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Technical Note AIVC 62

Energy and Indoor Environmental Quality of Low Income Households

Air Infiltration and Ventilation Centre
Operating Agent and Management
INIVE EEIG
Boulevard Poincaré 79
B-1060 Brussels
Belgium

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Energy and Indoor Environmental Quality of Low Income Households

M. Santamouris

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This report is part of the work of the IEA Energy Conservation in Buildings & Community Systems Programme - Annex V Air Infiltration and Ventilation Centre

Mattheos Santamouris
Associate Professor - Group Building Environmental Research
Physics Department - National Kapodistrian University of Athens
Panepistimioupolis, Building Physics 5 - 157 84 Athens, Greece
http://grbes.phys.uoa.gr

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Preface

International Energy Agency

The International Energy Agency (IEA) was established in 1974 within the framework of the Organisation for Economic Co-operation and Development (OECD) to implement an International Energy Programme. A basic aim of the IEA is to foster co-operation among the twenty-four IEA Participating Countries to increase energy security through energy conservation, development of alternative energy sources and energy research development and demonstration (RD&D).

Energy Conservation in Buildings and Community Systems

The IEA sponsors research and development in a number of areas related to energy. In one of these areas, energy conservation in buildings, the IEA is sponsoring various exercises to predict more accurately the energy use in buildings, including comparison of existing computer programs, building monitoring, comparison of calculation methods as well as air quality and studies of occupancy.

The Executive Committee

Overall control of the programme is maintained by an Executive Committee, which not only monitors existing projects but also identifies new areas where collaborative effort may be beneficial.

To date the following have been initiated by the Executive Committee (completed projects are identified by *):

1 Load Energy Determination of Buildings *
2 Ekistics and Advanced Community Energy Systems *
3 Energy Conservation in Residential Buildings *
4 Glasgow Commercial Building Monitoring *
5 Air Infiltration and Ventilation Centre
6 Energy Systems and Design of Communities *
7 Local Government Energy Planning *
8 Inhabitant Behaviour with Regard to Ventilation *
9 Minimum Ventilation Rates *
10 Building HVAC Systems Simulation *
11 Energy Auditing *
12 Windows and Fenestration *
13 Energy Management in Hospitals*
14 Condensation *
15 Energy Efficiency in Schools *
16 BEMS – 1: Energy Management Procedures *
17 BEMS – 2: Evaluation and Emulation Techniques *
18 Demand Controlled Ventilation Systems *
19 Low Slope Roof Systems *
20 Air Flow Patterns within Buildings *
21 Thermal Modelling *
22 Energy Efficient communities *
23 Multizone Air Flow Modelling (COMIS)*
24 Heat Air and Moisture Transfer in Envelopes *
25 Real Time HEVAC Simulation *
26 Energy Efficient Ventilation of Large Enclosures *
27 Evaluation and Demonstration of Residential Ventilation Systems *
28 Low Energy Cooling Systems *

29	Daylight in Buildings *
30	Bringing Simulation to Application *
31	Energy Related Environmental Impact of Buildings *
32	Integral Building Envelope Performance Assessment *
33	Advanced Local Energy Planning *
34	Computer-aided Evaluation of HVAC Systems Performance *
35	Design of Energy Hybrid Ventilation (HYBVENT) *
36	Retrofitting of Educational Buildings *
36 WG	Annex 36 Working Group Extension 'The Energy Concept Adviser' *
37	Low Exergy Systems for Heating and Cooling of Buildings *
38	Solar Sustainable Housing *
39	High Performance Insulation systems (HiPTI) *
40	Commissioning Building HVAC Systems for Improved Energy Performance *
41	Whole Building Heat, Air and Moisture Response (MOIST-EN)
42	The Simulation of Building-Integrated Fuel Cell and Other Cogeneration Systems (COGEN-SIM)
43	Testing and Validation of Building Energy Simulation Tools
44	Integrating Environmentally Responsive Elements in Buildings
45	Energy-Efficient Future Electric Lighting for Buildings
46	Holistic Assessment Tool-kit on Energy Efficient Retrofit Measures for Government Buildings (EnERGo)
47	Cost Effective Commissioning of Existing and Low Energy Buildings
48	Heat Pumping and Reversible Air Conditioning
49	Low Exergy Systems for High Performance Buildings and Communities
50	Prefabricated Systems for Low Energy Renovation of Residential Buildings

Annex V: Air Infiltration and Ventilation Centre

The Air Infiltration and Ventilation Centre was established by the Executive Committee following unanimous agreement that more needed to be understood about the impact of air change on energy use and indoor air quality. The purpose of the Centre is to promote an understanding of the complex behaviour of air flow in buildings and to advance the effective application of associated energy saving measures in both the design of new buildings and the improvement of the existing building stock.

The Participants in this task are Belgium, Czech Republic, Denmark, France, Greece, Japan, Republic of Korea, Netherlands, Norway and United States of America.

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1 Introduction

Low income households in developed and less developed countries suffer from serious indoor environmental problems like heat stress, lack of comfort and poor indoor air quality. This has a very serious impact on the quality of life and health of poor citizens. More than 2 million deaths per year are attributable to indoor air pollution from inadequate use of fuels, while thousands of low income citizens die because of high indoor temperatures.

In a general way poverty can be defined as a threshold below which people are considered as poor. This is usually expressed as a monetary amount or, as in Bangladesh, as daily caloric intake. Poor people can be identified by the lack of services to provide education, health, good housing, water, sanitation, etc, (Tipple 2001). Poverty can also be associated with concepts such as exclusion, vulnerability, powerlessness, isolation, humiliation, or deprivation (Jones 1999). Today, across the world, 1.3 billion people live on less than one dollar a day; while 3 billion live on under two dollars a day (Wolferson, 2000).

Poverty is among the major reasons of environmental degradation and unfortunately urban poverty is on the increase. In fact, as reported by the World Health Organization (WHO) poverty and inequality are two of the most important contributory factors to poor environmental conditions and poor health. It is characteristic that in 1970, the richest 20 percent of the planet had almost 30 times more income than the poorest 20 percent. In our days, this figure has doubled. The net income of the 358 richest people of the world is larger than the combined annual income of the poorest 45 percent of the world's population (Devuyst , 2001).

Energy consumption is an indicator of the quality of life. Energy is linked with all aspects of development and has a tremendous impact on the wellbeing of citizens, with respect to health, education, productivity, economic opportunities, etc. The current situation on energy supply and consumption is characterised by wide disparities between the developed and developing world. Almost, one third of the world’s population has no access to electricity while the second third has very poor access, (WEHAB, 2002). Although, 75 millions of people gain annually access to electricity, the total number of people lacking electricity does not change, (Jamal Saghir 2002). It is characteristic that the rich part of the world consumes 25 times as much as energy per person as the poorest people, (Jamal Saghir 2002).

