Energy in Architecture

Climate responsive design and the wisdom of Traditional Architecture

Ilaria Falcone
Department of Civil Engineering, University of Salerno, Italy – ifalcone@unisa.it

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Abstract

Thou the European Commission defined a strategy necessary to achieve the goal of a competitive sustainable and safe energy for the European Countries, lifestyle of western societies led to an increase in the consumption of primary energy, a future of low carbon dioxide emissions is an effective solution to support both economic development and the international energy situation. In the last years we have witnessed an increase concern for environmental impacts of building and for the quality of internal environment, this led to the raise of interest in "green buildings" and in climate responsive design. In order not to have discomfort indoor, to reduce energy consumption, to minimize pollution, bioclimatic design should be considered. Climate responsive design is part of an environmental approach to building development called ecological sustainable design (ESD), based on the understanding of the climate parameters which may be influential in the design process, id est: temperature, humidity, wind, vegetation, light, related to the geographical position. Looking carefully at traditional architecture all these aspect, or at least most of these, can be recognized in the wisdom of traditional construction practice. Traditional architectural solutions, thanks tended to maximize the use of energy contributions, both in terms of solar radiation and of natural ventilation provided by the external environment, and at the same time, to ensure proper shielding of windows.

The problem of sustainability in architecture can be approached from different points of view. Often the problem of energy consumption is analyzed with reference to the ex-novo design, but it is important to shift the focus on to how to apply the principles of sustainability to existing buildings, that is, to turns the attention to the issue of upgrading the energy efficiency and improving the performance of the building. Brutally "sustainability has been defined as the extent to which progress and development should meet the need of the present without compromising the ability of future generations to meet their own needs" [1].

Such a definition leaves plenty of room for interpretation of the readers. Therefore, probably, must be detailed and specified. To begin with, the term sustainability can be applied to many fields.

To better define the subject is still necessary to understand the basic principles that make a building sustainable, explore the concept of climate responsive design, and then moving to

