

Ανοικτό Πανεπιστήμιο Κύπρου

Σχολή Θετικών και Εφαρμοσμένων Επιστημών

Sustainable Energy Systems

Μεταπτυχιακή Διατριβή



**Utilizing Near Zero Energy Buildings in Different Locations in
Greece with Photovoltaics Systems**

Σταυρόπουλος Γεώργιος

Επιβλέπων Καθηγητής
Πάρις Φωκαΐδης

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Η παρούσα μεταπτυχιακή διατριβή υποβλήθηκε προς μερική εκπλήρωση των απαιτήσεων για απόκτηση μεταπτυχιακού τίτλου σπουδών στο MSc Sustainable Energy Systems από τη Σχολή Θετικών και Εφαρμοσμένων Τεχνών του Ανοικτού Πανεπιστημίου Κύπρου.

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Περίληψη

Οι κύριοι άξονες της διατριβής θα είναι η μελέτη περίπτωσης κτιρίων σχεδόν μηδενικής κατανάλωσης ενέργειας που χρησιμοποιούν σύγχρονες τεχνικές, καθώς και φωτοβολταϊκά συστήματα για παραγωγή ενέργειας και αυτοκατανάλωση με στόχο τη μείωση του ενεργειακού αποτυπώματος.

Η γενική συλλογιστική της διατριβής θα είναι η μείωση του ενεργειακού αποτυπώματος σε περιοχές της Ελλάδας, η εξοικονόμηση ενέργειας, η παραγωγή ενέργειας από ΑΠΕ, διαφορετικές περιπτώσεις μελέτης με διαφορετικά εξαρτήματα κάτω από διαφορετικά πρίσματα σε διάφορες περιοχές της Ελλάδας.

Summary

The main axes of the dissertation will be the case study of Near Zero Buildings using modern techniques, as well as photovoltaic systems for energy production and self-consumption with the aim of reducing the energy footprint.

The general reasoning of the dissertation will be the reduction of energy footprint in areas of Greece, energy saving, energy production from RES, different study cases with different components under different prisms in different areas of Greece.

Περιεχόμενα

1	Introduction	1
1.1	Theoretical Background – Literature View	3
1.2	Methodology	7
1.3	Work Plan	8
2	Zero Energy Buildings (ZEB)	11
2.1	Definitions on nZEB	14
2.2	nZEB Literature View	18
2.3	nZEB General Concept	21
2.4	Current Situation in Europe	23
3	nZEB Design	26
3.1	Designing an nZEB	26
3.2	Designing Parameters	29
3.2.1	Climate and Microclimate	30
3.2.2	Methods for Improvement of Microclimate	35
3.2.3	Morphology of Buildings	36
3.2.4	Size and Orientation of Openings	37
3.2.5	Fitting and Planning of Spaces	39
3.3	Structural Elements	40
3.3.1	Thermal Insulation	41
3.3.1.1	General Concept of Insulation	42
3.3.1.2	Optimal Insulation Levels	43
3.3.2	Walls	44
3.3.2.1	Exterior Wall Insulation	45
3.3.2.2	Energy Efficiency Options	46
3.3.3	Roofs	47
3.3.3.1	Flat Roofs	48
3.3.3.2	Cool Roofs	49
3.3.3.3	Energy Efficiency Options	50
3.3.4	Foundations and Floors	51
3.3.5	Frames	52
3.3.5.1	Air Sealing	54
3.3.5.2	Energy Efficiency Options	55
3.3.5.3	Shading Attachments	55
3.3.5.4	Insulating Technologies, Low – e Coatings and Attachments	56
3.3.5.5	Air Leakage	56
3.3.5.6	Triple Glazed Windows	57
3.4	Technical Systems	57
3.4.1	Heating Systems	57
3.4.1.1	Traditional Boilers and Furnaces	58
3.4.1.2	Condensing Boilers and Furnaces	59
3.4.1.3	Biomass Heating System	61
3.4.1.4	Pellet Stoves	62
3.4.1.5	Traditional Fireplaces and Wood Stoves	63
3.4.1.6	High Efficiency Fireplaces and Masonry Heaters	64
3.4.1.7	Electric Heaters	65
3.4.1.8	Heat Pumps	66
3.4.2	Passive Heating Systems	67
3.4.2.1	Systems of Direct Profit	67
3.4.2.2	Trombe Wall	68
3.4.2.3	Thermal Insulating Panels	69
3.4.2.4	Open Spaces	69
3.4.2.5	Other Passive Systems	69
3.4.3	Space Cooling	71
3.4.3.1	Split Systems and Packages Cooling Unit	71

3.4.3.2	Dehumidification Systems	72
3.4.3.3	Roof Fan	73
3.4.3.4	Passive Systems of Natural Cooling	73
3.4.4	Mechanic Airing	74
3.4.5	Water Heating	75
3.4.5.1	Instantaneous Water Heaters	77
3.4.5.2	Heat Pump Water Heaters	78
3.5	Electricity Production of RES	78
3.6	Co – Production	79
3.7	Lighting	80
4	nZEB in Europe	83
5	Designing nZEBs in Greece – The Role of the Building Envelope	89
5.1	Exploitable RES in Greece	90
5.2	Climate Zones in Greece	91
5.3	Properties of the Building – Model Building	93
5.4	Photovoltaics on Roof and Energy Consumption	97
6	Results of the Designed Building in Different Locations	99
6.1	Energy Results & Criteria	100
6.2	Organic Photovoltaics (OPV)	102
6.3	Greek Regulatory Framework for PV Self – Consumption	104
6.4	Modeling of PV System Electricity Flows	104
6.5	Calculation of Gross Electricity Bill Savings from PV Self – Consumption	105
6.6	Net Present Value (NPV)	107
6.7	Self – Sufficiency of Residential PV Systems Installed in Greece	108
6.8	Gross Electricity Bill Savings from PV Self – Consumption	109
6.9	Cost – Competitiveness of OPV Systems for Self – Consumption	111
7	Conclusion	112
	List of References	114

1. Introduction

Nowadays, we are all aware of the importance of energy. We are increasingly discovering that our demands for energy are becoming ever greater on the basis of the modern, technologically equipped, developed and demanding world we live in. But have we ever wondered what is going on with energy production? How can we have energy whenever and wherever we need it? Making it so easy and simple for us. With the touch of a button, in a household socket, encased in a simple battery (lead, lithium, nickel-cadmium, etc.). Clearly, it has become a reality, a daily habit, a simple move; we do not necessarily understand that behind simple daily moves that we all do lays an entire industry, a whole world, a microcosm of our society.

The study below will be a study on an nZEB building. A study, which also mentions historical events, ways of generating and exploiting energy in general and not only for domestic use.

The **methodology of the project** to be followed below will be fairly straightforward and reasonable. We will use comparative methods and tables for comparing sizes such as energy consumption from an energy grid or RES, cost of purchasing power units, investment costs, etc.

We will also use simple mathematical operations to compare energy sums, labour hour's costs, maintenance costs, equipment and employee costs, financial investments, etc.

More specifically, the project will follow the 3 steps below:

1. Collection of relevant data and information on nZEB and studies that have already been made.
2. Estimation of energy consumption and ways to reduce it with renewable energy.
3. Estimation of profitability based on the study and the impacts of carbon emission.

The basic scientific questions to be asked and calculated are in a nutshell: how can we reduce energy consumption, energy footprint, energy costs. Are we able to produce clean energy even in small-scale buildings. Are buildings optimizations a new territory that has to be explored in cases of producing / consuming energy in different sectors.

As technology continues to evolve every day, the emphasis placed on energy efficiency has transformed from a possibility into a necessity. The vital need to reduce emissions and regulate the environment has led to drastic changes in the building sector, from management to integration. The concept of Zero Energy Buildings or Net Zero Energy Buildings (NZE) is quickly gaining momentum for environmentally conscious consumers and companies.

Combining cost-optimal solutions in line with European policies to reach almost zero energy constructions (NZE) is an ongoing challenge. The evaluation of different configurations and the implementation of the best appropriate solutions by building and location can be reduced in energy consumption.

This paper develops a cost-optimal and energy efficiency optimization framework for buildings based on simulations. It uses a sequential search technique to combine energy and cost simulations to search for and find the most efficient combination of energy efficiency measures and renewable energy measures. The model is applied to a residential construction prototype, taking hourly climate data, construction processes, cost data and energy consumption into account. A cost database and a library have been developed and used in the optimization process, with the potential measures related to envelopes, appliances and systems. The calculations have included the possible effects of climate change on the estimated cooling loads. The paper shows that Greek demands for new NZEs in different urban areas are feasible. It describes how the nZE design in many places across Greece can best be achieved at the lowest cost. The results show how climate variation of the cost-optimal measures and how the selected options differ in each location. Isolation and building tightness in colder climates appear to be essential, while efficient devices and lighting in warmer locations are key measures. One key finding in the study is that new buildings at all locations are capable of reducing energy sources by 90% and beyond. Results also show the significant effect of efficient lighting and equipment on building energy performance. In order to achieve the nZEs

goal, it is confirmed that the integrated renewables and energy efficiency measures are important.

1.1. Theoretical Background – Literature Review

As technology continues to evolve every day, the emphasis placed on energy efficiency has transformed from a possibility into a necessity. The vital need to reduce emissions and regulate the environment has led to drastic changes in the building sector, from management to integration. The concept of Zero Energy Buildings or Net Zero Energy Buildings (nZEB) is quickly gaining momentum for environmentally conscious consumers and companies.

A "near-zero-energy building" is a very energy-efficient building whose virtually nil or very low amount of energy needed to meet its energy needs is largely covered by renewable energy sources, including energy is produced on site or near the building.¹

The aim of this essay is to contribute to the following modern problems:

- energy savings in buildings,
- maximum use of passive and active systems and devices,
 - with the aim of minimizing the need for buildings in energy,
 - and on the other hand with maximum exploit of renewable energy (sun, wind, etc.) so that our buildings can not only produce the energy they need but can even produce available surplus of energy for the central energy grid, with any corresponding economic benefit (ZEB building and nZEB),
- minimizing the pollution caused by the building sector.

For the implementation of Environmental Design in Greek reality and especially in adverse conditions, all possible arrangements are described and analyzed and experimentally tested in a building model.

¹ EU Directive 2010/31 / EU (Article 2)

It is difficult to find a building, which can be named the first Zero Energy/Emission Building (ZEB). One of the reasons could be that maybe ZEB is not a new concept for a building, it is just a modern name for buildings, from times before district heating and electricity, heated with wood or straw and lighted with candles and domestic animals. Nevertheless, in the late seventies and early eighties appeared few articles, in which phrases 'a zero energy house', 'a neutral energy autonomous house' or 'an energy-independent house' were used. It was the time when the consequences of the oil crisis became noticeable and the issue of the fossil fuels.

Sources and the energy use started to be discussed. However, those papers were mainly focused on the energy efficient technologies and passive solutions implemented in the building. Furthermore, only energy demand for space heating, domestic hot water and cooling were accounted in the 'zero', hence were they in fact buildings with zero energy use?

In the literature, over the decades, different ZEB's were described and evaluated, however almost in every paper the ZEB either was defined differently or no exact definition was used. Very often, the ways the zero energy goal was achieved, have significantly affected the ZEB definition. Recently, the lack of common understanding and common definition for ZEB became noticeable, since this building concept is thought to be an effective solution for decreasing the energy use and greenhouse gas emissions from the building sector.

In the literature dedicated to Zero Energy Building the authors frequently emphasize the lack of common understanding of what should be equal to 'zero'. This issue has been widely discussed in numerous publications however, the question: should "zero" refer to the energy, the exergy or the CO₂ emissions or maybe energy costs, **still has not been unambiguously answered.**

In a report, *Torcellini, et al. (2006)*, authors use the general definition for ZEB given by The U.S. Department of Energy (DOE) Building Technologies Program:

“A net zero-energy building (ZEB) is a residential or commercial building with greatly reduced energy needs through efficiency gains such that the balance of energy needs can be supplied with renewable technologies.”

The essay, takes into account that near-zero energy consumption buildings (nZEB) have:

- high energy specification building blocks,
- E / M installations of particularly high energy efficiency and
- a significant share of their energy consumption will be covered by renewable energy at local level.

Among others, the essay describes the ways that zero energy buildings and zero carbon buildings goals seeks maximum efficiency derive from the notion of neutralizing their source energy consumption and define this as zero energy consumption. The design process involves an integrative approach like:

1. reducing energy needs for heating and cooling by optimising the envelope and integrating passive heating and cooling techniques,
2. improving energy efficiency of active systems
3. and ways to incorporate renewable energy.

With the introduction of almost zero-energy buildings, the European Union is dynamically promoting energy savings in buildings, the largest final energy consumer in Europe.

The aim is to meet, inter alia, the 20% reduction targets for energy consumption by 2020 and 27% by 2030, respectively. Under EU Directive 2010/31 / EU (Article 2):

A "near-zero-energy building" is a very energy-efficient building whose virtually nil or very low amount of energy needed to meet its energy needs is largely covered by renewable energy sources, including energy that is produced on site or near the building.

Near-zero energy consumption buildings (nZEB) have:

- high energy specification building blocks,

- E / M installations of particularly high energy efficiency,
- a significant share of their energy consumption will be covered by renewable energy at local level.

Among others, each EU Member State must:

- Determine the energy requirements for both building envelope elements and the coverage of RES needs.
- Determine the technical characteristics of its buildings with near zero energy consumption, taking into account national, regional or local conditions, including a numerical indicator of the use of primary energy in kilowatt-hours per square meter per year (kWh / m²yr).
- Provide information on the policies and the economic or other measures taken to promote buildings with near zero energy consumption, including details of national requirements and measures for the use of renewable energy in new buildings and existing buildings that undergo a radical renovation.

Each EU Member State should also take the necessary promotion and funding measures to promote nearly zero-energy buildings.

The methodology for calculating the energy efficiency of nZEB buildings should:

- be harmonized in member states,
- There are quality control mechanisms for the process and
- there are penalties in cases of non-implementation.

All the above instructions, was the driving force for exploring such buildings. As mentioned above, in this report, a simulation will take place in the area of Greece through analysis and historical data of such buildings. In a nutshell, an nZEB building will be designed and will be studied based on software programs, by performance in different regions in Greece and under different circumstances.

The calculation methodology shall be determined taking into account at least the following:

- The actual thermal characteristics of the building (including its internal partitions):
 1. heat capacity,

2. thermal insulation,
 3. thermal bridges,
- The heating and hot water supply (DHW) installation, including the characteristics of their thermal insulation,
 - The installation of air conditioning, including its thermal insulation properties,
 - Physical and mechanical ventilation, which may include air-tightness,
 - The installation of general lighting (in tertiary sector buildings),
 - The design, location and orientation of the building, including external climatic conditions,
 - Passive and hybrid solar systems and solar protection,
 - Passive heating and cooling,
 - Indoor climatic conditions, also taking into account the conditions of indoor climate planning,
 - Internal loads.

1.2. Methodology

After studying the construction of a Near Zero Energy Building, a case study will be carried out with calculation programs for different regions of Greece. Data will be gathered based on the above, comparisons will be made and conclusions, improvements and proposals will be made for the best efficient operation of the above buildings

The essay refers to a RES use survey, in order to reduce energy footprint, energy consumption and carbon dioxide emissions. It promotes clean and green energy, and proposes solutions to similar countries based on existing RES technology. The main objective of the essay is to study and encourage different regions to use green energy for reasons such as:

- Little to no global warming emissions,
- Improved public health and environmental quality,
- A vast and inexhaustible energy supply,
- Jobs and other economic benefits,
- Stable energy prices,
- A more reliable and resilient energy system.

As mentioned above, the methodology followed will have a logical order and basically will be a comparison of results. Always based on the initial assumptions as mentioned above.

Initially, there will be an extensive research into the design of nZEB buildings. What kind of facilities do exist, what processes / procedures are taking place in nZEB buildings, what raw materials are needed for the above, in what ways and with which methods nZEB buildings are constructed, what emissions does an nZEB building like those have etc. The above will be studied from reliable sources such as, construction companies' data and studies that have already been made in the field of nZEB buildings

Then we will explore several methods with which we can reduce our basic problems, energy consumption and the emissions of our everyday lives i.e. our residential buildings. We will study the use of RES in such buildings, especially in the sectors that can be implemented in Greece, in particular. The clearest examples for Greece are wind power, solar energy according to studies for example. In certain places we could assume that geothermal energy could help our intensions.

According to our sources, at the end of the essay, a comparison of the energy sources of such a building with, or without RES, will be made. We will compare our results, from the point of constructing such buildings both from technical and economic point of view. In a nutshell, we will ask ourselves, whether the above are feasible in modern reality in Greece both at a technical and financial level.

1.3. Work Plan

The essay focuses on a study using RES for energy production and self-consumption in a building for residential use.

Initially, the subject was chosen in consultation with the supervising professor, then a first survey was conducted on the subject in finding sources and whether it was feasible to implement this topic / sources in such a study.

Subsequently, an initial build of a timetable was made to implement the study on the deadline given. The timetable is of course flexible, as there are difficulties that may not have been revealed yet or may have been overseen.

After analyzing the sources and finding any complications in the research processes, the main part of the sources was gathered and after extensive study we started noting and rejecting any unnecessary sources. At the same time, bibliography is collected, and a study of each chapter of the dissertation was made. Bibliography will be continuously added until the end of the essay, as new variables, new factors and data from different sources will be introduced.

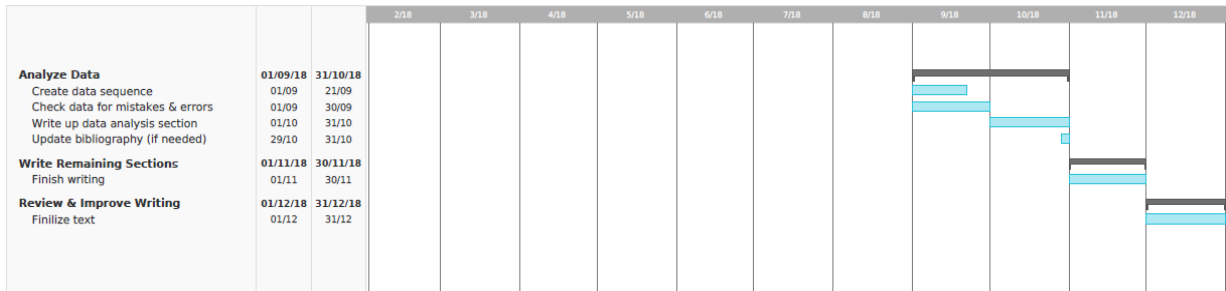
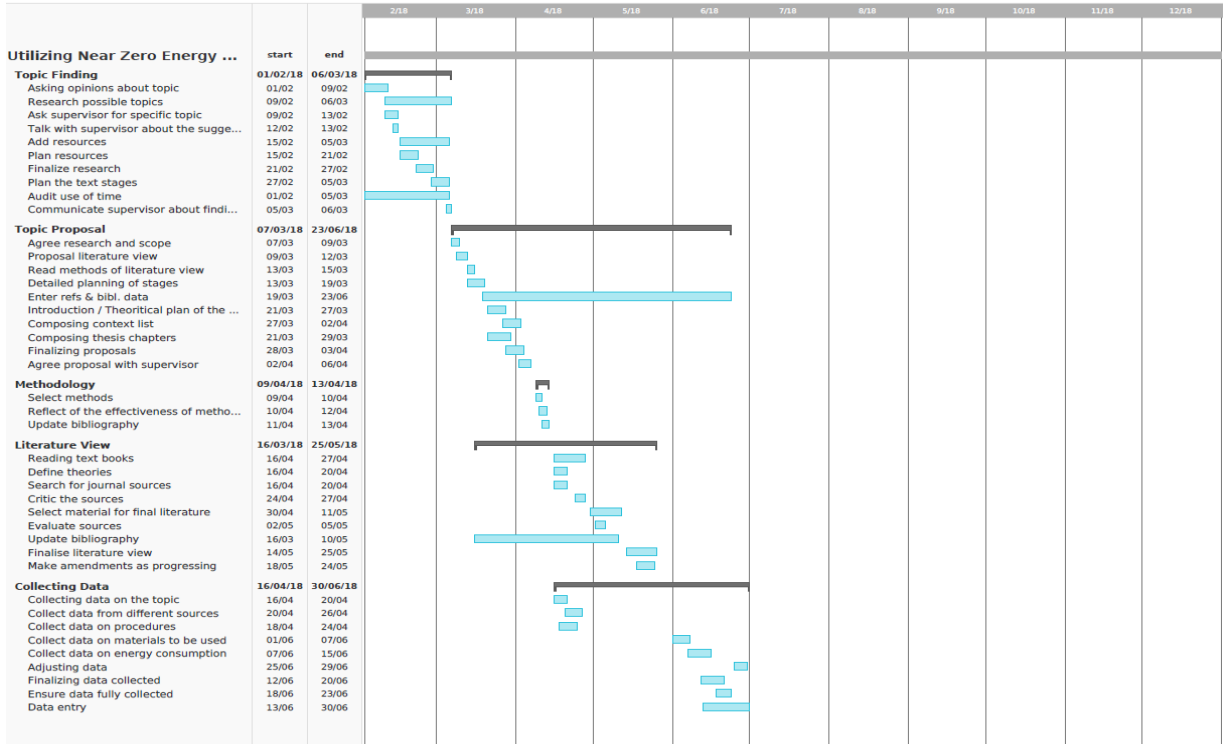
Furthermore, there is a comparison of the existing data - studies with innovative techniques that we propose for the ultimate purpose of diplomatic work, the reduction of energy consumption, using renewable sources.

Especially in Greece and these kinds of residential buildings, we refer to solar and geothermal energy according to Greece energy dynamic. Data in this field of research are collected by national studies – researches.

The most important phases of the project are:

- the design of such a building,
- the combination of the necessary building materials for the optimal result,
- the combination of electromechanical systems to maximize energy savings,
- the processing of the above items in different regions in Greece.

Most features of the study are based on older researches that have been made on near Zero Energy Buildings (nZEB), energy consumption for such installations, and the cost of operating such buildings. There are some assumptions and hypotheses in the research that we will study extensively, in order to be more accurate. The following diagrams show the actions, based on the dates to be followed, the flow of the study, the bibliography selection, etc., in order to carry out the study properly.



2. Zero Energy Buildings (ZEB)

Referring to Zero Energy Buildings means, **buildings with very high-energy efficiency**. *The virtually nil or very low amount of energy required should be generated from renewable sources, including the generated on site or near the building*². These buildings, however, do not cease to produce greenhouse gases, because when there is no available solar energy (egg cloudy, short winter and night) or wind power (to operate possibly installed wind turbines) meet their needs fed, by the electricity transmission network, hence also from conventional sources.

In practice, most zero-energy buildings receive **half or more of the energy required** to operate them from the grid. Buildings that generate more energy than they consume over one year (i.e. excess energy) are called "**positive energy buildings / energy plus buildings**"³, while those that consume little more than they produce, "**near zero energy buildings**"⁴ or **extremely low energy consumption buildings**" (near-zero energy buildings or ultra-low energy houses⁵).

Traditional (conventional) buildings are estimated to consume 40% of fossil energy produced in the EU and the US, and they also make a significant contribution to the production of greenhouse gases. The principle of "*zero energy consumption*" is a tool for reducing CO₂ emissions and dependence on fossil fuels. At present, zero-consumption buildings are not very widespread even in developed countries, but they are becoming more and more important and recognizable.

² <http://inzeb.org/%CE%BF%CF%81%CE%B9%CF%83%CE%BC%CF%8C%CF%82-zeb/>

³ <https://en.wikipedia.org/wiki/PlusEnergy>

⁴ http://wiki.cesba.eu/wiki/Nearly_Zero_Energy_Building

⁵ https://en.wikipedia.org/wiki/Low-energy_house

Most zero-energy buildings use the electricity transmission network to store their energy, but some of them are also independent. Energy is usually concentrated on the spot through a combination of RES (solar, wind) technologies, while savings are made through highly efficient cooling, ventilation and lighting heating systems. As the cost of conventional energy sources (from fossil fuels) tends to increase, while alternative energy technologies are declining, **the goal of zero consumption seems more and more feasible.**

The creation of modern zero energy buildings has been made possible by technological advances in construction methods but has also been greatly facilitated by academic research which, by collecting energy efficiency data from conventional and experimental buildings, has the potential to introduce them into computational simulation models and to anticipate the efficiency of new engineering solutions / projects.

Some of the advantages of zero-energy buildings are:

- the integration / combination of RES technologies that also offers the possibility charging of electric vehicles,
- Integration of plug-in electric vehicles – called vehicle-to-grid,
- the implementation of various zero energy balance plans / solutions, so they are considered "*smart buildings*",
- Implementation of zero-energy concepts.

The zero energy concept offers a wide range of approaches due to the multiple possibilities of producing and maintaining energy combined with the assessment of this energy in relation to many other parameters (depending on cost, CO₂ emissions, etc.)



Image 1 nZEB Poster

It is known that net zero energy buildings consume all the energy required, by the electricity grid and return that amount later in the course of one year or one day. These buildings often generate energy surpluses in relation to *'energy-plus buildings'*, or consume slightly more energy than they produce, *'near-zero energy buildings'* / *'ultra-low energy houses'*.

Houses made in traditional ways consume about 40% of the total energy needed by fossil fuels, both in the US and in Europe, contributing to the production of greenhouse gases. Nearly zero-energy buildings use the electricity grid as a large energy storage, but many times, they can be totally independent of the grid. Through the technological achievements in both the energy and construction sectors, it has been possible to create zero-energy buildings. These technologies include foam insulations, solar collectors, heat pumps, triple glazing insulating windows, etc. These technologies are constantly being developed through up-to-date researches and studies around the world, continuously collecting new energy performance data in both traditional and experimental buildings, configuring the results in software for further examination. **The net zero concept is applicable to a wide range of resources such as energy, water and waste.**

Energy is usually the first resource you need to target because:

- Unlike water, waste, solar energy, etc., heating fuel, electricity, heating oil are costly, where the primary objective should be to minimize consumption from traditional resources.
- Electricity and heating fuels have particularly high carbon footprint values. Whenever we lower these prices, we are able to reduce the carbon footprint of a building.
- In international trades, we are able to select, tested instruments aimed at reducing energy consumption and carbon footprint (insulating materials, heat pumps, triple glazing, photovoltaic systems, etc.).
- Governments have introduced subsidies and tax incentives⁶ for the installation of heat pumps, photovoltaic panels, triple glazing glasses etc., thus reducing the cost of building for the owners^{7,8}.

2.1. Definitions on nZEB

Although there is a general definition of '*zero net energy*' for buildings with similar characteristics, there are further definitions that differentiate between Europe⁹ and the Americas, based on the construction, consumption and generation rates.

Zero net site energy use

The amount of energy provided by renewable sources at the site is equal to the amount of energy that the building uses in this type of ZNE. This kind of building is commonly known as "*zero net energy building*," in the United States.

Zero net source energy use

This ZNE produces the same amount of energy used for transporting energy into the building. This type causes energy loss when generating and transmitting electricity. These zero-net site energy buildings have to generate more electricity than zero net site energy buildings.

Net zero energy emissions

Externally of US, a ZEB, also known as '*zero-carbon building*' or '*zero-emissions building*', is defined generally as one with zero net energy emissions. Under this definition, on-site

⁶ Federal solar panel tax credits, state incentives for solar panels, heat pumps and highly isolating triple-glazed glass windows are provided for example in the United States. There also are countries like Massachusetts with zero-interest or interest-rate lending to builders to buy heat pumps, solar panels and three-glass windows which they would not otherwise be able to afford. There has been a reported 5 ~ 10 percent of the house's value for getting an existing house to net zero energy. Investment profit was reported at 15 percent.

⁷ <https://greenzerocarbonhome.com/2018/06/how-much-money-did-we-save-and-how-much-carbon-dioxide-did-we-cut/>

⁸ <http://www.dsireusa.org/>

⁹ Torcellini, P.; Pless, S.; Deru, M. (June 2006). "Zero Energy Buildings: A Critical Look at the Definition" (PDF). National Renewable Energy Laboratory. Retrieved June 25, 2014.

or off-site fossil fuel emissions are balanced with the amount of on-site production of renewable energy.

Other definitions include not only emissions of carbon produced by the building in use, but also those produced in the building construction and the building's embodied energy. Others discuss on the need to include in the calculation the carbon emissions of transfers to and from the building. New Zealand's¹⁰ recent work has started to include energy from building users in zero energy building frameworks.

Net zero cost

In such buildings, the cost of energy purchases is offset by revenues from electricity sales to the on-site electricity supply. Such status depends on how utilities generate net electricity and the structure of the building's utility rate.

Net off-site zero energy use

If 100% of its energy is obtained from renewable energy sources, a building can be regarded as ZEB, even if the energy is generated off-site.

Off-the-grid

Off-the grid buildings are independent ZEB's that are not connected to an off-site power plant. They need a distributed generation of renewable energy and the capacity to store energy (wind does not blow when the sun is not shining, etc.). An energy self-sufficient house is a construction concept where one can achieve the balance between one's energy consumption and production hours or even less. Energy self-sufficient houses may be removed from the grid.

Net zero-energy building

A methodological framework is developed based on scientific analysis under the Joint Research Program "*Towards the Net Zero Energy Solar Buildings*"¹¹, allowing for different definitions, specific (climate) conditions and indoor requirements in accordance with country policy objectives: an overall conceptual understanding of a Net ZEB is energy efficiency and grid connected building, enabled to generate energy from renewable sources to compensate its own energy demand, as shown in figure 1.

¹⁰ Nsaliwa, Dekhani; Vale, Robert; Isaacs, Nigel (2015-08-01). "Housing and Transportation: Towards a Multi-scale Net Zero Emission Housing Approach for Residential Buildings in New Zealand". *Energy Procedia*. Clean, Efficient and Affordable Energy for a Sustainable Future: The 7th International Conference on Applied Energy (ICAE2015). 75: 2826–2832.

¹¹ "Net Zero Energy Solar Buildings". *International Energy Agency: Solar Heating and Cooling Programme*. 2014. Retrieved 25 June 2014.

