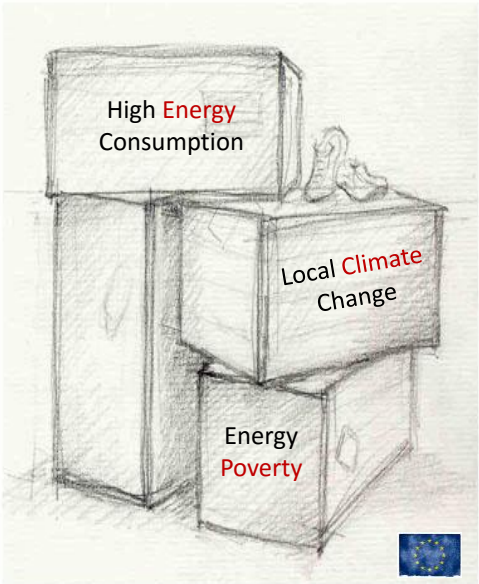
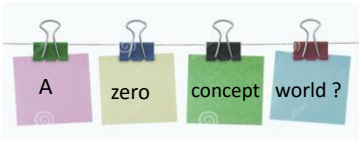
Energy Consumption in the European Built Environment
The Role of Cooling

M. Santamouris



The major problems of the built environment in Europe



The total European building stock is close to 24 billion m^2 and almost 75 % of them are residential buildings with an average floor space close to 87 m^2 per dwelling while the rest is tertiary buildings.

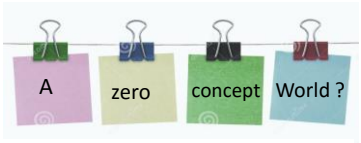
Almost 27 % of the total energy consumption in Europe is spent by residential buildings, while the rest, 14 % is consumed by the tertiary sector.

The average building energy consumption in the European Union countries , varies between 320 $kWh/m^2/y$ in Finland and 150 $kWh/m^2/y$ in Bulgaria and Spain, with a mean value close to 220 $kWh/m^2/y$.

Large differences in energy consumption exist between residential and tertiary buildings.

Dwellings consume on average almost 200 $kWh/m^2/y$ while the mean consumption of the non residential buildings is close to 295 kWh/m2/y.

Buildings consume almost 9 PWh and represent the 41 % of the total consumption



The energy consumption of the tertiary sector has a constant increase during the last 30 years. The increase rate is 1,1 % for the years 2010-2020.

Increase of the energy demand is because of the evolution of the services sector that increased by 1,3 % per year.

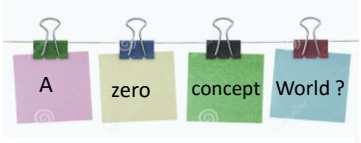
Services will be responsible for the 93 % of the additional energy to be consumed by tertiary buildings between 2000-2030.

Trade and office buildings are the largest energy consumers accounting each for about the 26 % of the global consumption of the tertiary buildings.

Space heating seems to be the end use presenting the higher energy consumption.

Energy spent for heating presents a constant decrease over time as a result of the important energy conservation measures applied in tertiary buildings.

The energy consumption of tertiary buildings is increasing constantly



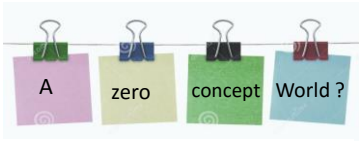
Despite the strict legislative framework, and the significant improvement of the energy efficiency, (1,4 % per year), the energy consumption of the residential buildings increased by 14 % between 1990 and 2012.

The electricity use increased by 60 % because of the very rapid penetration of electronic appliances and devices.

The final energy consumption in the residential sector in EU-27 was 307,321 ktoe in 2010, while the corresponding consumption for the year 1990, was 273,384 ktoe.

Increase of the energy consumption is attributed to various economic, social, political and technical reasons and mainly to the increase of the number of households and the increase of the occupied space per person

The energy consumption of the residential buildings is increasing constantly



Although the total energy consumption of buildings has increased, the specific consumption for heating purposes has decreased to about 15 % during the period 1997-2009.

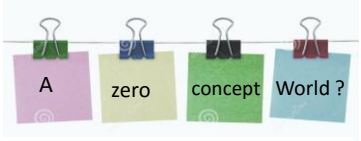
This may be attributed to the considerable lower consumption of the new dwellings built after 1997, representing almost 20 % of the total dwelling stock in 2009.

New dwellings consume almost 30-60 % less thermal energy than houses built before 1990,

Dwellings built in 2009 in Germany, present almost 58 % less energy consumption than those built in 1990.

The corresponding energy reductions in Sweden, Denmark, Slovakia and the Netherlands are 55 %, 53 %, 52 % and 50 %.