Important energy inequalities exist between the population both in the developed and developing countries. Important parts of the population spent a high percentage of their income for buying energy. When more than 10 % of the family income is spend for energy, the family is characterized as ‘energy poor’, while when expenditures exceeds 20 per cent of the income, the family is under ‘severe energy poverty’. It is characteristic that in UK almost 5.2 million people are considered as ‘energy poor’, (Press 2003)

Buildings is the major economic sector in the world and the quality of buildings shapes the life of citizens. Despite the increase of the budget devoted to construction, United Nations estimates, (UNCHS, 2001), that more than one billion of urban citizens, live in non appropriate houses mostly in squatter and slum settlements, while in most of cities in less developed countries between one and two thirds of the population live in poor quality and overcrowded housing, (Hardy et al, 2001), with insufficient water supply inadequate or no sanitation, non appropriate rubbish collection, no electricity and energy networks and under the risk of flooding and other environmental phenomena, (Caincross, 1990).

In the developing world, the use of open fires and of non appropriate fuels, in improperly ventilated overcrowding houses, create serious indoor air quality problems contributing to acute respiratory infections that that kill 4 million people a year, mostly children under the age of five years, (WRI, 1996). Existing studies suggests indoor concentrations of total suspended particulates 10 to 100 higher than the existing standards, (Saksena and Smith, 1999). A statement by WHO mentions that 'Day in day out, and for hours at a time, women and their children are subjected to levels of smoke in their homes often 100 times above agreed international safety standards'

In the developed world, inappropriate indoor environmental conditions, like extremely low or high temperatures, luck of ventilation, etc, cause heat strokes, heart attacks, bronchitis, pneumonia and other heat related illnesses and respiratory diseases. In hte UK alone there are around 40,000 excess winter deaths a year because of inappropriate indoor temperatures, (DETR 2001, Press 2003), Figure 1.1. In parallel, heat waves cause dramatic problems to vulnerable population liviing in poorly prepared households. In France the estimated death toll of the 2003 heat wave was about 15000 deaths. Studies in Europe and US, [Michelozzi et al, 1999, 2005, Klinenberg (2002)].show that the greatest excess in mortality was registered in those with low socioeconomic status leaving in buildings with improper ventilation.

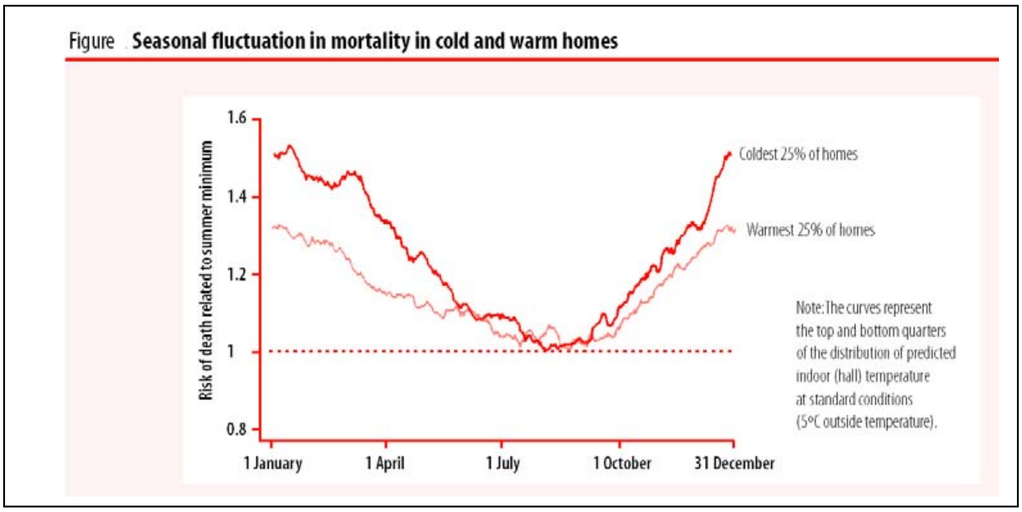

Figure 1.1 - Seasonal fluctuation in mortality in cold and warm homes in UK. (Figure from (Press 2003)

Design and use of proper indoor environmental systems, involving appropriate conditioning and ventilation techniques, have been found very efficient in decreasing indoor environmental stress and in decreasing indoor pollutants. Installation of proper ventilation systems, like smoke hoods, in poorly ventilated houses in Kenya have contributed to substantial reductions (80% in some homes) of respirable particulates and carbon monoxide, (Bates 2005).

This report, aims to examine the impact of the energy use, or non use, on the indoor environmental conditions in households occupied by low income people. Also, to investigate the specific physiological and air quality problems caused by the lack or the non appropriate use of energy, and to identify ways that proper ventilation techniques can assist vulnerable and poor population to improve indoor conditions and decrease the associated environmental stress.

2 Energy availability, poverty and indoor environmental conditions

2.1 Is energy available to poor people?

Energy is the most important engine for improving the quality of life and fighting poverty. Given that by 2020 almost 70 % of the world population will live in cities, and 60 % will be below poverty, World Bank estimates, (Albouy et al, 1999), that many of those will be energy poor. Thus, thousands of megawatts of new electrical capacity have to be added the next decades. Estimates, (Albouy et al, 1999), show that the cost of the new power generation plants over the next 30 years will amount over $ 2 trillion.

Developing countries pay already too much for energy. Citizens in these countries spent 12 % of their income for energy services, i.e. five times more than the average in OECD countries, (Serakeldim, 1995). In parallel, energy imports are one of the major sources of foreign debt. As reported at the last Johannesburg summit, (Birol, 2002), ‘in over 30 countries, energy imports exceed 10 percent of the value of all exports’, while ‘in about 20 countries, payments for oil imports exceed those for debt servicing’.

Electricity provision, use of non appropriate fuels for heating, cooking and lighting, and indoor air quality are major problems in less developed countries. In low-income cities (less than 750 US $/ person), only 70 % of the population is connected to grid, which provide electricity just for some hours per day.

The income of the households defines the type of fuel used for thermal processes. Low-income households choose cheep fuels like wood, kerosene or paraffin, while the higher the income, the more use of clean fuels, natural gas, or electricity is done, (Smith, 1990, 1994). As pointed out, this is a kind of an 'energy ladder', (Smith, 1990, 1994).

Studies have shown that households are able to switch over to modern fuels when their incomes reach $1000-1500, (Wadams 2001). Important economic barriers make access to modern fuels very difficult. Almost $ 600 has to be paid as a connection fee to the electricity grid, which by far beyond the means of urban poor, (Barnes et al, 2002).

A recent study in forty five cities of some less developed countries, (Barnes and Halpen, 2002), has shown that the lower income people consumes less energy while they make use of less convenient energy sources like wood and charcoal (Table 2.1). As expected the use of such energy sources indoors may be the source of serious pollution problems.

The cost of energy as well as its share on the total expenditures varies as a function of the economic status. The poorest 20 % of the households spend almost 15 to 22 % of their monthly income in energy. As shown in Figure 2.1, the lower the income, the highest the share of energy expenditures, (World Bank, 1995, Barnes et al, 1994). A similar situation is also found in the transition world, (Figure 2.2), (Wallace et al, 1987).