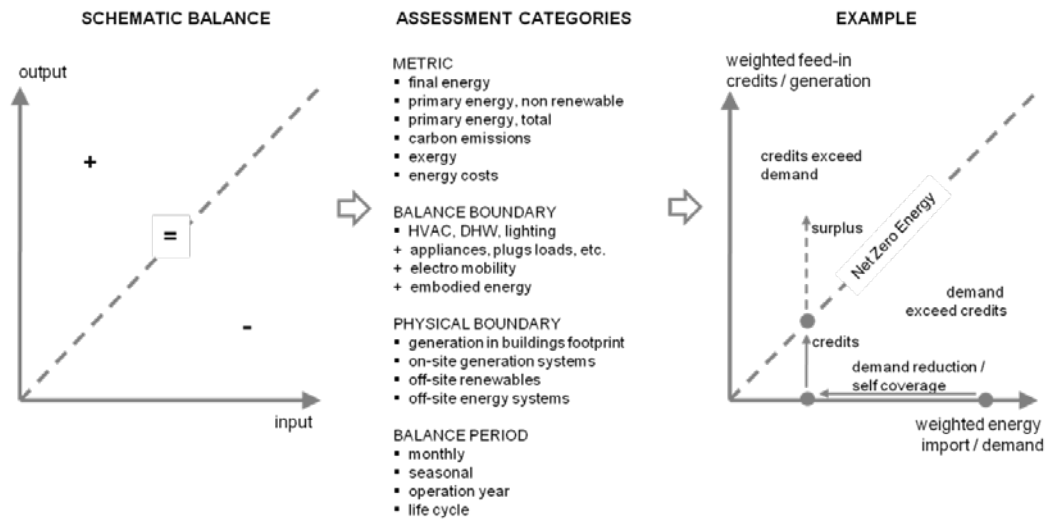


Figure 1 The Net ZEB balance concept: balance of weighted energy import respectively energy demand (x-axis) and energy export (feed-in credits) respectively (on-site) generation (y-axis).

The formulation of the term 'Net' places emphasis on the energy exchange between a building and the energy infrastructure / grid of each country. Thus, we create an interaction of the building and the network, thus buildings become the infrastructure of renewable energy sources. This connection, electrical grid and buildings, avoids the growing 'duck effect'¹² of seasonal energy storage and the growing demand for large energy consumers at regular intervals. The network is decompressed and works better without major damage and maintenance costs. The above concepts lead us to 2 actions:

1. Decreased energy demand, over specific time frames, through energy efficiency and passive energy use measures.
2. Derivative energy from RES.

However, the interaction created between Net ZEBs and the electricity grid, together with different plans for expanding these buildings, provokes reflections on the shifting of energy loads and reduced demand in peak hours.

Within this balance procedure several aspects and explicit choices have to be determined:

1. The construction system limit shall divide in physical terms the number of buildings in the balance (single buildings, buildings) and an equilibrium limit determining the energy utilizations (e.g. for heating, cooling, ventilation, hot water, lightning) that are

¹² https://en.wikipedia.org/wiki/Duck_curve

included in the buildings balance(e.g. in buildings footprint, on-site or off-site). It is important to note that options for the supply of renewable energy can be given priority (e.g. through transport or transformation, availability over the life of the building and the replication potential of the future, etc.). It can be argued that resources should have priority over off-site supply options within buildings or on-site.

2. The system transforms various energy carrier physical units into one metric (site / final energy / spring renewable energy, energy costs, equivalent carbon emissions and even energy or environmental credit) and allows for comparison and compensation between them in one balance (e.g. export electricity from photovoltaic sources can offset imported biomass). The relative value of energy carriers can be affected politically and therefore potentially asymmetrical and time-sensitive converters / weighting factors and the required energy generation capacity influenced.
3. The balance period is often considered to be one year (appropriate for all uses of operating energy). A shorter period (monthly or seasonally) could also be seen as well as a life cycle balance (including the incarnated power, which in addition to operational energy uses can also be annualised and counted).
4. Two balance types are possible to achieve the energy balance:
 - 4.1. Balance of energy supplied / imported and exported (the on-site monitoring phase can be included as an energy self-consumption).
 - 4.2. Furthermore, balanced energy demand (weighted) with (weighted) energy generation (no time consumption patterns, e.g. lighting, electrical equipment etc. for design as usual end-users).

Alternatively, a monthly net balance based only on residues per month is imaginable to be added to an annual balance. This may either be regarded as an import / export balance or a special case in which a "*virtual monthly self-consumption*," as shown in Figure 2, is assumed.

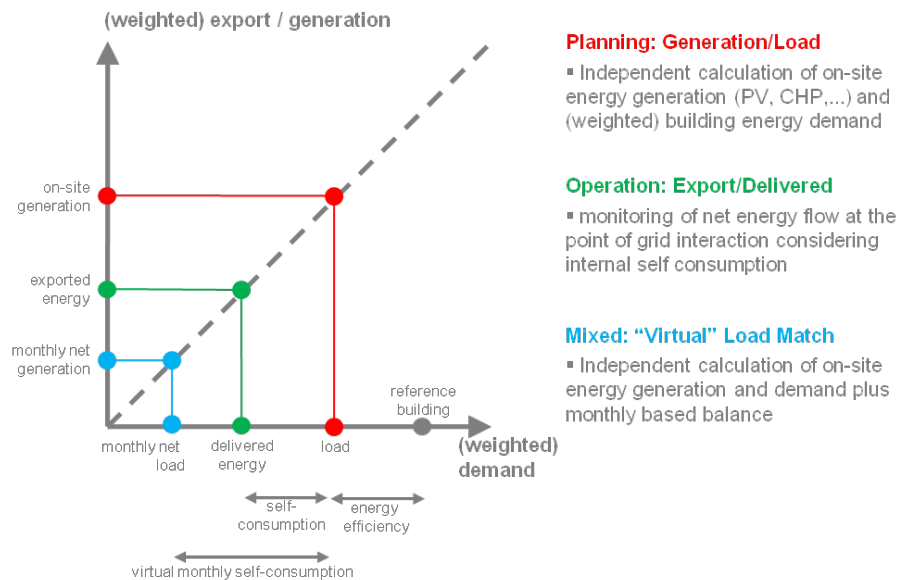


Figure 2 The Net ZEB balance concept: Graphical representation of the different types of balance: import/export balance between weighted exported and delivered energy, load/generation balance between weighted generation and load, and monthly net balance between weighted monthly net values of generation and load.

Net ZEBs are characterized by the ability to match their load and energy output (corresponding to the generated load and load consumption / load matching) and to operate dynamically and positively in relation to the needs of the power grid infrastructure (network interaction). Both can be expressed by suitable indicators which are intended as assessment tools only.

2.2. nZEB Literature Review

It is quite difficult to refer to a building and to name it the first Zero Energy / Emission Building (ZEB). One of the many reasons that we are not in a position to make this distinction is that ZEB's logic is not a modern logic referring to buildings; it is just a new-fashioned name for buildings. However, at the end of the 1970's and in the early 1980's, some articles appeared such as 'zero energy house', 'neutral energy autonomous house', etc. It was the moment when the oil crisis became visible for the first time. So, for the first time a conversation began on the use of fossil fuels. However, these articles focused on technologies and passive solution implemented in buildings. In a nutshell, only the hot water of use and the cooling-heating of a space were measured in 'zero'.

In the literature, within the decades, different variations of ZEB have been described and evaluated, however, almost in any report, ZEB was described differently, or no definition was given. Very often, depending on how the zero consumption target was described,

the definition of ZEB was affected. Recently, a problem has arisen with the different assumptions of the ZEB title, since buildings of this type are considered a solution for reducing energy consumption and reducing GHG emissions in the building sector.

The authors often emphasize the lack of common understanding of what should be equal to 'zero' in the literature dedicated to Zero Energy Building. However, this issue has been widely discussed in numerous publications; the question has not yet been answered unambiguously: should "zero" refer to energy, exergy or CO₂ emissions or perhaps energy costs.

The general ZEB definition of the US energy department (DOE) Building Technologies Program is used by authors in this report (2006): "*The Net Energy Building (ZEB) is a residential and / or commercial building with significant energy efficiency gains that can supply the balance of energy needs with renewable technologies*". They also point to clearly unrelated zero: "*There is no common definition or a common understanding of what it means, despite the excitement over the phrase zero-energy*".

Authors accent that the definition of Zero Energy Building can be characterized in different ways, depending from:

- the objectives of the project,
- the investor's intentions,
- the interest in environmental change and pollution reduction,
- the cost of energy.

In view of the above, a separation of the definition is made by noting the positive and negative effects of the most frequently mentioned definitions:

- **Net Zero Site Energy:** a ZEB site produces, when accounted for on-site, at least as much energy as it uses in one year.
- **Net Zero Energy Source:** A ZEB source generates at least the same level of energy it uses in a given year. The primary energy used for generating and supplying the energy at the location refers to the source energy. To calculate a

building's total source energy, imported and exported energy is multiplied by the appropriate site-to-source conversion multipliers.

- **Net Zero Energy Costs:** At ZEB costs, for the energy of the building owner, the amount of money paid by the utility is at least as much as the amount of money the owner pays the energy services and energy used during the year.
- **Net Zero Energy Emissions:** Net zero emissions generate at least as much renewable energy without emissions that it uses as it uses emissions

Finally, the authors conclude in the paper: "***For researchers, fundings, designers and evaluators, consistent ZEB definitions are necessary.***"

In various publications "*The Potential impact of Zero Energy Homes*," 2006, Torcellini et al (2006), "*Centerline*" (2008), Noguchi, (2008), Kilkis, (2007), Voss, (2008), the distinction between ZEB definitions made by Torcellini, et al. (2006) is discussable and applied.

However, review of the ZEB definitions, Kilkis (2007), refers to Torcellini and others (2006). *Kilkis* points out that the "zero" balancing should take account of the energy quantity and quality (exergy). Although the ZEB definition appears logical, "*explained Kilkis (2007)*", it is difficult to acknowledge the importance of exergy in evaluating the full environmental impacts of buildings. The building does not balance the exergy of heat it receives and provides, for instance, when the zero - electric energy plant is connected to the local energy system, receiving high temperatures and electricity and providing heat of the same quality at lower temperature and the same amount of electricity in the district. This ZEB continues to affect the environment as the negative exercise balance... If the district produces electricity in the heat and power plant and the ZEB produces electrical power in a micro-composite heat and power unit (*CHP*) and all have different environmental impacts and energies, or by the use of wind turbines.

The author therefore proposes for the ZEB a new definition, which defines the Net-Zero Energy Building as: "***A building that, for all electrical and other transfers in a certain period, has a total annual sum of zero exergy through the building-district border of a regional power system***".

At the same time, the two definitions for ZEB are differentiated between Mertz, et al. (2007), the net-zero energy building and a net-zero CO₂ (CO₂ - neutral) building. They are the result of limitation of resources and environmental impacts. *Mertz et al. (2007)* describes a Net Null Energy Home “... as a home that generates as much power as it consumes during the course of the year. The energy supply could be produced from a net zero home using photovoltaic panels, a wind turbine, or a biogas producer. This paper uses photovoltaic panels (PV) to compensate for electricity bought from the grid”. The issue of the different interpretations of the ZEB definition is discussed further in the International Energy Agency (IEA) report written by *Jens Laustsen* in 2008. The general definition of ZEB is *Laustsen (2008)*: “Zero Energy Buildings don't use fossil fuel but only obtain the required energy from energy from solar and other renewable sources.” Points by saying: “There is no precise definition of how to build or obtain an energy-saving building compared to the standards of the passive house. This may be a traditional building, supplied with very large solar photovoltaic and solar collectors systems in principle. It is a zero net power building if these systems provide more energy over a year than the use of the building”. Two definitions are mentioned in relation to the issue of what zero is *Laustsen, (2008)*, as well as *Mertz et al. (2007)*:

- **Zero Net Energy Buildings** are neutral buildings that provide as much energy for the grids as it uses from the grids for over a year. These buildings do not require any fossil fuel for heating, refrigeration, lighting or other energy applications, even if sometimes energy is obtained from the grid.
- **Zero Carbon Buildings** are buildings that use no carbon-dioxide-related energy over a year. These buildings are neutral or positive in terms of carbon emissions over the year in which they produce enough free carbon-power to supply energy. The buildings with zero carbon differs from the building with zero energy in the way they can use CO₂ - free electricity, like large windmills, nuclear power and solar photovoltaic systems which do not fit in the buildings or buildings construction site.

2.3. nZEB General Concept

Construction accounts for about 40% of the total energy consumption and 36% of European CO₂ emissions¹³. Reducing energy use and using renewable sources in the building industry in this way is crucial to reducing the energy dependency and greenhouse gas emissions. Outflow relief from structures is vital and up to 80% of the

¹³ <https://ec.europa.eu/energy/en/topics/energy-efficiency/buildings/nearly-zero-energy-buildings>

operating costs of the standard new structures can be spared regularly, without or at least at least minimal extra cost over the life of the measurement, through coordinated outline standards.

The importance of building zero energy is not new. They were published in the 1970, 1980 and 1990's in the bibliography¹⁴. However, world interests were subsequently shifted in 2000 in the ZEB project and many national and international programs for their study¹⁵ and implementation were developed. As a common strategy for all sectors since 1998 with the signing of Kyoto Protocol (EUROPA) and since then it acts in this direction to attain the individual objectives and commitments, the European Union has been importing and strengthening the concept of Energy Efficiency (Energy Efficiency, European Commission). The 27 member states specifically, set the energy saving target by 20% up to 2020, mainly through energy efficiency measures, and at the same time they have committed themselves to reducing greenhouse gas emissions by 80 ~ 95% by 2050.

The revised Energy Performance Directive of buildings (EPBD) was adopted in April by the European Commission, which requires almost zero energy building for all new buildings before 31 December 2020, meaning buildings almost with zero energy consumption, while new buildings occupied by or belonging to public authorities must meet the same criteria by 31 December 2018. In 2002 the EU Building Energy Policy Directive was adopted. It aims at improving buildings energy efficiencies, reducing emissions of carbon and reducing climate change impact.



Image 2 International Organization for Standardization

¹⁴ Esbensen and Korsgaard, *Performance of the energy house on Denmark*, Technical University of Denmark, 1977.

¹⁵ IEA SHC Task of 40/of ECBCS Annex 52 "Towards Net Zero Energy Solar Buildings", Strategic Research Centre on Zero Emission Building in Denmark, Research Centre on Zero Emission Building in Norway, Zero Carbon Hub in the United Kingdom etc.

The revision of Directive 2010/31/EU on energy efficiency was adopted on 19 May 2010. The new Directive proposes that buildings account for 40% of the EU's total energy consumption and that their energy consumption will increase as the sector expands.

The nZEB is relying on to take a leading role in energy - saving efforts as well as in reducing CO₂ emissions, which are the key energy objectives of Europe's approach. This will only be practicable if the structures are upgraded with a finished, strict and appropriate approach that is relevant to all countries information and results.

2.4. Current Situation in Europe

The EU speaks to the world's largest single economic market, with a large population of about 500 million people, to the largest per capita GDP, over 27 Member States. The EU is also a significant climate variation - from the cooler Nordic states and the mild sea coasts in the west to the hotter southern Mediterranean climate and the drier, easterly mainland climate. These climatic characteristics lead to a fundamentally unique energy need in buildings where Scandinavian and Eastern European countries tend to spend more heating days and hotter Mediterranean districts are gradually developing demand for space cooling. A high percentage of old wasteful structures in areas where there is a remarkable space heating requirement in the EU are represented in the construction sector. Thus, the vast majority of energy consumption in buildings across the EU is used for heating, and increased building envelopes and heating systems are the greatest potential for energy savings.

Most Europe buildings have not yet been upgraded to boost energy efficiency, and there is therefore an impressive investment fund potential. As is described in the directive, the almost zero energy building is designed to require little energy. In general, renewable energy generated in or adjacent to the small residual interest will be met. In the light of current circumstances, this definition organizes energy efficiency. Renewable energy sources in each area are not unrestricted and are not attainable to the same degree. The area of access to controlled systems based on wind or sunlight is normally very restricted, especially in urban areas. Biomass energy is in some cases only a sensible and cost-effective solution, too. If too many constructions use wood pellets for heating, then the required crude material is not sufficiently capable of redeveloping.

Much research has been done around the world in nearly Zero Energy Buildings. To complete energy savings, identical to zero or nearly zero energy consumption, the scientists were asked to study all the individual parameters in design, construction processes and technology installation of systems affecting energy performance of buildings. Zero Energy Building is a new concept for high - performance buildings, aiming to generate as much energy as it uses during a year.

Nevertheless, the European Directive¹⁶ almost defines zero energy buildings as buildings with a very high energy efficiency, determined by the energy efficiency measurement methodology of buildings and whose energy needs are largely covered by energy from renewable energy sources, including those produced on site or nearby. These buildings never cease to produce greenhouse gasses, however, since the use of electrical transmission grid or other conventional energy supplies to meet the needs of solar energies (i.e. on a cloudy day or on short winter days or during the night) or wind (for instance, likely to generate installed wind).

Buildings that deliver more energy than those which consume over a year's time, are called "*positive energy*", while those that spend less are called "*nearly-zero energy consumption*".

Since the most recent directives for European energy efficiency directives and plans for buildings are addressed by almost zero energy buildings and also the existing housing stock, scientific investigation is directed towards this aim. **This article will examine the improvement of energy in nearly zero-energy buildings (nZEB) in Greece in this direction.**

Low-energy structures typically include abnormal insulation state, extremely powerful windows, abnormal air snugness and normal / mechanical ventilation with exceptionally effective heat recovery to minimize heat and cooling requirements. The configuration of passive solar construction can contribute to abnormal its energy by facilitating solar heating work in winter and rejecting sun-focused warmth in summer and coordinating the sun-focused innovation (e. g. solar hot water and space heating collection systems, photovoltaic panels). In addition, other energy-saving measures, e.g.

¹⁶ DIRECTIVE 2010/31 / EU

at the location of a wind turbine to generate power or rainwater systems, can also be used. The majority of the Member States today does not have a definition of low and zero energy buildings that are perceived authoritative.

Renewable energy and resource efficiency are to be the foundation of sustainable European society and economy. This implies the large-scale use of almost zero-energy buildings (nZEBs) for the building industry. However, the large-scale uptake of NZEB construction and renovation remains a challenge for all players in the market. A considerable gap in reliable statistics on current market activities made evaluating the success of policymakers difficult.

3. nZEB Design

In order to be successfully planned, all possible designing and constructional meters that will diminish the energy demand should first be applied. To this extent, it will be assumed that the most case-based appropriate systems of Renewable Energy Sources (RES) that will cover to a significant degree the rest needs will be applied. During the whole planning procedure, we should keep in mind that the end goal should fulfill the prerequisites and the technical parameters defined in Regulatory Administrative Act 366/2014, as well as to draw buildings that will correspond to the needs of their users for more qualitative conditions of life, as summarized further in this paper.

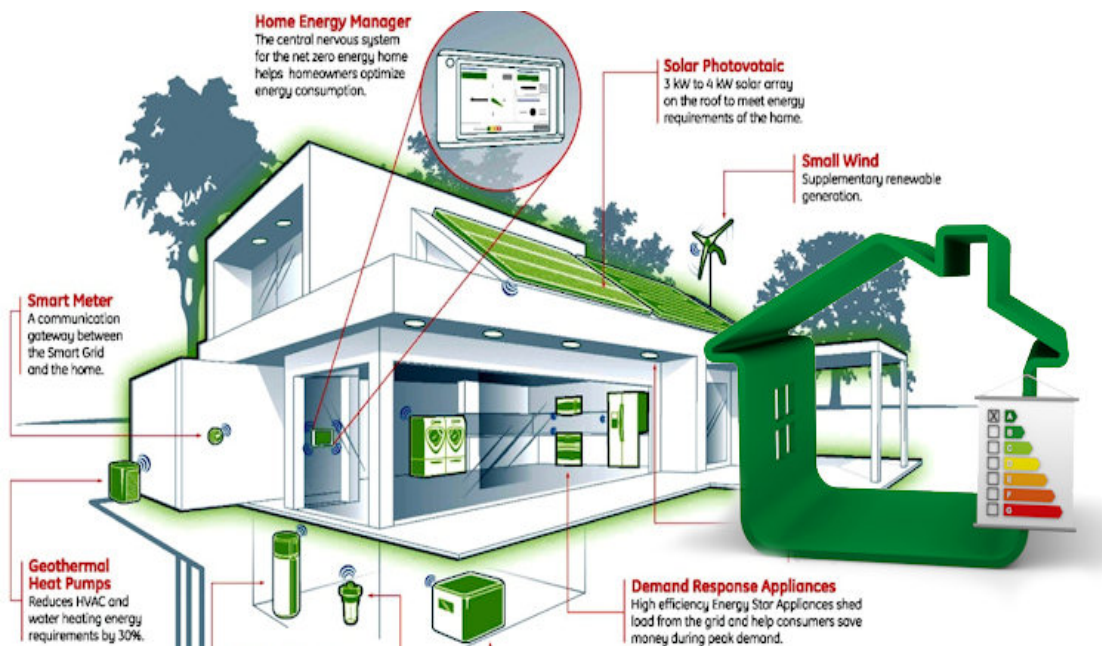


Image 3 Energy Efficient Houses

3.1. Designing an nZEB

1st Stage of Planning: Reduction of energy demand for heating, cooling and lighting

In an nZEB each possible effort will be assumed so that the states of thermal comfort are satisfied with the less possible use of heating and cooling systems. In order to achieve this, it is required that the nutshell of building is fabricated in a way that the losses

would be limited to the exterior environment and at the same time that an architectural plan would permit the user of the building to exploit the local conditions regarding breeze, heating, protection from the sun and natural lighting. What is more specifically recommended is stated below:

- Analysis of local conditions, such as the sun, the wind and the orientation.
- Improvement of geometry, form and arrangement of spaces in the building based on the analysis of local conditions.
- Sufficient heat insulation.
- Installation of frames along with systems of shading that will diminish thermal losses and will allow the exploitation of solar radiation to ensure heating and/or natural lighting, where considered necessary, and avoid the possibility of overheating.
- Adequate waterproof of building for evasion of heat loss through the air that enters from the frames or other elements of the nutshell.

2nd Stage of Designing: Technical systems of building of high energy output

Following the construction stage and the process of restricting to a great degree the energy demand for the building, it is supposed that we choose the suitable technical systems, where need be, in order to cover the needs in heating, air conditioning, domestic hot water (DHW), lighting and ventilation. The following is therefore recommended:

- **Air conditioning and heating:** In a building, where energy consumption is almost zero, the needs for air conditioning and heating will also be very limited. This is why the right dimensioning of the technical systems ought to be specifically taken into consideration. The planning of heating and air conditioning system should lead to the biggest possible total energy attribution of the system; this is to be achieved when choosing the most efficient parts or components of the system, i.e. pumps of high output in heaters and boilers, application of optimal meters of energy saving, such as the heat insulation of piping used for the distribution of heating, and optimal provision of system.
- **Domestic hot water (DHW):** The needs for domestic hot water depend exclusively on the lifestyle of the users of the building. In any case, the energy

required can diminish extensively with the correct decision and the choice of the suitable system of production of domestic hot water. Solar thermal used generally in houses, provided that they are installed in the correct orientation and bent, can deliver the greatest possible amount of boiling water. In addition, existing technologies, during the conversion of solar energy into electrical energy, keep up with the losses for the production of hot water. In addition, domestic hot water can be further produced from the rejected energy coming from other thermal activities, i.e. heating or aeration and cooling, that can occur in the building. As in the systems of air conditioning and heating, it is crucial at the designing to have corrected dimensioning and to be achieved the better possible total energy attribution of system of production of domestic hot water.

- **Lighting:** Lighting can prove to be a large part of energy consumption for specific sorts of buildings such as offices. Its confinement is possible to be achieved through a lighting system planning taking into consideration the operation of the building, the contribution of common lighting and the requirements of its users. When all the information is assessed and evaluated, then the required compel of lighting can be installed in every space. The use of automatisms can save energy in general though, therefore it is very important these applications to take into account the way the building is used.

3rd Stage of Planning: Cover of energy that is required in a great amount from RES

Almost null consumption is required for RES systems to be installed in a building, to produce thus the entire or a large part of a relatively small quantity of energy needed for the building. With a technical, economical and environmental data base, it will be assumed that the chosen RES system will cover a part of the energy needed for heating, aerating and cooling, domestic hot water, electricity or their combination. Given that it is technically possible, systems giving renewable energy in the time period required are more appropriate since they result in the energy autonomy of building, which means that the amount of energy created for the needs of the building is apparently the most important technical criterion when deciding upon the most appropriate RES system. Energy auto-production in an nZEB is a prerequisite to the greatest based on the events given by the market of electricity and the relation of cost-profit in a building's circle of life. Nevertheless, in any case, technical restrictions that concern every building separately, for instance the absence of available space, as well as more general

regulating restrictions, such as urban rules and the arrangements of support of RES, it should be seriously taken into consideration.

3.2. Designing Parameters

In general terms a Zero Energy Building (ZEB), or Net-Zero Energy Building (NZEB), uses all cost-effective measures to reduce energy usage through energy efficiency and includes renewable energy systems that produce enough energy to meet remaining energy needs¹⁷. The wording “*Net*” emphasizes the energy exchange between the grid connected building and the energy infrastructure¹⁸. In fact, most zero net energy buildings get part of their energy from the grid and return the same amount during the year, when their production of renewable energy is higher than the demand. Conversely, according to the EU Directive of 2010 (EPBD), *a near Zero Energy Building (nZEB) still requires a small amount of energy on a yearly basis*¹⁹. In the last years many definitions of NZEBs were given, depending on how and where this renewable energy is produced. The same acronym is often used for the similar concept of zero emissions buildings, which is slightly different. Regardless these definitions, the efficiency required to achieve zero or near-zero energy goals leads essentially to two different actions:

- reducing energy demand by means of energy efficiency measures and passive energy use,
- and generating energy from renewable sources.

There are several strategies when designing to make energy efficiency increase, including air tightness to avoid infiltration and mechanical ventilation systems with heat recovery to provide air conditioning and indoor air quality (IAQ). The designed energy balance of a ZEB can however be invalidated with an improper use of technologies by occupants, such as opening windows, changing the operative temperature or not providing the right maintenance of systems²⁰. Natural ventilation systems generally contrast with the principle of mechanical control of indoor environment²¹. The mechanical control of thermal comfort, rather emphasized in *ZEBs*, aims to reduce the interaction of users with the outdoor environment, which in turn clashes with the principles of psychological comfort. Moreover, the monitoring of ultra-low energy

¹⁷ US Department of Energy. *A Common Definition for Zero Energy Building*. September 2015. p. 1.

¹⁸ Pless S, Torcellini P. *Net-Zero Energy Buildings: A Classification System Based on Renewable Energy Supply Options*. NREL TP-550-44586; 2010.

¹⁹ Directive 2010/31/EU of the European Parliament and the Council of 19 May 2010 on the energy performance of buildings (EPBD); 2010.

²⁰ Liddament M.V. *Occupant Impact on Ventilation. AIVC Technical Report 53*. INIVE EEIG, Sint-Stevens-Woluwe (Bruxelles); 2001.

²¹ ASHRAE, 2016 *ASHRAE Handbook – HVAC Systems and Equipments*. Atlanta; 2016.

buildings in Italy has revealed that occupants rarely use mechanical systems properly and the energy consumption often exceeds the expected results. Thermal comfort²² is defined as that condition of mind which expresses satisfaction with the thermal environment and depends on physiological and psychological aspects. The former have been widely investigated by *Fanger* and other scholars, the latter seem to be neglected, at least in the current design. **Psychological aspects of comfort involve the interaction of occupants with the environment and vary with latitude, cultural and social factors.** Adaptive thermal models, essentially valid for free running buildings, are based on the assumption by Humphreys and Nicol: *'if a change occurs such as to produce discomfort, people react in ways which tend to restore their comfort'*²³. These models are entirely focused on psychological aspects and allow wider tolerances of indoor thermal comfort conditions than the physiological-only ones.

The entire effort for reduced energy demand is something that commences at the planning of a building, while the total consumption of primary energy is affected by the shape, geometry, orientation and the arrangement of internal spaces. These parameters to be chosen, when taking into consideration only the practical and aesthetic needs of users along with householders of buildings, can lead to the need of additional meters to applied having as end goal the accomplishment of the nZEB, making in this way the initial cost go higher. The reduction of energy consumption via planning in existing structures renovated and turned into nZEB is limited, it is recommended though, as the biggest possible exploitation of this factor is achieved, for example with the opening of new frames and with the suppression of the existing ones.

3.2.1. Climate and Microclimate

The arrangement of a building and its spaces when considering the microclimate and its relation to the neighboring buildings increases the exploitation of natural airing during summertime, of solar energy in winter and the natural fulfillment of needs for lighting. A significant factor for the reduction of energy demand in the buildings is their designing and construction in a way to correspond to the climatic conditions of the surrounding area. The climatic conditions range based on the geographic region and locality and as a consequence they should be vastly taken into account in order the needs of tenants of

²² ANSI/ASHRAE Standard 55-2013. *Thermal Environmental Conditions for Human Occupancy*.

²³ Humphrey MA, Nicol JF. *Understanding the Adaptive Approach to Thermal Comfort*. ASHRAE Transactions 104 (1); 1998. p. 991-1004.

building for breeze in summertime, warmth in winter and natural lighting to be covered. The climate is described by the atmospheric variables, known as climatic parameters. These parameters include humidity, temperature, coverage of clouds, raindrops (rain, snow etc.), solar radiation and wind. Below are various maps of Greece, interrelated with energy and different temperatures.

