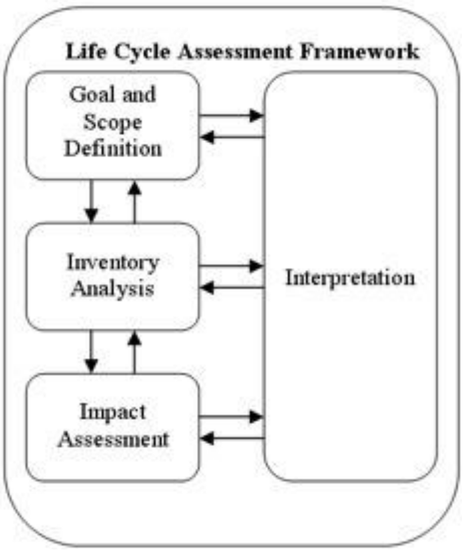


Figure - Steps of LCA methodology (ISO 14040 series)

In the Goal and Scope definition phase the objective of the study is defined. In this phase, the functional unit, that represents the quantification of the identified functions of the product, is defined. The primary purpose of a functional unit is to provide a reference to which the inputs and outputs are related. This reference is necessary to ensure comparability of LCA results.

The Life cycle inventory (LCI) is a list of input/output data with regard to the system being analyzed. It involves the collection of the data necessary to meet the goals of the defined study. The qualitative and quantitative data for inclusion in the inventory shall be collected for each unit process that is included within the system boundary.

The Life cycle impact assessment (LCIA) is aimed at evaluating the significance of potential environmental impacts using the LCI results. In general, this process involves associating inventory data with specific environmental impact categories and category indicators, thereby attempting to understand these impacts. The LCIA phase also provides information for the life cycle interpretation phase. The impact assessment phase consists of mandatory (classification and characterization) and optional (normalization, grouping and weighting) elements. The first step – classification – means sorting the inventory parameters according to the impact categories they contribute to. For example, methane has an impact on global warming as well as on Photochemical Ozone Creation Potential, therefore, during the classification; the emissions are assigned to both impact categories. Characterization means defining the impact an emission has with regard to a reference substance of an impact category. This conversion uses characterization factors. For example, Methane has an environmental impact on GWP that is 25 times higher compared to CO_2. As the GWP is calculated in kg CO_2 equivalents, the characterization factor of methane is 25.

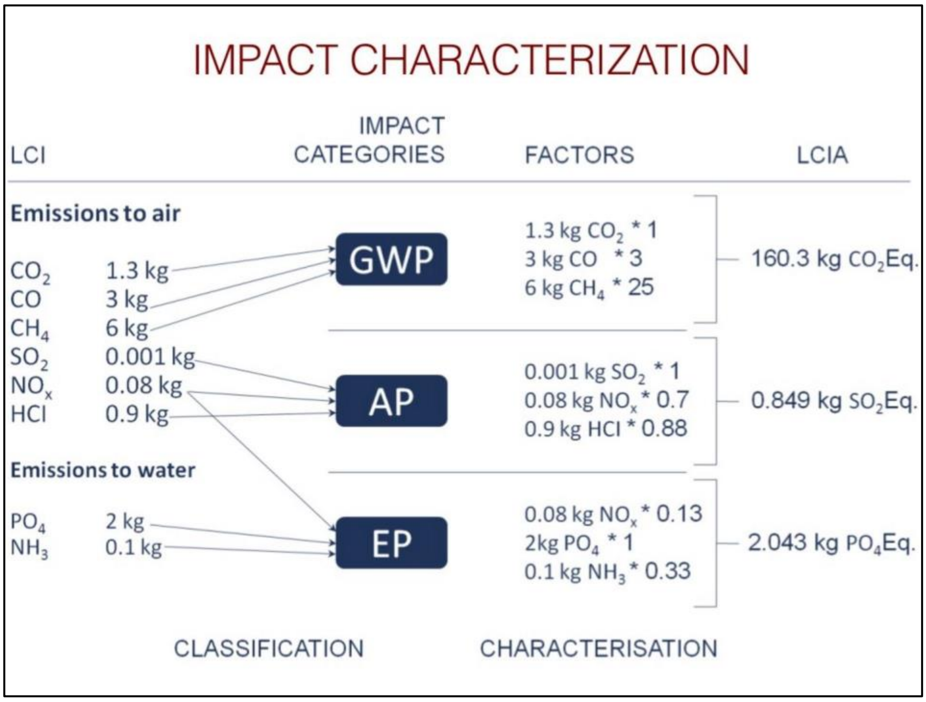


Figure - Impact Characterization Methodology

In LCA is necessary to consider which environmental impacts have to be taken into account. Inputs and outputs are converted into impact categories indicators related to some environmental priorities like Climate change; Nature and Biodiversity; Environment, health and quality of life; Natural resources and wastes. These are interpreted in terms of more operational impact categories.

Acidification Potential (AP) and Eutrophication Potential (EP) are chosen to address the priority of nature and biodiversity. The key pollutants relevant for these impact categories are SO_2 and NO_X which have been in the past, and in many cases still are, the main sources of damage to forests and soil.

The protection of human health and the improvement of the quality of life are amongst other measures addressed by controlling ground level ozone levels. The impact category “Photochemical Ozone Creation Potential” (POCP) addresses the issue of summer smog formation, especially in densely populated urban areas.

Ozone within the stratosphere provides protection from radiation; ozone has been documented to have effects on crops, other plants, marine life, and human-built materials. Substances which have been reported and linked to decreasing the stratospheric ozone level are chlorofluorocarbons (CFCs) which are used as refrigerants, foam blowing agents, solvents, (US Environmental Protection Agency 2008j).

The impact related to the Ionising Radiation includes the effects of releases of radioactive substances as well as direct exposure to radiation. Exposure to this type of radiation is both harmful for humans and animals.

Particulate matter (Respiratory inorganics) is a type of air pollution that is generated by a variety of human activities and causes a wide range of diseases.

The human toxicity potential (HTP) reflects the potential harm of a unit of chemical released into the environment is based on both the inherent toxicity of a compound and its potential dose.

For describing Climate Change, Global Warming Potential (GWP), also addressed as Carbon Footprint, is a globally accepted impact category. It generally comes from energy production, transportation, and conversion. To consider the varying greenhouse gas effects, a time horizon of 100 years is chosen, this indicator is also known as “GWP100”.

Life cycle interpretation is the phase of LCA in which the findings from the inventory analysis and the impact assessment are considered together. It should deliver results that are consistent with the defined goal and scope and which reach conclusions, explain limitations and provide recommendations. Life cycle interpretation is also intended to provide a readily understandable, complete and consistent presentation of the results of an LCA, in accordance with the goal and scope definition of the study.

What is Carbon Footprint

The term Carbon Footprint refers to the overall quantity of CO_2 and other greenhouse gas emissions, expressed in CO_2 equivalents, caused directly and indirectly by a product or an activity, or associated with the activities of an individual or an organisation. In the ISO14067:2013 definition, Carbon Footprint is the sum of greenhouse gas emissions and removals in a product system, expressed as CO_2 equivalents and based on a life cycle assessment using the single impact category of climate change. Methodologically the Carbon Footprint is generally based on International Standards on life cycle assessment (ISO 14040 and ISO 14044) series. Some of the standardized methodologies are:

- ISO 14067 specifies principles, requirements and guidelines for the quantification and communication of the carbon footprint of a product (CFP) and on environmental labels and declarations (ISO 14020, ISO 14024 and ISO 14025) for communication.
- ISO 16745, Sustainability in buildings and civil engineering works – Carbon metric of an existing building during use stage, Parts 1 and 2, will provide, in a simple way, a set of methods for the calculation, reporting, communication and verification of a collection of carbon metrics for GHG emissions arising from the measured energy use during the activity of an existing building, the measured user-related energy use, and other relevant GHG emissions and removals.
- Product Carbon Footprint Certification calculated based on the “PAS 2050, Publicly Available Specification” standard and the “Greenhouse Gas Protocol, Corporate Accounting and Reporting Standard”.

A simplified way to calculate Carbon Footprint is to use Emission factors; an emission factor is the coefficient which quantifies the emission per unit of activity. The final amount of an emission is estimated by multiplying the emission factor with the corresponding activity data (European Commission - How to develop a Sustainable Energy Action Plan (SEAP)). The Emission Factor reference unit for Carbon Footprint calculation is the CO_2eq.

When selecting the emission factors, two different approaches may be followed, the first one uses IPCC principles which covers all the CO_2 emissions due to energy and fuel use and consumption associated with electricity and heat/cold usage within the territory analysed (European

Commission - How to develop a Sustainable Energy Action Plan (SEAP)). The standard emission factors are based on the carbon content of each fuel, the baseline used in this project refer to the Default Emission Factors for the Member States of the European Union (Dataset Version 2017). Another method uses LCA (Life Cycle Assessment) emission factors; this method takes into consideration the overall life cycle of the energy carrier. All emissions of the supply chain are considered instead of just emissions of the final combustion.

Section 3 - Calculation and monitoring tools

In the last years different online tools have been developed to facilitate the evaluation of greenhouse gas emissions calculation and reduction.

The intent of most of it is to aware people that every action that we make has a consequence and that it is possible to reduce the emissions related to our choices by changing our behaviour.

For example, there are plenty of different Carbon Footprint calculators that allow the users to calculate the emission related to the daily actions like nutrition or mobility, and once calculated the estimated Carbon Footprint, often suggest simple tips to reduce their own impacts.

Considering the target of the European Union of reducing by 20% its total emissions within 2020, renovation of buildings have been defined as an urgent issue. The TEESCHOOLS tool wants to be an instrument to guide practitioners in a simplified energy audit and to steer to a more sustainable use of the energy sources in school buildings.

Summary

The European policies aim at reducing the greenhouse emissions with challenging targets. The building sector has been identified as one of the more significant and most of emissions derive from the use of energy for the heating and the cooling during the use phase. One of the indicators chosen to evaluate the impact on the environment of the use of buildings is the Carbon Footprint, this indicator represents the sum of greenhouse gas emissions and removals in a product system, expressed as CO_2 equivalents and based on a life cycle assessment using the single impact category of climate change. Two different approaches may be followed to calculate the Carbon Footprint, the first one uses IPCC principles which covers all the CO_2 emissions due to energy and fuel use and consumption associated with electricity and heat/cold usage among the entire Life Cycle, another one considers the carbon content of each fuel. To foster the knowledge of the Carbon Footprint simplified online tools have been developed in the last years, the TEESCHOOLS tool aims at being an orienting instrument in the schools energy and renovation of school buildings.

Consultation of documents and references

- Commission Recommendation (EU) 2016/1318 of 29 July 2016 On guidelines for the promotion of nearly zero-energy buildings and best practices to ensure that, by 2020, all new buildings are nearly zero-energy buildings
- IEA and UNDP, 2013: Modernising Building Energy Codes to Secure our Global Energy Future. Paris, France
- UNEP, 2015: Why Buildings? Buildings Day at COP21, 3 December 2015. Paris, France.
- Viola Polesello & Katie Johnson, Energy-efficient buildings for low-carbon cities - ICCG Reflection No. 47/March 2016
- European Commission - How to develop a Sustainable Energy Action Plan (SEAP) – Guidebook, Luxembourg: Publications Office of the European Union
- Koffi, Brigitte; Cerutti, Alessandro; Duerr, Marlene; Iancu, Andreea; Kona, Albana; Janssens-Maenhout, Greet (2017): CoM Default Emission Factors for the Member States of the European Union - Version 2017, European Commission, Joint Research Centre (JRC) [Dataset] PID: http://data.europa.eu/89h/jrc-com-ef-comw-ef-2017

Web Sites

- https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings
- http://www.improveyourschool.enea.it/

Self-assessment test

- Buildings are responsible for approximately:
    - 80% of energy consumption and 80% of CO_2 emissions in the EU.
    - 40% of energy consumption and 36% of CO_2 emissions in the EU.
    - 4% of energy consumption and 4% of CO_2 emissions in the EU.
- New buildings today consume:
    - twice as much as typical buildings from the 1980s.
    - half as much as typical buildings from the 1980s.
    - as much as typical buildings from the 1980s.
- The current Directive aims at accelerating the cost-effective renovation of existing buildings, with the vision of a decarbonised building stock by:
    - 2020
    - 2030
    - 2050
- The life cycle includes:
    - raw-material extraction, production, manufacture, distribution, use and disposal.
    - raw-material extraction and waste disposal
    - only the use phase
- The Life cycle inventory (LCI) is:
    - a list of input data with regard to the system being analyzed.
    - a list of output data with regard to the system being analyzed.
    - a list of input/output data with regard to the system being analyzed.
- The Life cycle impact assessment (LCIA):
    - involves associating inventory data with specific environmental impact categories and category indicators.
    - is a list of impact categories and category indicators.
    - Is a list of input data with regard to the system being analyzed.
- Life cycle interpretation is the phase of LCA in which:
    - the findings from the goal and scope definition and the impact assessment are considered together.
    - the findings from the inventory analysis and the impact assessment are considered together.
    - the findings from different studies are considered together.
- Carbon Footprint is:
    - Is the sum of ozone depletion gasses, expressed as CO_2 equivalents.
    - a greenhouse gas

  - Is the sum of greenhouse gas emissions and removals in a product system, expressed as CO_2 equivalents and based on a life cycle assessment using the single impact category of climate change
- An emissions factor is:
  - a representative value that relates the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant.
  - the sum of greenhouse gasses, expressed as CO_2 equivalents.
  - a representative value of gas.
- The TEESCHOOLS tool is:
  - an instrument to guide in the choice of best food
  - an instrument to guide practitioners in a simplified energy audit and to steer to a more sustainable use of the energy sources in school buildings
  - an instrument to quantity the energy use in schools

Maintenance and management of energy in schools

TITLE OF MODULE 6: **Maintenance and management of energy in schools**

- Presentation of the module [10 minutes]

This is the 6th module of the TEESCHOOLS E-learning course.

Maintaining, managing and reducing energy use can have significant economic, educational and social benefits for a school. Prioritising efficient energy consumption and management, not only helps reduce costs but it can also increase productivity, staff wellbeing and performance. Of course, there are also environmental benefits for schools that are able to reduce their overall carbon footprint.

All the school community can contribute to making savings. This includes the pupils, teachers, principals, caretakers, and administrative staff to cleaners and catering staff, as they all have an impact on energy use and should therefore be encouraged to contribute to the maintenance and management of energy in schools.

By establishing an energy management programme will help schools to get the most benefit from energy efficiency opportunities. It will also encourage a school to continue to use energy wisely and to make energy efficient thinking a part of their culture. Schools seeking to improve their energy efficiency are encouraged to take a whole of school approach to sustainability.

<u>What is included in the Module:</u>

This module consists of 4 sections, with a total duration of 3 hours, related to the Maintenance and management of energy in schools as follows:

1. Section 1: Energy and Environmental Impact [45 minutes]

   Sub Section 1: Energy in Schools
   Sub Section 2: Identify Energy savings
   Sub Section 3: Raising energy awareness
   Sub Section 4: Environmental Impact of schools

2. Developing and Implementing Maintenance and Energy Management Plan [45 minutes]

   Sub Section 1: Understanding the current situation
   Sub Section 2: Maintenance and Management of Energy in Schools
   Sub Section 3: Monitoring the use of Energy in Schools
   Sub Section 4: Using an Energy Audit

3. Section 3: Technical Considerations (scope of the energy audit) [60 minutes]

   Sub Section 1: The Building Envelope
   Sub Section 2: The Lighting System
   Sub Section 3: The HVAC systems
   Sub Section 4: Water Heating
   Sub Section 5: Office Equipment
   Sub Section 6: Kitchen Equipment [Appliances]
   Sub Section 7: Building Automation Systems

4. Section 4: Templates & Tools for Maintenance and Energy Management [30 minutes]

   Sub-Section 1: Simplified energy and environmental audit tool for schools
   Sub-Section 2: Energy management matrix by Carbon Trust
   Sub-Section 3: Guide to Operating and Maintaining Energy Smart Schools by the US Department of Energy
   Sub-Section 4: Template for establishing Roles and responsibilities in Schools
   Sub-Section 5: Planning templates and a schedule to assist schools

Besides the 4 main chapters there is also a resource chapter. The chapters go through a simple action-learning process designed to assist people in the relevant field to learn about the school's energy situation and then take action.

In the end of the Module, there are 15 questions for Self-Assessment, with a total duration of 45 minutes.

Additional / External information is provided throughout the Module.

- **Learning objectives of the module**

<u>Knowledge:</u>

- The importance of Maintenance and management of energy in schools.
- Impacts of Maintaining and managing energy in schools.
- Measures for the Maintenance and management of energy in schools.
- Opportunities and challenges for Maintaining and managing energy in schools.
- Familiarization with the necessary tools and guidance for the Maintenance and management of energy in schools

<u>Skills/Competence:</u>

- Explain the energy consumption in schools and its effects.
- Create and implement a system for Maintenance and management of energy in schools.
- Able to understand the main sectors of energy consumption in schools.
- Able to identify potentials for energy saving.
- Able to create or to select suitable tools and templates for energy management.

Section 1: Energy and Environmental Impact [45 minutes]

Sub Section 1: Energy in Schools

It is generally proven that there are many things we can do to use less energy and use it more efficient in schools. These actions include both energy conservation and energy efficient measures[13].

The first step in maintaining and managing energy in schools, is to examine what type of energy is used [is it electricity, heating oil, natural gas, LPG?] and where this energy is consumed [for lighting, heating, cooling, equipment?].

The typical energy consumption profile for school buildings is mainly differentiated based on the following conditions: location/climate, construction year/ trends, size, type, repair state and the amount / type of installed equipment. Other factors can also affect the energy profile of a school, like its design, its users' behaviour and its typical occupancy hours.

In the following examples, the typical consumption for UK school buildings and for primary schools in Cyprus, is provided. The main differentiations are due to the climate factors and construction trends:

[13] *Energy conservation is any action / behaviour that results in using less energy, whereas energy efficiency focuses on technologies that use less energy to perform the same tasks or the same amount of work.*

Figure 1a *Schools – percentage of energy use*

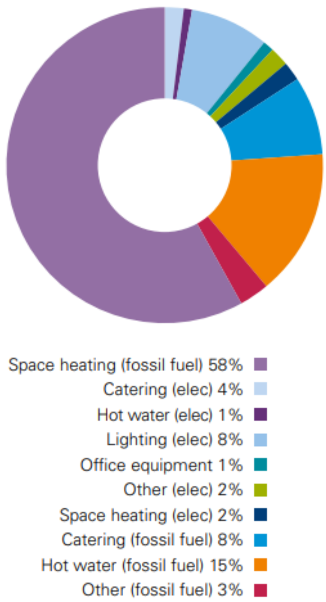


Figure 1b *Schools – percentage of energy cost*

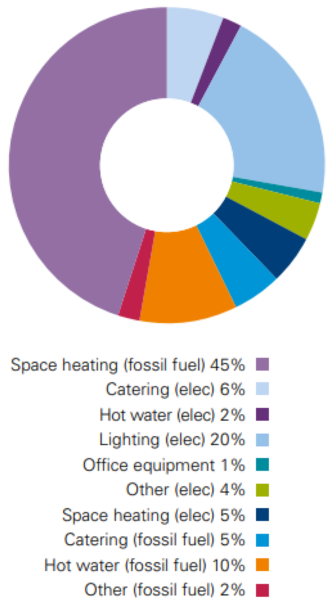


Figure 1: Energy Consumption in schools. Carbon Trust – Schools Learning to improve energy efficiency Published in the UK: March 2012. All rights reserved. CTV019. Source: https://www.carbontrust.com/media/39232/ctv019_schools.pdf

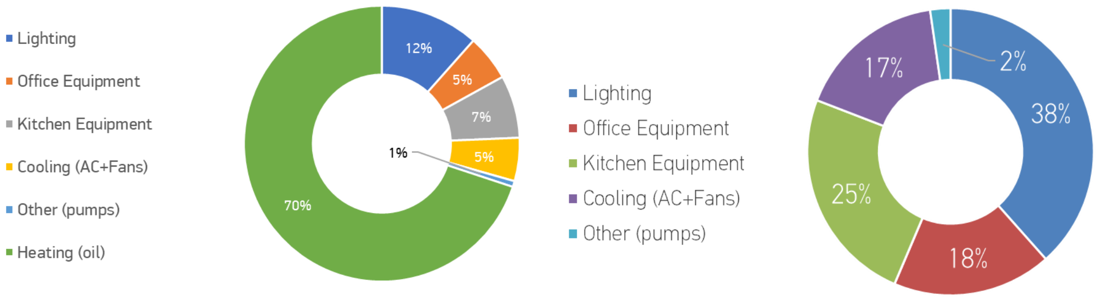


Figure 2: Left. Typical energy consumption for primary schools in Cyprus, Nicosia, Climate Zone 2.

Right. Typical electricity consumption for primary schools in Cyprus, Nicosia, Climate Zone 2.

Source: Cyprus Energy Agency

As it is indicated in the above energy pie-charts, energy consumption overall in schools can vary, nonetheless, the main areas of energy consumption in schools are similar. Therefore, when we refer to energy consumption in schools, this usually includes energy for Heating, Cooling, Lighting, Office Equipment and

Appliances. Hot water is not common for the vast majority of schools in the southern Europe[14].

The most common types of energy in European schools is oil and/or natural gas for heating, and electricity for all other sectors. Is noted that a lot of school buildings have installed RES to cover their energy needs, but more action is still needed. The most common technologies used are the solar thermal for water heating and PVs for electricity production [for more info, please see Module 9].

[14] Based on the energy audits results within the framework of TEESCHOOLS project.

Sub Section 2: Identify Energy savings

Schools, in general, are pushed to make the most of their resources, while providing a solid education for students. By being energy efficient and saving energy, more funds can become available for curricular resources or facilities.

The energy bills are often treated as a fixed portion of school expenses. Nonetheless, most schools have considerable room for improvement and savings. This addressable energy waste could be due to inefficient student/staff behaviour, incorrect settings, or lack of maintenance.

There are many opportunities to save energy, without investing in new equipment and large-scale interventions. Results can be achieved either by educating the users of the school for behaviour change [please see Module 13 for more info], either by suitable maintenance actions and by adopting and an energy management system.

Nonetheless, the first step to identify opportunities for Energy Savings is to collect relevant and updated information about the facilities and the energy use.

The followed questions, among others, can be used as a first approach[15]:

- *What tools and information do staff members currently use to effectively manage energy costs?*
- *What is the current status of Operations & Maintenance (O&M) energy savings practices in the district, and how are practices communicated to O&M professionals?*
- *Would changes in facility O&M practices likely produce significant operating savings?*

It is also important to ask the school's users about the improvements they would like to see in their school. Sample questions include[16]:

- *What types of energy waste do you see in the school?*
    - *Are the classrooms too hot or cold?*
    - *Are lights left on when no one is in the classroom or building?*
- *Is training on how to use energy efficiency controls, adequate in frequency (annual or biennial)?*

Energy surveys can also be used in order to identify opportunities for energy savings through the status of the facility, as it provides the starting point against which all facilities maintenance efforts and planning occur.

[15] Extracted from: *Guide to Operating and Maintaining Energy Smart Schools, US Department of Energy*

[16] Extracted from: *Guide to Operating and Maintaining Energy Smart Schools, US Department of Energy*

Sub Section 3: Raising energy awareness

After understanding where the energy is used in schools, its impacts and the opportunities to achieve savings, the next step is to raise energy awareness between all the relevant stakeholders.

School provides an excellent opportunity for pupils to be involved in responsible use of energy and water, helping them to understand how everyday actions impact on the environment. It provides practical, hands-on experience and gives an insight into the goals of sustainable development.

By introducing low carbon initiatives into schools, it can also enhance the educational experience for students.

Some indicative actions for implementation are:

- *making energy efficiency a priority of the school*
- *appointing energy 'champions', who are responsible for spotting energy waste and promoting energy efficiency*
- *seeking input to the energy plan and rewarding feedback*
- *celebrating achievements*
- *keeping people informed about new ideas*
- *making it fun by having activities or competitions around saving energy.*[17]

TIP: *A school's energy efficiency system provides a great learning opportunity for all students. There are several resources that provide a guide on how to build energy conservation into the curriculum.*

[17] Source: Energy use and conservation in schools, available at: https://www.education.govt.nz/school/property/state-schools/day-to-day-management/energy-use-and-conservation/

Table 1: An energy efficiency checklist [Source: Energy-Efficient Schools. A guide for trustees, principals, teachers, students, caretakers and energy managers. Available at:

http://www.enviroschools.org.nz/energy_efficient_schools_large.pdf]

What is my school doing around energy efficiency?		
We know what our total energy costs are	✓	×
We have the best supply contract in terms of price and carbon footprint	✓	×
We know how we compare to other schools	✓	×
We have conducted an energy audit recently	✓	×
We have an energy efficiency policy	✓	×
We monitor energy use	✓	×
We have an energy efficiency plan	✓	×
We model good energy-efficiency practices to students and parents	✓	×

Sub Section 4: Environmental Impact of schools

Figure 3: Source: https://www.freepng.es/png-zd0o60/download.html

The choices we make in the schools, have different economic, social and environmental impact. Schools have usually a medium environmental impact in comparison with other kind of buildings, such as industrial buildings, nonetheless, they are uniquely placed to take advantage of the strong links between staff, pupils, parents and the wider community in order to increase the environmental consciousness.

In addition to economic benefits and to the reduced operating costs, energy management in schools can also result to environmental benefits. Energy consumption in schools, has the greatest impact on the environment, thus reducing energy consumption is the simplest way to reduce the school's overall environmental impact. Is noted here that for every type of energy used in schools [electricity, oil, natural gas], there is different emissions factor, which usually provided on national level, and should be taken into consideration when calculating the carbon footprint of the school.

Energy saving reduces carbon emissions which helps the mitigation of climate change. Engaging pupils in improving their behaviour to save energy at schools, is an opportunity to translate global concerns into local action. It helps educate children about climate change, its causes and how to tackle it; and it raises awareness of the stewardship of non-renewable resources. These can also be taken home and on into future workplaces.

Additionally, by reducing carbon emissions through improving energy efficiency can enhance working conditions and comfort levels for staff and pupils, for example, by the elimination of draughts or overheating. This, in turn, can increase morale and pupils' productivity.

Tip: Learn more about carbon Footprint with the Carbon footprinting guide, available at: https://www.carbontrust.com/resources/guides/carbon-footprinting-and-reporting/carbon-footprinting/

Section 2: Developing and Implementing Maintenance and Energy Management Plan [45 minutes]

Sub Section 1: Understanding the current situation

The first step for the Development and the Implementation of an Energy Management Plan, is to understand that the energy bills (electricity, oil, gas etc), provide a variety of information that can support schools to understand their energy usage. This Information can assist schools to calculate energy benchmarks and evaluate the effectiveness of their Energy Management Plan.

Overall, the best time to consider energy use is before you start building – as this is when you can achieve an energy efficient building at the least cost and disruption. With the right planning and design, high energy performance can be achieved at little extra cost and will provide significant savings over the long term.

As this is not always the case though, for existing buildings, there are some general principles for energy efficient design and are as follows:

1. Reduce your energy needs
2. Meet your needs with renewable energy wherever possible
3. Use the most efficient systems available that suit your needs

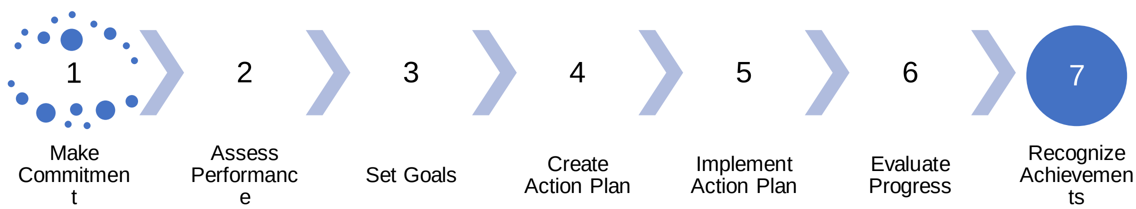


Figure 4: Process for achieving energy management

More info van be found in the series of ‘Saving energy in schools’ in the website of the Energy Efficiency and Conservation Authority (EECA) of New Zealand: https://www.eecabusiness.govt.nz

Sub Section 2: Maintenance and Management of Energy in Schools

Maintenance refer to all scheduled and unscheduled actions for preventing equipment failure or decline with the goal of increasing efficiency, reliability, and safety. '*A preventative maintenance program is the organized and planned performance of maintenance activities in order to prevent system or production problems or failures from occurring. In contrast, diagnostic or corrective maintenance is conducted to address an existing problem.'* It is noted that a number of energy efficiency measures can be carried out as part of routine maintenance procedures at no extra cost, like the proper regulation of the boiler or the replacement of air conditioner filters. To maintain optimum efficiency, check and clean all school facilities, systems and equipment, ideally based on manufacturer's advice.

In regards the management of energy, one of the first approaches is to reduce the energy waste and usage outside of school hours, as it can be one of the most effective energy efficiency strategies for a school. Some of this usage is required for equipment that needs to run full day such as computer servers. Nonetheless, in some cases it is estimated that up to 40% of all energy going into schools is non-productive and could be saved[18].

Other opportunities to manage the Energy in schools, is to adopt an energy-friendly behaviour with actions such as turning off lights, computers, printers, and office equipment, the heating and cooling systems and/or implementing shut down procedures for the period that the school is not operating [for more info on Behavioural Change, see the relevant Module].

TIP: The savings from improved shut down and switch-off behaviours can result in financial savings of up to 20% of a school's electricity costs.

<u>Bigger interventions in the school facilities are another approach to maintain and manage the energy in schools [for more information on this move to Section 3].</u>

The following Operation and Maintenance tasks have either low or no cost, and can produce low to moderate energy efficiency gains. *They were adopted from*

[18] *Energy efficiency in schools - A practical 'how to' guide for Victorian schools, © Sustainability Victoria ENG045, June 2016*

the U.S. Green Building Council Webinar Series, 'Energy Efficiency Strategies for Schools', Top Ten No Cost Ways to Lower Your School's Utility Bills and Top Ten Low Cost Ways to Lower Your School's Utility Bills:

Table 2: Operation and Maintenance tasks for school facilities [Source: Guide to Operating and Maintaining EnergySmart Schools, US Department of Energy]

O&M Measure	Brief Description	Estimated Magnitude of Significance [2]
Install programmable thermostats (HVAC)	Temperature controls can be programmed to shut down heating and cooling during periods when spaces are unoccupied	Above Average
Perform energy surveys and audits (Information)	Walk-throughs and more intensive audits can quickly identify O&M problems and solutions	Average
Keep doors and windows closed (Building Envelope)	Open windows waste heating and cooling energy	Average
Review cleaning and maintenance activities (Preventative Maintenance)	Consistent and scheduled cleaning and maintenance are key to extending equipment life and avoiding costly breakdowns	Average
Provide training for key staff (Preventative Maintenance)	Knowledgeable personnel are imperative to sustained energy efficiency from O&M	Moderate
Conduct a plug load survey and develop a plan (Plug Loads)	Computers and vending machines can waste energy if their settings are not properly set to shut down after inactivity	Moderate
Control exhaust fans (HVAC)	Shut down exhaust fans when building ventilation is off to avoid unwanted outside air	Moderate
Inspect outside air systems (HVAC)	Clean roof units and economizers for proper operation	Moderate
Install outdoor lighting controls (Lighting)	Timers and photosensors decrease wasted lighting for outdoor use	Moderate
Replace exit sign lights with LEDs (Lighting)	LEDs require much less maintenance and have longer lives than conventional lights so they are great fits for exit signs	Moderate

Best Above Average Average Moderate Small

Sub Section 3: Monitoring the use of Energy in Schools

The energy monitoring is essential for improving a building's energy performance and achieving energy savings. If you keep track of your energy use, you can see where it's being wasted. Studies support that any actions taken as a result of good energy metering and monitoring, can cut costs by at least 10%, just by knowing where energy is being used and by making a few changes.

In brief, monitoring includes:

- knowing your energy costs
- associating your school with other schools
- monitoring energy use over time
- appoint responsibility to energy teams [or energy management] for gathering relevant information
- setting targets

An online system or device to monitor daily electricity consumption can be used to understand energy usage and patterns in schools. These systems [loggers] take electricity data at regular intervals from the school's facilities and display the data via an online portal or display device. A daily monitoring allows schools to measure directly the results of any implemented measure for energy upgrade, without having to wait the electricity bills. Daily monitoring also allows schools to identify any unforeseen increases in electricity use.

Schools can also set up their own Energy Monitoring System by appointing roles, duties and responsibilities, by following an expert's advice [see next sub section], or by adopting relevant standards on energy [ie. *ISO 50001:2018, Energy management systems — Requirements with guidance for use*]. Nonetheless, is important to keep in mind that when implementing an Energy Monitoring System, suitable Energy Saving Indicators should be established.

Targets should be clear, measurable, realistic and based on a thorough understanding of the current energy consumption and of the saving potentials.

There are several ways in which you can express energy-saving targets, such as:

- reduced energy consumption - either overall or by a particular department

- reduced emissions of carbon dioxide equivalents (CO_2)
- improved return on investment from energy efficiency activities
- increased students' awareness
- increased number of staff given energy efficiency training

A proposal for the involvement of the different actors in the Energy Monitoring, is indicated in the below tables.

Table 3: Roles and Responsibilities in a school's energy monitoring system Essential (up) and Desirable (down) [Source: A whole school approach Involving the school community in reducing its carbon footprint Carbon Trust, Published in the UK: May 2010. CTV037v2 © Queen's Printer and Controller of HMSO. Available in : http://www.greensuffolk.org/assets/Greenest-County/School/Energy-Guides/A-Whole-School-Approach.pdf

Who can do what?	Headteacher/ Deputy	Teacher	Governor	LA Energy Manager	Pupil	Bursar Administrator	Caretaker Site Manager	Energy Coordinator
Desirable Actions								
Conduct energy walk rounds	✓	✓		✓	✓	✓	✓	✓✓
Advise on technical measures				✓✓			✓	✓
Advise on energy purchasing				✓✓				
Identify all energy-using systems/equipment					✓		✓✓	✓
Identify controls, timers, set points							✓✓	✓✓
Maintain energy-using equipment							✓✓	
Sanction appropriate investment	✓✓		✓			✓		
Apply for relevant grants	✓					✓		✓✓
Provide regular progress reports						✓		✓✓

✓ Could do the task ✓✓ Best suited for the task

Actions are divided into 'essential' and 'desirable'. A single tick means the person in a particular job function is likely to be well suited to the task. For some tasks, a number of different people could be involved, for example, conducting energy walk rounds. Other tasks are of a more specialist nature (such as energy purchasing). A double tick indicates the person who is likely to be the best choice for the task.

Who can do what?	Headteacher/ Deputy	Teacher	Governor	LA Energy Manager	Pupil	Bursar Administrator	Caretaker Site Manager	Energy Coordinator
Desirable Actions								
Conduct energy walk rounds	✓	✓		✓	✓	✓	✓	✓✓
Advise on technical measures				✓✓			✓	✓
Advise on energy purchasing				✓✓				
Identify all energy-using systems/equipment					✓		✓✓	✓
Identify controls, timers, set points							✓✓	✓✓
Maintain energy-using equipment							✓✓	
Sanction appropriate investment	✓✓		✓			✓		
Apply for relevant grants	✓					✓		✓✓
Provide regular progress reports						✓		✓✓

✓ Could do the task ✓✓ Best suited for the task

Actions are divided into 'essential' and 'desirable'. A single tick means the person in a particular job function is likely to be well suited to the task. For some tasks, a number of different people could be involved, for example, conducting energy walk rounds. Other tasks are of a more specialist nature (such as energy purchasing). A double tick indicates the person who is likely to be the best choice for the task.

Sub Section 4: Using an Energy Audit

An Energy Audit can provide a significant input to understand the energy usage of a school, as this can vary considerable between the different facilities. Through the Energy Audit, the most effective activities and strategies for reducing energy use will be identified.

In specific, energy audits can identify both practice or behaviour improvements, and infrastructure and equipment upgrades. They include assessments of buildings and equipment and recommendations of service options to increase efficiency, reduce waste, and save money. They are based on past and current energy usage and can be used to establish the ‘baseline scenario’.

They can be conducted by schools themselves, (student conducted walkthroughs facilitated by teachers or inhouse facilities personnel conducted walkthroughs), nonetheless the use of a professional energy auditor (third party), is preferable.

An energy audit will also identify your school’s out-of-hours usage and recommend solutions for saving energy.

An audit should identify:

- where energy is being used
- wasteful practices
- opportunities to save money
- maintenance work that could improve energy efficiency
- if capital investment would improve energy efficiency.

The energy report, which is the output of the energy audit, should provide a number of prioritised recommendations for saving energy and improving internal conditions, based on technoeconomic criteria· nonetheless, which of these recommendations a school adopts, is depended on the resources available to the school. Is noted that many of the audit recommendations can be of very low cost.

A Life Cycle Cost Analysis [LCCA] for each proposed scenario, compared to the current scenario, should be used for an integrated technoeconomic assessment.

For Europe, the relevant standards of the series EN 16247, should be used as reference for the energy audit. In accordance to the EN 16247-1:2012 Standard, the procedure to be followed is:

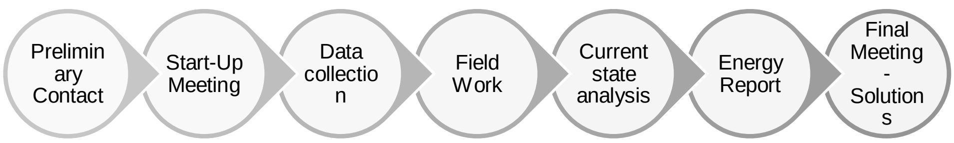


Figure 5: Procedure for energy audits based on the EN 16247:1 Standard

Section 3: Technical Considerations (scope of the energy audit) [60 minutes]

Foreword:

While the users and energy usage patterns within a building frequently change, its physical structure and major equipment remain mostly constant. These underlying energy “assets” have a significant impact on how efficiently energy is used within a building, irrespective of how the building is operated or how its occupants are behaving.

For a typical school, energy consumption is attributed to the following main categories:

1. Building Envelope
2. The Lighting System
3. The HVAC System
4. Water heating
5. Office Equipment
6. Kitchen Equipment [Appliances]
7. Building Automation Systems

An analysis to identify actions for energy savings and to address issues included in the above categories, is provided in the following Sub Sections.

Sub Section 1: The Building Envelope

While it is easiest to achieve high energy performance of the building envelope in new buildings, the existing building envelopes also can be optimized for energy efficiency. Energy audits or qualified experts can identify potential retrofit options for energy and performance upgrade. These options might require large capital expenditures, but they tend to result in improved indoor conditions and not just in cost savings, improving significantly occupants’ health and comfort.

Tip: Retrofits can be complex and expensive, but they are always worth appraising.

One of the first approach to a building envelope is to monitor doors and windows and maintain the integrity of the building envelope by finding and repairing leaks. All doors and windows should be closed when the air conditioning or heating system is operating.

Sealing help minimize air infiltration and can reduce energy waste. In combination with applying weather-stripping to the building’s elements [foundation, walls, and roofs], can also protect the building from water leaks that cause mold growth, a major health problem in schools. Moisture can come from leaks in the roof, walls, or windows, from failures in plumbing, or from condensation on cool surfaces, such as pipes and air ducts.

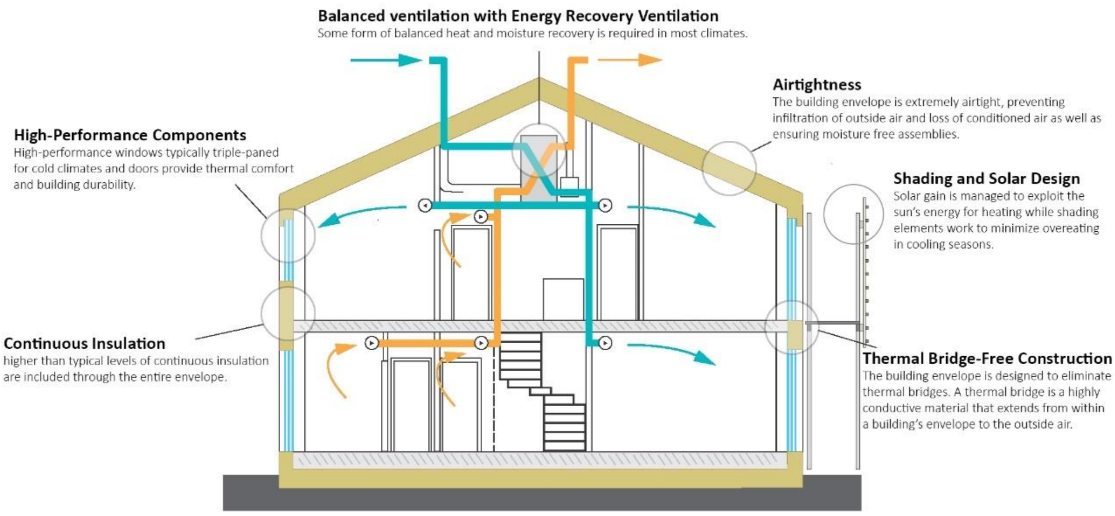


Figure 6: Passive Building Strategy for Commercial Buildings, the Building’s envelope

[Source: http://www.jamesco.com/passive-building-strategy-for-commercial-buildings/]

When a building is being retrofitted (large-scale interventions), is important to consider measures for upgrading the building’s elements [roof, floors, exterior wall types, windows, and doors]. Many of these options will have a higher upfront cost than their inefficient counterparts, therefore technoeconomic analysis[19] is necessary.

If the building is not thermally insulated [mainly roof and walls], then thermal insulation, especially for the roof, should be a priority, as roof is responsible for a great proportion of heat losses in buildings. Windows' replacement should take place when the frames are underperforming [leaks, apparent wear] or when they are equipped with single glazing. In the case of double glazing, and when the frame is at a good state, then replacement of the windows is not a priority due to the high capital cost. Nonetheless, other measures [ie. Low-emissivity coating, stable / moveable shading], should be taken into consideration. Passive design and Nature-Based Solutions, in regard the building's envelope is of upmost importance.

Tip: For more information on Nature-Based Solutions see: *'Towards an EU Research and Innovation policy agenda for Final Report of the Horizon 2020 Expert Group on 'Nature-Based Solutions and Re-Naturing Cities'* - Directorate-General for Research and Innovation Climate Action, Environment, Resource Efficiency and Raw Materials, 2015

Finally, as schools often use prefabricated classrooms to house overcrowded students or temporary laboratories/special education classrooms, it should be kept in mind that these spaces are often entirely powered by electricity, and the operating cost per unit may be as much as twice that of a conventional space. Portable classrooms should be properly insulated and checked for air leaks.

Note to be taken: Adapted from Cottrell & Vermeulen Architecture Ltd:

"Refurbishment projects are known to be more complex and costly, but a preference for new build schools on the basis that refurbishments are less able to meet carbon reduction targets neglects to take account of the 'built in' or embodied energy of an existing building. Recent studies have shown that new build constructions can emit over four times the amount of CO_2 than comprehensive refurbishments."

To find out more about designing schools, see the 'Designing Quality Learning Spaces' available at:

[19] *Techno-economic annalysis is a methodology framework to analyze the technical and economic performance of a process, product or service.*

https://www.education.govt.nz/school/property-and-transport/projects-and-design/design/design-standards/designing-quality-learning-spaces/

Sub Section 2: The Lighting System

Students need good quality light to perform tasks since well-lit spaces are essential for an effective teaching and learning environment. As a result, lighting is usually one of schools' largest areas of energy use. In order to create well-lit spaces, while meeting the requirements in schools, there are some basic, cost-effective, tips to be followed[20]:

- *Make the most of natural daylight, while avoiding glare and excessive cooling loads [eg. By using daylight blinds]*
- *Choose light colours for walls and ceilings to help create a comfortable and pleasant environment*
- *Use light sources with a high colour rendering index and a 4000 K[21] colour temperature to improve visual comfort and to help keep students alert*
- *Have zoning for lights so that staff can dim lights or switch them off when they're not needed*
- *Use lighting that focuses students' attention on focal points like lecture stands, without creating glare for their teachers.*

[20] Is noted that for some countries, technical guides and predefined requirements exist for lighting design in commercial buildings.

[21] *Low-colour temperature light bulbs are described as 'warm' because they have more red light. High-colour temperature bulbs are 'cool' because they have more blue light. A bulb's ability to make objects appear their true colour (as viewed in natural sunlight) is called colour rendering. Rendering ability varies significantly between bulbs from excellent (incandescent and tungsten halogen lamps) to poor (low-pressure sodium lamps).*

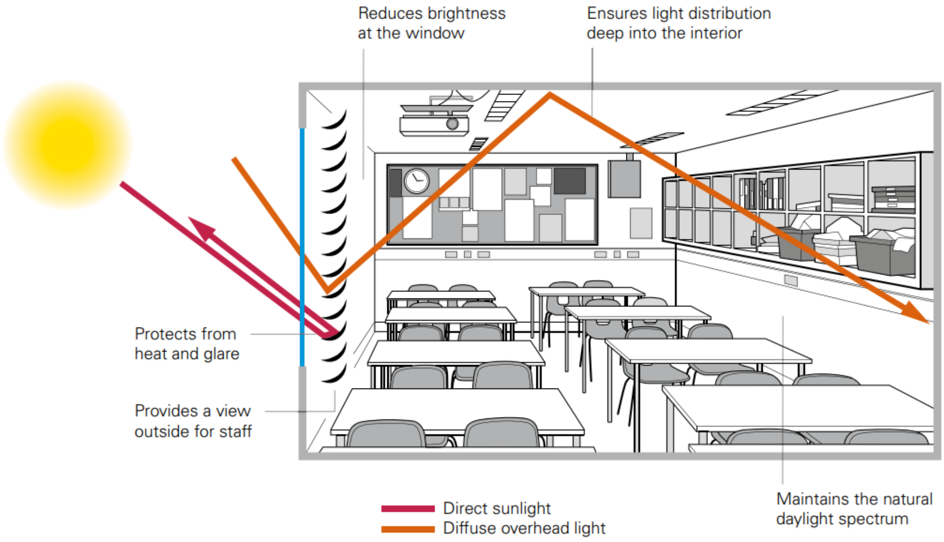


Figure 7: The benefits of daylight blinds - For window facing south, use horizontal blinds to direct daylight onto the ceiling and walls where possible. This helps to direct diffused sunlight into the classroom while reducing glare and excessive heat.

[Source: Carbon Trust – Schools Learning to improve energy efficiency Published in the UK: © The Carbon Trust 2012. All rights reserved. CTV019, Available: https://www.carbontrust.com/media/39232/ctv019_schools.pdf]

Installing energy efficient lighting is a simple way for schools to reduce their energy consumption. As far as regards the types of light usually met in schools, those are numerous and depend on the needs and the school's existing state:

- **Light emitting diodes (LEDs) –** Proposed for the new installations / replacements
- Compact fluorescent lamps (CFLs)
- Incandescent bulbs
- Halogen bulbs
- High intensity discharge (HID) bulbs &
- Mercury vapour bulbs

You can read more about the type and features of energy efficient light bulbs on the New Zealand's Energy Efficiency and Conservation Authority (EECA) website: https://www.eecabusiness.govt.nz/technologies/lighting/types-of-light/ .

Another approach to significantly reduce energy use from the lighting system is to install occupancy/ movement and daylight sensors. Occupancy sensors automatically turn off lights in a space after that space has been unoccupied for a period of time. Daylight sensors dim lights when sufficient daylight is present in the space.

Of course, a correct behaviour of the users can also result to energy savings for the lighting system. Some measures to be adopted are:

- Encourage students and staff to only turn on lights they need inside the classroom [*Adopt a 'switch off' campaign]*
- Label the groups of switches to help staff and students identify different lighting switches and to 'switch off' the lights
- Ask students to take a walk around the school to look for over-lit areas, and you can remove unnecessary light fixtures to save energy

Tip: Making good use of daylight in a classroom can reduce lighting costs by 20% and improve student learning outcomes.