Table 2.1 - Fuel Use in forty five cities by ease to access to electricity, (Waddams, 2001)

Access to electricity in city	Average Monthly Household income (US Dollars)	Average Population (Thousands)	Wood	Charcoal	Kerosene	LPG	Electricity
			Percentage of Households using Fuel				
Very Difficult	33	23	56.4	73.4	57.6	26.6	21.1
Difficult	67	124	72.3	33.5	65.2	21.8	42.8
Easy	62	514	24.1	62.7	50.4	21.6	47.7
Very Easy	77	1153	22.1	34.5	42.6	47.8	90.5
			Fuel Use, (kg of oil equivalent per capita per month)				
Very difficult	33	23	1.31	10.09	0.35	1.49	0.24
Difficult	67	174	7.27	2.54	0.46	0.91	1.24
Easy	62	514	2.83	7.20	.1.10	0.50	2.00
Very Easy	77	1153	1.71	1.75	1.75	2.00	2.79

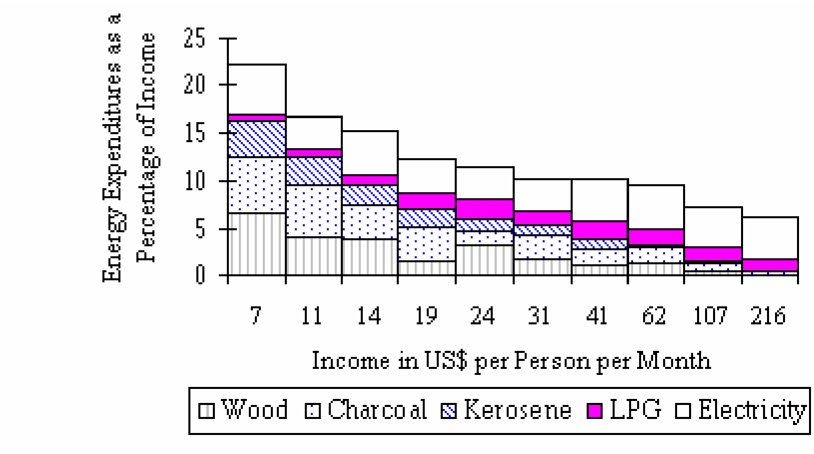

Figure 2.1- Energy Expenditure as a percentage of income. Average Income Deciles for 45 cities in 12 countries, (World Bank, 1995, Barnes et al, 1994)

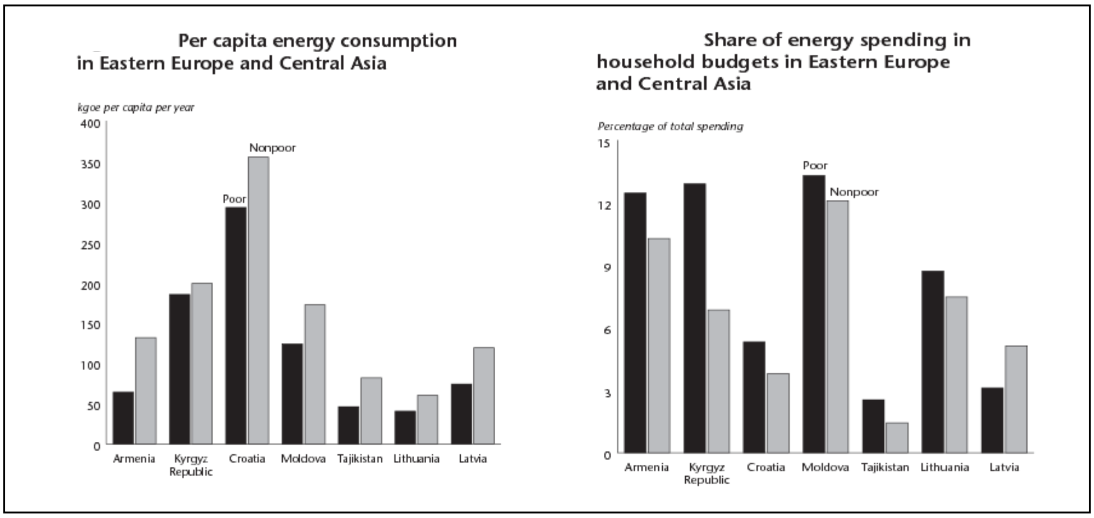

Figure 2.2 - Per capita energy consumption and share of energy spending in household budgets in Easter Europe and Central Asia, (Wallace et al, 1987)

As it concerns the developed world, the cost of energy is a major problem for a high percentage of population. Fuel poverty is defined as the number of households spending in excess of 10% of income on home heating, while when expenditures exceeds 20 per cent of the income, the family is under 'severe energy poverty'

Fuel poverty is completely different to poverty. Income support can eliminate seriously poverty, however, fuel poverty requires both an income assistance but also important investments to improve households as fuel poverty is the result of both low income and low energy performance of domestic buildings.

A study carried out by Eurostat in 14 European countries has shown that a very high part of the European population of affected by fuel poverty, (Healy J.D. and J. Peter Clinch). Figure 2.3 shows the main results of the study. According to the study Southern European population suffers highly from fuel poverty. Estimations show that fuel poverty in Portugal varies between 38-62 % of the population. In Spain, fuel poverty touches 20-43 % of the population and in Greece 25-36 %. Fuel poverty in Northern European countries is lower than in Southern Europe but quite high in absolute numbers.