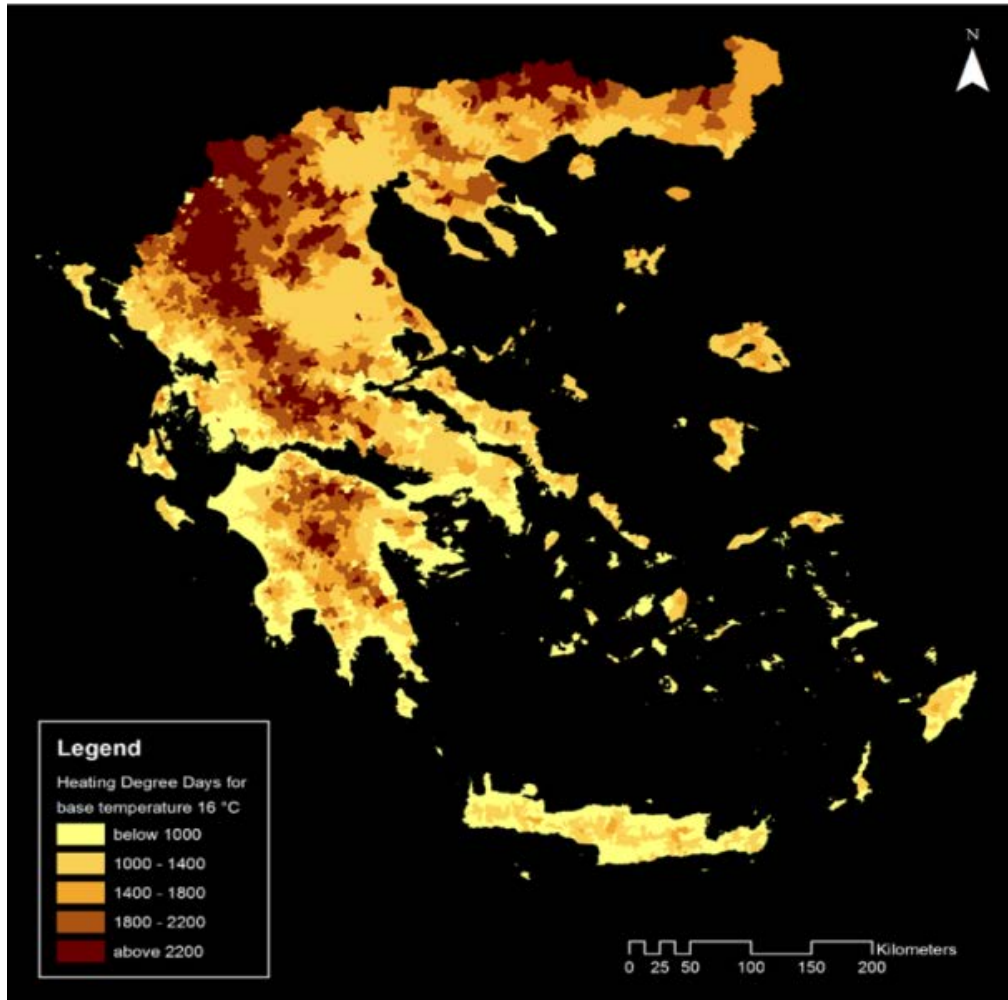


Image 4 Heating degree – days (°C*days) for base temperature 16°C in Greece.

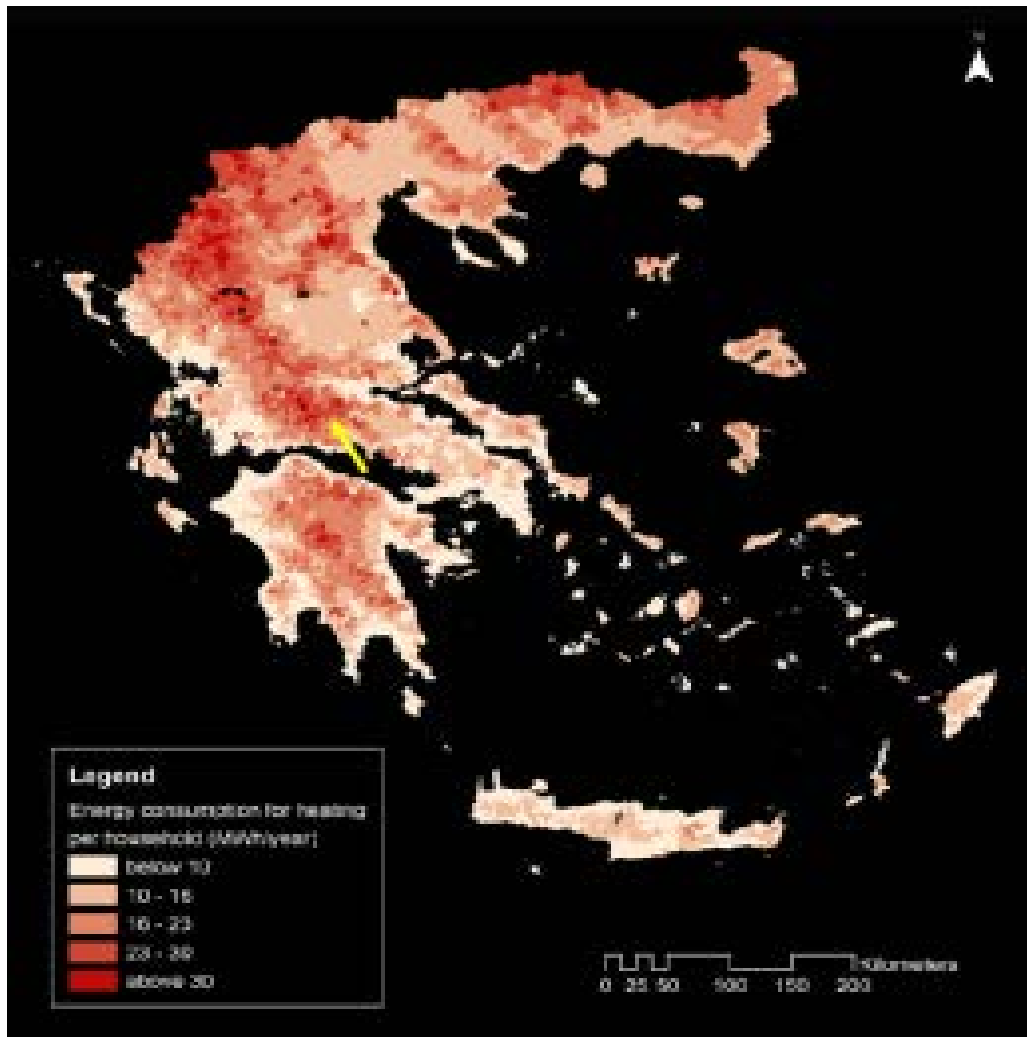


Image 5 Annual thermal energy consumption in MWh household, in Greece.

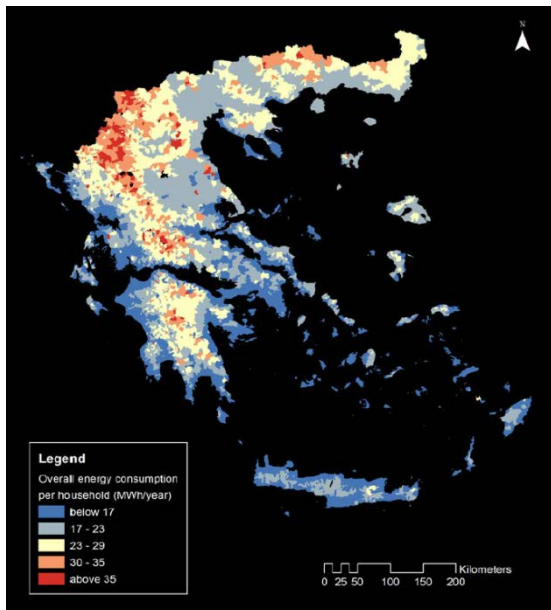


Image 7 Total annual energy consumption in MWh household, in Greece.

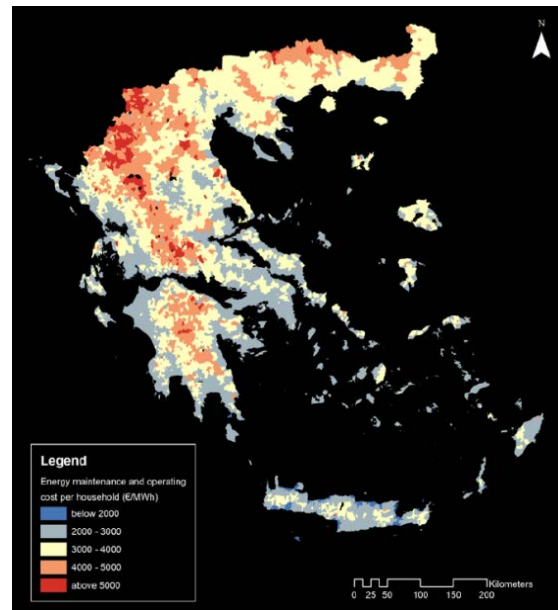


Image 6 Total annual energy costs per household in Greece.

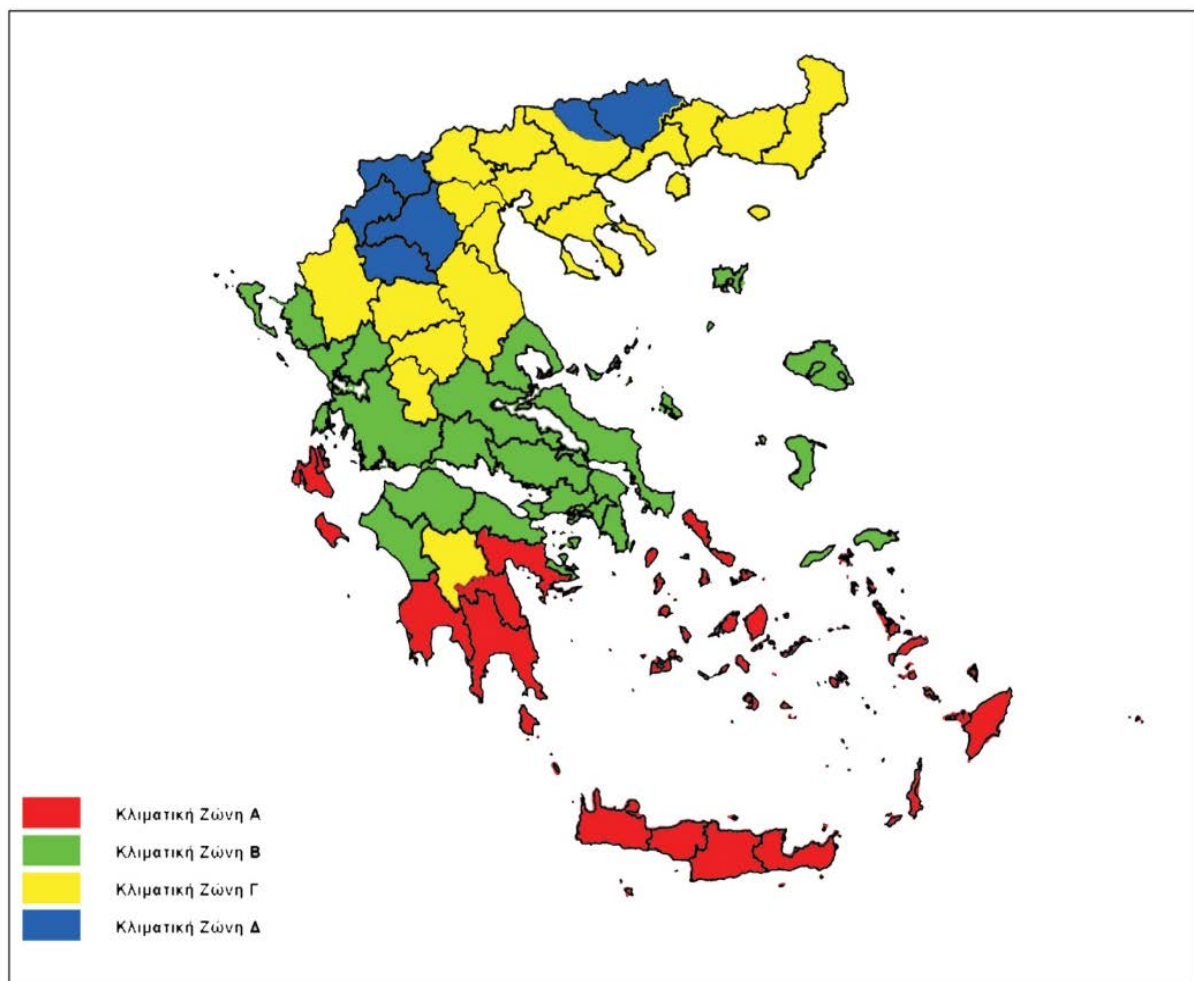


Image 8 Zones in Greece for Calculating the Energy Efficiency of Buildings²⁴

These meteorological areas form essential data for the evaluation of energy output of a building and will be used, as a result, to achieve conformity with the most allowed energy consumption as determined in FEK (Government Gazette) 407-B-2010 - KENAK. In real conditions, however, the configuration of the climate in a region is interrelated to the fluctuations of many climatic factors, such as the temperature of air and the surface of soil, the direction of airy masses, the intensity of solar radiation, the cloud, the rain, the ionization of atmosphere, the relative and absolute humidity etc. In order to characterize the climate of a region, other local factors, such as the altitude, its geographic width, the place concerning existing aquatic masses and the morphology of ground are to play a significant role.

The morphology of the soil and the bas-relief of a region can decrease, modify or intensify the alteration of numerous climatic variables, such as the radiation based on the power of the sun, the temperature of air and soil surface, the direction of breezy

²⁴ ΦΕΚ 407-B-2010 - KENAK.

masses, the relative and absolute humidity, the clouds the rain etc. in various ways.

More specifically:

- The more the altitude increases, the more extreme the phenomena turn out to be and the more abrupt the variances in temperature and humidity often are.
- If the bas-relief of region is level, similar conditions will prevail in the whole under review region.
- When an inclining surface faces the South, there is better insulation, while when it faces the North, shading is empowered.
- Inclining surfaces and recessions in the bas-relief lead to different levels of temperature and movement of air in various points of region.
- Cold air tends to be concentrated in the recessions embossed; as a consequence, air temperature is lower in such regions.
- Moreover, the speed of air increases in airy side of an inclining bas-relief. The speed of air reaches the highest point in the tops-edges and becomes negligible in the side of the inclining bas-relief that is not extremely windy.
- The stocking of water in a subsidence of the bas-help conceivably prompts to the formation of aquatic mass, which can increase the levels of humidity and/or decrease air temperature.

Water demonstrates a relatively high latent heat of evaporation and special heat. Compared to most surfaces on earth, aquatic masses present thus slight change in the temperature of their surface during the day, while they release relatively big quantities of heat in the environment during the night.

In addition, due to evaporation aquatic surfaces allow refrigeration and create cooler conditions in the surrounding area during the day. The acceleration of air in the aquatic surfaces increases the rhythm of evaporation and the percentages of the humidity produced in the region where the aquatic mass exists.

Creating the proper microclimate around the building can blunt climate's unfavorable characteristics and exploit those ones contributing to the reduction of energy consumption in the building. If, however, the proposed interventions are not suitable, they can cause the opposite result. In addition, better results can be achieved if the microclimate is to be regionally shaped, that is in terms of settlement (urban or rural

region), neighborhood, cluster of buildings, street or space between the buildings or in the same building.

3.2.2. Methods of Improvement of Microclimate

Microclimate can improve and saving of energy in the environment can be achieved as follows:

- **Creation of intermediary spaces** (more equitable exploitation of overdraft, creation of patio). The amount of natural light that reaches the spaces developed around the patio depends mainly on patio's geometry, light penetrability to patio's roof, lateral walls' reflectivity and patio's flooring.
- **Suitable planting** (or even planting of loft) **for sufficient shading**, insolation, protection from the wind, increase of internal profits.
- **Creation of systems of suspension of plants** (e.g. pergolas) and systems of water.
- **Use of materials friendly to the environment**, with certification ensuring that no harmful elements are contained (as austenitic steel, raw clay, lime, glue from caoutchouc). (Moffat and Schiller, 1981)

It is possible that the suitable configuration of vegetation faces high temperatures in summertime, permits adequate insolation in winter and naturally directs the winds with the desirable vegetation. Simultaneously, it protects from the erosion of adjacent soil, it helps in the reduction of noise pollution and generally improves the quality of air. Even trees without leafage²⁵ prevent by 40-80% the infiltration of solar radiation.

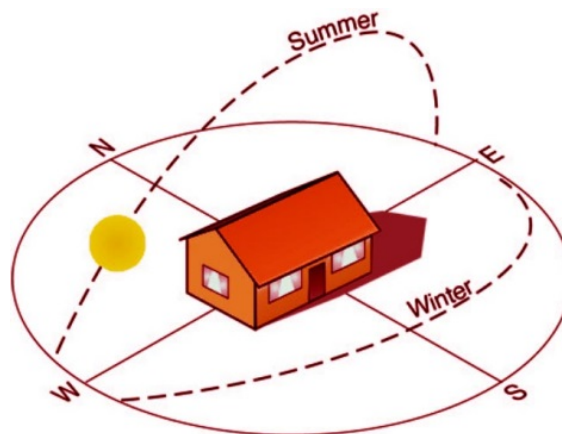


Image 9 Building Orientation

²⁵ Characteristically, a large-scale tree evaporates about 1460 kg of water during the day and thus makes a crucial contribution to the overall breeze.

3.2.3. Morphology of buildings

Those morphological parameters of a building with the most important effective demand of energy are **the degree of report of the nutshell, the size of openings and the choice of loft or roof**²⁶. The degree of report of the nutshell is the ratio of the area of the totally exposed surface to the area of flooring. When the degree of report of nutshell is low, a reduction of thermal losses and thermal profits is achieved. In order to make buildings have decreased ratio of nutshell is recommended:

- In two-storey detached houses the exposed surface of walls to the surface of flooring to range from 2.5 until 3.
- In detached houses on the ground level the exposed surface of walls to the surface of flooring to not exceed 1.

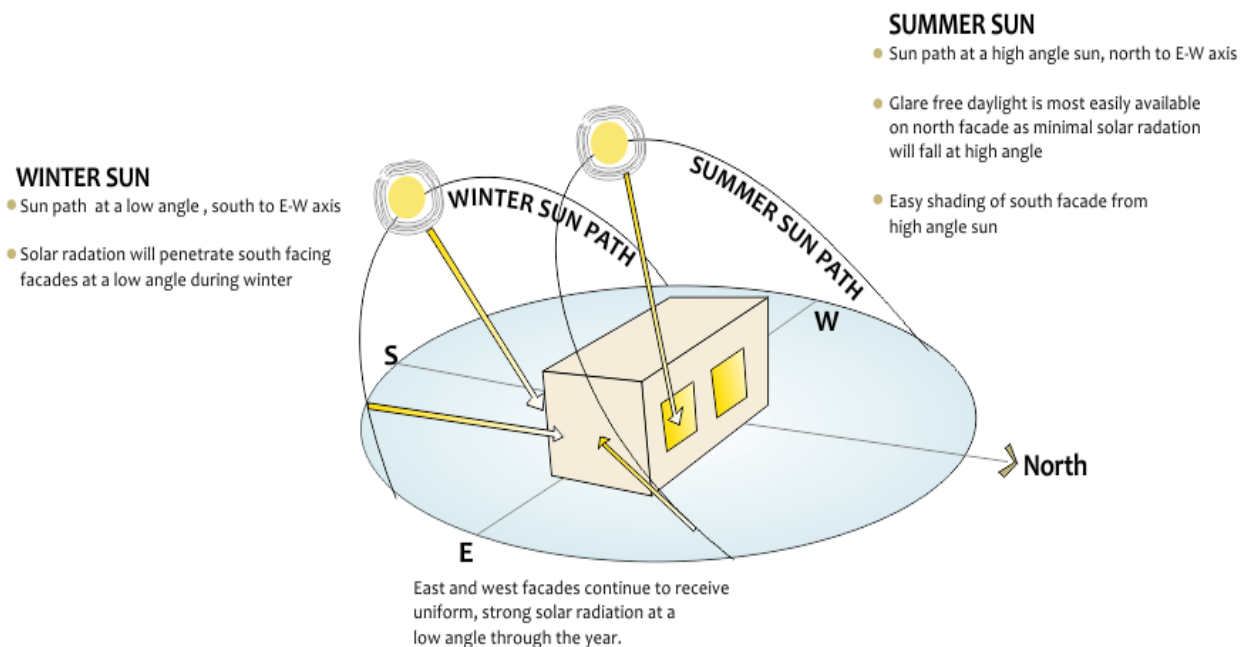


Image 10 Building Orientation

²⁶ The building as natural solar collector in winter:

The southern direction guarantees the larger facet of the building, with differences of +30 percent in the east or west direction. In the event that orientation is not guaranteed (which is regarded as ideal), an adequate creation of nutshell ledges with fundamental southern axis is recommended. With a more constant rhythm and improved distribution, the South side of buildings accepts direct solar radiation in a larger percentage. The building insulation parameter is measured by the use of solar diagrams. In winter, the control of insolation bases on the following relationship: the distance of the structure that lies and the obstacle existing= 1,5x height of the obstacle. An existing manufacture or building may be an obstacle. The east and west are the most unfavorable directions in terms of natural light. The low sun position in the orientation east and west creates intense blindness problems. (Christian Democrats, S.K., 2010)

3.2.4. Size and Orientation of Openings

The frames can actually present important designing challenges while, apart from thermal losses, they get solar radiation, which decreases the demand of energy for heating in winter but, at the same time, increases the demand of energy for air conditioning in summertime. Thus, the size and the point to be placed affect the demand of energy for air conditioning and heating. The size of openings as the ratio of the area of openings to the area of the facets of the building should be defined in such a way that the total charges of heating and cooling have the smallest possible rate.

A more effective approach is to define the size of the openings based on the orientation. For buildings aimed for residences it is recommended:

- Big openings in the **South** for insolation of the internal spaces in winter, allocating however suitable shading, preventing direct solar radiation in the spaces, during summertime.
- Average openings in the **East and West**, since the insolation of internal spaces in these sides lasts for a few hours. Having so much impact on the cost of cooling, the openings in the Eastern and mainly in the Western side should be thus properly shaded.
- Relatively small openings in the **North** even if the intensity of light is constant, as there are no solar profits for the internal spaces; therefore, the north openings are considered mainly for the losses of heat.
- Openings of mediocre to big size in **Southern-eastern and Southern-western** side depending on the hours of use of the internal space.

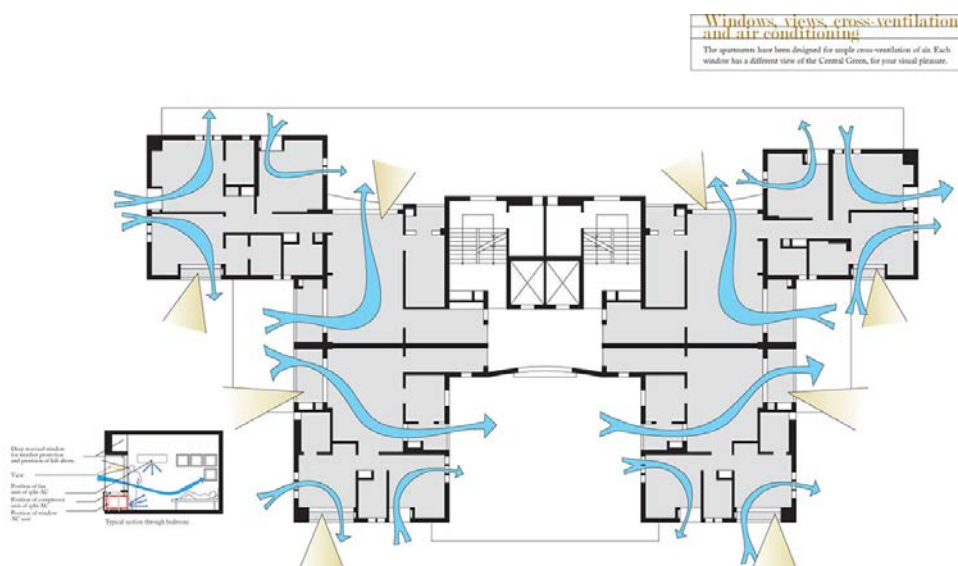


Image 11 Windows views, cross-ventilation and air conditioning

Moreover, the orientation and the size of frames concerning the profile of the wind can increase or decrease the natural airing, since the selection of frames that open inwards, outwards or slide influence the quantity of air entering the interior of the building. In order to guarantee a good distribution of air flow in the interior of the building, the direction of wind while entering and exiting should not be the same; if the flow of the air happens in a straight line, then it just passes in the room without big circulation and good ventilation. Strategically, the frames should be placed in a way that the air is coordinated. Not only does natural airing contribute to the reduction of demand of energy in air conditioning, but also has an important role to the improvement of the feeling of comfort of the people living in, since it reinforces the inflow of fresh air in the building.

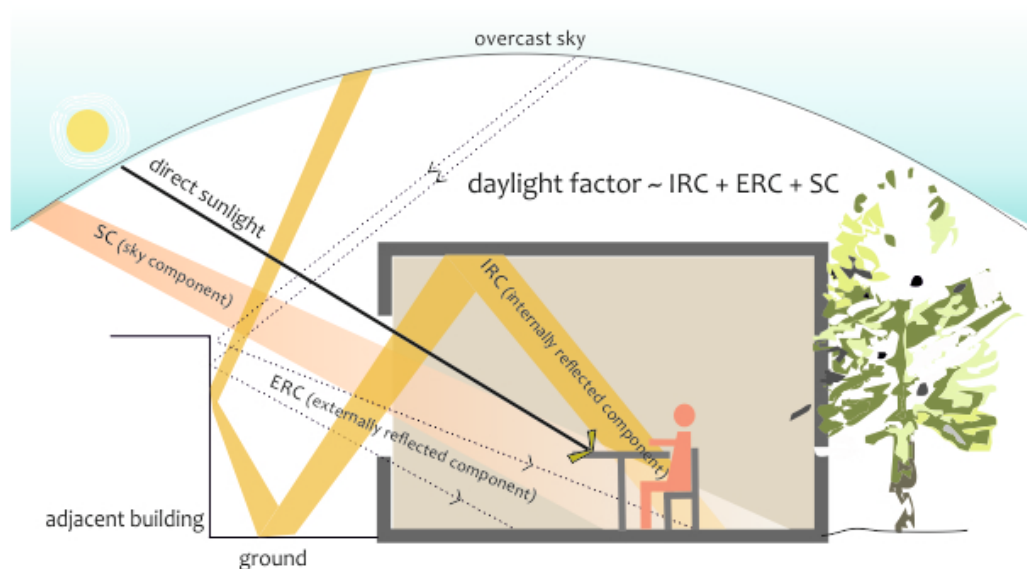


Image 12 Exploiting Sunlight in Buildings

A widely propagated way of reducing the demand for cooling in summertime is the exploitation of the colder air during night hours by opening the windows, freezing thus the thermal mass of the nutshell of the building at night. However, all the proportional openings allowing the biggest possible exploitation of this factor from the user should exist in the planning without disregarding the matters of safety of the building.

Cantilevers (sheds, such as a balcony) and walls, as well as the building itself, when shading the frames, affect the demand of energy for air conditioning and heating. Although these structural elements exist to serve the functional or aesthetic needs of the

building, their adaptation, if feasible, must depend on the orientation and the size of the frame that they shade, in order to contribute to the reduction of demand for energy. For instance, cantilevers in the south that are in the height of the sun parlor allow the insolation of the internal space in winter and provide satisfactory shading in summertime, while it is likely that cantilevers in the north have no impact on the energy output of the building.

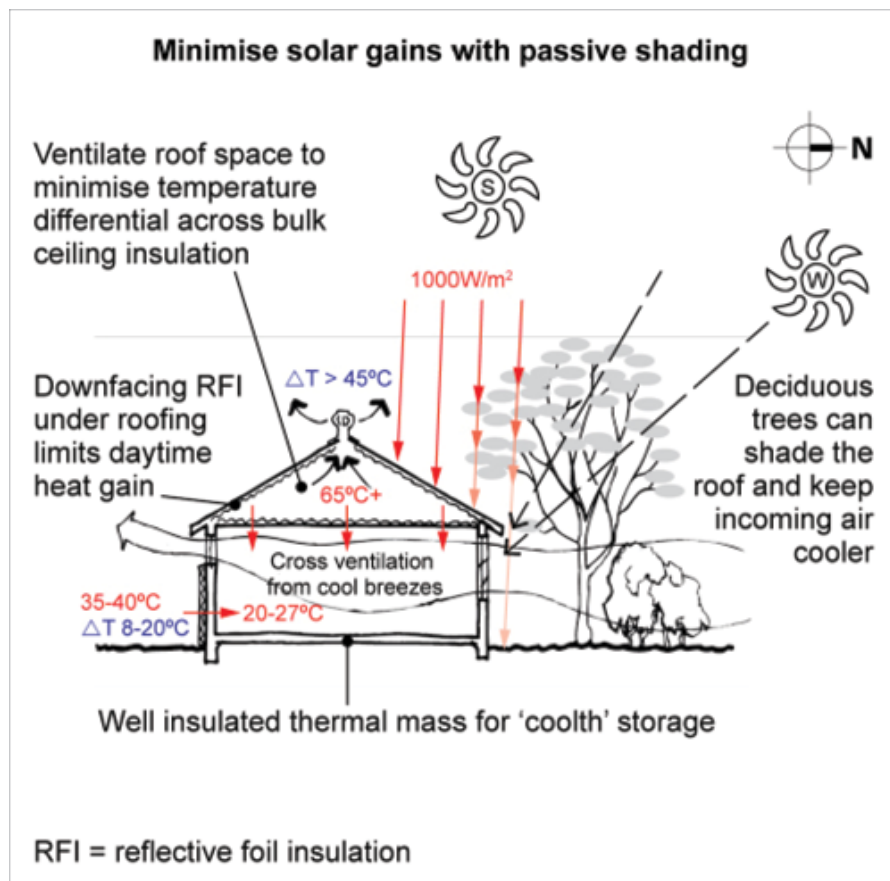


Image 13 Building Orientation and Shading for Solar Exploitation

3.2.5. Fitting and Planning of Spaces

The energy output is achieved when the comfort of the users in a space is maintained with the minimum possible dependence on technical systems. The needs of the users of a building for comfort are mainly fulfilled when they are adapted based on the internal conditions.