Table 4: Energy Efficient Lighting Options [Source: Carbon Trust – Schools Learning to improve energy efficiency Published in the UK: © The Carbon Trust 2012. All rights reserved. CTV019, Available: https://www.carbontrust.com/media/39232/ctv019_schools.pdf]

Existing lamp type	Uses	Energy efficient option	Energy saving/benefits	Application notes
Tungsten light bulbs	General lighting, a common bulb for domestic applications	Replace with compact fluorescent lamps (CFLs) in the same fitting	75% saving plus longer lamp life	General lighting – modern CFL replacements may also be acceptable for display lighting
38mm (T12) fluorescent tubes in switch-start fittings	General lighting, commonly used in classrooms, corridors and office spaces	Replace with equivalent 26mm (T8) triphosphor fluorescent tubes of lower wattage	8% saving plus longer lamp life	General lighting, but even better when used with modern fittings (see below)
High-wattage filament lamps or tungsten halogen lamps as used in floodlights	For lighting large spaces, such as gymnasia, tennis courts, assembly halls, sportsfields, playgrounds	Replace with metal halide or high wattage compact fluorescent lighting	65-75% saving plus longer lamp life	Floodlighting and some general lighting situations
Mains voltage reflector lamps, filament spot and flood types	General lighting, often applicable to areas that need bright light and good colour rendering, such as workshops/ art studios	Replace with low-voltage tungsten halogen lighting or metal halide discharge lighting	30-80% saving for equivalent lighting performance	If low-voltage tungsten halogen spotlights are installed, there is further saving by using infrared (IRC) bulbs instead of the standard bulbs
Fluorescent fittings with the old 2ft 40W, and 8ft 125W fluorescent lamps	General lighting, commonly used in classrooms, corridors, and office spaces	Replace with efficient fittings using reflectors/ louvres or efficient prismatic controllers with high-frequency electronic or low loss control gear	30-45% saving with much improved lighting quality. The use of high frequency electronic control gear eliminates flicker, hum and stroboscopic effect	General lighting
Fluorescent fittings with opal diffusers or prismatic controllers which are permanently discoloured	General lighting, commonly used in classrooms, corridors, and office spaces	Replace with new prismatic controllers or replace complete fittings as above	No reduction in energy consumption but increases the amount of light by between 30% and 60%	General lighting

Table 5: Action Checklist for Lighting [Source: Saving energy in schools: lighting, Available: https://www.eecabusiness.govt.nz/assets/Resources-Business/schools-action-sheet-3-lighting.pdf]

	Action checklist
	Agree with staff on a process for turning lights off at the end of the day, at the end of the week, and for school holidays.
	Ensure windows are cleaned regularly and trim overhanging trees and plants.
	Clean lights and fittings annually. As lighting systems age, lighting levels can drop by over 50%.
	Paint walls and ceilings high gloss white to reflect daylight around the room.
	Ensure the level of lighting is appropriate for each area in use. Around 240 lux is recommended as the minimum for the working plane (i.e. desks) in classrooms, but other tasks or learning areas may need more light. See www.rightlight.govt.nz for a guide or for specific technical guidance, see the standard AS1680.
	Look for over-lit areas and carry out selective 'de-lamping' where possible, concentrating on areas near windows and doors, corners, skylights, over computers and televisions, and corridors.
	Rather than waiting for individual fluorescent lamps to fail, replace every lamp in your school at the same time (called 'bulk re-lamping'). Put aside an extra 7% and use these up as lights fail.
	Your school may also still have the old 'blackboard lights', which are no longer useful and create glare on whiteboards. Disconnect these.
	Install lighting controls to take advantage of daylight. This can be as simple as rewiring banks of light switches to enable staff to turn off lights in areas of the classroom that have good access to daylight.
	Consider installing light fittings with electronic dimmers. This means that as natural daylight increases, the lights automatically dim to maintain constant light levels.
	Install occupancy sensors in offices and other areas that are often empty. This ensures the lights are off when the room is un-used but automatically turn on when someone enters.
	Consider installing timers that turn lights turn off at the end of each class. Occupants then manually switch lights back on if they are needed for the next class.
	Replace traditional incandescent lamps with compact fluorescent lights (CFLs) in small spaces and with linear fluorescent tubes in larger spaces. T5s are thinner fluorescent tubes that use less energy than the standard T8s. Talk to your supplier about the right lamp for your needs.
	Consider installing LEDs in lights that must be on continuously such as exit signs. While the upfront cost is higher than ordinary bulbs, they will last much longer, saving on maintenance costs.
	Install efficient outdoor lighting. Where possible use fluorescent fittings. Sodium lamp fittings are generally the most efficient but may an issue where colour rendition is important for security cameras.
	Install a single daylight sensor to control all outdoor lighting - this means only one sensor needs to be maintained.

Sub Section 3: The HVAC systems

Heating and cooling [when applicable], are usually the largest and most expensive energy users in a school. Savings made in heating and cooling can have a positive impact on energy bills with even simple, low-cost measures.

Some basic, cost-effective, tips to be followed:

- For heating and cooling:

- *Only heat or cool rooms you are using and when needed*
- *Implement "dress for the weather" policies*
- *When using heating or cooling, close all windows and doors whenever possible to prevent losses*
- *In winter, set your school's thermostat to 18°C–20°C and in summer set it to 24°C–27°C*
- *To prevent over-heating and over-cooling, modern split systems can be re-programmed for temperature limits and to automatically turn off via the remote*
- *Check thermostats regularly and make sure that users know how to use them*
- *Ensure thermostats are not influenced by draughts, sunlight, heaters or ICT equipment*
- *Settings should reflect the activity taking place within the space*
- *Ensure that heaters and vents are not obstructed by any equipment and that filters are kept clean and free of dust*
- *Use timers or make someone responsible for switching off systems when they're not needed.*

- For heating:

- *Open shades on windows that are receiving heat from direct sunlight.*
- *Make sure all pipes are lagged and the boilers are serviced regularly.*[22]
- *If you don't have a central heating system, consider that heat pumps are more efficient than fan or radiant heaters, but they are more expensive to run than central heating and have to be replaced more often*
- *Temperature needs can vary during the day so check the system operating hours match the times when heating is most needed.*

- For cooling:

- *If the temperature is not too hot, try using alternative ways to keep cool - Open windows instead to allow natural -cross- ventilation*

[22] The cost of operating an inefficient boiler is more than the money you save not maintaining it.

- *Use fans instead of ACs when the temperature is under 26°C as they are much cheaper to install, operate and maintain.*
- *Turning on AC & fan simultaneously while lowering AC temperature by 2-3°C, can speed up cooling and save 10% of electricity*
- *Set a policy or system limit where students and staff can turn on the AC only when temperature rises above a set point use*
- *Close shades on windows that are receiving heat from direct sunlight*
- *Ensure that vents aren't blocked by curtains or other obstacles.*
- *Tie a ribbon to the vent of each aircon unit / diffuser so you can visually tell if it is actually turned on or off.*

To find out more about the HVAC systems, look at the information sheet 'Saving energy in schools: heating and cooling', provided by the Energy Efficiency and Conservation Authority (EECA) of New Zealand, Available at: https://www.eecabusiness.govt.nz/sectors/education/

Proceed with the systems' upgrade only when necessary· when they are highly underperforming, or when is suggested after the energy audit. This is because mot of the times, a proper maintenance and operation of the existing systems, can have significant impact on energy savings and on their performance.

Table 6: Action Checklist for Heating systems [Source: Saving energy in schools: heating and cooling, Available: https://www.eecabusiness.govt.nz/assets/Resources-Business/schools-action-sheet-2-heating-and-cooling.pdf]

	Action checklist
	Keep your heating system simple and make sure staff know how to use it.
	For heating systems that are manually controlled, agree with staff on a process and responsibilities for turning off heating in unoccupied spaces, after hours and over holidays.
	Limit the amount of electrical equipment in each classroom to prevent overheating. For example, supply computer monitors to each classroom but store all the CPU functions in one central location where the heat load can be managed.
	Consider installing controls that automatically shut down heating after hours and between classes, but let teachers manually turn on heating when needed.
	Consider a centralised control system which can control lighting, heating and hot water from a central PC. Remote access is also possible.
	Consider upgrading to a zoned heating system which allows you to selectively heat only the parts of the building complex that need it (e.g. west-facing rooms in the morning).
	Schedule regular maintenance, filter changes and cleaning for boilers and other heating systems – at least once a year to ensure best performance.
	Check insulation regularly as it can deteriorate over time. Pay particular attention to ceiling cavities.
	Install automatic door closers to prevent heat loss, particularly on exterior doors.
	Where sun through a window is regularly causing overheating in a classroom, consider retrofitting solar glass, sunshades or adjustable blinds.

Sub Section 4: Water Heating

Although hot water is usually around 10% of a school's energy use, you can still make savings. Nonetheless, if schools have showers, and/or a swimming pool, heating the water can be around 50% of its energy use.

Some basic, cost-effective, tips to save energy heating water:

- *Put flow restrictors on hot water taps*
- *Use efficient shower heads [when applicable]*
- *Make sure small hot water boilers, are switched off at the end of the day*
- *Unplug hot water cylinders that aren't needed*
- *Repair dripping taps*
- *Choose a hot water system that suits your usage as larger systems will waste money by heating water that isn't required*
- *Install new water systems if the existing systems are outdated - In some cases, it may be beneficial to install energy efficient electric instantaneous hot water heaters*
- *If electricity is used to provide hot water, it may be worthwhile upgrading to another source*
- *Solar thermal system for water heating can be installed*
- *Use swimming pool covers properly and keep them in good repair [when applicable]*

TIP: *Pool covers minimise evaporation and reduce the heating energy required by as much as 70%. To be effective, they need to be maintained in good condition and used consistently*.

To find out more about the Water Heating systems, look at the information sheet 'Saving energy in schools: water heating', provided by the Energy Efficiency and Conservation Authority (EECA) of New Zealand, Available at: https://www.eecabusiness.govt.nz/sectors/education/ .

Table 7: Action Checklist for Heating systems [Source: Saving energy in schools: water heating, Available: https://www.eecabusiness.govt.nz/assets/Resources-Business/schools-action-sheet-4-water-heating.pdf]

	Action checklist
	Create an energy saving culture at your school. Get staff and students on board, and set targets for energy use (including hot water).
	Remind staff to rinse dishes with cold water and ensure dishwashers are used on eco settings and run only when full.
	Check your hot water temperature thermostat isn't set higher than necessary. Water shouldn't be more than 40°C at the tap (Ministry of Education's health and safety guidelines) and must be 60°C at the cylinder to prevent the growth of Legionella bacteria.
	Fit flow restrictors to high-use hot water taps. Flow control aerators cost a few dollars and can halve the volume of water used while still giving good pressure.
	Install efficient showerheads in changing rooms. They provide good even pressure and temperature without wasting energy or water.
	Make sure smaller hot water boilers such as the zip in the staffroom are switched off at the end of each day.
	Replace washers or fittings on any dripping hot taps promptly.
	Ensure boilers are maintained regularly, in line with manufacturer's recommendations. They should be tuned and set correctly to avoid incomplete combustion.
	Wrap electric hot water cylinders to prevent heat loss. Insulate the cylinder and pipes within at least a metre of the cylinder.
	Insulate any high-use hot water pipes and external hot water pipes.
	Get an electrician to decommission hot water cylinders that aren't needed. There are often numerous under-sink hot water cylinders in schools that are never used.
	Turn off hot water cylinders during holidays. Often these are left running 24/7, all year round. Timers can be fitted on existing cylinders to shut down on weekends and holidays.

Sub Section 5: Office Equipment

Computers, ICT and office equipment can account for a third of a school's total energy consumption. The increased use of electrical equipment in schools nowadays is having an effect on electricity bills. Nonetheless, there are many opportunities for cutting costs and making energy savings across this sector as well.

Some simple ways to reduce consumption are:

- *Shut down computers and switch off monitors when not in use*
- *Electronic whiteboards, printers, photocopiers and other stand-by appliances, should be turned off at the end of each day*
- *Screensavers are energy intensive so set your screen to 'none'*
- *Recharge tablets and other devices during off-peak times [if applicable] to reduce costs*
- *When pursuing new office equipment, this should have an appropriate specification and an Energy label that confirms their efficiency*
- *Match the equipment to the task (eg. Set default printing to double-sided (duplex) and reduce the print size of documents where possible)*
- *Place heat-emitting equipment, such as printers and photocopiers, in a separate, naturally ventilated area with good airflow to prevent overheating and to remove potential emissions from the equipment*
- *Make someone responsible for switching off electronic equipment at the end of the day or when is not used or install timers for automatic control*

TIP: ***Before spending any significant amount on equipment, it's important that you get expert advice on energy consumption and ongoing running costs.***

Table 8: Typical Energy Consumption figures for types of ICT equipment [Source: Carbon Trust – Schools Learning to improve energy efficiency Published in the UK: © The Carbon Trust 2012. All rights reserved. CTV019, Available: https://www.carbontrust.com/media/39232/ctv019_schools.pdf]

Equipment type	Average power consumption while in use (watts)	Standby energy consumption (watts)
PC (processor only)	74	6/36*
PC monitor	100	4/7*
Inkjet printer	17	9
Laser printer	280	18
Fax machine	82	7
Photocopier	400	103

*Two sets of data correspond to 'deep sleep' and 'sleep' mode respectively

Table 9: Action Checklist for Equipment and appliances [Source: Saving energy in schools: equipment and appliances, Available: https://www.eecabusiness.govt.nz/assets/Resources-Business/action-sheet-5-saving-energy-in-schools-equipment-and-appliances-feb-2011.pdf]

	Action checklist
	Make sure all computers, copiers, printers and other IT and office equipment are turned off at the end of each day.
	Make sure power management is enabled wherever possible on computers and other equipment.
	Make it a school policy to turn off monitors whenever they're not in use for more than a few minutes.
	Avoid screen savers – they're not necessary on modern monitors and consume more energy than allowing the monitor to dim when not in use. Turn off monitors when not needed.
	Beware when browsing – some web pages have active banners or animations that don't allow the computer to revert to sleep mode – close these down at the end of each session.
	Talk to staff and agree on a shut down procedure for weekends and school holidays. If staff will be using office equipment over breaks, ask them to take responsibility for ensuring everything is switched off.
	Keep track of how much standby loads are using over time by reviewing your power bills and checking off-peak energy use, and by using an electronic power usage tool, e.g. www.esis.com.au/Loggerssmall/Power-Mate.htm. You could involve students in the process.
	Plug the electronics for each work station into one power strip and get users to turn the strip off when they have finished using the computer.
	Consider timer switches for areas where there are several pieces of equipment grouped together.
	Make it a school policy that all new equipment and appliances will be ENERGY STAR models.
	When upgrading, consider replacing desktop computers with laptops, and old CRT monitors with LCD screens.

To find out more about Office Equipment, look at the information sheet 'Saving energy in schools: equipment and appliances', provided by the Energy Efficiency and Conservation Authority (EECA) of New Zealand, Available at: https://www.eecabusiness.govt.nz/sectors/education/ .

Sub Section 6: Kitchen Equipment [Appliances]

The energy consumption of the kitchen equipment and other appliances should not be overlooked in schools. School kitchens and canteens can be responsible for a big proportion of the overall energy consumption, especially in full-day schools.

Schools can make significant energy savings by choosing energy efficient appliances, especially when making purchase decisions. Purchasing energy-efficient appliances such as refrigerators, heaters, dishwashers and ovens, can have a great impact on school's power bill. Selecting the right sized appliance will also help to reduce energy costs.

Some basic, cost-effective, tips to save energy from schools' appliances are:

- *Implement regular maintenance checks on refrigerators and freezers as they consume significant amounts of energy and they are continuously used*
- *When pursuing new appliances, these should have an appropriate specification and an Energy label that confirms their efficiency*
- *Position fridges and freezers away from heat sources*
- *Set the fridge thermostat at the right level for the contents and keep in mind that freezers operate more efficiently when full*
- *Check the seals are intact and cold air is not escaping*
- *Ensure the doors are not be left open or opened unnecessarily*
- *Defrost regularly*
- *Turn off fridges during holiday periods and when appropriate*
- *If it is not possible to turn off all fridges, consolidate the contents of fridges so that some can be turned off*
- *Do not switch on too soon the catering equipment as most modern equipment reaches optimum temperature quickly*
- *Switch off ovens, grills and fryers immediately after use and ensure appliances are not on standby*
- *Witch off equipment, lights and extraction fans when not in use*
- *Reduce drying times on dishwashers and allow residual heat to finish the drying process*
- *Make someone responsible for putting up reminders in the staff kitchen and canteens about using appliances efficiently*

To find out more about Appliances, look at the information sheet 'Saving energy in schools: equipment and appliances', provided by the Energy Efficiency and Conservation Authority (EECA) of New Zealand, Available at: https://www.eecabusiness.govt.nz/sectors/education/ .

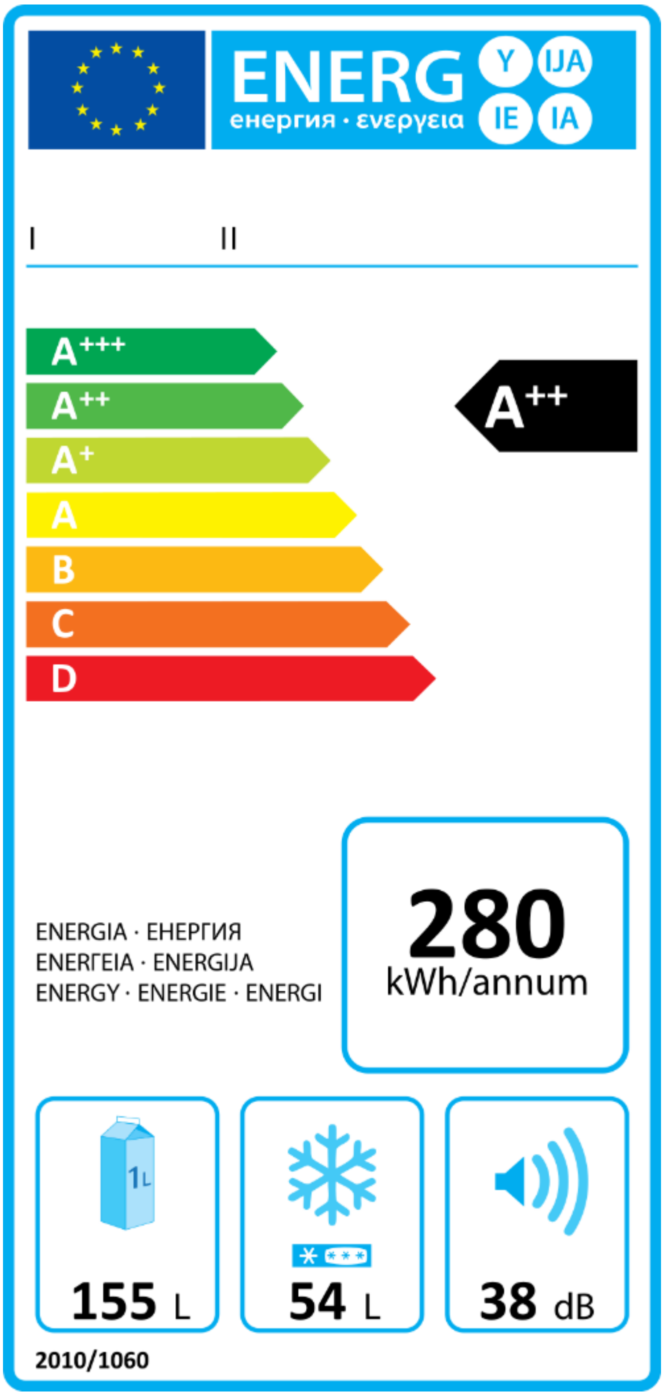


Figure 8: European Union energy label for appliances

[Source: https://en.wikipedia.org/wiki/European_Union_energy_label]

Sub Section 7: Building Automation Systems

When considering energy savings in schools, the installation of energy or building management systems are very significant. Energy or building management systems are information technology (IT) systems and software that can completely automate the energy use of a building. In specific they switch power to different appliances and areas of a building on and off as needed, and can work with the lighting, heating, cooling systems, IT and other energy uses.

Some facilities choose to use a Building Management System (BMS) or Industrial Control System (ICS) to monitor energy use.

'*A BMS controls building services equipment and can generate alarms when the system cannot provide the specified conditions or when equipment fails. An ICS co-ordinates and controls industrial equipment, generates alarms and reports on trends.'*

It is worthwhile to look at the cost of enhancing an existing BMS or ICS to provide the reporting function of an energy monitoring and targeting system.

Energy management software allows organisations to monitor and report energy use and emissions, check against benchmarks and target energy efficiency. Several systems are available for schools, their capital costs are quite high, but they can cut energy costs significantly. An energy auditor can provide a technoeconomic assessment about how long it would take to recoup capital costs through energy savings.

For more info:

Energy Efficiency and Conservation Authority (EECA) of New Zealand - Software to measure and manage energy Saving energy with computer power: https://www.eecabusiness.govt.nz/assets/Resources-Business/software-to-measure-and-manage-energy-june-2011.pdf

Section 4: Templates & Tools for Maintenance, Energy Management and Monitoring [30 minutes]

Foreword:

When deciding to proceed with Maintenance, Energy Management and Monitoring in school facilities, is important to use suitable Templates and Tools to simplify the procedures. Having benchmarks or energy use indices against which to compare performance and progress is also very helpful.

Both the Templates and the Tools can be created from the school's staff, however there are many already developed and available for use. Some of these examples are presented in the current section. These examples were selected through a variety of available materials, as a first indication.

For more information, refer to the sources mentioned.

Sub-Section 1: Simplified energy and environmental audit tool for schools

A simplified energy and environmental audit tool composed of two modules, was created from the TEESCHOOLS project and is available through the website:

http://www.improveyourschool.enea.it/

The set of the user-friendly tools contains:

- The 'Energy profile module' of the building: it calculates the energy index of the school building and estimates its energy performance
- The 'Renovation options module': it calculates the potential energy and CO_2 savings of the school building and helps in selecting the most promising renovation options
- A database of innovative best practices for renovation of school buildings in the Mediterranean area
- A list of available financing opportunities in Mediterranean area

Figure 9: Source: http://www.improveyourschool.enea.it/

Sub-Section 2: Energy management matrix by Carbon Trust

By using the energy management matrix, an energy team can understand and assess how the school is performing. This tool can help schools assess their strengths and weaknesses across the six main areas of energy management:

- *Policy – what commitments has the school made?*
- *Organisation – whose job is it to manage energy at the school?*
- *Training – are staff aware of the issues and their role in tackling them?*
- *Performance measurement – what systems are in place to give you the data needed?*
- *Communicating – are staff, pupils, parents and the board interested in reducing the school's carbon footprint? Do they know what to do and what has been achieved?*
- *Investment – spending money on energy saving programmes and equipment can pay back. Does the school make the most of investments?*

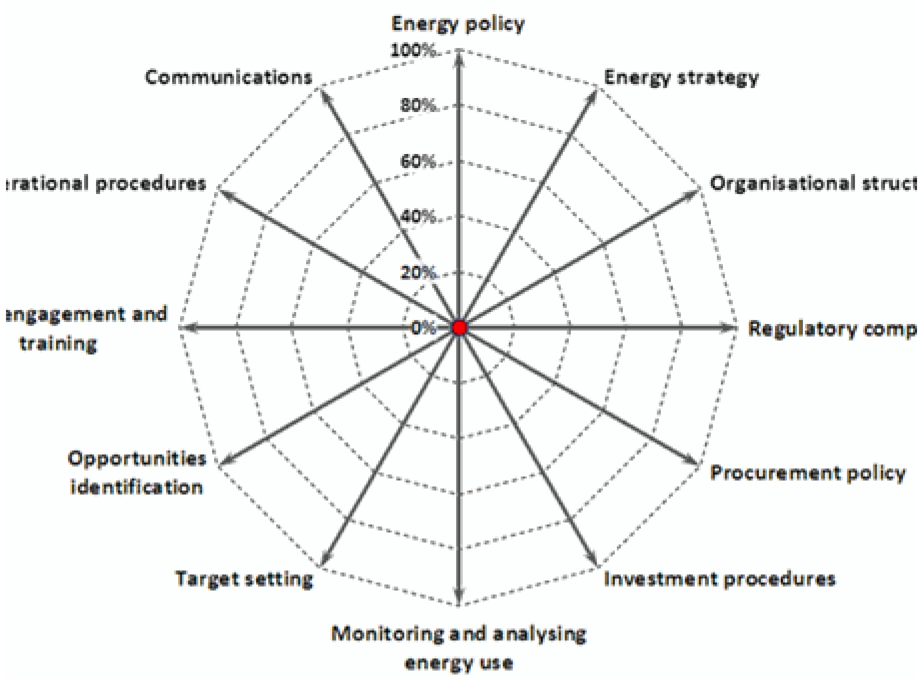


Figure 10: The Energy Management Matrix gives a quick high-level assessment of strengths and weaknesses across six areas of energy management, whereas the Energy Management Assessment (EMA), presented above provides a more detailed appraisal of your energy management performance across twelve key areas.[Source: https://www.carbontrust.com/resources/tools/energy-management-self-assessment-tool/]

For more info and other available templates:

Carbon Trust 'A whole school approach - Involving the school community in reducing its carbon footprint'. Available:
http://www.greensuffolk.org/assets/Greenest-County/School/Energy-Guides/A-Whole-School-Approach.pdf

Sub-Section 3: Guide to Operating and Maintaining Energy Smart Schools by the US Department of Energy

This Guide offers a range of available templates and references to Identify Energy Savings and to Developing and Implementing an Energy Management Plan. Its Templates and guidelines are customizable and can be used for planning and implementing energy focused operations and maintenance for districts with all levels of experience, available funding and staffing resources.

Questions for Administrators/Senior Facility Staff

Energy Policy and Building Operations Procedures

1) Does the district have an overarching energy policy and a procedures manual of standard O&M practices that are actively applied in all schools?
2) If yes, when were these policies developed and last presented to O&M and administrative staff members?
3) Are O&M staff members aware of these policies and actively adhering to their objectives?

Building Energy Information

4) Who receives the utility bills? Are they reviewed and tracked for accuracy by the facilities staff?
5) Is annual district energy use increasing or decreasing? What is the explanation?
6) Are energy costs increasing or decreasing?
7) Is energy usage tracked monthly, and who does the tracking?
8) If yes, does the district periodically compare the energy consumption of specific buildings and use this information to identify problems in specific schools?
9) If yes, is this information made available to the principal and the operations staff at individual schools?
10) How does energy use per square foot at certain schools compare to use at schools at this and other districts?

School Condition and Operations

11) What is the age and general condition of each building?
12) What are the major problems with respect to school physical plants, such as advanced age, poor system or temperature control, indoor air quality, and staffing?
13) Has building profile/inventory information, such as size, occupancy, heating fuel type, and age, been collected, validated, and made available?
14) Does the central office or maintenance director currently have software, such as Computerized Maintenance Management System (CMMS), or other capabilities to plan, track, or schedule maintenance activities at individual schools, particularly for large systems such as heating and cooling systems?
15) Have recent energy audits been performed in schools? Were there any recommendations for changes in O&M practices? Were the recommendations implemented?
16) Which schools, if any, have computerized energy management systems (EMS)? Are these systems working effectively? Are outside vendors providing quality service? Do district and building staffs know how to operate them?
17) Briefly describe the district's vacation and weekend shutdown procedures. Are these applied in all schools?

O&M Staffing

18) What role, if any, do outside vendors or other public sector agencies play in building O&M? What is the quality of this service?
19) What level of training, if any, has been provided to custodial or maintenance staff that is relevant to energy management?
20) Identify any specific training needs that would enhance staff members' ability to manage energy costs at individual schools.
21) Does the district recognize or otherwise reward staff or individual schools for improvements in operating costs at specific facilities?

Figure 11: Example of helpful material: Questions for Staff During Initial Data Gathering

EA Prerequisite 1: Building Operating Plan • Template for Building Operating Plan for Schools

Equipment Inventory and Run Time Schedules

Building:	Last Update:
Responsible Building Operator:	

Item Description	Occupied Hours Weekdays	After Hours Weekdays	Weekends and Holidays	Vacation Periods
[Examples]				
PU-1 (Room 101)				
RTU-1 (Rooms 102, 103, 104, 105)				
AHU-01 (Building 06)				
AHU-02 (Wing A, 2nd Floor)				
DX-1				
Chiller (250 t)				
Cooling Tower				
Boiler #1 (Natural Gas)				
Parking Lot Lights				
Overhead Walkway Lights				
Tennis Court Lights				
Field Lights				

Figure 12: Example of provided template for Building Operating Plan for Schools

The Guide is available through the following website:

https://www.energy.gov/eere/downloads/guide-operating-and-maintaining-energysmart-schools

Sub-Section 4: Template for establishing Roles and responsibilities in Schools

In this specific template, from the '*Energy efficiency in schools. A practical 'how to' guide for Victorian schools'*, actions are divided into 'essential' and 'desirable' [similar to the example provided by the Carbon Trust in Section 2, Sub section 3]. A tick means the person in a particular job function is likely to be well suited to the task. For some tasks, a number of different people could be involved. Other tasks are of a more specialist nature. A tick with a grey background indicates the person who is likely to be the best choice or the task.

See the relevant template:

Who can do what?

Actions	Principal	Teacher	Parent	Student	Bursar/ Administrator	Maintenance officer	Energy/ Sustainability Co-ordinator
Essential							
Policy and planning	**✔**	✔	✔		✔		✔
Identify responsibilities/ energy team	**✔**						
Leading role in Whole School Approach	✔	**✔**					
Identify curriculum opportunities		**✔**					✔
Raise awareness of staff and pupils	✔	✔		✔	✔	✔	**✔**
Active participation in no cost measures		✔		**✔**	✔	✔	✔
Read meters regularly						**✔**	✔
Record/ analyse/monitor energy consumption				✔	✔		**✔**
Identify areas of avoidable waste		✔		✔	✔	**✔**	✔
Review progress towards targets and benchmarks	✔		✔		✔	✔	**✔**
Desirable							
Conduct energy walk-rounds	✔	✔		✔	✔	✔	**✔**
Advise on technical measures						✔	✔
Advise on energy purchasing							
Contribute to curriculum issues	✔	**✔**		✔			✔
Identify all energy using systems/ equipment				✔		**✔**	✔
Identify controls, timers, set points						**✔**	✔
Maintenance of energy using equipment						**✔**	
Sanction appropriate investment	**✔**		✔		✔		
Apply for relevant grants	✔				✔		**✔**
Provide regular progress reports					✔		**✔**

☐ Best suited for task
✔ Could do the task

Figure 13: Roles and responsibilities template. [Source: 'Energy efficiency in schools. A practical 'how to' guide for Victorian schools'. Available at: https://www.sustainability.vic.gov.au/School]

Sub-Section 5: Planning templates and a schedule to assist schools

The Guide '*Energy-Efficient Schools. A guide for trustees, principals, teachers, students, caretakers and energy managers'*, provides a description of how schools can reduce energy use and cost. It aims to assist schools to:

- improve energy efficiency
- move towards sustainability, and
- model good energy efficiency practice.

Among others, it provides three planning templates and a schedule to assist schools. An example of these templates is presented below:

Table 10: Energy audit template - Assists schools to determine their energy use and type. Ideally, students use the template as part of their learning [Source: Energy-Efficient Schools. A guide for trustees, principals, teachers, students, caretakers and energy managers. National Energy Research Institute (NERI) in partnership with The Enviroschools Foundation and the Energy Effi ciency and Conservation Authority (EECA)]. Available at:

http://www.enviroschools.org.nz/energy_efficient_schools_large.pdf]

Energy use	Detail	How many	Load	Time on	Use	Energy source	Renewable energy
			Watts	**Hours per day**	**kW per day**	**Fuel type**	**Y/N/Mixed**
Lighting	Low-energy lamps High-energy lamps						
	Lighting organisation Good ☐		Could be improved ☐			Poor ☐	
Heating	Boiler / radiators Coal stoves Gas heaters Electric heaters Air conditioning Swimming pool						
Equipment	Computers Printers Photocopiers Projectors Whiteboards Faxes TVs Video recorders Speakers Lawn mowers Power tools Pool filter pump Fridges Dishwashers Microwaves						
Hot water	Storage cylinders Kitchen instant Kitchen jugs Coffee machines						
Transport	Vans Buses Staff who car pool, walk, bike, bus, or train Students who car pool, walk, bike, bus, or train						
Energy monitor:				**Date:**			

Table 11: Longer-term planning template [Source: Energy-Efficient Schools. A guide for trustees, principals, teachers, students, caretakers and energy managers. National Energy Research Institute

(NERI) in partnership with The Enviroschools Foundation and the Energy Effi ciency and Conservation Authority (EECA)] . Available at:

http://www.enviroschools.org.nz/energy_efficient_schools_large.pdf]

Energy efficiencies	Scheduled	Comment
Control systems • Can heating be centrally controlled? • Are switches easily accessible? • Does switching enable specific areas only to be lit? **Lighting** • Are the fittings appropriate? • Is light saving technology in place: timers, dimmers, or occupancy detectors? • Do interior paint colours minimise lighting requirements?		
Insulation Are the following insulated: • Ceilings? • Windows – double glazing? • Underfloor? • Walls?		
Solar water heating • Is the swimming pool heated by solar power?		
Boiler • Does the boiler use renewable energy? • Does the boiler have a timer and is it working properly? • Has the boiler been tuned in the last year (does it smoke, run hot, or run erratically)?		
Does all equipment have a: • High energy-efficiency rating? • Manual switch-on / automatic switch-off system?		
School transport energy • Are school vehicles efficient energy users? • Is there a transport plan?		

- **<u>Conclusion of the module [5 minutes]</u>**

As it can be concluded, maintaining, managing and reducing energy use can have significant economic, environmental and educational/social benefits for a school, providing the best possible learning environment where students can set strong foundations.

A school needs to be treated as a small community, which will work together at every level, in order to meet its predefined targets. All people involved, have an impact on energy use and should therefore be encouraged to contribute to the maintenance and management of energy in schools. This is also a great way to equip them with practical skills and knowledge that they can use on a daily basis, both in and out of school.

In addition to the reduced environmental impact and the lower cost of energy, which is very important, especially for public schools, there is also a bigger advantage. This concerns the increased productivity and wellbeing, and of course the increased performance, both for the students but also for the school's staff, making the adoption of a well-established Energy Management System [Plan] a 'one-way' road for the schools. Having low energy consumption but not meeting the above preconditions, is not a comparable measure.

Overall, the importance of Energy Management in schools provides:

- Economic benefits
- Reduced Operating Costs
- Increased Return on Investment
- Environmental benefits
- Emissions Reduction
- Prevent Pollution
- Social benefits
- Productive learning environment

Tangible and measurable targets should be set for energy savings and always keep in mind the importance of Energy monitoring to allow the evaluation and readjustments of the implemented actions -if necessary-. It is also a good idea to reinvest those savings and further improve the energy performance and the quality of the school.

Schools in quest of to improve their energy efficiency, should take a whole of school approach towards sustainability while awareness and sensitivity campaigns should be implemented in parallel actions. This is because schools have a unique opportunity -and responsibility-, to set an example for communities in the campaign to reduce our carbon footprints.

- Self-assessment [45 minutes]

1. **1.** Which action is proposed as the first step to maintain and manage energy in schools?
    a. Install renewable energy sources and efficient equipment / appliances
    b. Identify where more energy is used and what kind of energy is
    c. Install thermal insulation in the building's envelope and upgrade the windows

2. **2.** The energy bills are often treated as a fixed portion of school expenses …
    a. Nonetheless, most schools have considerable room for improvement and savings
    b. And there is no easy way to reduce the amount of money spend on these.
    c. Nonetheless, investing in new equipment and large-scale interventions can reduce the amount of money spend on these.

3. **3.** How energy awareness can be -successfully- activated in schools?
    a. Not taking into consideration inputs and/ or feedback from students as they might lead to misconceptions
    b. Appointing energy 'champions' and celebrating achievements
    c. Making it compulsory for students to take relevant exams

4. **4.** What can be the site effect of reducing carbon emissions through improving energy efficiency in schools?
    a. Aggravation of climate change
    b. Increasing the school's carbon footprint
    c. Enhancement of working conditions and comfort levels for staff and pupils

5. **5.** When is the best time to consider energy use in schools?
    a. During the designing phase
    b. Within the first year of operation
    c. In the first 5 years of operation

6. **6.** What is the purpose of a preventative maintenance program?
    a. It is conducted to address an existing problem
    b. It is conducted to avoid system problems or failures from occurring
    c. It is conducted to provide information on the systems' state

7. **7.** What amount of energy going into schools is non-productive and could be saved?
    a. Around 10% - 20%

b. Around 30% - 40%
c. Around 50% - 60%

8. What targets should be set when implementing an Energy Monitoring System in schools?
   a. Targets deriving from thorough understanding of the current energy consumption
   b. Targets which are significantly better than the current situation
   c. No targets should be set when implementing an Energy Monitoring System

9. What can be identified through an energy audit?
   a. Practice or behaviour improvements
   b. Infrastructure and equipment upgrades
   c. Both of the above

10. Which is the European Standard used for Energy Audits?
   a. The EN 12831series of standards
   b. The EN 15316 series of standards
   c. The EN 16247 series of standards

11. If the building envelope of the school is underperforming [great heat losses/gains] then:
   a. Thermal insulation of the roof should be a priority
   b. Replacement of the aluminium frames should be a priority
   c. Thermal insulation of the walls should be a priority

12. When aiming to achieve a well-lit environment in classrooms then:
   a. Light sources with a low colour rendering index and a 3000 K colour temperature should be used
   b. Light sources with a high colour rendering index and a 4000 K colour temperature should be used
   c. Light sources with a high colour rendering index and a 2000 K colour temperature should be used

13. What are the recommended temperatures for the school's thermostats?
   a. In winter, 22°C–24°C and in summer 21°C–24°C
   b. In winter, 20°C–22°C and in summer 26°C–29°C
   c. In winter, 18°C–20°C and in summer 24°C–27°C

14. When making purchase decisions for equipment and appliances in schools is important to:
   a. Look for any Energy label that confirms their efficiency
   b. Get expert advice on energy consumption and ongoing running costs
   c. Select only those who are labelled as A+++

15. Energy or building management system in schools:
   a. Allow the monitoring and reporting of energy use and emissions
   b. Improve the comfort conditions in the school
   c. Can not work with the heating and cooling systems

Consultation of documents and references

- *Guide to Operating and Maintaining Energy Smart Schools, US Department of Energy* - U.S. Department of Energy & Council of Educational Facility Planners International (CEFPI) participating sponsor

- *Energy efficiency in schools. A practical 'how to' guide for Victorian schools.* © Sustainability Victoria ENG045, June 2016. Publication co-produced with Department of Education and Training. Authorised and published by Sustainability Victoria, Level 28, Urban Workshop 50 Lonsdale Street Melbourne Victoria 3000 Australia.

  Accessibility: This document is available in PDF and Word format on the internet at www.sustainability.vic.gov.au

- **Energy-Efficient Schools. A guide for trustees, principals, teachers, students, caretakers and energy managers. National Energy Research Institute (NERI) in partnership with The Enviroschools Foundation and the Energy Effi ciency and Conservation Authority (EECA)]. Available at:**

  http://www.enviroschools.org.nz/energy_efficient_schools_large.pdf

- Series of 'Saving energy in schools' in the website of the Energy Efficiency and Conservation Authority (EECA) of New Zealand: https://www.eecabusiness.govt.nz

- *Designing Quality Learning Spaces'*. Available at: https://www.education.govt.nz/school/property-and-transport/projects-and-design/design/design-standards/designing-quality-learning-spaces/

- Carbon footprinting guide, available at: https://www.carbontrust.com/resources/guides/carbon-footprinting-and-reporting/carbon-footprinting/

- **A whole school approach Involving the school community in reducing its carbon footprint Carbon Trust - Published in the UK: May 2010. CTV037v2 © Queen's Printer and Controller of HMSO. Available in : http://www.greensuffolk.org/assets/Greenest-County/School/Energy-Guides/A-Whole-School-Approach.pdf**

- **Carbon Trust – Schools Learning to improve energy efficiency - Published in the UK: © The Carbon Trust 2012. All rights reserved. CTV019, Available: https://www.carbontrust.com/media/39232/ctv019_schools.pdf]**

- *'Towards an EU Research and Innovation policy agenda for Final Report of the Horizon 2020* - Expert Group on 'Nature-Based Solutions and Re-Naturing Cities' - Directorate-General for Research and Innovation Climate Action, Environment, Resource Efficiency and Raw Materials, 2015

- *Saving Energy at Home and School Student and Family Guide* – Available at: https://www.need.org/files/curriculum/guides/Saving%20Energy%20Student%20Guide.pdf

- *Environmental design in schools, Making schools feel and work better* - Government Architect New South Wales, October 2018. Available at: https://www.governmentarchitect.nsw.gov.au/resources/ga/media/files/ga/manuals-and-guides/better-placed-environmental-design-in-schools-2018-10-29.pdf

For more sources:

- 'New Zealand's Energy Efficiency and Conservation Authority (EECA) website: https://www.eecabusiness.govt.nz/technologies/lighting/types-of-light/

- *School of the Future,Towards Zero Emission with High Performance Indoor Environment:* Available at: https://www.school-of-the-future.eu/index.php

- From Carbon Trust Publications:

Related publications

Fact Sheets

Assessing the energy use in your building (CTL172)

Technology overviews

Building fabric (CTV014)

Heating, ventilation and air conditioning (CTV046)

Lighting (CTV049)

Low temperature hot water boilers (CTV051)

Office equipment (CTV005)

Renewable energy sources (CTV010)

A whole school approach – management guide (CTV037)

Low carbon refurbishment of buildings – management guide (CTV038)

Innovative approaches. Windows, Lighting, ventilation

Presentation of the module

Ventilation and Lighting are two basic functions of a building in general and consequently of a school building. In this learning module, innovative approaches of ventilation and lighting in schools will be examined. The purpose of applying these methods is to reduce the energy consumption of the school building and at the same time to increase the level of comfort, wellbeing and healthiness of teachers and students.

Ventilation is very important for the indoor air quality of a building. Fresh air needs to insert the building at all times while stale air to be directed out of the building. When this exchange takes place during the winter time, heat is also thrown out of the building as the cool fresh air gets inside and the warm "used" air goes outside. To prevent this from happening and reduce the loss of energy, a mechanical ventilation system can be used which includes a heat recovery system. This can significantly reduce the heat loss caused by ventilation up to up to 85-90%. Following, the possibilities of such systems as well as innovative applications will be presented.

The **lighting** system of a building is usually a major energy consumer. LED technology has already reduced the energy consumption quite significantly the last decade compared to typical lamps and fixtures (such as incandescent, fluorescent, halogen etc.). However, apart from it, the way lights are controlled can be of a great benefit both for energy consumption reduction and visual comfort. Automated control of the lighting system can lead to an important decrease in electricity use for lighting. In the following paragraphs it will be explained how this can be achieved.

1. Educational Objectives:

- To be familiar with the concept of heat recovery in mechanical ventilation
- To learn about innovative approaches of ventilation that can be applied in school buildings
- To learn about the type of lighting controls available and suitable for school buildings
- To understand the contribution of such systems in reducing energy consumption

In the following paragraphs innovative approaches of ventilation and lighting systems in school buildings will be described and explained. First, the section of ventilation will be presented and the lighting section will follow.

2 Ventilation in School Buildings and Innovative Approaches

2.1 The importance of ventilation

In general, ventilation is the procedure of replacing the air of an internal space with fresh air from outside. The reason for this is because the content of the air in an indoor environment changes due to various procedures that can take place (e.g. cooking, breathing etc.). Indoor air contains CO_2 from breathing, humidity and even contaminants from various sources. In most buildings ventilation is used to keep CO_2 concentration and humidity below undesirable levels in order to provide good indoor air quality for the building users.

Specifically in school buildings, ventilation is even more important due to the fact that young students spent many hours per day in classrooms. Young people are more vulnerable to bad environmental conditions than adults since their lungs are still growing up and so, more sensitive to air quality related health problems. Health issues caused by poor indoor air quality can be simple eye irritation, sense of fatigue and even spreads of colds and flu or other worse infections.

Apart from the above, studies have shown that CO_2 concentration in the indoor air can affect a human in a negative way when it is higher than a specific value. The higher the concentration the worse the effects on people while after a level it can also be very unhealthy and dangerous. In the picture below various thresholds of CO_2 concentration are presented with their respective impact to humans.

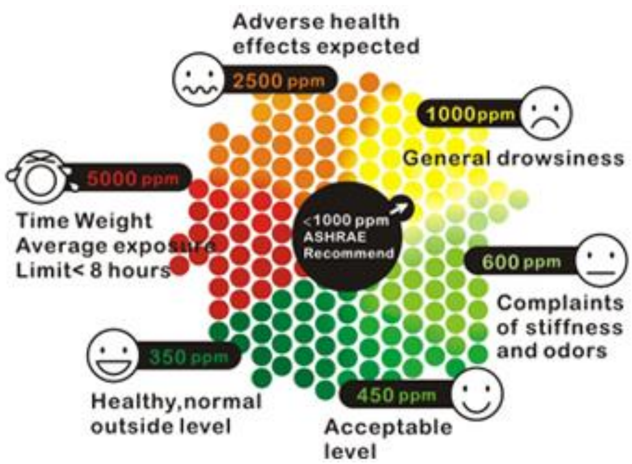


Figure 3.1: CO_2 Concentration level and its impact on people

As it is depicted CO_2 concentration is measured in ppm (parts per million) and a general level below of which indoor air is considered acceptable is the 1000 ppm as recommended by ASHRAE (American Society of Heating Refrigeration and A/C Engineers).

Humidity levels are also a factor that can create unpleasant indoor atmosphere. If it is warm, high humidity makes building users feel even warmer and if it is cold it makes them feel colder. Depending on the humidity levels of the fresh air ventilation usually helps to create better humidity levels indoors. Ideal indoor humidity ranges between 45%-55% (ASHRAE recommendation). However ventilation is only capable of adjusting indoor ventilation in specific conditions and external weather and other systems are necessary to achieve optimum levels which are not going to be further analyzed.

Ventilation measures and standards

First of all, ventilation in a building is expressed as the amount of fresh air getting in the building per unit of time, the **airflow rate**, e.g. m^3/h or lit/min. Another way of doing so is with air changes per unit of time and most commonly air changes per hour (ac/h). One ac/h means that a specific building with specific volume changes all of its indoor air every hour.

Each country has its own standards about the requirements of ventilation in various categories of buildings. The lowest levels of ventilation are usually required in residential buildings where the concentration of people per area is low and the highest is usually in high populated buildings and hospitals. Table 3.1 below, presents the values of minimum requirement for ventilation for various building categories in m^3/h per person and per m^2 of floor area, as it is defined in the Greek building energy performance regulation guidebook.

Table 3.1: Minimum requirements of fresh air flow rate in various builing types

Type of Building Use	Fresh air [m^3/h/person]	Fresh air [m^3/h/ m^2]
Residential	15	0.75
Hotel	20	3
Restaurant	25	17.5
Café	25	20
Theater	25	25
Exhibition, museum	20	10
Conference room	25	27.5

Educational (classrooms)	**22**	**11**
Hospital (general)	35	10.5
Shop	22	3
Office	30	3
Library	30	6.6

According to the standard *EN 15251* the minimum requirements for airflow rate in a typical classroom of 30 students and around 60 m^2 are shown in table 3.2.

Table 3.2: Minimum requirements of fresh air flow rate in various builing types

Classification	**Fresh air [m^3/h]**
New buildings	900
Existing buildings	510

Natural Ventilation

Natural ventilation uses the natural effects of wind and buoyancy as well as the pressure difference, that move fresh air into a building by its typical openings, doors, windows or other openings intended for ventilation or/and other use (e.g. roof openings, skylights). Natural ventilation is usually the case for residential buildings.

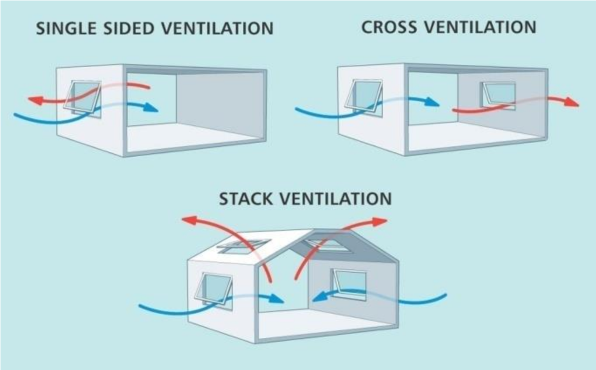


Figure 3.2: Types of natural ventilation depending on the location of windows and openings

Most of the existing school buildings in Europe and especially in warmer regions provide fresh air to classrooms and other spaces by means of natural ventilation and in most cases manually by opening the windows. The main disadvantages of this type are listed below:

- Natural ventilation does not always provide adequate airflow rates and depends on the external conditions like wind speed and direction, temperature.
- Location of the windows may not favor natural airflow.
- The manual operation of windows also relies on teachers will to open or close them.
- Natural ventilation causes heat losses in the winter.

The main advantage of natural ventilation is that it does not have any installation, maintenance and running costs. However, to achieve an adequate natural airflow rate depends a lot on the location and type of the openings in a classroom. If this has not been taken into account in the design phase, it is very difficult to fix it afterwards.

In Greece, a typical school building type usually has classrooms with windows at both sides allowing for a cross flow of air to happen. This is usually a good practice to allow the necessary airflow to take place and ventilate the classroom. The problem of the heat loss however of the natural ventilation especially during the winter remains.