1. J. Steele, *Sustainable architecture: principles, paradigms, and case studies* (New York: McGraw-Hill Inc, 1997).

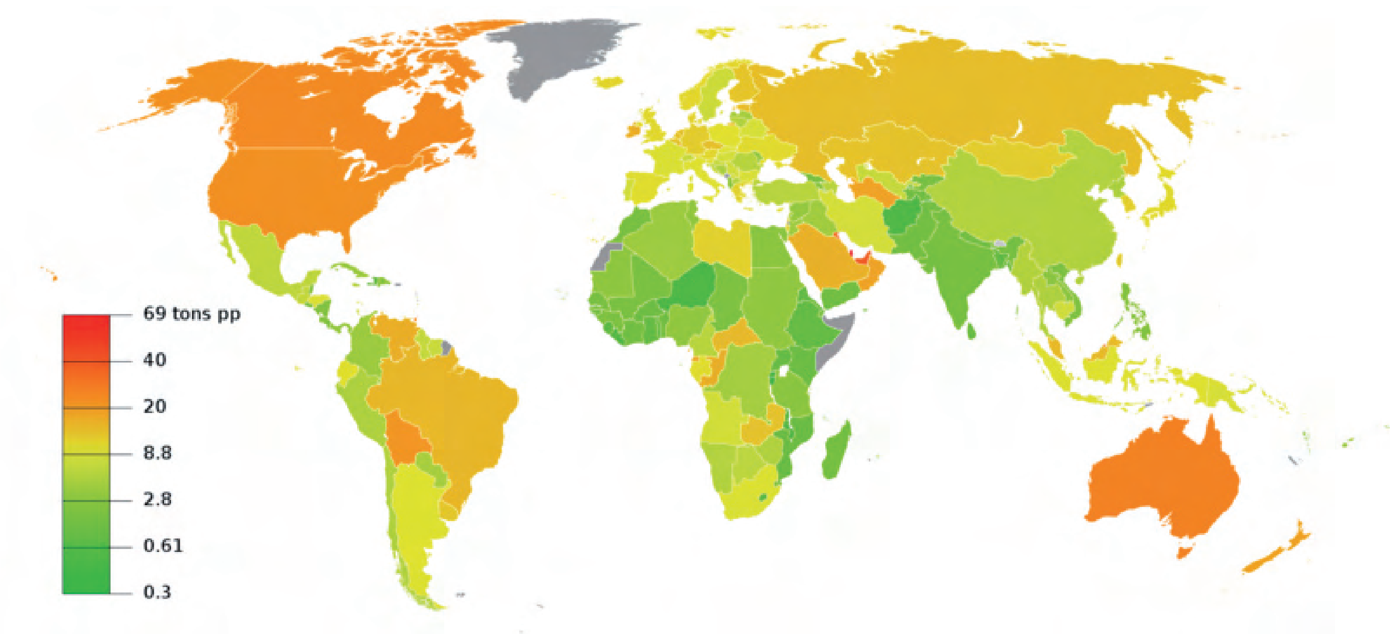


Figure 1 – CO_2 Emissions Distribution levels per Capita, World Population.

how these concepts can be applied to the present case.
"In Europe, 50% of material resources taken from nature are building-related, over 50% of national waste production comes from the building sector, and also 40% of energy consumption is building-related".[2 3] The European Commission defined a strategy necessary to achieve the goal of a competitive sustainable and safe energy for the European Countries, through a document that identifies priority actions for the next 10 years, by building an energy system more efficient, a market at competitive prices, energy supplies more secure, etc..
In addition, the International Energy Agency points out, in its report on the energetic perspectives, that the revolution hoped for a long time to respond to the issues related to climate change is actually a process already in progress.
A future of low carbon dioxide emissions is an effective solution to support both economic development and the international energy situation. In Italy, however, investment in low-carbon technology sector, despite a good growth rate, are unbalanced in favour of projects for power generation, while have almost zero shares for technological innovation. In our country it is necessary to identify policies and tools to enable a technology growth. The percentage composition of demand by source, confirms the specificity of Italy, in comparison with the average of the 27 countries of the European Union, concerning greater use of oil and gas, electricity import, small contribution of solid fuels 7% of primary energy consumption, and the non-use of nuclear power.

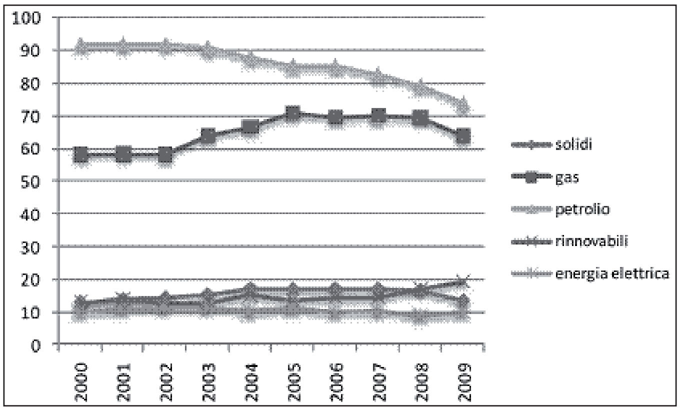


Figure 2 – Energy consumption by source. Years 2000-2009. Source: ENEA based on MSE data. Years 2000-2009. ENEA, "Rapporto Energia e Ambiente 2009".

2. D. Anink, C. Boonstra, J. Mak, *Handbook of sustainable building: an environmental preference method for selection of materials for use in construction and refurbishment* (UK: James and James, 1996).

3. M. AboulNaga, K. Al-Sallal, R. El Diasty, "The impact of city urban patterns on building energy consumption in hot climates: Al-Ain city as a case study," in *Proceedings of ISES Solar World Congress*, (S. Korea: Taejon 1997): 170–81.

The *Rapporto Energia e Ambiente* 2009 by ENEA on energy consumption in end-use sectors of energy shows:
- a small but significant decline in consumption in the transport sector (-1.8%);
- a variation of opposite sign in the Civil sector (+3.5%) related to climate variability (gas +5%, electricity to +3%, and renewable +9%);
- a significant drop in consumption of "industry (-20%) in agreement with the sharp drop in industrial production (-13.3%).