In the southern side of a building, getting the thermal profits from the sun, the winter is more pleasant, more luminous, giving at the same time the possibility of passive solar systems to be integrated. Spaces that are intended for longer use and for many hours a

day are recommended to be placed in this side, considering however the necessary factors of solar protection for evasion of overheat in summertime. For example, these spaces in a house include basically the lounge, while in a hotel they include the reception.

The north side of a building in the winter is much colder and less luminous due to the small quantity of sun light it gets. For this reason, spaces that are to be used for few hours or not air-conditioned are recommended for the north side, for example stairwells, stocking spaces and the space of quartering cars. This creates an area of interception of thermal losses from the main spaces and the spaces of intensive use, while simultaneously protecting them from the cold winter winds. At the same time, it should be mentioned how important northern openings are for the nightly airing of a building in summertime.

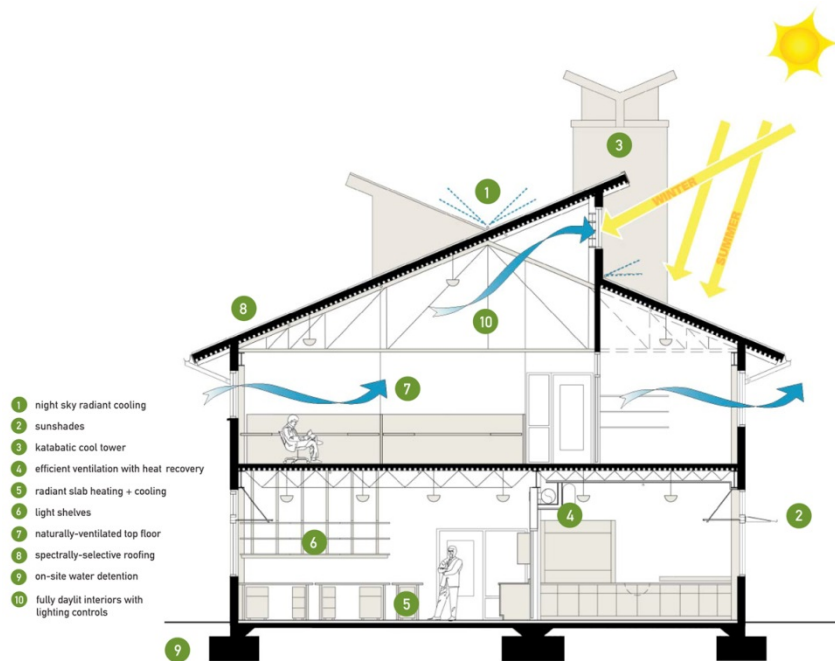


Image 14 Sustainable House Model

3.3. Structural Elements

The selection of the suitable structural elements of the nutshell of the building is a crucial factor in nZEB. The maximum average factors of thermal transmittance for nZEB are determined in the FEK 89 – 19 May 2008²⁷, however the decision on what the

²⁷ The European Directives adopted by the European Commission on Energy Efficiency are:

- **Directive 2002/91:** Energy Performance of Buildings (3661/2008 – 3851/2010 – KENAK/2010).
- **Directive 2006/32/EC:** Energy End-Use and Services (3855/2010 – 2011/ESCOs).
- **Directive 2010/31/EC:** Energy Performance of Buildings (recast of Directive 2002/91/EC – 4122/2013).
- **Directive 2012/27/EC:** Energy Efficiency (4342/2015).

maximum acceptable limits are or how much lower than these they should be is based on the optimization of the cost-profit relation. Furthermore, the effect of the structural elements on the energy output of the building in among other factors the same important in nZEB as their thermal transmittance and their exposure in the solar radiation.

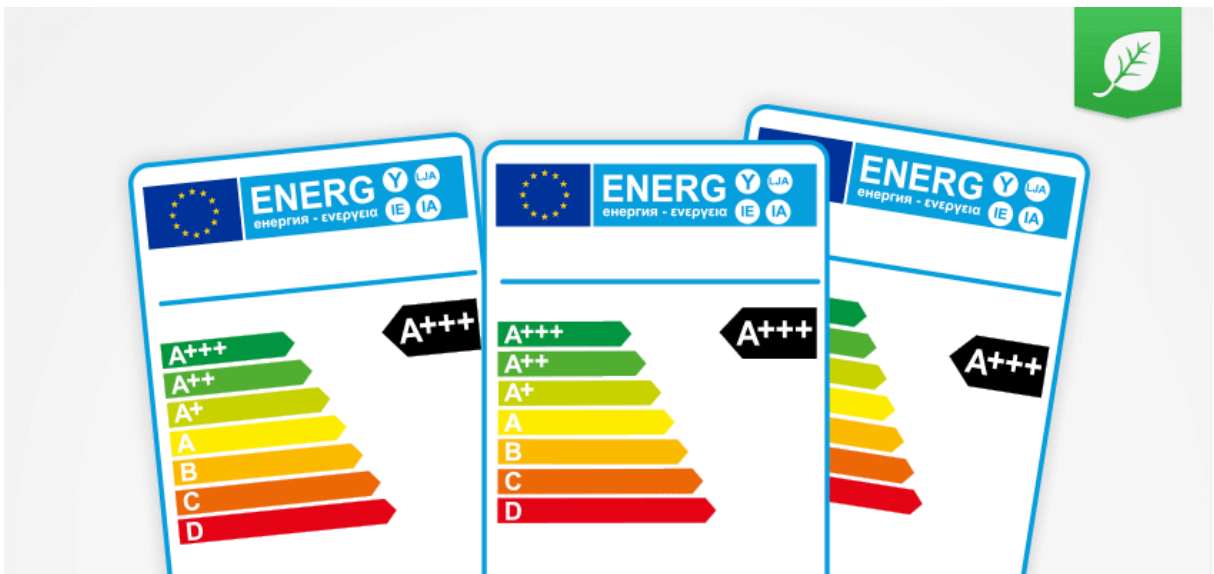
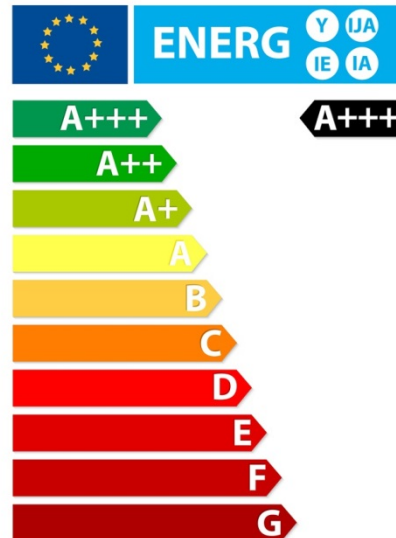
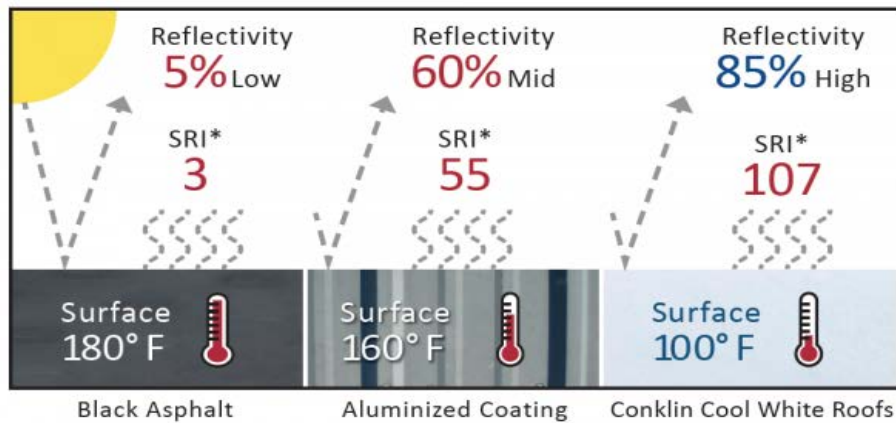


Image 15 Energy Certificate

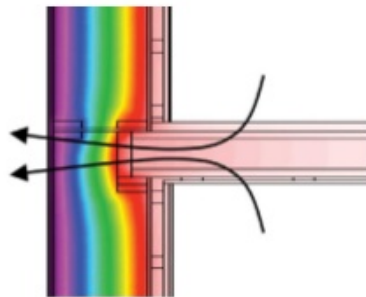
3.3.1. Thermal Insulation

Thermal insulation in walls and roofs reduces heat transfer between the inside and the outside and helps maintain indoor temperature, offering a healthier environment, sound control and, the most important, lower electricity bills. Insulation helps keep indoor space cooler in summer months and warm during winter.

There is a wide range of materials to choose from including fibre glass, mineral wool, rock wool, expanded or extruded polystyrene, cellulose, urethane or phenolic foam boards and cotton. They are generally in the form of amorphous wool or rigid sheets, or require in-situ pouring. Insulation is rated in terms of R-value; higher R-values denote better insulation and are translated into more energy savings, much needed to meet NZEB design goals.



nZEB | Construction



Thermal Bridges

Thermal bridging occurs in building envelopes where there are gaps or breaks in the insulation envelope creating pathways for heat loss.

Thermal bridging also occurs in building envelopes when materials with higher thermal conductivity (such as steel, timber and concrete) are used. These materials, if not properly detailed, will create pathways for heat to bypass the thermal insulation.

- Types of Thermal Bridges:
- Linear Thermal Bridges
 - Repeating Thermal Bridges
 - Non-Repeating Thermal Bridges
 - Geometrical Thermal Bridges

Heat always looks for the path of least resistance



Noel Hughes | 19th December 2017

Scott Tallon Walker Architects

Image 16 Thermal Insulation

3.3.1.1. General Concept of Insulation

Walls, roofs, foundations and floors represent the largest external area of most residential and services sub-sector buildings and where most heat losses occur. Proper insulation keeps out excess heat in hot weather, reduces heat loss in cold weather and helps maintain a comfortable indoor environment. There are many types of insulating

material and certain types are better suited to different applications. Decisions on specific applications are best taken at a local and regional level while taking into account a variety of factors, including fire and safety standards, material and labor costs.

Although the greatest energy savings are obtained from the initial installation of insulation, existing buildings in cold climates with no or very little insulation offer the greatest saving potential. Significant energy saving potential exists also in new constructions in developing countries where insulation is often not installed.

Higher levels of insulation, or the last marginal unit of insulation, have a reduced effect compared to the initial level of insulation installed. Insulation to the greatest level justified is a fundamental principle based on the life-cycle costs when constructing a building or when retrofitting an existing building. The marginal cost of installing additional insulation is generally low. If a minimal amount of insulation is installed, it may have an immediate efficiency improvement, but large savings will not be realized and future retrofits are unlikely to be cost effective. Higher levels of insulation²⁸ can be justified during new construction or deep renovation by considering full-system impacts that allow downsizing of mechanical equipment in accordance with life-cycle cost assessment.

3.3.1.2. Optimal Insulation Levels

The primary factors determining optimal levels of insulation are the climate, the energy cost, the heating system type and efficiency, and the installed insulation cost. Analysis is often conducted at a national or local level in order for recommended or required levels of insulation to be established in accordance with various building policies such as mandatory building codes. A European study was conducted and demonstrated optimal levels of insulation for various cities using specific climatic data and expected energy costs (ECOFYS, 2007). These results, along with recent building codes implemented in Germany, the coldest region of Canada, and for electrically heated homes in Sweden, are the key results of this study.

However, the values are not directly comparable because the climates vary significantly. For example, Sweden has three times the number of heating degree days on average than does Spain. This shows the complexity of deriving optimal levels of insulation and

²⁸ Kossecka, E. & Kosny, J., 2002.

implementing building codes. Put into perspective, uninsulated walls or roofs have U-values that may range from 3 W/m² K to 10 W/m² K. Insulated walls from the 1960s and 1970s in developed cold climates may be in the range of 0.5 W/m² K to 0.8 W/m² K.



Image 17 Wall Insulation

3.3.2. Walls

Most of the world's wall construction consists of a "stick built" framing structure (wood or metal studs) or a high thermal mass structure (stone, masonry or concrete). Framing structures allow for cavities to be filled with insulation but the structural parts are considered as thermal bridges or areas with significantly higher heat transfer properties. High thermal mass structures were often built without any insulation but benefit from their thermal mass. Older framed structures often did not have insulation in cavities²⁹.

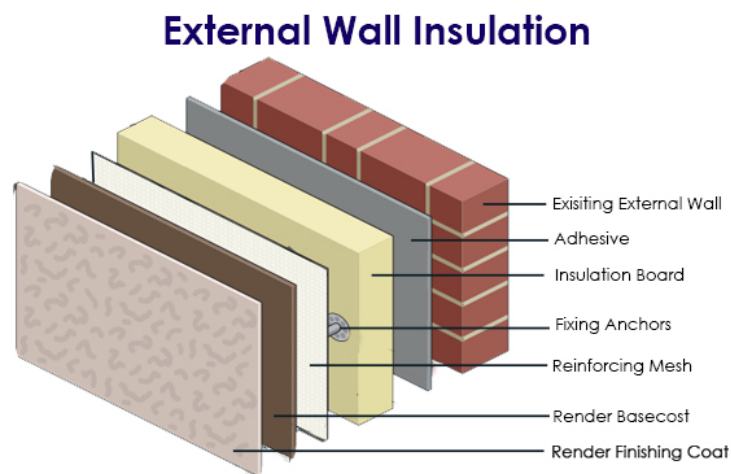


Image 18 Wall Insulation

²⁹ Apothesis, TEI of Crete, 2014.

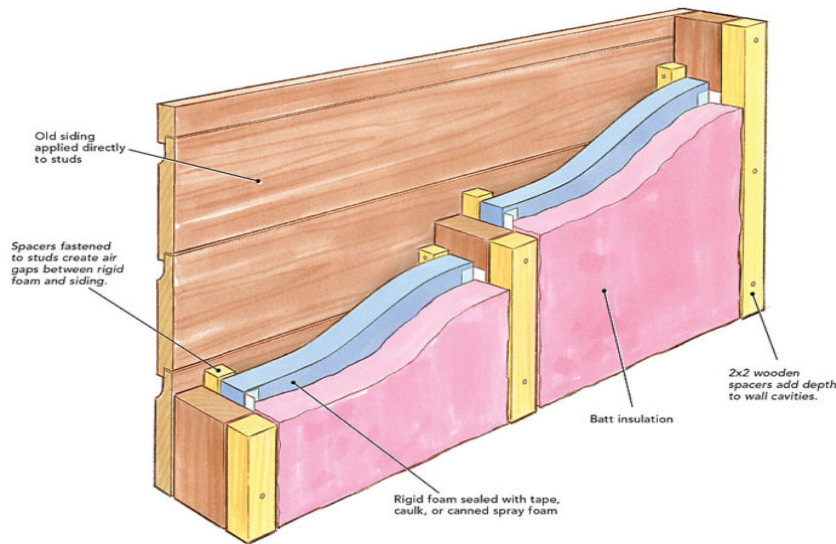


Image 19 Wall Insulation

3.3.2.1. Exterior Wall Insulation

In most developed countries, it is very common to insulate the walls resulting in general great outcome. Concerns are raised regarding the proper workmanship and not installing optimal levels of insulation, but for the most part, new buildings are far more thermally resistant to heat flow than the existing stock of buildings. Efforts are made for the increase of insulation levels, and the most effective approach to date is to add insulation that will be applied to the entire wall. Ideally we consider this as an added layer of exterior insulation applied to the structural sheathing but before the rain screen or cladding. Another common approach regarding the majority of recent buildings in Europe and on services sub-sector buildings in North America is to add EIFS, also called external thermal insulation composite system (ETICS), which embed insulation under a stucco or cementitious type of finish.

Exterior insulation produces effective results and can be applied to existing buildings. However, recladding of the building is required and is rarely cost effective with the exception of a major refurbishment or a full “deep” renovation, where other system benefits can be applied, such as significant reduction of the capacity of the space conditioning equipment. EIFS can be installed on old as well as modern buildings and can be found in mature markets. Significant efficiency improvement is achieved by the elimination of thermal bridges and the additional insulation to the entire wall. Other types of viable retrofits include blowing insulation into cavities that are not insulated. This can be achieved when insulation is like an air barrier. Extensive interior renovation

is required when interior insulation is added. Usually this is the only I only option when renovating historic, classified buildings.

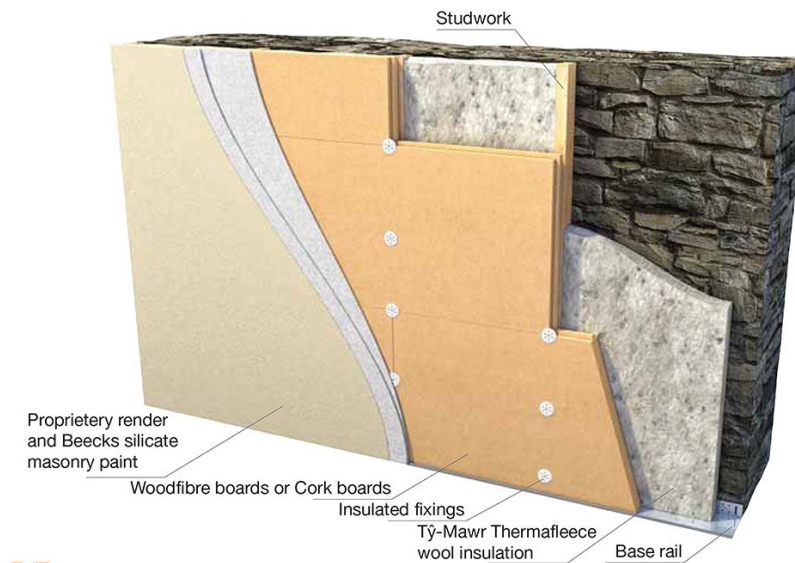


Image 20 Wall Insulation(EIFS)

3.3.2.2. Energy Efficiency Options

Over the last years other new approaches become popular regarding however a small number of the new walls constructed. One increasingly common approach is the use of SIPs, consisting of an insulating foam core (e.g. polyurethane or polystyrene) sandwiched between two structural facings, typically oriented strand board (OSB³⁰). Another new technique consists of ICFs, resulting in cast-in-place concrete walls that are sandwiched between two layers of insulation, such as polystyrene. The forms³¹ are interlocking modular units that are dry-stacked (without mortar) and filled with concrete on site.

Application procedures have been improved with the use of insulation materials in the case of retrofit options. For instance, it is more effective to install spray foam in wall cavities and therefore provide air sealing. It is also useful for difficult-to-access places, such as crawl spaces and certain attics. Installing insulation can be made more complex³² owing to concerns with air permeability and water vapor permeability. The

³⁰ These panels are manufactured in a factory and are assembled on site with the help of a crane, usually in a few days.

³¹ While these systems provide excellent performance and have the flexibility of adding varying levels of insulation to achieve the optimum for the location, they are usually limited to new construction.

³² It is very important not to create an environment that will have high relative humidity and result in the growth of mould. Researchers from Fraunhofer Institute of Building Physics (IBP), Holzkirchen, Germany and Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee, United States have developed a moisture design tool to help predict system performance and eliminate potential issues associated with building retrofits.

best time to retrofit walls is during major renovation when a full systems perspective can be applied.

It is of high importance to introduce enforceable building codes that require insulation in developing countries and updated codes that require higher levels of insulation in cold climate developed countries. In many Northern European countries higher insulation levels are required for new construction. However, the global savings offered that better insulation offers when it comes to new constructions are not exceptional, especially in places that already require fairly high levels of insulation for new construction (most OECD countries). Deep renovation in buildings with low or no insulation will lead to the greatest overall savings. While insulation is increasingly popular and common in developing countries and is often applied on building codes, much work is needed especially on enforcement. This might sound challenging, but the opportunity is great.

3.3.3. Roofs

There are two predominant roof geometries:

- pitched (sloped) roofs and
- flat roofs (or low-sloped roofs).

Most pitched roofs have an attic space allowing buffering of the thermal impacts of roofs and are used to install mechanical equipment in some countries. This could be considered as an obstacle, when the mechanical equipment is in unconditioned space that can be extremely hot in summer. Sloped roofs with cathedral ceilings (pitched roofs without attics that are open to the living space) are probably the biggest challenge for insulation, as the primary location for insulation is within the depth of the structural members. Pitched roofs are most common in locations with significant snow loads. Flat roofs are mostly used in large services sub-sector buildings and in many urban buildings around the world.

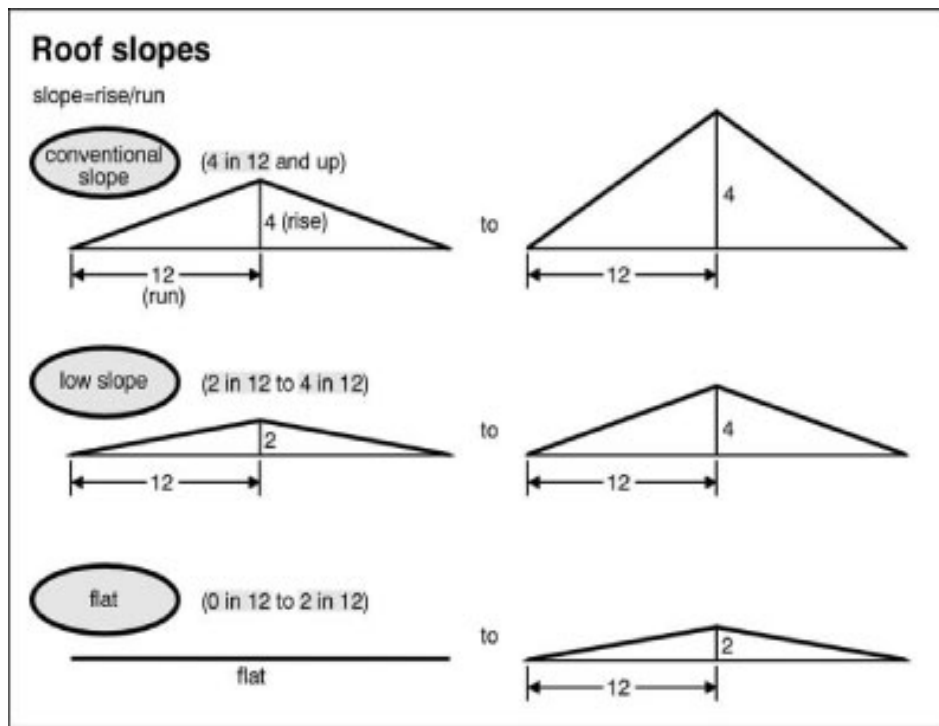


Image 21 Roof Slopes

3.3.3.1. Flat Roofs

The position of the thermal insulation divides flat roof constructions as either “cold” or “warm” roofs. Despite the fact that they are not recommended anymore, cold flat roofs were fairly common and remain so in some parts of the world. In such roofs, the thermal insulation is laid between the joists below the structural deck. The structural elements of a cold roof easily suffer the damaging effects of thermal movement and the insulation layer is more sensitive to moisture build-up. In a warm roof, the insulation is installed above the structural deck. Ventilation of the insulation layer is not required. This approach is very effective due to the fact that limitations on thermal performance are not determined by the roof structural and joist height. Optimal insulation thickness is determined predominantly on the basis of life-cycle cost effectiveness. For existing roofs, parapets (low surrounding walls) and access doors the thickness of insulation added can be limited, but generally most parts of the roof can be subject to additional insulation without major difficulty or excessive cost. Adding insulation to attics of pitched roofs is fairly common practice. Air leakage between the conditioned space of the building and attic can be of high importance due to the chimney effect, wiring, piping, chimney and attic access penetrations, and interfaces with partitioning walls. Proper insulation and air sealing of attics are crucial for both new construction and

retrofits. While some builders and insulation installers carry this out, in most parts of the world it is not considered as a highly validated process.

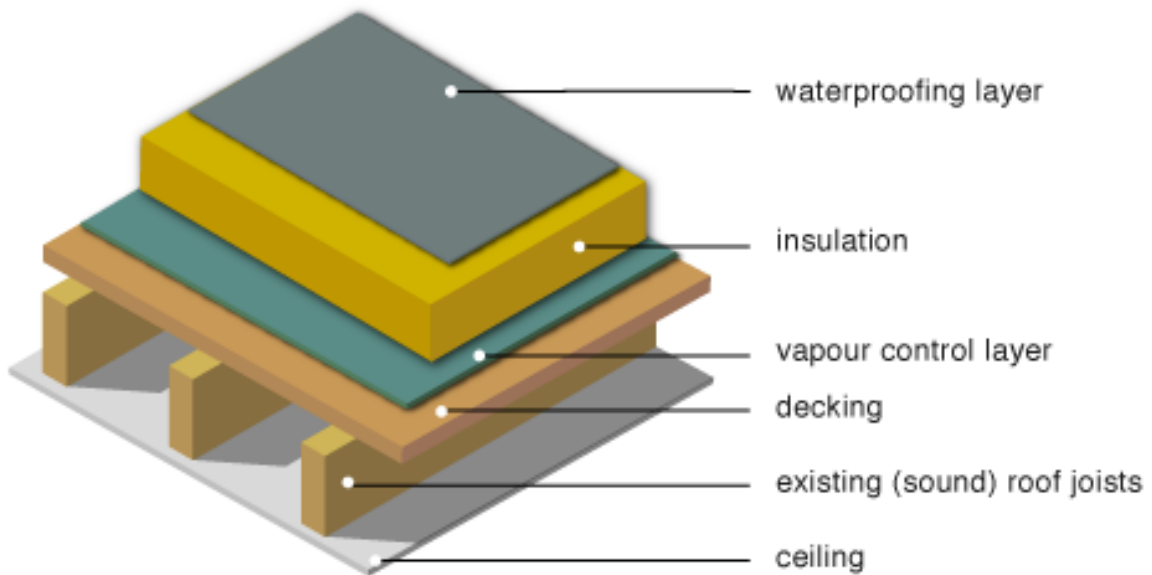


Image 22 Flat Roofs

3.3.3.2. Cool Roofs

In places with hot climates, it is better to reject as much heat as possible from the roof surface and to prevent any heat build-up from migrating to the attic or conditioned space. Cool roofs, simply white in color, reflect visible and near-infrared light very well. Roof performance degrades with environmental particulate soiling and biological growth over time and in order to ensure accurate energy-saving measurements, aged ratings are specified in policy programs. Recently, the detailed roofing rating requirements were included in a concept of a cool roof providing performance criteria of solar reflectance and thermal emittance after a roof sample has been aged (weathering tests in a variety of climates) for a certain period, such as three years. The highest-quality aged white roofs can reflect 80% of the sun's energy compared to black roofs that reflect only 5% to 10% (CRRC, 2013). There are also cool - colored roofing products that visibly look the same as typical roofs, but which reflect the near-infrared portion of sunlight. Depending on the color and the performance, these products reflect about 30 ~ 50% of the sun's energy.

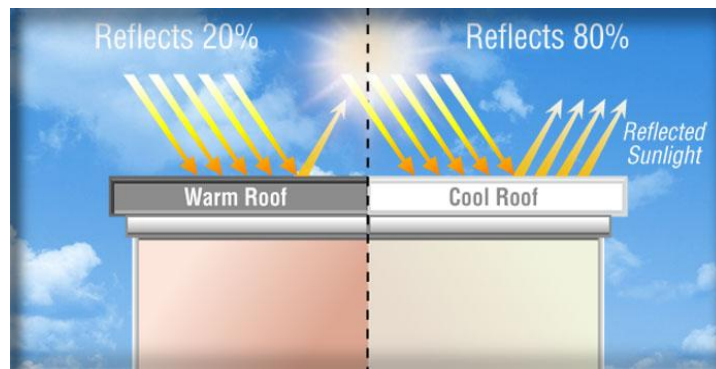


Image 23 Cool Roofs

3.3.3.3. Energy Efficiency Options

Energy efficient roofing systems need to exceed insulation. Properly sealed ceiling planes for pitched roofs are needed for all climates, and cool roofs are important in hot climates. Efficiency programs for the promotion of advanced roofing should ensure that air infiltration and reflectivity criteria are included along with insulation requirements. Radiant barriers (with low-emissivity surfaces) on the underside of roof decks can also contribute both to hot and cold climates, despite the fact that they are usually more cost effective in hot climates for reasons of cooling benefits. It should be also taken into account that they are not installed on the floor of an attic where they will accumulate dust and finally no longer be effective.

Often in North American homes, mostly in the United States, there are air distribution systems that are located in the attic. These can be quite inefficient, especially when they are not fully air sealed and insulated. The energy efficient approach includes homes constructed with the ductwork integrated into the conditioned space. However, many builders have rejected this since it can conflict with architectural designs. A new concept to mitigate this problem has been the conversion of the attic into a semi-conditioned space by insulating the roof plane instead of the ceiling plane (floor of the attic). This solution constitutes a significant improvement over traditional attics with leaky ceiling planes, but the designer must be especially careful in order to avoid moisture problems in the structural sheathing of the roof.

Roofing materials and designs beyond cool roofs can contribute to improved energy efficiency. For example, clay or concrete tiles are very common in many countries. The tiles usually offer two advantages. Firstly, they provide thermal mass in order to mitigate solar energy, and secondly, they are usually installed on counter battens that

provide a vertical ventilation path below the tile. Thermal mass retards the heat gain and much of it can be removed by ventilation. As the sun sets, remaining stored energy will “*return*” to the environment. Additionally, unglazed tiles, which are common in many regions, have a naturally high solar reflectance (about 0.40). These tiles also store moisture that can have an added cooling benefit.

3.3.4. Foundations and Floors

A variety of basic configurations is included in foundations, such as full basements, crawl spaces and slabs on grade. All configurations exist in all climates, but certain configurations are more prevalent in certain regions. It is of great importance to think about adding insulation in all applications, but mostly in colder climates. In hotter climates, foundations offer ground coupling and can actually be a source of heat rejection. The portions of the basement, crawl space or slab that are exposed to the environment above the grade are of great concern.