The energy consumption for heating is decreasing constantly

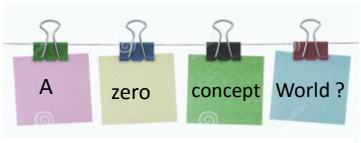


Space heating is the most energy consuming end use representing 71% of the total consumption of households, followed by water heating with 12%, cooking with 4% and lighting, air conditioning and other appliances with 15%,

Energy consumption for cooling is increasing rapidly in most of the Southern European countries. The highest cooling energy consumption is presented in Cyprus, where dwellings are spending about 670 kWh per year, followed by Malta with 540 kWh/year.

Very high increasing rates are observed in most of the southern European Countries because of the very rapid penetration of air conditioners. In particular, between 2005 and 2009 the energy consumption for cooling has increased almost by 100 % in Bulgaria, and by 30% in Spain and Italy,

The energy consumption for cooling is increasing constantly



Energy consumption in the building sector is subject to significant economic, environmental and social factors and perturbations.

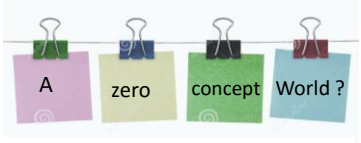
Past and present experience demonstrate that it is an extremely sensitive sector presenting a high variability in economic and environmental variations.

Financial problems oblige part of the population to consume less energy and satisfy partly their needs.

It is characteristic that during the financial crisis of 2007-2012 the energy consumption of the residential buildings has decreased by 4 %, while in countries with a deeper economic problem like Portugal, Slovakia and Ireland the decrease was 16 %, 22 % and 22 % respectively.

It is characteristic that because of the serious economic recession in Greece, the consumption of heating oil was reduced by 68,7 % in just one year,

The impact of economy on the energy consumption of buildings



The Cooling energy consumption is increasing because of the following reasons :

a) Increase of the living standards

b) Non appropriate quality of the building stock

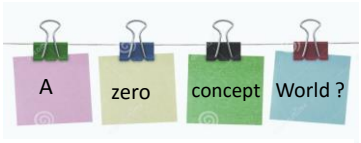
c) Global and Local Climate Change

d) Rapid Penetration of Electric and Electronic Appliances

e) Lack of Awareness on Alternative Cooling Technologies

f) Low peak electricity Prices for everyone

Why Energy Consumption for Cooling is increasing ?

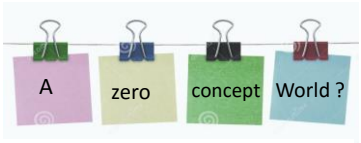


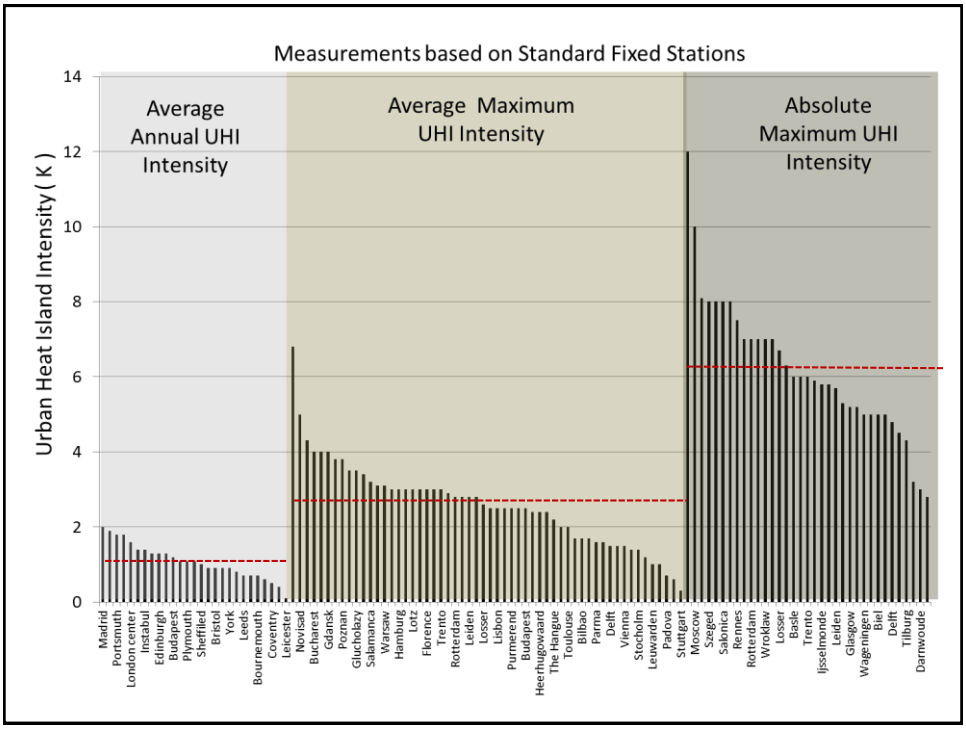
Climate change is a major issue for Europe. Increase of the ambient temperature and higher frequency of heat waves have an important impact on the energy and environmental quality of the built environment and increase the vulnerability of the local population.