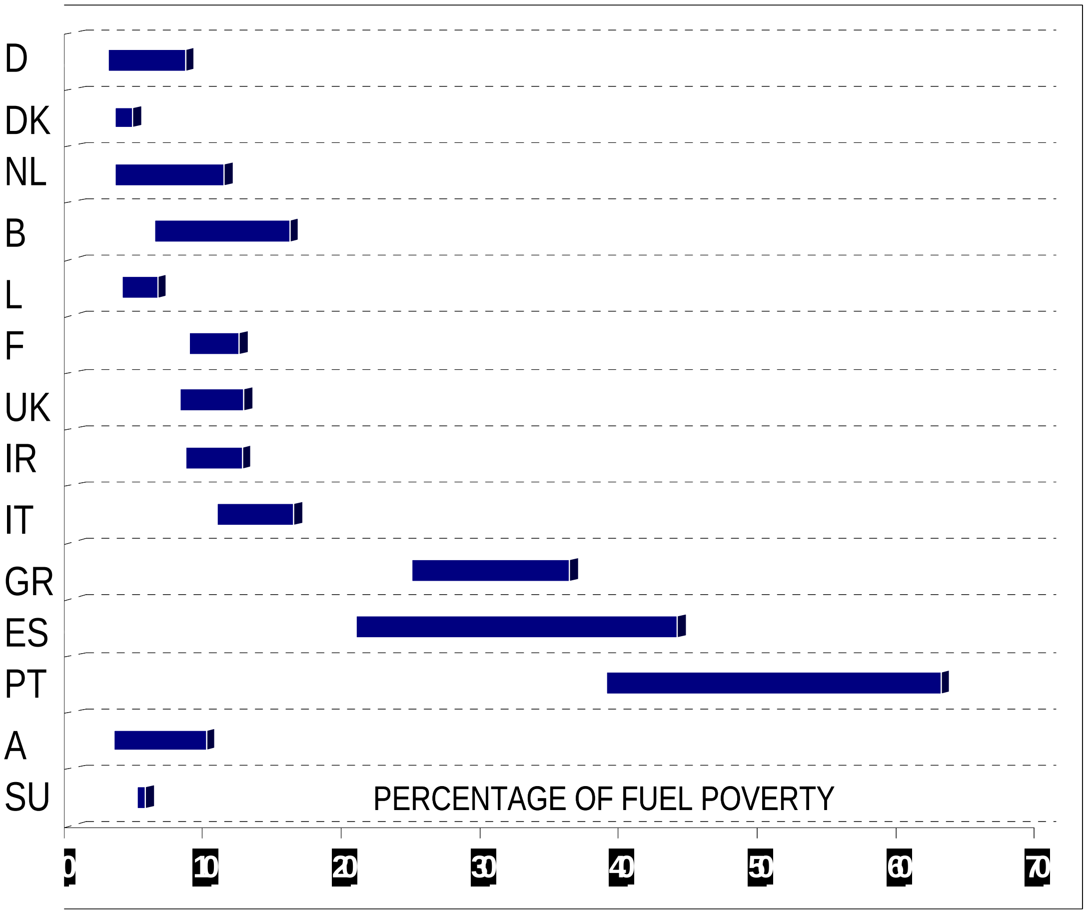

Figure 2.3 - Estimated percentage of fuel poverty in 14 European countries. Data are from Healy and J. Peter Clinch, 2002

In UK, the lowest quintile of the population spends almost 6.6 % of the monthly income for energy, while the corresponding percentage for the highest quintile is close to 2 %, (Saghir, 2002). Almost 27 per cent of all households (around 5.3m) are fuel poor while 5 per cent are in severe fuel poverty, ie needing to spend over 20 per cent of their income to achieve satisfactory heating. In an other report, (Fuel Poverty in UK, 2002), the total number of energy poor households in UK are estimated close to 5630000, i.e. 23,5 % of the total households.

In Ireland, estimations show that 17,6 % of the households are energy poor, (Heally and Clinch, 2004), around 226000 houses. About 27 % of the fuel poor houses, around 4.7 % of the total housing stock, is suffering from chronic fuel poverty. Also, 12,7 % of the households suffer from intermittent levels of fuel poverty, i.e. occupants are occasionally unable to heat their homes.

A recent study carried out in almost 1100 households in Athens, has shown that the relative cost of heating and electricity is much higher for poor than rich people. Figure 2.4 gives the mean heating energy consumption per person and area unit. As shown, the lower the income the higher the cost of heating per person and unit of surface. It is obtained that the cost per person and m² for the lower income group is to about 127 % higher that the corresponding cost of heating for the richest group, (Santamouris et al, 2007).

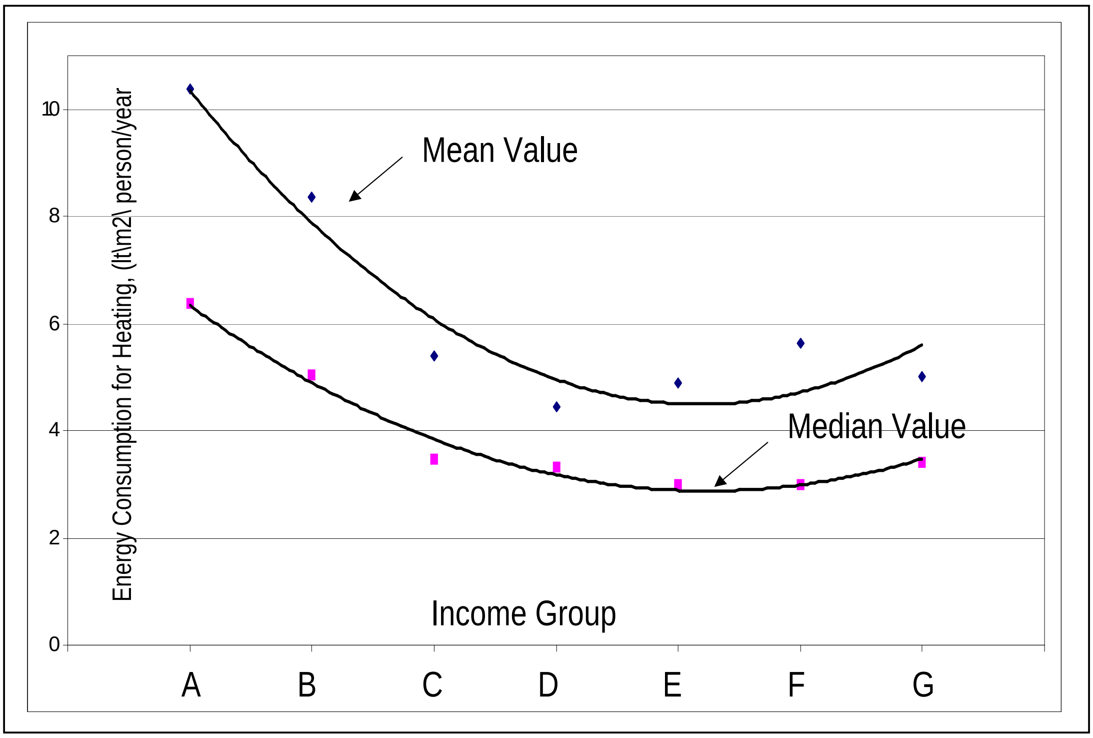

Figure 2.4 - Mean and median primary energy consumption for heating, (lt oil /person/m²/year), for all income groups. Data are from Data are from the Greek study on energy and poverty and refer to the Greek residential stock, Santamouris et al, 2007

In parallel it is found that the lower the income the higher the cost of electricity per person and unit of area. As calculated, (Figure 2.5), low income people pays almost 67 % more per person and square meter than high income people.