Similar to walls, the addition of exterior insulation is preferred by the majority and is included in mandatory building codes in many cold countries. However, compliance raises problems because the addition of insulation during foundation backfilling can be labor intensive. Adding insulation to slab edges can also be difficult for buildings that may not add exterior insulation to above-grade wall sections. The interface between the slab edge and the wall is an important construction detail that needs to be carefully addressed.

The vast majority of crawl spaces and basements in cold climates are in need of retrofitting. Insulating on interior walls is viable, but much attention needs to be given to mitigate any moisture problems. This concern has been the subject of continuing debate among global building researchers and is receiving more attention as problems with other components of the building envelope have been solved.

Insulating floors that are over basements or crawl spaces is an easy measure for new construction and in some retrofits. This turns the basement into semi-conditioned space serving as a buffer zone and is useful. However, if the space is used and conditioned, then the insulation value will be wasted. Prior to insulating, any floor penetrations

should be properly sealed. Similarly to attics, if ductwork is located in the basement or crawl space, then it should also be properly sealed and insulated.

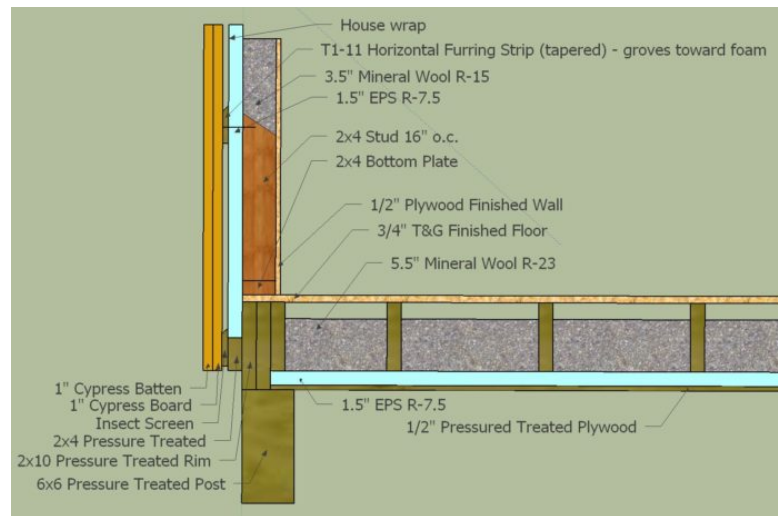


Image 24 Insulated Floors

3.3.5. Frames

Windows have an important impact on energy consumption. While it is difficult to estimate, **windows are most likely responsible for 5% to 10% of the total energy consumed in buildings in OECD countries.** They serve many functions, including access to the building, outlook, entry of daylight and safety egress, and in many cases they provide ventilation as a fresh air inlet. Most of the times, windows should let in as much light as possible, but it should be taken into account that heat gain in summer needs to be minimized, while in winter it should be maximized.

One of the challenges for windows is to optimize the heat flow depending on the season. If the building is heated and the outdoor temperature is cold, the window should retain heat in the building, minimize losses and let in as much solar radiation as possible. On the other hand, if the temperature inside the building is too hot and cooling is needed, the windows should keep out the warmth of the sun and if possible provide opportunities to shed heat from the building. The overall thermal performance of a building material or window is specified as thermal transmission (typically described as a U-value³³). It is a measure of the rate at which heat passes through a component or structure when a temperature difference is maintained across the material.

³³ [https://en.wikipedia.org/wiki/R-value_\(insulation\)#U-value](https://en.wikipedia.org/wiki/R-value_(insulation)#U-value)

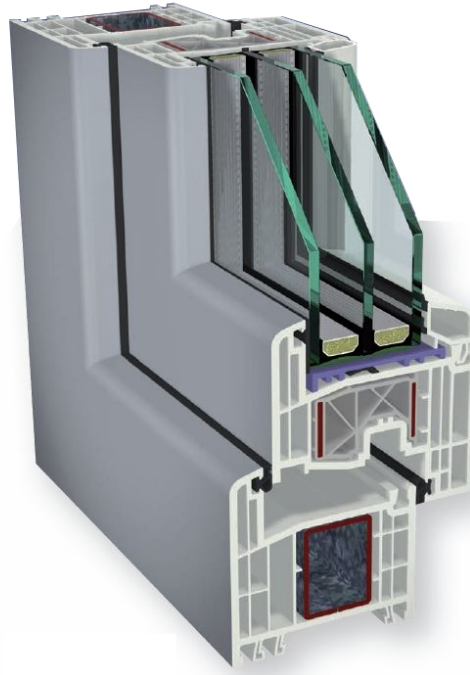


Image 25 Ecological Type of Frame

Difficult concepts and techniques are required in the measurement including conduction, convection and radiation losses. There are many technical measuring considerations for windows. Another common term is thermal resistance (typically shown as an R-value³⁴), which for all practical purposes is the inverse of thermal transmission. R-value is mostly meant to be a performance metric for consumers of a building material such as insulation. The higher the R-value, then the lower the heat loss will be. Conversely, lower U-values are best.

Whole-window performance highly depends on its design, including whether it is fixed or is one of a variety of operable types to allow natural ventilation. Window construction includes framing materials, glazing, coatings, and spacers between panes of glass, inert gases for the reduction of convection within cavities, thermal breaks and operating hardware. While the technical characteristics of windows are very complex, it has been simplified for policy makers and consumers through the use of window rating programs. The standards specify the methodology to derive U-values and SHGC for the entire window.

³⁴ [https://en.wikipedia.org/wiki/R-value_\(insulation\)](https://en.wikipedia.org/wiki/R-value_(insulation))

Nowadays, it is still common to see windows being specified by the center-of-glass characteristics rather than for the entire window system. It is important to specify whole-window performance to ensure the true energy features are taken into account. Unfortunately, there are still many windows being sold throughout the world today that are only single glazed with clear glass and inefficient metal framing. These have U-values of approximately 5.6 watts per square meter kelvin ($W/m^2 K$). The majority of OECD countries in cold climates have chosen double glazed windows with low-e coatings, non-metallic frames and inert gas for the residential sub-sector, with U-values of approximately 1.8 $W/m^2 K$. Several European countries have recently passed even stricter building code requirements that are around 1.1 $W/m^2 K$.

However, due to high structural requirements for many services sub-sector buildings, aluminum framed windows are still the material mostly chosen. Services sub-sector windows are generally larger and framing materials are less important with large glazed areas, and many new aluminum frames have thermal breaks so the total performance degradation is not as poor as might be considered. Using the latest state-of-the-art low-e coatings, solar heat gains can be low while maintaining natural light to reduce lighting energy consumption. Always more and more parts of the world start to adopt low-e glass, but many things are still required before being mandatory in building codes, as used in cold OECD countries.

3.3.5.1. Air Sealing

In many buildings, it is normal for air to move in (infiltration³⁵) and out (exfiltration³⁶) of the structure. A common name for this is called air leakage and is usually measured using a term called air changes per hour (ACH). Natural weather conditions, such as wind and temperature differences, can increase air leakage. Also, mechanical duct systems can create pressure differences between the inside and outside of a building, which can also contribute to the problem. For the measurement of ACH, the structure is pressurized and multiple air leakage rates are collected over a range of pressures. The most common specification to rate air leakage is at 50 Pascal (Pa), and at this high pressure it is not uncommon for old leaky homes to have ACH of 10 to 20. Actual pressures during normal building operation are much lower. Simulations on a large

³⁵ [https://en.wikipedia.org/wiki/Infiltration_\(HVAC\)](https://en.wikipedia.org/wiki/Infiltration_(HVAC))

³⁶ [https://en.wikipedia.org/wiki/Ventilation_\(architecture\)](https://en.wikipedia.org/wiki/Ventilation_(architecture))

number of building types in widely varying climates concluded that the potential for heating and cooling energy savings attributable to reduced air leakage ranged from 5 ~ 40%. However, with reasonably tight structures in cold climates, the typical savings were around 20 ~ 30%.

3.3.5.2. Energy Efficiency Options

The replacement of poorly performing windows is the most direct way for the improvement of their energy efficiency. While window replacement for the sole purpose of saving energy is rarely cost effective, in situations where the window is being replaced due to structural instability, inoperability, appearance, obscured glass from broken seals, or a variety of other reasons, it is almost always cost effective to upgrade to more efficient windows. Significant progress has been made in recent years for windows used in the services sub-sector.

3.3.5.3. Shading Attachments

Beyond replacing windows, there are ways to upgrade existing window systems when it is impossible to replace them. It is easier to reduce solar heat gain in hot climates than to reduce U-values in cold climates, because the energy of the sun can be reflected. Shading materials perform best when they are installed on the exterior of the building, and these include shutters, awnings, solar shades and a variety of other shading devices. Interior shading with highly reflective surfaces, such as a bright white color, can also be effective but has less effect, if low-e glass is installed. A very effective technology is window films that can significantly reduce solar heat gain while maintaining a view to the outdoors. Window films have full product performance ratings in the United States in accordance with the National Fenestration Rating Council, but generally more work is required on the full complement of window attachments worldwide.



Image 26 Shading Equipment

3.3.5.4. Insulating Technologies, Low-e Coatings and Attachments

A significant advance in window technology over the last 20 to 30 years has been the development of low-e window coatings that are very thin transparent metal films. Low-e coatings have the ability to reduce the thermal loss from windows and also to reflect solar energy.

There are two primary types of low-e glass:

- Sputtered with lower emissivity and less heat loss but is required to be protected within a double glazed unit,
- and pyrolytic, which does not need to be protected from ambient air and is best suited to storm window panels.

New low-e window films can also contribute to the reduction of U-values by as much as 42% when installed on single glazed clear glass windows. Insulated cellular shades (that look like honeycomb) can also reduce U-values on windows and are more effective in cold climates. Proper installation is essential for the minimization of air flow between the shade and the window to ensure that full improvement is achieved. A well-known method to improve the performance of existing windows is the addition of a storm window panel. Performance of a single glazed clear glass window with a low-e storm window is very close to the performance of a new double glazed low-e window with a wood or vinyl frame. This is of great importance since the large stock of inefficient, single glazed windows can be altered to perform in comparison to the performance of new building code-compliant windows at about half the cost.

3.3.5.5. Air Leakage

Windows, especially in older buildings, are also responsible for a major portion of air leakage or air infiltration. This is further discussed detailed below, but storm panels have been proven to reduce whole-building infiltration by 5.7 ~ 8.6%. New windows are generally much tighter fitting than existing windows. However, concerns are raised regarding the oldness of the windows that may allow greater air leakage than when first manufactured. This is predominately due to thermal cycling from high-temperature exposure under direct sun conditions in the summer and during cold winters. Materials

such as vinyl, which are very prevalent and have low thermal conductivity, unfortunately have high thermal coefficients of expansion. Manufacturers have to consider this when developing window designs. Generally, European windows have operating hardware that allows for a gasket to be closed very tightly and achieve very low infiltration rates.

3.3.5.6. Triple Glazed Windows

Currently, in most cold climate OECD countries, much effort is made for the promotion of high-performance windows. Triple glazed windows have been available for many decades but have not achieved large market share in any country. Triple glazing that was more prevalent in Northern European countries has decreased due to the development of low-e coatings. However, this trend is about to change due to recent stricter building regulations. Furthermore, newer more affordable higher-performing double glazed windows have two low-e coatings, one on the inside of the outer pane and a second pyrolytic coating on the room interior side of the inner pane of glass. The combination of this new glass package with a higher-performing frame, total performance can equal triple glazed low-e windows with standard frames. The recommended policies for windows follow the climate and technology maturity.

3.4. Technical Systems

The choice of suitable technological systems in nZEB can be a major challenge, given that the requirements to be met are relatively small, but this should be achieved in the most efficient way, without reconciling the comfort conditions. In nZEB it is also essential for the coverage of part of the energy required to install the production systems from renewable energy sources. RES systems should be placed to reduce the amount of energy required by the electricity network and/or other energy suppliers to be imported into building.

3.4.1. Heating Systems

The space and water heating sector regularly uses conventional heating systems, including boilers, burners, biomass stoves, and electrical heaters as individual applications or combination water and space heating systems. Significant improvements in efficiency in space and water heating can be achieved through available, highly

efficient conventional technologies, which are already viable on the market, including condensed and heat pumped boilers. This is an important first step when heating equipment is replaced in existing building stocks. However, it is necessary to move forward towards highly effective technologies, such as advanced heat pumps and solar thermal technologies. The following sections describe the major building heating technologies as well as their typical efficiency, constraints and expected technical developments.

3.4.1.1. Traditional Boilers and Furnaces

Traditional boilers and furnaces tend to have less than 80%, low to medium efficiency. In addition to technical limitations, the energy usage of distribution losses and high combustion temperatures, notably in large buildings, as discussed below, compared to condensing boilers and furnaces. The design of the system can also impact the efficiency of heating. In particular in warmer months when the heated water requirement requires a heater operation which, if not, wouldn't be needed. For example, combination space and heating systems are generally less efficient than separate boiler and heating systems. Due to their operation at higher temperatures to produce steam, forced heaters are generally less efficient than hot water boiler systems. Heating markets in most OECD countries dominate conventional furnaces and boilers due to relatively modest capital costs and traditionally low operating costs. They can also be used in nearly any kind of property. It is versatile. In European housing and commercial applications, for example, central heating systems using building-scale boilers remain a popular option for both spacious heating. It is estimated that 59% of European Union households in 2005 had heating-powered natural gas boilers and 20% had oil-fired boilers. From 2007 to 2011, boiler sales in Europe continued to lead, with boiler sales in 2010 increasing by 2% relative to other heating technologies. In the United States and Europe, nearly 72% of the power consumed in 2010 is from traditional fossil fuels. In particular, gas-fired systems represent almost half of the total use of heating power, despite the decrease of overall sales of gas and oil boilers over the last few years.

Natural gas continues to be one of the common fuels for space and water warming, particularly in regions with strong distribution networks of gas in other OECD and non-OECD countries in Europe and in Eurasia. Russia and China have a lower proportion of fossil and natural gas fuel than OECD countries. However, the greater use of

conventional district heating (Russia) and biomass (China) which could significantly be improved through enhanced heating and cogeneration technologies can explain these smaller shares.

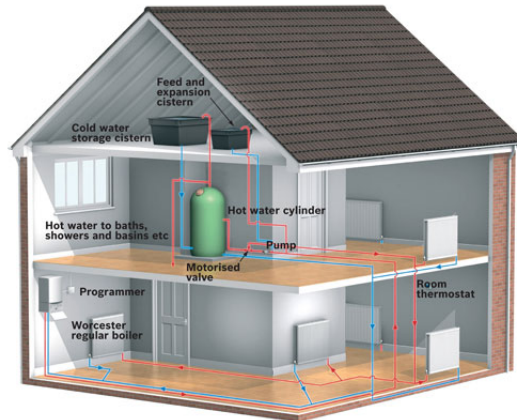


Image 27 Regular Boiler System

3.4.1.2. Condensing Boilers and Furnaces

Hot gasses from the combustion process are passed through a heat exchanger and released through the flu in a traditional, non-condensing boiler or furnace. The latent water heat is used by condensing boilers and furnaces to increase system efficiency. Hot gasses are transported to the water vapor produced by burning through a second heating exchanger. The condensing of the water vapor reverts heat to the system, which reduces the temperature gradient of combustion.

The efficiency of a typical non-condemning boiler or furnace is approximately 70% ~ 84%, while condensing boilers and furnaces generally have more than 90% efficiency³⁷. Natural gas is the most common fuel used for condenser heaters, but can also be used with fuel oil or LPG.

³⁷ ACEE, 2012

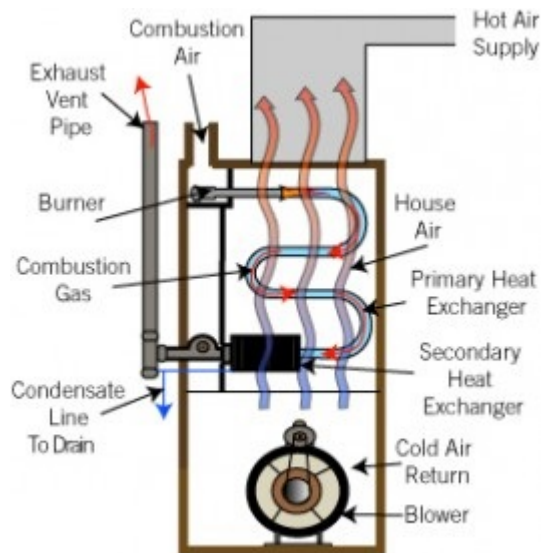


Image 28 High Efficiency Furnace

ENERGY STAR²³⁸ ratings in the United States indicate that products comply with the U.S. Environmental Protection Agency's strict energy-efficiency guidelines. Qualified boilers ENERGY STAR have annual rating of 85% (3 or higher) of fuel utilization efficiency. The capacitor boilers can have an AFUE of 95% or more, where the AFUE could be raised to 97% by additional improvements in boiler technology.

These improvements include:

- Electronic ignition, avoiding the need for pilot light always to be heated.
- New combustion systems which extract extra heat from the same amount of fuel.
- Drained combustion by fueling the burner with external air, reducing drafts and increasing safety.

Condensing boilers provide a unique system approach which benefits new buildings and retrofits. The exhaust chimneys may be made of cheaper materials with lower flue temperatures. For instance, the use and horizontal extension of low cost polymers, which can be much easier and less expensive than traditional chimneys, is possible. The installation of a condensing boiler can be more complex in the retrofit applications with existing fireplace or flue stacks, although a low-cost polymer, winded or non-corrosive polymer chimney can often be used to decrease prices for the condensing boils if a retrofit is necessary.

³⁸ https://en.wikipedia.org/wiki/Energy_Star

In addition, flue or ventilation damping systems to prevent the air from being lost by chimneys if the equipment is not firing and intermittent ignition systems replacing pilot lights in older boilers and furnaces, can be used for regular and condensation boilers and furnaces. Further improvements include Modulating aqua stats, also known as outdoor resets, to control and modify the temperature of hot water in the boiler depending on the outside temperature, e.g. during warmer summer months. The water can be used for water resets. These systems can save between 5% ~ 10% on space and hot water heating energy consumption. Programmable thermostats that adjust the heating and cooling needs of existing heating and cooling systems to a preset schedule can also save between 5 ~ 15%.

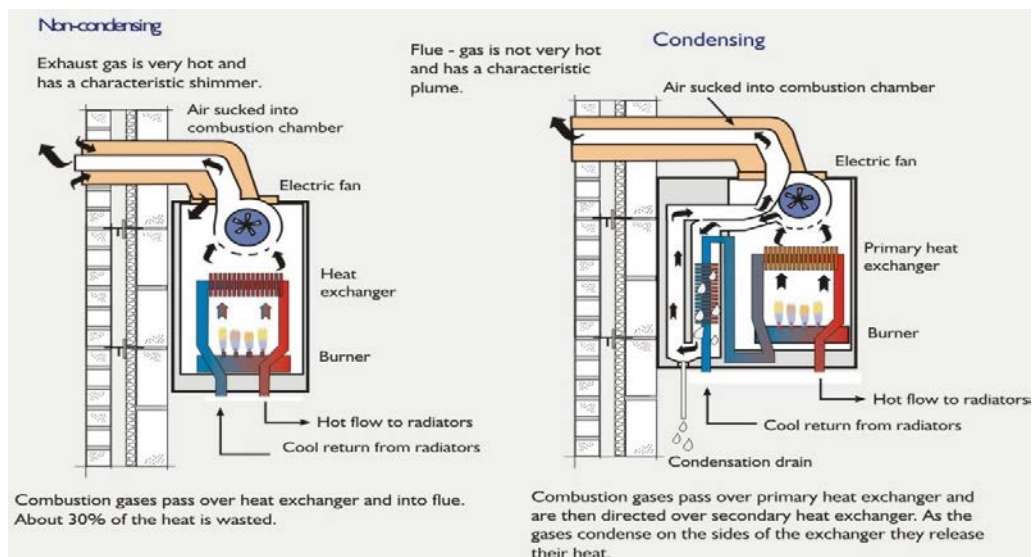


Image 29 Non-Condensing VS Condensing Boiler

3.4.1.3. Biomass Heating System

Biomass is used to produce nearly 30% of global space and water heating. This, broken by end-use, means that approximately 25% of global energy used for heating in residential areas and almost 55% used for heating in residential water is generated using biomass. Water and space heating biomass varies between open fires and high-efficiency stove technologies. In OECD countries the use of bio-mass in cold northern and northern climates ranges from less than 5% of the heating of space and water to 35%, while the average use for OECD remains below 10%. Mass fuel (e.g. wood and cattle dung) remains a common way to heat buildings and water in many non-OECD countries.

In some developing regions traditional biomass accounts for up to 90% of the energy consumed by space and water heating. Over 70% of household space and water heating is produced using biomass in India, the Association of Southeast Asian Nations and Africa. In areas where there is a high share of spatial heating significant improvements in the use of traditional biomass are possible. This includes not only numerous non-OECD regions with biomass still the main means of heating homes, but also many colder areas of the OECD, such as Canada and Nordic Europe, in which biomass is often used as the primary or the secondary means of heating homes. Biomass provided for example 40% of total demand for heat in Sweden in 2008³⁹.

The use of more efficient heating technologies for biomass, such as high-efficiency fireplaces, advanced wood furnace combustion and pellet stoves, can drastically improve the efficiency of biomass heating applications in the buildings industry. Emissions from exhaust gases, including dangerous contaminants such as carbon monoxide or particulate matter, could also be significantly improved. Modern biomass applications also cover combined heat production and power generation, more efficient than electricity or heat production alone and can achieve conversion efficiency of approximately 70% ~ 90%.

3.4.1.4. Pellet Stoves

A pellet stove is a biomass-fired, solid fuel or pellet-fueled space heating system. Sawdust, waste paper, grain kernels and small wood chips can be made from a variety of bio-mass sources. Wood pellet stoves, the most common wood pellet, are mostly compacted under high pressure and consist of wood sawdust. Multi-fuel pellet furnaces can heat the biomass pellet combinations with other solid fuels.

In general, the combustion and heating efficiency of pellets are higher than that of other conventional wood heating technologies and, because of cleaner heating, they produce less emissions. The majority of pellet stoves range at about 80 ~ 85% and usually have enough capacity to heat the house or building of apartment. Efficiencies of 90% or higher can be achieved when operated at nominal thermal output.

³⁹ <https://www.iea.org/newsroom/news/2010/november/world-energy-outlook-2010.html>

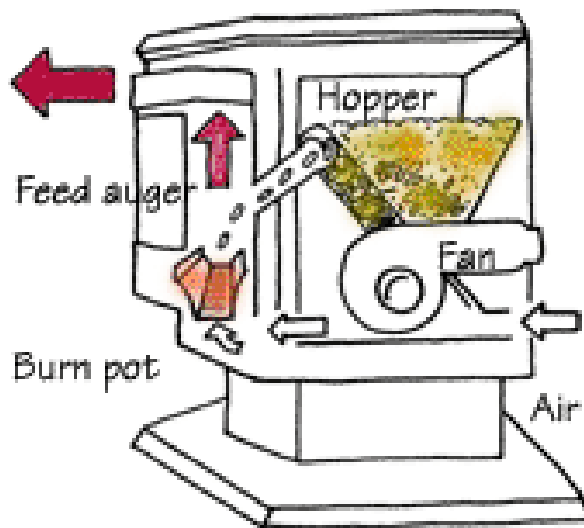


Image 30 Typical Pellet Stove Diagram

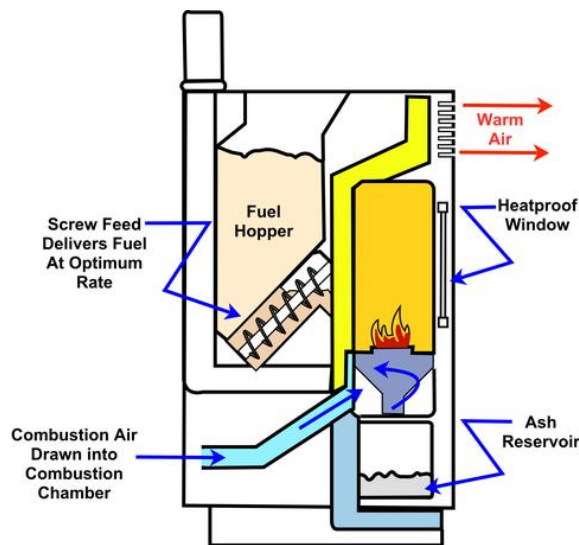


Image 31 Pellet Stove Work

3.4.1.5. Traditional Fireplaces and Wood Stoves

Open fires, traditional masonry fires and wood-burning stoves, in particular in developing regions, are frequently utilized for space and water heating. Wood stoves and open fires are inefficient, with high air pollutants emitted, including carbon monoxide and oxides of nitrogen. Fireplace open masonry is also ineffective in energy, draws heated fireplaces into large amounts for combustion and exhaust. Wood cookers are more efficient than traditional open fires but still generally have less than 70% efficiency. They also emit large volumes of dangerous atmospheric pollutants. In contrast, new catalytic stoves produce significantly less exhaust fumes, with higher efficiencies of between 70 ~ 80%. These state-of - the-art combustion stoves are also

safer because fuel gas heating prevents creosote buildup (flammable chimney deposition). They are also safer for everyday use. The same technology (a catalytic damper) can be used to increase energy efficiency and reduce fuel emissions with existing wood-burning appliances.



Image 32 Traditional Fireplace

3.4.1.6. High Efficiency Fireplaces and Masonry Heaters

The use of heating technologies similar to advanced wood combustion stoves significantly improve the efficiency of high-efficiency fireplaces. The flue collars, the tightly fitted fireplace gates, the fire box and the heat exchangers are fitted. Some advanced chimneys can also be adapted to distribute heat in a building with conducts.

Masonry stoves generally produce much more heat and less pollution than conventional wood stoves. Combining a masonry mass (e.g. refractory concrete) and an exhaust system in the firebox, macerating heaters can deliver a combustion efficiency of up to 90% while maintaining a long term high temperature. Once or twice a day a little heated fire may suffice to warm a house for 12 to 20 hours. The absorption and heat release of the masonry heaters means, however, that heat from the cold start cannot be produced quickly.

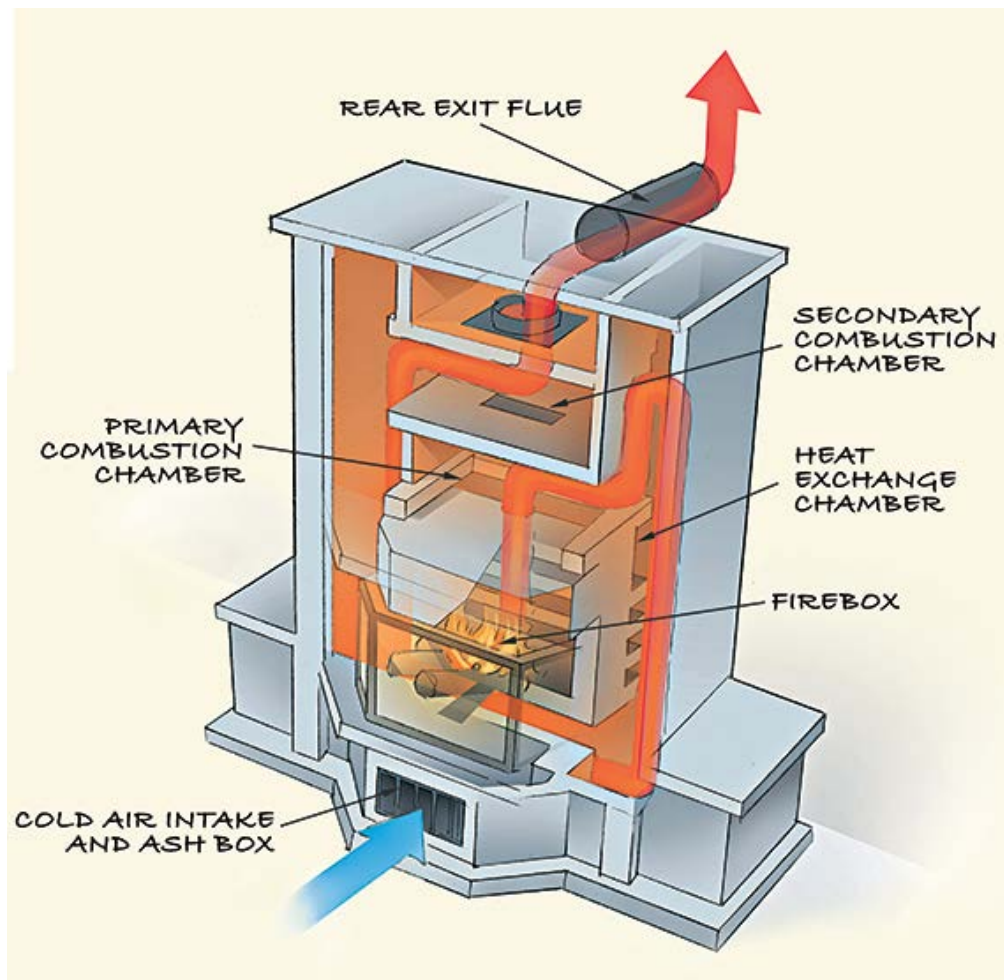


Image 33 Masonry Heater

3.4.1.7. Electric Heaters

The electricity production accounts for about 15% of global space and water heating. Electricity accounts for 1/3 of the OECD's total energy consumption of water heating and 5 ~ 15 % of domestic heating. Electricity accounts for less than 5% of residential water and spacious heating in China, India, ASEAN countries and most of Africa, although this figure is up to 21% in other non-OECD regions. Electricity accounts for almost one quarter of global water and space heating services in the services sub-sector.

In principle, electric heating is very efficient because almost all electricity is converted into heat. Although they are mostly used for electric furnaces, baseboards or wall thermal heaters, and increasingly radiant floor heating, electric resistance heaters may have various forms. Electric furnaces in forced air supply heated air via ventilation networks, while heating systems generally deliver the heat to an area directly from a base board, wall and radiant systems.