Figure 3.3: Operable windows of a classroom in a primary school of Voula in Attiki, Greece (photo taken from the school energy audits)

Mechanical Ventilation

A Mechanical ventilation system uses air ducts and electric fans to force the fresh air to the indoor environment and remove the exhaust air outdoors. It can be from a simple local system even without any actual ducts, mounted to the building's façade, to a more complex system with a duct network and a central air handling unit. Depending on the building it can be a centralized or many decentralized systems.

Another differentiation in ventilation systems is if it is a mixing or displacement type. The position and the kind of devices can either mix fresh air with the indoor air (mixing) or make fresh air gradually take the place of all the stale air of an indoor space (displacement). The latter is more effective and lower airflow rates are required comparing to the first one. Mixing ventilation is more common and the airflow rates in the standards usually refer to it rather than the displacement type.

Most of the mechanical ventilation systems have variable fan speeds which can be selected by its controls. In this way, the airflow rate can be adjusted in order to meet the standards of the specific classroom or other space of the school like a library or a theater based also on the number of students are using it.

All types of buildings apart from residential ones are usually equipped with some kind of mechanical ventilation. However, as it was mentioned before, that is not the case for school buildings of the Mediterranean region.

The advantages of mechanical ventilation in school buildings are:

- Ensure indoor air quality in classrooms and other spaces due to the fixed/adjusted airflow rates.
- Avoid excessive heat loss in the winter due to difficult to control natural ventilation by operable windows.
- Minimize heat loss in the winter by using mechanical ventilation with heat recovery
- Ability to combine ventilation controls with local automations or a BEMS for optimum control and energy use. (schedule, presence sensors, air quality sensors)
- Can be combined with humidification/dehumidification for achieving optimal indoor air quality.

A disadvantage of a mechanical ventilation system is its cost compared to natural ventilation. This cost can be compensated by the energy savings it may be achieved using for example heat recovery in the winter period. Mechanical ventilation systems also need regular maintenance and hygienic inspection in order not to become source of pollutants and do more harm than good.

The main barrier in the case of school buildings is the difficulty of installing a mechanical ventilation system and its components in an old building due to its architectural design and lack of adequate space.

The main advantage of mechanical ventilation in terms of energy saving is the possibility to be combined with a heat recovery unit. This is a component that is connected with the main inlet and outlet of the ventilations ducts. Its function is to transfer a portion of the heat of the stale warm outgoing air to the fresh cold inlet air. This happens with a heat exchanger which allows two flow streams to exchange heat and in some cases moisture, via a thin wall-layer without mixing. There are various types of heat exchangers for ventilation systems. Depending on the direction of the flow of the fresh and stale air, they are divided in parallel flow, (single or multi)cross flow and counter flow.

Figure 3.4: Basic function of a ventilation heat recovery system

Depending on the type and other parameters, heat recovery system can achieve an efficiency of 50% to as much as 90%. With heat recovery a building can dramatically reduce heat loss from ventilation in the heating season and consequently reduce energy consumption for heating. During mild periods, when the ambient temperature is close to the indoor set point temperature, the heat recovery is bypassed. Heat exchanger needs more fan power to flow the air through it so when there is no reason for heat recovery it can be bypassed. This can be also controlled with an ambient temperature sensor.

Innovative approaches for school buildings

In this subsection will be analyzed how it can be possible to apply innovative ventilation systems exploiting the advantages of the ventilation types and strategies with the aid of automations. It will be demonstrate how this can be beneficial for an existing school building in terms of energy saving, thermal comfort and good indoor air quality. In general, it is much easier for existing building to apply strategies involving decentralized ventilation systems and units. This reduces the interventions needed in the building, where usually there is not much space to use. For this reason, the innovative approaches examined will be based on decentralized systems. In any case, the control of the systems can always be centralized if there is a desire to gather all controls in one place (e.g. BEMS).

Approach 1 – Natural ventilation with window actuators and various sensors

This approach combines natural ventilation of school classrooms and other spaces with automated control of the windows opening-closing. This is achieved by installing actuators that can open or close the windows automatically by receiving the relevant order from a set of sensors. These sensors can be:

- CO_2 concentration sensor
- Temperature/humidity sensor
- Presence sensor

With such a system windows will open for example when CO_2 concentration exceeds a specific value that is not acceptable for the school indoor environment (1000-1500 ppm). When the CO_2 concentration drops below this value, windows will close again avoiding heat losses. An alternative is a presence sensor that keeps windows open when students are in the classroom. A different approach could be a timer that is programmed to open the windows based on a schedule.

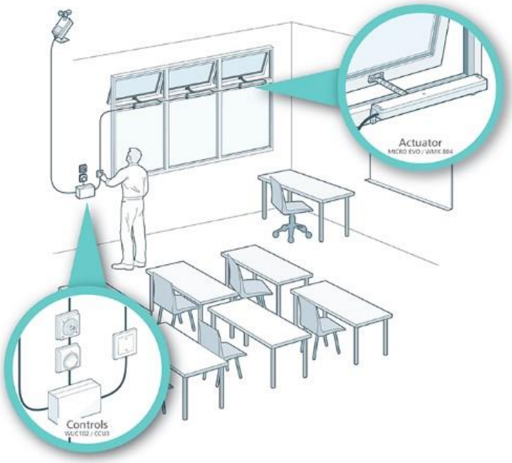


Figure 3.5: Schematic of a natural ventilation system with sensors and actuators at the windows (source: https://www.tealproducts.com/natural-ventilation-control)

The advantages and disadvantages of such an approach are presented in the table below:

Natural ventilation with window actuators and various sensors	
Advantages	• Ensure good indoor air quality • Minimize heat losses by closing the windows when not necessary • Minimum intervention in the building • Low cost
Disadvantages	• Heat recovery not possible • Only applicable in spaces that existing windows and openings can provide adequate air flow for ventilation

Approach 2 – Mechanical ventilation local units with heat recovery and various sensors demand control

This approach suggests a decentralized mechanical ventilation system with heat recovery, controlled by sensors like in approach 1. In each classroom, office or other space small ventilation units are located under the window sill or above the window near the ceiling or at an external wall in order to be able to exchange air with the environment. Extra pieces of ducts may be required in order to achieve better distribution of the fresh air.

The control of the units is done by a sensor or a set of sensors (CO_2 concentration, presence, temperature, timer-schedule). Most of the ventilation units usually have variable speed fans to adjust the airflow in the desired levels. Heat recovery is also applied for the winter to minimize heat loss. Three schematics of the above described systems are shown in the figures below.

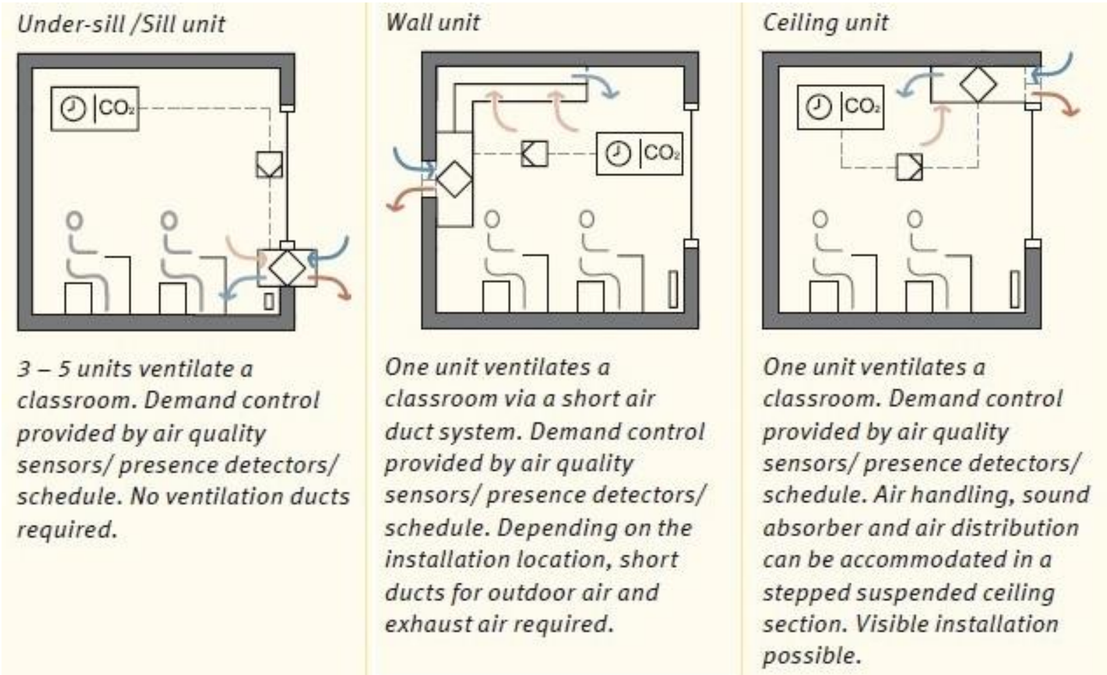


Figure 3.6 : Examples of various types of small ventilation units with heat recovery and automated control in a classroom.

The advantages and disadvantages of such an approach are presented in the table below:

Mechanical ventilation local units with heat recovery and various sensors	
Advantages	• Ensure good indoor air quality • Minimize heat losses due to heat recovery • Mediocre intervention in the building shell • Automatically controlled based on selected variables
Disadvantages	• Cost • Maintenance needed

Approach 3 – Mechanical ventilation with heat recovery integrated in window frames

The main idea of this approach is that ventilation occurs through the frames of the windows while they are closed. This means that no extra holes are need for exchanging air with the environment, which makes it an ideal solution for retrofits. Replacing windows is one of the main intervention in old school buildings undergoing an energy renovation. With this innovative application, new windows can be combined with a mechanical ventilation system also equipped with heat recover. The frame of the proposed window is relatively thicker than a compatible frame allowing the integration of fans and small heat recovery units inside its void. Examples of such window system are depicted in the pictures below.

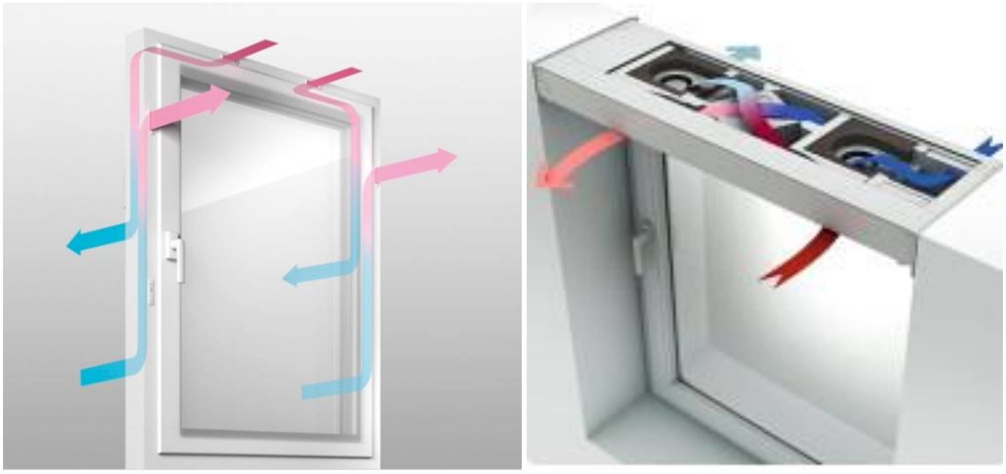


Figure 0.1

Mechanical ventilation with heat recovery integrated in window frames	
Advantages	• Ensure good indoor air quality • Minimize heat losses due to heat recovery • Low intervention in the building shell – combined with windows replacement
Disadvantages	• Cost • Low air flow rates per frame

Heat recovery efficiency of these systems tends to be less than a typical heat recovery unit of a bigger or a centralized unit. This means around 50 – 60 % but it still offers a significant heat loss reduction from ventilation. Air flow rates achieved through a single window frame are low and may not reach the standards of a school classroom. However, if there are enough windows and all of them have integrated ventilation the airflow rates could be sufficient.

Simple case study of heat recovery in ventilation

In order to get a better idea of how much energy could be saved when using heat recovery a simple case study of a classroom will be examined. The assumptions of the case study are the following.

Classroom area: 50 m^2
Number of Students: 25
Airflow rate (fresh air standards): 572 m^3/h
Ambient average temperature: 10 ^oC
Indoor temperature set-point: 20 ^oC

The heat loss due to ventilation without heat recovery is calculated with the following formula:

$H_v = c_p \rho q_v (t_i - t_o)$ *where,*

H_v *= ventilation heat loss (W)*
c_p *= specific heat air (J/kg K) = 1.01 kJ/kg K = 1010 j/kg*
ρ *= density of air (kg/m³) = 1.204 kg/m³*
q_v *= air volume flow (m³/s)*
t_i *= inside air temperature (°C)*
t_o *= outside air temperature (°C)*

$H_v = 1010 \times 1.204 \times 572/3600 \times (10\text{-}20) = 1930\ W = 1.93\ kW$

This means that during one day of 6 hours of occupation (from 08.00 – 14.00) of a classroom the amount of energy loss is 1.93 x 6 = 11.6 kWh every day which means around 11.6 x 90 school days of winter period (Nov – March). That is equal to around 1000 kWh annually per classroom. With a heat recovery unit of 70 % efficiency 700 kWh of this amount is saved.

700 kWh of saving in heating demand means:

- 933 kWh of oil consumption (with an overall efficiency of the heating system 0.75)
- 92 liters of oil or 89 m^3 of natural gas
- 246 kg of CO_2 emissions with an oil boiler or 183 kg of CO_2 with a gas boiler

Lighting Control in School buildings – Innovative approaches

Lighting is responsible for a big portion of the energy consumption of a building. A lot of factors determine the lighting operation and use in a building and consequently the electricity consumption. Some of them are the type of lighting bulbs, fixtures and systems, the type of use and standards of luminance levels, the daylight available, the hours of use and last but not least the users and how they operate the lights in a building.

It was found that the Greek pilot school buildings of TEESCHOOLS consume around 60-70% of their total electricity for lighting purposes. This corresponds to a 25-35% of the total energy end use. All of the pilot buildings are equipped with linear fluorescent lighting fixtures in the majority of their spaces. The first and most obvious intervention of a renovation study is to replace all these fixtures with new LED technology lighting systems. Such a measure would reduce electricity consumption for lighting from 50% to 70%.

However, apart from the type of the technology that is used, the way lights are operated by the building users is of great significance and hides a further potential for energy saving. Lights in a classroom of a typical school are manually operated by simple on and off switches and in some cases they are divided in two groups. The teacher is usually the one who decides when to turn on or off the lights, based on the daylight conditions, glaring, type of course in the class etc.

National standards set specific values of luminance level that has to be met in various types of buildings. More specifically, the standards set the requirements for the luminous flux per unit area measured in lux. For school buildings the Greek regulation requirement in the classrooms is 300 lux and 500 lux in the offices at a desk height of 80 cm from the floor. In a typical school classroom there are big openings and therefore plenty of daylight during the teaching hours. This is verified by actual measurements that were taken during energy audits in the Greek pilot schools. In fact, in most of the pilot schools values of 300 – 400 lux were measured with the lights turned off and higher values with all the lights of the classroom turned on.

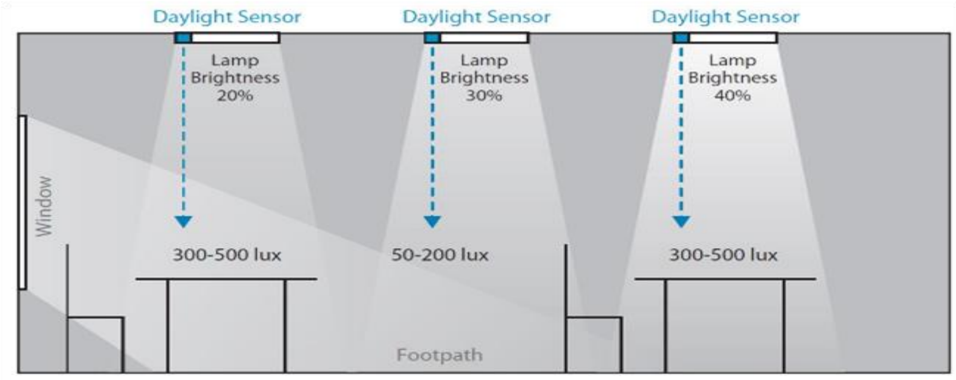
Figure 4.1:Luxometer in classrooms at the Greek pilot school buildings

This means that artificial lighting may not be always necessary for achieving good visual comfort. However, it is not possible to optimally adjust the artificial lighting according to available daylight due to limited control options, on-off of one or two groups of lighting fixtures in each classroom or office space.

For the reasons mentioned above, a lighting control approach for school buildings that aims to minimize electricity consumption for lighting is described below. The approach applies different strategies in classrooms and offices compared to other common spaces like corridors and restrooms.

<u>Strategy for classrooms and offices</u>

In a typical school classroom there are usually big windows in one side and smaller ones on the opposite side. In a typology like this, daylight can be utilized and contribute a lot to the necessary visual comfort as it was already mentioned. The proposed system is consisted of at least three groups of dimmable LED fixtures which are separately controlled by special sensors that measure luminous flux in different zones which the classroom has been divided to. In this way, at every moment visual conditions are optimized based on the available daylight. A schematic of this approach is provided below for better understanding.



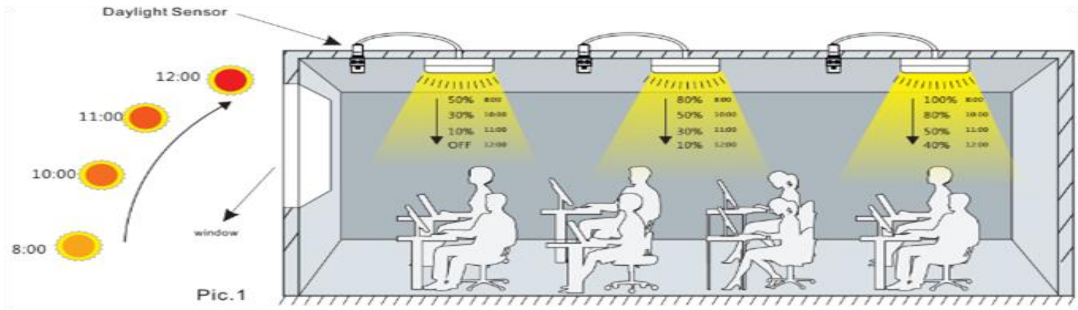
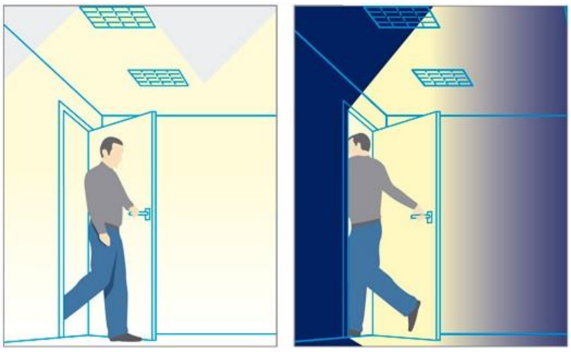


Figure 4.2 Two schematics of suggested lighting control strategy for classrooms

As it can be seen, sensors adjust the lamp brightness in order for luminous flux to be 300 lux (for classrooms) or 500 lux (for offices) on desk level on every zone. Between the zones, it can be less. A general timer could also turn off the lights after a specific hour in order to be sure lights will not stay on when class is empty, unless there is a central BEMS that control lights.

Strategy for the rest of the common spaces

In corridors and restrooms, standards demand a luminous flux of 100 lux. These spaces however are not used all the time and a presence sensor can be installed. In this way lights will be turned on only if someone is walking there or using the space. For the outdoor lights on the building's façade or on the school yard, motion sensor control in combination with a daylight sensor would be the most appropriate solution. These lights are used mainly for safety reasons during the night.



Energy saving that is achieved using automated control in lighting is not very easy to be estimated. Some guidebooks provide reducing factors depending on the type of automation and the building use. Greek technical guidebook of the national building performance regulation defines a 0.6 reducing factor for dimmable lights with daylight sensors only in spaces with available daylight and a 0.525 reducing factor for dimmable lights with daylight sensors in combination with auto switch off when nobody is present. For Motion or presence detector the relevant factor is 0.8. However, in each specific building the reduction depends on various factors and only with actual metering of electricity consumption can occur safe results.

Summary

In these learning modules, innovative methods for reducing energy consumption for ventilation and lighting has been explored. The main idea of these approaches is to use sensor based control of the systems. In this way it is ensured that the right levels if ventilation and lighting are achieved in a classroom with the minimum energy consumption. Thermal comfort and wellbeing matches low energy use. This is translated of to lower cost and less environmental impact.

While natural ventilation is the most common case for Mediterranean schools, mechanical ventilation provides many advantages. Innovative approach of ventilation system were proposed, that are suitable for retrofitting existing buildings. Applying the proposed ideas, indoor air quality can be ensure while heat loss due to ventilation needs will be minimized. The approaches presented were:

1. Natural ventilation with window actuators and various sensors
2. Mechanical ventilation local units with heat recovery and various sensors
3. Mechanical ventilation with heat recovery integrated in window frames

The first is a natural ventilation based approach while the other two suggest some kind of mechanical ventilation system with heat recovery. All of the methods use sensors to control the ventilation function of the indoor spaces. With a simple case study one can get an idea of the energy saving potential of a heat recovery ventilation system.

The other function of a building the module deals with is lighting. Apart from modern lamp technologies, controls of the lighting system in every indoor space can have an impact on energy consumption. Depending on the type of a school building space a different strategy is proposed. All strategies use various type of sensors to achieve a reduced energy consumption. The methods suggested were:

1. Classrooms and Offices: Daylight sensors with dimmable lights
2. Indoor common spaces: Presence sensor for lighting control
3. Outdoor spaces: Motion and daylight sensor for safety during the night

Energy savings achieved on these measures can be estimated based on reducing factors given by guidebooks of national building regulation or other literature.

Self Assessment

Question 1: *Which CO_2 concentration is considered above acceptable levels?*

1. 500 ppm
2. 800 ppm
3. 3000 ppm

Question 2: What is considered as an advantage of natural ventilation?

1. It doesn't consume any energy
2. It allows people to control air flow
3. It minimizes heat loss in winter

Question 3: How can a mechanical ventilation system help to reduce energy consumption for heating in the winter?

1. By including a heat recovery unit
2. By reducing the airflow rate
3. By keeping the windows closed

Question 4: When the heat recovery of a ventilation system should be by-passed

1. In Spring and Autumn
2. In very cold weather
3. When ambient temperature is equal or higher than the indoor temperature

Question 5: What does a heat exchanger do in a ventilation system with heat recovery?

1. It mixes the fresh air with the inside air.
2. It enables exhaust air to transfer part of its heat to the inlet fresh air

3. It adjust air flow rate according to the outdoor temperature

Question 6: Why the use of CO_2 sensors is proposed in the approach for ventilation systems in schools?

1. Because they warn students for high CO_2 concentration levels
2. Because they enable the ventilation system to be controlled based on the fresh air demand.
3. Because of them heat recovery is achieved in ventilation systems

Question 7: Which of the following is responsible for high heat loss due to ventilation?

1. Big temperature difference between external and internal environment
2. High airflow rate
3. Both of the above

Question 8: Where approach 1 for ventilation would be suitable for?

1. A school without small windows at the classrooms
2. A school that interventions should be kept to minimum
3. A school that has a lot of students per classroom

Question 9: Why lights in a classroom have to be divided in groups for the proposed lighting control approach?

1. Daylight does not illuminates all parts of the classroom with the same intensity
2. Front rows of desks need more light.
3. In order for the teacher to choose what lights to turn on or off.

Question 10: Why light fixtures of the proposed approach for classrooms and offices need to be dimmable

1. In order to achieve the optimum luminous flux at desk level depending on the daylight
2. In order to save electricity
3. Both of the above

Question 11: In what kind of classroom the control lighting approach is not expected to achieve significant energy savings

1. A classroom with big windows at two of its walls
2. A classroom with a few small windows
3. A classroom with many students

Question 12: Which of the following better describes the idea of the approaches that were proposed in this module?

1. Ventilation and lighting optimization based on user needs
2. Sacrificing thermal and visual comfort for energy saving
3. Enabling students to take control of the building systems

Bibliography

BINE Information Service “Ventilation in schools – Better learning conditions for young people” 2015

Innovative approaches. PCM's, cool materials and glass technologies

Abstract

The EU targets for reducing the impact of human activities on the environment have resulted in challenging requirements, particularly for the energy performance of new and existing buildings.

Several technological advances give the possibility to improve considerably the energy performance of the building envelope. The need to comply with challenging energy requirements boosts the application of high performance envelope solutions.

This module deals particularly with innovative materials for the building envelope, that constitute a step forward in terms of energy performance compared to today's standards. The module is divided in three main sections:

1. **Cool materials**: Highly reflective materials that help reducing the demand for air conditioning during summer by reflecting solar irradiation.
2. **Phase change materials:** Materials that melt/solidify at human comfort temperatures, allowing to increase the thermal inertia of the envelope.
3. **Innovative insulation systems:** A selection of new insulation systems that can be used instead of, or in combination with, traditional ones in order to achieve higher levels of thermal insulation.

Learning objectives

1. Understand the importance of cool materials in improving the performance of the envelope during summer and in mitigating the heat island effect.
2. Learn how to apply the concept of phase change materials to the improvement of the thermal inertia of a building.
3. Extend the knowledge of innovative insulation systems beyond standard materials.

Section 1: *Cool materials*

A relevant part of the incoming heat to a building is connected to solar irradiation. Depending on the latitude of the location, and on local weather conditions, solar irradiation can become the major contributor to the building heat balance, and hence to the demand for cooling.

The use of materials with high reflectivity to solar radiation is an ancient passive measure to reduce solar heat gain. It's the case of white or clear external surfaces and tin-glazed tiles, which are typical of the traditional architecture in the area of the Mediterranean and in the Middle East.

Ordinary white materials reflect a significant part of solar energy in the visible spectrum (0.4-0.7 μm). More innovative, reflective materials are characterized by high solar reflectance and high infrared emittance.

The solar reflectance index (SRI) expresses both properties through a single value, ranging from 0 (standard black surface) to 100 (standard white surface).

Very "hot" materials can have negative values, while very "cool" materials can have SRI greater than 100.

Beside natural materials with high reflectivity to solar radiation, several "cool" materials, generally coatings, have been developed in the last decades. They include:

- cool white materials, which reflect solar radiation both in the visible and in the infrared spectrum;
- cool coloured materials, developed by using infrared reflective pigments and other techniques; the reflectance in the infrared spectrum is higher than conventional materials with the corresponding colour
- cool materials whose thermal properties are improved by integrating phase change materials (PCMs);
- thermochromic coatings, which according to the environmental temperature change reversibly their visible colour, and therefore have high absorption during winter and high reflectance during summer.

Figure 2: Examples of roof covers: standard versus "cool" shingles

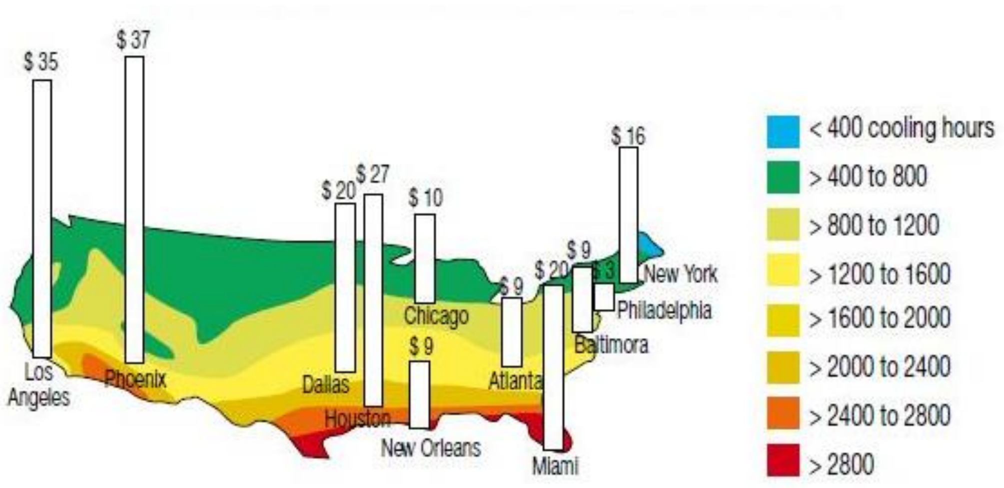


Figure 3: Average savings resulting from the application of cool materials in the US

Advantages and disadvantages of "cool materials" (in terms of energy savings and thermal comfort) are related to climate conditions. During winter, reflecting incoming solar radiation reduces solar gains, hence increasing the demand for heating. This makes cool materials appropriate for warm climates: the warmer the climate the higher the energy savings, while a careless application of cool materials (for instance in cold climates) might even lead to an increase in the overall energy demand of the building. These materials are also more effective in poorly insulated buildings.

Beyond directly reducing the energy demand for summer air conditioning, cool materials have an important role in the mitigation of the "heat island" effect, especially when used on pavements (roads, parking spaces etc.) and roofs. This phenomenon leads to a higher ambient temperature in the city centre when compared to suburban and surrounding rural areas, and is mainly related to the high density of buildings that absorb solar radiation, the lack of green areas, the use of highly absorbing materials, the characteristics of the urban canyons and the production of heat related to human activities. By reducing the heat absorbed by opaque surfaces, cool materials can take a crucial role into reducing this effect, hence providing a positive effect on the local air temperatures in cities during summer.

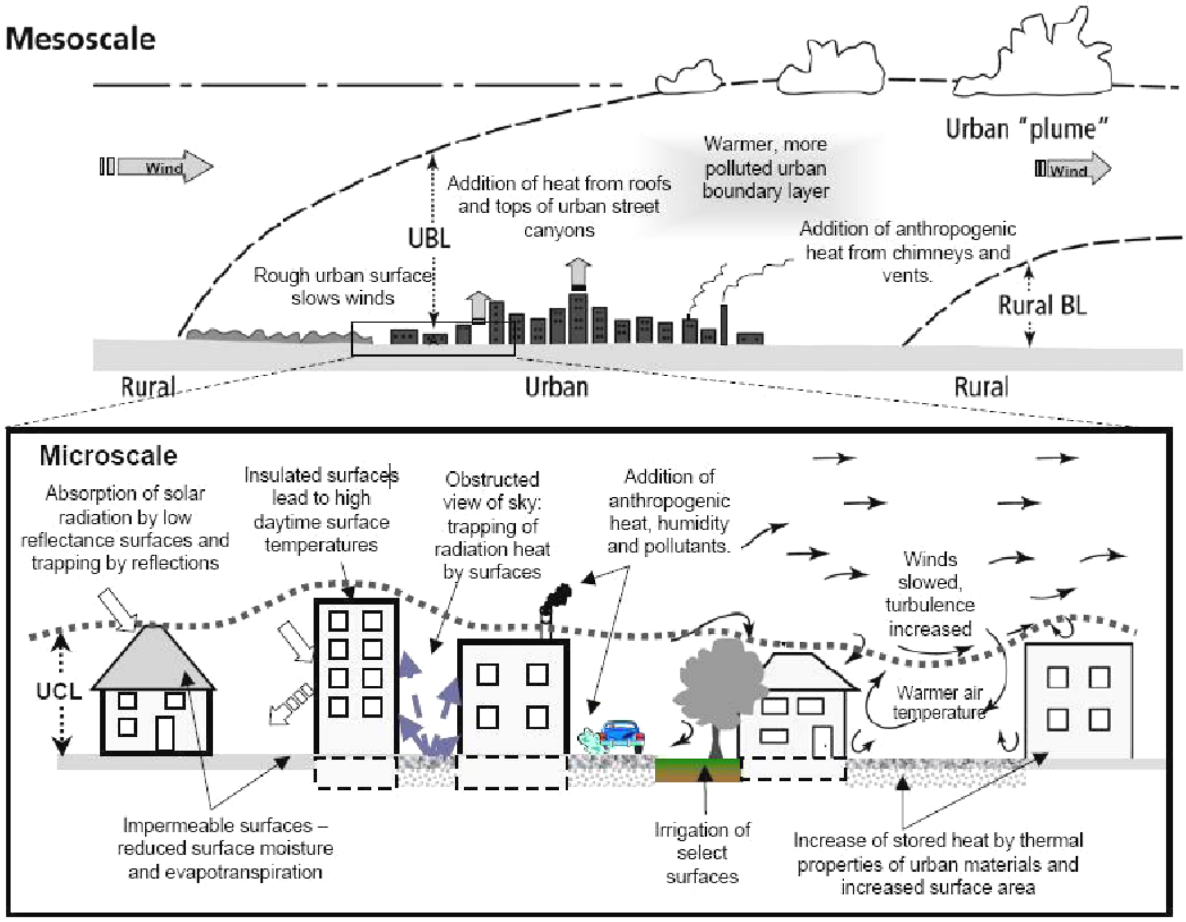


Figure 4: Graphical explanation of the heat island effect. From James Voogt, How Researchers Measure Urban Heat Islands

Section 2: Phase change materials

While extreme temperatures can reach high peaks (e.g. below 0°C during winter, and up to 35-40°C during summer) in most temperate countries, daily average temperatures are much closer to human comfort temperatures. This suggests that shifting the external loads could lead to substantial energy savings.

Increasing the thermal inertia of a building represents one possible solution to this challenge. Brick walls of a sufficient thickness can shift the heat gains by more than 12 hours, hence achieving the intent of reducing substantially the heating and cooling loads. For several reasons, however, it is not always possible to achieve this effect so easily. For instance, adding thermal inertia to an existing building only using "standard" materials might become a real challenge.

Phase change materials (PCM) are a technology that can overcome this gap. PCM use the latent heat of phase change (such as ice melting / water freezing) to store and release heat at a constant temperature. In practice, a PCM will store heat during the day by undergoing a melting process, thus changing its state from solid to liquid. As the temperature drops, the material will release energy and return to a solid state. Compared to standard materials only storing sensible heat, PCMs have a higher thermal capacity per unit of weight/volume.

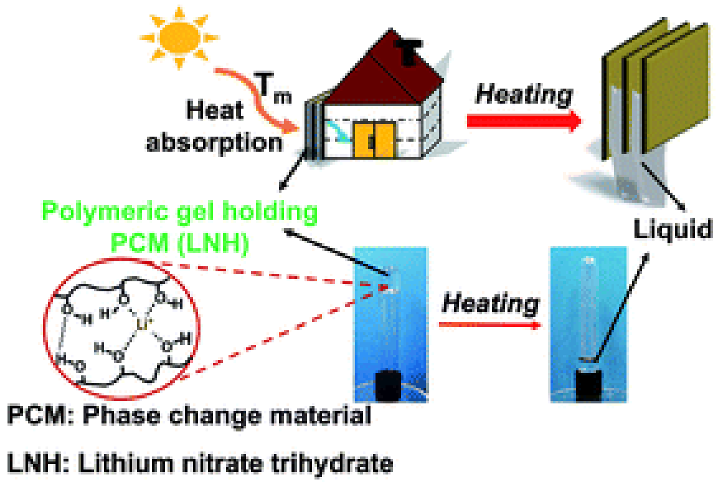


Figure 5: Working principle of phase change materials. From Karimineghlani et al. (2017), "A temperature-responsive poly(vinyl alcohol) fel for controlling fluidity of an inorgani phase change material", Journal of Materials Chemistry A (24)

In presence of air conditioning systems, the use of PCMs leads to a reduction of the HVAC energy demand, particularly during summer. When no air conditioning is available (or, more commonly, when only heating systems are installed), PCMs can lead to a more stable and comfortable indoor climate during summer. The selection of the specific PCM to be used depends on a number of properties, such as:

- Phase change temperature: normally between 22°C to 28°C for human comfort applications
- Latent heat of liquefaction: Higher latent heat means higher thermal inertia per kg

- Thermal conductivity: Higher conductivity results in faster thermal responses.
- Other non-energetic properties such as toxicity and durability.

PCMs are generally divided into organic (paraffins and non-paraffins), inorganic (hydrated salts) and eutectic PCMs (*melting composition of two or more components; the mixture can consist of inorganic with organic, organic with inorganic and organic with organic*).

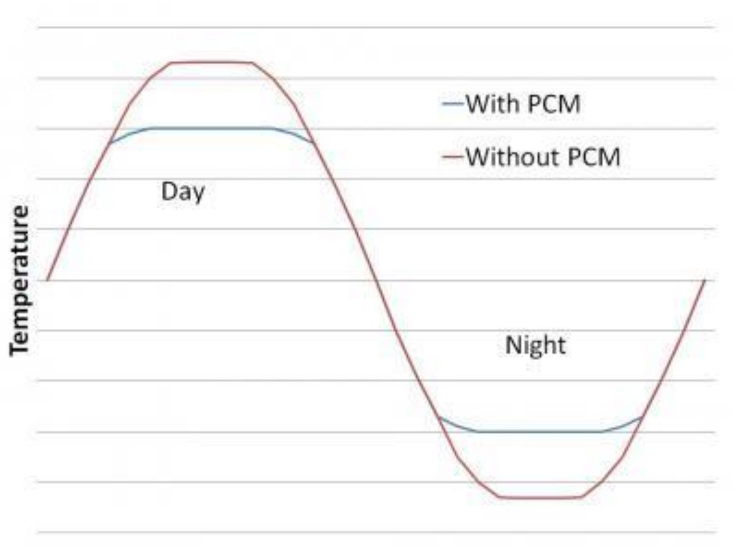


Figure 6: Effects of the use of PCM on the indoor climate conditions. It can be noted that the average temperature is constant, but the peaks are shaved. From cliamtetechwiki.org

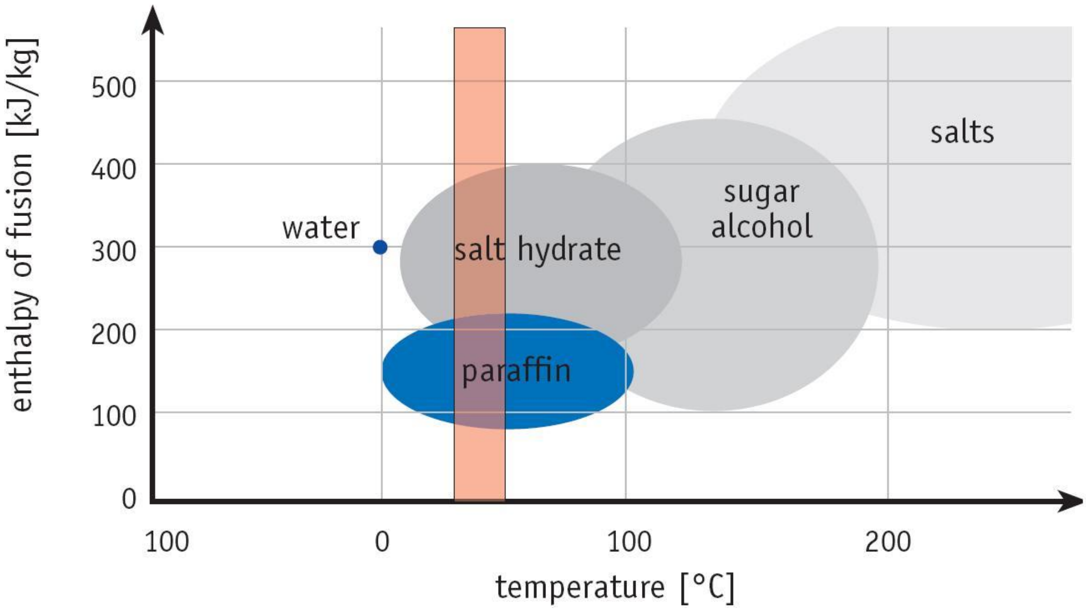


Figure 7: Typical phase change materials based on phase change temperature and enthalpy of fusion. It can be noted that paraffines and salt hydrates are the most suitable ones, based on their fusion temperature. From climatetechwiki.org

Since the majority of PCMs for building applications go through a liquid phase, PCM encapsulation is preferred to direct incorporation and immersion of PCMs in building materials, in order to avoid problems such as leakages. PCMs are encapsulated following two main methods: microencapsulation and macroencapsulation. They differ from each other in size and shape given to PCMs. The shell materials commonly used for microencapsulation consist of organic polymers or silica.

Common applications of PCMs are in wallboards but solutions are available for floors (floor tiles), roofs, shutters and windows. They can also be used in plasters and current research focuses on the incorporation of PCMs into fibrous thermal insulation materials.

Section 3: Innovative insulation systems

3.1 Reflective technology for thermal insulation: radiant barrier and reflective insulation

Most thermal insulation systems are designed to reduce heat transfer through conduction (and, to a minor extent, through convection). This is the case of the most common insulating materials, such as mineral wool, fiberglass, and different types of plastic and natural fibres.

Heat is however transferred also through a third mechanism: radiation. Depending on the specific situation, radiative heat transfer can represent a major contribution of the overall heat transfer.

Reflective technologies for thermal insulation are used to reduce the heat transfer by thermal radiation. The main idea behind thermal insulation using reflecting technologies is that of having a gap between two layers, normally filled with air, where the two layers facing the gap are at different temperatures. By covering one, or both of the surfaces facing each other with a thin layer of a material that tends to reflect, rather than absorb radiative heat, it is possible to dramatically reduce the heat transferred by radiation.

Insulation technologies based on reflection are generally categorized as either radiant barriers or reflective insulation.

Radiant barriers are generally installed in attics primarily to reduce summer heat gain and reduce cooling costs. When the sun heats the roof, it increases its temperature and heat travels by conduction through the roofing material to the attic side of the roof. At this point, the hot, inner surface of the roof radiates heat towards the cooler attic surfaces. A radiant barrier reduces the radiant heat transfer from the underside of the roof to the other surfaces in the attic, and it was shown that their use can reduce cooling costs by 5% to 10% when used in a warm, sunny climate. Radiant barriers are, however, more effective in hot climates than in cool climates, where it is usually more cost-effective to install more thermal insulation than to add a radiant barrier.

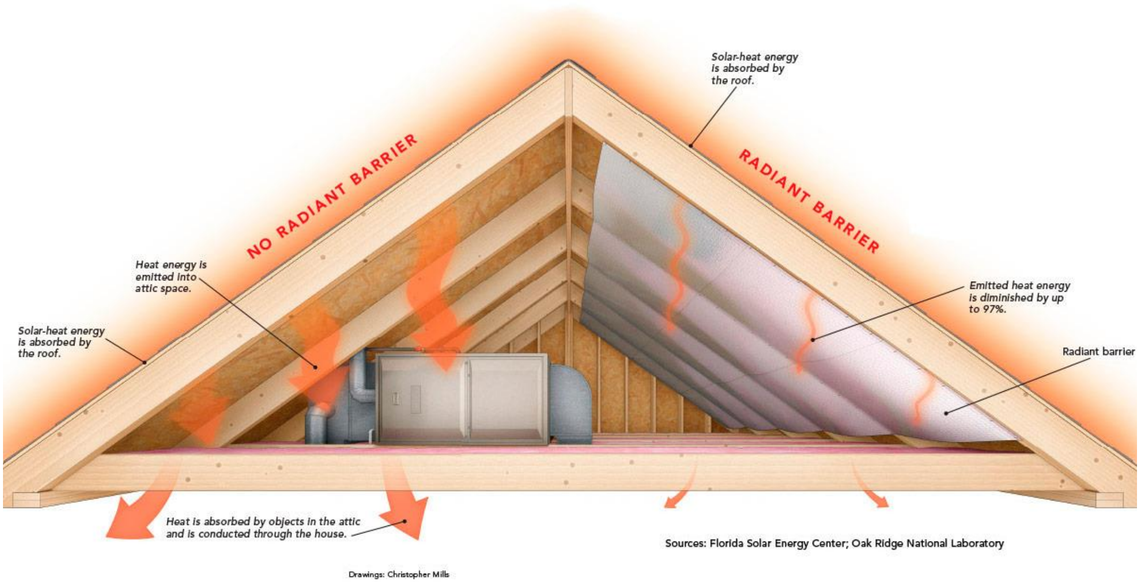


Figure 8: Working principle of a radiant barrier installed in an attic. From finehomebuilding.com

Reflective insulation consists of one or more low emittance surfaces separated by air spaces, generally placed on an insulating support layer that supports the foil and provides a small thermal resistance to the insulation system. The airspace needs to be thin enough not to allow for convective motions, hence in the order of 1-2 cm, and it can be either a single cavity, or enclosed in bubbles. Reflective insulation is used in the same way as a standard insulation layer, unlike radiant barriers, making it possible to measure the resistance (R) of the reflective insulation, although this value strongly depends on the installation and on operating conditions. Compared to standard insulation materials (e.g. mineral wool), reflective insulation does not degrade with time and it is not affected by humidity. It serves best as insulation during summer, while it is less efficient for winter insulation.

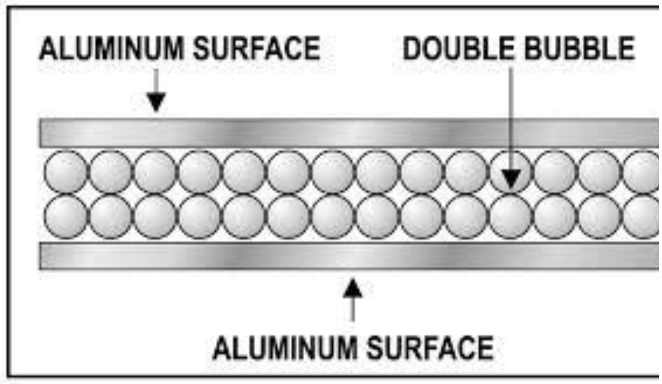


Figure 9: Construction principle of reflective materials

Figure 10: Example of a roll of reflective material

3.2 Vacuum Insulation panels (VIP)

Heat is transferred through three mechanisms, that normally happen at the same time: conduction, convection, and radiation. The first two require a medium (in the case of convection, it has to be either liquid or gas). Radiative heat exchange can be reduced to almost zero using reflective surfaces. So what happens if the two reflective surfaces are separated by a thin layer of vacuum?

A vacuum insulation panel (VIP) consists of a porous core enveloped by an air and vapour tight barrier. The structure of the core is of an “open-pore” type, that allows for the air to be evacuated, thus allowing creating vacuum.

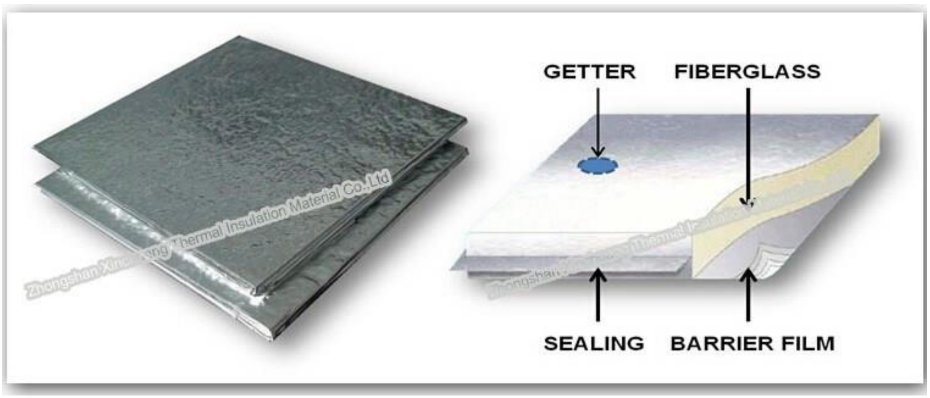


Figure 11: Example of vacuum insulated panel

Vacuum insulation panels (VIP) make use of this strategy to obtain much higher performance compared to standard insulating materials. The equivalent conductivity of a VIP (0.004 $\frac{W}{mK}$) can be as much as 10 times lower compared to e.g. mineral wool, making it possible to achieve the same performance with a much lower thickness.

As far as the core is concerned:

- The pore diameter of the core needs to be small, otherwise a very low pressure is necessary to obtain low thermal conductivity
- The pore structure needs to be completely open, in order to evacuate the gas easily;
- The core needs adequate compressive resistance;
- The material has to be impermeable to infrared radiation, to reduce radiative heat transfer

Materials used for the VIP core include fibre-powder composites, polycarbonates, phenolic foam, ultrafine glass fibres.

The envelope has to maintain vacuum in the VIP core. The conservation of this condition is crucial for the thermal performance of the panel. The envelope is made of

- A **sealing layer** (inner layer): it generally consists of low or high density polyethylene.
- A **barrier layer** (middle layer): aimed at protecting against water vapour and air transmission through the envelope; it is generally an aluminium foil or a multilayer laminate.
- A **protective layer** (outer layer): against external stresses and damages.

VIP's very high performance makes them particularly attractive when space is limited. However, their durability raises concern, as any damage to the envelope can completely compromise the thermal performance. In addition, the fact that panels cannot be cut to fit the surface that they are used on makes it necessary to design them for the specific application.