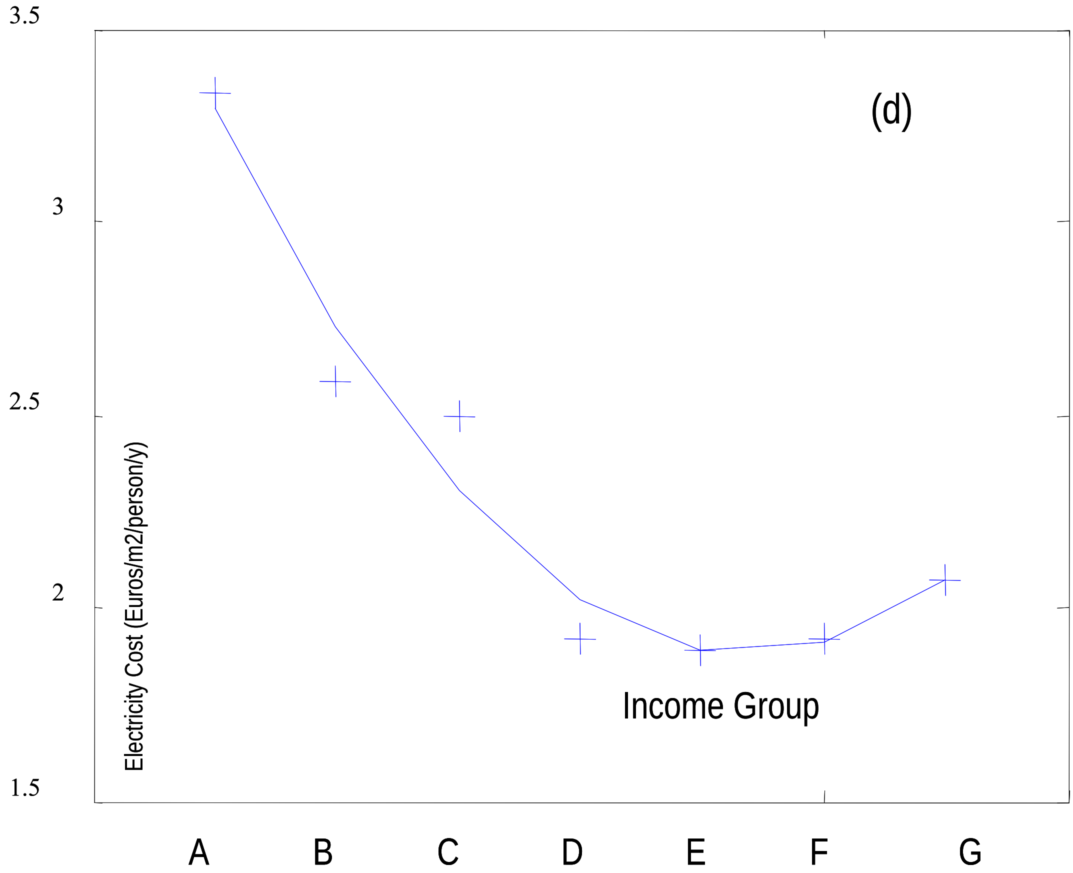

Figure 2.5 - Variation of the Median Electric Energy Cost per m² and person for all income groups, Data are from the Greek study on energy and poverty and refer to the Greek residential stock, Santamouris et al, 2006

Continuous increase of energy prices, has a very serious impact on low income people. As calculated, the increase of the oil price from 35 to 70 $/barrel, has increased the percentage of fuel poor household in Athens, Greece, from 1.6 % of the population to 8.4 %. In parallel, it has increase the percentage of fuel poverty in the low income groups from 16 % to 36 %. As calculated, a 10 $/barrel increase of the oil price brings about 2.1 % of the households in fuel poverty.

Thus, the relevant question is how much and how far the lack of energy or the use of non appropriate fuels causes indoor environmental problems and damages the well being and the health of people ?

2.2 Do Poor People Pays An Indoor Pollution Penalty?

The growth of large cities in developing countries has been companied by an increase in urban poverty mainly because of the increasing gap between incomes and land prices, and the failure of markets to provide housing for low-income groups. As reported by the United Nations, (UNEP, 2002), 'in cities of the less developed world, one out of every four households lives in poverty; 40 per cent of African urban households and 25 per cent of Latin American urban households are living below locally defined poverty lines'.

Poverty is mainly concentrated in specific social groups and in particular locations as the economic reality in these countries, forces low-income groups to settle in deteriorated and marginal lands in or around cities without access to basic infrastructures and services. Perhaps the major of the basic needs in poorer areas of cities in less developed countries include, the use of 'affordable and decent housing which contributes to ensure, health, security, development, empowerment, well-being, and urban functional efficiency.

Indoor air quality problems in developing countries are an extremely serious problem. While in developed countries IAQ problems arise from low ventilation rates and the emission of building products and materials, the inhabitants of less developed countries face problems related to pollutants generated by human activities, in particular by combustion processes because of the use of ovens and braziers with imperfect kitchen and stove designs.

As reported in (World Bank, 2000), 'today about half the population of the world continues to rely for cooking and associated space heating on simple household stoves using unprocessed solid fuels that have high emission factors for a range of health-damaging air pollutants' Compared to modern fuels like gas, solid fuels produce 10-100 times more respirable particulate matter per meal, (World Bank , 2000). Measurements made in kitchens of homes in India showed particulate levels 35 times the one hour standard and nearly 100 times the 24 hour standard recommended in industrialised countries.(Bitan, 1992). In parallel, other pollutants, like carbon monoxide, formaldehyde, polycylic aromatic hydrocarbons, benzene, and 1,3-butadiene also reach much high concentrations. As reported by the WHO, in some areas of China and India, the use of coal in houses leads to high indoor concentrations of fluorine and arsenic with consequent health effects, (World Bank, 2000).

Most of the houses have no adequate ventilation. According to World Energy Council and FAO, (WEC and FAO, 1999), family homes in rural areas of Africa generally consist of multiple-use buildings, where the same room or few rooms are used for cooking, sleeping and working. In many cases, the total indoor volume is less than 40 cubic metres. These homes often have minimal ventilation, which may be further reduced during rainy seasons and cold spells.

Studies in India, (Singh et al, 1996), have shown that only a 25 % of the low income households have an adequate ventilation, (Table 2.2), while almost 60 % of all households have a poor ventilation.

Table 2.2 - Income group and ventilation conditions in India, (Singh et al, 1999)

Housing facilities of the households sampled of Aligarh city (%)

	Status		Use of house		House type		Area of house		No. of rooms		Area of rooms		Ventilation	
Income group	Own house	Tenant	Res.	Res./ Comm./ Ind.	Brick	Mud/ that.	<300 ft²	>300 ft²	<4	>4	<60 ft²	>60 ft²	Adequate	Poor
Very low	75	25	50	50	50	50.0	100	—	100	—	100	—	25	75
Low	64	46	86	14	75	25.0	92	8	96	4	78	22	54	46
Medium	40	60	56	44	100	—	92	8	85	15	70	30	43	57
High	78	22	92	8	100	—	44	56	36	64	32	68	20	80
Very high	82	18	91	9	100	—	36	64	18	82	9	91	73	27
Total	58	42	73	27	93	7	78	22	72	28	59	41	42	58

High indoor concentration of pollutants poses a tremendous health threat to the population. Worldwide, close to 2.8 millions of deaths are attributed to IAQ problems and about 2 million deaths per year are attributable to indoor air pollution from cooking fires, (WEHAB, 2002). Recent studies of the WHO shown that 30 to 40 per cent of 760 million cases of respiratory diseases world-wide are caused by particulate air pollution alone. 'Mostly, these health effects are caused by indoor air pollution due to open stove cooking and heating in developing countries' (World Bank, 2000). Studies in Latin America, Asia, and Africa shown that, indoor air pollution is also responsible for pregnancy-related problems such as stillbirths and low birth weight. It has also been associated with blindness (attributed to 18 percent of cases in India) and immune system depression.(Kirk R. Smith, 2000)

In particular in India, it is estimated that 500 000 women and children die each year due to Indoor air pollution related causes as almost 75 % of the population relies to traditional biomass fuels, (Kirk R.

Smith, 2000). This is close to 25 % of the deaths worldwide attributed to indoor air pollution problems.