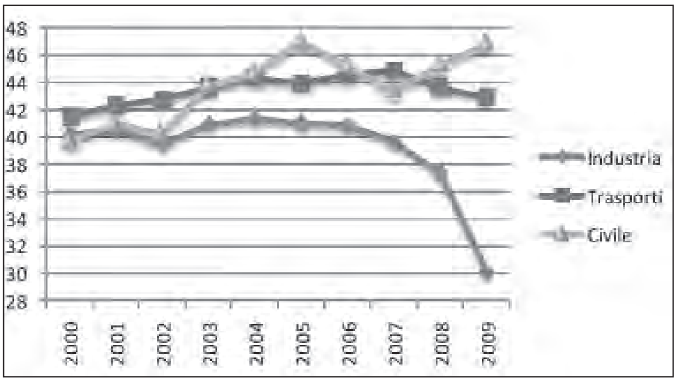


Figure 3 – Final energy consumption by sector. Source: ENEA on MSE data. ENEA, "Rapporto Energia e Ambiente2009".

As noted in the chart above, the domestic sector, unlike the others, in recent years has had a growing trend in terms of energy consumption. To act in the domestic sector is therefore important.
Furthermore, through simple measures, and the direct involvement of the population, it is possible to act on a large scale, a necessary condition to make the intervention effective. ENEA scenarios show how, in the domestic sector, a massive use of more efficient technologies will provide for reductions in fuel consumption by up to 12% already in the year 2020, about 4 Mtoe less than the evolving trend (according with the draft of the *Piano straordinario per l' Efficienza e il Risparmio Energetico*, of March 2010). In the long run the reduction compared to the reference scenario may further increase, up to 29% (of the sector consumption) in 2050. These results are obtained primarily through efficiency improvement of the Italian high-tech sector for air conditioning (winter and summer) and production of hot water.
Although in recent years progresses have been made in this direction, the scenarios show that there are still plenty of room for improvement.For example greater use of high-efficiency condensing boilers, high-performance heat pumps and air conditioners, may guarantee to reduce consumption by about 3 Mtoe within 2020. Energy use for domestic hot water and kitchen use, are more or less the same, while electricity use is growing fast, (mainly because of the standard comfort that has been changing, and an increasing consump-

tion of energy for summer cooling and dehumidification can be registered).

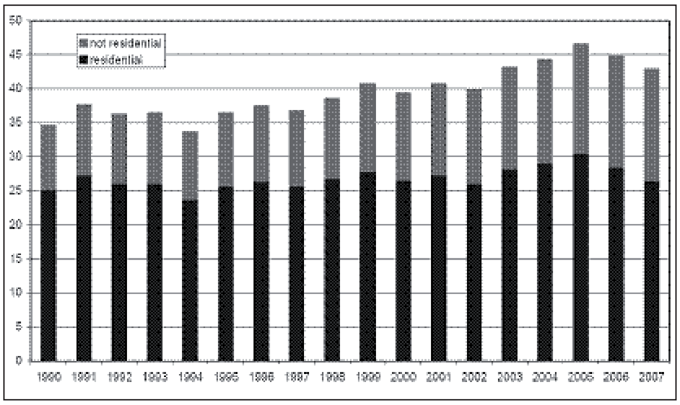


Figure 4 – Energy and use in Italian buildings since 1990. Grey: non residential, black: residential. Source: M. Zinzi, G. Fasano, M. Citterio, Impact, compliance and control of legislation in Italy, ENEA, Brussel Sptember, 2009.

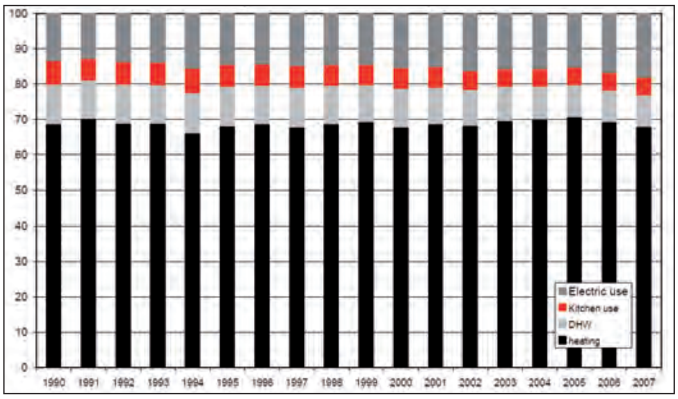
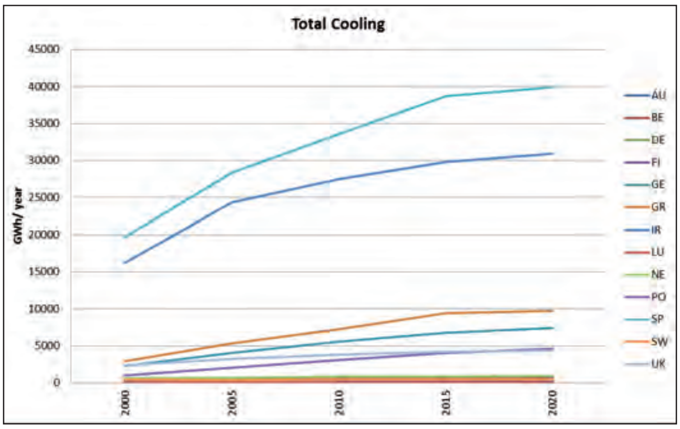