Conclusion

The challenges set by the increasing need of reducing energy demand because of climate change will also be met by technological improvements. Recent developments offer to professionals working in the built environment several solutions that dramatically improve the energy performance of buildings, without compromising comfort, durability, and at low cost.

In this module, we have presented some of these new technologies, focusing on the building envelope, that we consider the most promising for the purpose.

- **Cool materials** are highly reflective materials that help reducing the demand for air conditioning during summer by reflecting solar irradiation. They are particularly effective in hot climates and in highly-populated areas, where they help limiting the "heat island" effect.
- **Phase change materials** are materials that allow increasing the thermal inertia of the envelope by melting/solidifying at appropriate temperatures. This allows shaving peak demands during the hottest (or coldest) hours. They are mostly effective in warm climates.
- **Innovative insulation systems** are a selection of new insulation systems that can be used instead of, or together with, traditional ones in order to

achieve higher levels of thermal insulation. **Radiant barriers** and **reflective insulation** systems are based on limiting the radiative heat exchange, and are mostly used in attics (radiant barriers) and in the form of insulating panels (reflective insulation). Vacuum insulation panels act on all three heat transfer mechanisms, and can perform up to 10 times better compared to standard insulation systems.

The appropriate use of these technologies, in combination with a correct understanding of the application environment and an appropriate design of the HVAC systems can lead to achieving a NZEB design even in the most challenging situations.

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- http://www.polyglass.com/
- http://coolroofs.org/

About phase change materials:

- https://www.designingbuildings.co.uk/wiki/Phase_change_materials
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About innovative insulation systems:

- https://vipa-international.org/vacuum-insulation-panels
- https://na.industrial.panasonic.com/products/hvacr-appliance-devices/vacuum-insulation/lineup/vacuum-insulation-panel

Study questions:

1. Are cool materials convenient in all types of climates?
    a. Yes: they reduce the energy bill both in winter and in summer
    b. Yes: they only reduce the energy bill during summer, but have no effect on the winter performance
    c. No: In cold climates they do not have any positive effects
    d. No: In cold climates the gains during summer are not balanced by the increase in winter heating resulting from the loss of solar gains.
2. How do phase change materials contribute to reducing the energy demand of a building?
    a. They increase the level of insulation: a material during phase change has a very low conductivity
    b. They increase the thermal inertia of the envelope, thus allowing to “shave out” the temperature peaks
    c. They prevent the formation of humidity, which deteriorates the insulation layer
    d. The phase change increases their volume, hence reducing their conductivity
3. Which of the following systems work(s) according to the same principle as a vacuum insulation panel? (Note: there might be more than one correct option)
    a. A thermos
    b. An airspace cavity
    c. A Dewar flask (if you don’t know what it is, Google it!)
    d. A sweater

4. What is the difference between radiant barriers and reflective insulation? (Note: there might be more than one correct option)

a. Radiant barriers work best in winter, reflective insulation in summer

b. Reflective insulation limits convective heat transfer, while radiant barriers acts on radiative heat exchange

c. Reflective insulation requires a layer of still air between two reflective layers. Radiant barriers are used on open air spaces instead

d. They are both mostly effective in warm climates, but reflective insulation is more versatile.

Sustainable renewable solutions in schools. Thermal, photovoltaic solar energy, and geothermal. Practical application cases

Thermal. Solar heating of School Buildings

Presentation of the module

In this module, the potential of solar energy for heating building spaces will be presented. Solar energy is widely used in the southern Europe for the production of domestic hot water (DHW) but it can be also used for heating spaces in houses or other type of buildings. Heading to a future with nZEB buildings solar energy has to be exploited to the fullest. A heating system that is enhanced by solar energy could make a promising contribution in reducing a building's energy consumption.

The main components of such a system are the solar collectors like in DHW production but larger surface is needed for space heating. The potential is higher in the Mediterranean countries because of the higher number of hours of sunshine. In general it is not feasible to just rely on the sun for space heating. This happens mostly because of the very large solar collector area that is needed in order to cover big loads of space heating and the variability in weather and sunshine during a day especially in the winter when heating is needed. However, a typical heating system can be aided with thermal energy coming from solar collectors increasing the overall system's efficiency. In this way the amount of fuel or electricity that is needed for heating can be minimized.

Educational Objectives:

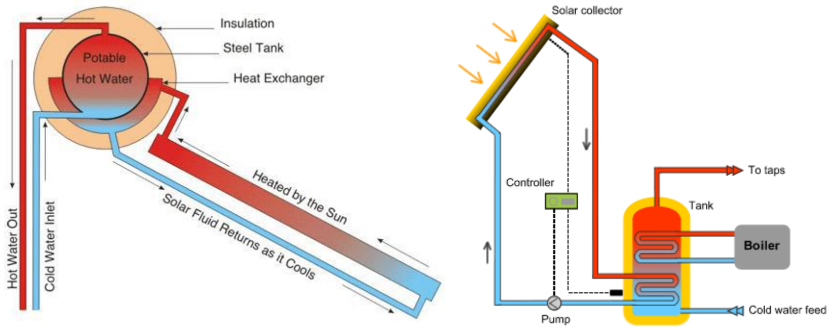
- To be familiar with basic principles of a solar thermal system function and basic components
- To understand the contribution of a solar thermal system in the overall efficiency of the heating system of a school building
- awareness of the local community in achieving significant energy savings
- capacity to select the most appropriate incentive for energy renovation project

Thermal solar system for heating spaces

Introduction in solar systems for heating

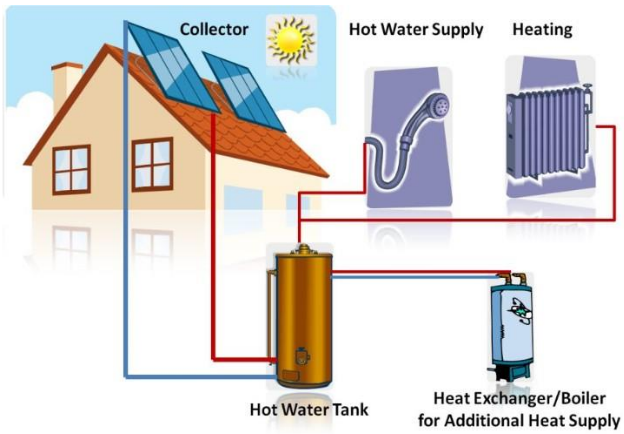
Solar systems for heating or solar thermal systems are based on a technology designed to harness sunlight for its thermal energy (heat). This heat is often used for heating water used in homes, businesses, swimming pools, and for heating indoor spaces of the buildings (space heating). In order to heat water using sunlight, a solar thermal collector heats a fluid that is pumped through it. As the fluid is pumped through the collector, the fluid becomes heated. The now heated fluid then is pumped out of the collector and transfers its thermal energy to water through a heat exchanger that is usually installed in a hot water storage tank. This water is either DHW or is used in a space heating circuit. When it is used for both DHW and space heating it is often called a “combi system”.

A solar thermal system that is designed only for DHW production can be as simple as the one depicted in the following figure. The characteristic of this system is that the hot water storage tank is located above the solar collector and in this way the hot fluid is circulated naturally. When the hot water storage tank is located elsewhere, usually lower than the collectors, then a pump is needed to move the fluid around the circuit. A controller is also needed to give the order to the pump based on water temperature measurements.



Natural and biased flow solar systems for DHW

In a space heating system the storage of the hot water is usually also lower than the collectors’ level and larger than a DHW system. For this reason it is a forced flow system using pumps and controls. The water that is heated in the storage tank by the solar energy is then distributed to the terminal systems like radiators, fan coils or floor heating.



Sketch of a combi solar system

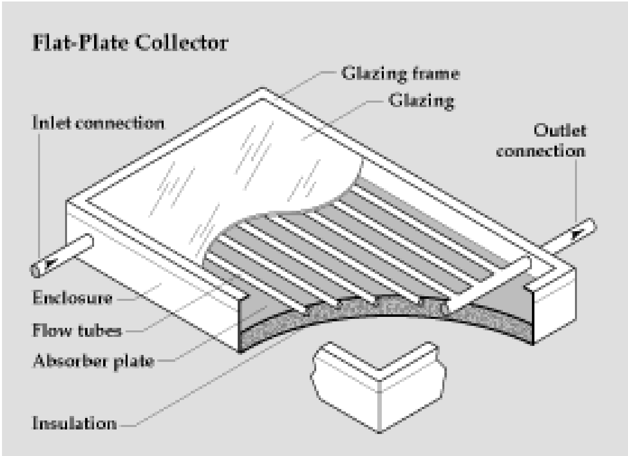
Solar space heating systems are designed to provide large quantities of hot water for residential and commercial buildings. A typical system includes several components:

- **Solar collectors** absorb sunlight to collect heat. The heat is then transmitted to the fluid (heat transfer fluid) that flows in the collector in tubes. There are various types of collectors depending on the application and are explained further below.
- **Heat transfer fluid** (also called solar fluid) is a fluid that is used as the medium to transfer heat from the solar collector to the storage tank. The fluid is usually a mix of a glycol with water that has some thermal properties ideal for the solar system (e.g. low freezing point, high boiling point etc)
- **Pumps** are used in active systems to circulate the fluid through the solar collectors. A controller is used to turn the pump on when the sun is shining and off for the rest of the time. Pump size depends on the size of the system and the height the water has to rise.
- **Heat exchanger** is used in closed-loop systems to transfer the heat from the fluid to the water without mixing the liquids. They are located inside the storage tank.
- **Storage tank** holds the hot water. The tank can be a modified water heater, but it is usually larger and very well insulated. The tanks of solar thermal systems usually have two heat exchangers one for the solar fluid to transfer its heat to the water and one for another heat source to contribute to the solar energy and it is called auxiliary system and will be explained below. Specialty or custom tanks may be necessary in systems with very large storage requirements. They are usually stainless steel, fiberglass, or high-temperature plastic. Concrete and wood (hot tub) tanks are also options.
- **Monitoring system** used by system owners to measure and track system performance.

Solar collector types

The solar collectors that are meant for solar heating in buildings and their task is to absorb heat from the solar irradiation are divided in two categories: the **flat plate collectors** and the **evacuated tube collectors** and are described below. Another type of collectors are those which use parabolic surfaces to concentrate the sunlight onto water pipes or onto a single point in order to reach very high temperatures to generate steam in solar thermal power plants thus they are not used for building applications.

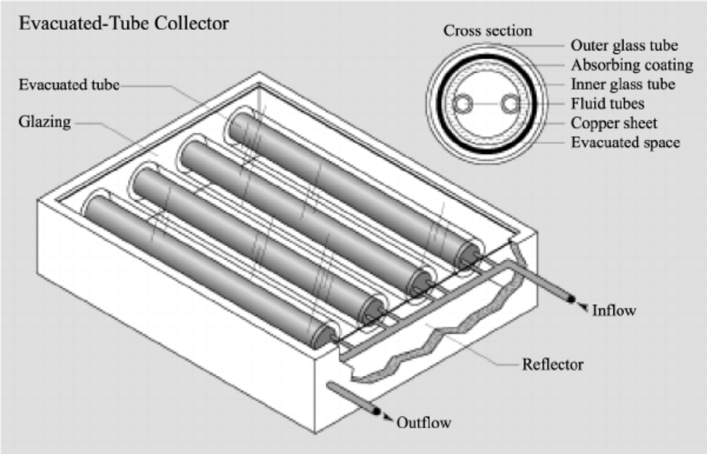
The flat plate collectors are simply metal boxes that have some sort of transparent glazing as a cover on top of a dark-colored absorber plate. The sides and bottom of the collector are usually covered with insulation to minimize heat losses to other parts of the collector. Solar radiation passes through the transparent glazing material and hits the absorber plate. This plate heats up, transferring the heat to either water or air that is held between the glazing and absorber plate. Sometimes these absorber plates are painted with special selective coatings designed to absorb and retain heat better than traditional black paint. These are often called selective collectors. The plates are usually made out of metal that is a good conductor usually copper or aluminum.



Flat plate collector components schematic

Flat plate collector arrays on top a building roof

Evacuated tube collectors are very efficient at retaining a large percentage of the heat collected from the sun. Each tube works independently from the others, and is surrounded by a double wall tube of glass. In between the double walls is a deep vacuum, producing an effect which greatly increases its thermal insulation. This design allows the sunlight to pass through the glass, but allows very little heat to escape. In many evacuated tube collectors heat pipe technology is used. A copper heat pipe is inside the evacuated tube, held in place by thin pieces of metal, called heat transfer fins. The heat pipe is also under a vacuum, which allows the water inside to boil at a much lower temperature. As the water boils, the vapor rises to the top of the heat pipe, which sits inside the collector's header. Water or heat transfer fluid (usually a water/glycol mixture) passes through the header, where it comes in contact with the tops of the heat pipes, thus heating up rapidly. Evacuated tube solar collectors are well-suited to commercial and industrial heating applications and can be an effective alternative to flat-plate collectors for domestic space heating, especially in areas where it is often cloudy as they tend to absorb better the diffuse solar irradiation than the flat plate collectors.



Evacuated tube collector components schematic

Control of the fluid circulation

Two types of control schemes are commonly used on solar collectors on building-scale applications: on–off and proportional. With an on–off controller, a decision is made to turn the circulating pumps on or off depending on whether or not useful output is available from the collectors. With a proportional controller, the pump speed is varied in an attempt to maintain a specified temperature level at the collector outlet. Both strategies have advantages and disadvantages, largely depending on the ultimate use of the collected energy.

Hot water storage tank

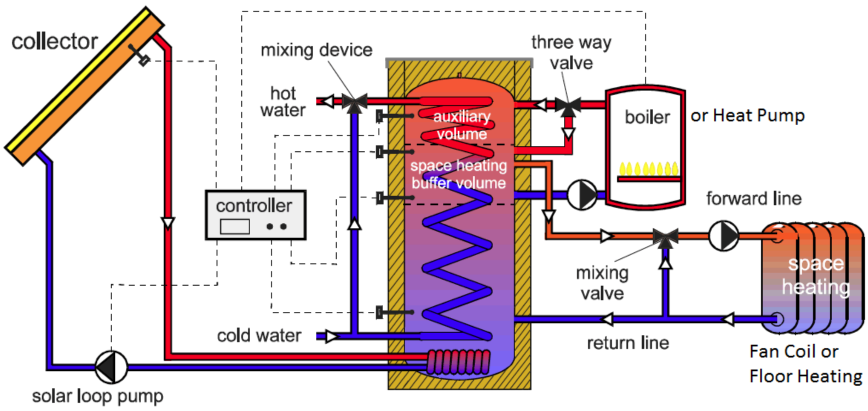
A solar heating system usually requires a big storage tank. A lot of research has been done about the ideal relation between the surface area of the solar collectors and the size of the storage tank. This depends on a lot of variables and specifications of each case study. One of the main characteristic of each case is how big the mismatch between solar radiation and the actual heating load is. Due to morning school hours, the mismatch is not big however when it is sunny the temperature tend to be milder and less heating load is needed. Short term or long term heat storage is also a factor affecting storage tank size. The simplest case of a solar thermal heating system is short term heat storage. Seasonal and annual heat storage is also possible but requires very large water tanks.

Solar thermal system for heating spaces characteristics

Now that all components and main characteristics have been described, the general function of a complete solar heating system is going to be briefly presented. As it was mentioned before, solar energy cannot cover by itself the heating load of a building. An auxiliary system helps the heating system to raise the water temperature to the desired levels. These levels are strongly depended on the type of terminal systems. If conventional radiators are used water of 60-80 °C is needed while fan coils would require 40-50 °C. A floor heating system needs water of maximum 45 °C but in bigger volume than other systems because of big length of piping.

The water storage tank of the system has two heat exchangers, one for the solar collector loop and one for the auxiliary system loop. The water in the tank is heated up to a temperature from the sun and the rest of the heat needed for the heating system to be effective is given by the auxiliary system. The later can be an oil or gas boiler or a heat pump. When the terminal systems of the building are no high temperature radiators a heat pump is the most ideal auxiliary heat source. The reason for this is because the efficiency of a heat pump (COP) increases as the inlet water temperature increases. The same heat pump that heats up water from the mains that is at 10 °C and water from the storage tank that is 30 °C will be much more efficient in the second case. Higher efficiency means less electricity consumption and energy savings.

In general, the percentage of solar energy utilization in solar heating systems is called solar utilization factor. The higher it is the highest is the solar energy exploitation. The factor expresses the ratio of the total solar energy that falls onto the solar collectors and the total thermal energy that is eventually gets into the building spaces. On the other hand, the solar fraction is defined as the amount of the solar energy provided for heating divided by the total energy required for heating.



A schematic of a solar thermal system for heating spaces and DHW with an auxiliary system

In the case of school buildings, a solar thermal system for heating classrooms and offices could contribute to great energy savings for heating. School hours are usually in the morning till noon or early afternoon. This means that school operation coincides with sunshine hours when the weather is not rainy or cloudy. Water in the storage tank will be also warm if the previous day was sunny and it will start getting warmer again in the morning. Old school buildings in the Mediterranean area usually have high or low temperature radiators as terminal systems. Low temperature radiators would be a more efficient solution to combine with a solar thermal system and a heat pump. Low temperature radiators are bigger in size but space is not usually a problem in typical school classrooms.

Each building case and its potential for a solar thermal system is unique and has to be designed as so. However, simulation software nowadays can be of great help for the designer to optimize such systems and minimize energy consumption for heating in schools and other types of buildings.

For further research a reference of 5 case studies of solar thermal systems (both solar heating and cooling) is given below:

http://www.cres.gr/cres/files/xrisima/ekdoseis/ekdoseis_EN3.pdf

4. Practical application case (Thermal):

Schools – Karlovac County

The project signed between HEP ESCO and the Karlovac County was implemented on the basis of two contracts, covering energy efficiency measures on electromechanical systems and building envelope. In total, the Project encompasses about 20 energy efficiency measures in eight schools, the value of equipment and works being about 8.2 million kuna.

The energy efficiency measures on electromechanical systems included modernization of indoor lighting and heating systems in four schools. Modern fluorescent lamps with electronic dimmers were installed, whereby interior lighting has been improved and energy consumption reduced.

Besides lighting improvement, electricity-related measures included installation of reactive energy compensator. Heating modernization included installation of automatic heating controls responding to external temperature, thermostatic valves for room temperature control and replacement of a worn hot water boilers with a new high-efficient boilers. All of these measures have resulted in reduced energy consumption for heating, contributing to energy efficiency.

Regarding energy efficient measures on building envelope, in four schools obsolete external carpentry (old wooden windows) was replaced with multi-chamber PVC carpentry and low-heat loss glazing. Thermal insulation of the façade of one school was also performed. These structural measures significantly reduce the level of heat energy required for heating, contributing directly to savings.

After all works were carried out and HEP ESCO Project completed, the schools were left with modern equipment and improved heating and lighting systems which are less costly to use and maintain.

It is also important to point out that energy efficiency measures on building envelope significantly reduced heating energy demand**.**

Implementation of this project resulted in improvement of comfort and work conditions for all users of the school buildings.

This Project has disencumbered the local community while achieving significant financial and energy savings. Project was to change the behaviour of users, by means of managing buildings in a continuous & energy efficient manner.

Table 2 List of energy efficiency measures and savings

Measure:	Approximated savings
Reconstruction of boiler room (installation of new energy efficient and automatic regulation)	Up to 14%
Installation of thermostatic valves	Up to 5%
Modernization of indoor lighting	Up to 38%
Replacement of old windows with new PVC windows	Up to 43%
Thermal insulation of the building envelope	Up to22%




Figure 12 Energy efficiency measures (before and after implementation)

Summary

In this module a brief description of how it is possible to exploit free solar energy for heating spaces was described. The basic components and function principles of solar heating systems were presented. From the solar collectors to controls and hot water storage tank, a solar thermal system has to be tailored for each case study and matched with a suitable auxiliary system to maximize efficiency. The mismatch of when solar radiation occurs and when heat load are demanded is solved with appropriate sizing of the system, which means solar collector area and hot water storage tank. For this reason schools could be of great cases for solar thermal systems as they operate during morning hours and usually tend to have plenty of empty roof space. Finally the combination of a solar thermal system with a heat pump is an ideal solution for increasing the heat pump efficiency and decreasing energy consumption.

Solar collectors (evacuated tube) on top of a building with the appropriate inclination

Self Assessment

Question 1: A solar thermal system can be used:

4. For generating electricity in school buildings
5. Only for the production of domestic hot water
6. For heating spaces in school buildings

Question 2: A solar thermal system:

4. uses solar collectors for the heating of water that is then used for domestic hot water or for heating indoor spaces
5. has the same function with a P/V system, but is cheaper
6. uses geothermal energy for heating spaces in a building

Question 3: The main contents of a solar thermal system include:

4. p/v panels, boiler, electrochemical elements, a controller and tubes
5. a solar collector, a pump, a controller, a heat exchanger and a water storage tank
6. a heating pump, a controller, a wind turbine and a battery

Question 4: What is a solar fluid?

4. An oil liquid used for the collection of the solar energy
5. It's a fluid transferring heat from the solar collector to the hot water storage tank
6. A liquid collected by a thermal system through solar radiation

Question 5: The 2 main types of solar collectors are:

4. Spherical collector & narrow line collector
5. Evacuated tube collector & flat plate collector
6. Transparent collector & rainbow collector

Question 6: What would be the most ideal combination of auxiliary system and terminal systems for a solar heating system in terms of energy efficiency?

1. Gas boiler with radiators
2. Oil boiler with fan coils
3. Heat pump with under-floor heating

Question 7: In a building with a solar thermal system the higher the solar fraction is:

1. The lower the solar energy exploitation is
2. The higher the energy savings for heating
3. The less water is heated in the storage tank

Question 8: Which of the following is not energy renovation?

1. A boiler service
2. Modernization of heating systems
3. Replacement of boiler with a new high-efficiency boiler

Question 9: The purpose of M&V is:

1. To ensure marketing and visibility of implemented measures
2 To monitor energy consumption and verify the achieved savings
3 To maintain the technical systems in the building

Question 10: Which of following energy efficiency measures can generate savings above 40 %:

1. Modernization of indoor lighting
2. Measures on building envelope (thermal insulation and window replacement)
3. Reconstruction of the boiler room

Question 11: Which of following energy efficiency measures generate savings in average of 5 %:

Reconstruction of boiler room (installation of new energy efficient and automatic regulation)

1. Installation of thermostatic valves
2. Replacement of old windows with new PVC windows
3. Modernization of indoor lighting
4. Thermal insulation of the building envelope

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https://energyeducation.ca/encyclopedia

Photovoltaic solar energy

TITLE OF MODULE 9: Sustainable renewable solutions in schools. Photovoltaic solar energy. Practical application cases.

- Presentation of the module [15 minutes]

PRESENTATION

This is the 9th module of the TEESCHOOLS E-learning course.

Renewable energy is, indisputably, a core issue in the world today. Renewable energy technologies utilise natural and recurring energy sources to generate power. The installation of renewable energy sources nowadays is a priority, from local to international scale, as they have multiple benefits. It is not only the fact that they reduce the energy costs, but they are also important for a variety of other reasons.

By using energy from renewable sources -such as the sun, the wind or the water-, instead of fossil fuels, the global warming emissions are reduced, creating a better and healthier environment. At the same time, Renewable Energy Sources (RES), reduce air and water pollution, they provide low operation cost and help to keep energy prices stable. The importance of clean, affordable energy has never been more relevant.

However, like every other technology, RES have also some challenges which should be taken into consideration. In specific, they are vulnerable to weather and other climate events, they might provide limited supply of energy and they are usually[23] characterised by a high capital cost. Moreover, most RES systems require a large space to set up, and they are not available in all areas due to climatic, technical or legislative limitations.

Overall there are various renewable energy sources for the generation of electricity such as the:

- Solar energy;
- Wind power;
- Hydraulic power;
- Biomass;
- Electricity production through cogeneration systems.

Nonetheless, at the scale of school buildings and during their refurbishment, only some generation systems can easily be integrated. One of the most advanced solutions is the installation of Photovoltaic Solar Energy which is presented in this Module. The electricity generation using photovoltaic panels, has both financial and environmental interest for educational buildings.

<u>What is included in the Module:</u>

[23] As the technologies are advancing, the prices of the RES are reducing. This is more obvious in the case of Photovoltaic systems, where it observed a significant reduction in their capital costs over the last years.

This module consists of 5 sections, with a total duration of 3 hours, related to the sustainable renewable solutions in schools and in specific, to the Photovoltaic solar energy, as follows:

- Section 1: Introduction of RES/PV. European legal supporting framework [30 minutes]
- Section 2: Energy from Photovoltaic Systems [30 minutes]
- Section 3: Design of PV solar plants [30 minutes]
- Section 4: PV system typologies [45 minutes]
- Section 5: PV systems in schools [45 minutes]

The chapters go through a simple action-learning process designed to assist people in the relevant field to learn about the photovoltaic energy as a sustainable renewable solution in schools. Besides the 5 main chapters there is also a resource chapter provided in the last part of the module.

In the end of the Module, there are 15 questions for Self-Assessment, with a total duration of 45 minutes.

Additional / External information is provided throughout the Module.

Learning objectives of the module

Knowledge:

- The importance of the Renewable Energy and in specific of the electricity production from PV systems
- The European legal supporting framework for RES
- The basic parts of the PV systems
- How energy is produced from PV systems
- The basic steps for understanding and designing a PV system
- The variety of the existing PV systems
- How PV systems are implemented in schools

Skills/Competence:

- Able to explain the European framework for RES
- Able to explain the energy production from the PV systems
- Able to identify PV systems and their components
- Able to explain the existing PV technologies
- Able to create and implement a scenario for the installation of a PV system in schools

CONTENT OF THE MODULE 9

Introduction of RES/PV. European legal supporting framework

The use of renewable energy sources is seen as a crucial element in energy policy, reducing the dependence on imported fossil fuels and the respective emissions, and decoupling energy costs from oil prices. The EU has adopted policies in order to support the use of RES. In specific, in December 2018, the new revised Renewables Energy Directive (2018/2001) entered into force – establishing a new binding renewable energy target for the EU for 2030 (with a clause for a possible upwards revision by 2023), of at least 32% share from renewable sources in gross final energy consumption (member-state specific targets not yet agreed on).

This is the 2nd target set at EU level, with the first one set on 2007[24], at 20% energy from renewable sources in gross final consumption of energy and it is one of the important indicators of the Europe's '2020 strategy'. Each EU Member State has adopted the European Directive and set its own 2020 targets on national level. The national targets take into account the Member States' different starting points, renewable energy potential, and economic performance. A database with all the available national renewable energy action plans for 2020 is available at: https://ec.europa.eu/energy/en/topics/renewable-energy/national-renewable-energy-action-plans-2020.

By 2017, the share of renewables in EU energy consumption reached the 17.5% in gross final energy consumption. The aggregate results and the status of each EU member state are shown in the following diagram.

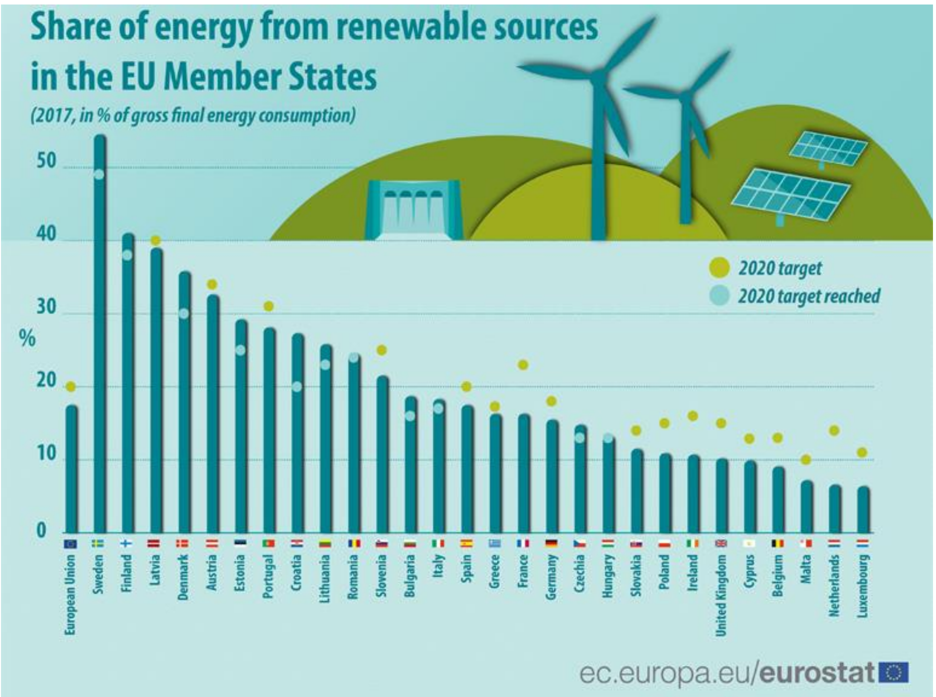


Figure 13: Share of energy from renewable sources in gross final consumption of energy in the European Union (EU). Eleven EU Member States have already reached their 2020 renewable

[24] The European Council in 2007 adopted ambitious energy and climate change objectives for 2020 – to reduce greenhouse gas emissions by 20%, rising to 30% if the conditions are right(2), to increase the share of renewable energy to 20%, and to make a 20% improvement in energy efficiency.

energy targets since 2015 (eurostat newsrelease, 27/2019 - 12 February 2019).

More information about the status of Energy from Renewable Sources for each member state can be find on:
https://ec.europa.eu/eurostat/web/energy/data/shares .

N.B. Regulation (EC) No 1099/2008 of the European Parliament and of the Council, Directives 2001/77/EC and 2003/30/EC of the European Parliament and of the Council, and Directive 2009/28/EC, established definitions for different types of energy from renewable sources.

It should be noted that having a binding Union renewable energy target for 2030, will keep encourage the development of renewable energy technologies. It will also leave greater flexibility for Member States to meet their greenhouse gas reduction targets in the most cost-effective way and in accordance with their specific circumstances. For this purpose, each Member State should also establish a financial framework aiming to facilitate investments in renewable energy projects[25].

Regarding the electricity production from RES, small-scale installations have been proved to be of great benefit to increase public acceptance and to ensure the rollout of renewable energy projects, in particular at local level. In order to ensure partaking of such small-scale installations, specific conditions, seem to still be necessary to ensure a positive cost benefit ratio, in accordance with Union law relating to the electricity market.

Table 3: Proportion of electricity production from RES, for the EU countries on the first year of available data (2004) & last year of available data (2017). Source: Eurostat, https://ec.europa.eu/eurostat/web/energy/data/shares

	2004	2017
Electricity		
Hydro	29,483.6	30,001.7
Wind	4,920.7	29,814.5
Solar	62.5	10,265.9
Solid biofuels	3,269.7	8,140.6
All other renewables	2,402.5	8,459.0
Total (RES-E numerator)	**40,139.1**	**86,681.7**
Electricity generation from all sources		

[25] Support schemes for electricity from renewable sources have been demonstrated to be an effective way of fostering deployment of renewable electricity.

Total (RES-E denominator)	**280,705.0**	**281,914.6**
RES-E [%]	**14.30%**	**30.75%**

Energy from Photovoltaic Systems

Solar energy, defined in the simplest of terms, is the energy emitted by the sun in the form of solar radiation. Solar energy, as renewable energy, is being used to produce electricity or hot water without damaging natural resources and is gaining popularity at global level for the past years. Private consumers and governments are now investing on solar energy to produce electricity.

Electricity production from solar energy, takes place through the photovoltaic systems. Photovoltaics are consisting of silicon solar wafers (solar cell) which are electrical devices that convert the energy of light directly into electricity by the photovoltaic effect[26]. All photovoltaic cells are made from semiconductor materials. Usually this is silicon (Si), but one also finds cadmium sulphide (CdS), cadmium telluride (CdTe), alloys of copper. PV cells are linked together to create a typical PV module, which in turn are linked together into a PV array.

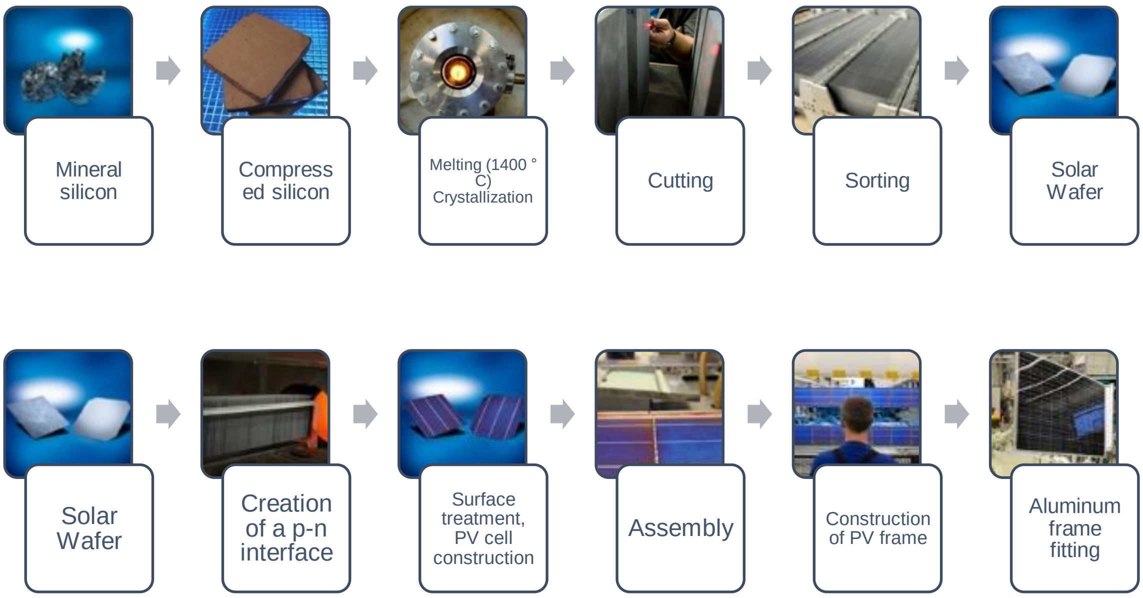


Figure 14: Production Process for Photovoltaics: From the mineral silicon to Wafer (soalr cells)

[Source of Pictures: Solarworld AG]

[26] When the silicon is combined with one or more other materials, it exhibits unique electrical properties in the presence of sunlight. Electrons are excited by the light and move through the silicon. This is known as the photovoltaic effect and results in direct current (DC) electricity.

Photons incident on the surface of a semiconductor will be either reflected from the top surface (loss), will be absorbed in the material (production) or, failing either of the above two processes, will be transmitted through the material (loss). Photons falling onto a semiconductor material can be divided into three categories based on their energy compared to that of the semiconductor band gap:

- Eph < EG Photons with energy Eph less than the band gap energy EG interact only weakly with the semiconductor, passing through it as if it were transparent.
- Eph = EG have just enough energy to create an electron hole pair and are efficiently absorbed (ideal case).
- Eph > EG Photons with energy much greater than the band gap are strongly absorbed [the extra energy is eliminated by the electron as heat].

For more information see: *A collection of resources for the photovoltaic educator* at: https://www.pveducation.org/index.php .

The most suitable sites for PV modules are exposed to good levels of sunshine year-round, are free of shade, and facing as close to north as possible. At European Level, the dynamic for solar energy production is significantly high, especially in the southern and central Europe, as it ranges between 1200 to 1800 kWh production per installed kWp. The photovoltaic power potential in specific, is shown in the next figure.

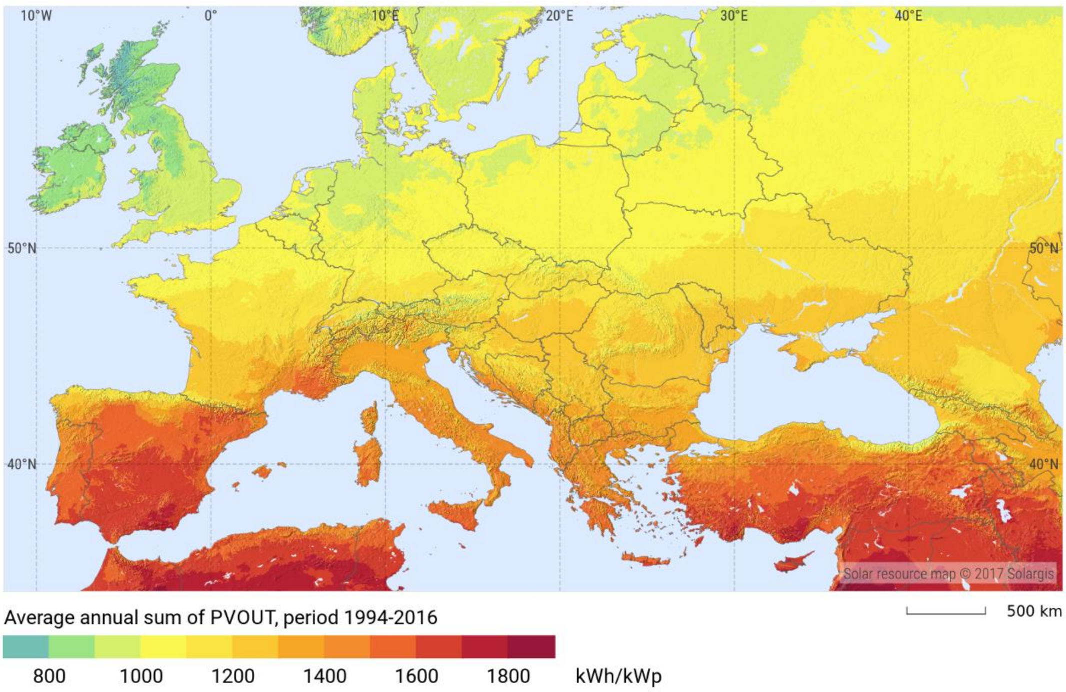


Figure 15: Solar resource map of Europe. Adapted from: https://solargis.com/maps-and-gis-data/download/europe

For Geographical Assessment of Solar Resource and Performance of Photovoltaic Technology see the tool: Photovoltaic Geographical Information System (PVGIS), available from: http://re.jrc.ec.europa.eu/pvgis/

The PV panel (see in the below figure), consists of the silicon semiconductor surrounded by protective material in a metal frame. The protective material consists of a transparent silicon rubber or butyryl plastic bonded around the cells, which are then embedded in ethylene vinyl acetate. A polyester film (such as mylar or tedlar) makes up the backing. A glass cover is used to protect the panel from the elements.

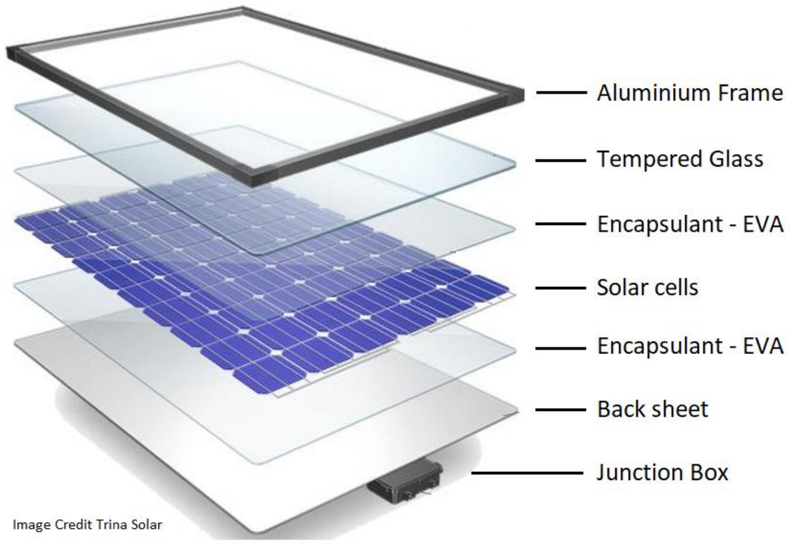


Figure 16: Layout of a standard PV panel [Source: Trina Solar]

PV modules are designed to last for around 25 years, and little maintenance is needed. They are also modular, which means that is easy to add more modules if more power is needed. In addition, the cost of PV systems has reduced in recent years and looks to become increasingly cost-effective over time.

Both PV modules and PV panels undergo a series of tests at their manufacturing plant in accordance with certain regulations before being put on the market. Tests are certified to withstand mechanical, thermal and other stresses to achieve a lifetime of more than 20 years. These must be carried out to determine the electrical characteristics included in the relevant descriptive leaflets given by the manufacturers, who are responsible for the correctness of the electrical characteristics.

Solar PV panels are tested under an industry standard - "Standard Test Conditions (STC)". By using a fixed set of conditions, all solar panels can be more accurately compared and rated against each other. There are three standard test conditions which are:

- Temperature of the cell: 25°C. The temperature of the solar cell itself, not the temperature of the surrounding.

- Solar Irradiance: 1000 W/m^2. This number refers to the amount of light energy falling on a given area at a given time.
- Mass of the air: 1.5. Refers to the amount of light that has to pass through Earth's atmosphere before it can hit Earth's surface.

'Standard operating conditions' (SOC) of PV panels is a set of reference photovoltaic device measurement conditions consisting of:

- Solar radiation intensity (irradiance) in PV panels: 800 W/m^2
- Ambient air temperature T_α = 25 °C
- Average wind speed 1 m/s
- Southern orientation and measurements at sundial
- Measurements under open circuit conditions

PV panels can be connected with different ways based on the needs and the technical considerations.

- Connect in a row: It is used in cases where a voltage greater than the voltage supplied by each PV panel separately needs to be achieved. The photovoltaic panels to be connected in series must have the same short-circuit current.
- Parallel connection: It is used in cases where a current greater than the current supplied by each PV panel separately needs to be achieved. The photovoltaic panels to be connected in parallel must have the same open circuit voltage.
- Mixed connection: It is used to increase current and voltage at the same time at values that are not available from simple PV panels. From a technical point of view, the mixed connection is a combination of the row connection and the parallel connection and therefore applies to those connections. The voltage of this array is determined by the elements connected in series while the total current from the parallel groups.

For the requirements for testing, documentation and maintenance of the PV systems, the standard EN 62446-1 is used. This defines the information and documentation required to be handed over to a customer following the installation of a grid connected PV system. It also describes the commissioning tests, inspection criteria and documentation expected to verify the safe installation and correct operation of the system.

Design Solar PV systems

PV installation components

a. Solar Panels

Regarding the available technologies of PV Solar panels, those vary. The most important technologies are presented below:

Monocristallyne (mono-Si)

Most efficient > 20%
- Construction from single Si crystal
- Best performance high temperatures, it degrades in low-sunlight conditions
- Requires least area for a given power

Figure 30. Source: Source: Ecofutur Solar Company

Polycristallyne Silicon (poly-Si)

Less efficient around 16%
- Construction by fusing different crystals of Si
- Performance best at moderately high temperature, it degrades in low-sunlight conditions
- Requires less area for a given power

Figure 31. Source: Source: Ecofutur Solar Company

Thin film

Least efficient around 12%
- Constructed by depositing 1 or more layers of PV material on substrate.
- Best performance high temperatures, and performance less affected by low-sunlight conditions
- Requires large area for a given power

Figure 32. Source: Hangzhou Amplesun Solar Technology Co., Ltd

Other technologies (Concentrated Solar)

A concentrating photovoltaic (CPV) system converts light energy into electrical energy in the same way that conventional photovoltaic technology does. The difference in the technologies lies in the addition of an optical system that focuses sunlight collected on a large area onto a small sized solar cell.

Figure 33. Source: Source: Ecofutur Solar Company

b. Inverters

The PV inverters convert the DC current of the PV solar panels to AC current (Grid electricity).

The PV inverters have a function called MPPT (Maxium Power Point Tracking) to draw the maxiium power from the solar installation.

Figure 34. Some inverters in a PV installation in coonstruction. [Source: Source: Ecofutur Solar Company]

c. Connection protection boxes and cables.

Indoor or outdoor boxes with string fuses protection and switches

The cables or wires are made from copper or Aluminium. The conductor cross-section must be calculated according the Current and distance in DC part and AC part.

Figure 35. A worker making connections in the protection boxes of a PV installation in construction. Source: Source: Ecofutur Solar Company

d. PV regulator

It regulates the amount of charge coming from the PV solar panels

It must ensure the protection of the batteries from overload (from the solar generator) and from deep discharge (by cutting off supply to the users). It can also control the starting of a back-up generator.

Figure 36. Source: https://www.victronenergy.com.es/

e. Batteries

Batteries store and produce energy as needed. In PV systems, they capture surplus energy generated by your PV system to allow you to store energy for use later in the day. Like technologies such as **fuel cells**, a battery converts chemical energy to electrical energy.

Figure 37. A serie of batteries. [Source: Ecofutur Solar Company]

f. Power meter

Measures electrical energy generated from solar installation.

Figure 25. A power meter. [Source: Ecofutur Solar Company]

PV parameters, to design an installation

a. Solar Irradiance

Solar irradiance (SI) is the power per unit area (watts per square metre, W/m^2), received from the Sun in the form of electromagnetic radiation.

You can check the irradiance of a location in the Photovoltaic Geographical Information System (PVGIS): http://re.jrc.ec.europa.eu/pvg_tools/en/tools.html#PVP

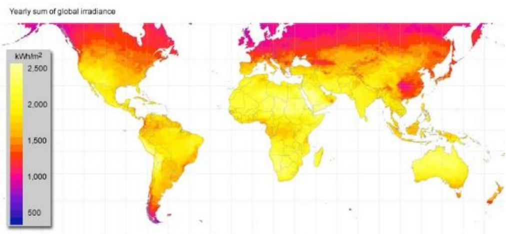


Figure 39. An irradiance world map [Source PVGIS software]

b. PV Slope

The photovoltaic (PV) slope is the angle at which the panels are mounted relative to horizontal. A slope of 0° corresponds to horizontal, and 90° corresponds to vertical. With fixed-slope systems, a slope roughly equal to the latitude typically maximizes the annual PV energy production. The azimuth specifies the direction towards which the panels slope.

Figure 40. Source: Ecofutur Solar Company

c. PV Azimuth

The photovoltaic (PV) azimuth is the direction towards which the PV panels face. Due south is 0°, due east is -90°, due west is 90°, and due north is 180°. With fixed-azimuth systems, the panels are almost always oriented towards the equator (0° azimuth in the northern hemisphere, 180° azimuth in the southern hemisphere).

The wrong azimuth angle could reduce the energy output of a solar PV. In the northern hemisphere, between the latitudes of 23 and 90, the sun is always in the south. Therefore, the modules on an array are directed to the south in order to get the most out of the sun's energy. In the southern hemisphere, it is the opposite.

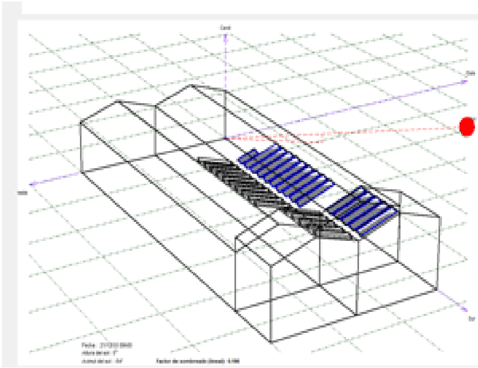


Figure 41. Own elaboration

d. Shadows

A solar cell mounted outdoor is exposed to many things, including changing light conditions with shadows over some of the cells. In addition, the solar cells can be covered by leaves or brid droppings, which also leave some of the cells in shadow. These shadows naturally lead to a decrease in productivity as less light hits the cells.

Figure 42. Source: Ecofutur Solar Company

e. Ventilation/ Temperature

A good module ventilation helps to keep down its temperature. When the temperature of the module increases, therefore also the temperature of the cells, there is a reduction of the voltage and power delivered by the system

Figure 43. Source: Ecofutur Solar Company

For mono or multicrystalline modules, the temperature has negative influences on the delivered power with temperature coefficients that vary from approximately -0.4%/°C until -0.5%/°C. There is therefore essential to ensure, whenever possible, passive ventilation on the back of the module that favors the cooling.

Types of photovoltaics systems installation

There are many classifications of types of photovoltaics systems. This section describes those considered most important to get an overview of the different configurations of PV installations will be treated.

Based on power connection

Depending on whether the installation is isolated or connected to the electricity grid, there are three types of installations:

f. On-grid or grid-tied solar power system

On-Grid PV systems are designed to operate in parallel with the electric utility grid and interconnected with it.

Grid Connected PV Systems have solar panels that provide some or even most of their power needs during the day time, while still being connected to the local electrical grid network during the night time.

Solar powered PV systems can sometimes produce more electricity than is actually needed or consumed; with this installation diagram, this extra or surplus electricity is fed directly back into the electrical grid network.