Other studies increase the number of premature deaths in India because of the IAP problems, up to 3300000 per year. Table 2.3 summarises most of the recent estimates on premature mortality in India because of the IAP problems, (adapted from Smith 1994). The severity of the problem is shown by studies aiming to estimate the burden of disease in India for selected major risk factors and diseases. As shown in Figure 2.6, (Smith, 1994) mortality because of indoor air pollution problems is at a very high rank.

Table 2.3 - Estimate of annual premature mortality from air pollution in India (thousands of deaths), Adapted from Smith 1994

Outdoor exp., (‘000)	Indoor exp., (‘000)	Reference
50–300	850–3300	(18)
84	590	(19-20)
200	2000	(21)

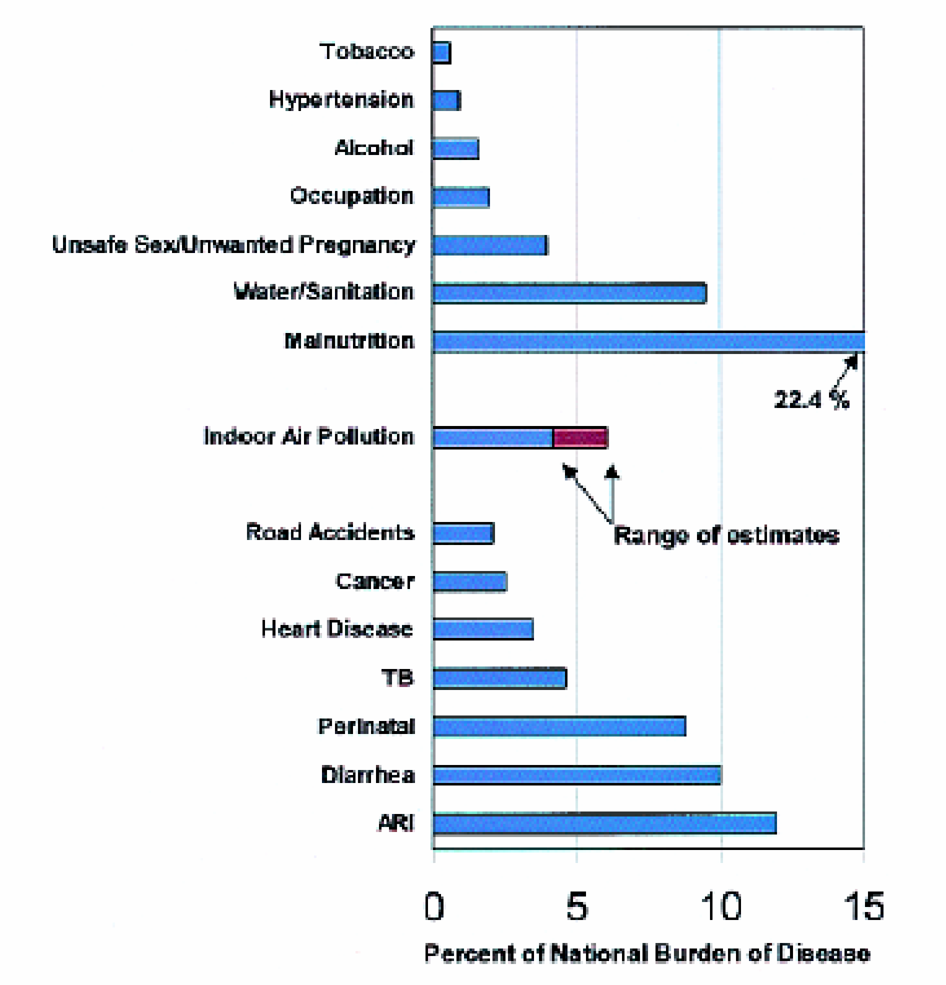

Figure 2.6 - Estimated burden of disease (DALYs) in India for selected major risk factors and diseases compared with that from indoor air pollution, (Smith, 1994)

It is evident that proper ventilation of buildings combined with more efficient appliances can contribute highly to reduce the concentration of indoor pollutants and protect public health.

2.3 Housing conditions and thermal stress in low income households

As already discussed, improper indoor environmental conditions in low income households cause serious comfort and health problems and increase mortality. Low temperatures during the winter season cause 40,000 excess winter deaths in UK. This country together with Ireland present the highest rates of mortality in Northern Europe during winter, (Healeay and Clinch, 2004). An important part of mortality result in non well heated housing, (Clinch and Healy, 2000; Curwen, 1991).

In fact, the quite recent study of Eurostat, (1996, 1999), has shown that there is a high percentage of households in Europe without central or electrical heating system. The mean percentage of the households without heating is given in Table 2.4 for 14 European countries. As shown, the unheated houses ratio varies between 90 % in Portugal to 2 % in Denmark.

Table 2.4 - Households without central or electric storage heating, (% of households)

Households without Central or Electric Storage Heating (% of Households per Countr

	1994	1995	1996	1997	Mean
Germany	12.4	10.3	8.6	15.3	11.7
Denmark	3.2	1.8	1.0	1.0	1.8
Netherlands	14.4	13.2	12.7	11.4	12.9
Belgium	25.8	24.3	24.0	21.4	23.9
Luxembourg	7.6	6.9	5.4	-	6.6
France	10.6	10.1	9.8	8.9	9.9
UK	14.8	12.1	10.7	10.0	11.9
Ireland	23.8	20.8	19.8	16.4	20.2
Italy	26.6	18.6	17.3	17.7	20.1
Greece	44.7	46.9	46.4	44.7	45.7
Spain	71.6	69.9	65.2	62.2	67.2
Portugal	92.5	92.1	92.2	89.9	91.7
Austria	-	19.8	17.9	10.0	15.9
Finland	-	-	3.4	16.3	9.9

In parallel, a very high part of the population declares unable to heat properly their houses. Table 2.5 gives the relative percentage for the 15 countries under examination. As shown, almost 75 % of the Portuguese families is unable to heat homes properly, while the lower percentage is found in Germany, (1.6 %).

Table 2.5 - Households unable to heat home adequately, (% of households per country)

Households Unable to Heat Home Adequately (% of Households per Country

	1994	1995	1996	1997	Mean
Germany	2.0	1.5	1.4	-	1.6
Denmark	4.2	2.9	2.8	2.6	3.1
Netherlands	2.0	1.8	2.0	2.2	2.0
Belgium	4.6	4.1	2.8	3.0	3.6
Luxembourg	2.6	3.1	3.5	-	3.1
France	8.5	7.3	7.0	5.8	7.2
UK	8.9	6.2	5.3	2.7	5.8
Ireland	8.0	5.9	6.5	5.1	6.4
Italy	22.4	22.7	20.6	20.3	21.5
Greece	46.8	45.5	46.8	42.9	45.5
Spain	58.7	57.7	53.3	49.7	54.9
Portugal	75.8	74.9	73.8	72.9	74.4
Austria	-	2.5	1.9	1.8	2.1
Finland	-	-	4.7	4.7	4.7

Housing conditions vary as a function of income. Santamouris et al, (2007), has reported that there is a very clear relation between the income level and the percentage of non insulated dwellings in Athens, Greece. It is found that the higher the income the higher the percentage of insulated buildings, (Table 6). It is characteristic that only 28 % of people of the poorest group lives in insulated buildings, while the corresponding figure for the richest group is close to 70 %. Also a very clear relation between the percentage of buildings with double glazing and the income levels is found. The higher the income the higher the percentage of buildings with double glazing. The differences between the income groups are quite high. For the poorest group the percentage of double glazed buildings is 24 % while for the richest group the corresponding figure is 67 %, (Table 6). Finally, insulated buildings with double glazing are quite rare for the lower income groups, (8 %), Table 2.6, while the corresponding percentage increases to 60 % for the high income group. As previously, the higher the income the higher the percentage of buildings with insulation and double glazing.