3.4.1.8. Heat Pumps

Heat pumps are a multi-faceted system, which allows the space heating, cooling and hot water to be provided from all three service units. In 2010, heat pumps accounted for approx. 8% of global space heating and cooling power consumption and space cooling (e.g. air conditioners). Asia prevails over the total installed heat pumps, with in the residential and service sectors estimated 400 million room air conditioners and an additional 46 million air conditioners packaging in 2009. The use of heat pumps for heating and cooling systems is also increasing, despite its share in the international heating market still below 1%. Heat pumps are an advanced technology that transfers thermal energy to a heat sink using a vapor compression cycle that uses natural thermal gradients. Although other cycles, including thermally-driven pumps, are mainly used for air conditioning, the majority of thermal pumps are used by an electric motor. There are a limited number of globally installed solar heat pump cooling systems.

Heat pumps are characterized by the use of a natural temperature gradient to convert low-grade heat to useful heat. Heat can even be removed from outdoor air, water, and soil in the winter as long as the coolant used in the heat pump is lower than heat. In general, the efficiency at point of use is greater than 250%, it provides a more useful heat input (or output) than that used to run the appliance (e.g. input of electricity).

The efficiency of the thermal pump can be described by means of a performance coefficient (COP) under test conditions. For instance, the three heating COP equals efficiency 7 (i.e. 3 units of heat for one commercial energy input unit), which corresponds to 300 percent. Over the past 30 years, the efficiency and performance of heat pumps have greatly increased. For example, in the majority of regions, the COP of the best air conditioners, which are the ground-source heat pumps, has grown from less than three to between five and six. These improvements in performance have been achieved by advances in individual components and better system integration.

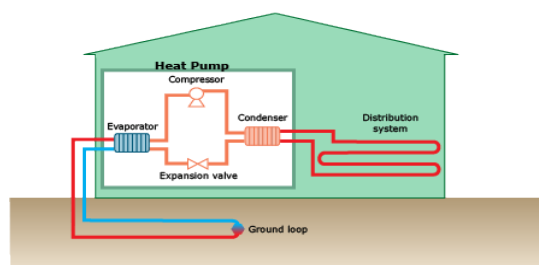


Image 34 Typical Use Of Geothermal Energy With Heat Pumps

3.4.2. Passive Heating Systems

As far as nZEB heating is concerned, the passive heating systems are very popular and widely used. Those that exploit the solar radiations for heating or refreshing and do not use mechanical means for heat transfers in space are considered passive solar systems. They are based on the natural flow of thermal energy, the natural properties of building materials and they collect energy and store it appropriately through the structural elements of nutshell.

In systems with direct or indirect solar profit, passive solar heating systems are distinguished:

- System for direct profit.
- Thermic wall (mass wall or solar wall), more usual Wall of Trombe type.
- Solar sun-space.
- Passive solar collectors or air collectors.
- Open spaces.

The choice of a better passive system to be used on an individual basis depends on the climate conditions in each area, the use of building and the desired energy results, combined with cost and expected damping.

3.4.2.1 Systems of Direct Profit

The systems that develop the collected solar energy from suitable orientation openings are called direct profit systems. More specifically, the winter solar radiation is greater in the Southern openings. Similarly, in summer the northern openings collect a consistent light, while in winter they show considerable losses.

The solar walls (without isolation) with the sunshades are shaped by masonry. Through these, the solar energy is collected and subsequently transmitted in other spaces as heat. It is supported that the difference between the Trombe wall and the wall mass assigns openings whereas the wall mass does not. The energy collection and storage occurs during the daytime and mostly during high solar reporting hours.

They can contribute in the saving of energy by a percentage of 10 ~ 40% (according to measurements, energy records, and bioclimatic building simulations in different regions of the country). In aestival months with mobile exterior panels, special protection is required.

3.4.2.2 Trombe Wall

The Trombe wall is a cemented wall of approx. 30 ~ 40 cm with external black paints and is available alone or double glazed from a distance from 5 ~ 10 cm from the wall. It is oriented to the south and protects space with mobile sunscreen from thermal losses during the winter night and overheating in the summer. There are apertures that facilitate the movement of the air due to differing temperatures, above and below the wall and its full length. The removal in the summer of the warm air via a skylight on the above part of the glazing becomes also necessary.

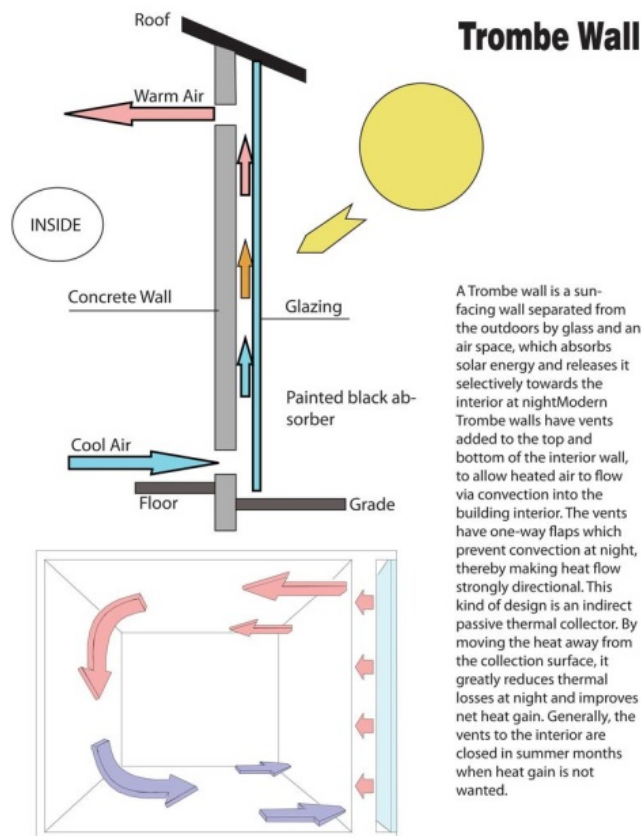


Image 35 How Trombe Wall Works

3.4.2.3 Thermal Insulating Panels

Without the existence and operation of a thermal mass, it constitutes systems of similar production and operation. The fundamental difference from the other wall is that the panel is thermally insulated by the heat insulation gap, and the heat is only transported through conductive (transported) air transports from the gap, which is transportable through the cassettes or drives in internal space.

In addition, thermal isolation panels usually lead to an absorbent gap metal plate for larger outputs on the outside surface of the wall.

In the winter, solar radiation that heats up on a collector (glass surface) is thus altered in thermal form and transported through the cases to the outside of the panel in the internal space. Openings in the lower part permit the thermal isolation panel to rise from the interior of the building. This operation will be reversed during the aestival. Openings in the beyond glazing department allow hot air to move to the outside, resulting in the building cooling.

3.4.2.4 Open Spaces

It should be underlined that the coating of surfaces in the overdraft spaces must be done with the appropriate materials. Specifically, after studies, we are able to say that outdoor surface coating materials play an important role in the thermal and visual environment. Large vegetation prevents reflections of solar energy and radiation, while simultaneously playing a major role in 'pumping' fresh air through the evapotranspiration of the leaves of plants. Therefore, instead of coating surfaces, it is preferable to select plates, which allow the growth of vegetation or to use impermeable layers for the water.

3.4.2.5 Other Passive Systems

A description of the green roof which is also in this category should be made, except for the passive systems which have already been analyzed at large in the previous unit.

Green roof

In the roof of the building (roof garden) is the green roof. It is a vegetation layer that is specially designed in the loft of buildings. It reduces the building heating and cooling load and improves the thermal comfort conditions in the interior. The planting of the roofs consists of a vegetation layer.



Image 36 Example of Green Roof

There are many benefits, most significantly from the use of Green Roof Systems technology:

- Building heating cost reduces
- Noise pollution reduction
- Protection and seating of buildings
- Building value improvement
- Building improved microclimate
- Air quality improvement
- Creation of a natural environment for plants and animals
- Reduction of the elect of plants and animals

More particularly, the climate in major urban centers can be significantly improved, the profit resulting from the decrease in temperature, the generation of oxygen and pollutant and dust absorption. In high sunlight, it has been found that the temperature difference between a planted roof and a flat roof or with single insulation could reach 3 ~ 6 ° C.

3.4.3. Space Cooling

The consumption of energy by buildings with cooling space has increased by almost 60% between 2000 and 2010, representing about 4% of the global energy consumption of buildings in 2010. In OECD countries, cooling energy consumption, as a percentage of overall buildings, is more than in non-OECD areas, although the demand for comfort continues to increase, cooling energy uses are growing rapidly in non-OECD countries. Cooling energy use also depends on regional climates: cooling accounts for up to 10% of total building energy consumptions in hot climates, while cooling typically represents less than three percent of household energy consumptions in cooler regions with higher demand for heating, such as Canada. Global space cooling usually takes place using electricity, but natural gas coolant equipment accounts for a considerable proportion in certain regions, such as the OECD Pacific.

Conventional air conditioning and cooling technologies are standardized products in residential and service sub-sectors worldwide, including air conditioners and chillers. The region remains Asia and Pacific, followed by OECD Americas and OECD Europe (BSRIA Limited, 2011), as the biggest regional market in sales air conditioning units. The sales of air conditioners in China accounted for over 25 percent of global sales in 2010, with Japan and the US closely following. Most air conditioners today operate with less efficiency than maximum, and significant energy efficiency improvements and design are possible. A major energy efficiency opportunity lies in a lack of rigorous analysis of building cooling requirements and conception that many cooling systems today are oversized.

3.4.3.1. Split Systems and Packaged Cooling Unit

The standard technology for air conditioning worldwide is a vapor compression cooling cycle. Units, including ducted or ductless units and packaged and split units, are available in various configurations. In Europe and North America, single-space packaged unit conditioners, particularly in the domestic sector, are the most common type of air-conditioning.

Large, packaged air-conditioner units with air distribution pipes are standard products where the central packed unit contains a condenser and compressor evaporator in one case, often on the roof or side of a building. Electric or gas heating systems are often included.

Split systems are typical for indoor air distribution and outdoor heating systems, which are equipped with heat exchanger and fan. Mini-split systems in most of Asia are very common and very similar to ordinary split systems but have little capacity. Multiple small units are usually per apartment or dwelling. The great advantage of mini-split systems is that they are without ducts and the inner unit is fully within the thermal shell. Another advantage of mini splits is that only the spaces you want are cooled. Both larger and mini-split systems can be reversible to both heat and cool.

COPs of air-conditioners in many parts of the world have a tendency to range from 2.5 to 4.0, with COPs in certain countries approaching 6 for a small class (2.2 kilowatt kW). Due to increasing space refrigeration demand in both regions of the OECD and non-OECD regions, it is crucial to reduce cooling energy consumption in building envelope systems and properly tailor high-efficiency air conditioners. Technical improvements in existing cooling technology include variable-speed fans that lower their electrical output when the coolant cycle is not working, fan operating high-efficiency motor systems that use less electricity.

3.4.3.2. Dehumidification Systems

The moisture removal in buildings around the world, particularly in the service sector, is becoming increasingly significant with high levels of fresh air needed for building ventilation. With higher thermal resistance, the control of humidity can also become a larger portion of refrigerating loads. Therefore, dehumidification can improve the general feeling of comfort in buildings and reduce the need for space refreshment. Desiccant air conditioning systems are an emerging technology that offers a drying method before they enter the premises.

The main advantage of dehumidifying desiccant systems is that they are removing moisture from outdoor air, which enhances the temperature control of conventional air conditioning systems. The dehumidification from cooling load allows a significantly

higher temperature and hence significantly higher COPs for the heat pump. The dehumidifying systems of desiccants work by turning a wheel consisting of material for desiccating moisture through an air stream of supply or process that is then dried out before being directed into the house by the desiccant. The wheel continues to rotate with drying air through a reactivation or recovery air stream, which dries out the waste heat from the condenser of the heat pump. Air that is hotter or drier than processed air can reactivate with desiccants.

3.4.3.3. Roof Fan

The use of roof fans can help to reduce energy consumption for air conditioning in different building spaces. Their positioning on the roof increases air movement in the room. The usual roof fans are estimated to be effective in a radius of 1.8 m from the place at installation height 2.5 m over the floor. The increase in air movement allows air conditioning systems to operate simultaneously at high temperatures. The air conditioner can increase its temperature at 2°C and achieve the same thermal comfort level when it covers 80% of the size of the fan.

In addition, using the roof fan allows the air-conditioning system to evade the operating system during transition periods of the year, or some summer nights, where the temperatures for the rest of the day may be very low. Even more efficient are the combination of a roof ventilator roof with properly directed and dimensioned openings and shade systems. Its positioning is mainly carried out in residences but may be helpful and useful in a range of other building types as offices and event spaces

3.4.3.4. Passive Systems of Natural Cooling

The techniques for the achievement of proper cooling are:

- Natural airing
 - Open throughout airing (daily or nightly)
 - Airing with mechanic means (fans of various type)
 - Chimney or tower of airing and solar chimney
 - Ventilated nutshell
- Cooling through ground
 - underground or semi-underground buildings

- Subsurface pipeline system
- Cooling via radiation in the nightly sky
- Evaporative cooling

The main designing and constructional regulations in the nutshell of building, for the protection from the overheat at the duration of summertime, are:

- Sun protection of the building from the direct solar radiation, with shading of its openings.
- Suitable color and corresponding texture of exterior surfaces.
- Sufficiency of thermic mass of building.
- Heat insulation of nutshell of building.
- Natural airing of internal spaces, with natural or forced-mechanically way for the removal of accumulated heat.
- Radiation of heat to the nightly sky.
- Configuration of microclimate, use of suitable vegetation, creation of aquatic surfaces and suitable materials of coating the floorings (cold materials, water permeable materials etc.).

3.4.4. Mechanic Airing

Mechanical ventilation systems are applied locally or centrally so that fresh air is imported into the building and / or exported from the building. For maintaining high air quality in certain types of building, the installation of mechanical airing is essential, as the airing cannot be carried out in a natural way. In nZEB the buildings are very airtight and reduce air infiltration, making the installation of mechanical airing however more probable. It needs installation of ventilators and fans that increase energy consumption, especially when this is central.

When the heat recovery system is included in this, the mechanical airing can positively work to the energy output of a building. In other words, when the fresh air being imposed, is heated or cold, part of the already-heated or frozen air being exported. This can also be the main method of heating, especially in the winter, as thermal costs are very limited in nZEB. In addition, mechanical airing can be used as part of the night cooling strategy. Outside air, which has less temperature than the air in the building, can

be imported in the summer months by mechanic systems. This application can develop in buildings that remain closed and are not used during the day.

The replacement of all indoor air with lower temperatures at night and cooling of the indoor construction mass allows for delayed operation of the air conditioning system and / or higher temperature operation. Night-time ventilation is more efficient when the building has a high heat capacity, while it has a greater capacity to store cool air energy on its internal surfaces and reassign it during the daytime. In times when outside temperatures are not particularly high, a controlled intake of air can also help with the use of air conditioning.

3.4.5. Water Heating

The household water heating industry (i.e. drinking water) in most OECD countries, especially in the residential subsector, is the leading energy consumer in buildings. Conventional water heating consumption in non-OECD countries is rising rapidly with the increase in household wealth. In the Middle East, for example, energy consumption grew almost 40% between 2000 and 2010, with almost 90% produced by the traditional gas and oil technologies. Nearly 40% of building energy is used in water heating, where traditional biomass is still a common form of heating water in China, Africa and Latin America.

The majority of countries worldwide use standard heating and storage technologies to produce heated water, with the exception of certain non-OECD areas where the traditional biomass is still used to produce hot water. Conventional heating systems include gas or electric water storage heaters for producing and keeping hot water in the same unit, and combined boiler units for both domestic water use and space heating. Often these units have a separate storage tank.

Conventional heating systems for storing water are often low to moderately effective, as the tank walls are not subject to standby heat loss if warm water is not required. Improved tank insulation can significantly reduce standby heat loss, and newer high efficiency storage tank water heaters with standby losses can have efficiency up to 90

percent. In the building system design, it is also important to consider the location of the store tanks (e.g. cooler basements or garages) as heat losses are not present.

In order to meet growing energy consumption for hot household water, in particular in the residential sub-sector, it is necessary to implement advanced hot water solutions including instant and heat pump water heaters. The reduction of demand for use of hot water is in further considerations. For example, the installation of low-flow showerheads and faucets, with reduced tube-run lengths, reduced central water pressures and the purchase of more efficient devices will also be examples of options for reducing demand. Examples include changed behavior of the occupant, to promote shorter-time showers, selected over long-time baths and setting the temperatures of the water heater to reduce the energy consumption of the water heater.

In formal residences, energy demand for domestic hot water is usually 15 kWh / m² per year. In an energy class B residence this accounts for approximately 10 percent of total energy demand (not including electricity requirements and external lighting). The energy demand of hot water, where the energy demand for heating and cooling is more limited, can be 20% and is equal, or even greater than the energy demand for space heating. In some other buildings, such as hotels, fitness centers and dining spaces, there is also high demand for hot domestic water. The annual demand for energy per meter is low in office buildings. If the offices constitute major building complexes, the energy consumption as absolute number can be large.

For those reasons it is necessary to estimate the production and distribution of hot water as optimally as possible. It is advisable as:

- Storage and distribution losses have fallen. The losses include the interrelationship of the size of storage containers, the length of the piping of hot water distribution and the heat insulation level. The heat insulation container and pipeline heat insulation in the best possible level and the system's location planning near the water heating system are important meters to reduce the energy demand of nZEB. The reduction in pipe length is more feasible in the building where cooking facilities and hygiene are combined.

- An extent technically and economically feasible, with solar system in use, for producing hot water. The solar system can cover 50 ~ 80% of domestic hot water requirements in homes. The correct dimensioning and positioning of the system is important for the best possible production. The "*Solar Systems Technical Guide*" provides information about their installation
- Use of energy, for the production of hot water with the rejected energy, from the heating system or air-conditioning. For domestic hot water, the energy rejected in summer from the air conditioning system can be channeled with an alternator of heat. The same alternator can also be used in the winter or in a central heating system. However, the reduction in the efficiency of the heating system should be considered, since if a meter is not properly designed, the total consumption of primary energy in the building can increase rather than decrease.
- The system of a high efficiency heat pump for the production of hot water is examined exclusively. This meter can significantly lower the primary energy consumption for hot water while an ideal solution is possible where there is no room for boiler and/or solar installations. But this measure cannot be the best economical measure if demand is low.

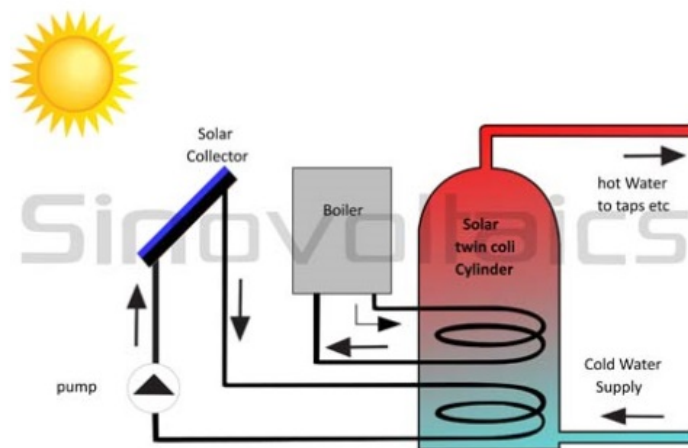


Image 37 Typical Solar Water Heater

3.4.5.1. Instantaneous Water Heaters

Using a gas burner or an electric heating coil, instantaneous water heaters are able to provide hot water after user demand. The above technology can also be combined with

tankless systems using heat exchangers. Of course, these systems, without tanks, have lower performance if boilers fail or operate without normal basis (summer months). Instantaneous water heaters are used as water preheaters and have been developed extensively as appliances of a complete installation versus conventional resistive heaters. One of the most important advantages of Instantaneous water heaters is that this technology is able to eliminate storage losses and reduce losses from piping networks considerably.

Studies carried out in 2010 at the United States, Energy and Environment Center, have shown that systems without storage tanks combined with high efficiency boilers can be up to 40% more efficient than standard water heating systems. While Instantaneous water heaters help save energy compared to conventional hot water heaters (conventional storage water heaters), they can also have quite high operating costs and high electricity consumption, making it difficult for nZEBs and the electricity grid to work. Gas instantaneous condensing water heaters (space heating) are able to offer greater energy savings and are more available in most areas of the planet. They are quite expensive, but they have high performance and low standby losses. They can cater hot water for large installations with increased hot water demand. If a hot water storage tank is required, condensing gas technologies can be used with insulated tanks.

3.4.5.2. Heat Pump Water Heaters

With the aim of further reducing the energy consumed for water heating, technology has led to the use of heaters with heat pumps. Continuously increased in popularity in international trade, heaters using heat pumps are evolving in technology, as opposed to the minimum rate of installation in the world. An example of the development of heat pumps is given by Japan, as it had annual sales of 100,000 heat pumps in 2004, and in 2011 it reached 500,000 annual sales. Heat pumps are constantly evolving in our day, such as Japanese Eco-Cute electric heat pumps, using CO₂ as a refrigerant.

3.5 Electricity Production from RES

After the introduction of all passive measures in an nZEB building, the generation of electricity for self-consumption is the solution for further reduction of the energy consumption of the building, both for the primary activities of the building and for

covering the small energy needs that can be presented. Also, in many cases, it may be the only solution to meet the renewable energy targets required by the international terminology of nZEB, since the application of renewable energy systems to heating and cooling cannot succeed the overall objective and meet the need for optimal financial implementation. Motivations have been provided by the EU for the production of electricity from RES in the framework of the regulation of energy production. The above must be taken seriously into account before making a decision. The above variables are in a position to be affected by:

- The type of establishment,
- The size of the production system,
- The proportion of energy produced and consumed in relation to the energy grid.

Therefore, we need to be able to calculate the energy profile of the building before we take hasty decisions. This estimate should be as accurate as possible in order to be able to calculate the size of the system that we will need to build so that our system meets our annual building needs, both in the long run and in real time. It should be noted that any electricity needs that are not covered by the nZEB definition should be taken seriously (external lighting, swimming pools, electrical appliances, ventilators, etc.).

At present, the most widespread system for producing energy from RES is the photovoltaics systems, either on land or on roofs of buildings. The optimum power generation and consumption can be determined largely by the type of photovoltaic system, the orientation, the capacity of the panels, etc. The application of this system has limitations of availability and suitably oriented space on the roofs of the buildings.

3.6 Co-Production

Today, we are in a position to refer to technologies that work with co-production. Some of these systems are able to deliver electricity and heat from the same source. The thermal energy is recovered from the cogeneration unit and can be used for different user needs such as space heating, domestic hot water, etc. When the above systems are able to provide cooling in space, the system is called trigeneration systems.

The performance of the co-generation systems is many times greater than conventional systems, as co-generation plants exploit the heat that would be useless with conventional electricity generating systems. The reduction in energy consumption can also be reduced if biomass or solar energy is used, compared to conventional fuels in cogeneration systems in the nZEB buildings, thus contributing to meeting the requirements and reducing the carbon footprint of the building. Cogeneration and trigeneration systems can be suitably applied to types of buildings that, due to their use, have a high demand for heating and electricity.

3.7 Lighting

In order to construct an nZEB either from zero or through renovation, it is necessary to reduce energy consumption from lighting points. More specifically, it is estimated by studies that in a building shell with good insulation, the energy for lighting the space represents about 50% (several times more than 75%) of the total consumption of the building. This energy required for the illumination of space derives from the installed power for lighting as opposed to the available natural lighting and the automation of lighting in general. Installing spotlights without creating any negative consequences for users is a basic piece of study for nZEBs. In particular for nZEB buildings used as an office, there is a specific obligation with regard to the installed power for lighting, which should not exceed $10 \text{ W} / \text{m}^2$.

The initial step in this direction is to maximize the use of natural lighting (especially in regions with little sunshine). The structure of the different sections of such a building should take seriously into account the course of the sun during the day (annually) in order to optimize natural light from the shell openings. Window openings on the southern sides of buildings are enough to increase natural lighting and overall solar gains, as opposed to openings on the northern sides that provide diffuse lighting and far fewer solar gains. The openings must be created in different directions in order to have an equilibrium effect on the levels of illumination in space. But let us not forget that the needs for lighting and solar gain vary in quantity and quality per region.

The quality, amount of distribution, for natural lighting depends on:

- The geometry of each, different space (height/width),
- The position and the surface of each opening,

- The type of glazing that is used,
- The shape of each glass.



Image 38 Natural Light Application in Museum Louvre, Abu-Dhabi

Natural light with constant intensity can be produced by wide openings, with drawbacks creating differences in the luminous intensity zones in space, all alongside – parallel to the opening side. On the other hand, high-angle (vertical) openings provide better illumination in areas with a long distance from the opening, but varying in the intensity of daytime lighting. The higher the opening, the more light it will yield to the farthest districts.

In distant, faraway areas, underground areas, areas where natural light is generally not easily reached through openings (openings cannot be created - cellars, underground, etc.), the use of artificial lighting can be reduced by installing an artificial solatube. With this technique the sunlight is trapped with a dome that is created in the building's roof and then this natural light is deposited in the position we want with the use of a reflex tube.

Another technique for the contribution of natural lighting to an nZEB building is to increase the indirect lighting of each space. This is done with selected light colors, with walls with a glossy texture, lined or coated on the adjacent surfaces of the building in order to reflect the solar radiation in the spaces. Surfaces that are colored with light colors show a fairly low absorption of solar radiation and high values in its reflection.

With dark and rough surfaces, we get the exact opposite effect. As long as we are able to exhaust all the possibilities of taking advantage of natural light from day to day, we should do a dimensioning study with the choice of appropriate light points and general light sources, always having the optimum optical visibility (not much bright effect, not too dark effect)

The choice of high energy and low consumption lamps (light bulbs) is easy, as today, all light bulbs have energy labeling. Light bulbs that include voltage transformers offer higher output, low power consumption and low energy losses from their own parts.



The use of energy to illuminate a building can be reduced by a smart energy consumption monitoring system (according to user's needs), partially automated, with the aim of consuming energy for lighting only when it is required by users to reduce consumption times. This enables users to select the quality and quantity of lighting themselves, with motion detectors, plant detectors, and light sensors. In all the above cases, automation and central control systems take into account the availability of natural lighting which varies according to the location, area, environmental conditions, weather, etc.

4. nZEB in Europe



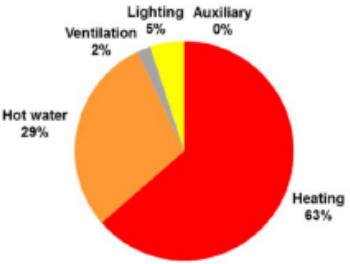
Based on the growth and the continuously acceleration of progress, it is imperative that the pilot projects for energy-efficient buildings (nZEB) are to be increased, in order to improve the building sector and constantly receive feedback with the aim of improving constructions through our experience. It is necessary to spread that these types of buildings (the most optimized types of buildings) are efficient, advanced, pioneering, technologically sufficient, supported by a multitude of technologies, economically feasible, etc. All this is done, only with continuous presentations of such buildings between designers and people in general.



Numerous examples of nZEB from around the world, in different regions, with different needs, different construction costs, different uses of buildings, etc. are available in the bibliography. These buildings have exciting design, surprising energy performance and minimal economic constraints. For the benefit of the readers of this thesis, it is necessary to present some of these technological achievements⁴⁰ at regional and national level.