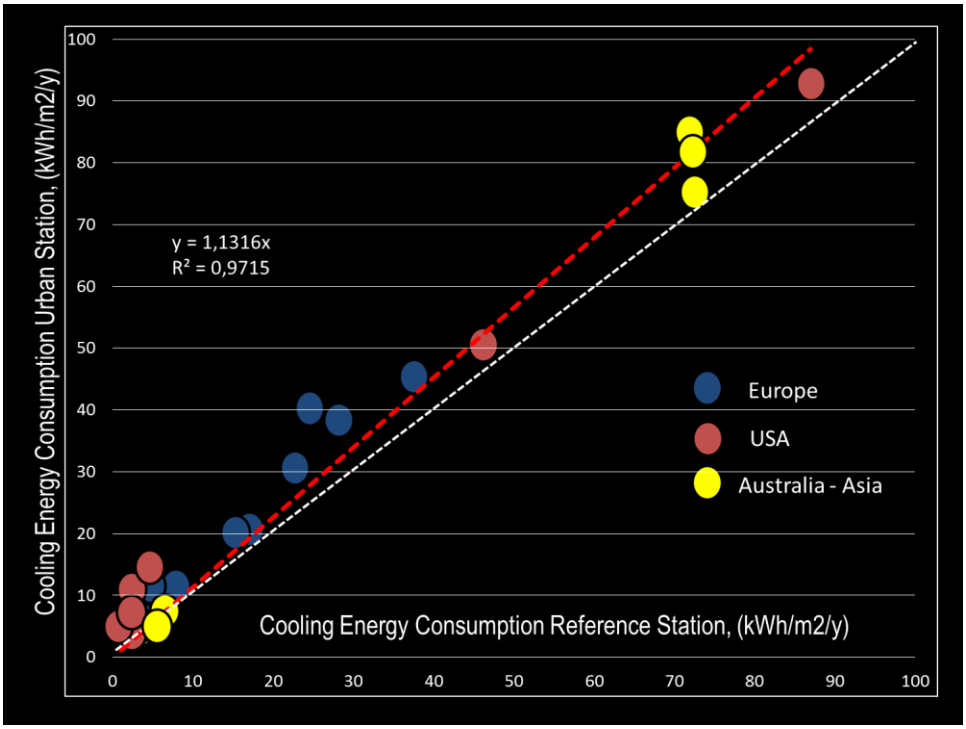
Given that 74 % of the European population live in urban zones, urban climatic conditions and local urban climate change affect a very significant part of the European population and have a serious impact on the global energy and environmental quality of the built environment.

Higher urban temperatures increase the energy consumption for cooling, raise the concentration of pollutants, deteriorate thermal comfort conditions and create important health problems to vulnerable populations

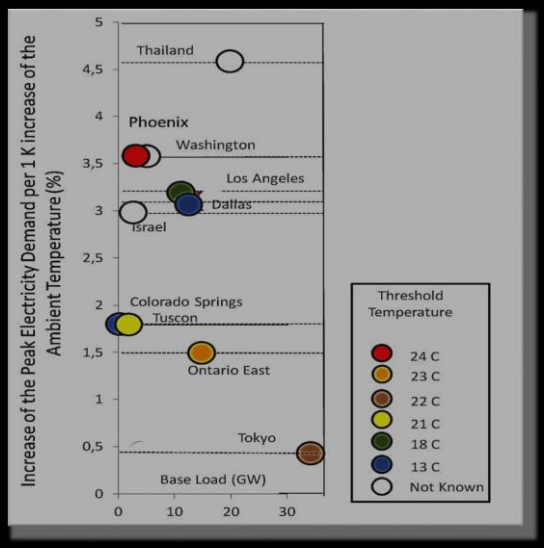
Local and Global Climate Change have a serious impact on the energy balance of Europe




Measurements based on Standard Fixed Stations
Urban Heat Island Intensity (K)
Average Annual UHI Intensity
Average Maximum UHI Intensity
Absolute Maximum UHI Intensity
0
2
4
6
8
10
12
14
Madrid
Portsmuth
London center
Instabul
Edinburgh
Budapest
Plymouth
Sheffiled
Bristol
York
Leeds
Bournemouth
Coventry
Leicester
Novisad
Bucharest
Gdansk
Poznan
Glucholazy
Salamanca
Warsaw
Hamburg
Lotz
Florence
Trento
Rotterdam
Leiden
Losser
Lisbon
Purmerend
Budapest
Heerhugowaard
The Hangue
Toulouse
Bilbao
Parma
Delft
Vienna
Stocholm
Leuwarden
Padova
Stuttgart
Moscow
Szeged
Salonica
Rennes
Rotterdam
Wroklaw
Losser
Basle
Trento
Ijsselmonde
Leiden
Glasgow
Wageningen
Biel
Delft
Tilburg
Darmwoude