Figure 5 – Percentage Energy uses in residential sector per typology of Energy use. Source: Rapporto Energia e Ambiente ENEA 2008.

The lifestyle of western societies led to an increase in the consumption of primary energy needed to cool the buildings, with enormous impact on the environment. In particular, Mediterranean countries had a significant increase in energy consumption in summer due mainly to the use of air conditioners.

In Europe, Italy is leading both for the number of square meters provided that in the growth forecasts, followed by Spain. According to studies EECCAC[4] demand for summer cooling will become up to four times higher by 2020. To deal with this question common to many European countries, the European Community in 2005 launched the "Keep Cool" programme with the aim of illustrating the features and benefits of sustainable cooling systems, to propose regulatory changes and to encourage economic incentives.

While in the commercial sector the major saving's opportunities are offered by the improvement of energy management systems, in the residential sector, next to the update of heating/cooling systems, the crucial problem is the choice of a correct solution for the building envelope.



TOTAL COOLING - GWH/YEAR					
Country	Year				
	2000	2005	2010	2015	2020
AU	469	549	633	689	707
BE	274	422	559	681	708
DE	71	122	180	232	260
FI	206	210	229	242	246
FR	5010	8213	10954	13240	14071
GE	2286	4012	5542	6785	7415
GR	2909	5365	7269	9399	9734
IR	127	180	222	252	264
IT	16209	24336	27445	29795	30890
LU	11	18	23	27	29
NE	605	690	797	869	892
PO	1020	2049	3072	4039	4621
SP	19689	28333	33573	38719	39915
SW	391	378	403	421	425
UK	2359	3227	3826	4241	4401
TOTAL	51636	78104	94727	109631	114578

Figure 6 – Cooling only energy consumption by country and year.

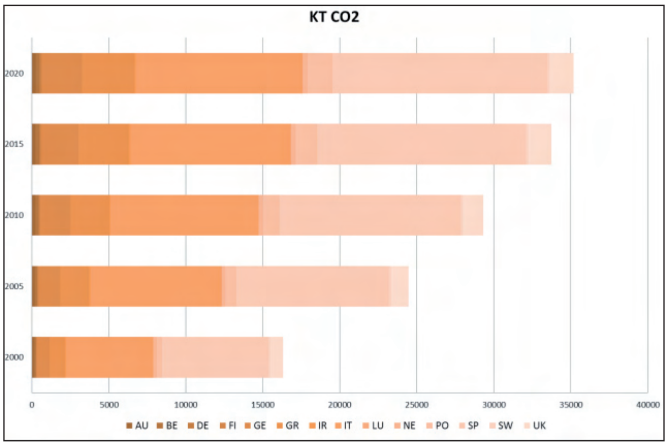
That's why this research work analyses how act cleaver to reduce consumption, taking into account the boundary conditions, i.e climatic conditions and regulatory framework.

EPIQR (energy performance, indoor environment quality and analysis of refurbishment cost) defines retrofit actions as those ones which upgrade and improve the building (or building element) to a higher standard than was originally planned for the apartment building.

Recently the main solution to gain the standards of comfort indoor has been the use of heating and cooling systems which led to the so called "universal climate"; it means that,

4. J. Adnot et al., *Energy Efficiency and Certification of Central Air Conditioners – Final report*, (2003): 16.

whatever the climate outside, it is possible to have always the same climate condition indoor (about 25°C and 50% of humidity) almost everywhere, without concern for place.