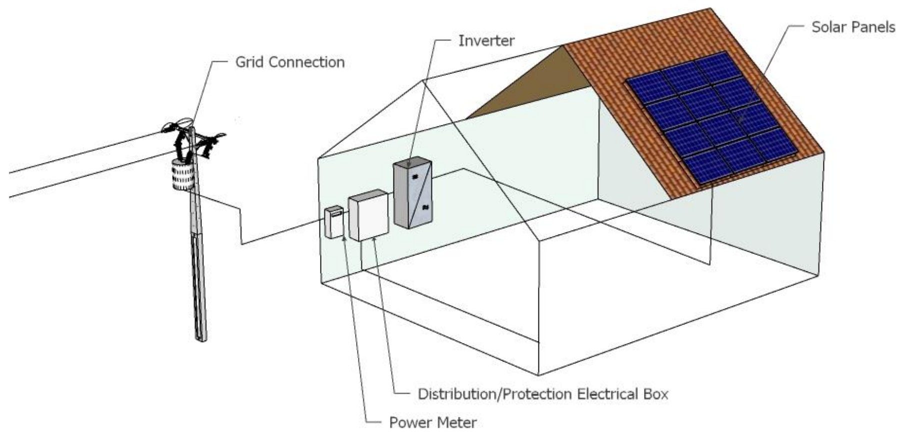


Figure 31. Drawing of a grid-tied solar power system. [Own elaboration]

g. Grid-tied system with battery back-up or grid-hybrid system

This type of connection is similar to the previous one but in this case, when the PV systems can sometimes produce more electricity than is actually needed or consumed, it's stored in batteries.

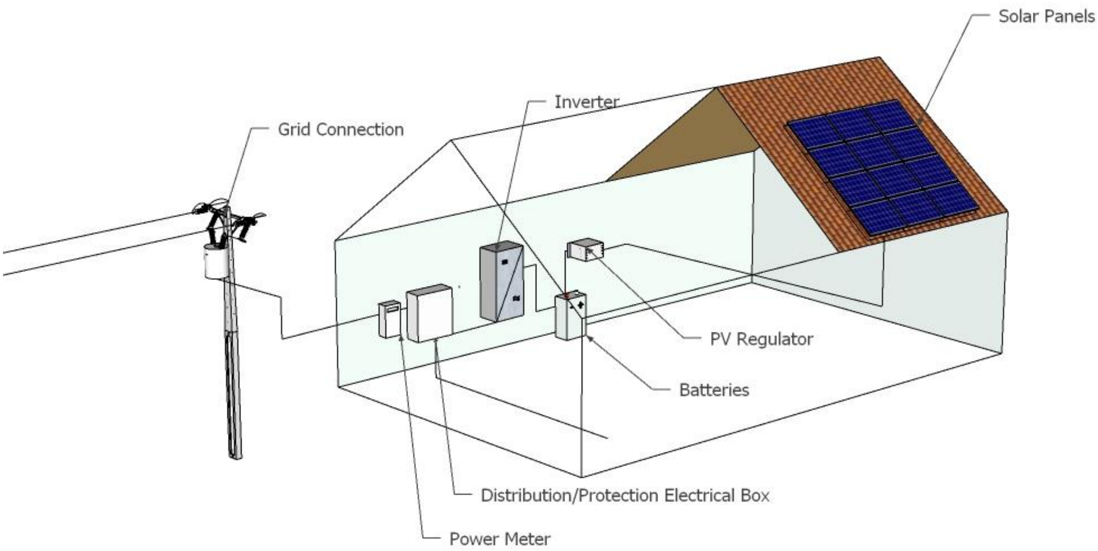


Figure 32. Drawing of a grid-hybrid system. [Own elaboration]

h. Off-grid solar power system

In the off-grid solar power system type, the PV system is completely disconnected from the utility power grid. Storage batteries are required to store power from sun, and use when required.

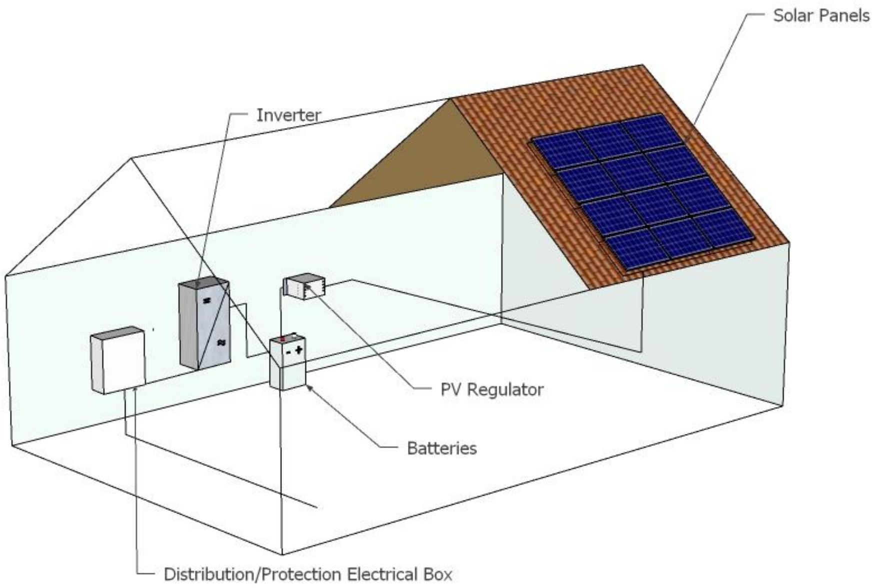


Figure 33. Drawing of a off-grid solar power system. [Own elaboration]

Based on the mounting

The solar array can be either fixed mounted or mounted on a sun tracking rack that follows the sun.

a. Fixed mounting structures

Figure 47. A PV installation made with fixed structure. [Source: Ecofutur Solar Company]

Fixed mounting structures of module/array are oriented towards true south and tilted at fixed angle. The main advantage of this type of mounting is its simplicity of mounting and maintenance. The most important disadvantage is the less production compared with tracking installations, modules do not get good exposure in the morning and evening hours of the day.

b. Tracking structures

Tracking PV installations are installations mounted on tracking structures. Trackers can follow the sun along only one axis (east-west) or can have dual axis (east-west and tilt angle) for complete seasonal compensation. They can be motor driven (powered by the battery) or solar powered themselves.

The great advantage of this type of installation is the higher production than fixed mounting installations, by mounting the modules on tracking structure, gains in total daily output of power of 30% or greater can be achieved because the modules are facing the sun directly during all the sunshine hours.

FIgure 48. A tracking PV installation. [Source: Ecofutur Solar Company]

The main drawback is the maintenance, which must be exhaustive due mainly to the moving parts of the system and the sensors, which must always be kept in optimum conditions for a correct operation of the whole.

For large utility scale PV systems have the modules mounted on dual axis trackers can be interesting, to maximize module output and minimize average costs. But for small scale array/modules use of trackers is an economical issue. The gain provided by the tracker (in terms of reduced number of modules for given load) has always to be compared with the investment and maintenance cost of the tracker.

Based on the location

Another possible classification of photovoltaic systems is according to the location in which they are installed.

a. Solar farm

A solar farm, sometimes referred to as a photovoltaic power station, is typically a large decentralized solar array supplying electricity to the power grid. Solar farms go through a rigorous planning procedure before they are approved. This can take into account the suitability of the specific site, any potential impact on the area, relevant renewable energy targets or other legal or administrative requirements.

Figure 49. Solar Farm. [Source Ecofutur Solar Company]

b. Rooftop PV installations

Figure 50. Rooftop PV installation. [Photo by

Rooftop solar is a photovoltaic system that has its solar panels mounted on the rooftop of a residential or commercial building. Rooftop mounted systems are smaller than solar farms and as opposed to it the power production of most of them are partial or totally destined to self-supply.

Rooftop installations can be made on both flat roofs and inclined roofs, always with an auxiliary structure to fix the modules. In the first case, the auxiliary structure give the correct slope to the panels, while in the second case the panels are integrated into the roof, that is, respecting the plane of the roof.

This is probably the most widespread form of installation of photovoltaic panels.

c. Building Integrated Photovoltaics System

Building Integrated Photovoltaics is the integration of photovoltaics into the building envelope. The PV modules serve the dual function of building skin—replacing conventional building envelope materials—and power generator.

In this type of installation, PVs need to be considered as an integral part of the energy strategy of the building and of its functioning. The integration of panels with the other building elements is critical to success. Appearance and aesthetics are, as ever, especially important.

There are different forms of integration of photovoltaic systems in buildings, but mainly we could make two types of classifications. On the one hand, depending on its application, we could divide them into roof and façade integration. On the other hand, we can describe the main existing products, which in this case are foils, tiles, modules and solar cell glazing.

In relation to the efficiency of this type of installations, it is important to emphasize design. In this sense, the ventilation of integrated systems presents a challenge to be taken into account because it has to find a balance that allows to solve the inversely proportional relationship between temperature and efficiency of the photovoltaic panels and the comfort of the interior of the building.

Figure 38. Roof-integrated PV installation. [Photo by telex4 on Foter.com / CC BY]

Figure 39. Window-integrated PV installation. [Photo by Payton Chung on Foter.com / CC BY]

d. Other type of mountings

In addition to the PV installations described in the previous sections, there are many other isolated supports where you can find photovoltaic installations. Within this category, we find the structures whose function is to provide shade, mainly in parking lots, traffic signs, streetlights or lighting devices and even vehicles.

All these devices have the common characteristic that the installed power is much lower than in the rest of the systems already explained. In addition, except in the case of shadows, most other devices use the energy generated directly in the structure that serves as support.

Figure 40. A PV installation on a traffic sign. [Photo by Les_Stockton on Foter.com / CC BY-NC-S]

Figure 41. PV installation integrated on a boat. [Photo by nicolas.boullosa on Foter.com / CC BY]

Based on the using of generated energy

a. Self-supply

Self-consumption is that the producer of energy consumes all or part of this energy produced in the vicinity of the place of production. The storage of energy in this case is possible, as well as the dumping of part of the production into the grid. It is very common that this type of consumption occurs in installations in domestic roofs.

b. Direct supply into the electricity grid

In this type of installation, all the production is discharged to the grid in exchange for an economic benefit, without the possibility of having part of the production to supply equipment of the production plant. This configuration is typical of solar farms.

c. PV-direct systems

PV direct systems are designed to operate independent of the electric utility grid, and are generally designed and sized to supply certain DC or AC electrical loads. The simplest type of stand-alone PV system is a direct-coupled system, where the DC output of a PV module or array is directly connected to a DC load. Since there is no batteries in direct-coupled systems, the load only operates during sunlight hours, making these designs suitable for common applications such as ventilation fans, water pumps, and small circulation pumps for solar thermal water heating systems.

In many PV direct systems, batteries are used for energy storage, like in solar traffic signals, streetlights, etc.

Figure 42. PV installation on a streetlight. [Photo by NAVFAC on Foter.com / CC BY]

Figure 43. PV installation on a electrical bike. [Photo by Richard Masoner / Cyclelicious on Foter.com / CC BY-SA]

PV systems in schools

Since utility costs are one of the few areas of a school's budget that cannot be trimmed without negatively affecting the learning environment, many schools are exploring the benefits of solar power. School facilities are excellent candidates for solar conversion, particularly large campuses that have vacant land areas and spread out over a wide geographic area. In addition, most school buildings have large, flat rooftops that are ideal for rooftop solar PV or solar thermal systems.

Nowadays, solar thermal and PV systems are considered the most common solution for RES in schools. The majority of energy in schools is used during the day with smaller proportion being used at night, so it makes sense to offset the energy used from the grid with solar PV installations. For school buildings, it is also worthwhile to be able to feed power generated to the public grid during holiday periods.

It was also observed that schools who embrace solar power tend to have a policy on energy sustainability and students are likely to observe their schools' approach to renewable energy and learn how they can impact their community/family awareness for renewable energy.

Overall, schools with sustainable and renewable energy:

- Reduce their environmental impact
- Obtain some of their daily energy requirements from solar power
- Teach students about sustainable energy sources
- Demonstrate solar PV system technology [important for public schools]

Nonetheless, there are some considerations and measures to be taken, when thinking to install a PV system in school:

- Acquire the previous electricity consumptions for at least 3 years [to establish the needs and therefore the capacity of the system]
- Consider the possible renovations/extensions of the school and the change of needs in the future
- Consider that the energy needs of the schools differ widely, as do schools' capacities and capabilities to implement PV systems
- Be informed about the available incentive schemes [if applicable]
- Be informed about the available electricity rates
- Be informed about the existing relative legislation / spatial policy
- Choose a placement where the system will be protected from possible vandalization

The most common type of PV installations in schools is the Roof-Mount Solar Installation due to the ease of mounting panels on a flat roof. These panels are also economical and require minimal maintenance. Parking Lot Solar Canopy is also another solution met often. Moreover, if a facility has awnings in areas with high sunlight exposure, panels can be added to generate solar power [Solar Shade Awnings]. A facility with large areas of open land might choose ground mount panels [Ground-Mount Solar Installation]. These panels can potentially generate more power than an exclusively roof mounted system, especially if they include an optional tracker system designed to maximize energy generation throughout the day. In the cases where a facility doesn't have enough available roof space or when roof-mount panels are impractical, Pole-Mount Solar Installation is used to maximize exposure to sunlight. This solution requires a large spot of open land, so it is limited.

Newer types of solar solutions for schools are the Building-Integrated PV Systems and the Solar Shelter Installations where detached facilities can generate solar power, if necessary.

Renewable energy is suitable for most schools including those that are constructing new buildings, those that have completed energy efficiency upgrades and schools with high exposure to sunlight.

NB: Installers of solar photovoltaic and solar thermal energy shall be certified by an accredited training programme or training provide.

Figure 44:Oriel Academy West London, Hounslow Road, Hanworth, Middlesex [Source: http://www.sunenergygroup.net/oriel-academy]

Figure 45: IDEA Public Schools 'Green' Headquarters In Weslaco, Texas [Source: https://albaenergy.com/idea-public-schools-powers-up-with-alba-energy/]

Figure 46: Solar panels at Casey Middle School in Boulder, Colorado. [Image credit: Dennis Schroeder / NREL]

Conclusions [10 minutes]

To conclude, it seems that solar energy is an option for energy and power source that schools should opt to. Solar power is an immense source of directly useable energy and is very valuable when it comes to preserving the Earth's environment and resources. It also helps to become less dependent on other more costly and damaging forms of power such as fossil fuels. Furthermore, educating young people about the importance of solar energy plays a critical role in creating a more sustainable future for our planet.

The benefits of RES surpass their challenges and the variety of the existing systems and technologies offer a solution for almost every requirement. In specific, there are different technologies and typologies of PV installations (solar farms, on roof, fixed, trackers, on grid, self-consumption etc.), and parameters to have in mind to design efficiently a solar plant (irradiance, slope, azimuth, losses etc). Whatever system is studies, the first step is to reduce a school's current energy use, as saving electricity is usually much cheaper than generating it.

It is important to note that in December 2018, the new revised Renewables energy directive (2018/2001) entered into force – establishing a new binding renewable energy target for the EU for 2030 of at least 32%, with a clause for a possible upwards revision by 2023. Nonetheless, the target for each Member State, will be available at later stage.

Consultation of documents and references

- Sustainable energy in schools, Solar Power systems and environmentally friendly schools. Australia. Available on: https://www.sustainableschools.com.au/

- Sustainable Refurbishement of School Buildings - *A guide for Designers and Planners*. Sophie Trachte & André De Herde, June 2014. This handbook is produced from material developed in the course of IEA SHC Programme Task 47 Solar Renovation on Non-Residential Buildings. Available on: http://www.iea-shc.org/Data/Sites/1/publications/subt.D.School%20Renovation.022015.pdf

- Series of 'Saving energy in schools' in the website of the Energy Efficiency and Conservation Authority (EECA) of New Zealand: https://www.eecabusiness.govt.nz

- DIRECTIVE (EU) 2018/2001 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 11 December 2018 on the promotion of the use of energy from renewable sources (recast). Available on:

  https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32018L2001&from=EN

- National renewable energy action plans for 2020 for each Member state: https://ec.europa.eu/energy/en/topics/renewable-energy/national-renewable-energy-action-plans-2020

- *A collection of resources for the photovoltaic educator* at: https://www.pveducation.org/index.php .

- Best Practice Guide - Photovoltaics (PV). Sustainable Energy Authority of Ireland. https://www.seai.ie/resources/publications/Best_Practice_Guide_for_PV.pdf

- A guide to photovoltaic (PV) system design and installation. California Energy Commission. https://www.abcsolar.com/pdf/endocon.pdf

- Handbook for Solar Photovoltaic (PV) Systems. Energy Market Authority (EMA) and the Building Construction Authority (BCA) of Singapore. https://policy.asiapacificenergy.org/node/172

- Sunflower Solar website http://www.sunflower-solar.com

- Solar Reviews website https://www.solarreviews.com

- Calculo Solar website
  https://calculosolar.com

- Metartec website
  https://www.metartec.com

- PVSyst photovoltaic software website
  http://files.pvsyst.com/

- Power From Sunlight website
  https://www.powerfromsunlight.com

- Fuel Cell Store website
  https://www.fuelcellstore.com

- Photovoltaic Geographical Information System (PVGIS)
  https://ec.europa.eu/jrc/en/scientific-tool/pvgis

- Infinity PV website
  https://infinitypv.com

- Building Integrated Photovoltaic website
  http://www.bipv.ch

- Civic Solar website
  https://www.civicsolar.com/

- Quest Garden website
  http://questgarden.com

- Ecofutur website
  http://www.ecofutur.es

Questionnaire

1. The new revised Renewables Energy Directive (2018/2001) entered into force, established as a new binding renewable energy target for the EU for 2030 the proportion of:
    a. at least 35% share from renewable sources in gross final energy consumption
    b. at least 32% share from renewable sources in gross final energy consumption
    c. at least 20% share from renewable sources in gross final energy consumption

2. Regarding the electricity production from RES at local level
    a. Small-scale installations have been proved to be of great benefit
    b. Small-scale installations have been proved to not be successful
    c. Large-scale installations have been proved to be of great benefit

3. Which is the most common semiconductor material for the PV cells?
    a. cadmium telluride (CdTe)
    b. cadmium sulphide (CdS)
    c. silicon (Si)

4. Which of the following are typically considered loss mechanisms for photovoltaic devices?
    a. reflection and transmission
    b. absorption and reflection
    c. absorption and transmission

5. During the "Standard Test Conditions (STC)", which fixed set of conditions is used?
    a. Temperature of the cell: 25°C, Solar Irradiance: 1000 W/m^2 & Mass of the air: 2.0
    b. Temperature of the cell: 20°C, Solar Irradiance: 1200 W/m^2 & Mass of the air: 1.5
    c. Temperature of the cell: 25°C, Solar Irradiance: 1000 W/m^2 & Mass of the air: 1.5

6. Parallel connection in PV arrays is used:
    a. In cases where a current greater than the current supplied by each PV panel separately needs to be achieved.
    b. In cases where a voltage greater than the voltage supplied by each PV panel separately needs to be achieved.
    c. Parallel connection is never used in PV arrays.

7. Which standard is used for the testing, documentation and maintenance of the PV systems?
    a. The EN 62446-2 standard
    b. The EN 60446-1 standard
    c. The EN 62446-1 standard

8. What solar cells are most efficient?
    a. Monocrytaline
    b. Thin film
    c. Depends on temperature conditions

9. What component controls the overload and deep discharge of PV batteries?
    a. Protection electrical boxes.
    b. PV Regulator.
    c. Power meter

10. What PV Slope maximises the solar energy annual production?
    a. 30º
    b. 35º
    c. Depends on the location; typically the slope roughly equal to the latitude.

11. What PV parameter do we need to solve the annual energy production?
    a. Azimuth
    b. Slope
    c. Both

12. What are the main components in an off grid solar installation?
    a. Modules, inverter, battery and power meter
    b. Modules, inverter, grid connection and power meter
    c. Modules, inverter and battery

13. Indicate which of the following statements is false:
    a. The advantage of tracking photovoltaic installations is the higher production than fixed mounting installations.
    b. A fixed mounting photovoltaic installation has more maintenance than a tracking one.
    c. For small-scale photovoltaic installation, the use of trackers is not recommended because it is not profitable.

14. Which of the aspects cited below represents a challenge in the integration of panels in buildings?
    a. The calculation of the power to install
    b. Ventilation of the modules
    c. Positioning of the modules (roof or façade)

15. Which is the most common type of PV installation in school buildings?
    a. The Parking Lot Solar Canopy
    b. the Roof-Mount Solar Installation
    c. the Ground-Mount Solar Installation

Geothermal

E-MODULE: SUSTAINABLE RENEWABLE SOLUTIONS IN SCHOOLS HEAT PUMPS

MODULE PRESENTATION

This module will introduce a high efficiency system typology that allows to produce heat, cold and hot domestic water by exploiting the heat exchange with the ground. This type of plant is classified as a renewable source.

There are many reasons home and business owners choose geothermal systems for heating and cooling. They cost very little to operate, they last many years, and they operate quietly. In addition to these benefits, environmentally conscious homeowners also choose geothermal systems because they are better for our planet.

Although in the past geothermal systems were only available to the most expensive homes, these systems have become so affordable that tens of thousands of homes are being built or retrofitted to take advantage of geothermal energy. Compared to other HVAC systems, geothermal systems have much lower life cycle costs.

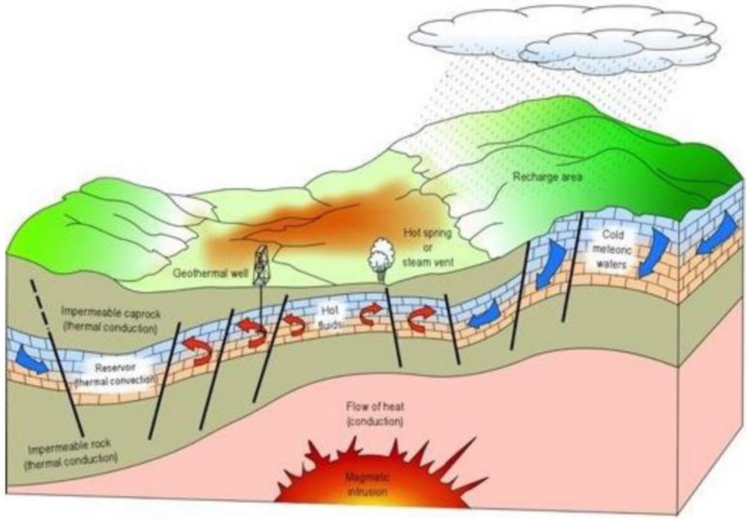
Geothermal heating and cooling systems are the most environmentally friendly option for heating and cooling your Lexington home or business — here’s why:

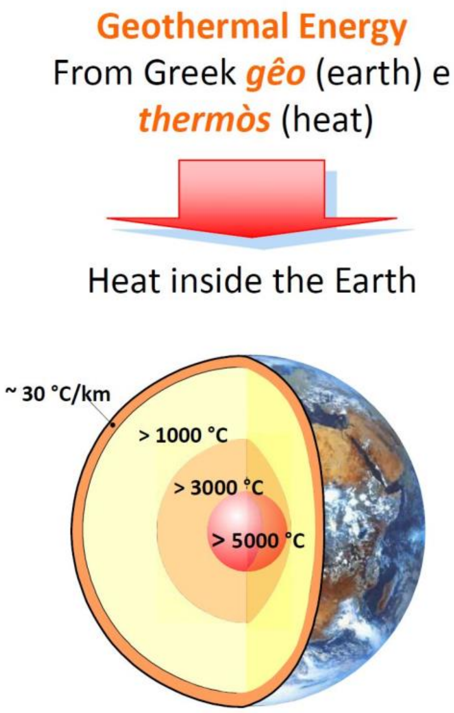
Geothermal ground source heat pump systems are one of the most energy efficient, environmentally clean, and cost-effective space conditioning systems available. About 70 percent of the energy used by a geothermal heat pump system comes in the form of renewable energy from the ground. High-efficiency geothermal systems are on average 48 percent more efficient than gas furnaces, 75 percent more efficient than oil furnaces, and 43 percent more efficient when in the cooling mode.

Geothermal heat pumps (GHPs) have been in use since the late 1940s.

The term "Geothermal Heat Pump" is used to mean a "Ground Source Heat Pump". The term "Shallow Geothermal Energy" is – somewhat confusingly – used to refer to heat in the first 100 metres of depth (even though the heat present does not come from the centre of the earth).

They use the constant temperature of the earth as the exchange medium instead of the outside air temperature.





Although many parts of the country experience seasonal temperature extremes -- from scorching heat in the summer to sub-zero cold in the winter—a few feet below the earth's surface the ground remains at a relatively constant temperature. Depending on latitude, ground temperatures range from 7°C to 21°C. Like a cave, this ground temperature is warmer than the air above it during the winter and cooler than the air in the summer. The GHP takes advantage of this by exchanging heat with the earth through a ground heat exchanger.

Even though the installation price of a geothermal system can be several times that of an air-source system of the same heating and cooling capacity, the additional costs are returned to you in energy savings in 5 to 10 years. System life is estimated at 12-15 years for the inside components and 50+ years for the ground loop.

A Geothermal Heat Pump can be an efficient means of saving money and saving carbon emissions if carefully designed for space heating of an appropriately designed building. Geothermal heat pumps can cut energy costs anywhere from 50–70% over conventional heating and cooling systems.

Economic Performance

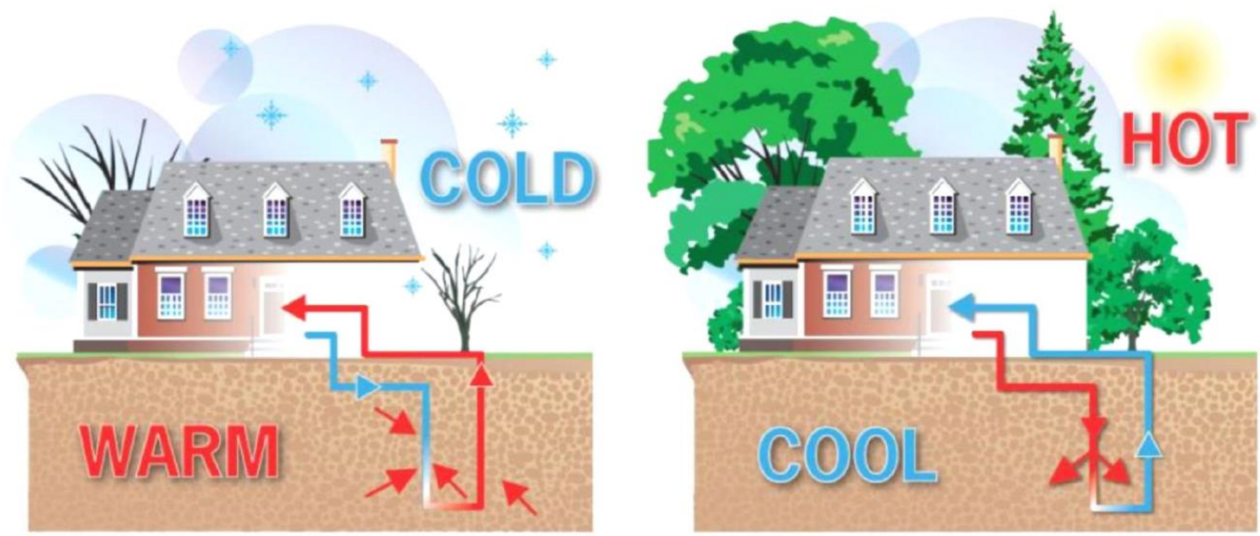
- **Bottom Line**
  - **Most Energy Efficient Heating & Cooling System Available**
  - **Comfortable with a High Degree of Owner Satisfaction**
  - **Reduces Energy Cost by 20% to 35%**
  - **Adds 2 – 4% to the Total Cost of New Construction**
  - **Incentives, Credits and Alternate Financing may be Available**
  - **Typical 5 to 10 year payback**
  - **Generally best Life Cycle Costs**

- **Each Commercial Facility is Unique**

Relative to air-source heat pumps, they are quieter, last longer, need little maintenance, and do not depend on the temperature of the outside air. Considerations including utility rates for electricity, natural gas, or other fuels can impact decisions to implement this technology.

These energy savings can be reinvested into school programs.

Students, staff and guests will enjoy the superior comfort and consistent temperatures provided by a geothermal heat pump system, as it circulates a more constant volume of air at a lower air temperature. This constant air circulation can help improve a school’s indoor air quality, which may lead to fewer health problems for students and staff, while providing a clean and comfortable learning environment. Geothermal heat pump systems help maximize usable space by reducing the size of the school’s mechanical facilities and freeing up space for classrooms, gymnasiums, libraries, etc. Aside from these advantages, a geothermal heat pump system is environmentally friendly and can help demonstrate a school’s commitment to environmental stewardship.



The first priority should be to ensure that the building is well insulated (and well managed). All new buildings should follow the General Building Regulations, have high insulation built in and be well constructed to minimise heat loss through air leaks.

Because a geothermal heat pump is more efficient when producing a lot of warmth – as opposed to a small amount of heat – the distribution system in the building should match this: a large area of underfloor heating distributing warmth is more efficient than a small area of radiators emitting high temperatures (and causing draughts).

The key to the efficiency of a heat pump is the Coefficient of Performance: the "CoP". In spite of the first law of thermodynamics, which tells us that energy can neither be created nor destroyed, a heat pump in a good installation can yield up to four units of heat for each unit of electricity consumed. The geothermal heat pump is not creating this energy, but merely separating a medium temperature from the ground into warmth (which can be used for heating) and cold (which can be returned to the ground).

The CoP will vary with each installation, but the lower the output temperature to the heat distribution system the higher the CoP will be.

The input temperature is also critical to the CoP of the heat pump. The higher the input temperature from the ground, the lower the amount of work needed from the heat pump, the higher the CoP will be. In fact, the critical factor is the "uplift" between the source temperature and the output temperature.

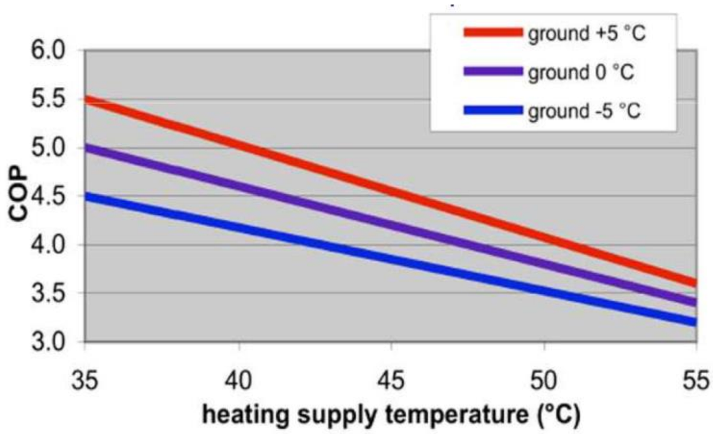
$$COP = \frac{\textit{useful heat}}{\textit{electric power input}}$$

COP variation with temperatures

Heat distribution system	supply/ return temp.	COP[1]
Conventional radiators	60/50°C	2.5
Floor or wall heating	35/30°C	4.0
Modern radiators	45/35°C	3.5
Hydronic convectors	48/38°C	3.5

Normally a geothermal heat pump starts with a ground temperature of about 10-14°C: this is the natural temperature of the ground at a depth of six metres.

The CoP is critical because, although a pump can be efficient, electricity is more expensive than gas. If you do not get a high CoP from your heat pump it could be cheaper to use a gas boiler for heating. In terms of carbon saving a heat pump releases no CO_2 on site, but you should consider the CO_2 emitted at the power stations to create the electricity you use.



Heat pumps offer significant emission reductions potential, particularly where they are used for both heating and cooling and where the electricity is produced from renewable resources (i.e. PV panels).

Ground source heat pumps are characterized by high capital costs and low operational costs compared to other HVAC systems. Their overall economic benefit depends primarily on the relative costs of electricity and fuels, which are highly variable over time and across the world. Based on recent prices, ground-source heat pumps currently have lower operational costs than any other conventional heating source almost everywhere in the world. Natural gas is the only fuel with competitive operational costs, and only in a handful of countries where it is exceptionally cheap, or where electricity is exceptionally expensive. In general, a homeowner may save anywhere from 20% to 60% annually on utilities by switching from an ordinary system to a ground-source system.

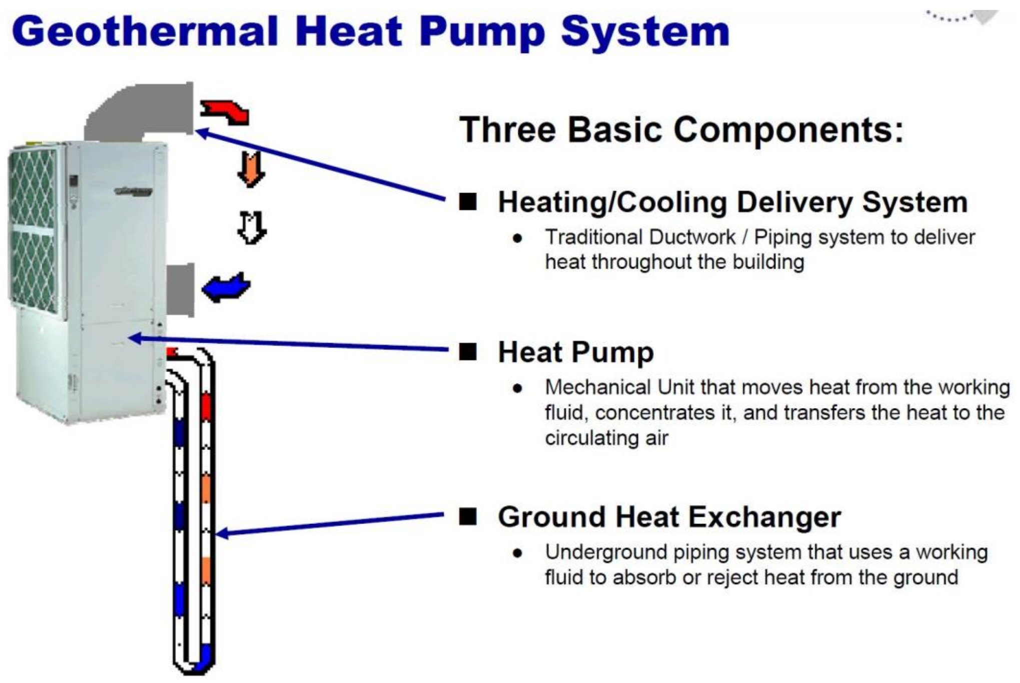
EDUCATIONAL OBJECTIVES

1. TO LEARN ABOUT TYPES OF TECHNOLOGY

2. APPLY HEAT PUMPS TO REAL CASES

3. TO LEARN ABOUT TYPES OF TECHNOLOGY

Geothermal Heating and Cooling Systems provide space conditioning -- heating, cooling, and humidity control. They may also provide water heating -- either to supplement or replace conventional water heaters. Geothermal Heating and Cooling Systems work by moving heat, rather than by converting chemical energy to heat like in a furnace. Every Geothermal Heating and Cooling Systems has three major subsystems or parts: a geothermal heat pump to move heat between the building and the fluid in the earth connection, an earth connection for transferring heat between its fluid and the earth, and a distribution subsystem for delivering heating or cooling to the building. Each system may also have a desuperheater to supplement the building's water heater, or a full-demand water heater to meet all of the building's hot water needs.



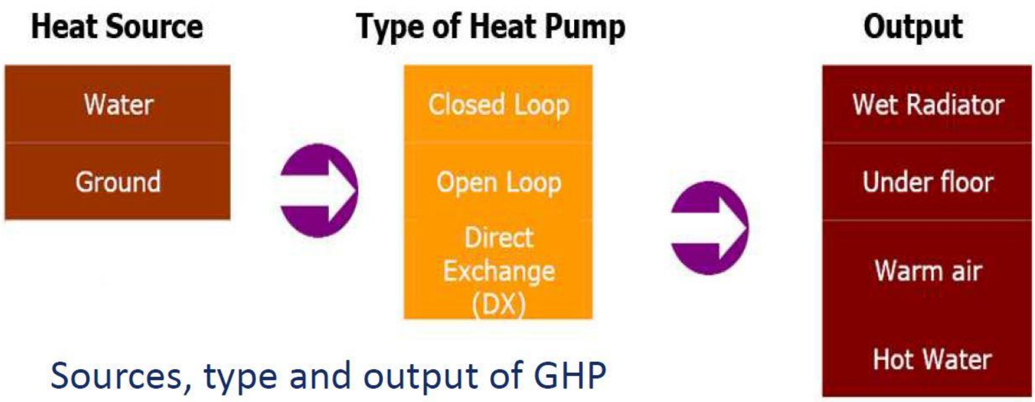
The geothermal heat pump is packaged in a single cabinet, and includes the compressor, loop-to-refrigerant heat exchanger, and controls. Systems that distribute heat using ducted air also contain the air handler, duct fan, filter, refrigerant-to-air heat exchanger, and condensate removal system for air conditioning. For home installations, the geothermal heat pump cabinet is usually located in a basement, attic, or closet. In commercial installations, it may be hung above a suspended ceiling or installed as a self-contained console.

As with any heat pump, geothermal and water-source heat pumps are able to heat, cool, and, if so equipped, supply the house with hot water. Some models of geothermal systems are available with two-speed compressors and variable fans for more comfort and energy savings. Relative to air-source heat pumps, they are quieter, last longer, need little maintenance, and do not depend on the temperature of the outside air.

A dual-source heat pump combines an air-source heat pump with a geothermal heat pump. These appliances combine the best of both systems. Dual-source heat pumps have higher efficiency ratings than air-source units, but are not as efficient as geothermal units. The main advantage of dual-source systems is that they cost much less to install than a single geothermal unit, and work almost as well.

Distribution Subsystem

Most residential geothermal systems use conventional ductwork to distribute hot or cold air and to provide humidity control. (A few systems use water-to-water heat pumps with one or more fan-coil units, baseboard radiators, or under-floor circulating pipes.) Properly sized, constructed, and sealed ducts are essential to maintain system efficiency. Ducts must be well insulated and, whenever possible, located inside of the building's thermal envelope (conditioned space). Geothermal heating and cooling systems for large commercial buildings, such as schools and offices, often use a different arrangement. Multiple heat pumps (perhaps one for each classroom or office) are attached to the same earth connection by a loop inside the building. This way, each area of the building can be individually controlled. The heat pumps on the sunny side of the building may provide cooling while those on the shady side are providing heat. This arrangement is very economical, as heat is merely being transferred from one area of the building to another, with the earth connection serving as the heat source or heat sink only for the difference between the building's heating and cooling needs.



Sources, type and output of GHP

Water Heating

Many residential-sized systems installed today are equipped with desuperheaters to provide domestic hot water when the system is providing heat or air conditioning. The desuperheater is a small auxiliary heat exchanger at the compressor outlet. It transfers excess heat from the compressed gas to a water line that circulates water to the house's hot water tank. In summer, when the air conditioning runs frequently, a desuperheater may provide all the hot water needed by a household. It can provide four to eight gallons of hot water per ton of cooling capacity each hour it operates. A desuperheater provides less hot water during the winter, and none during the spring and fall when the system is not operating.

Because the heat pump is so much more efficient than other means of water heating, manufacturers are beginning to offer "triple function," "full condensing," or "full demand" systems that use a separate heat exchanger to meet all of a household hot water needs. These units cost-effectively provide hot water as quickly as any competing system.

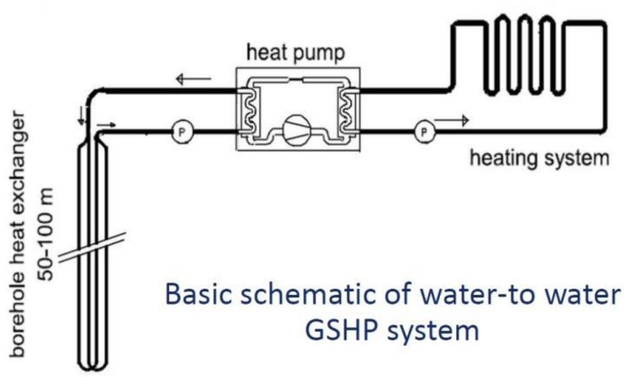
The water heating system that is installed in the Finger Lakes Institute is an on demand system. This system provides hot water as soon as there is a demand for it. Using this type of system eliminates the need to heat stored water like a conventional hot water tank requires.

A ground source heat pump system can be used not only for heating, but also for

cooling.

The configurations manufactured are:

- water-to-air,
- water-to-water, and
- water to air split type



Basic schematic of water-to water GSHP system

The water to water geothermal heat pumps are usually grouped together in a mechanical space, and can be treated as a conventional heater/ chiller plant. Basic schematic of water-to air GSHP system The unit sizes range from 3 tons to 30 tons. The most common type of heat pump used with GSHP systems is a “water-to-air” unit ranging in size from 3.5 kW to 35 kW of cooling capacity.

Types of Systems

Geothermal systems use the earth as a heat source and heat sink. A series of pipes, commonly called a "loop," carry a fluid used to connect the geothermal system's heat pump to the earth.

Closed and Open Loops There are two basic types of loops: closed and open. Open loop systems are the simplest. Used successfully for decades, ground water is drawn from an aquifer through one well, passes through the heat pump's heat exchanger, and is discharged to the same aquifer through a second well at a distance from the first. Generally, two to three gallons per minute per ton of capacity are necessary for effective heat exchange. Since the temperature of ground water is nearly constant throughout the year, open loops are a popular option in areas where they are permitted. Open loop systems do have some associated challenges: Some local ground water chemical conditions can lead to fouling the heat pump's heat exchanger. Such situations may require precautions to keep carbon dioxide and other gases in solution in the water. Other options include the use of cupronickel heat exchangers and heat exchangers that can be cleaned without introducing chemicals into the groundwater.

Increasing environmental concerns mean that local officials must be consulted to assure compliance with regulations concerning water use and acceptable water discharge methods. For example, discharge to a sanitary sewer system is rarely acceptable.

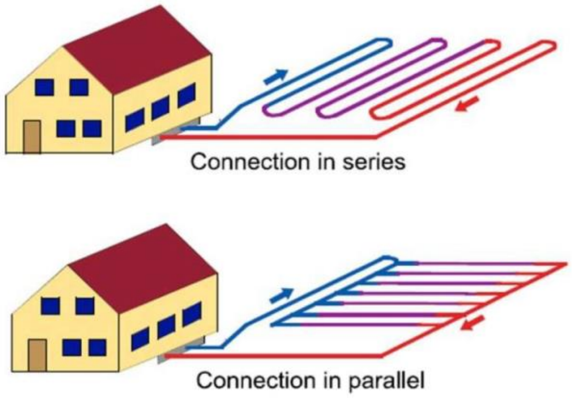
A closed loop system is being used for the Finger Lakes Institute. Closed loop systems are becoming the most common. When properly installed, they are economical, efficient, and reliable. Water (or a water and antifreeze solution) is circulated through a continuous buried pipe keeping. The closed loop system is environmentally friendly because water in the loop prevents contamination to the external environment.

The length of loop piping varies depending on ground temperature, thermal conductivity of the ground, soil moisture, and system design. (Some heat pumps work well with larger inlet temperature variations, which allows marginally smaller loops).

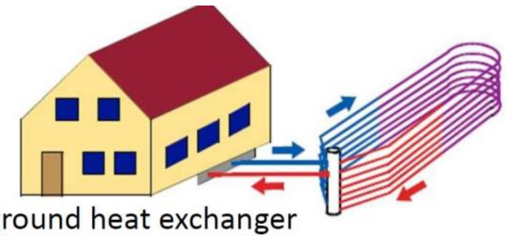
The various shallow geothermal systems comprise:

⇨ horizontal ground heat exchangers	1.2 - 2.0 m depth (horizontal loops)
⇨ borehole heat exchangers	10 - 250 m depth (vertical loops)
⇨ energy piles	5 - 45 m depth
⇨ ground water wells	4 - >50 m depth
⇨ water from mines and tunnels.	

Horizontal Loops Horizontal closed loop installations are generally most cost-effective for small installations, particularly for new construction where sufficient land area is available. These installations involve burying pipe in trenches dug with back-hoes or chain trenchers. Up to six pipes, usually in parallel connections, are buried in each trench, with minimum separations of a foot between pipes and ten to fifteen feet between trenches.



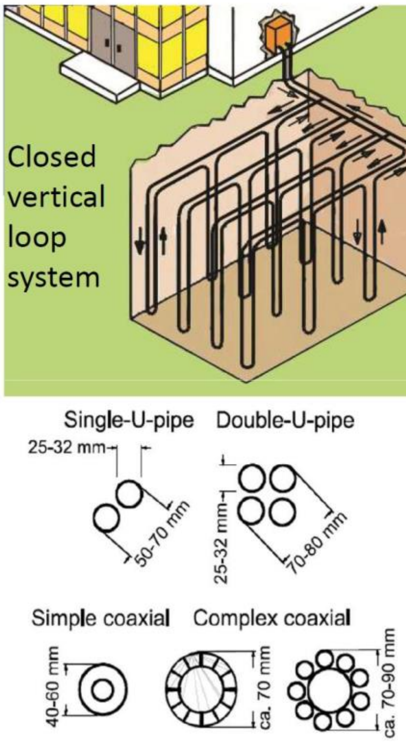
Closed horizontal ground heat exchanger

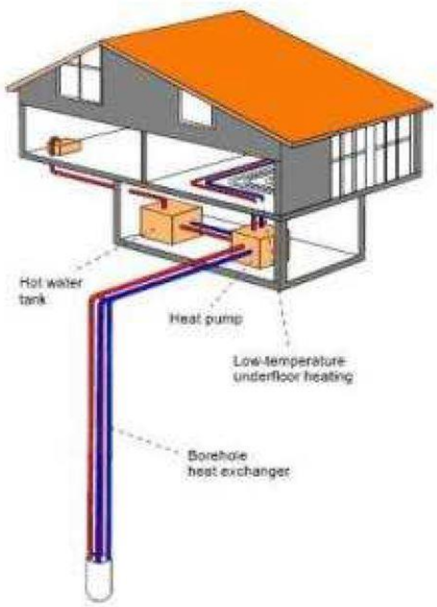


Trench ground heat exchanger

Vertical Loops Vertical closed loops are preferred in many situations. For example, most large commercial buildings and schools use vertical loops because the land area required for horizontal loops would be prohibitive. Vertical loops are also used where the soil is too shallow for trenching. Vertical loops also minimize the disturbance to existing landscaping. For vertical closed loop systems, a U-tube (more rarely, two U-tubes) is installed in a well drilled 100 to 400 feet deep. Because conditions in the ground may vary greatly, loop lengths can range from 130 to 300 feet per ton of heat exchange. Multiple drill holes are required for most installations, where the pipes are generally joined in parallel or series-parallel configurations.

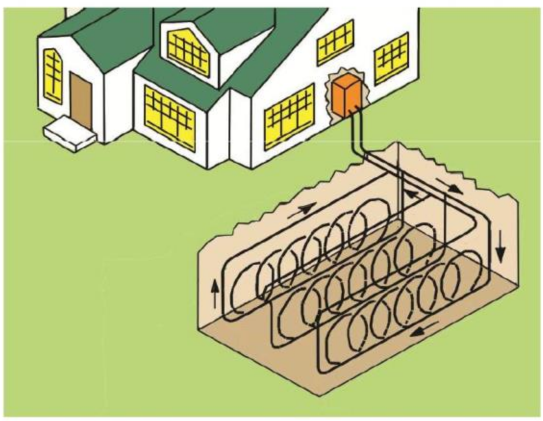
A vertical loop well field, being used for the Finger Lakes Institute, consists of 20 wells, drilled to a depth of 100’.There are 5 (clusters) of 4 wells spaced approximately 12 feet on center, The depth and number of wells was determined by the estimated heat and cooling load required maintain a comfortable environment for the occupants.



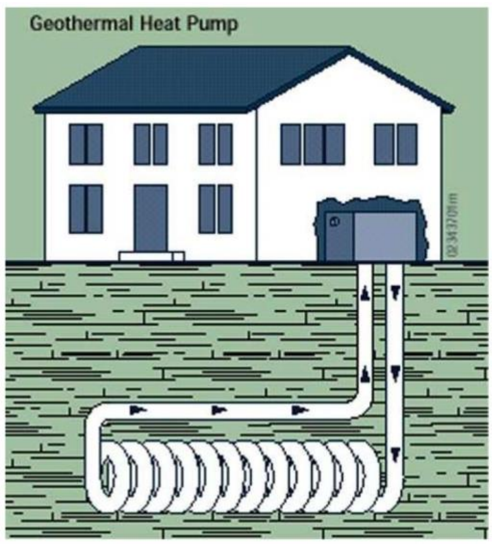


Slinky Loops

Increasingly, "Slinky" coils -- overlapping coils of polyethylene pipe -- are used to increase the heat exchange per foot of trench, but require more pipe per ton of capacity. Two-pipe systems may require 200 to 300 feet of trench per ton of nominal heat exchange capacity. The trench length decreases as the number of pipes in the trench increases -- or as Slinky coil overlap increases. (Illustration below shows a slinky coil in a pond).