Cooling Energy Consumption Urban Station, (kWh/m2/y)
Cooling Energy Consumption Reference Station, (kWh/m2/y)
y = 1,1316x
R² = 0,9715
Europe
USA
Australia - Asia
0
10
20
30
40
50
60
70
80
90
100

THE IMPACT ON PEAK POWER DEMAND

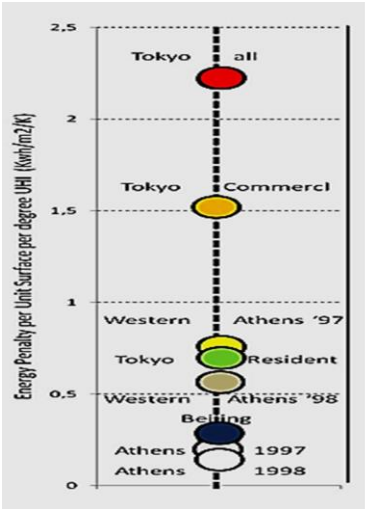


The peak electricity demand of electricity per degree of increase of the ambient temperature varies from 0,4 % for Tokyo to 4,6 % for Thailand.

In average, there is a penalty on peak electricity demand of about 20 W per person and degree of temperature increase

Source : M. Santamouris et al On The Impact of Urban Heat Island and Global Warming on the Power Demand and Electricity Consumption of Buildings–A Review, Energy and Buildings, 2015

THE IMPACT ON ENERGY



The index related to Global Energy Penalty per unit of city surface and per degree of the UHI intensity, GEPSI,

It presents the same characteristics as the GEPS index taking into account the average UHI intensity characteristics in the considered city.

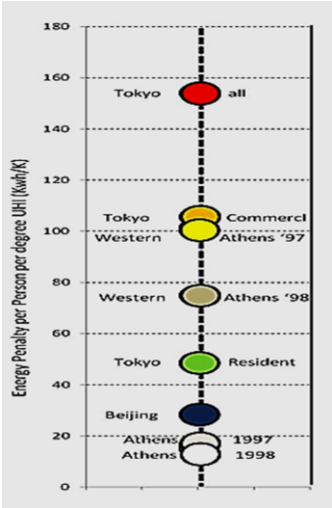
Values of GEPSI, vary between 2,2 kWh/m^2/K for Tokyo to 0,17 kWh/m^2/K for the Municipality of Athens.

UHI triggers A Global Energy Penalty per unit of city surface and per degree of the UHI intensity, GEPSI, close to

0,8 kWh/m^2/K,.

Source : M. Santamouris On The Energy Impact of Urban Heat Island and Global Warming on Buildings, Energy and Buildings, 82, 2014

THE IMPACT ON ENERGY



Global Energy Penalty per Person and per degree of the UHI intensity, GEPPI

It has the same characteristics as the GEPP index while it includes the local UHI intensity as additional information.

Values of GEPPI varied between 15 kWh/k for the Municipality of Athens to 154 kWh/K for Tokyo.

UHI triggers an average Global Energy Penalty per Person and per degree of the UHI intensity, GEPPI, close to

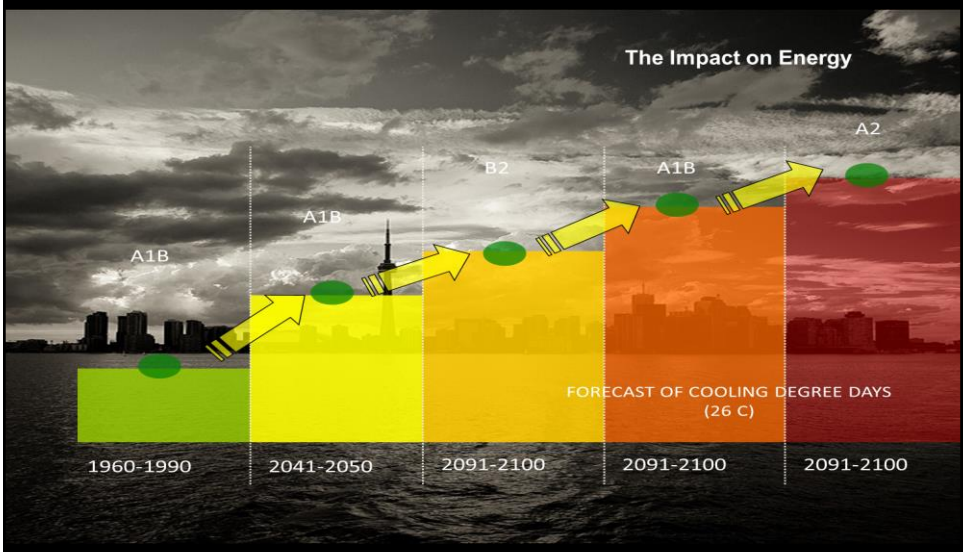
68 kWh/p/K.