⁴⁰ Selected examples of NZEBs, Hans Erhorn Heike Erhorn-Kluttig, 2014

Efficiency House Plus with E-mobility in Berlin					
Author(s):	Heike Erhorn-Kluttig, Hans Erhorn, Antje Bergmann, Fraunhofer Institute for Building Physics				
Illustration:					
	© Schwarz (BMVBS)				
Project aim:	This pilot building generates its own energy and makes it available to the users and the electric vehicles. Excess energy is fed back into the grid or stored in a battery. An annual positive energy balance is required for primary and final energy use.				
Building address:	Fasanenstraße 87a, 10623 Berlin				
Building type:	Residential	Non-residential	Public	New	Renovated
	X			X	
	Single-family house with 2 floors				
Building size:	203 m ² useful floor area (*A _N *, with A _N =0.32*V _{gross}), 138 m ² living area				
Building envelope construction:	The floor, the walls and the roof are made of timber panels filled with up to 52 cm of cellulose insulation. The windows have triple glazing. Thermal bridges have been minimised. Photovoltaic modules cover the roof and the façade. All house elements can be separated and moved to another location or be disposed of once the lifetime of the building has expired.				
Building envelope U-values:	Wall	0.11 W/m ² .K			
	Window	0.70 W/m ² .K			
	Roof/ceiling to the attic	0.11 W/m ² .K			
	Cellar ceiling/ground slab	0.11 W/m ² .K			
Building service systems:	The house is heated by a central heating system with an air-to-water heat pump and floor heating. A balanced mechanical ventilation system with 80% heat recovery and a building energy management system with touch pads are installed. The PV systems on the roof and façades generate electricity that is used by the building, fed into the grid or stored in a battery. The battery, with a capacity of 40 kWh, is made of 7,250 single second-hand battery cells formerly used in electric cars.				
Included renewable energy technologies:	The air-to-water heat pump uses ambient energy from the outside air. Two large photovoltaic fields are installed: 98 m ² monocrystalline PV modules on the roof and 73 m ² thin-film modules on the façade.				
Final energy use:	Calculated		Calculation method:	DIN V 18599, Effizienzhaus Plus-Rechner [Efficiency house plus calculator]	
	Measured	X	Monitored in year:	2012/2013	

Final energy use (cont.):	Heating	20.8 kWh/m ² .year	<p>Electrical appliances 23%</p> <p>Lighting 4%</p> <p>Ventilation + pumps + automation 25%</p> <p>Hot water 13%</p> <p>Heating 34%</p>
	Hot water	8.1 kWh/m ² .year	
	Cooling	0.0 kWh/m ² .year	
	Ventilation incl. pumps and automation	15.3 kWh/m ² .year	
	Lighting	2.6 kWh/m ² .year	
	Electrical appliances (household electricity)	14.3 kWh/m ² .year	
	Total	61.1 kWh/m ² .year	
	E-mobility	19.6 kWh/m ² .year	
	PV energy gener. thereof self-used	- 65.6 kWh/m ² .year	
	thereof fed-in	- 32.3 kWh/m ² .year	
	thereof fed-in	- 33.3 kWh/m ² .year	
	Electr. from grid	28.8 kWh/m ² .year	
	Electricity surplus	- 4.5 kWh/m ² .year	
	Primary energy use:	Electr. from grid	
Electr. fed-in		-93.2 kWh/m ² .year	Primary energy factor: 2.8 (PEF 2014)
Total		- 24.1 kWh/m ² .year	
Renewable energy contribution ratio:	107% of the total final energy		
Improvement compared to national requirements:	78%	Compared to:	Maximum primary energy use according to EnEV 2009. (Household equipment, e-mobility not taken into account. PV generated electricity accounted up to monthly electricity use).
Experiences/ lessons learned:	The test family enjoyed living in the house without having a bad conscience because of using conventional energy. As the ventilation system was not manually controlled, it introduced warm external air into the rooms in summer, which became a problem. The measurements show that the goal of the efficiency house plus has been achieved, but only 25% of the electricity used for e-mobility could be covered.		
Costs:	The costs of the house are rather high, with 1,080,000 € for construction and 566,000 € for the building service systems. This is partly due to the high ambition (plus energy) and the ability to divide the house into different materials in the event of deconstruction. There is a network of efficiency houses plus with more than 20 buildings of the same energy performance level. These houses show that the additional costs compared to a regular new building can be decreased by about 50,000 €.		
Funding:	Research program "Efficiency house plus". The Federal Building Ministry (BMUB) supports the construction of buildings which produce significantly more energy than required for their operation. The pilot projects are assessed by a scientific support program. The goals are to improve energy management in modern structures and further develop necessary building envelope and renewable energy components.		
Marketing efforts:	<ul style="list-style-type: none"> - Network of more than 20 efficiency house plus pilot projects - The house can be visited and is used for events - BMUB website includes videos, a blog by the users, actual monitoring results, etc. - Official opening by Chancellor Angela Merkel 		
Awards:	The design by architect Werner Sobek won the architectural competition for the BMUB pilot project. Case highlighted in February 2014 on EU's BUILD UP portal.		
Links to further information:	<ul style="list-style-type: none"> - website: http://www.bmvi.de/DE/EffizienzhausPlus/effizienzhaus-plus_node.html - case on BUILD UP: http://www.buildup.eu/cases/40001 - monitoring report of Fraunhofer Institute for Building Physics: link - videos: http://www.youtube.com/watch?v=mNCZxovLHRo; http://www.youtube.com/watch?v=LgLVuFWHlgM 		

Maison DOISY							
Author(s):	Marie-Christine Roger, Loïc Chery, Fabien Auriat, Ministère de l'Ecologie, du Développement Durable et de l'Energie Involved organisations: Villa Tradition, Promotelec						
Illustration:							
Project aim:	To produce a French NZEB.						
Building address:	143 avenue de la Rochelle - 79000 Niort						
Building type:	Residential	Non-residential	Public				
	X						
	Single-family house		<table border="1"> <tr> <td>New</td> <td>Renovated</td> </tr> <tr> <td>X</td> <td></td> </tr> </table>	New	Renovated	X	
New	Renovated						
X							
Building size:	158 m ² net floor area						
Building envelope construction:	The building has brick walls insulated with mineral wool on the inside. The ceiling, made of reinforced concrete, has a mineral-wool insulation.						
Building envelope U-values:	Wall	0.205 W/m ² .K					
	Window	1.45 W/m ² .K					
	Roof/ceiling to the attic	0.138 W/m ² .K					
	Cellar ceiling/ground slab	0.138 W/m ² .K					
Building service systems:	Heating is provided by a gas-condensing boiler and delivered by a floor-heating system. DHW is generated by solar thermal collectors and supported by the boiler. A single-flow ventilation system with humidity sensors was installed to maintain the quality of the indoor air.						
Included renewable energy technologies:	Nearly 4 m ² of solar thermal collectors were installed on the roof to cover part of the DHW consumption.						
Final energy use:	Calculated	X	Calculation method:	National standard (<i>méthode Th-BCE</i>)			
	Measured		Monitored in year:	-			
	Heating		20.80 kWh/m ² .year				
	Hot water		9.50 kWh/m ² .year				
	Cooling		0.00 kWh/m ² .year				
	Ventilation		0.65 kWh/m ² .year				
	Lighting		1.70 kWh/m ² .year				
	Electrical appliances (household electricity)		unknown				
	Auxiliary energy		0.15 kWh/m ² .year				
	Total		32.80 kWh/m ² .year				
	Solar thermal energy contribution		7.70 kWh/m ² .year				
Primary energy use:	Electricity	6.50 kWh/m ² .year	Primary energy factor: 2.58				
	Gas	30.30 kWh/m ² .year	Primary energy factor: 1				
	Total	36.80 kWh/m ² .year					
Renewable energy contribution ratio:	21% of the total final energy						
Improvement compared to national requirements:	21%	Compared to:	Maximum primary energy use according to RT2012 (46.90 kWh/m ² .year).				
Links to further information:	http://www.observatoirebbc.org/site/construction/fichepedagogique?building=BGJG3H#economiques						

ECOsil				
Author(s):	Gian Mario Varalda, Agenzia Provinciale per l'Energia del Vercellese e della Valsesia Architect: Gianni Carlo La Loggia Building contractor: Impresa La Loggia Giuseppe			
Illustration:				
Project aim:	The building minimises energy requirements and the remaining energy needs are covered by an innovative and efficient system, integrated with renewable sources.			
Building address:	P. Isacco 50, 13039 Trino (VC) Italy			
Building type:	Residential	Non-residential	Public	New
	X			X
	Single-family house with 2 storeys			
Building size:	185 m ² heated floor area			
Building envelope construction:	External walls are made of autoclaved aerated concrete blocks with external thermal insulation (EPS and cellulose fibre). The ground slab is created with disposable formwork for ventilated underfloor cavities; the roof has a wooden structure and is insulated with wood fibre. The windows have triple glazing and wooden frames with aluminium-clad exterior. Thermal bridges have been minimised. Solar thermal collectors and photovoltaic panels cover the roof.			
Building envelope U-values:	Wall	0.18 W/m ² .K		
	Window	1.00 W/m ² .K		
	Roof/ceiling to the attic	0.18 W/m ² .K		
	Cellar ceiling/ground slab	0.21 W/m ² .K		
Building service systems:	The heating system is based on a condensing boiler (modulating between 5 and 25 kW) fuelled by natural gas, and it provides support to the DHW also. Radiant wall panels supply heat to the rooms. The heating system includes renewable energy, with 4 solar thermal collectors and a 500 liter storage. To provide good indoor air quality, a mechanical ventilation system with heat recovery was installed.			

Included renewable energy technologies:	The solar thermal system (flat-plate solar collectors) has 9.32 m ² and covers 96% of the needs for DHW. In addition, there are PV panels (monocrystalline) with a peak power of 2.94 kW _p .			
Final energy use:	Calculated		Calculation method:	According to EU Directive 2002/91/CE, 16/12/2002. According to the Decree n. 34, 29/09/2004 of the President of the Autonomous Province of Bolzano.
	Measured	X	Monitored in year:	2012/2013
	Heating		25.81 kWh/m ² .year	<p>A pie chart illustrating the distribution of final energy use. The largest portion is Heating at 60% (red), followed by Lighting at 36% (yellow), and Hot water at 5% (orange).</p>
	Hot water		2.05 kWh/m ² .year	
	Cooling		0.00 kWh/m ² .year	
	Ventilation		in use but not measured	
	Lighting		14.88 kWh/m ² .year	
	Electrical appliances (household electricity)		unknown	
	Total		42.74 kWh/m ² .year	
	PV generated electricity		~ 3,200 kWh/year 17.32 kWh/m ² .year	
Primary energy use:	Total		23 kWh/m ² .year	
Renewable energy contribution ratio:	67% of the total final energy			
Improvement compared to national requirements:	80%	Compared to:	Heating energy consumed by traditional building, according to the CASACLIMA certification.	
Experiences/ lessons learned:	The family living in the house is very satisfied with the energy performance of their dwelling. The energy bill has been very low, so it demonstrates that the goal has been achieved.			
Costs:	The final cost of these buildings was 350,000 € each, which represents a 25% cost increase compared to a similar building using traditional solutions.			
Funding:	As this project was partially financed by the Piedmont Regional Administration with a 50% refund of the additional costs, the impact of such costs was significantly reduced.			
Marketing efforts:	These low-energy buildings were designed and built according to the Bolzano CASACLIMA protocol and they obtained the official CASACLIMA golden certification for the first time in the territory of the Province of Vercelli. Since 2010, the buildings have been visited by architecture students.			
Awards:	The house received CASACLIMA A classification, which refers to buildings with a heat consumption of less than 30 kWh/m ² .year. The project was illustrated in the KlimaHaus n. 2 April 2011 magazine, and it has won first prize in the 2013 Best Practice S.A.E.E. contest organised by ValoreClima of the Province of Vercelli.			
Links to further information:	http://www.architettologgia.it/ http://europaconcorsi.com/projects/242014-Gianni-Carlo-La-Loggia-ECOsil http://www.agenziacasaclima.it/it/rete-casaclima/la-rete-casaclima/casa-eco-sil-2/111-11045.html http://www.consorziouniver.it/it-IT/news-eventi/i-vincitori-del-concorso-best-practice/			

5. Designing nZEBs in Greece - The Role of The Building Envelope

According to the 2010 Energy Performance of Buildings Directive (EPBD), new buildings are required to follow the path of nearly zero energy buildings (nZEBs) construction standards by 2020. Of course, a strict definition of what is nZEB from the legal framework of European integration is yet to be determined. It is clear, that the basic principles of these buildings are to reduce their energy requirements to a minimum and to meet the energy needs of residents / users to the greatest extent possible from renewable energy sources. The study has focused on the optimal reduction of energy needs in a typical building in Greece. A standard, model building was designed and studied in different parameters. The impact of several, different parameters (insulation, openings, shading, and photovoltaic energy) were studied and evaluated. The same building was used for the four climatic zones of Greece (according to K.E.N.A.K.) and was evaluated under dynamic simulations for the determination of energy requirements. Optimal and more constructive solutions for the different climatic zones are based on different combinations of several parameters. The microclimate study and the more accurate and more detailed calculation of the parameters are able to save 30% of energy and reduce the energy consumption of the building to less than 50 kWh / m².

More than 40% of energy consumption comes from the construction sector, as well as about 37% of CO₂ emissions in the EU. EU Directives EPBD 2010 and EED 2012 determine the largest part of the legislative framework for reducing the energy consumption of buildings. Under the EPDB, it is stipulated that all new buildings in 2020

should be nZEBs. A strict definition of the NZEB is simply excluded, but the directive is able to identify the basic concepts of such a building by providing flexibility for each Member State to improve and implement it in national law.

High energy performance and near zero consumption are achieved according to the EPBD directive. Low energy consumption must be largely achieved through the use of renewable sources including renewable energies on-site or in the nearby area. As has been said for Europe, **in Greece, the building sector is responsible for 34% of the total energy consumption** according to the Technical Chamber of Greece. **Building sector represents 67% of the country's total energy consumption and contributes 43% to CO₂ emissions.** The energy upgrade of the construction sector in Greece is considered to be necessary. Alignment with the European Directives mentioned above, has led to the issuance of the Energy Performance Regulation to the Building Sector (K.E.N.A.K.), which is in essence the European Union's EPBD Directive, applicable to the Greek standards. The strict definition of nZEB, as in the rest of Europe, is certainly not defined in Greece.

The ever-increasing reconstruction, increasing energy efficiency and the ongoing climate change in the country makes nZEB a promising solution for green growth, sustainability and energy sustainability and safety in the energy sector. The study is not only about the role of the envelope of a building to achieve all of the above. Parameters that greatly affect energy efficiency were examined, a building model was developed to study energy requirements by location / climate zones and results with promising solutions for energy savings were analyzed extensively. The direction towards reducing energy consumption in buildings is the first and probably the most important step in achieving long - term goals in the region of Greece, as the country is able to cover the largest part of its energy needs (if there is a proper structure) from RES.

5.1. Exploitable RES in Greece

The energy production in Greece in 2014 was a total of 50,380 GWh. The dominant fuel used is lignite with RES to follow by 22% of the energy production. Greece in the effort

to develop RES in order to tackle climate change and save natural resources has set a target of 20% of the energy produced by 2020.

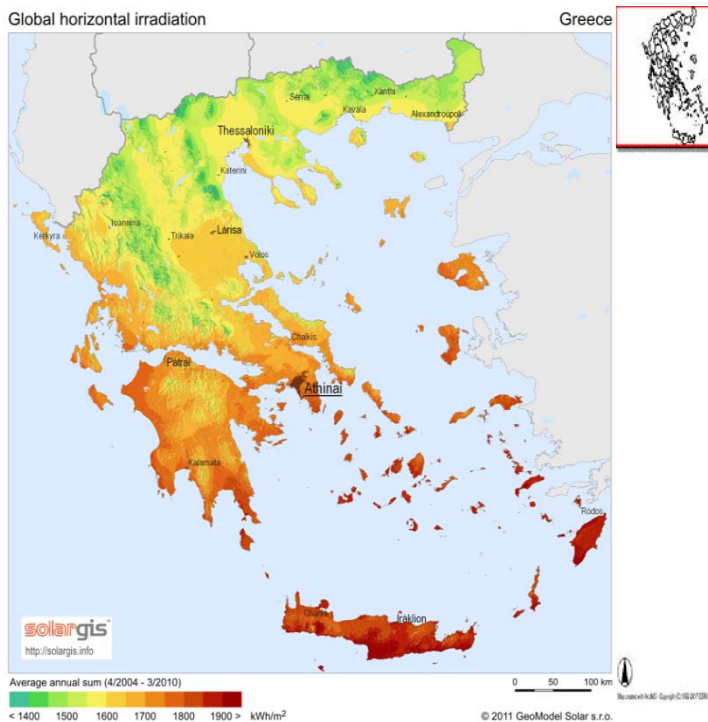


Image 40 Solar Energy Potential in Greece

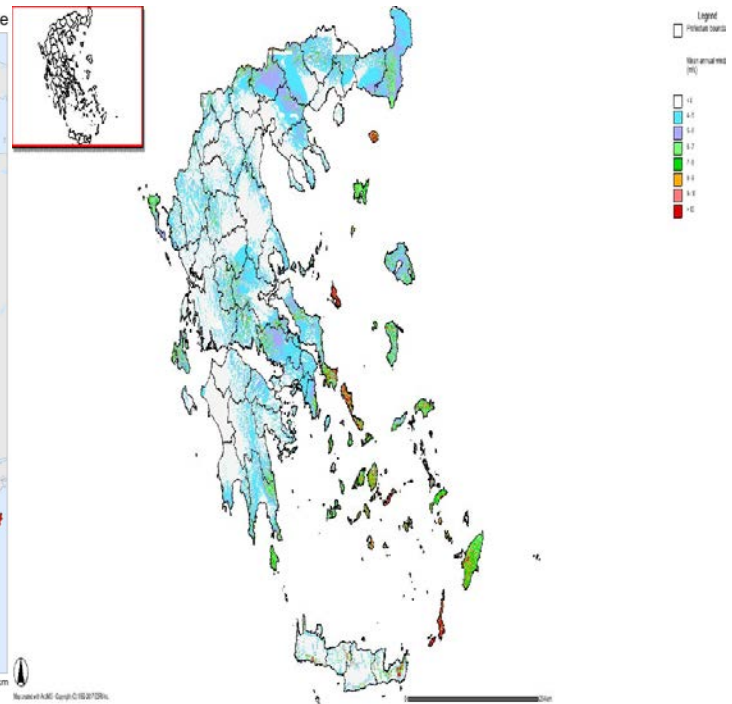


Image 39 Wind Energy Potential in Greece

As we see from the maps mentioned above, Greece is at a point that can combine many, alternative, forms of energy sources. In particular, it is of interest for this study, to take serious into account the irradiation maps for solar systems, at least for a start, as we have mentioned above, it has several possibilities as a country⁴¹.

5.2. Climate Zones in Greece

The climate in Greece is considered to be Mediterranean and is composed of mild and rainy winter days, relatively warm and dry during the summer days. Greece due to its geographical area and climate has been creeping through periods of sunshine throughout the year, even in the winter. Greece is located in the south - eastern part of Europe (34° and 42° parallel N., with a meridian range of 19° to 28° E). It is surrounded by sea on 3 of its 4 sides.

⁴¹ Greece offers, due its geological conditions, a **promising potential for geothermal utilisation** of its subsurface matter. Geothermal sources and flows are known, but steps have been taken, only by direct use of these sources, such as for greenhouse heating. No steps have been made implementing into the Greek Energy Power Supply. Nevertheless, sufficiently high enthalpies are present to utilize the geothermal potential indirectly to produce electricity. The hydropower potential includes processed results from CRES's measurements of flows for streams with exploitable water flows or measurements that have been performed from other relative offices (PPC, Ministry of Agriculture, Ministry of Public Works and Environment). Results constitute the theoretical **small hydro potential** and are the basic input for all calculations.

The climate of Greece is dominated by a large variety of microclimates, all within the Mediterranean climate⁴², which microclimates can play a major role in the energy development of the site. The phenomenon of microclimates is due to the influence of the topography of the country relative to the masses of air coming from the sources of humidity of the central Mediterranean, changing the microclimate. Thus, the weather in Greece encompasses many, different variants, from the dry climate of the capital, Athens, to the wet climate of northern and western Greece.

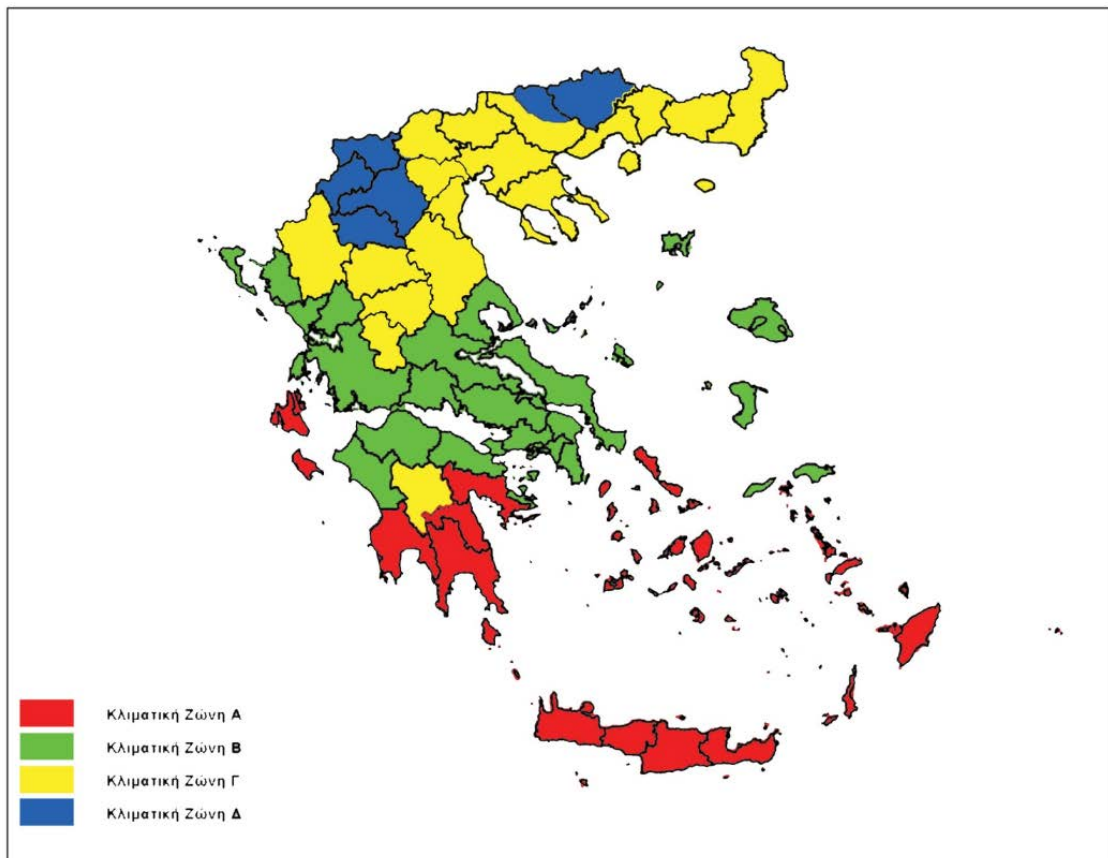


Image 41 Climate Zones in Greece, According to K.E.N.A.K.

Based on climatic reasons, the year in the wider region of Greece can be divided into 2 main seasons. A season, more cold and rainy (October ~ March) and another more warm and dry (April ~ September). The coldest months of the first period are January and February with minimum temperatures between 0 ~ 10 degrees Celsius, depending on the area. Constant rainy days in Greece are considered rare, even during the winter season, where the sky is not clear. Rainy and cold days of winter are often interrupted by sunny days (e.g. Halcyon days). The winter season is much softer in the islands of the Aegean and the Ionian compared with northern, mainland and eastern Greece. The

⁴² <https://rizosdimitris.blogspot.com/2012/01/4.html>

summer season is stable with warm and dry seasons, clear sky, bright and warm sun, without rainfall. However, this does not prevent the occurrence of short and rapid rains / storms in the part of mainland Greece. The warmest and driest period of the country is at the end of July and the beginning of August with maximum temperatures of 30 ~ 36 degrees Celsius. During the hot and dry season in Greece, high temperatures decrease more in coastal areas, from the sea breezes and from the northern winds to the mainland and the Aegean.

5.3. Properties Of The building – Model Building

The designed model building is representative of the Greek residential average structure. For the purposes of defining the typologies and materials of the model building, the official data from the 2011 population-homes census provided by the Hellenic Statistical Authority (ΕΛ.ΣΤΑΤ.) were used. The composition of the architecture was aligned with the basic principles of energy-saving construction (passive house design).

A two-story detached house with a basement and a roof terrace is the model building (Image 42). The structure of the load bearing is made of reinforced cement. The total area of the house's residential areas is about 180 m² and corresponds to a house that is designed to accommodate a family of four. The building's main facade faces south.

The modular building elements have been designed and comply with its minimum requirements according to the Hellenic Energy Performance Regulation in the Building Sector, (Κ.Ε.Ν.Α.Κ.). The isolation layer is placed on the outside of all construction elements. **The insulation layer has been calculated in such a way as to meet the minimum requirements of the regulations with the thermal transmission U-value of each building element.** For most elements of a **vertical structure** (shaving walls, infilling walls, columns) **the thickness of the insulation is 8 cm and the balcony floor (ground and non-heated spaces) is 5 cm.** The selected insulation material was **polystyrene expanded**, which is the most common material in Greece for insulation.

The opening type also corresponds to the most widely used type in Greece and complies with the regulations' minimum standards. Aluminum frame with thermal break and double glazing are available for all openings in the model building. The heat transfer of

$U_f=2,799 \text{ W / m}^2\text{K}$, $U_g=1,793 \text{ W / m}^2\text{K}$ and the solar heat gain (SHGC) was calculated by **0,595** for the **frame and glazing**.

The Design Builder software was used to run dynamic hourly simulations and define building energy requirements. The model building was initially designed in the software's 3d drawing interface and the input data was set for all simulations. The profile was calculated at 16 hours a day, 7 days a week and 12 months per year for a typical residential building. The occupation rate for the particular area of the model building was **0,016 people / m²**, which corresponds to **4 people**. The winter and summer **comfort temperatures** were determined at **20 °C and 26 °C**, **natural ventilation** was determined at **4,17 liters per person** and **infiltration rates** were at **0,7 ac / h**. In addition, a simple simulation HVAC system includes a heating oil generator (**PR=0.935**) and a **cooling air conditioned unit (EER=3.000)**. All input information was defined according to the Hellenic regulatory standards.

Greece is divided into four different climates according to the regulation of Hellenic countries, according to the number of days of heating. In all four climate zones in Greece, the model building was examined. The climate data files for each climate zone were thus used for simulations in a representative city. **Heraklion, Athens, Thessaloniki and Kozani** are the cities whose climatic records have been used and they are corresponding to climate areas (A, B, C and D).



Image 42 Perspective drawing of the model building

INSULATION LAYER THICKNESS AND U-VALUE OF THE BUILDING ELEMENTS IN ALL CLIMATE ZONES OF GREECE				
Building Elements	Zone A, B, C		Zone D	
	Thickness	U-value	Thickness	U-value
shear wall	8	0,377	8	0,377
wall	8	0,337	8	0,337
wall adjacent to ground	5	0,581	5	0,581
floor over ground	5	0,565	5	0,565
terrace	8	0,376	9	0,34
floor over non-heated space	5	0,51	5	0,51
balcony floor	8	0,338	9	0,338

Table 1 Insulation layer thickness / u-value of the building elements

The energy needs of the model building, which were designed on the basis of the minimal regulatory requirements, were calculated primarily in each climate zone. In order to minimize the energy requirements of the building in every climate zone, a series of simulations where various parameters were differentiated, were conducted. The parameters examined relate especially to the isolation layer, the openings and shading devices of the building envelope.

The density of the isolation layer has been first examined and its impact on the energy demands of the building. Polystyrene is expanded into the typical insulation material used in Greece. The insulation layer in the model construction, as described above, starts at 8 cm for all vertical building elements and the flat terrace, following the minimum standards of the Hellenic rules. Each simulation gradually reduces the U-value of building components, as the isolation layer thickness increased every 2 cm until the final thickness was checked by 20 cm. The simulations only distinguished the thickness of the vertical construction elements and of the terrace.

A new type of isolation was the second parameter to be investigated. For using Vacuum Insulation Panels rather than conventional insulation materials, energy requirements of the building were calculated. Substantial thermal conductivity ($\lambda=0,007$ W/mK) and low thickness 5 cm³ are characterized by vacuum insulation panels.

In addition, two more types of openings with energy efficiency have been tested. The type of apertures examined dispose of less thermal frame and glazing transmission as well as a lower coefficient for solar heat gain (SHGC).

Finally, the impact of shading devices on the building's energy performance was investigated. On the southern facade of the building were placed horizontal aluminum overhangs, while on the western and eastern facades, louver panels with high reflectivity blades.

Two different protocols tested the louvres:

- The blades were always steady at an angle of 45°.
- The blades were adapted from users.

Every separate parameter was investigated and comparable to the model building constructed according to the minimum standards of the regulation, as well as all potential combinations of the parameters. Table 2 presents briefly the 12 different scenarios.

Scenario	
Scenario 0	Model Building - Insulation Layer 8cm
Scenario 1	Insulation Layer 10 cm
Scenario 2	Insulation Layer 12 cm
Scenario 3	Insulation Layer 14 cm
Scenario 4	Insulation Layer 16 cm
Scenario 5	Insulation Layer 18 cm
Scenario 6	Insulation Layer 20 cm
Scenario 7	Vacuum Insulation Panels (VIP)
Scenario 8	Opening Type 2 / $U_f=2\text{W/m}^2\text{K}$ / $U_g=1,269\text{ W/m}^2\text{K}$ / $\text{SHGC}=0,419$
Scenario 9	Opening Type 3 / $U_f=1\text{W/m}^2\text{K}$ / $U_g=0,719\text{ W/m}^2\text{K}$ / $\text{SHGC}=0,385$
Scenario 10	Overhangs
Scenario 11	Overhangs + louvres (user operated)
Scenario 12	Overhangs + louvres (steady)

Table 2 Scenarios Examined

5.4. Photovoltaics on Roof and Energy Consumption

Referring to photovoltaics (PV)⁴³, we mean devices that are able to convert light energy into electricity using semiconductors that exhibit the photovoltaic phenomenon. We are referring to a phenomenon that is studied by physic, photochemical and electrochemical factors.

Solar panels are used by typical photovoltaic systems. Each typical photovoltaic consists of a number of cells that generate electricity. Photovoltaic system installations can be installed on the ground, on roofs, or even on walls. The mounts of these photovoltaic systems can be either fixed or use a solar tracker to follow the direction of the sun.

Solar PV has several advantages as a form / source of energy:

- The construction and operation of such systems does not create pollution and greenhouse gas emissions.
- As far as energy needs are concerned, photovoltaics show simple scalability and silicon as a basic component is present in large quantities on the earth's crust.

There is of course a significant disadvantage with regard to photovoltaic systems, that is, the output power of such a system is directly dependent on direct sunlight, so **about 10 ~ 25% of energy is lost if no sun monitoring / tracking system is used**. Cells lose their orientation if they do not regularly follow the direction of the sun. **Another disadvantage is that dust, clouds, and many other elements in the atmosphere can reduce the output power of the photovoltaic system**. An important issue is the **concentration of power generated during the hours corresponding to the main insolation of the energy grid**, which are usually inconsistent with the spikes of demand for energy from human activity. If current energy demand and consumption patterns do not change and adapt to such scenarios, electricity should obviously be stored and remain active for future use.

The photovoltaic systems have been used for a long time in more specialized applications, and in recent years we have seen the autonomous and grid-connected

⁴³ <https://en.wikipedia.org/wiki/Photovoltaics>

photovoltaic systems (1990 and onwards). A massive expansion in the photovoltaic systems markets took place around 2000 when Germany issued funding for about 10,000 roofs for photovoltaic mounting.

Technological advances in the sector and the increasing speed of construction have drastically reduced the cost, reliability and efficiency of such facilities. Governments that provide financial incentives such as net metering and feed-in tariffs for photovoltaic systems, have further strengthened the power of photovoltaics in the power sector. **Today, more than 100 countries are now using photovoltaic systems around the globe.**

Photovoltaic is now the third strongest form of renewable energy behind hydroelectric and wind power. More than 300GW installed photovoltaic power was available by the end of 2016, thus covering about 2% of global energy demand. The largest derivative of photovoltaic systems remains Germany with China, Japan and the United States following up closely. Photovoltaics are able to recover the energy required for their construction in 1.5 years in southern Europe and 2.5 years in the northern part of Europe.