Closed horizontal-Slinky loop system



Pond Loops

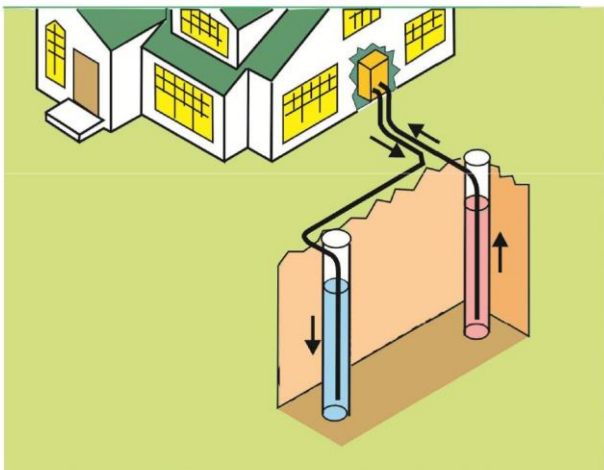
Pond closed loops are a special kind of closed loop system. Where there is a pond or stream that is deep enough and with enough flow, closed loop coils can be placed on the pond bottom. Fluid is pumped just as for a conventional closed loop ground system where conditions are suitable, the economics are very attractive, and no aquatic system impacts have been show.

Pond Loop

- **Most *Cost Effective* closed loop design**
- **Pond Depth – 12 – 15 ft minimum maintained depth**
- **Pipe Length – One 300 ft. coil per ton (minimum)**
- **Capacity – 10 to 20 tons/acre of pond**

Open loop systems (groundwater systems)

Groundwater systems are more efficient than closed loop systems. The technology "normal" groundwater wells is used for energy extraction. The temperature of groundwater is practically constant all over the year and as such it is the best carrier of thermal energy.



Open ground water loop system

Technical limitations

For systems using the underground for seasonal storage of heat and cold, the source

of energy for storage may be different:

- waste heat from industrial process cooling
- waste cold from heat pump evaporators,
- technical limitations such as load, duration, temperatures, availability.

Geological limitations

The geological requirements differ according to what type of system is to be installed:

- Closed loop systems are in general applicable in all types of geology.
- Open systems require a geology containing one or several aquifers.

Hydro geological limitations

The hydro geological conditions in practice govern the design of any open loop system.

For the design and realization of such systems essential are: type of aquifer, geometry, groundwater level and gradient, textural composition, hydraulic properties and boundaries.

For closed loop systems these parameters are of less importance, but can in some cases constitute limiting conditions.

Climate conditions

Climate plays an important role in the application of GSHP systems. One essential condition is that the ambient temperature of the ground is reflected by the average temperature in the air.

Another climate factor is the humidity. In hot climates with a high humidity, there will be temperature requirement for cooling that allows condensation.

2. APPLY HEAT PUMPS TO REAL CASES

2.1 Morgan Academy, Dundee, UK-Scotland

Exemplary design categories: community use and involvement, cultural and historical value.

How the facility meets the needs of education and communities:

Morgan Academy is a Grade 'A' listed building and a Dundee landmark which was destroyed by fire in 2001. Its restoration involved a complex design to rigid standards, dictated by Historic Scotland, to ensure that the Grade A listed building classification was maintained. This baronial style architecture has been preserved as part of Scotland’s architectural heritage. The building incorporates the historic architecture of the façade while developing a modern teaching facility within the footprint of the original building. he project demonstrates that historical architecture and new designs can be integrated to provide a functional teaching facility in a modern environment. Key architectural features, including the tower and spiral staircase, have been maintained and utilised for special education classes. The bulk of the interior space, however, has been transformed into a bright, modern teaching facility designed to meet the new technological age in learning and teaching. All rooms are equipped with network connections and overhead interactive LCD projectors. The large hall and social area provide a focus and meeting area for the school, enhancing the ethos and sense of belonging for the pupils.

Various sustainability issues were considered, including the use of renewable energy sources, energy efficiency and recycling of materials. **Geothermal heat pumps**, using natural heat source from the ground, were installed and partly funded from a £100K grant from the Energy Savings Trust. A photovoltaic panel, to produce electricity generated by the sun, will also be installed to power the heat pumps. This will be partly funded by a grant from the Department of Trade and Industry. Sun tubes for natural lighting, local control of room temperatures and presence detectors for lighting were all installed. Stonework, slates, lead and windows were all recycled and timber used was from FSC approved forests.

Involvement of users and the local community in the planning and design process:

This project was implemented through a partnership agreement between client, contractor, consultants, and associated sub-contractors and sub-consultants. The design process was ongoing when the client representatives, which included the headmaster, teaching staff and pupils, joined the project team. All these groups were consulted and about the key features, including spacious social areas and corridors to allow free, unhindered access; extensive use of modern methods to ensure natural light reaches all areas of the building; and a safe environment gained by the extensive use of CCTV and anti-vandal measures.

Project costs: GBP 18,000,000.00

Source: 3rd CELE Compendium of Exemplary Educational Facilities (2006)

Facility Information

LEVEL OF EDUCATION:	Lower secondary, Upper secondary
YEAR OF COMPLETION:	2004
TYPE OF PROJECT:	Renovation
FUNDING:	public
MANAGEMENT:	public
TYPE OF FACILITY:	permanent
NO. OF STUDENTS:	944 full-time (2011)
NO. OF TEACHERS:	83.3 FTE (2011)
GROSS FLOOR AREA:	7870 m^2

2.1 Pietrelcina elementary school

Pietrelcina (BN), Italy

Need: Heating

Heating Capacity: 126 kW

School building

The primary school of Pietrelcina, Municipality in the province of Benevento, has installed a group of gas absorption heat pumps that use renewable geothermal energy for high efficiency heating and producing domestic hot water

2.2 Buon Pastore Kindergarten

Ravenna, Italy

Need: Heating

Heating Capacity: 80 kW

School building

The new Buon Pastore Kindergarten in Ravenna, which includes four sections for a total of more than one hundred children, stands on a land owned by the city and was built thanks to a municipal investment. The one-storey building has an area of around 650 square meters. The structure is made up of two buildings that open like a fan, allowing the surrounding green space to enter between them.

The entire structure with wooden cover, has been conceived, both in the form and in the plant choices, to minimize consumption.

The heating and DHW production are carried out with absorption heat pumps powered by gas and air source renewable energy.

CONCLUSION

Geothermal energy is a largely CO_2 free renewable energy source available at virtually every location. The technology is proven to reliably meet heating, cooling and electricity supply needs. Geothermal also promotes local economic development and job creation. It also is a significant contributor to energy security. Further deployment of this renewable resource requires a strong commitment by public authorities and the private sector. A major barrier to increased deployment of geothermal energy remains awareness of the technology. The support of public authorities plays a key role in promoting geothermal energy.

To deploy geothermal energy, it is crucial that a balanced framework is put in place to provide security of investment for project developers and stability through support schemes, as well as adequate licensing and regulatory conditions. The framework must consider the specificities of geothermal energy technologies as well as a long-term perspective for development.

Investment in research and innovation is directly linked with the deployment of geothermal energy: research shows the correlation between the number of kilometres of exploration drilling and the number of geothermal heating systems.

Therefore it is necessary to solicit European Commission, the European Parliament, the EU Member States and the associated Countries to intensify the support to research, development and innovation in geothermal energy, and to launch a European Geothermal Exploration Campaign that addresses the key barrier to the development of the technology.

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SELF ASSESSMENT TEST

1. Geothermal heat pumps are economically an advantage or a disvantage?
   g) An advantage
   h) A disvantage
   i) A disvantage compared to traditionale gas boilers
2. Heat pumps offer significant emission reductions potential: it is true?
   a) Yes
   b) No
   c) It depends on the climate

3. What does a heat pump do?

   a) Heat pumps transfer heat stored in the Earth or ground water into a building.
   b) Heat pumps run oil furnaces.
   c) Heat pumps are part of a solar array.

4. Why is geothermal energy similar to solar energy?

   a) Both are fossil fuels.
   b) Both are sources of renewable energy.
   c) Both are cheap to harness.

5. Can a heat pump also be used to cool a house?

   a) Yes
   b) No
   c) Maybe

6. Which of the following terms best describes a type of geothermal system that pumps ground water directly from a well into a building, and then allows the water to leave the building?

   a) closed-loop
   b) open-loop system
   c) horizontal

7. What type of geothermal system is a vertical loop?

   a) closed-loop
   b) circular-loop
   c) open-loop

8. What percentage of a home's cooling and heating needs can a heat pump provide?

a) 100%
b) 50%
c) 75%

9. Which of the following statements is true?

a) Geothermal energy improves indoor air quality.
b) Geothermal energy cannot be used to heat office buildings.
c) Geothermal energy is cheap to install.

10. How much money can a geothermal heating system save consumers on their energy bills?

a) 20 to 60%
b) 10 to 20%
c) 5 to 10%

Which of the following terms best describes a geothermal system in which an antifreeze solution is continuously circulated?

a) closed-loop
b) vertical
c) horizontal

•

Financial solutions for school's renovation. The incentives.

TITLE OF THE MODULE:

Financial solutions for school's renovation. Incentives.

Presentation of the module:

The aim of this module is to provide a basic information and guidance on available financing models for energy renovation of public buildings, including schools. Three main models are presented: self-financing, debt-financing and grant schemes. The features of each model are explained and possible variants within each model are given. Apart from these three dominant models, some new, innovative ways of financing energy renovation projects are explained, like crowdfunding and on-bill financing. The available sources of funding at the EU level are also given in this module.

Educational objectives:

- understanding the basic financing models available for energy renovation of public buildings
- competence to understand and analyse applicability of these models for energy renovation of buildings;
- capacity to select the most appropriate incentive for energy renovation project.

Content of the module:

1. Introduction

As any activity, energy renovation has its related costs, which vary according to the depth of the refurbishment, i.e. number and complexity of implemented energy efficiency (EE) measures. Therefore, any decision on energy renovation of a building must carefully evaluate these costs and ensure financing, in order to reap the benefits after the implementation.

There are several possible solutions for financing EE projects in the public sector and more specifically in schools. The most common financing models include:

i. Own funding (self-financing)
ii. Loans (debt-financing)
iii. Grants (non-refundable incentive)
iv. Public-private partnership (PPP) and
v. Energy performance Contracting (EPC).

This module deals with the first three models. Besides them, some alternative financing models are also presented and discussed. Due to their specificities and significance, the PPP and EPC models are presented in the separate Module: Financial solutions for school's renovation. PPPs and EPCs.

Apart from the general financing models, this module will also present possibilities for the use of EU investment and technical assistance programmes at EU level. Use of these funds may significantly contribute to the wider energy renovation. Not only that they can be used as an investment support, they can also be used to develop all the documentation needed for energy renovation of public buildings. Namely, often the public sector is lacking both money and capacities even to prepare project documentation for energy renovation projects, hence this kind of support is also seen as an incentive for energy renovation.

2. Financing models for energy renovation of public buildings

2.1.1. Own funding (self-financing)

Traditional financing of projects in cities and municipalities relies dominantly on the use of own budget. One of the financing challenges facing municipalities, more often for smaller municipalities rather than larger ones is the insufficient revenue base with which to fund projects (not only EE projects, but also other development projects as well). An insufficient revenue base, which may be the result of a small number of tax-paying commercial businesses and/or high-income residents, can reduce the availability of adequate funds for capital investments. Municipalities depending on revenue transfers from regional or national governments often have limited revenue-raising powers. Such limitations imply that any decision to invest in an EE project either requires the municipality to reallocate funds or convince higher levels of government that the EE project is economically viable. This may often not be a simple task. Reliance on transfers from other levels of government also exposes municipalities to the risk that permitted levels and uses of funds may be affected by changes in national budgetary or political priorities. This introduces further uncertainties and makes commitment to multi-year programs of capital expenditures more difficult.[27]

[27] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH: "CF4EE - Crowdfunding for Energy Efficiency", October 2016, available at: http://www.ieadsm.org/wp/files/2016-10-28-CF4EE-Feasibility-Study-final.pdf

One of the solutions may be in the establishment of a **revolving fund**.

Revolving (loan) fund is defined as a fund set up for specified purposes with the proviso that repayments to the fund may be used again for these purposes. Revolving funds at a city/municipality level can be a sustainable solution for providing long-term financing of EE investments in public buildings and infrastructure. Under typical revolving EE funds, loans are provided to cities/municipalities to cover the initial investment costs of EE projects. The savings resulting from reduced energy consumption and improved EE are then used to repay the loan to the fund until the original investment is recovered, plus interest and any fees or service charges. The repayments can then be utilized to finance additional investments in EE, thereby leading to the revolving fund. Such funds can often offer lower cost financing with longer tenors and reduced security requirements than commercial loans, since both the borrower and lender are publicly owned. [28]

The main issue in establishing revolving funds is initial capital (seed) of the fund. Initial funding sources needed to establish such a revolving fund may include city's/municipality's own funds (from the budget), government allocations or grants/loans from donors or other external sources. Such funds may be established and managed by a single city/municipality, but often they are established also at regional or even national level offering financing to multiple cities/municipalities. In such cases, the funds are often managed by competitively selected fund manager with its compensation tied to the fund's performance. In case of revolving funds established at a single city/municipality level (internal), they can be excellent centres of expertise at a city/municipality level enabling long-term holistic approach considering total costs and benefits of projects.

The illustrative, simple presentation of a revolving fund structure and operation is shown in the Figure 47.

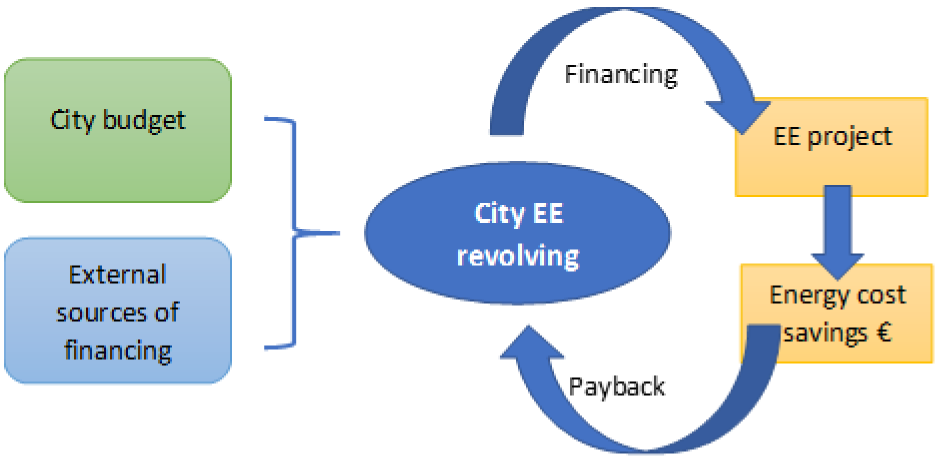

Figure 47 – Illustration of Revolving Fund for energy efficiency projects in public sector[29]

[28] IBRD & World Bank: „Financing Municipal Energy Efficiency Projects", gudance note #2 developed under Energy Sector Management Assistance Program (ESMAP), July 2014, available at: https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/FINAL_MGN1-Municipal%20Financing_KS18-14_web.pdf

[29] Energy Cities: „Financing the energy renovation of public buildings through Internal Contracting", guidebook prepared within Infinite Solutions Project, February 2017, available at: http://www.energy-cities.eu/IMG/pdf/guidebook_intracting_web.pdf

Example 1: Revolving EE fund in City of Koprivnica, Croatia

When it comes to energy efficiency and innovative financing solutions, city of Koprivnica is among the leading local and regional authorities in Croatia. Together with its strategic partner - Regional Energy Agency North (REA North) – it explored the opportunity to set up a local energy revolving fund that would finance its sustainable energy actions in the public sector. The Fund was established in late 2015 and became operational in 2016. The Fund will finance the implementation of energy efficiency projects that aim at greater reduction of energy use and significant financial savings resulting from lower energy bills and maintenance costs. The Fund is also expected to improve the way energy investments are planned, designed and implemented (e.g. preparation or procurement of energy related documentation), to speed up and simplify decision making about the investments and bring the financial benefits. The initial size of the fund - seed money - is 20,000 EUR but it will attract money from other sources as well. The simple scheme of the Fund is as shown in Figure 47*1.*

More info can be found at: http://www.energy-cities.eu/Koprivnica-Croatia

2.1.2. Loans (debt-financing)

When it comes to loans, i.e. borrowing, national governments often impose limits on borrowing by municipalities to prevent them getting into financial difficulties. These restrictions may take the form of limits on the use of loan funds and/or on the total amount that municipalities may borrow. In both cases, EE projects are likely to lose out, because they are not typical capital expenditure projects that can be readily assessed and approved by higher authorities. In addition, when debt ceilings are in place, EE projects, with relatively low public profiles, are likely to have a lower priority than other pressing or mandated needs.

Nonetheless, in cases where dept financing is possible, financing sources (banks, investors, etc.) require confidence on the project performance through the entire life cycle (confidence therefore on savings and cash flows over the years). A sound and complete technical/financial plan with a clear definition of the complete process necessary to ensure performance from initial audit through ongoing commissioning and M&V (Measurement & Verification) will be needed for the bankability of the EE project. The most common debt-based financing instruments are:

- loans from banks that come in a large variety of types and always imply debt and interest rates;
- bond issuing, which in general terms, is a debt instrument issued by the public body in order to raise money. The issuer must pay a fixed amount each year until the certificate of debt reaches its predetermined maturity date;
- leasing, in most cases, in effect, is a hire - purchase agreement without the requirement of an initial deposit.

Incentivised form of loans is referred to as **soft loan**. Soft loans are dedicated credit lines for EE measures extended to end users at preferential terms in terms of maturity and/or interest rates. Such credit lines are often provided by national or international development banks (such as European Investment Bank (EIB) and European Bank for Reconstruction and Development (EBRD) and are further distributed to designated markets through regional partner retail banks.

Incentives in loan financing may also come in the form of **guarantees**. Guarantees provide a means of transferring risk from a lender or financier to another entity that is better placed and willing either to manage or absorb the risk. For municipal EE projects, loan guarantees typically are provided by donors. However, in some cases, a municipality or a higher level of government may provide the guarantee. Credit and risk guarantees can be distinguished. Credit guarantees will cover the loss from a loan default regardless the reasons behind this loss. Risk guarantees will, on the other hand, cover only the loss caused by a specific risk. Guarantees usually cover less than 100% of the loss on default of the loan, making sure this way that entity taking the loan also takes over some part of the risk. Guarantees are, therefore, a risk sharing mechanism and as such may facilitate bank financing of city/municipal EE projects.

Example of soft loans and guarantees offered for city/municipal EE projects is found in Bulgaria and is described below.

Example 2: Energy Efficiency Loans and Guarantees in Bulgaria

Bulgarian Energy Efficiency and Renewable Sources Fund (EERSF) was established pursuant to the Energy Efficiency Act, with intergovernmental agreements between the Global Environment Facility (through the World Bank), the Government of Austria and the Government of Bulgaria. It is the only institution in Bulgaria for financing energy efficiency investment projects.

EERSF offers loans to municipalities with interest rates 4-7% and maximal tenor up to 7 years. Minimal financial participation of the client in the proposed project should be at least 10%. There are no additional conditions on the loan and the monthly payment schedule is to be prepared in relation with beneficiaries' needs. Loan amount can be from 30,000 to 3,000,000 BGN. Unntil teh end of 2015, EERSF has provided financing for 98 municipal EE projects, the total investment of which was 36.8 millin BGN with the EERSF's share in loan of 24.1 millin BGN.

EERSF offers also partial credit guarantees to share in the credit risk of EE finance transactions and to improve loan terms for project sponsors. The partial credit guarantees covered potential loan loss claims up to 80 percent of the outstanding loan principal (portfolio) of the financial institution, with guarantee fee 0.5-2.0% of the guarantee balance per year and individual guarantee commitments not exceeding 800,000 BGN.

More info can be found at: http://www.bgeef.com/display.aspx?page=products

And finally, **green municipal bonds** are also a form of debt-financing. Although they are still not widely used, the mechanism is worth mentioning due to its huge potential. Green bonds are bonds which are usually issued by private companies, local or regional authorities or international organisations for the development of projects with environmental benefits. In 2014, the market grew rapidly, with $36.8 billion issued, triple 2013 levels, driven by interest from insurance and pension funds seeking to address their concerns about climate change. In 2015, $41.8 billion of green bonds was issued, out of with more than $5 billion were issued by cities, municipalities or provinces. While 46% of the proceeds from Green Bonds are used to support renewable energy, only 20% go into energy efficiency. While development banks and corporations are the largest issuers of green bonds, the share of cities and municipalities in issuing green bonds is much lower, but it is continuously growing especially in 2014 and 2015. This rapidly growing market has the potential to help cities attract new investors and competitively priced capital to low-carbon and climate-resilient infrastructure investments. The financial benefits of issuing green municipal bonds are access to low-cost debt capital markets and investor diversification, while issuing of bonds can also be used for marketing of climate change plans, increased collaboration between financial and environmental departments within city/municipality administration and raising citizens' awareness on environmental issues of a city/municipality. In order to be successful and deliver desired targets, the process of issuing green bonds must be carefully structured and the following steps should be respected:

1. Identify qualifying green projects and assets – it is important that project that is to be financed by issuing of bonds is „green" (eligible projects under green/climate bonds are: green buildings, green infrastructure, clean transportation, industrial

efficiency, agriculture, bioenergy and forestry, clean water and clean energy projects, waste management and methane reduction);

2. Arrange independent review – verification provides confidence of investors and confirms the quality of the project;
3. Set up tracking and reporting - to ensure all proceeds are applied to green projects, the sum of the cash on hand and amounts invested in assets or projects must not be less than the amount of the bond;
4. Issue your green city bond - the usual steps apply here, as for any other conventional bond:
5. Monitor use of proceeds and report annually - at least annually, issue a public report to confirm that the funds are still properly allocated to green projects.

Example 3: Green bonds of Île-de-France, City of Paris, France

French market of green bonds is very well developed. Green bonds are issued by companies but also by city administration. Île-de-France issued firstly issued its green bonds in April 2014. It raised 600 million €. Maturity of the bond is 12 years, with annual coupon 2.375%. The demand was very strong with 175 % oversubscribed. Socially Responsible Investment buyers dominated as they bought 84% of the issue.

More info can be found at: http://www.paris-europlace.com/en/our-priorities/green-bonds

2.1.3. Grants (non-refundable incentive)

Most of available grant schemes are based on the use of European Union structural and investment funds (ESI). EE projects in buildings belong to projects that generate net income after completion, i.e. the energy cost savings of the project are treated as net income.

Under the preamble (paragraph 13) of the Delegated Regulation 480/2014, as well as under recital (paragraph 58) of Regulation 1303/2013 of the EU, it is necessary to accurately calculate net income to ensure the efficient use of Union funds and to avoid over-financing of projects. Determining the share of co-financing by the Union should reflect the rule of non-profit - grants must not result in earning a profit. If they are profitable, it is necessary to conduct a financial analysis to determine the financing gap, the assessment of the need for grant and the amount of potential grants.[30] Therefore, the purpose of co-financing through grants is to close the financing gap that is generated in energy efficiency projects when the investment in energy efficiency cannot be paid off from savings on energy costs.

The formula for calculating the financing gap is:

$$\boldsymbol{NPV(i,N)} = \sum_{t=0}^{N} \frac{\boldsymbol{R_t}}{(\boldsymbol{1}+\boldsymbol{i})^{t}} = \boldsymbol{R_0} + \sum_{t=1}^{N} \frac{\boldsymbol{R_t}}{(\boldsymbol{1}+\boldsymbol{i})^{t}}$$

where:

$\boldsymbol{NPV(i,N)}$	net present value of the project
$\boldsymbol{i} -$	discount rate
$\boldsymbol{N} -$	period of project evaluation
$\boldsymbol{R_0} -$	initial investment

30 GUIDANCE FOR BENEFICIARIES of European Structural and Investment Funds and related EU instruments, EC, 2014 (http://ec.europa.eu/regional_policy/sources/docgener/guides/synergy/synergies_beneficiaries.pdf)

$\boldsymbol{R_t = R_1 \dots \dots R_N -}$ net income = annual energy cost savings and maintenance costs

The net present value is the difference between the sum of discounted net income over the entire project implementation period and the amount of investment costs. The net present value represents measure of added value today that results from the undertaken investment. In case the project has a negative net present value, it corresponds to the amount of the financing gap. The financing gap represents a part of the investment that needs to be co-financed by grants so that the net present value of the project corresponds to the amount of zero.

After calculating the financing gap in an absolute amount, it is necessary to determine the project co-financing rate. The co-financing rate is obtained as the ratio of the financing gap amount and the amount of initial investment in the energy efficiency project.

The formula for calculating the required co-financing rate is as follows:

$$co - financing\ rate = \frac{NPV\ (i, N)}{R_0}$$

If the project is co-financed by grants with the co-financing rate calculated according to the aforementioned model, the energy efficiency project in buildings will achieve net present zero value and will be economically justified.

2.1.4. Alternative models for financing energy renovation

There are new, innovative financing models emerging for energy renovation of buildings that can address both overarching barriers to wider implementation of EE projects at city/municipality level – lack of capacities and limited access to capital. The most important are public-private partnership (PPP) and energy performance contracting (EPC), to which the whole separate module is dedicated.

In this section, some other interesting models will be presented as they may be utilised for stimulating energy renovation. These are crowdfunding and on-bill lending.

Crowdfunding is the mobilization of funding for projects from a large number of investors ('the crowd') using internet-based platforms and online processes. The size of the investment of an individual investor can range from very small (say €50) to large (several thousand Euros). Crowdfunding is generally divided into four different modalities:

- Donations – the oldest form of crowdfunding, using the internet to fundraise for projects, causes, and organizations;
- Rewards – in exchange for a contribution, the crowd investor receives a non - financial return, such as new music CD, the production of which was crowdfunded, or vouchers to make purchases in a specific shop;
- Debt – the crowd investor provides a loan to a project or to another person (e.g. peer-to-peer lending) and expects in exchange interest payments and the return of the principal;
- Equity – the crowd investor acquires a share in a company and expects dividends and/or a value increase in return. Here the crowd participates in upside and downside risks of the business.

For EE project debt and equity crowdfunding are of importance. Firstly, because energy efficiency projects are generally assumed to be cost - recovering and hence can offer a financial return to investors. Second, because debt and equity crowdfunding have a greater potential to scale up, and therefore are more relevant when considering financing a growing pipeline of energy efficiency projects with costs often exceeding €100,000 and therefore typically beyond the scope of donations or reward crowdfunding.[31] Typical crowdfunding process includes the phases as shown in the Figure 48.

Crowdfunding is still not widespread model for financing energy efficiency projects. There are many crowdfunding platforms (CFP) available in the field of clean energy (especially renewables, which appear to be more attractive than EE projects), but very few of them in Europe are specialised solely for energy efficiency. Some of the pioneer CFPs are Bettervest or ECONEERS in Germany.

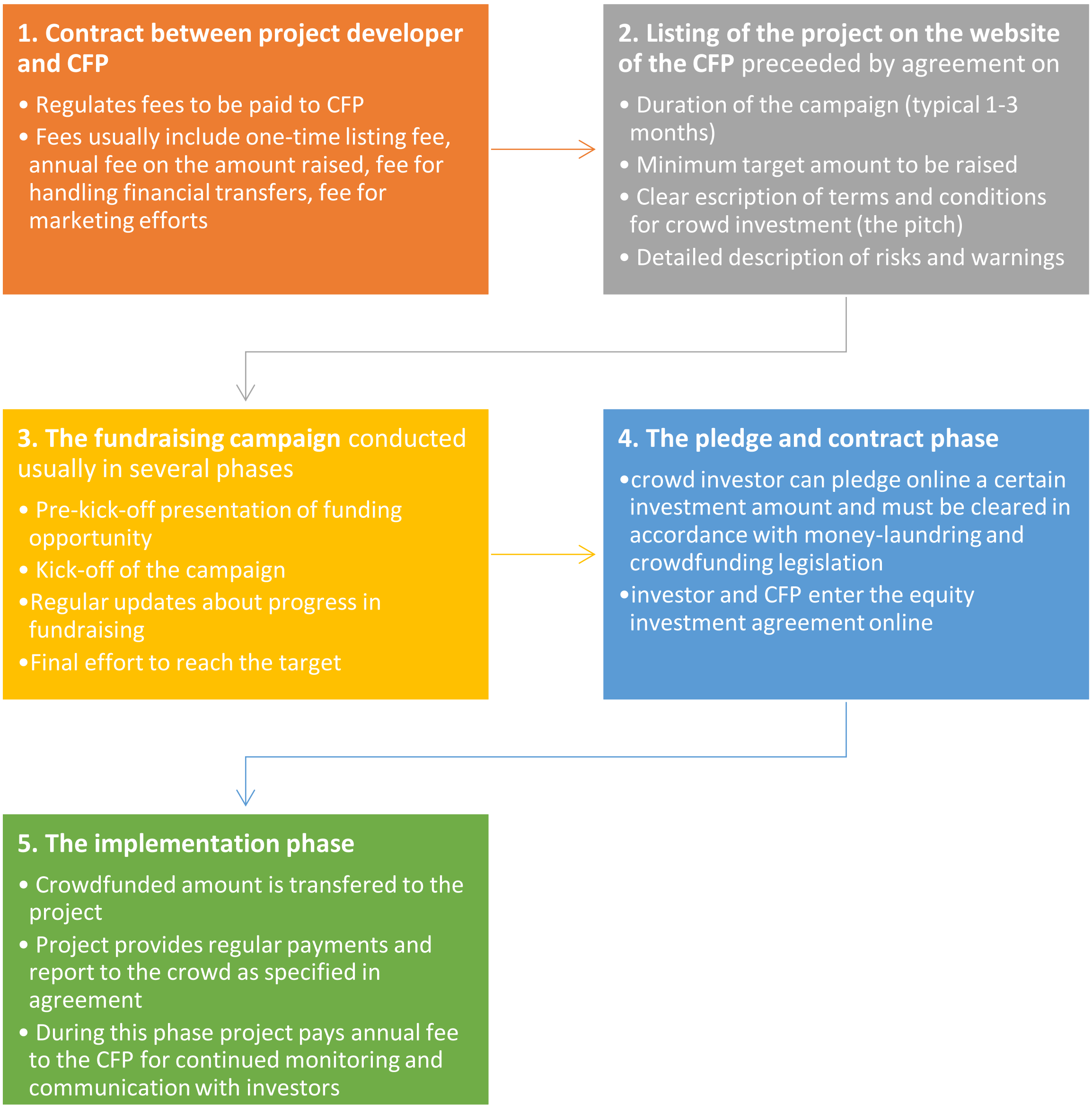

Figure 48 – Typical crowdfunding process

[31] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH: "CF4EE - Crowdfunding for Energy Efficiency", October 2016, available at: http://www.ieadsm.org/wp/files/2016-10-28-CF4EE-Feasibility-Study-final.pdf

One recent example of CFP for energy efficiency is found in Croatia and is described in the box below.

Example 4: Energy Efficiency Crowdfunding in Croatia – croenergy.eu

North-west Croatia Regional Energy Agency (REGEA) has been established in 2008 by Zagreb County, Karlovac County, Krapina-Zagorje County and City of Zagreb under the framework of the Intelligent Energy Europe programme. In 2015, REGEA started the unique CFP in Croatia – Croenergy.eu. The aim was to establish a platform that will be used for EE, RES and other green projects and to test this innovative way of financing in Croatia. The first crowdfunding campaign was launched under the name "You and me, for kindergarten in Pregrada". It aimed at gathering 80,000 HRK for closing the financial construction of the project for thermal insulation of building envelope (walls and roof) of the kindergarten in town of Pregrada. The town ensured grants from Croatian Environmental Protection and Energy Efficiency Fund and from Ministry of Economy, however still 80,000 HRK were missing. The campaign was based on donations. Depending on the amount of donation, the crowd investors received symbolic gifts, like thank-you cards, T-shirt, name listed in the permanently displayed donors list at the kindergarten wall. Donations ranged from 10 to 2,000 HRK. The campaign was a remarkable success. It surpassed the targeted amount and eventually 97,092 HRK was gathered from 215 crowd investors. In April 2016 the energy refurbishment of Pregrada's kindergarten was completed.

REGEA with its CFP Croenergy.eu has demonstrated that Crowdfunding for public EE projects is possible. There were two campaigns at this platform, all directed to improvement of conditions in public schools.

More info can be found at: http://croenergy.eu/

The other promising financing model is **on-bill lending**. On-bill lending is a method of financing energy efficiency improvements that uses the utility bill as the repayment vehicle. The term on-bill financing has become an umbrella term for any financing program that includes charges on a utility bill32. However, there are several models that are successfully applied, dominantly in the USA, while the model is still not widespread in the EU. The first model is actual on-bill financing (OBF). The main characteristic of this model is that utility is a lender. Ratepayer funds collected for energy efficiency programs are the most common funding source, but utility shareholder funds can also be used. OBF is the most commonly used on-bill model, probably because utilities can implement them entirely by themselves, with no costs associated with negotiating terms or recruiting third-party capital providers. Second model is on-bill repayment, in which the capital provider is a third party, and the utility operates as a repayment conduit for that third-party capital provider. A utility may opt to use its own funds to offer administrative support or credit enhancements. And third model is tariffed on-bill. In tariffed on-bill model EE upgrades are financed not through a loan, but rather through a utility offer that pays for upgrades under the terms of a new, additional tariff. This tariff includes a cost recovery charge on the bill that is less than the estimated savings. The on-bill charge is associated with the meter at the address of the property or facility where upgrades are installed, and the cost recovery charge is treated as equal to other utility charges on the bill. Because the cost recovery is tied to the property's meter rather than the property owner, the tariffs remain in force regardless of

[32] American Council for an Energy-Efficienct Economy (ACEEE): „On-Bill Energy Efficiency", available at: http://aceee.org/sector/state-policy/toolkit/on-bill-financing

a change in occupancy, whether that is due to a new tenant, a point of sale, or a foreclosure. New occupants are obligated to pay tariffed charges until utility cost recovery is complete.

Typical on-bill model structure is presented in Figure 49.

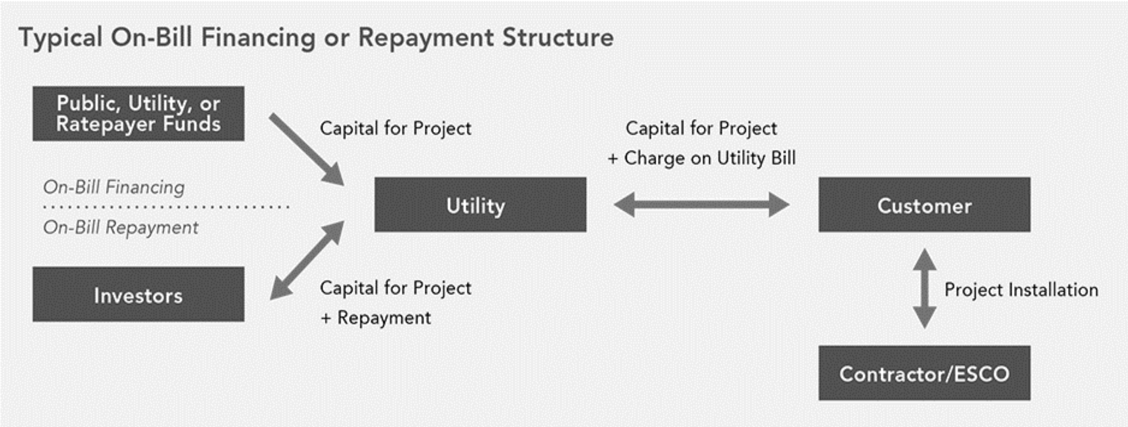

Figure 49 – Typical on-bill model structure[33]

On-bill financing is the most utilised in the residential sector, where two the most known examples are Green Deal34 in the UK and Pay As You Save (PAYS®)[35] in the USA. Recently, unitalities in the EU are starting their on-bill programmes as a part of **energy efficiency obligation scheme** imposed by article 7 of the EED. However, these programmes also focus on households or commercial sector consumers. Examples of on-bill financing for city/municipality EE projects in the EU were not found.

3. Financing sources for energy renovation of public buildings at EU level

EU budget is closely linked to the five priorities of the EU 2020 strategy: employment; research and development; climate/energy; education; social inclusion and poverty reduction. The most important funding instruments that finance sustainable energy investments (hard measures) are the European Structural and Investment Funds that are co-managed by the European Commission and Member States. The European Investment Bank is also becoming more and more active in financing local energy transition and climate projects. This funding could give a significant boost to local energy transition. The most important financing programmes are shortly presented hereafter.

3.1. European Structural and Investment Funds

[33] Source: https://betterbuildingssolutioncenter.energy.gov/financing-navigator/option/bill-financingrepayment

[34] Within Green Deal scheme, utilities help households to improve household goods such as boilers and are reimbursed via the energy bill. More info can be found at: https://www.gov.uk/green-deal-energy-saving-measures/overview

[35] The Pay As You Save® system enables building owners or tenants to purchase and install money-saving resource-efficient measures with no up-front payment and no debt obligation, but thorugh tariff payments as long as they occupy the location where the measures are installed. The monthly charge is always lower than the measure’s estimated savings and it remains on the bill for that location until all costs are recovered. More info can be found at: http://eeivt.com/wordpress/

European Structural and Investment Funds 2014-2020, are a package of funds delivered through Operational Programmes (OP) negotiated by regional authorities with the European Commission. Each OP defines strategic goals and investment priorities for each region and country involved. The OPs are managed by authorities at national or regional level in the partnership with the European Commission. Within the European Structural and Investment Funds the ERDF and Cohesion funds are the instruments that generally provide major funding for EE Energy Efficiency measures:

- **European Regional Development Fund (ERDF)** aims to strengthen economic and social cohesion in the European Union by correcting imbalances between its regions – example of the ERDF use for energy renovation of public buildings with more than 200 million EUR grant can be found in Croatia (https://mgipu.gov.hr/naslovna-blokovi-133/about-the-ministry-139/scope-of-the-ministry/european-structural-and-investment-funds-8173/8173), while more info on ERDF can be found here: http://ec.europa.eu/regional_policy/en/funding/erdf/
- **Cohesion Fund (CF)** is aimed at Member States whose Gross National Income (GNI) per inhabitant is less than 90 % of the EU average. It aims to reduce economic and social disparities and to promote sustainable development. The Cohesion Fund can also support projects related to energy or transport, as long as they clearly benefit the environment in terms of energy efficiency, use of renewable energy, developing rail transport, supporting intramodality, strengthening public transport, etc. For the 2014-2020 period, the Cohesion Fund concerns Bulgaria, Croatia, Cyprus, the Czech Republic, Estonia, Greece, Hungary, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia and Slovenia. More info: http://ec.europa.eu/regional_policy/en/funding/cohesion-fund/

3.2. Other European Investment Funds

The European Energy Efficiency Fund (eeef) targets investments in the member states of the European Union. The final beneficiaries of eeef are municipal, local and regional authorities as well as public and private entities acting on behalf of those authorities such as utilities, public transportation providers, social housing associations, energy service companies etc. Investments can be made in Euro, or local currencies, however the latter is restricted to a certain percentage. More information can be found at: http://www.eeef.lu/eligible-investments.html

European Fund for Strategic Investments (EFSI) is an initiative launched jointly by the EIB Group - European Investment Bank and European Investment Fund - and the European Commission to help overcome the current investment gap in the EU by mobilising private financing for strategic investments. With EFSI support, the EIB Group will provide funding for economically viable projects where it adds value, including projects with a higher risk profile than ordinary EIB activities. It will focus on sectors of key importance where the EIB Group has proven expertise and the capacity to deliver a positive impact on the European economy, including: Strategic infrastructure including digital, transport and energy; Education, research, development and innovation; Expansion of renewable energy and resource efficiency; Support for smaller businesses and midcap companies. For information on how to apply for a loan under EFSI see: http://www.eib.org/efsi/how-does-a-project-get-efsi-financing/index.htm

3.2.1. Project Development Assistance

Project realisation may be fostered with lighter instruments such as grants for technical assistance, in this case the funding is related to feasibility and market studies, programme structuring, business plans, energy audits and financial structuring. In other words, no money for project activities but only (a minor fraction) for a sound project development through a preliminary study.

ELENA is a joint initiative by the EIB and the European Commission under the Horizon 2020 programme and provides grants for technical assistance focused on the implementation of energy efficiency, distributed renewable energy and urban transport projects and programmes. The grant can be used to finance costs related to feasibility and market studies, programme structuring, business plans, energy audits and financial structuring, as well as to the preparation of tendering procedures, contractual arrangements and project implementation units. Typically, ELENA supports programmes above EUR 30 million over a period of around 2-4 years and can cover up to 90% of technical assistance/project development costs. Smaller projects can be supported when they are integrated into larger investment programmes. The annual grant budget is currently around EUR 20 million. Projects are evaluated, and grants allocated on a first-come-first-served basis. More information is available at: http://www.bei.org/products/advising/elena/index.htm

4. Summary

As for any other investment, for energy renovation projects the crucial question is availability of capital needed for realisation of the investment. Although energy renovation projects are in their nature revenue generating projects, i.e. revenue is in the form of energy cost saving, the high up-front investment is a significant barrier. In order to stimulate energy renovation investments, appropriate financing models should be selected. The usual selection is between self-financing, debt-financing and grant schemes. Combination of these models is also possible.

Self-financing may be very limited due to poor revenue base of a municipality. Grants from EU or national sources may help as well as some innovative ways of collecting funds, such as crowdfunding. More lasting securement of own funding for energy renovation may be achieved by establishment of in-house revolving fund.

When it comes to loans, i.e. borrowing, national governments often impose limits on borrowing by municipalities to prevent them getting into financial difficulties. These restrictions may take the form of limits on the use of loan funds and/or on the total amount that municipalities may borrow. If bowering capacity exists, incentive in form of soft loans, i.e. loans with preferential terms in terms of maturity and/or interest rates may stimulate energy renovation. The most innovative debt-financing model for energy renovation, used recently by larger municipalities, are green municipal bonds.

Grant schemes are available for national or EU energy efficiency related funds and programmes. They are usually combined with self- and debt-financing and reduce the need for up-front capital, hence improve the feasibility of the project. In these schemes, the available grant rate is calculated using the financing gap methodology, in order not to over-incentivise the project.

At the EU level there are available sources of funding for both energy renovation and preparation of the documentation needed for energy renovation. These include, as the most important once, ESIF, EEEF, EFSI and ELENA.

Consultation of documents and references

1. Training material on energy efficiency in public buildings - Financial aspects, interreg-CE Project TOGETHER; available at: https://www.interreg-central.eu/Content.Node/TOGETHER/Training-material-on-financial-aspects.pdf
2. Financing buildings energy renovation, Infinite Solutions Project: http://www.energy-cities.eu/spip.php?page=infinitesolutions_en
3. Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH: "CF4EE - Crowdfunding for Energy Efficiency", October 2016, available at: http://www.ieadsm.org/wp/files/2016-10-28-CF4EE-Feasibility-Study-final.pdf
4. IBRD & World Bank: „Financing Municipal Energy Efficiency Projects", gudance note #2 developed under Energy Sector Management Assistance Program (ESMAP), July 2014, available at: https://www.esmap.org/sites/esmap.org/files/DocumentLibrary/FINAL_MGN1-Municipal%20Financing_KS18-14_web.pdf

Self-assessment test

2. Which of the following is not a financing model for energy renovation?
    1. Self-financing
    2. Debt-financing
    3. Portfolio financing
3. What is the most important feature of a revolving fund?
    1. Repayments are used for the same purpose
    2. Repayments are used for any purpose
    3. There are no repayments
4. What is not the characteristic of soft loan?
    1. Preferential (lower than commercial) interest rate
    2. Preferential (higher then commercial) interest rate
    3. Zero interest rate
5. Which of the following is not a debt-financing?
    1. Municipal revolving fund
    2. Soft loan
    3. Municipal green bonds
6. Grant schemes should:
    1. Bring an extra profit to the project
    2. Not bring an extra profit to the project
    3. Not be used
7. Method of financing gap is based on the calculation of:
    1. Simple pay-back of an investment
    2. Net present value of an investment
    3. Internal rate of return of an investment
8. On-bill financing cannot be implemented without:
    1. It can always be implemented
    2. ESCO
    3. Utility
9. Crowdfunding is based on the:
    1. Large number of small investors
    2. Small number of large investors
    3. Only one investor
10. Technical assistance for development of project documentation can be obtained from:
    1. ELENA facility
    2. EU Parliament
    3. Commercial bank
11. European structural and investment funds used dominantly used for energy efficiency are:
    1. CF and EFSI
    2. ERDF and CF
    3. EEEF and ERDF

Financial solutions for school's renovation. PPPs and EPCs

TITLE OF THE MODULE:

Financial solutions for school's renovation. PPPs and EPCs.

Presentation of the module:

The aim of this module is to provide a basic information and guidance in the use of public-private partnership (PPP) and energy performance contracting (EPC) models for energy renovation of public buildings, including schools. These models provide a viable option to traditional procurement of building renovation works and can tackle two most important barriers to energy efficiency improvements in the public sector:

- unavailability of up-front capital needed for energy efficiency (EE) investments and
- lack of technical knowledge and capacities to develop, implement and monitor EE projects.

PPP model is not developed for EE but rather for large public infrastructure projects that cannot be implemented without engagement of the private capital. As they are not designed specifically for EE projects and their implementation implies very complex administrative procedure, they will be only briefly presented.

Much more attention is devoted to EPC model in this module. EPC proved to be very successful in achieving energy savings while taking over the risks and limiting needs for financial resources on the customer side. In this module EPC concept is explained and different models presented. The module includes an explanation of EPC process from identification of the potential projects and clients, preparing successful tenders, going through the procurement procedure and finally implementing the EPC project.

Educational objectives:

- understanding of main features of PPP model
- competence to understand and analyse applicability of EPC model for energy renovation of buildings;
- capacity to select the most appropriate financing model for energy renovation project.

Content of the module:

5. Introduction

As any activity, energy renovation has its related costs, which vary according to the depth of the refurbishment, i.e. number and complexity of implemented energy efficiency (EE) measures. Therefore, any decision on energy renovation of a building must carefully evaluate these costs and ensure financing, in order to reap the benefits after the implementation.

There are several possible solutions for financing EE projects in the public sector and more specifically in schools. The most common financing models include:

i. Own funding (self-financing)
ii. Loans (debt-financing)
iii. Grants (non-refundable incentive)
iv. Public-private partnership (PPP) and
v. Energy performance Contracting (EPC).

The first three modelsas well as some innovative financing models are presented in the Module: Financial solutions for school's renovation. Incentive. This module deals with the PPP and EPC models, as two most promising off-balance financing models.

6. Public Private Partnership

A public-private partnership (PPP) is an arrangement between a public authority and a private partner designed to deliver a public infrastructure project and service under a long-term contract. Under this contract, the private partner bears significant risks and management responsibilities. The public authority makes performance-based payments to the private partner for the provision of the service (e.g. for the availability of a road) or grants the private partner a right to generate revenues from the provision of the service (e.g. tolls from users of a bridge). Private finance is usually involved in a PPP. When properly prepared, PPP projects can provide significant benefits to the public sector as well as to the project users.

PPP arrangement differs from conventional public procurement in several respects. In a PPP arrangement the public and private sectors collaborate to deliver public infrastructure projects (e.g. roads, railways, hospitals) which typically share the following features:

- a long-term contract between a public procuring authority (the "Authority") and a private sector company (the "PPP Company") based on the procurement of services, not assets;
- the transfer of certain project risks to the private sector, notably with regard to designing, building, operating and/or financing the project;
- a focus on the specification of project outputs rather than project inputs, taking account of the whole life cycle implications for the project;
- the application of private financing (often "project finance") to underpin the risks transferred to the private sector; and
- payments to the private sector which reflect the services delivered. The PPP Company may be paid either by users through user charges (e.g. motorway tolls), by the Authority (e.g. availability payments, shadow tolls) or by a combination of both (e.g. low user charges together with public operating subsidies).

The rationale for using a PPP arrangement instead of conventional public procurement rests on the proposition that optimal risk sharing with the private partner delivers better "value for money" for the public sector and ultimately the end user.

PPP arrangements are more complex than conventional public procurement. They require detailed project preparation and planning, proper management of the procurement phase to incentivise competition among bidders. They also require careful contract design to set service standards, allocate risks and reach an acceptable balance between commercial risks and returns. These features require skills in the public sector which are not typically called for in conventional procurement.[36] This is the reason why this model is not widely used for energy renovation of buildings, which are typical of lower values and administration costs for preparation of PPP contracts might be too high.