Source : M. Santamouris

On The Energy Impact of Urban Heat Island and Global Warming on Buildings, Energy and Buildings, 82, 2014

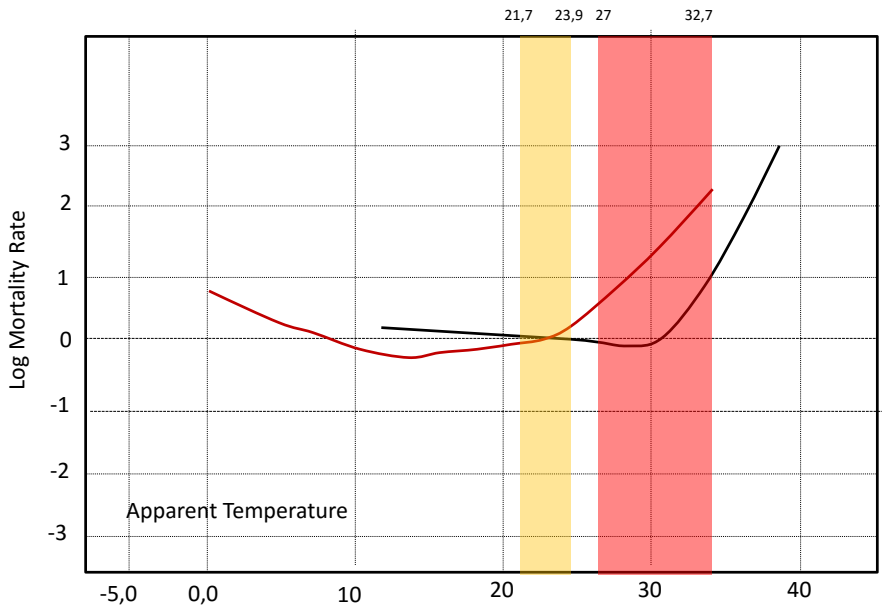
FORECAST OF THE FUTURE ENERGY CONSUMPTION

20



Source : D.A. Asimalopoulos
M. Santamouris et al

Modelling the energy demand projection of the building sector in Greece in the 21st century Energy and Buildings, Volume 49, June 2012, Pages 488-498



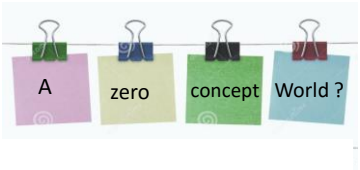
Energy poverty is a threat for Europe. Energy poverty is 'the situation in which a household lacks a socially and materially necessitated level of energy services in the home',

Energy poverty is a problem for over 150 million Europeans who are unable to pay bills and maintain comfortable standards'.

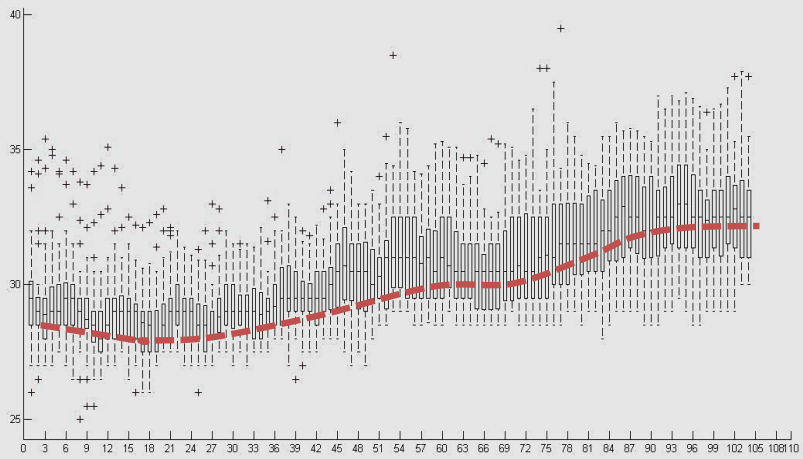
This is particularly valid for the citizens of the States with GDP below the EU average, where over 30% of the population face energy poverty.

It has a very serious impact on the quality of life of citizens affecting indoor comfort conditions, social attainment and health.