Table 2.6 - Percentage of households living in insulated buildings, buildings with double glazing and insulated buildings with double glazing

Income Group	Percentage of Households living in insulated Buildings	Percentage of Households living in buildings with double glazing	Percentage of Households living in insulated buildings with double glazing
A : < 9000 Euros / y	28,0	24,0	8,0
B : 9000-13000 Euros / y	39,0	33,0	23,2
C : 13000 – 24000 Euros / y	43,0	41,0	27,3
D : 24000 –36000 Euros / y	54,0	50,0	37,6
E : 36000 – 63000 Euros / y	68,0	62,0	51,3
F : 63000 – 100000 Euros / y	73,0	65,0	63,2
G : > 100000 Euros / y	70,0	67,0	60,0

A recent study carried out by the European Statistical Office, has found that some 12.7% of all European households contain damp patches, (Healy J.D. and J. Peter Clinch, 2002). Figure 2.7 gives the average percentage of Households with Damp Spores. As shown, the southern European countries are suffering worst, with almost 33,4 % of households in Portugal, 21.5 % in Spain and 18.8 % in Greece presenting damp spores. The average incidence in Northern Europe is close to 8 %, with a percentage close to 16.3 in France, 14.4 % in Belgium and 13 % in UK,

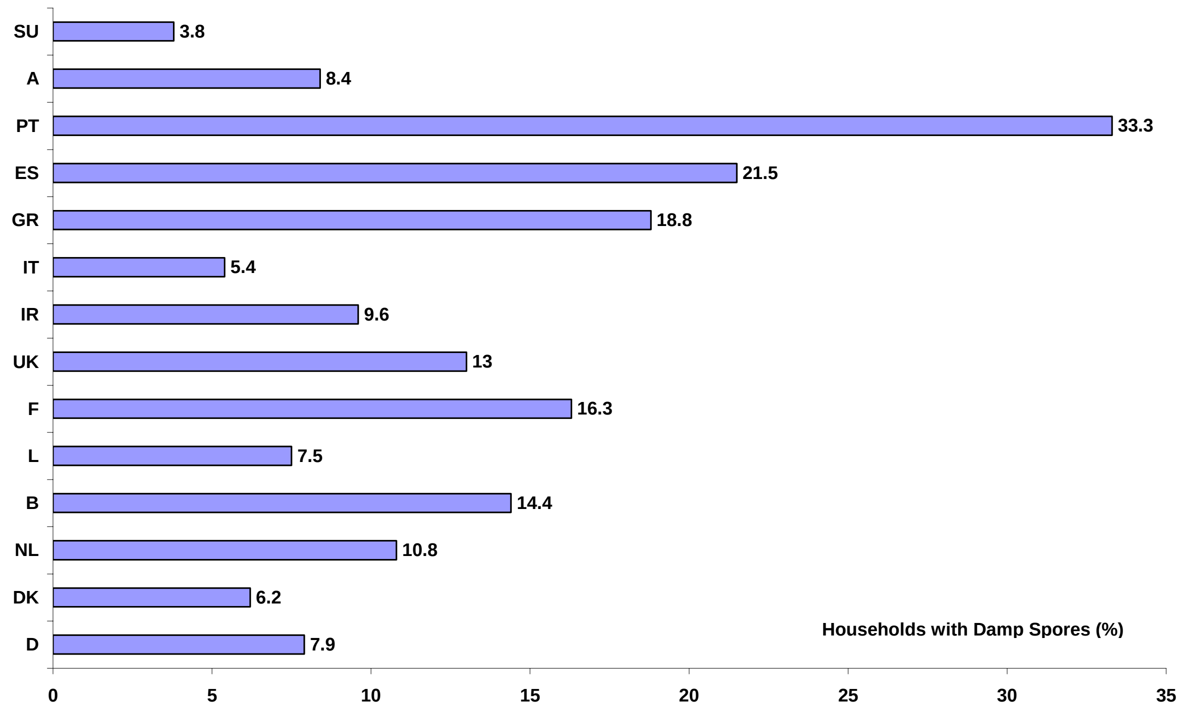

Figure 2.7 - Average Percentage of Households with Damp Spores. Data refer to some European Union Countries and are from Healy and J. Peter Clinch, 2002

The presence of damp spores in houses is very important from a public health perspective, as a chronic exposure to damp is associated is the source of important respiratory and cardiovascular diseases, (Williamson et al, 1997).

In UK, a recent study has examined the relation between health problems and energy efficiency indicators, (SAP). It is found that generally, problems of arthritis, rheumatism and wheezing tended to decline as the SAP rating rose, but an interesting pattern for asthma is reported. A decline in asthma in the first three SAP groups is found, followed by a rise in the most energy efficient group. In parallel, as reported mould generally decreases as SAP increases, but in the highest quintile of SAPs there is a noticeable increase in mould for both small and large households. As reported, relative humidity and ventilation play a key role and that far more attention should be paid to ventilation provision, (DETR 2001).

An other study in UK, has shown that many health effects in Britain are associated with high levels of humidity, (Baker 2001). This is due to the strong association between high humidity and mould and dust mites. Damp and mould growth are strongly related with nausea, breathlessness, backache, fainting and bad nerves among adults and respiratory symptoms, while dust mites flourish in houses with high relative humidity and poor ventilation. Dust mites are associated with the development of asthma and allergies. A study of Energy Action Scotland, 1999, has shown that the level of asthma was 1.6 times higher in households that reported dampness, than in households without dampness.

Non proper indoor environment and non adequate ventilation may be the source of important social cost for additional health treatment. In a recent study, (Bardsley 2000), the healthcare cost of people living in 107 homes on a poor estate in East London were compared against those of people living in homes in a similar improved estate. It is found that the average annual health costs of a person living in the unimproved estate were £512, compared with £72 for a person in the improved estate.

In Ireland, a recent survey has shown a strong relation between fuel poverty and condensation and an ever stronger relation with household damp. Here, the incidence of fuel poverty is almost four times that found among households without damp spores, ((Healy and Clinch, 2004). It is evident that low indoor temperatures and inadequate ventilation are the major reasons of the problem

In Scotland, National Asthma Campaign Scotland, has asked the local government to make sure that damp homes ‘don’t turn into havens for dust mites by including ventilation measures in their Fuel Poverty Statement’. The Campaign was concerned ‘that increasing the temperature in damp homes without taking action to improve ventilation will turn homes into the warm humid environment that house dust mites thrive upon’

In Greece, a study in about 25 houses in Athens, (Santamouris et al, 2007), has identified a relation between infiltration losses and income. Figure 2.8 shows the variation of the infiltration rate, (ACH at 50 Pa), for various income groups. As shown, the lower the income the higher the infiltration rate of buildings, and thus the higher the required energy consumption to achieve comfort during the winter and summer period.