7. Energy Performance Contracting

6.1.1. What is Energy Performance Contracting?

Energy performance contracting may be seen as a form of PPP. Energy performance contracting (EPC) is when an energy service company (ESCO) is engaged to improve the energy efficiency of a facility, with the guaranteed energy savings paying for the capital investment required to implement improvements.

The terms "energy services" [37] and "energy service companies (ESCO)" [38] are already well known and established in the energy efficiency field. They were defined already in the Energy Services Directive (2006/32/EC). The Directive 2012/27/EU on energy efficiency (EED) imposes obligations on Member States to support energy services market. The following provisions for energy services apply:

1. **Member States shall promote the energy services market and access for SMEs to this market by**:

(a) disseminating clear and easily accessible information on:

(i) available energy service contracts and clauses that should be included in such contracts to guarantee energy savings and final customers' rights;

(ii) financial instruments, incentives, grants and loans to support energy efficiency service projects;

(b) encouraging the development of quality labels, inter alia, by trade associations;"

[36] EIB European PPP Expertise Centre: http://www.eib.org/epec/g2g/intro2-ppp.htm

[37] 'Energy service': the physical benefit, utility or good derived from a combination of energy with energy efficient technology and/or with action, which may include the operations, maintenance and control necessary to deliver the service, which is delivered on the basis of a contract and in normal circumstances has proven to lead to verifiable and measurable or estimable energy efficiency improvement and/or primary energy savings

[38] 'Energy service company' (ESCo): a natural person or legal entity that delivers energy services and/or other energy efficiency improvement measures in a user's facility or premises, and accepts some degree of financial risk in so doing. The payment for the services delivered is based (either wholly or in part) on the achievement of energy efficiency improvements and on the meeting of the other agreed performance criteria

(c) making publicly available and regularly updating a list of available energy service providers who are qualified and/or certified and their qualifications and/or certifications in accordance with Article 16.

(d) supporting the public sector in taking up energy service offers, in particular for building refurbishment, by:

(i) providing model contracts for energy performance contracting which include at least the items listed in Annex XIII;

(ii) providing information on best practices for energy performance contracting, including, if available, cost- benefit analysis using a life-cycle approach;

(e) providing a qualitative review in the framework of the National Energy Efficiency Action Plan regarding the current and future development of the energy services market

2. **Member States shall support the proper functioning of the energy services market, where appropriate, by**:

(a) identifying and publicising point(s) of contact where final customers can obtain the information referred to in paragraph 1;

(b) taking, if necessary, measures to remove the regulatory and non-regulatory barriers that impede the uptake of energy performance contracting and other energy efficiency service models for the identification and/or implementation of energy saving measures;

(c) considering putting in place or assigning the role of an independent mechanism, such as an ombudsman, to ensure the efficient handling of complaints and out-of- court settlement of disputes arising from energy service contracts;

(d) enabling independent market intermediaries to play a role in stimulating market development on the demand and supply sides.

There are many initiatives to promote energy services and ESCO model in the EU, due to its potential to remove several important barriers to energy efficiency in public sector:

- unavailability of up-front capital needed for EE investments and
- lack of technical knowledge and capacities to develop, implement and monitor EE projects.

ESCOs are companies that work on a basis of energy performance contracts (EPC). In an EPC arrangement, the ESCO is responsible for optimizing building services systems and system operations in existing buildings across all branches of construction and maintenance. The main service provided by the ESCO is a guaranteed level of savings over a defined period.

Prior to engagement of an ESCO (**EPC provider**), an energy consultant (**EPC facilitator**) is engaged to identify opportunities for energy savings, ranging from operating practices, to maintenance, controls and equipment investments. The technical support and experience in energy efficiency provided from EPC facilitators can help to improve the customers' confidence and, therefore, create the conditions for a successful EPC project.

An EPC is a contractual arrangement between the beneficiary (or customer) and the provider of energy efficiency measures (ESCO), where investments (equipment, installation works and operation services) are paid for in relation to a contractually agreed level of energy efficiency improvements and other energy efficiency criteria, such as financial savings.

The key principle of EPC is that it allows funding energy efficiency measures with predicted cost reductions, avoiding capital requirements on the beneficiary's side.

An EPC is a way to deliver infrastructure improvements to organisations that lack knowledge of energy equipment performance, energy management skills, and capital funding. Cash-poor, but nonetheless creditworthy organisations are therefore good potential customers for Energy Performance Contracts.

Those organizations wishing to improve their energy efficiency and to reduce energy related costs might engage consultants, equipment suppliers or energy service providers to assist in this goal. Both sides have common interests and expectations, as they both benefit from achieved savings.

For the customer, the key advantages of EPC are:

- It allows to refurbish and modernise buildings and facilities;
- It provides long-term, guaranteed cost savings with zero or minimal investment;
- It consistently reduces an organisation's environmental impact;
- It allows outsourcing energy saving tasks to external service providers which are remunerated based upon their performance.

An EPC merges three types of contract into one: a contract for the refurbishments work, a credit contract and a service contract. Its approach is based on the transfer of economical and or technical risks from the client to the EPC provider, based on performance guarantees given by the EPC provider. The EPC provider's remuneration is therefore based on demonstrated performance: the main measure of this performance is the level of energy savings.

6.1.2. EPC models

The main idea of EPC model is provided in the Figure below.

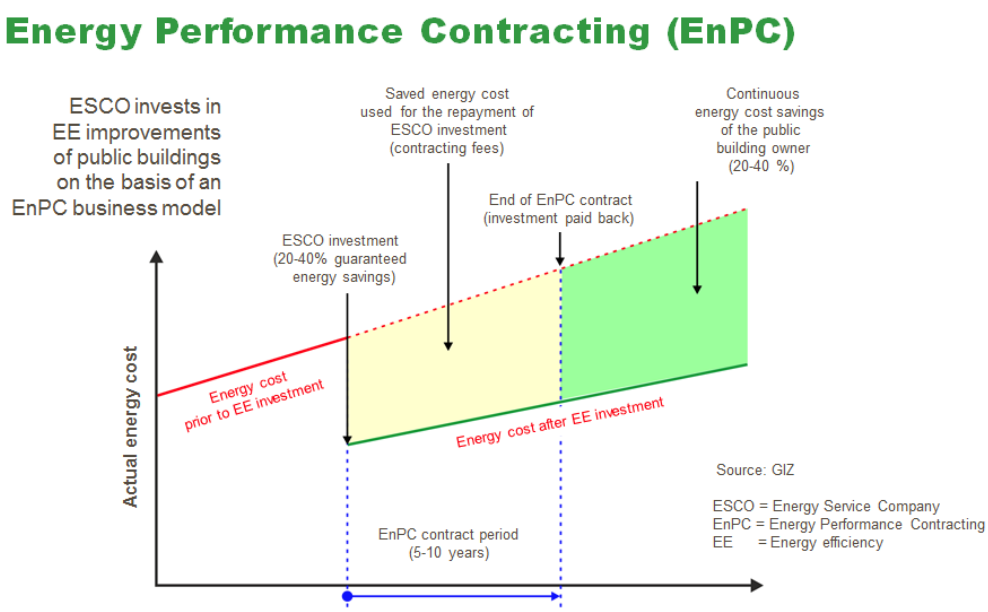

Figure 1 – Basic concept of EPC and ESCO operation[39]

There are several EPC models; hereby the three most common ones are explained.

Guaranteed savings

The EPC provider designs and implements the project and guarantees the energy savings. If the savings are less than expected, the EPC provider covers the shortfall. Usually a third party provides the financing directly to the customer; the EPC provider may facilitate the financing arrangements.

In a typical guaranteed savings contract the customer takes out a loan from a financier to finance the investments in energy savings. The customer contracts with the EPC provider to implement the energy savings works. The provider assumes performance risk by guaranteeing energy savings. The customer pays the provider on acceptance of the installation, possibly withholding a portion until savings have been verified.

The customer may also pay the provider an ongoing fee to verify savings annually or maintain the equipment. If savings are insufficient, the EPC provider pays the difference between what was achieved and what was guaranteed. The savings are valued based on a fixed energy price agreed at the outset. Here the provider takes the performance risk, the customer takes the energy price risk and the financier takes the credit risk.

Shared savings

The EPC provider designs, finances and implements the project, verifies energy savings and shares an agreed share of the actual energy savings over a fixed period with the customer. The EPC provider may receive financing directly from a third party.

In a typical shared savings contract the EPC provider offers the capital (perhaps out of its own funds or out of a loan from a third party financier to cover the cost of the investments in energy savings).

Typically, the term of the contract and the loan will match, and the provider share of the savings will exceed the loan repayment costs. Importantly, the financier is taking the risk that the provider may be unable to repay the loan; if the provider is a small or medium enterprise, the cost of credit may be quite high. In some cases, the energy savings may be valued based on prevailing energy prices, which means the provider also takes the energy price risk. These considerations generally mean the provider is a large enterprise with strong balance sheet and access to capital markets.

Although this contract arrangement can specify that the EPC provider will guarantee, rather than share, the savings, the provider is likely to prefer to share. Sharing savings incentivizes the customer to minimize energy use and reduces the energy performance risk.

Variable contract terms

The EPC provider designs and implements the project and verifies the energy savings. If the savings are less than expected, the contract term can be extended to allow the provider recover its full payment. A variable contract term arrangement is similar to a shared savings, except that it reduces the risk for the provider if the quantity or value of savings is less than expected.

[39] Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH: "Assessing Framework Conditions for Energy Service Companies", September 2012, available at: https://www.giz.de/fachexpertise/downloads/giz2013-en-esco-guide.pdf

A variation of this arrangement is called 'first out', in which case the EPC provider receives 100% of the verified energy savings each year until it has received its original capital plus an agreed profit. At that point, the contract ends and the owner starts receiving all the savings. The advantage of this arrangement is that it reduces the amount of time the customer and EPC provider are bound together.

Energy supply contract

In the case of Energy Supply Contracting (ESC) efficient supply of useful energy such as heat, steam or electricity is contracted, measured and delivered in physical units (such as MWh), thus it resembles district heating or cogeneration supply contracts. The energy service provider takes over the planning and construction of energy production and distribution systems or systems for measurement and control technology, the financing and operation of systems and the supply including maintenance during the contracted period. The service provider may also take over the purchase of fuel and electricity.

Energy saving measures are usually taken only on the energy supply side (boilers efficiency, etc.) as there is no motivation for the energy service company to implement measures on the energy demand side.

There is a number of ways in which the client pays for the ESC services. In Europe, most commonly, the price consists of the two following parts:

- The fixed part of the price covers all the investment. Usually the contract stipulates a minimum threshold volume for the take-off. When the client's takes-off is below this threshold, the fixed unit fee that has to be paid is higher.
- The variable part of the price covers operating costs including costs of fuel.

6.1.3. EPC process[40]

The five basic steps necessary to initiate and complete the process of awarding an energy performance contract are summarized in Figure 2. As shown, the process begins with the identification of a potential energy efficiency project and concludes with the successful obtainment of savings through installed equipment.

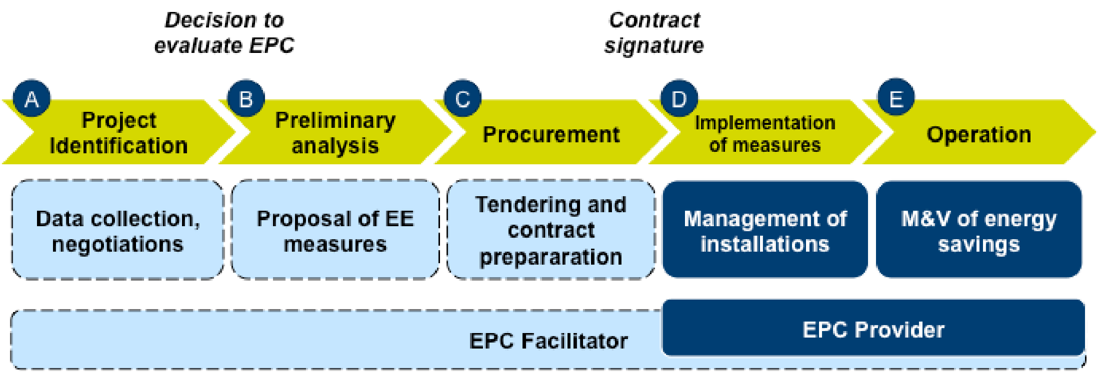

Figure 2: EPC process summary

[40] This section is based on the deliverables of the project TRUST-EPC-South, available at: http://www.trustepc.eu/en/public-deliverables

Project Identification

This initial step can be supported by an EPC facilitator, or by the end user if it has a good degree of energy efficiency knowledge. It usually involves the collection and analysis of data related to energy uses, the benchmarking of all major consumptions in the evaluated facility, and the development of a simple energy audit analysing equipment, estimating consumption factors based on the energy bills of the previous years.

Often, it makes economic sense to combine several facilities into a single project. Multiple building projects with excessive energy costs are usually very attractive and allow the agency to finance and obtain a greater number of energy improvements through a single procurement process.

Preliminary analysis

Rather than pre-determining a detailed scope of work specifying which energy efficiency measures the beneficiary should undertake, the EPC model uses the technical expertise of the EPC facilitator or provider to help identify and assess the most cost-effective energy savings opportunities.

This analysis involves a general technical overview of the selected project site. The EPC facilitator or provider will need enough technical details to adequately assess the opportunities to develop and implement a successful project. Generally, such information includes the facility's size, its energy uses, equipment, hours of operation, occupancy level, maintenance problems and it takes into account any planned equipment replacement or building renovation works.

Procurement procedure

The final customer, when looking to appoint the appropriate EPC provider, should look out for the key factors illustrated in Figure 3.

It is recommended to have preliminary meetings and site visits scheduled with all candidate EPC providers with the purpose of answering any questions related to the facilities and clarify technical matters. An EPC facilitator can very well support this process. A preliminary cash flow analysis should be offered by the candidate EPC provider to illustrate how the project will perform, financially, over the term of the contract.

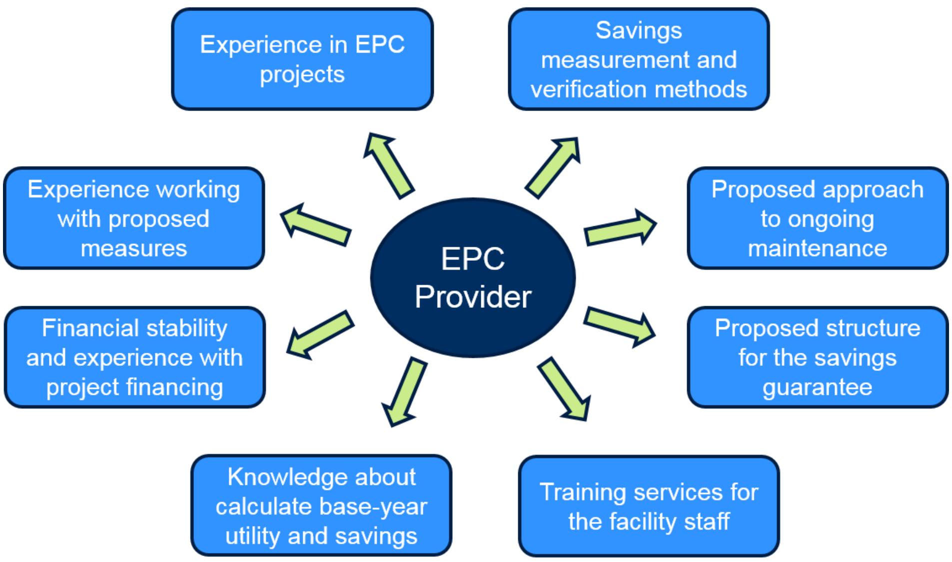

Figure 3: Skills of an EPC provider

Signature of contract and implementation of measures

The final Energy Performance Contract serves as the blueprint for how the project will operate over the contract term. The EPC should specify each party's role and responsibilities and should explicitly state how the project is expected and guaranteed to perform. Due to the long-term nature of this relationship, the contract should be specific yet flexible enough to accommodate both current and future facility needs.

The main body of the contract frames the basic legal provisions and allocates specific responsibilities to each party. It specifies governing laws, conditions of default and remedies, regulatory requirements (e.g., insurance, labour and wage rates, code compliance, etc.), and indemnification provisions. The contract can be customized to accommodate additional terms and conditions as necessary

Since individual projects and circumstances vary, companies should seek appropriate legal advice about individual EPC projects and work closely with them to incorporate any special contract terms and conditions into the final contract.

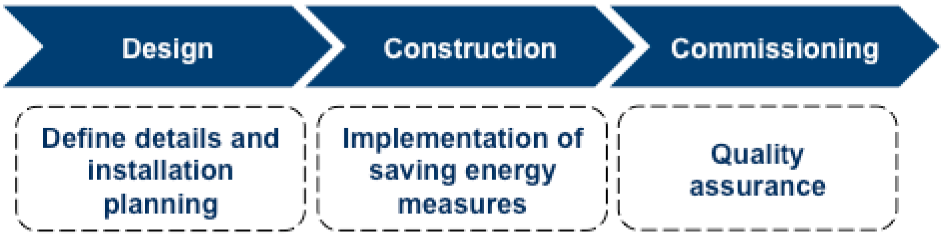

Figure 4: Project implementation phases

Before the start of the actual realization of the energy saving measures, it is necessary to properly plan for its different steps:

- The **design** phase, which consists of the final design details and installation planning for the agreed-upon energy efficiency measures;
- The **construction** phase, which consists in the completion of the installed energy saving measures, focusing on the review and approval process and regular monitoring of the construction process for quality assurance;
- The **commissioning** phase, to assure that the installed energy saving measures are operating as designed.

Operation

The foundation of an Energy Performance Contract is the assumption that the installed energy efficiency measures will result in reduced energy use, allowing the corresponding cost savings to be used to repay the investments over the foreseen duration of the contract.

The final step of the EPC project process, therefore, consists in the operation of the energy efficiency measures, including monitoring of their performance, monitoring of achieved savings, executing necessary maintenance activities, and ensuring standards of service and comfort over the lifetime of the EPC contract.

Measurement & Verification (M&V) is the formal process of determining and documenting that the installed energy efficiency measures are producing the guaranteed savings. The International Performance Measurement & Verification Protocol (IPMVP) is the most commonly used and recognised market standard for EPC projects. When properly applied, it can accurately estimate energy savings of a project, estimate emissions reductions from energy savings and quantify improvements in indoor environmental quality.

Supervision of the M&V process, continuous commissioning, and effective maintenance are all essential tasks to maximise an EPC project performance. Annual review meetings with the EPC provider are recommended in order to supplement the regular tracking of maintenance activities or standards of service and comfort; they also serve as an annual opportunity for facility staff and the EPC provider to discuss strategies for optimizing project results.

6.1.4. Key elements of the EPC

The key elements, which have to be included in the EPC contract, are the following:

- Guarantee of savings – the ESCO guarantees a certain amount of yearly savings to be achieved throughout the duration of the contract. The contract has to clearly define what happens if the guaranteed savings are not achieved, i.e. there has to be a clear description of how the ESCO settles the negative difference between guaranteed savings and actual achieved savings. Further, it has to clearly define the procedure for the case of exceeding the guaranteed level of savings, which sets a method of distribution of access savings between the client and the ESCO.
- The volume of investment to bring the guaranteed savings and a commitment by the client to pay the investment after its installation.
- Clear definition of a reference scenario (baseline) of the future energy consumption that is to be set in physical units. For all financial and economic purposes the reference scenario is calculated in current prices. The contract specifies a rate of inflation to be used for the reference scenario calculation.
- Obligation of the ESCO to provide a report on yearly savings evaluation that documents the actual amount of achieved savings in the respective year – in both physical and monetary units.
- Responsibility of the ESCO to design and implement the energy saving measures correctly.
- Obligation of the client to provide pre-agreed conditions for implementation of the energy saving measures.
- Planned duration of installation of the investment.
- Ownership transfer of the installed energy saving technologies to the client.
- Means of payment for the services and savings. Usually these are paid as a monthly fixed advanced payment agreed by both parties. At the end of each year of the contract, after the savings evaluation documented in the report on yearly savings, the payments are settled.
- Declaration of the purpose of operation of the facility on which the Energy Performance Contract is effectuated.
- Length of the contract.
- Method of recalculation of the guaranteed savings in case any of the input parameters differs from the presumptions defined in the reference (baseline) energy consumption scenario.
- Final report – prior to the end of the paying-off period the ESCO hands over to the client the final report including the total amount of cost savings, guaranteed savings, given reduction in the price and bonuses calculated for the entire paying-off period, etc.

Publicly available model contracts prove to be the successful instrument to boosting energy service market.

8. Summary

PPP and EPC models are viable alternative to traditional procurement of building renovation works and can tackle two most important barriers to energy efficiency improvements in the public sector:

- unavailability of up-front capital needed for energy efficiency (EE) investments and
- lack of technical knowledge and capacities to develop, implement and monitor EE projects.

PPP is an arrangement between a public authority and a private partner designed to deliver a public infrastructure project and service under a long-term contract. The rationale for using a PPP arrangement instead of conventional public procurement rests on the proposition that optimal risk sharing with the private partner delivers better “value for money” for the public sector and ultimately the end user. On the other hand, PPP arrangements are much more complex than conventional public procurement. They require detailed project preparation and planning, proper management of the procurement phase to incentivise competition among bidders, careful contract design to set service standards, allocate risks and reach an acceptable balance between commercial risks and returns. These features require skills in the public sector which are not typically called for in conventional procurement. The administrative burden related to the preparation of PPP projects and contracts may be very high, neve for smaller scale projects, like energy renovation of a single buildings, this model may not be appropriate.

Energy performance contracting (EPC) is when an energy service company (ESCO) is engaged to improve the energy efficiency of a facility, with the guaranteed energy savings paying for the capital investment required to implement improvements. Energy services and EPC are heavily promoted in the EU and the Member Stated are, according to the EED, obliged to promote them and to ensure the proper functioning of energy service markets. An EPC merges three types of contract into one: a contract for the refurbishments work, a credit contract and a service contract. Its approach is based on the transfer of economical and or technical risks from the client to the EPC provider, based on performance guarantees given by the EPC provider. The EPC provider’s remuneration is therefore based on demonstrated performance: the main measure of this performance is the level of energy savings.

The most usual models of EPC are: Guaranteed savings; Shared savings; Variable contract terms and Energy supply contracts.

The EPC process includes the following phases: project identification; preliminary analysis; procurement of energy services; implementation of EE measures and operation.

Publicly available model contracts prove to be the successful instrument to boosting energy service market. The energy performance contract shall contain: guarantee of savings clause; the volume of investment; reference scenario (baseline); obligations of the ESCO; obligation of the client to provide pre-agreed conditions; planned duration of installation of the investment; ownership transfer of the installed energy saving technologies to the client; means of payment for the services and savings; length of the contract; method of recalculation of the guaranteed savings in case any of the input parameters differs from the presumptions defined in the reference energy consumption scenario and final reporting.

Consultation of documents and references

1. EIB European PPP Expertise Centre: http://www.eib.org/epec/g2g/intro2-ppp.htm
2. Blending EU Structural and Investment Funds and PPPs in the 2014-2020 Programming Period - Guidance Note, January 2016, available at: https://www.eib.org/attachments/epec/epec_blending_ue_structural_investment_funds_ppps_en.pdf
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4. EPC in practice – Guide for Customers, April 2016, developed within TRUST-EPS-South project, available at: http://www.trustepc.eu/en/public-deliverables
5. Energy Performance Contracting Manual for EPC beginner markets, prepared within the framework of project “Transparense – Increasing Transparency of Energy Service Markets”, available at: https://www.enpc-intrans.eu/language/en/knowledge-centre/publications/

Self-assessment test

12. In the context of contracting works and/or services, PPP stands for:
    1. Purchase Power Parity
    2. Public-Private Partnership
    3. Point-to-Point Protocol
13. PPP contracts are usually made for:
    1. Large public infrastructure projects
    2. Promotional and educational projects
    3. Small-scale investments
14. PPP contracts are usually not used for energy renovation of a single building because:
    1. Lack of money in the public sector
    2. Bad marketing related to PPP projects
    3. Complex and lengthy administrative procedure to develop, procure and contract PPP project
15. Energy services are widely promoted in the EU through:
    1. Energy Efficiency Directive
    2. Renewable Energy Directive
    3. Consumer protection associations
16. EPC stands for:
    1. Efficiency Performance Contracting
    2. Energy Performance Contracting
    3. Energy Performance Certificate
17. The main feature of the EPC is:
    1. Customer takes over all risks
    2. Lower price in comparison with traditional contract for works
    3. Guaranteed energy saving
18. EPC facilitator:
    1. Is always an ESCO
    2. Supports the customer in identification of EE project
    3. Ensures financing to ESCO
19. In the process of procuring an energy service, it is important to obtain from the bidders:
    1. Cash flow analysis of the projects over the duration of the project
    2. Main design for energy renovation
    3. Detailed overview of all cost items
20. After the signing of the EPC the following activities are performed in the specified order:
    1. Construction, design, commissioning
    2. Design, M&V, payments
    3. Design, construction, commissioning
21. The purpose of M&V is:
    1. To ensure marketing and visibility of implemented measures
    2. To monitor energy consumption and verify the achieved savings
    3. To maintain the technical systems in the building

Smartschool and mobility.

Presentation of the module:

Improving the energy performance of Europe's building stock is vital to achieve the EU's 2020 targets and to meet the longer term objectives of EU climate strategy as laid down in the low carbon economy roadmap 2050. The respective EU directive on the energy performance of buildings (EPBD) and the EU directive on Energy Efficiency are the main legislative instruments of European Commission for improving the energy efficiency of European buildings. A key element of the EPBD is its requirements regarding Nearly Zero-Energy Buildings (NZEBs), stating the adoption of national and regional Plans to reach a set of targets for new and old buildings. To accomplish this task a multidisciplinary approach is required allowing to evaluate technical solutions in their economic, social and environmental aspects.

In this context, this module aims to provide principal knowledge to professionals, end-users and stakeholders (i.e. Municipalities) regarding the installation of a remote monitoring and control system (BEMS – Building Energy Management System) in public school buildings, providing solutions regarding the energy management, the monitoring of the internal climate conditions and classroom's air quality, and remote control (including automations) of the existing schools systems such as energy systems of the building (i.e. pv panels, geothermal & micro cogeneration, boiler), air conditioning, ventilation systems, lighting systems etc.

The module will present an overview of different functions and services that should be taken into consideration by stakeholders in order to achieve energy savings, to improve the energy performance of the building, to decrease the energy consumption and the carbon footprint of the school building, decrease the operational cost and improve climatic building conditions.

The ultimate goal is to inform, educate and transfer existing knowledge to old and new generations regarding the Monitoring & Management Energy Systems that can be applied at public schools, by transforming the local economies into low-carbon ones.

This module will assess and present different functions of a BEMS system that can transform an energy-intensive school building into a smart and energy-efficient one. The module contains 5 different sections, each one of it presents a different function provided by a BEMS system, transforming a regular school building into a Smartschool. These functions are:

1. **Introducing Building Energy Management System** (Section 1)
2. **Functions of a BEMS system & advantages compared to individual modules** (Section 2)
3. **Hardware & installation factors** (Section 3)
4. **Communication network of BEMS** (Section 4)
5. **Example of Services controlled by BEMS** (section 5)

Learning objectives of the module:

1. To provide principal knowledge to stakeholders-professionals regarding building monitoring & management systems that can be installed at public schools.
2. To present how a BEMS system (smartschool) can contribute to enhanced indoor comfort conditions of the school building.
3. To present how a BEMS system (smartschool) can improve the energy performance of the school buildings.
4. To understand how a BEMS system (smartschool) can save cost from the energy consumption (electricity & fossil fuel).

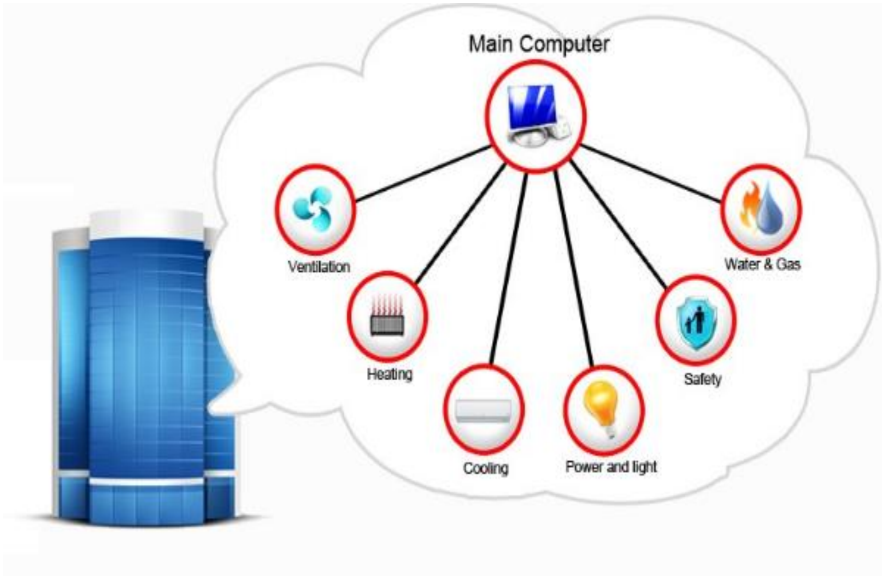
Section 1: Introducing Building Energy Management System (BEMS)

The Installation of an energy management system that allows the remote monitoring and control most of the energy-consuming activities of the building (i.e. heating, cooling, lighting) as well as the management of the activities related with the safety and the indoor comfort conditions of the building (air quality, ventilation, accessibility, lifts, fire alarm etc.) can transform the regular school building into a SMARTSCHOOL. The control systems for school building services can be integrated either using connections to a common PC – based network or through "gateways" installed for each of the separate services. These can be programmed to provide a communications network between the separate systems.

The remote monitoring, control and management of the building energy-consuming activities, the safety systems and the indoor comfort conditions can be achieved by installing a Building Energy Management System (BEMS). The term BEMS can vary from country to country and the same systems can be found as BMS (Building management system) or EMCS (Electronic Management and Control System in USA) or BAS (Building Automation System).

A smartschool can provide multiple benefits not just for its end-users but also for the local society. In particular, a smartschool can contribute to:

- Energy efficiency, optimizing the use of energy systems and decreasing energy consumption,
- Money savings to Municipalities,
- Decrease Carbon footprint arise from the operation of the building,
- Improve the air quality, the comfort conditions and the classroom's indoor climate,



Picture 1 – BEMS system

1.1 Main advantages of BEMS systems:

- ✓ Very useful for large school buildings with many classrooms and spaces
- ✓ Turning off the heating or cooling in empty classrooms or other spaces
- ✓ Ensure lights are not turned on after class
- ✓ Adjust the indoor comfort per classroom for ideal conditions
- ✓ Save energy by running the building smart and efficiently and avoid energy waste
- ✓ When having a BEMS it is then easy to identify further energy saving opportunities

1.2 Disadvantages:

- ❑ Unless correctly specified, installed and operated a BEMS system can increase cost and environmental impacts.
- ❑ Need for a skilled operator to ensure maximum efficiency.
- ❑ An integrate system with automations such as BEMS is more vulnerable to failure compared to a number of systems operating independently.
- ❑ Difficult and costly installation of a full BEMS system in an old school building

1.3 Expected Energy Savings:

The Energy Savings are circa 15-30 % compared to a regular school buildings (that do not use BEMS system)

N/B: The Energy savings can be essentially increased if a school uses innovative approaches for the windows, the lighting, the ventilation or/and has high energy efficiency systems (i.e. thermal / PV / geothermal / micro cogeneration energy systems).

1.4 Indicative Cost:

An indicative cost regarding the installation of BEMS system in a public school building varies from 25 – 75 € / m^2, depending on the level of automation and the attributes/activities that will be provided by the system.

In general the cost of the installation of the BEMS system will be lower for a new building and more expensive for an old one.

Section 2: Functions of a BEMS system & advantages compared to individual modules (systems)

A BEMS system may provide different functions/services. The main functions that can be applied in a public school building are:

2.1 - Control of the school building

A BEMS system can provide automatic and remote control (switch on/off, programming etc.) of heating, lighting and cooling systems of the school building as well as block the operation of selected activities such as elevator's operation, enable of fire alarm, operate/programming the ventilation system, provide access to specific areas of the building etc.

The operator can control and plan all these functions, through a main computer/ control room (more details about the required hardware is described in section 3) optimizing school operation and activities.

Furthermore, a BEMS system can optimize fuel/air mixtures for boilers (oxygen trim) and maximize the use of outside air for cooling of air-conditioned school building, minimizing the energy consumptions and the respective cost.

2.2 - Monitoring of school building status & environmental conditions

A BEMS system can be a very useful tool for the monitoring of the school building status (i.e. if there is damage in any facilities such as in the elevator, if the fire alarm goes off etc.) and the indoor comfort conditions (i.e. sense flows and temperatures, humidity, CO_2 concentrations etc.). The operator can modify the environmental conditions of the building properly through automations, ensuring that the most comfort for the users conditions have been reached while on the same time an eco-mode operation of the systems has been achieved.

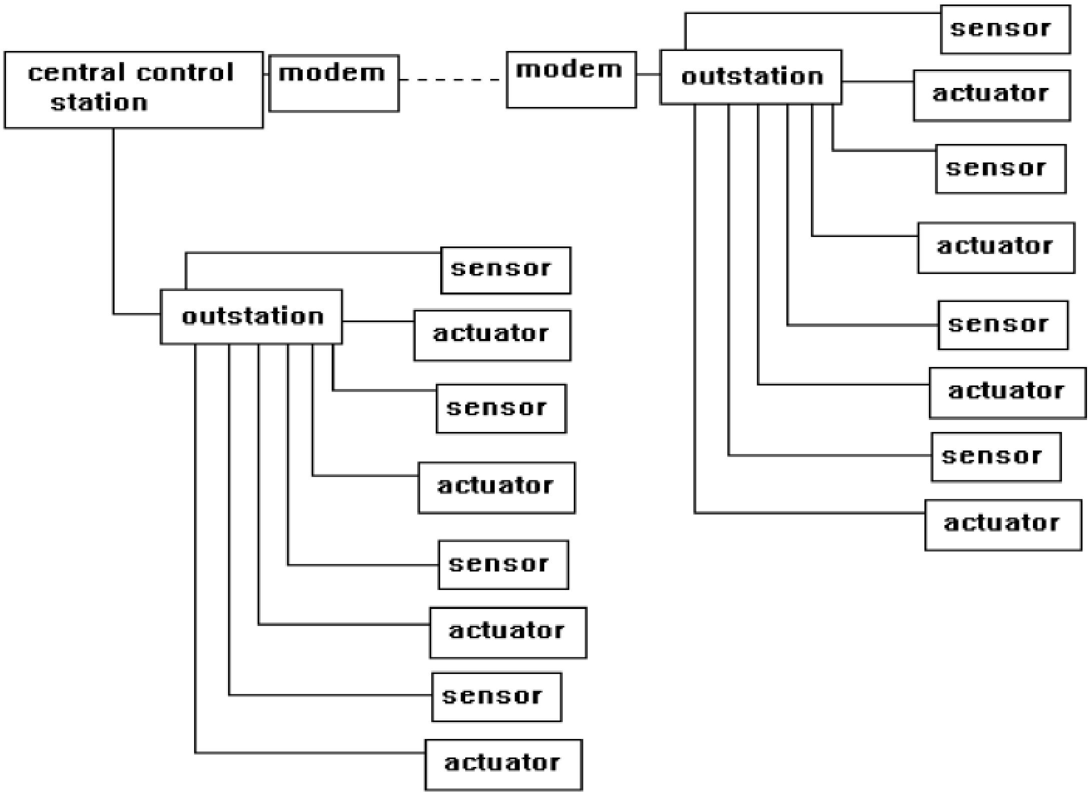
2.3 - Provision of Energy management information

A BEMS system can provide essential data regarding the energy consumption of the building. In particular, BEMS can provide statistics and information related to the energy flows and consumptions of the building at hourly, daily, weekly, monthly and annually level as well as evidence of the comfort conditions of the building. This data can be very useful in order to identify trends and the most energy-intensive periods, address the high energy demand with the most sustainable and less expensive way (energy & cost effective solutions) and assess the effectiveness of the measures.

2.4 - Scope for relaying information to and from remote outstations and central supervisory station

The BEMS system consists of a set of electronic equipment including sensors, actuators and a processing system that controls and monitors the environmental control services in a building. Heating, lighting and air conditioning systems are all require controls so the spaces which they service enjoy the environmental conditions demanded. Compared to conventional controls that are typically dedicated to control only one function, the BEMS systems are more sophisticated as they can be programmed to control all the energy consuming-systems in a building to provide the conditions required, and to minimize energy consumption and costs. So a BEMS system is an integrated one either using connections to a common PC – based network (i.e. over a modem) or through “gateways” installed for each of the separate services. These can be programmed to provide a communications network between the separate systems. The main functions of such a system are:

- **monitoring & data collection** (energy, building climatic conditions – indoor comfort, audit of safety & security parameters, accessibility factors etc.),
- **sharing & assessing** it in order to apply efficient and sustainable measures that will reduce the building cost operation and the will improve its energy efficiency,
- **saving time** going round inspecting and reading meters,
- **adjusting** all clocks for summertime – **programming** the systems,
- **providing a Visual Display Unit, keyboard & printers (control room)** to the building manager in order to easily monitor and control the building in a sustainable/efficient way.



Picture 2 – Distributed intelligence system with modem link (BEMS)

2.5 - How a BEMS contributes to energy savings

One of the principal benefits of BEMS is the ability to monitor energy activities (i.e. energy systems, air conditioning, lighting etc.) and store the data for recall at a later time, to indicate trends. For instance, if a building's specific heat consumption (i.e. energy consumed in heating divided by the inside-outside temperature difference) is gradually increasing, it may indicate some damage to the insulation or some part of the building fabric which is gradually getting worse, through water leaking in or some other such mechanism. Once such a trend is observed, action can be taken to track down the source.
With current day prices of electronics steadily reducing, the cost of a BEMS system is often comparable with that of simpler, less sophisticated control system.

Briefly, a BEMS system can:

- Minimise unnecessary use of the school building. Through BEMS we are able to programming the operation of the energy systems, the lighting and the ventilation system of specific classrooms of the building (switching them off wherever these are not needed according to the schedule of the classes).
- Optimise Energy efficiency of the school building (again through automations and programming of the energy-consuming activities/systems)
- Enable improved standard of operational maintenance.

- Enable improved standards of overall energy management.
- May encourage higher levels of energy awareness.

Section 3: Hardware & Outputs

As was mentioned in subsection 2.4, a BEMS system consists of a set of electronic equipment including sensors, actuators and a processing system that controls and monitors the environmental factors in a building. Heating, lighting and air conditioning systems are all require controls so the spaces which they service enjoy the environmental conditions demanded. Compared to conventional controls that are typically dedicated to control only one function, the BEMS systems are more sophisticated as they can be programmed to control all the energy consuming-systems in a building to provide the conditions required, and to minimize energy consumption and costs. The following subsections present briefly the main hardware and functions of a BEMS system.

3.1 – Sensors & Actuators

For the monitoring and the management of the building systems (i.e. heating, ventilating systems, air conditioning & lighting systems etc,) sensors are required to detect the value of a variable such as temperature or the position of a valve, and actuators to vary the position of a valve or damper and switch items of the building on or off. Conventional controls may be electrical, pneumatic, mechanical, or a combination of these.
The sensors used for a BEMS system need to have an electrical output signal which can be transmitted to the outstation or central station (see Picture 2).

- For temperature measurements, Platinum Resistance Thermometers (PRT) or thermistors may be used, needing a 2, 3 or 4 wire connection and a current source. Thermocouples are somewhat simpler, as they need only a 2-wire connection, and no current source.
- For flow measurement, a flow-meter with a coil embedded in the outer casing can be used. This gives an electromagnetic pulse for every rotation of the rotor, the pulse rate having a fixed relationship with the flow rate.
- For pressure measurements, a Bourdon gauge can be linked mechanically to a potentiometer, to give variations of electrical resistance with pressure from 1-2kΩ. Piezo-electric sensors give a more accurate measure of pressure, but are more expensive.

Sensors to detect the position of dampers or valves may be electro-mechanical - potentiometers linked to an arm attached to the valve. Microswitches or magnetic reed switches may detect whether an item of a building such as a damper is open or closed. These may be linked in a voltage circuit so that a voltage is ‘on’ or ‘off’.

Besides the sensors, a BEMS system also consists of actuators. **An Actuator** is a component of a machine that is responsible for moving and controlling a mechanism or system, for example by opening a valve. In simple terms, it is a "mover". An actuator requires a control signal and a source of energy.

Picture 3 - Actuators

3.2 – "Intelligent" sensors

The simplest form of sensor measures a quantity, or checks the state of a piece of equipment, and transmits a voltage or current along a pair of wires to the central station or outstation. To reduce the amount of processing carried out by the central processor or outstation, 'intelligent' sensors may be used. These undertake some processing of raw data or present it in a form more acceptable to the computer.

For instance, a flowmeter frequency may be converted directly to a flowrate. An intelligent temperature sensor may contain Analogue to digital (A/D) or binary converter. The sensor assembly may need a chip and a serial communications link.

3.3 – first Stage of signal processing

This may be carried out by an 'intelligent' sensor or an outstation, to reduce the communication necessary to the central station, and may include elimination of unsatisfactory data and processing to a more useful form.
It may provide:

- A/D conversion
- Signal filter & condition
- Check signal against upper and lower limits
- Check rate of change of signal against limits
- Issue alarm if limits exceeded
- Compute mean and Standard deviation of one or several parameters
- Process raw data to meaningful form, e.g. using heat meter, flowrate converted to heat flow rate
- Auto-calibrate and error correction

All these functions could also be carried out at the outstation or central computer, but if it is done in the sensor, 'rubbish' or meaningless data is eliminated at the outset, and later processing is minimised. Also, the more data transmitted the greater the chance of errors.

3.4 – Output from Sensors

The output from the sensors must obviously be in a form which the next step of processing can deal with. This must be an electrical signal, between the outstation and central station, typically 4-20mA, 0-5V.D.C. signals, serial bit stream to the respective (RS232 or 422) protocol. The communications protocol is decided by the manufacturer; items may or may not be compatible between manufacturers. To save on data communication, a system can be configured to report only a change of state or a fault condition. If the data depart as sound, or there is no change in the measured value, then no report is sent.

3.5 – Output from actuators

From outstation or central station, electrical signals must be sent to the device actuators to switch on items of building or adjust valves. 4 types of device to be driven are:

I. Relays and contactors - on/off state only to switch fan, pump, motor, compressor
II. Motorised dampers - open/close or fully variable
III. Control valves - open/close or fully variable
IV. Closed loop controllers - electronic or pneumatic

3.6 – Types of output

Analogue signal 4-20 mA or -0-5 V.D.C

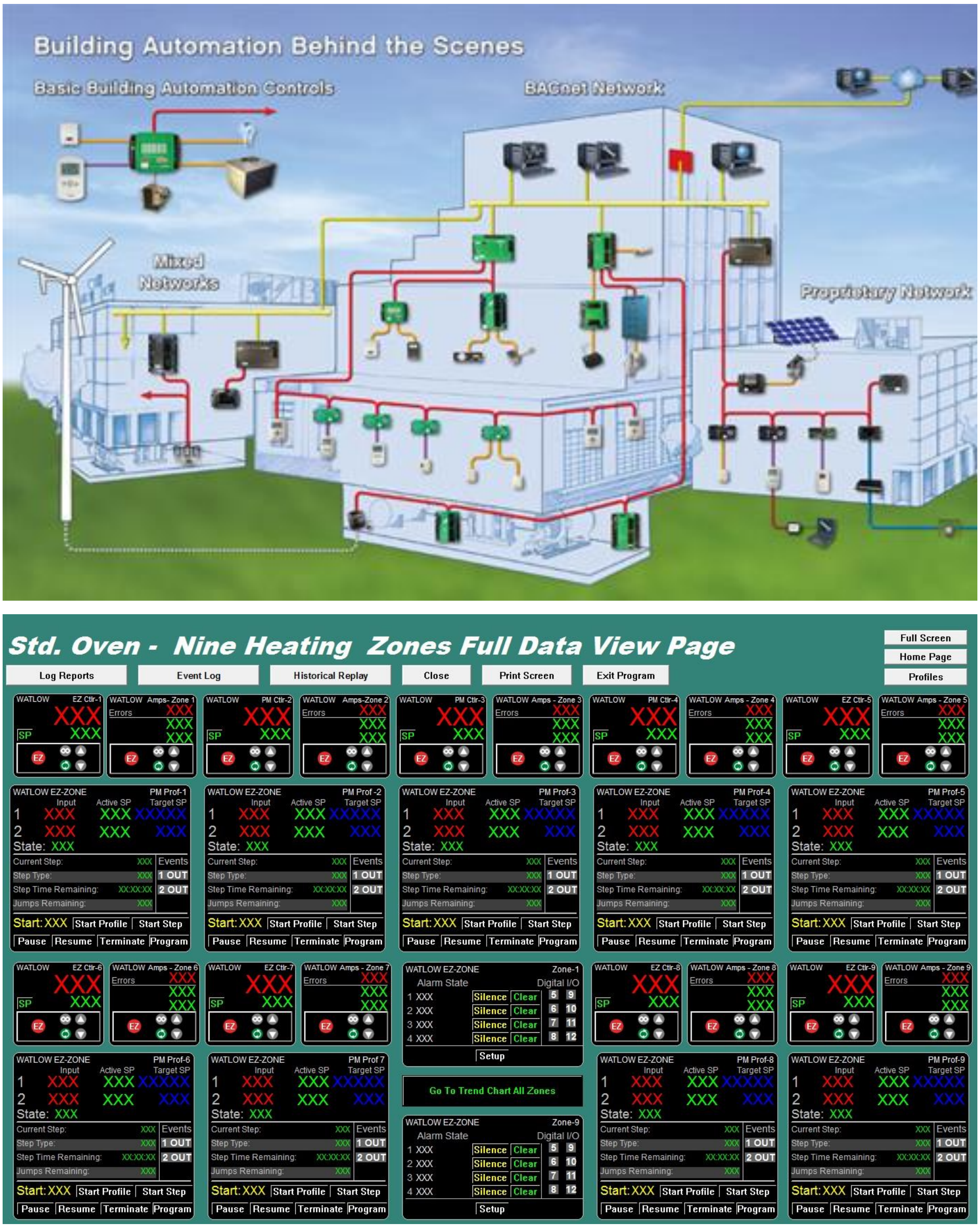
- Status signal to drive relay. Mark/space (e.g. 0V or 5V).
- Pulse train frequency proportional to magnitude
- Coded message in RS232 protocol
- Valve and damper position control
  - ✓ Stepper motor
  - ✓ Resistance sensor + potentiometric balance network
  - ✓ Electro-pneumatic converter

N/B: For fans etc., it has often (but not always) been better to use on/off switching and vary the mark/space ratio, rather than use a variable speed motor - equipment is cheaper and may be easier to control. Now, variable speed control via an inverter usually proves more economical.

Section 4: Communication network

As mentioned above (sub-section 2.4), a BEMS system consists of a set of electronic equipment including sensors, actuators and a processing system that controls and monitors the environmental control services in a building. A BEMS system is an integrated one either using connections to a common PC – based network (i.e. over a modem wireless or not) or through "gateways" installed for each of the separate services. These can be programmed to provide a communications network between the separate systems.
In general, a communication needed between the building/sensors and outstation to indicate among others:

- On/off status, (e.g. is a pump on, is a valve fully open or fully closed).
- Position of valves, dampers, etc. which can be in any position between fully open and fully closed.
- Values of variables e.g. temperature (analogue values or pulses).



Picture 4 – Indicative screen displays of BEMS system

4.1 - Data collected & sent

The data collected & sent is assessed from the scope of the outstation and from central station.

i) From outstation to central station:

- Summary of information describing condition of plant controlled by the outstation
- Results of computations performed by the outstation
- Requests for data, e.g. temperature setpoint
- Historic plant data for analysis
- Copies of programmes stored by the outstation, needed by control
- Failure reports

ii) From Central station to the outstation:

- Requests for information on plant status and values of variables
- Control instructions and data, e.g. setpoints
- Programmes to download to the outstation

Section 5 - Example of Services controlled by BEMS

This section presents 3 basic examples of services that can be controlled by BEMS system.

5.1 – Electrical load management

A substantial proportion of fuel costs is accounted for by electricity such as in public school buildings with air conditioning and high lighting loads.