KT CO_2					
Country	Year				
	2000	2005	2010	2015	2020
AU	164	192	221	241	248
BE	96	148	196	238	248
DE	25	43	63	81	91
FI	72	73	80	85	86
FR	1754	2874	3834	4634	4925
GE	800	1404	1940	2375	2595
GR	1018	1878	2544	3289	3407
IR	44	63	78	88	93
IT	5673	8518	9606	10428	10812
LU	4	6	8	9	10
NE	212	242	279	304	312
PO	357	717	1075	1414	1618
SP	6891	9916	11751	13552	13970
SW	137	132	141	148	149
UK	826	1129	1339	1484	1540
TOTAL	18073	27335	33155	38370	40104

Figure 7 – Numerical results about CO2 emissions due to cooling in Europe.

But this way of design is absolutely improper from an energetic point of view, designers should respect the natural climate and should consider more the historically used strategies for environmental control, given a particular building function, design and context.

Thankfully in the last years we have witnessed an increase concern for environmental impacts of building and for the quality of internal environment, this has led to the raise of interest in "green buildings" and in climate responsive design.

In order not to have discomfort indoor, to reduce energy consumption, to minimize pollution, bioclimatic design should be considered.

Climate responsive design is part of an environmental approach to building development called ecological sustainable design (ESD), it is based on "the way buildings form and structure moderates the climates for human goods and well-being"[5]. The interaction between a building and the external environment depends mainly on the climate:

- cold climate requires a defensive strategy;
- buildings in warm climate, instead, have to filter the climate in a multitude of ways.

In order to optimize the relationship between the site, climate and building, climate responsive design requires both analytical and synthesis skills of the architects.

The main principle at the base of the climate responsive design is the understanding of the climate parameters which may be influential in the design process, id est: temperature, humidity, wind, vegetation, light, related to the geographical position.

As R. Hyde defines Climate Responsive Design in his book, it is possible to identify three main kind of condition:

- global condition (created by the dominant geographical features of land, sea, sun and air.);
- local condition (dependent on dominant features of water, topography, vegetation and built environment);
- site condition and building context (interaction of local condition and the building).

The problem is that the weather is quite difficult to predict, so designers have to use a "patter", a methodology, in order to design in an appropriate way.

The problem becomes to "adapt" design objectives with what the climate factor made necessary. Even if it may sound simple, the application of all these strategies is not!

There are a lot of parameters that need to be taken into consideration.

The first ones are site and building context, it means that it's necessary to understand the climate (micro and macroclimate) and the site potentiality, these led to the understanding of the building response to the climate (as it was in the vernacular architecture were climate, site and elements of the building generate the building form).

A strategy, which can be split in two levels, may be followed:

Level 1: relate the general building and the environmental control;

Level 2: analyse specific aspect of the building.

A really careful analysis of the site is important, the factors affected by the site are:

- temperatures, that can be modify by vegetation or topography;
- solar radiation, in fact shading from vegetation or other buildings can affect solar access to the building (= heating and light);
- airflow, modified by ground condition, with velocity grow-

5. R. Hyde, *Climate Responsive Design- A study of building in moderate and hot humid climate* (London: Spon Press, 2000).

ing with high, elevation and orientation are key factors;
- evaporative cooling, affected by topography and vegetation.

Another key aspect in the microclimate is the context, the rural one is represented by the prevalence of natural feature compared to the manmade, vegetation, proximity to ocean, sea, hills (that can provide shadows) are all aspects important in the design process, and are also aspects to consider in retrofitting actions.

In the suburban context, instead, the main issue can be the provision of airflow for ventilation, the higher density of the building, the less access to the building for the wind floe. In the urban context density of building is very high, this led to the so called *urban climate*, that has many different characteristic from the macroclimate of the area.

The fabric and spatial extent of urban context affects temperature, humidity, wind, and solar radiation, at the macroscale, but even at the microscale, land coverage, high of buildings, and orientation.

Microclimate produces the so called "microscale effects" for example the creation of shade in urban open spaces, provides the ideal environment for outside living, while the macroclimate produces "macroscale effects" one of the main effects is the so called "heat island" i.e. nocturnal elevation in temperatures as compared to the rural temperature.