6. Results of the Designed Building in Different Locations

This thesis presented the potential to minimize the basic energy requirements / demands of a building in different zones of Greece in order to achieve a total energy reduction and buildings of almost zero consumption. The dynamic analysis with simulators that have been made, indicate that the increased thickness of insulating layers is the optimal solution aiming the reduction of total energy requirements of a four - person family building. In addition, an economical and flexible solution is the application of openings in the building with thermal characteristics. Another solution is the on-site shade of the building, which leads to energy savings in the hottest climatic zones. The use of innovative insulating materials with fairly low thermal conductivity and permeability (VIP) creates a fairly new solution that combines energy efficiency and aesthetic results. Lastly, as mentioned, the use of photovoltaic in the roofs for self-consumption, net metering, etc. can quite increase the energy performance of a building.

Greece composes a complex climate map that is able to lead us to the construction of near zero energy buildings. As mentioned, Greece has an eco-friendly climate that gives us access to a variety of RES that can be exploited / used appropriately, for different energy demands that prevail. A milestone that is presented is the requirement for heating and cooling during the most time of the year. From the results, we are able to understand that **the demand for energy is directly linked to different factors, directly affecting the energy performance of a building**. For a detailed survey of parameters, it is necessary to finalize a large set of parameters and to determine the

right combination of parameters so that we will be able to optimize the energy needs at different locations, depending on the microclimates of each region, thus achieving a step closer towards nZEB buildings.

6.1. Energy Results & Criteria

The energy demands from each simulated scenario were compared with the energy demands of a model building designed on the basis of the Minimal Standards of the Hellenic Energy Performance Regulation (K.E.N.A.K) in the building sector. The climate zones are recalled to come down from the warmest to the coldest, where zone A is the warmest one and zone D corresponds to the coldest one.

The results suggest that **an increase in the thickness of insulation layers of conventional materials like expanded polystyrene significantly reduces the building's heating demand.** In conjunction with the increase in the thickness of isolation, the cooling demand of a residential building for a low occupancy is negligible. The thickness increases can be a straightforward, efficient solution, for cold weather zones like zones C and D. Simulation findings suggest that the annual total energy demand of the buildings in cold climates zones C and D decreases by 13.65% / 11.77% and 13.12% in climate zones A and B by 20 cm of insulation layer of convective materials (Expanded Polystyrene).

Innovative Vacuum Insulation Panels (VIP)⁴⁴ are a significant contributor, according to the simulation results, **to decreasing building heating and cooling demands compared with conventional insulation products.** For the warm-climate zone A and the remaining three climatic areas in Greece, a total annual energy savings were estimated at 13.56% (with approximately 15.69%). In addition, VIP has the additional benefit of the thin layer of isolation, which ensures an elegant construction while ensuring high efficiency. The results of the simulation of better opening types suggest that low SHGC openings have a significant effect on the reduction in cooling demand. **Solar heat gain affects the amount of solar radiation that inserts the building interior and thus reduces SHGC's solar gains, which is considered beneficial in warmer zones,** such as zones A and B. For example, two better types of openings reduce the total annual energy requirement of construction in the warm

⁴⁴ https://en.wikipedia.org/wiki/Vacuum_insulated_panel

climate zone A by 8.46% and 10.83% respectively, whereas the same type of opening only contributes by 2.61% and 4.67% to the building's energy saving in the cold climate zone D, respectively.

The shading devices have shown that they are extremely favorable for warm climate zones, because they significantly reduce solar gains and consequently the building's cooling demand. Results showed in warm climate zone A that shading systems can save 8.63% energy as the only solution. Shading devices, however, contribute to the heating demand surcharge. This will only be beneficial if the cooling demand is decisively important for total energy consumption in warm climate zones A and B. On the contrary, the shading equipment surcharges the total annual energy demand of the building for cold climate areas C and D, in which cooling demand represents a small proportion of total energy requirements. In the coolest climate zone D, it was characteristically established that shading devices supplement the total annual building energy demand by 1.05%. **It should be noted that the louvres with steady blades proved more efficient than the ones operated by users, probably because the users followed an inappropriate schedule.**

The series of simulations last but not least showed that the parameters for each climatic zone are combined to optimize the building's energy savings within a single zone. Only the **use of improved opening types and shading devices on the building's facades can save up to 14% of energy** in the warmest climate zone A. The remaining three colder climate zones can **result in energy savings of up to 30% by increasing the layer thickness of the isolation to around 20 cm and by using more efficient opening types and shading devices.**

Climate Zone	Annual Energy Saving (%)	Annual Energy Consumption (kWh/m ²)
A	14	29,05
B	24	41,07
C	20	55,23
D	30	55,25

Table 3 Total Annual Energy Savings and Energy Consumption Based on the Optimal Combination for Every Climate Zone

6.2. Organic Photovoltaics (OPV)

Photovoltaics (PV) are a promising renewable energy technology to address the challenges of sustainability. The reduction in PV module costs and higher home energy prices have made more financially attractive the consumption of PV-generated electricity than grid exports. **Organic photovoltaics (OPV)⁴⁵ are an emerging thin film photovoltaic technology that is promising environmental and economic performance** of PV technology will be significantly improved. Previous studies estimated the cost of current and future OPV technology, but in real market conditions and especially under the self-consumption schemes, the attractiveness of investment in OPV systems was not evaluated. In this study, we study self - consumption of electricity from conventional and organic PV systems in households.

Photovoltaic solar (PV), one of the most promising technologies in the race for climate change, is seen globally. In the European context, in spite of the challenges in the operational management associated with the large scale penetration of the residential and industrial energy source, the integration and load management of energy storage and electric vehicles by active end-users, **photovoltaic systems will be key players in improving the energy performance of the building sector (Directive 2012/27/EU).**

In recent years, ever declining PV module costs have brought financial attractiveness to self-consumption of PV power as well as higher residential electricity prices and decreasing feed-in tariffs than to exports to the grid. However, the cost of electricity generated by PV is still not sufficiently low to compete on the electricity market, but reliant on government support with self - consumption and net metering systems. If electricity production technologies such as fossil fuels and wind power are to compete on the market, further cost reduction is needed. Following these trends the self-consumption of PV electricity and its economy as in PV only systems or in combination with the batteries have been assessed by a growing number of recent literature studies.

The emerging thin film PV technology, organic photovoltaics (OPV), offers the promise of greatly enhancing the environmental and financial performance of PV technology. In order to absorb light and convert light into electricity, OPV uses abundant, non-toxic organic molecules or polymers, and usually consists of multiple layers, which are placed

⁴⁵ https://en.wikipedia.org/wiki/Organic_solar_cell

under low-energy plastic foils, high-performance and coating print. Previous studies, such as pilot-wide OPV solar parks installed in Denmark and a portable solar charger, HeLi-on, have demonstrated applications in OPV technologies. OPV technologies showed the potential of lower environmental impacts over conventional PV silicon based technologies in terms of environmental impacts, ranging from 32% ~ 98%, depending on the category of environmental impact (i.e., climate change, acidification, human and environmental toxic effects, etc.).

Because of shorter lives and lower power converting efficiencies, up to now OPV module cost could not compete at the market stage. Preliminary cost estimates and calculated cost targets and financial indicators were the focal point of early OPV economics studies. Recent studies estimate the cost of commercial production on the basis of real pilot - scale data. In particular, *Machui et al.*⁴⁶ estimated that the cost of OPV modules could reach 0,05 ~ 0,6 € /W_p, under industrial processing (depending on the efficiency, choice of material and structure achieved), thus outperforming traditional photovoltaic technologies. *Gambhir et al.*⁴⁷ also showed that the OPV estimates are very similar in terms of leveled electricity costs (LCOE) to established PM technologies, while the more optimistic estimates showed that OPV costs can be more than 50% lower than the costs associated with established PV technologies. **Although previous studies have evaluated and compared OPV costs to costs associated with established PV technologies, until now the appeal of investment in OPV has not been investigated under the real conditions of the market.**

Another aspect that will be examined in this study is to examine this matter and assess the competitiveness of current and potential future OPV systems installed under Greece's current self - use schemes on household roofs with a 20-year investment period. The country has an interesting case because it offers various settings (e.g. availability of solar energy, etc.) as explained in the essay. Although the study focuses heavily on OPV systems, the methodology developed and the detailed analysis of regulatory and market frameworks for PV are generic and applied to all PV technology.

⁴⁶ Machui F, Hösel M, Li N, Spyropoulos GD, Ameri T, Søndergaard RR, et al. Cost analysis of roll-to-roll fabricated ITO free single and tandem organic solar modules based on data from manufacture. *Energy Environ Sci* 2014;7:2792.

⁴⁷ Gambhir A, Sandwell P, Nelson J. The future costs of OPV - A bottom-up model of material and manufacturing costs with uncertainty analysis. *Sol Energy Mater Sol Cells* 2016;156:49-58.

6.3. Greek Regulatory Framework for PV self-consumption

Greece has plenty of solar energy sources (1700 kWh / m²) and is a part of southern Europe. Greece has not yet made full use of its potential for integration of wind and solar energy in terms of renewable energy. Greece has relied on attractive feed-in-tariff schemes in the past years in the context of PV regulatory framework to encourage the adoption of photovoltaic systems. PV regulatory frameworks in the country currently focus on supporting the installation of self-consumption PV systems for photovoltaic electricity that allow consumers to lower their electricity bill costs. In particular, net metering schemes exist under which overproduced electricity can be exported to the grid and credited to the consumer for consumption at another time when PV generation is not sufficient to cover the consumption of electricity. Greece has a period of 1 year to network photovoltaic and electricity generation. Excess electricity exported to the grid following netting is not compensated. The HEDNO⁴⁸ (Hellenic Electricity Distribution Network Operator) distribution grid operator in Greece has an administrative role.

6.4. Modeling of PV System Electricity Flows

A model was developed to simulate electricity flows with a self-consumption PV plant at an average residential electricity consumer. For a typical year, time series data sets were developed on electricity consumption and solar radiation values and used as inputs for the model. For **the modeling of electricity flows, during the 20-year time horizon (2017 ~ 2036) of the OPV system model the same type of year was assumed and replicated.** The electricity consumption data for Greece were modeled on 15-minute load profiles which consist of average consumption data of an average 29 residential consumers in the various areas of various years. The solar irradiation profile (**1700 kWh / m² annual irradiance level**) was derived from the EU Geographic Information System for Photovoltaics. As representative of one - family households in Greece with no electric heating, **electricity consumption was assumed at 4000 kWh / year.** In calculation of the electrical generation from the OPV system, the solar irradiation data were used for the horizontal plant system, a range of installed capacity value from 1 to 10 kWp (typical residential PV system) and an 80% performance ratio (PR):

⁴⁸ <https://www.deddie.gr/en/>

$$\text{PV generation} = \text{irradiation} * \text{installed capacity} * \text{PR}$$

The time series of data sets on generation and consumption of electricity were compared on a time-scale (15 min for Greece) to simulate the flows of electricity. Two simple rules have been followed in this comparison:

- if generation of PV was less than consumption, the grid deficit was imported,
- the PV was exported to the grid if the production of PV was higher than consumption.

On this basis, over one typical year (i.e., every year within the period 2017 ~ 2036) the total amounts of self - consumed PV generation and imports and exports were calculated. This also enabled the self - sufficiency (SS) calculation, which is a common metric used to explain how PV generation can cover the electricity requirements of its installation site and is defined as the proportion of the self - consumed PV production to the consumption of electricity over an annual period. The field of independence was broadened in our present study to provide **regulatory and economic perspectives, covered not only the physically self-consumed generation of PV, but the total amount of photovoltaic power generation equal to power consumption in the net period of one year**. Therefore, self – sufficiency has been calculated in this study based on:

$$SS = \frac{\text{generation equal to consumption during netting}}{\text{consumption}}$$

6.5. Calculation of Gross Electricity Bill Savings from PV self - consumption

In this phase, gross bills of electricity (excluding the cost of the PV system) were calculated as the difference between the PV - free household and the PV - free household over the investment period of 20 years. This was a generic calculation for all PV technology.

Electricity Bill Components	Tariffs / Fees in 2017	Tariff / Fees between 2018 and 2036
Electricity Supply Charges		
Subscription fee	4,80€ / quarter	Annual Increase by 2% Following inflation
Electricity Tariff	0,0946€ / kWh	Annual Increase by 2% Following inflation
Regulated Charges		
Transmission Grid Fee	0,13€ / kVA / year	Annual Increase by 2% Following inflation
Transmission Grid Tariff	0,00527€ / kWh	Annual Increase by 2% Following inflation
Distribution Grid Fee	0,54€ / kVA / year	Annual Increase by 2% Following inflation
Distribution Grid Tariff	0,0213€ / kWh	Annual Increase by 2% Following inflation
Services of General Interest	0,00699€ / kWh	Annual Increase by 2% Following inflation
Special Duty for Renewables	0,02477€ / kWh	Annual Increase by 2% Following inflation
Other Charges	0,00007€ / kWh	Annual Increase by 2% Following inflation
Duties & Taxes		
Special Consumer Tax	0,0022€ / kWh	Annual Increase by 2% Following inflation
Special Duty	0,50%	0,50%
Value Added Tax	13%	13%

Table 4 Electricity Bill Components, Tariffs, Fees for Residential Electricity Consumers with/without PV Self-Consumption in Greece (25kVA)

Table 4 for Greece, describes the electricity billing components, tariffs and various types of charges:

- electricity generation costs payable to the power supply company under competitive market conditions,
- transportation and distribution charges corresponding to electric power grid costs,

- other charges, including state taxes such as VAT, financing of support schemes for renewable energy, etc.

The '*Special Duty*' was calculated on the basis of total (before VAT) fees, excluding the '*Special Duty for Renewables*', for a household in Greece and the VAT was computed on the basis of the total fees, excluding the '*Special Duty*'. The electricity tariff was calculated on the basis of net electricity imports in the case of PV self-consumption, general interest services were calculated on the basis of the electricity consumption (i.e. 4000 kWh / year). Moreover, all of Greece's tariffs and charges, except the '*Additional Charges*' as in previous studies, were assumed to increase every year after the inflation rate, as assumed by the inflation rate of 2 %.

6.6. Net Present Value (NPV)

The Net Present Value (NPV) method was used to evaluate the cost-competitiveness of OPV. In finance, the NPV is a means of assessing the profitability of an investment by calculating the current value of future cash flows (returns) and cash outflows (costs) over the investment period. The first capital costs of the acquisition and installation of OPV system and the cash inflows of an annual power bill savings over the 20th life time of OPV system were calculated in this study:

$$NPV = \sum_{\text{year}=1}^{20} \{(\text{bill savings}_{\text{year}}) / (1 - \text{real DR}_{\text{year}})\} - \text{OPV system costs}$$

The actual discount rate (DR) was calculated on the basis of the following equation, which assumed the nominal 5% discount rate and the inflation rate estimated during the investment period. The inflation rate for Greece was considered to be similar and equal to 2 %:

$$\text{real DR} = \frac{\text{nominal DR} - \text{inflation rate}}{1 + \text{inflation rate}}$$

If the NPV outcome was good, the investment would be profitable and would lead to a loss if not. The highest (positive) NPV result was achieved after calculating the NPV of OPV systems for the range of 1 ~ 10 kWp capacity.

6.7. Self - Sufficiency of Residential PV Systems Installed in Greece

Figure 3 shows the self - sufficiency ratios obtained under the existing regulatory frameworks and installed in Greece for a residential PV system operating under the Greece's scenario. The autarky ratios in Greece varied from 34 to 100% depending on photovoltaic capacity.

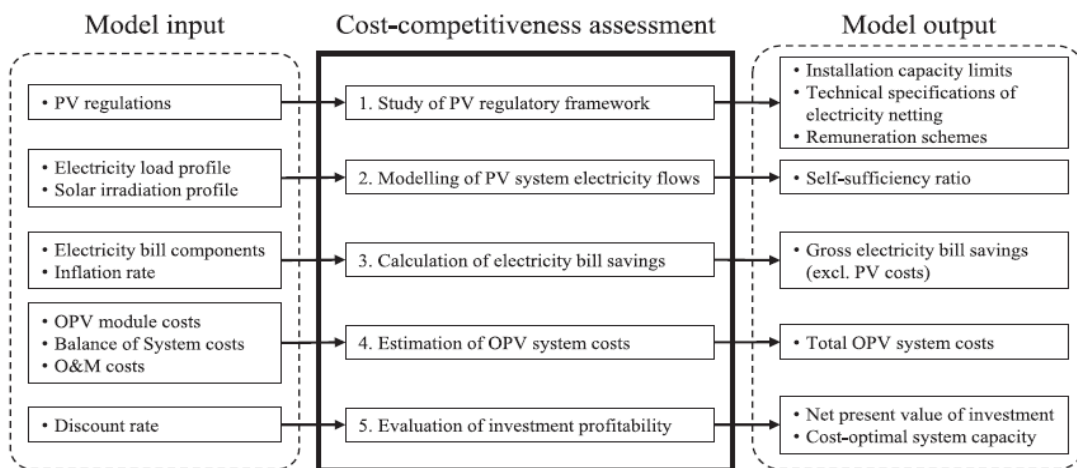


Figure 3 Steps taken and key model input and output to assess the cost-competitiveness of OPV self-consumption

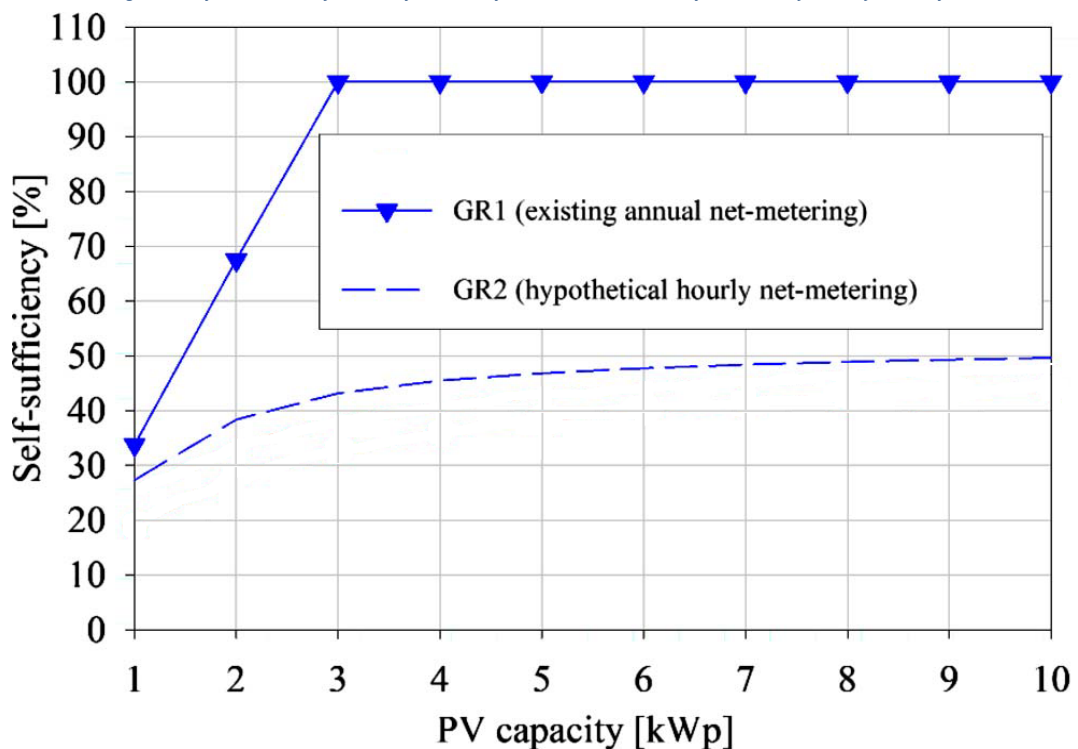


Figure 4 Self-Sufficiency Potential of Residential PV Systems with a 4000 kWh/y Electricity Consumption in Greece

We calculated the self - consumption curve by simulating a hypothesis setting of a netting period of 15 minutes for a discussion on the impact of different grid periods (see Figure 2). In this hypothesis, the Greek curve is between 27% ~ 50% self - sufficient, thereby confirming the important influence of the net - metering framework. The literature has produced similar results.

For example, the self - consumption of residency photovoltaic systems installed in multiple European countries with a netting period of 15 minutes has been calculated by *Quoilin et al*⁴⁹ and average self - consumption ratios of around 35% for Greece and 30 ~ 37% for six countries considered (including Romania, Denmark, Italy, Portugal and France). Instead of calculating the autonomy of residential consumers for a variety of PV capacity, *Quoilin et al.* have considered only systems with an annual PV generation ratio of 1:1 to annual consumption. For this study to be compared, the PV system corresponds to a self-sufficiency value of 39% at a capacity of 3kWp capacity for GR2 in order to offer a comparison to this study (a direct comparison to the auto - sufficiency performance calculated in Greece based on the current netting year is calculated). So there is a relatively good agreement, although with a less extensive, between our findings and those found by *Quoilin et al.*

6.8. Gross Electricity Bill Savings from PV Self - Consumption

This section provides a technologically neutral perspective for the major savings in energy bills (e.g. excluding of photovoltaic systems cost) from photovoltaic self - consumption in Greece. Figure 5 shows the results calculated as the proportion of the savings on the NPV from bill of electricity excluding the costs for the PV system for the electricity bill for a period of 2017 ~ 2036. As shown in the Figure 5, savings from residential PV systems in gross electricity bill reach 75% in Greece for a 10kWp PV system.

⁴⁹ Quoilin S, Kavvadias K, Mercier A, Pappone I, Zucker A. Quantifying self-consumption linked to solar home battery systems: Statistical analysis and economic assessment. *Appl Energy* 2016;182:58–67.

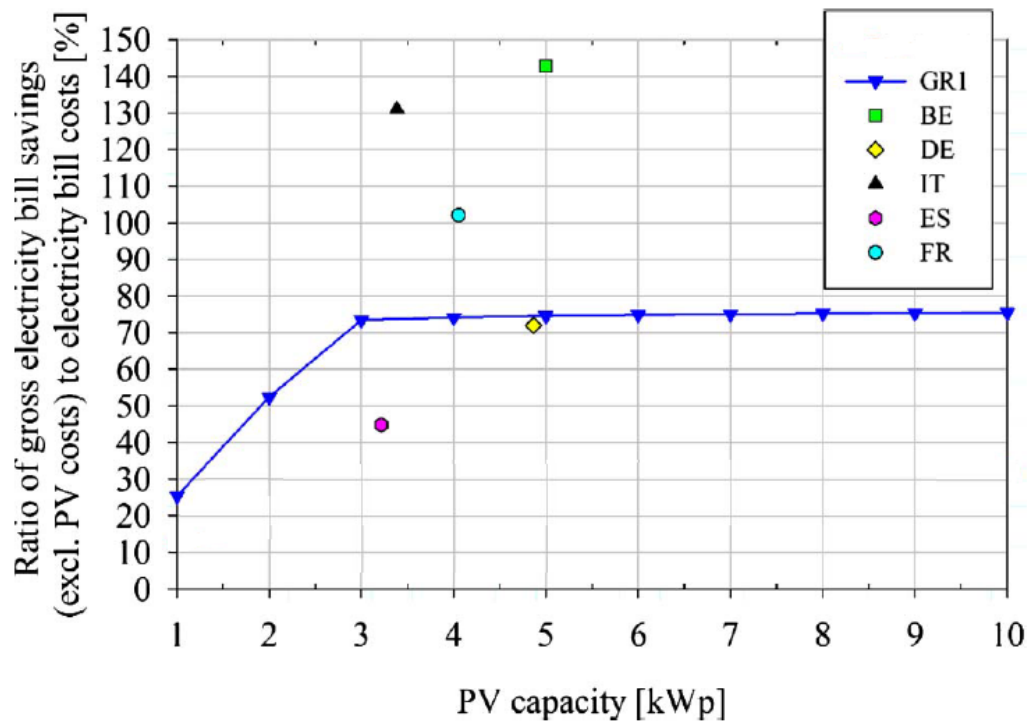


Figure 5 Ratio of gross electricity bill savings (i.e. excluding PV investment costs) to electricity bill costs over the investment period 2017 ~ 2036

The analysis reveals that Greece offers both, residential PV owners and photovoltaics / providers a financially more attractive market. Greece therefore appears to be offering an easier market for emerging PV technologies like OPV. Our findings can be compared with previous literature findings. The results of the photovoltaic revenues obtained from Belgium, Germany, Italy, Spain and France, with 2014 as the base year of the investment, can be seen in Figure 5. The PV revenue for these five countries has been calculated based on the original data in *De Boeck et al*⁵⁰ with assumptions of an inflation rate of three percent and a real discount rate of two percent, to make comparisons with the results of our study. The Greek results are the same as those of De Boeck for Spain and Germany, but far lower than those of Belgium, Italy and France. This is because all the countries, except Spain, had PV regulatory arrangements in De Boeck et al with subsidies and/or net metering that enable the remuneration of excess electricity exported.

⁵⁰ De Boeck L, Van Asch S, De Bruecker P, Audenaert A. Comparison of support policies for residential photovoltaic systems in the major EU markets through investment profitability. *Renew Energy* 2016;87:42–53

6.9. Cost – Competitiveness of OPV Systems for Self - Consumption

Figure 6 plots calculated profitability of investment in Greece's OPV system, based on the three levels of the OPV's cost, to residential consumers with annual electricity consumption of 4000 kWh. As shown in the picture, the results of the NPV based on the pilot - scale OPV cost level, 6a, have shown negative value to the Greece, irrespective of the OPV capacities and thus would be unviable for investment in OPV in Greece for an overall system cost of EUR 13,42/W_p. Conversely, the figure 6b results for Greece are reasonably positive. Each curve has the highest NPV result for the optimal investment solution. In Greece, a 2.5kW_p OPV system with 1504€ NPV was the optimum investment solution which achieved a 12% reduction in the bill of electricity. These results indicate that investing in OPV at an overall system cost of € 2.72/W_p in Greece would yield significantly increased profits.

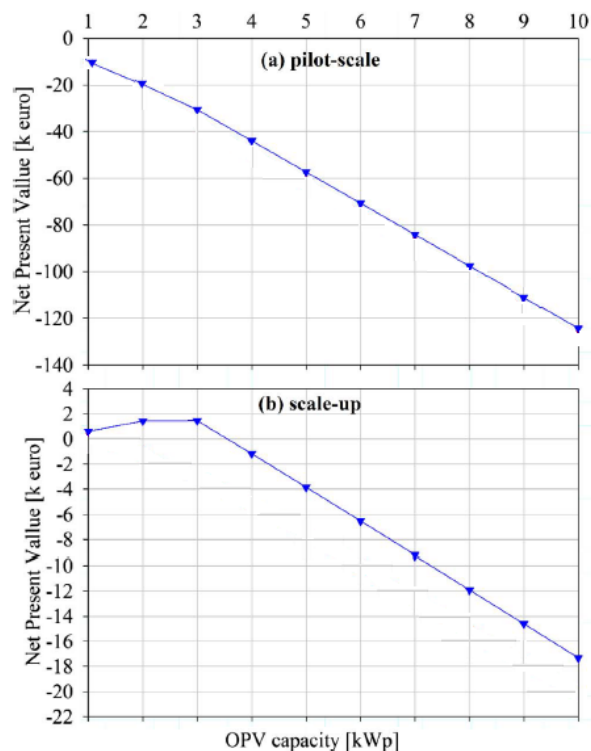


Figure 6 Net present value of OPV self-consumption in Greece for pilot scale (a) and scale up (b)

7. Conclusions

In order to achieve almost nil energy constructions, this study presents the potential to minimize the total energy demand of a building in Greece. **The simulation analysis shows that the increased isolation layer thickness provides a simple, highly effective solution to reduce the building's total annual energy requirements.** Furthermore, the **application of openings with improved thermal properties, the use of shading devices, and other simple, constructive solutions can lead to considerable energy savings in warm climate zones.** The use of innovative thermal insulation materials such as the VIP, provides a very promising building solution that combines a high level of energy performance with esthetics.

Greece's climate characteristics form a complex map that leads the way to nearly zero buildings. Greece's temperate climate provides numerous renewable sources of energy that can be used to address low energy demands. Nevertheless, the demand for heating and cooling over the entire year makes it more difficult to achieve the objective. **The results of the simulation analysis show that overall energy demand depends on several factors which can affect the building's energy performance.**

This study evaluates among others, the self-consumption of electricity from conventional and organic photovoltaic systems installed in European residential buildings in Greece. The results show Greece's improved self-sufficiency, primarily due to a more favorable photovoltaic regulatory system and secondly due to difference in the level of solar radiation and the timing between the consumption of electricity and solar irradiation. Our analysis shows that the performance of a given country in PV self-consumption could vary greatly depending on the three main factors:

- PV regulatory framework,
- Solar irradiation,
- Electric consumption profile.

Therefore researchers are encouraged to carry out **new studies with location-specific information when investigating PV self-consumption**, rather than relying on existing studies with assumed similar geographical and policy contexts. The methodology developed, fully described above, should be employed and used by adapting country and policy input data to other countries. The **economic analysis of photovoltaic self-consumption in residential houses shows that Greece offers a considerably higher profit computed as savings on gross electricity bill** (i.e. not costs for photovoltaics). This shows that PV technology developers should carefully evaluate many countries to identify financially attractive environments and prioritize them. In particular, our study evaluates OPV systems as to whether they can provide profitable investment for households on the basis of self-consumption of electricity.

OPV technologies therefore have a profitable opportunity for business in specific areas, encouraging investors in the renewable energy sector to pursue an expansion of OPV's production capabilities. Although this work has not covered, future, similar studies on residential PV systems should further explore the potential influence on the economic profile of the household's overall energy system by **combining the PV system with other systems and additional components** such as battery storage, electric vehicles or heat pumps. In addition, the environmental impact of residential PV systems with battery storage capacity should be evaluated with studies moving toward sustainable energy systems. Most importantly, studies should assess whether added storage batteries may or may not contribute to reducing the environmental impact while necessary for increasing the use of renewable energy.

In order to identify the right combination of parameters for optimizing the energy performance of the building and reducing its energy requirements, a series of different parameters must be investigated to take the first crucial step towards achieving nearly zero energy buildings.

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