It is the result of combined factors like the insufficient family income, the poor quality and the low size of the house and the possible high energy prices, while other demographic drivers may play an important role



THE IMPACT ON INDOOR SUMMER COMFORT



Source : A. Sakka , M. Santamouris et al

On the thermal performance of low income housing during heat waves, Energy and Buildings, Volume 49, June 2012, Pages 69-77

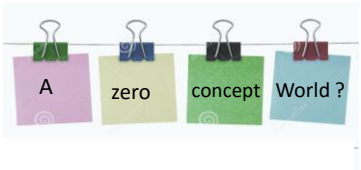
The need to reduce the energy consumption of the building sector, is widely recognized.

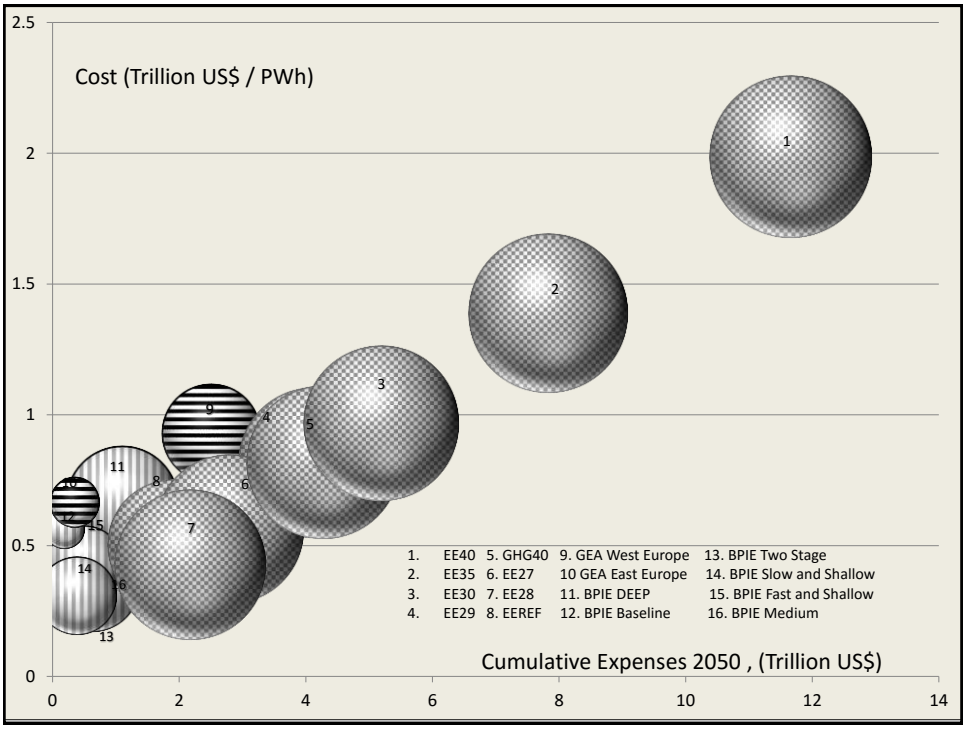
It can be achieved through deep retrofitting of the building stock combined with a radical reduction of the needs of the new buildings.

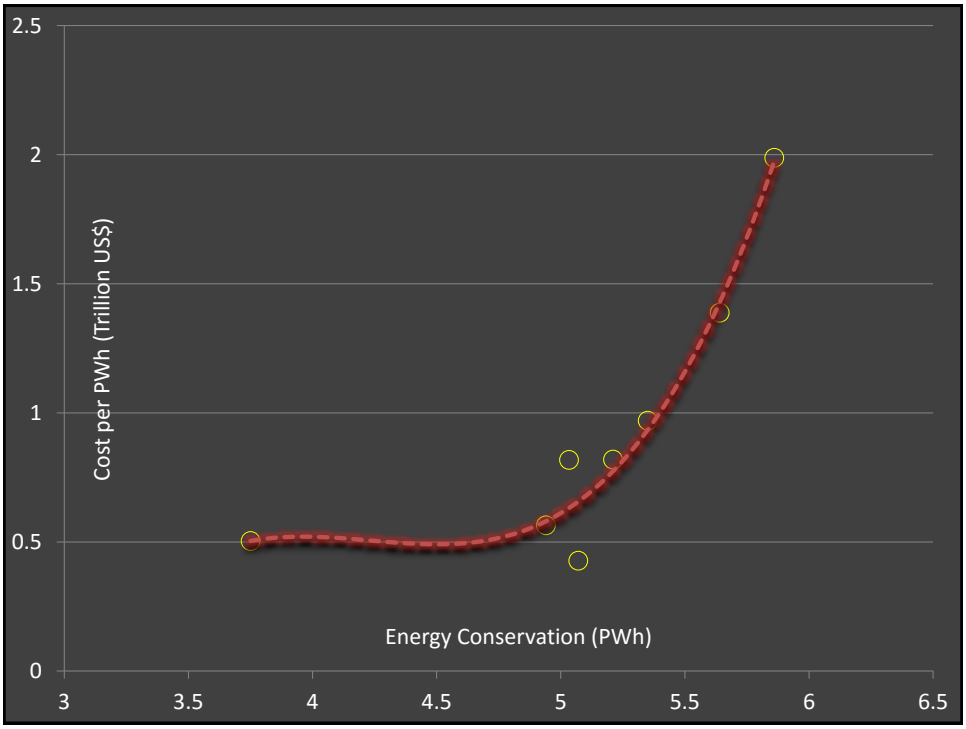
The level of the required investments to minimize the energy consumption is considerably high, while the impact on the economy and the society is very significant and may create an intensive growth while offering substantial opportunities for development.