The "island" extends both vertically and horizontally. To take advantage of the microclimate conditions careful considerations on orientation, airflow, environmental factor, is required, it means a careful site investigation.

Site investigation includes a collection of data on microclimate condition of the site, in order to use the data for an environmental analysis, and finally it led to conceive a climate responsive project. Looking carefully at traditional architecture all these aspect, or at least most of these, can be recognized in the wisdom of traditional construction practice.

Figure 8 – Palacio de la Ciudadela a Montevideo, Arch. Sichero 1958. Web site: http://www.skyscrapercity.com/

Geographically, Italy lies in the temperate zone. Because of the considerable length of the peninsula, there is a variation between the climate of the north, so close to the centre of Europe, and that of the south, surrounded by the Mediterranean sea.

The weather conditions in a particular region will affect the life, and thus the architecture, which is in many cases a mirror of the needs and priorities of the life of people.

Traditional local architectures, also known as vernacular architectures, differentiated by latitude, are an example of harmonizing buildings with nature its features. This also applies to the architecture of the Mediterranean region, which, as said before, is characterized by very specific climatic conditions, presenting sometimes humid summers, not very cold winters but rainy, thanks to the strong mitigating effect of the sea. The Mediterranean traditional architecture evolved to produce buildings that would be in harmony with the harsh climates of its various regions.

Figure 9 – Grid to natural ventilation on windows and doors. From T. Contri "Antoni Gaudì, l'Architetture – I protagonisti" La Biblioteca di repubblica – l'Espresso April 2007; p. 68.

To better understand the properties of modern building envelopes in the Mediterranean area is necessary, first, to analyse the properties of traditional enclosures. But which definitions can be given to the Mediterranean architecture? And which characteristics distinguish it?

Actually, building typologies are few and simple, as they have always complied with the territory according to simple paths of rationality and geometry. Architecture adapted to the uneven nature of the ground, repeating row houses in linear settlements along the sea coasts, or along main roads of the countryside, or expressed in isolated buildings that identify scenic viewpoints.

If you consider that the architectural culture has accepted the challenge of energy conservation as a driver of development and as a commitment to safeguarding the environment, we must not forget that Mediterranean architecture is, from this point of view, an effective model, tested for centuries to address these issues.

In fact, traditional architectural solutions, thanks to the aforementioned climate, tended to maximize the use of energy contributions, both in terms of solar radiation and of natural ventilation provided by the external environment, and at the same time, to ensure proper shielding of windows.

"While the traditional Mediterranean residences provided shelter from extreme climatic conditions with various methods without consuming a lot of energy, the mechanization and the internationalisation caused the rejection of the tried methods and the lack of knowledge of building physics stripped the building structure from its basic operations and they left the building in the mercy of climate."[6]

Solar radiation has always been regarded by humans as a principal source of energy, enough to significantly influence the traditional building techniques.

The Mediterranean architecture has been characterized, during different historical periods, by solutions that had a relatively high number of openings, simple or complex, sometimes large, but always with shading systems. Due to the geometry of the openings, properly shielded, the sun could hardly penetrate and affect the interior surfaces for a major fraction of the day during summer.

With a proper dimensioning of the openings of two important objectives are achieved in the design of the traditional shells: the onset of natural ventilation and, simultaneously, the filtering of solar radiation.

Open or semi-open structures, such as terraces, loggias, balconies and porches, have helped to enrich the Mediterranean architecture and complete architecturally the tradi-

6. Despina K. Serghides, "The Wisdom of Mediterranean Traditional Architecture versus Contemporary Architecture – The Energy Challenge," *The Open Construction and Building Technology Journal*, no. 4 (2010): 29–38.

tional building.
But vernacular architecture in the Mediterranean climate has features far more extensive and complex, some basic points are:

- The location of the building and its orientation, chosen in such a way as to guarantee the ability to operate a natural cooling provided by the cross ventilation of rooms.
- The presence of massive walls capable of providing significant inertial characteristics of the building envelope.
- The use of building materials with low thermal conductivity that can reduce the total amount of energy transmitted through the outside walls
- The optimization of the size and location of openings through side walls and roof, both with regard to heat transfer and day light;

Men have gradually learned that many aspects participate in the operation and function of the thermal regulating mechanism such as: topography, construction it means morphology, materials and even the layout and use of internal spaces.