In many countries a commercial consumer pays not only for the units of electricity used, but also a maximum demand charge. When the tariffs are agreed with the electricity supply company, they include a statement of the maximum demand the company is likely to require. If demand during a billing period exceeds this value, an additional charge is made during this period which relates to the actual maximum demand. To avoid these additional charges it may be possible to switch off some (non-essential) items of plant as others are switched on. Staggering machine start-up and shedding loads according to pre-set priorities can reduce or eliminate maximum demand penalties. For example, electric motors use more power at start-up than when they have reached a steady speed. Thus, switching on more than one motor at the same time may create a huge demand, but only for a short time. Nevertheless, maximum demand charges would be incurred. The BMS can be programmed to stagger start-up times and save on these charges. Similarly, in items such as water heaters and refrigeration plant there is considerable thermal inertia, and switching off for short periods, while other plant is switched in, may avoid high cost penalties without impairing performance. Note that this does not actually save energy but does reduce costs to the consumer and is therefore an important feature of the BMS.

5.2 – Heating Control

Most non-domestic buildings have some form of automatic control of space heating. This has for many years been based on relatively simple electromechanical or hard-wired electronic systems using time-switches, bi-metallic thermostats, electromechanical relays and similar devices. Typical control functions are:

- Time based on/off switching of hot water circulation pumps
- Modulation of circulation water temperature using three-way mixing valves and an external temperature compensator
- Space temperature set-point control using standard room thermostats

These technologies are well-established but modern microprocessor technology is able to offer considerable improvements in performance over conventional systems. Using microelectronics, time programming can be much more detailed and flexible than with conventional time-switches, which might only be capable of providing one ON and one OFF action for each day of the week, or at most several ON/OFF switching over a 24 hour cycle, which is repeated every day of the year. Microprocessor systems can provide many separate programs catering for several Ons and Offs for each of the days of the week, or even a year, and covering more than one channel. The latest systems employ thermistors which are much more accurate than bi-metallic thermostats; since they have a smaller dead zone and control differential than bi-metallics, they provide closer control of temperatures.
Several thermistors can be employed to determine space temperatures in different areas of a building or zone and provide, through averaging, a much more representative measurement than is possible with a single room thermostat. Additional features such as holiday timings can also be added, plus frost protection, changes in summertime holiday etc. It is time consuming and often inconvenient to physically alter the settings on conventional heating controllers, and furthermore, there may be a number of them spaced round a site or building. With microprocessor control they can all be adjusted from one console. Microprocessor units may also incorporate self-adapting software that 'learns' the thermal behaviour by comparing actual temperatures with the target at a given time and making appropriate adjustments so that the difference is gradually reduced. The same can be done for stop times.

5.3 – Air conditioning control

In Mediterranean countries, the air conditioning in schools is practically essential for staff comfort and efficiency, and even in cooler countries it is becoming more widespread, particularly in modern highly-glazed deep-plan buildings where there are high internal heat gains from office electrical equipment.
Many air conditioning systems are oversized to cope with the hottest conceivable day with some remaining capacity to spare. As a result, compressors run most of their lives at well below full load and consequently well below peak efficiency. In addition, the design of the air circulation and heat transfer systems sometimes results in simultaneous cooling of one part of a building and heating of another,

sometimes even heating and cooling in the same room at the same time, which is obviously wasteful.

It can be difficult to achieve savings on existing air conditioning systems. If the plant is oversized it is not usually cost effective to replace it with smaller items purely on the ground of energy consumption. If pumps etc. are in need of replacement because they are worn out, then for long term energy savings it is often better to replace them with appropriately sized items. On a large refurbishment scheme where the whole HVAC system needs replacing, then obviously the most energy efficient system should be considered. It should also be considered whether it is better to treat the building as one zone or use multi-zone. A single-zone system treats all areas the same and may be controlled only by sensors in one room. This results in some savings on plant, perhaps, but spaces which are not occupied may be conditioned. A multi-zone system, where the air delivery to a zone is controlled either by the occupant or by the setting of the controls in that particular zone, may be better as the zone can be shut off when not needed (e.g. fan-coil or room induction units).

The use of thermistors instead of bi-metallic thermostats means smaller control differential/ larger number of sensors can be used and readings averaged/thermistor measures temperature and can control actuator position depending on deviation from set point (i.e. not on/off).

In pre-computer based systems, the modules are dedicated to one function - sensing temperatures and operating a valve - while the computer-based systems are more flexible. The output from the temperature sensor can be transmitted to a number of places or used for a number of functions - then several valves etc. can be operated from it and the temperatures and settings saved to memory, and recalled later to review the behaviour of the system.

Conclusions - Summary:

As “smartschool” is considered a school that uses building management systems that can provide functions such as monitoring, automations and remote control of several systems such as energy efficient systems (PV, geothermal, etc.), lighting, ventilation, safety, accessibility systems of the school building.

A smartschool may have multiple benefits, not just for its end-users but also for the local society. In particular, a smartschool can contribute to:

- Energy efficiency, optimizing the use of energy systems and decreasing energy consumption,
- Money savings to Municipalities,
- Decrease Carbon footprint arise from the operation of the building,
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The remote monitoring, control and management of the building energy-consuming activities, the safety systems and the indoor comfort conditions can be achieved by installing a Building Energy Management System (BEMS). The term BEMS can vary from country to country and the same systems can be found as BMS (Building management system) or EMCS (Electronic Management and Control System in USA) or BAS (Building Automation System).

The main advantages of a BEMS system are:

- ✓ Very useful for large school buildings with many classrooms and spaces
- ✓ Turning off the heating or cooling in empty classrooms or other spaces
- ✓ Ensure lights are not turned on after class
- ✓ Adjust the indoor comfort per classroom for ideal conditions
- ✓ Save energy by running the building smart and efficiently and avoid energy waste
- ✓ When having a BEMS it is then easy to identify energy saving opportunities

The BEMS system consists of a set of electronic equipment including sensors, actuators and a processing system that controls and monitors the environmental control services in a building. Heating, lighting and air conditioning systems are all require controls so the spaces which they service enjoy the environmental conditions demanded. Compared to conventional controls that are typically dedicated to control only one function, the BEMS systems are more sophisticated as they can be programmed to control all the energy consuming-systems in a building to provide the conditions required, and to minimize energy consumption and costs. So a BEMS system is an integrated one either using connections to a common PC – based network (i.e. over a modem) or through "gateways" installed for each of the separate services. These can be programmed to provide a communications network between the separate systems. The main disadvantages are:

- ❑ Unless correctly specified, installed and operated a BEMS system can increase cost and environmental impacts.
- ❑ Need for a skilled operator to ensure maximum efficiency.
- ❑ An integrate system with automations such as BEMS is more vulnerable to failure compared to a number of systems operating independently.

The Energy Savings are circa 15-30 % compared to a regular school buildings (that do not use BEMS system)

N/B: The Energy savings can be essentially increased if a school uses innovative approaches for the windows, the lighting, the ventilation or/and has high energy efficiency systems (i.e. thermal / PV / geothermal / micro cogeneration energy systems).

Self Assessment:

1. What are the advantages of a BMS system over stand-alone controls?

a. less expensive

b. Do not need any sensors

c. They provide information and energy consumption trends

2. What are the advantages of a distributed-intelligence BMS system over an individual module?

a. Reduced communication time & costs

b. Easy to be installed

c. Do not need a modem

3. Select two features of a BMS which might help save energy.

a. Assessing of energy management information & provide automatic switch on/off of heating, lighting systems

b. Remote control of the building energy system and set of alarms

c. Provide evidence of comfort conditions & integrate the indivuals buiding systems

4. which one of the following features of a BEMS make it useful for long-term energy management strategy?

a. The sensors and the actuators

b. Data & trends about energy flows and consuptions

c. Evidence comfort conditions

5. Why is control with a BMS potentially more accurate than with older stand-alone controls?

a. Due to the fact that uses a BEMS systems uses actuators&sensors and modems for two ways communication exchanging data from/to the central station and outstation

b. Due to the fact that the BMS systems are very sophisticated compared to the individuals modules

c. Due to the fact that the BEMS systems have fixed algorithms

6. In which case does a school building considered as a “smart” one:

a. When a BEMS system is installed on the building

b. Only If it uses a high energy efficient systems (PV, geothermal etc.)

c. When the average IQ of the students scores above 130

7. What do the terms of BEMS and EMCS mean?

a. Building Energy Management Systems and Electronic Management and Control System

b. Building Energy Monitoring Systems and Environmental Marine Control Systems

c. Building Energy Management Systems and Environmental Maritime Control Systems

8. Which one of the following functions, a smartschool cannot provide:

a. Electric transportation of students and teachers

b. Automations in the operation of the lighting, ventilation systerms

c. Optimasation of fuel/air mixtures for boilers (oxygem trims)

9. What can an actuator do:

a. Provide data regarding the energy flows and consumptios of the systems

b. Provide evidence of comfort conditions

c. Move and control a mechanism or a system

10. Which one of the following is not a BEMS function:

a. Monitoring of Energy consumption & environmental conditions

b. Assess effectiveness of the measures

c. Provide a market research for efficient energy systems

11. What could be the energy savings from a school that has a BEMS system installed?

a. 30-15%

b. 40-65%

c. over 65%

Bibliography:

- Heriot Watt University – Edinburgh, Scotland, “Building Energy Management”

Behavioural change at schools

Content:

TITLE OF MODULE 13: **Behavioural change at schools CEA**

Presentation of the module

Energy usage is indispensable, and the demand for energy has dramatically increased globally. A reduction of energy usage needed for Europe and its Member states to meet its energy goals by the year 2030. Europe will adopt and implement policies which are aiming to reduce the gas emissions into the atmosphere with significant system changes, such as switching from a dependence on fossil fuels to the use of renewable energy sources and encourage people to change their behaviour to more energy behaviour.

The critical issue of global warming creates the need to develop and implement behavioural changes in our daily life. Europe is adopting and implementing policies in order to reduce the emission of CO_2 into the atmosphere. However, all sectors of society have a key role to ensure the reduction of energy consumption, and to achieve the goals of a sustainable environment. Policymaking and human behaviour are the fundamentals factor for the reduction in energy consumption.

Several approaches proposed for achieving environmentally sustainable behaviour. Behavioural models implemented to understand what consumers do, and why they do so. It is very significant to analyse consumer behaviour and develop a framework with consumer's users with energy, energy use and energy efficiency behaviour.

Raising the environmental awareness of children must begin early at school, where children are socialised, shaping viewpoints and behaviours, setting the foundation for their future life. The role of the teacher and any authority figure in this effort is paramount. Teachers can influence their students and contribute to more suitable behaviour of the younger generation regarding energy and the environment. Education is an apparent key in boosting young children behaviour, and it's essential to ensuring embodied the ecological values into their behaviour.

By educating students in the classroom about the right decisions, it is making their ability much higher by reducing brain cycles. If the knowledge is on the front of their mind, an individual will not have to think as hard about what is right. This reduction in complex thought also saves time. By creating more environmental classes and increasing participation from each student, it pushes sustainability into the realm of a social norm.

Educational Objectives

Knowledge:

- What is Behavioural Change, Theories and models?
- How behavioural change is related to energy efficiency/conservation?
- Policies about energy efficiency
- Methods that implemented in schools for behavioural changes
- What are the measures of raising awareness?
- About climate change and the greenhouse effect

Skills/Competence:

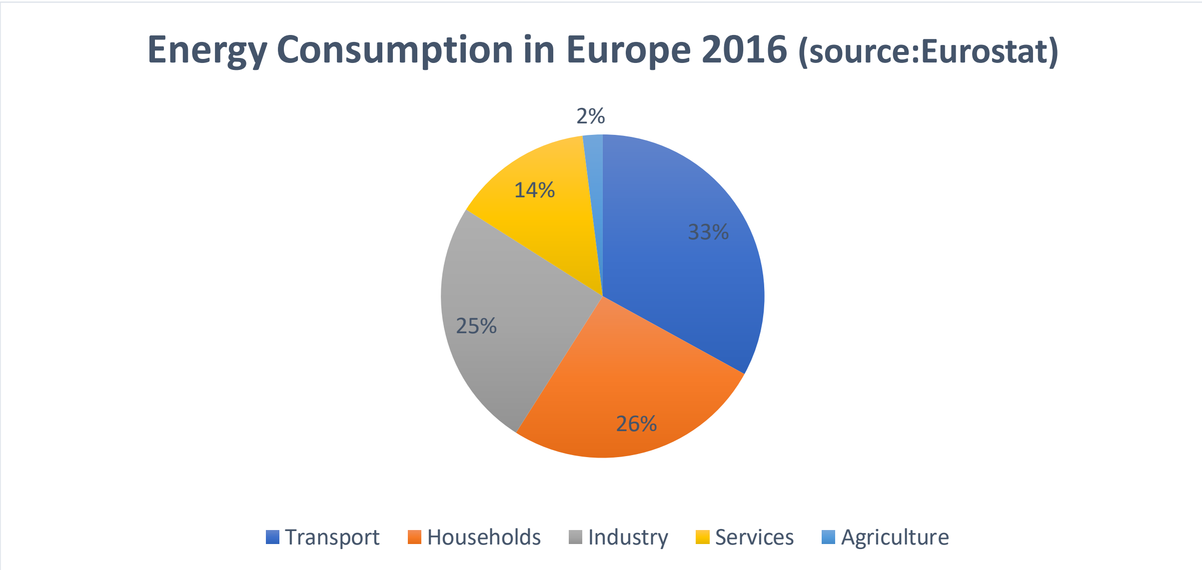
- Applying the methods of behavioural change in schools
- Demonstrate and implement successful examples of other schools
- Explain about climate change
- Able to run a campaign about energy conservation
- Able to educate students about the importance of energy efficiency
- Able to coordinate energy teams
- Able to select the most efficient steps to achieve behavioural change

1. Behavioural Change *(sources: 1. Theories and models of behaviour and behaviour change – Forest Research., 2. Predicting and changing behaviour: A reasoned action approach- Ajzen, Albarracin, Hornik-2007, 3. Methods and approaches to understanding behaviour change- William Robert Avis-2016)*

1.1 Overview: Energy use and Behavioural Change

Energy usage is indispensable, and the demand for energy has dramatically increased globally. A reduction of energy usage needed for Europe and its Member states to meet its energy goals by the year 2030. Europe will adopt and implement policies which are aiming to reduce the gas emissions into the atmosphere with significant system changes, such as switching from a dependence on fossil fuels to the use of renewable energy sources and encourage people to change their behaviour to more energy behaviour.

Different categories of the economy consume energy: households (i.e., energy consumed in the residential sector), transport (e.g., rail, road, domestic aviation or inland shipping), industry, services (including commercial and public services) and agriculture & forestry. The sectors that consumed the most energy, the transport sector (33 % of final energy consumption) consumes the most energy, followed by households (26 %), industry (25 %), services (14 %) and agriculture & forestry (2 %) *(source: Eurostat-*https://ec.europa.eu/eurostat/home*)*



The effects of human activities regarding energy consumption are contributing to climate change. Recent evidence of this matter found that human activities are leading to increased levels of greenhouse gases in the atmosphere, causing an increase in global warming. For these overwhelming evidence, that the Earth's climate has changed due to human activities, the United Nations signed the Paris Agreement, an international treaty designed to keep the average global temperature of the Earth below two degrees Celsius to prevent the rise of the temperature and pursuing efforts to limit the temperature increase to 1.5 degrees Celsius. *(source: https://unfccc.int/process-and-meetings/the-paris-agreement/what-is-the-paris-agreement)- video:* https://www.youtube.com/watch?v=3tnDjCA4peY, https://www.youtube.com/watch?v=I-4F5MJEeqs)

The transition to more sustainable behaviour could improve energy efficiency and energy conservation measures. However, given that by changing consumer behaviour is one of the main factors that society has on the environment, any action or choice that a consumer makes has a direct and indirect impact on the environment.

Energy consumption in buildings depends on a variety of factors, such as user behaviour, the energy efficiency of complex systems and weather conditions. However, in recent years studies have shown that changing energy behaviour of the users of a building can lead to significant savings in energy and money.

The most overlooked resource to get us to a sustainable energy future is humanity, and we can achieve this resource with no material science, by just changing our behaviour. Many factors of society have essential roles to play and engaging people to ensure they manage energy to be more efficient.

Energy consumption has raised over the last decades, and it is necessary to use power responsibly and engage to achieve the energy goals by the year 2030. Energy consumers need to tackle the efforts and the challenges that need to implement for more environmentally sustainable behaviour.

1.2 Theories and Models of Behavioural Change

Policymaking and human behaviour are the keys to achieve a reduction in energy consumption. Moreover, lots of researches have addressed theories and methods of behavioural changes of the energy consumers, and according to a literature review of 2000 references (articles and books), the behavioural change of energy consumption can potentially save about 19% of energy consumption (Kok et al.,2007). The effectiveness of saving energy was due to changes in conservation, awareness, small investments, and lifestyle.

Most studies done in the past on changing behaviour has shown that developing public policy and personal skills, strengthening community action and creating supportive environments are key factors leading to the desired behaviour. One of the popular theories is the Theory of Planned Behaviour (TPB- Ajzen and Madden 1986), adopting a cognitive approach to explaining behaviour on an individual’s attitudes and beliefs. The theory evolved the relation between attitude (personal beliefs about the value of behaviour), subjective norms (social environments value of behaviour) and behavioural intention (a combination of both, predicts behaviour). According to Hardeman (2002:149), this theory is more useful to identify targets for change than offer suggestions on how these cognitions may change.

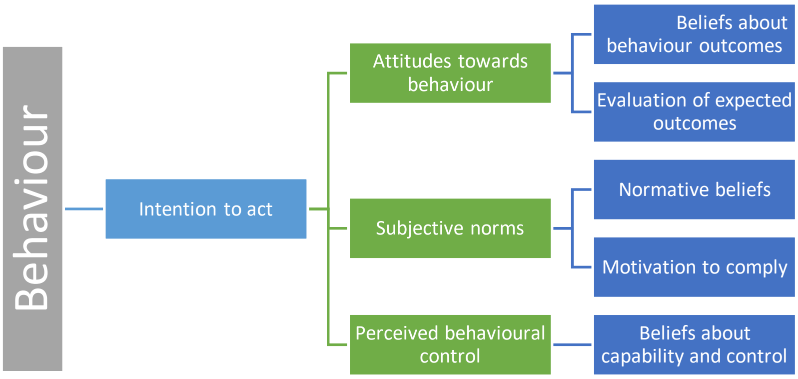


Figure1. The Theory of Planned Behaviour (adapted from Munro et al.2007) source: Forestry, sustainable behaviours and behaviour change: Theories- 2012)

Moreover, Triandi's theory of interpersonal behaviour is an example "where the behaviour of habit considered" (source: Understanding Behaviour Change- Prager K. – May 2012). Hence, this theory shows the effective factors of behavioural intentions and demonstrates the facilitating conditions which must allow intentions to become realised. Based on Triandi's theory, behaviour in any situation is "a function partly of intention, partly of the habitual responses, and partly of the situational constraints and conditions. Hence, the behaviour is influenced by "moral beliefs, but the impact of these is moderated both by emotional drives and cognitive limitations.

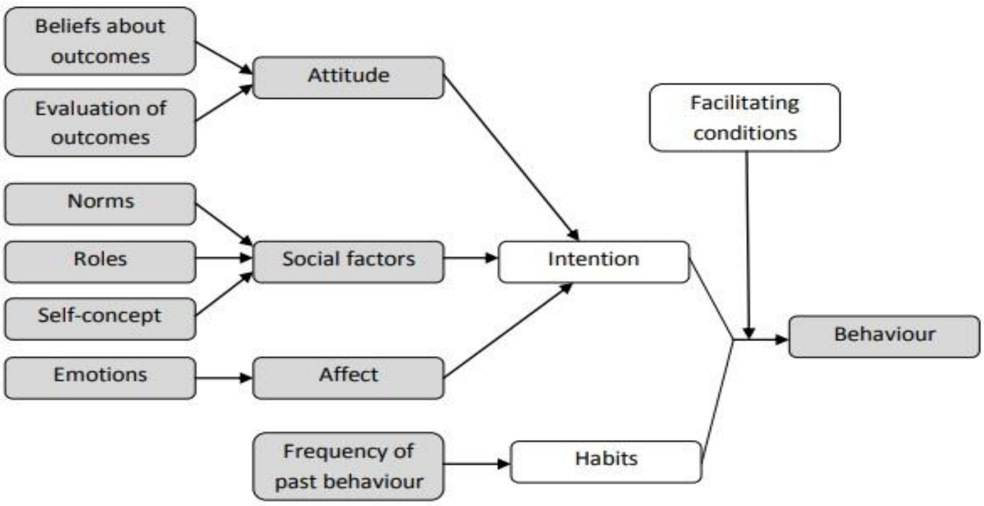


Figure2. Triandi's theory (source: Forestry, sustainable behaviours and behaviour change: Theories- 2012)

In 2012, the scientist Shove addressed the conceptual framework for Social Practice, based on the theory of Reckwitz(2002). Social Practice Theory contains three elements that together construct the social practice and shape the practice in their process of interaction. This theory is being applied to the analysis of human behaviour, in the context of energy use and consumption. The three elements model of the Shove are:

- **Materials**: The physical objects that permit or facilitate certain activities to be performed in specific ways
- **Meanings:** Images, interpretations or concepts associated with activities that determine how and when they might be performed
- **Procedures**: Skills, know-how or competencies that permit, or lead to activities being undertaken in specific ways

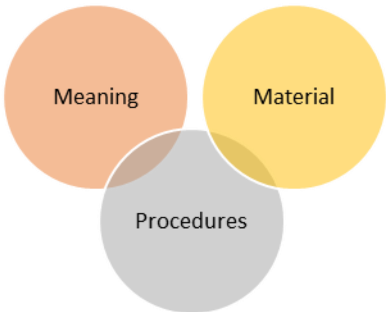


Figure3. Social Practise Theory

Video: https://www.youtube.com/watch?v=nZsxuD3gExE

1.3 Energy efficiency measures and behavioural change *(source: Achieving energy efficiency through behaviour change: what does it take? – European Environment Agency 2015) – video:* https://www.youtube.com/results?search_query=behavioura+energy)

Several approaches proposed for achieving environmentally sustainable behaviour. Behavioural models implemented to understand what consumers do, and why they do so. It is very significant to analyse consumer behaviour and develop a framework with consumer's users with energy, energy use and energy efficiency behaviour. Given the interaction between energy efficiency and energy consumer's various measures where examine how they have been used to change behaviour:

- **Feedback:**

Feedback is a major factor that is raising energy awareness and changing consumers behaviour. Different ways to provide feedback to energy consumers are shown in the table below:

Types of feedback	
Direct feedback — available on demand **Learning by looking or paying**	• Direct displays • Interactive feedback via a PC • Smart meters - operated by smart cards - two-way (automatic) metering

	• Trigger devices/consumption limiters • Prepayment meters • Self-meter-reading • Meter reading with an adviser • Cost plugs
Indirect feedback — raw data processed by the utility and sent out to customers **Learning by reading and reflecting**	• More frequent bills based on meter readings • Frequent bills based on readings plus historical feedback • Frequent bills based on readings plus normative feedback (comparison with similar households) • Frequent bills plus disaggregated feedback • Frequent bills plus the offer of audits or discounts on efficiency measures • Frequent bills plus detailed annual or quarterly energy reports
Inadvertent feedback **Learning by association**	• New energy-using equipment • Distributed renewable energy generation • Community energy-conservation projects and the potential for social learning
Energy audits	• Undertaken by a surveyor on the client's initiative • Undertaken as part of a house sale/purchase or other mandatory surveys • Carried out on an informal basis by the consumer

Table.1 Types of feedback on energy consumption (source: Darby,2006)

- **Communication and engagement:** information and promotion, training, personal advice and one-to-one engagement, demonstrations, benchmarking, commitment, goal-setting, labelling, prompts, modelling
- **Economic incentives and disincentives:** subsidies, levies, surcharges, taxes, bonuses, tax differentiation, tax refunds, financial instruments such as interest-free loans, rewards and penalties;
- **Regulatory:** General laws and rules, specific exemptions, covenants and agreements, regulated versus dynamic energy pricing.

2. Behavioural Change at Schools

(source: 1. Achieving energy efficiency through behaviour change: what does it take? – European Environment Agency 2015, 2. http://learningforsustainability.net/behaviour-change/, *3. Changing Energy Behaviour: Guideline for behavioural Change Programmes- Intelligent Energy -2009 4. Saving Energy by behavioural Changes- Kester, William James, Gerber)*

2.1 Introduction

Raising the environmental awareness of children must begin early at school, where children are socialised, shaping viewpoints and behaviours, setting the foundation for their future life. The role of the teacher and any authority figure in this effort is paramount. Teachers can influence their students and contribute to more suitable behaviour of the younger generation regarding energy and the environment. Education is an apparent key in boosting young children behaviour, and it’s essential to ensuring embodied the ecological values into their behaviour.

Every school is a small community, in addition to the students and the teachers, we also have the administrative staff, the cleaning staff, the technical staff and people working at the schools' canteens. All these people are also important for energy efficiency and the environmental approach of a school, and therefore, when speaking for behavioural change, one should not only focus on students.

Energy use is an important part of school expenditures. You can always make changes to the infrastructure or improve already existing equipment or to acquire new, more efficient equipment. Those things end up costing a lot of money to start, and then, years later, you most probably run into the same problems. Factors which influence the attitudes of students towards energy efficiency are the features of their family environment, their energy education at school and social interaction. Through the activities of an appropriate educational curriculum, the students can revise their values, understand the good called energy and learn to use it rationally.

Figure4: Source:https://www.freepik.com/free-photos-vectors/background

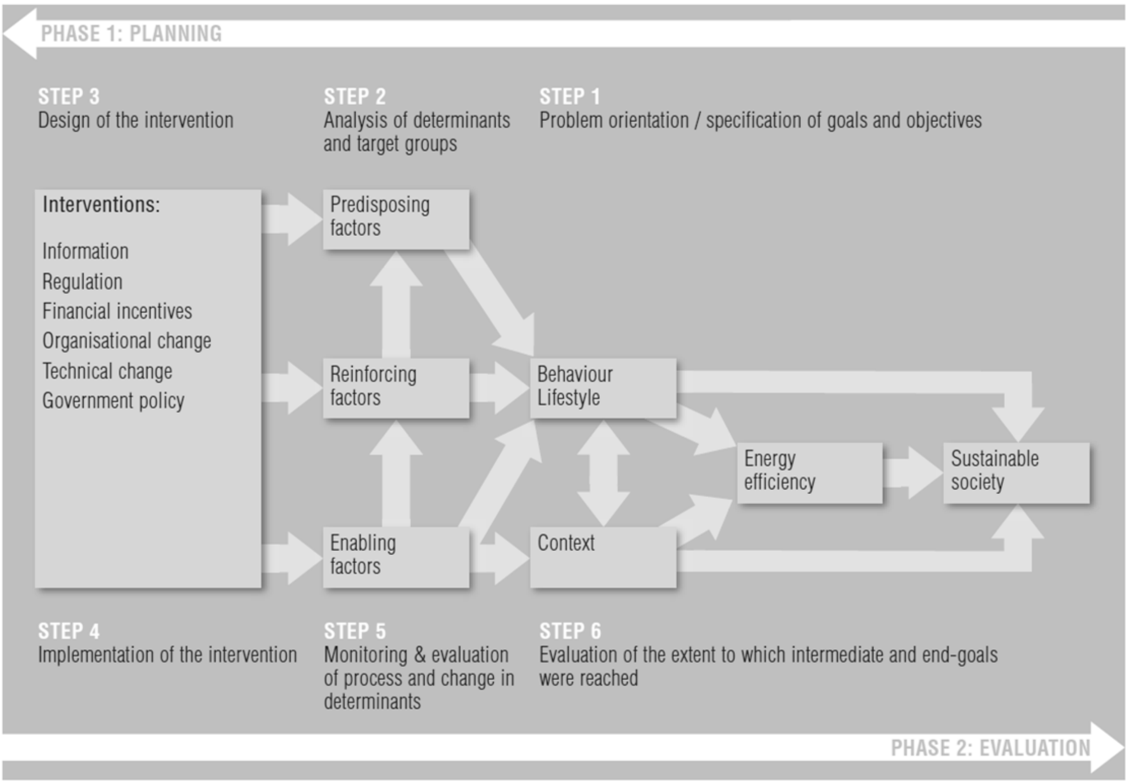
2.2 Challenges for energy saving through behavioural changes

The energy transition is a challenge and needs to be taken into consideration the behavioural issues of how people react to everyday decisions and situations. The design and delivery of behaviour change programmes related to energy efficiency can differ greatly when comparing domestic to non-domestic consumers. The potential for savings through behaviour change is thought to be more significant in the domestic environment, where there is more direct control over energy consumption.

In the non-domestic sector, initiatives are generally delivered at the organisational or sub-organisational level, and there is no direct link to the personal wealth of the individual employees. The motivation for users/employees to engage in energy efficiency behaviours is therefore very different. Generally, it is believed that people do not behave rationally concerning energy usage in places that they are not responsible for energy bills. Thus, this is mainly because they would not benefit directly from initiatives to reduce energy consumption in a commercial setting. Furthermore, there are no direct economic incentives or impact to proceed with energy savings, due to a high number of user's effort is less apparent and when feedback is at group level the results of once actions cannot be evaluated.

2.3 Model of Changing Energy Behaviour

Figure 4. Planning and evaluation model



Source: Changing Energy Behaviour - Guidelines for Behavioural Change Programmes, Madrid 2009

This model was initially aimed at directing change/behaviour change processes in health promotion. The ideas and insights that can be drawn from this model are beneficial in the field of energy conservation, and it can be a helpful tool for changing processes in this area.

It starts with a clear definition of the problem and the desired solutions. It is vital to define the exact problem before moving ahead. The next step is to look at the factors that influence the process. This is important because in the field of energy conservation, especially, there still is a strong tendency to develop objectives that focus on instruments, rather than on the problem itself. The model is presented in two main phases: the planning phase and the evaluation phase.

2.4 How is behavioural change implemented in schools?

First of all, the first step is to identify, how much energy savings are possible to achieve through some behavioural changes. An excellent way to start is the monitoring of energy use, where feasible and identify where energy conservation can be applied. Hence, the next measure is to look at what are the best practices in order to start programs that will create behaviour changes and save energy on a school setting. Another measure is to take expert advice to assist with the choice of the best possible decision for the school.

Following these steps, you must find ways to put an objective measurement on the potential savings from the desired behaviour changes. Reviewing successful changes that have been made at other schools would be a good beginning. Thus, an energy saving plan with targets should set and review it according to monitoring information and build commitment to energy saving across the school. Also, in order to make people more responsible for the energy saving plan, you can give the users and managers a vital role in proposing ideas and measures to save energy.

Moreover, raising energy awareness among the users and employees of the schools going beyond the original target. By changing their energy behaviours, thereby, influencing families and friends to do the same.

Video: (https://www.youtube.com/watch?v=ycdke8MTSCI)

2.5 Education and Raising energy awareness

Reducing energy consumption in school will be achieved through raising awareness of the importance of energy conservation and through changing the habits of the users (students, teachers, caretakers).

2.5.1 Educate Users

(Sources:1.https://www.need.org/files/curriculum/guides/Saving%20Energy%20Student%20Guide.pdf 2. http://www.wisions.net/files/uploads/PREP_06_Energy_in_Schools.pdf, 3. http://assets.wwf.org.uk/downloads/making_a_start_energy_saving_school.pdf, *4. How to handle the Energy Team- an Educational Guidebook for Caretakers- Euronet 50/50 max)*

- Climate Change – Environmental Problems

(source: 1. https://www.ipcc.ch/, 2. https://climate.nasa.gov/)

Climate change and environment is considered as one of the most critical problems of modern civilization at the global level. Extreme weather phenomena, intense rainfall, heatwaves, droughts, hurricanes have been exacerbated in recent years.

The causes of environmental problems need to address in human relationships with nature. The solution to these problems will arise through the actions of the political leaders, governments, industry and citizens all over the world. That is why it needs awareness and public awareness campaign on the issue and the consequences of climate change, as well as the ways to deal with them, by changing some habits in our daily life.

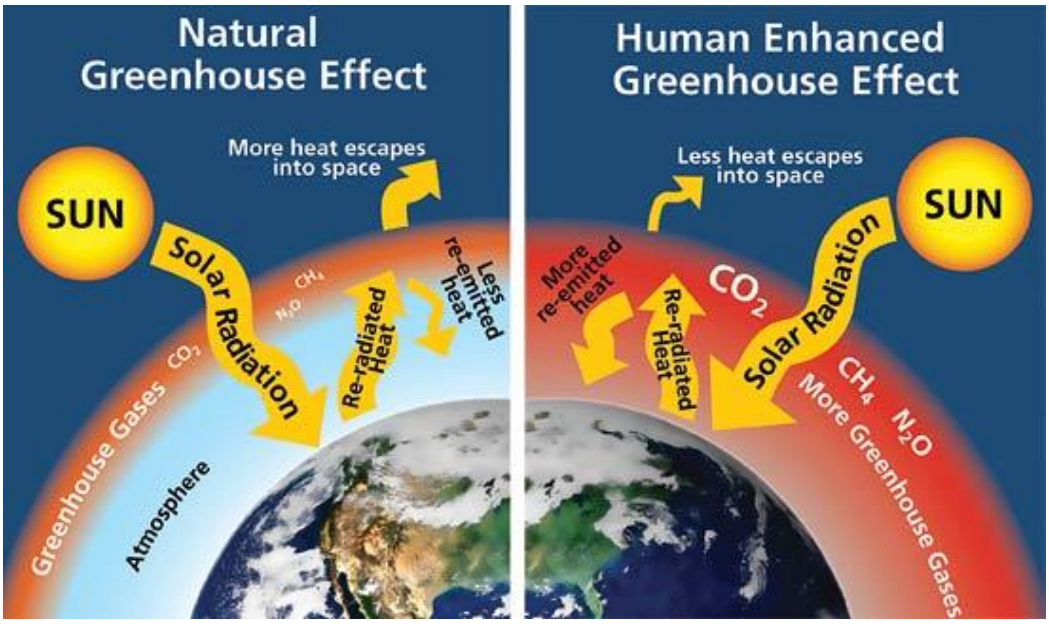
(Source: Credit: Left - Mellimage/Shutterstock.com, center - Montree Hanlue/Shutterstock.com)

Videos:
*(1.*https://www.youtube.com/watch?v=G4H1N_yXBiA,*2.*https://www.youtube.com/watch?v=XFmovUAWQUQ, 3. https://www.youtube.com/watch?v=FWsM9-_zrKo

- Learning the greenhouse effect *(Source: (https://climatekids.nasa.gov/greenhouse-effect/,* http://climatechange.lta.org/get-started/learn/co2-methane-greenhouse-effect/*)*

The sun rays heat the Earth's surface. As the temperature on Earth increases, the heat returns to the atmosphere and some of it is absorbed or reflected Earth by the greenhouse gases that exist in the atmosphere, such as carbon dioxide (CO_2), water vapour, nitrogen oxide, methane and ozone. This natural process is called a greenhouse effect, and it is the one that is responsible for life on our planet.

Due to the impact of human activity on the environment in the last century, the concentration of greenhouse gases in the atmosphere, 80% of which is CO_2, is now higher than in the past 650,000 years. This effect increases the average temperature of the Earth. The greenhouse effect causes the Earth's temperature to rise due to the terrible increase in carbon.



Source: (http://climatechange.lta.org/get-started/learn/co2-methane-greenhouse-effect/)

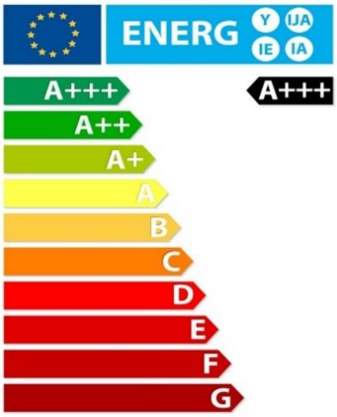
Video: (https://www.youtube.com/watch?v=BPJJM_hCFj0 ,https://www.youtube.com/watch?v=9h7P8gWpolQ,)

- Measures of Energy Conservation (https://extremelowenergy.com/top-tips-to-save-energy-in-schools/, https://www.myledlightingguide.com/blog-ways-to-save-energy-at-school)

- Acquiring information on the heating system and how to save energy
- Acquiring information on water heating and how to save energy
- Learning the ideal temperatures for summer and winter in the classrooms. In winter, set school's thermostat to 18°C–20°C and in summer set it to 24°C–27°C.
- Acquiring information on the energy consumption of various equipment

  [*Energy Efficiency- class A++, consume five timeless energy than conventional devices*]- [*We do not leave electrical appliances in standby mode. Energy waste is also done, when we leave electrical appliances, such as TV, stereo, computer, in standby mode. That is why we close the electrical devices from the main switch.*]

  Source:(http://www.europarl.europa.eu/news/en/press-room/20160701IPR34483/energy-efficiency-of-home-appliances-meps-call-for-more-ambitious-a-to-g-scale, https://www.assemblymag.com/gdpr-policy)



- Learning the right use of lighting and acquiring information on the light levels in a class
  [*When we move from one class/office of the school to another, we must turn off the lights, even if we are missing just for a little while. At the same time, it is a good idea to use as much as possible it becomes more daylight by opening the curtains in the classrooms. Also important is to clean the lamps as the dusty bulbs consume more energy than the cleaner.]*

- Learning about the various types of lighting equipment and how to save energy

  [*Lighting: Switching to energy –efficient lighting is one of the fastest ways to cut your energy bills—a) CFL Lighting : Last 10 times longer and use about one-fourth the energy of traditional incandescent bulbs b)LED Lighting: Use only about 20%-25% of the energy and last up to 25 times longer than traditional incandescent bulbs*]

- Learning the meaning of recycling and reuse
  Source:(.http://greendot.com.cy/sites/default/files/inlinefiles/2018%20Full%20Presentation%20ENG.pdf)

[A simple habit that all students, teachers, staff and parents can adopt and therefore contribute to the protection of the environment is the recycling and reuse. Recycling {paper, glass, aluminium} Reuse {bags, paper, glass bottles, etc} – Prefer the product whose packaging can either recycled or made from recycled materials].

Source:(https://brewongleeec.com/2015/11/05/schools-recycle-right-challenge-national-recycling-week-5-13th-october-2015/)

- Learning how power is related to cost
- Acquiring information on the use of energy in the school
- Learning about the behavioural changes
- Learning how to take action and change behaviours
- Creating stickers and applying them invisible, meaningful areas for the users to see
- Learning how to read the electricity bill

2.5.2 Raising Energy awareness

It is essential for school authorities and school managers to show their support for energy efficiency. You can do this by:

- making energy efficiency a priority
- appointing energy 'champions', who are responsible for spotting energy waste and promoting energy efficiency

  [The role of the champion could be to identify energy waste, keeping students up to date about the measures of energy saving, and recommending new initiatives. Hence, the staff could also have a "champion", that could monitor power bills and keeping staff up to date about energy conservation.] https://www.eecabusiness.govt.nz/assets/Resources-Business/action-sheet-1-involving-staff.pdf

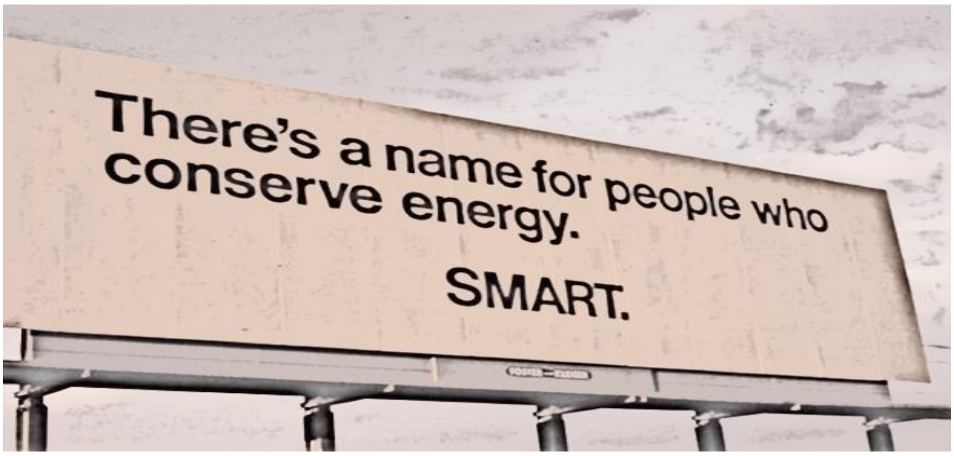
- seeking input to the energy plan and rewarding feedback

- celebrating achievements
- keeping people informed about new ideas
- making it fun by having activities or competitions around saving energy.
- running an energy conservation campaign and motivating students/staff.

Examples:

Energy Saving - Why?

- Cut carbon dioxide emissions, reduce climate pollution.
- Helps people live healthier, longer lives.
- Improves the quality of life, more comfortable and more productive.
- Saves you money. Using less energy through efficiency measures is good for your economy and your wallet.
- Ensure the availability of energy sources for future generations



- ✓ **Making smart decisions when choosing appliances**
- ✓ **Being mindful of your daily energy consumption**
- ✓ **Adopting simple energy habits**

Many argue that the best way to teach children about energy is through interactive and educational activities and gamification, which improve active learning and class engagement. It is a fact that up to now, educational materials have been mostly in the form of schoolbooks and brochures. The design and production of new interactive activities in schools is an important step to provide the necessary background for better understanding and productive discussion between the children on these topics. Also, it will help teachers to organise their lessons on energy better, emphasising the role of energy in everyday life.

By educating students in the classroom about the right decisions, it is making their ability much higher by reducing brain cycles. If the knowledge is on the front of their mind, an individual will not have to think as hard about what is right. This reduction in complex thought also saves time. By creating more environmental classes and increasing participation from each student, it pushes sustainability into the realm of a social norm.

2.5.3 Ideas for actions

Having the experience and participate in learning energy conservation, students/staff can be supportive and empower their impact to make a difference in the environment. Hence, they must be able to recognise the importance of learning from the experiences of other schools and implement the ideas that will make their goal to be achieved easier. Some ideas for actions that could be implemented in schools are:

- Energy training for the cleaning staff

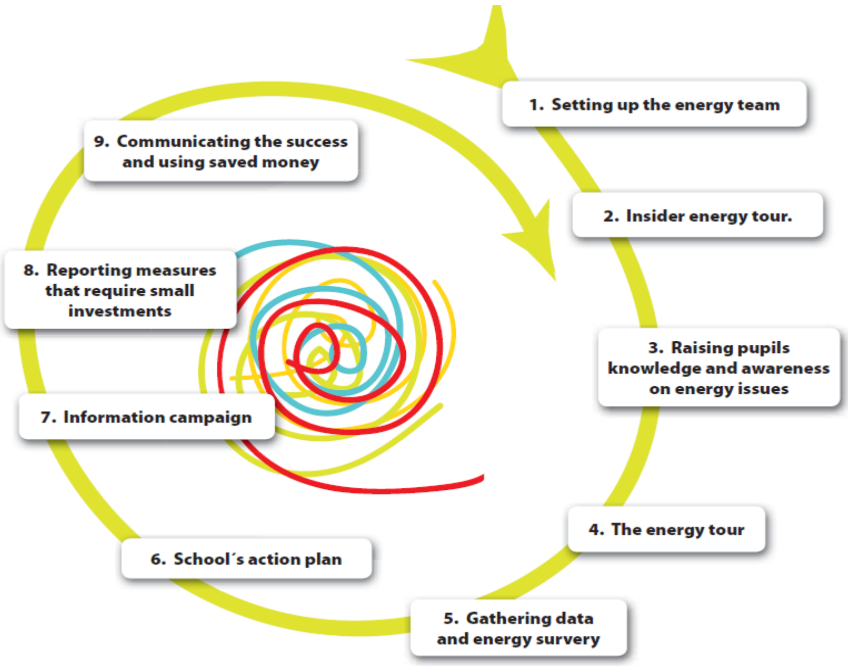
- Day without energy in the schools
- Re-thinking the space uses in order to save electricity
- Research project on energy inspired by the energy team
- Conduct an energy survey
- Exhibition of old electric equipment
- Observe the monthly consumption figures
- Spend a day without shopping
- Sculptures from wastepaper
- Transferring awareness from schools to families
- Workshop on energy saving and energy labelling
- Use the public transportation. walk or cycle
- Recycling for our future
- Cooking with Renewable tastes so good!

A successful example:

EURONET 50/50 max [http://www.euronet50-50max.eu/en/]

The project Euronet 50/50 max was based on students, teachers and other users of public buildings and its goal was to raised awareness of energy efficiency. The 50/50 project used a methodology that implemented in the previous project 50/50 %, which sees 50% of the savings returned to users of public buildings through a financial pay-out, with the remaining 50% representing a net saving for the local authority that is paying the bills. An energy team was set up in each school participating in the Euronet 50/50 project. The main tasks were to report the measures and the actions that needed to be taken to improve the energy conservation, running a promotional and awareness campaign on the importance of energy efficiency and disseminate these methods in other schools in order to implement the measures.

The purpose of this project was to provide a simple way – the 50/50 methodology – to achieve energy savings without making significant investments, basically through behavioural changes in the use of the facilities. The project has helped to raise awareness and assist the corporate organization of users in public buildings. In schools, teachers and pupils have come together in teams to promote energy savings in each school, working with the main aim of reducing consumption and CO_2 emissions. Moreover, their share of the savings is used to improve educational activities.



(Source: Euronet 50/50 max)

3. Conclusions:

Change of attitude and behaviour with regard to the sustainable use of energy is necessary. It is important that students understand the significance of rational energy management so that they can create positive attitudes towards the management of natural resources. Education on energy issues plays a key role in the formation of student behaviour. The application of initiatives regarding energy saving within school units can only bring benefits and lead towards reduction of energy cost. Students are also given opportunities to appreciate activities regarding energy saving and disseminate what they learnt in their wider social environment.

An effort to implement a non-routine element would cause some disorientation and civil unrest for a little while, but eventually people would get acclimated especially if this element is more appealing through comfort, simplicity, and through ease of access. People do not like being told what to do, in any circumstance. So, introducing different lifestyle changes in increments cannot be stressed enough. Adaptability is a key element of survival for any species. If we are unable to adapt to small lifestyle changes like using the bus instead of your own car, then our future is bleak in terms of sustainability.

Agreements could be made to ensure that schools consume a certain percentage of recycled/reusable products and aim at purchasing energy star appliances. Encouraging these, the school's carbon footprint will be significantly reduced, and it will be easier for the students to maintain an environmentally friendly behaviour.

Influence people's relationship with energy, don't change the products, change the people. (*source: Ted's speaker-Opower Company*)

Note: Please use each source as a link for more information and guidance!

4. Self-assessment:

1. A reduction of energy usage needed for Europe to meets its energy goals:
a) By the year 2025
b) By the year 2050
c) By the year 2030

2. The two main sector that consumed most energy according the Eurostat:
a) Households, Transport
b) Agriculture and forestry, Household
c) Transport, Industry

3. Energy consumption depends on:
a) Climate change, weather conditions, user behaviour
b) User behaviour, energy efficiency of complex systems, weather conditions
c) Society, Complex systems, Climate Change

4. According to theories and models of behavioural change can be achieved due to:
a) Changes in conservation, awareness, small investments and lifestyle
b) Social Environment, Awareness
c) Purchase of energy efficient appliances

5. The theory of Planned Behaviour explains:
a) Behaviour on an individual attitude
b) The relation between attitude, subjective norms and behavioural intention
c) The relation between attitude and behavioural intention

6. According to Triandis' theory, behaviour is:
a) A function partly of intention, habitual responses and situational constraints
b) A function of social factors, intention, attitude
c) A function partly of emotions, beliefs and intention

7. The main elements based on Social Practise Theory are:
a) Meaning, Material, Procedures
b) Meaning, Material, Intention
c) Material, Procedures, Norms

8. Factors to achieve environmentally sustainable behaviour are:
a) Direct/Indirect Feedback, Energy Audits, Economy incentives

b) Communication, Economy incentives, Feedback
c) Communication and engagement, Economic incentives and Regulatory

9. Factors that influence the attitudes of students regarding the energy usage are:
a) Acquire new equipment, Energy Education and Social Interaction
b) Acquire new equipment, Energy Education and Family Environment
c) Energy Education, School and Social Interaction, and Family Environment

10. Steps to implement behavioural change in schools
a) Raising awareness, campaign, energy efficiency measures, energy teams, monitoring energy usage, purchase new efficiency appliances
b) Identify how much energy savings are possible, best practices to save energy, assistance from an expert, monitoring energy consumption, set an energy plan and create energy teams, raising awareness
c) Monitoring electricity bill, raising awareness of energy efficiency, set an energy plan, energy teams

11. Educate the consumers of energy includes knowledge of:
a) Climate change, measures of energy conservation, running a campaign
b) Climate change and Environmental Problems, Greenhouse effect and how to read electricity bill
c) Climate change, greenhouse effect, measures of energy conservation

12. Some of the main measures of energy conservation are:
a) Acquire new energy efficiency appliance, Recycling and reuse, turn off the light
b) Not cooking, acquire new energy efficiency appliance, use less electricity
c) Right use of lighting, Raising energy awareness, Recycling and reuse, turn off the light