In parallel, large scale energy investments should boost energy related scientific developments and innovations and should promote technological breakthroughs

Innovating to Zero : Minimizing the Energy Consumption of Buildings




Cost (Trillion US$ / PWh)
2.5
2
1.5
1
0.5
0
0
2
4
6
8
10
12
14
Cumulative Expenses 2050 , (Trillion US$)
1. EE40 5. GHG40 9. GEA West Europe 13. BPIE Two Stage
2. EE35 6. EE27 10 GEA East Europe 14. BPIE Slow and Shallow
3. EE30 7. EE28 11. BPIE DEEP 15. BPIE Fast and Shallow
4. EE29 8. EEREF 12. BPIE Baseline 16. BPIE Medium

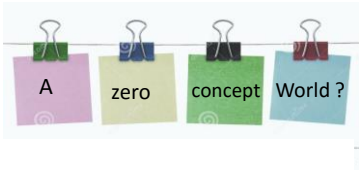

Cost per PWh (Trillion US$)
2.5
2
1.5
1
0.5
0
3
3.5
4
4.5
5
5.5
6
6.5
Energy Conservation (PWh)

Policies aiming to minimize the energy consumption of buildings should concentrate on three main technological axes aiming:

a) to increase the global energy efficiency of the building energy systems in order to seriously decrease the energy load and the final needs,

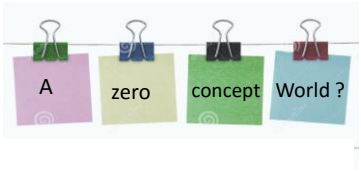
b) to supply the remaining energy load through clean and renewable technologies and

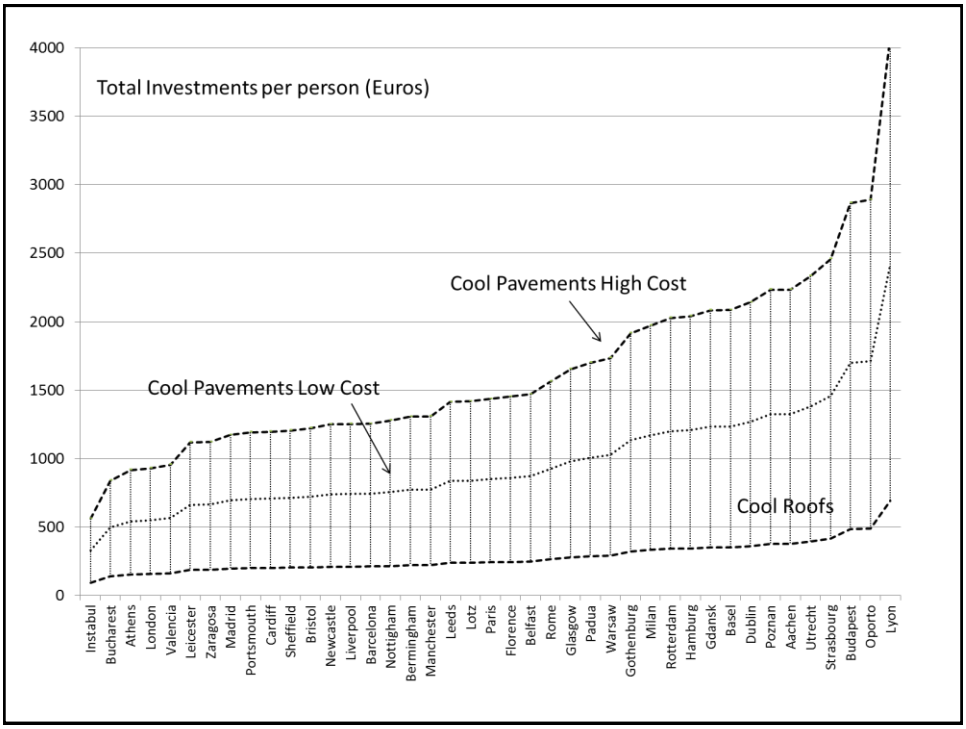
c) to optimize the management of the energy and environmental systems of the buildings through the use of smart and intelligent technologies