Figure 10 – Trulli in Alberobello – Puglia (Italy) and a “dammuso” in Pantelleria (Italy).

Site was important too, the presence of vegetation, of water, or simply of other construction affects thermal performance of the building.
The more they learned that in hot regions ventilation is necessary for comfort and hygiene; even in warm summer days when the building interior is colder than the outdoor, that’s why in traditional buildings a great deal of attention was given to ventilation especially to the pre-treatment of air.
Other architectural aspects and structural elements which exist in the old houses that reflect the traditional wisdom are solarium and the courtyard.
“In the countries of Mediterranean and the regions with hot climates, in which the sun is desirable in the winter while in the summertime the cooling and ventilation is necessary, the solarium and the courtyard are indispensable solar features of houses, unique elements of local architecture.
Both components, although outdoor, open spaces of building, they are focal elements around which the various activities of all other spaces, are composed and synthesised whether the house is found in the plains or in the mountains, in the village or in the city.
They form the heart of the dwelling spatially, socially and environmentally.
They are important architectural characteristics and they show the instinctive approach of passive solar design and planning that contributed in the climatic configuration of the Mediterranean house.
Their form evolved naturally from the climatic conditions, the needs of the family and the social structure of community.
Always adjoining each other they act upon as transit spaces and connect and unite the exterior with the internal building layout.
They are extensions of the house outwards and simultaneously extensions of the exterior spaces indoors.”[7]
So we can say that the elements and architectural features, which are now the basis of a sustainable design, such as solar greenhouses, ventilated facades, or massive wall systems, are essentially applications derived from the study of compositional aspects of vernacular architecture and its characters.
Through a process of trial and error our predecessors have found ways to cope with the extremes of climate. The influence of western cultures is, however, all pervading.
The trend towards an internationalized style of building could result in a reduction in the traditional solutions, which have served several cultures well for many centuries.
Certainly, the architecture of the Mediterranean provides an interesting and alternative points of analysis and evaluation of construction technology comparing the criteria of simplicity with those of more advanced technology, those based on tradition with those addressed in the trial, makes valid the principles of insulation and thermal inertia, giving the designer a variety of solutions rational, reliable and effective in the long run.
It seems evident that, for a correct design of a building, it is

7. *Ibid*.

not possible irrespective of an analysis of the climate and of evolutionary parameters of the buildings in that area.
"The selection of the appropriate design strategies, derived from a bioclimatic analysis, compatible with each other and other architectural aspects, could considerably reduce the cost of a building by minimizing, the mechanical means for cooling and heating".[8]
In particular those arrangements typical of Mediterranean houses (natural ventilation, thermal insulation, solar control) should be re-considered in building practice to reduce energy consumption for heating and cooling.

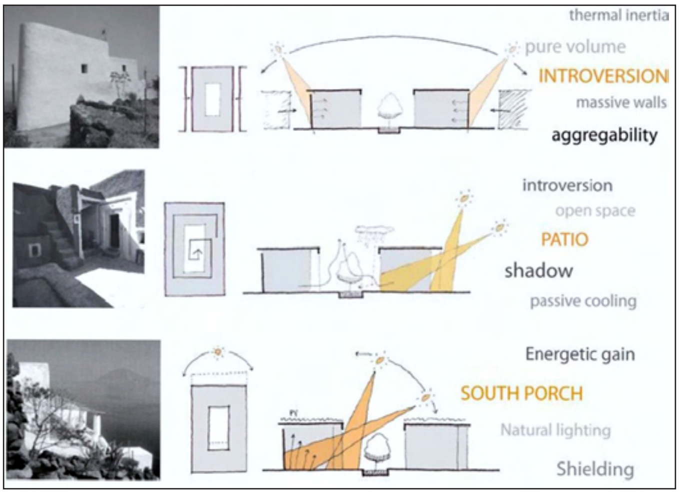


Figure 11 – MED in Italy - The Sustainable Mediterranean House, Tradizione Mediterranea, web site: http://www.medinitaly.eu/it/progetto_mediterranea.

8. M. Santamouris, "Natural cooling techniques," in *Proceedings Conference workshop on Passive Cooling* (Ispra: Italy, 1990).

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