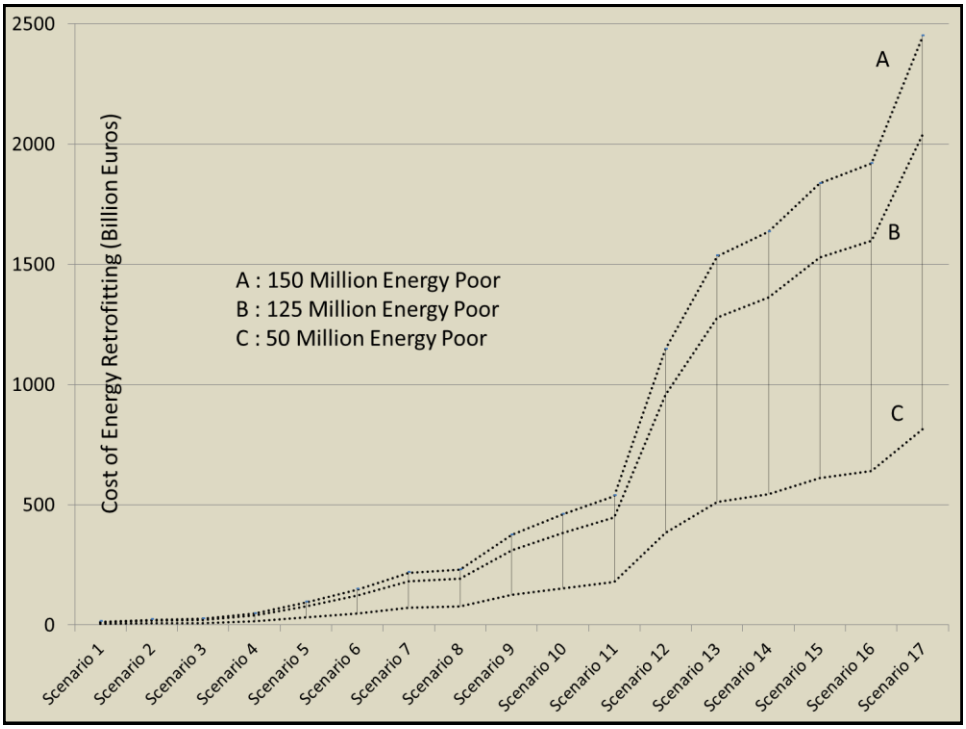


Smart products for the envelope like natural and hybrid ventilation components and cool coatings are very attractive and it is foreseen that the corresponding market will increase rapidly in the future.

In parallel, high performance HVAC systems, are the most rapidly developing industrial sectors and it may reach 162 billion Euros by 2018 presenting a growing rate of 10,5 %.




Total Investments per person (Euros)
4000
3500
3000
2500
2000
1500
1000
500
0
Cool Pavements High Cost
Cool Pavements Low Cost
Cool Roofs
Instabul
Bucharest
Athens
London
Valencia
Leicester
Zaragosa
Madrid
Portsmouth
Cardiff
Sheffield
Bristol
Newcastle
Liverpool
Barcelona
Nottigham
Bermingham
Manchester
Leeds
Lotz
Paris
Florence
Belfast
Rome
Glasgow
Padua
Warsaw
Gothenburg
Milan
Rotterdam
Hamburg
Gdansk
Basel
Dublin
Poznan
Aachen
Utrecht
Strasbourg
Budapest
Oporto
Lyon


Cost of Energy Retrofitting (Billion Euros)
2500
2000
1500
1000
500
0
A : 150 Million Energy Poor
B : 125 Million Energy Poor
C : 50 Million Energy Poor
A
B
C
Scenario 1
Scenario 2
Scenario 3
Scenario 4
Scenario 5
Scenario 6
Scenario 7
Scenario 8
Scenario 9
Scenario 10
Scenario 11
Scenario 12
Scenario 13
Scenario 14
Scenario 15
Scenario 16
Scenario 17

High Energy consumption of the building sector, local climate change and energy poverty are the major problems of the built environment in Europe. Cooling is increasing rapidly and may be the major consumption component in the future.

The three sectors are strongly interrelated presenting very significant synergies

Existing policies aiming to reduce the energy consumption of the buildings usually underestimate the importance and the impact of the local and global climate change as well as the technical, social and economic implications related to the energy poverty.

Failure to consider all issues in an integrated and holistic way may inevitably result in higher energy consumption for cooling and social discrepancies.

Innovating to zero the built environment of Europe assumes a minimization of the energy consumption of buildings, eradication of the energy poverty and mitigation of the urban heat island and the local climate change.

Such an objective, although it seems very ambitious is an unequivocal choice that will create substantial opportunities for future growth and will alleviate the population from the consequences of the specific problems and will create short, medium and long term benefits and opportunities.