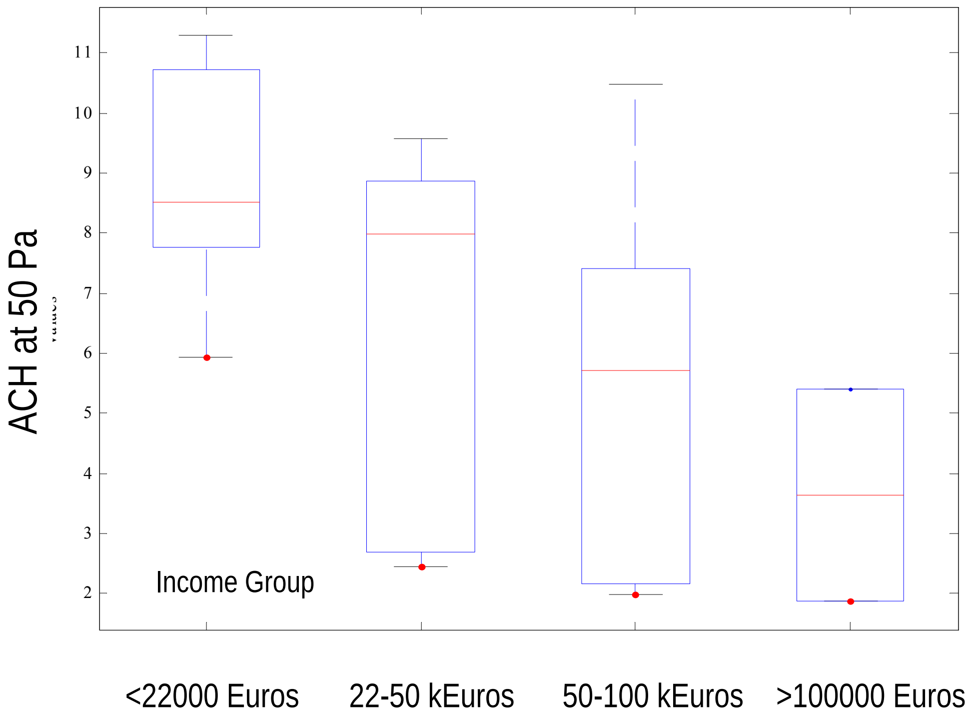

Figure 2.8 - Variation of the air changes at 50 Pa in 25 Houses in Athens for various income groups, Data are from the Greek study on energy and poverty and refer to the Greek residential stock, Santamouris et al, 2007

In USA, the American Association of School Administrators, 2001, has reported that schools with the highest concentrations of students living in poverty (70 percent or more eligible for free or reduced-price lunch) were more likely to suffer from a range of facilities problems. It is found that ventilation is the environmental issue most likely to be perceived as unsatisfactory, with 26 percent of respondents reporting this problem.

An other study in US, has examined the exposure to the fungus Alternaria alternata of American houses. The fungus is an important risk factor for asthma and allergic rhinitis. It is found that demographic factors, like race and poverty had the greatest influence on Alternaria levels, with both white race and low income contributing consistently to higher Alternaria levels in US homes, (Salo et al, 2005). A similar study, (Stevenson 2001), has found that African American and Mexican American children are substantially more likely than white children to be sensitized to allergens important in asthma. Differences in indoor allergen sensitivity are consistent with racial differences in asthma morbidity. The findings suggest that racial disparities in housing, community, or both environmental factors play a role in determining national patterns of asthma morbidity. However, the authors mention that not a clear relation to poverty was found.

High indoor temperatures and lack of ventilation during summer are the sources of important health problems in hot climates. A serious increase of mortality rates is observed in Southern European countries during the recent heat waves. The heat wave of August 2003 in Europe has been an extreme meteorological event with dramatic consequences.

During the summer period, high ambient temperatures and heat waves cause dramatic problems to vulnerable population living in overheated households. In France the estimated death toll of the event was about 15000 deaths. In Rome, excess mortality was observed throughout the summer, but predominantly during the three heat waves observed [Michelozzi et al, 1999, 2005]. The first heat wave (9 June–2 July) was associated with an increase in mortality of 352 deaths; a total of 319 excess deaths occurred during the second heat wave period (10–30 July) and 180 excess deaths during the third (3–13 August). It has to be pointed out that the greatest excess in mortality was registered in those with low socioeconomic status in Rome (+17.8%), living in poor households. According to the Eurosurvellance (2005), an estimated 22 080 excess deaths occur in England and Wales, France, Italy and Portugal during and immediately after the heat waves of the summer of 2003. Additionally 6595-8648 excess deaths have been registered in Spain, of which approximately 54% occurred in August, and 1400-2200 in the Netherlands, of which an estimated 500 occurred during the heat wave of 31 July-13 August. In parallel, it is reported that approximately 1250 heat-related deaths occurred in Belgium during the summer of 2003, almost 975 excess deaths during June-August in Switzerland and 1410 during the period August 1-24 in Baden-Württemberg, Germany. Studies in Europe, [Michelozzi et al, 1999, 2005]. show that the greatest excess in mortality was registered in those with low socioeconomic status leaving in buildings with improper heat protection and ventilation..

Klinenberg (2002) focuses on a July 1995 heat wave in Chicago, USA, one of the deadliest in American history, that killed between 485 and 740 Chicagoans. A large proportion of the victims lived in Single Room Occupancy (SRO) hotels. It is reported that only about half of the residents had fans, and many lived in rooms with sealed windows they could not open. It is also reported that even if some of the elderly victims had had air conditioners in their homes, many would not have used them because of their more pressing fear that they could not pay their utility bills, which would result in complete loss of all of their power. Even in Canada, during 2005, at least six Toronto residents living in poor rooming houses died during a heat wave, (Crowe 2005).

In a similar study in Greece, (Santamouris, 2007), the relative use of air conditioning has been assessed for the various income groups. A very high increase of the installed a/c per household is observed as a function of income, Table 2.7. The mean value for the lower income group is close to 0.6 units/house, while the corresponding value for the upper income class is close to 2.15. The percentage of households with at least one installed air conditioner varies from 48 % to 69 % for the lower and upper income classes respectively.

Table 2.7 - Number of air conditioners units per households, percentage of households with at least one air conditioner, number of air conditioners per person, number of air conditioners per square meter of households and number of air conditioners per square meter and person.

Income Group [Euros / y]	Number of air conditioning units per household	Percentage of Households with at least one air conditioning unit	Number of air conditioners per person	Number of air conditioners per square meter of households, (x100)	Number of air conditioners per square meter and person, (x 1000)
A : < 9000	0,60	48 %	0,47	9,8	7,4
B : 9000-13000	0,84	53 %	0,40	1,1	6,1
C : 13000 – 24000	1,1	60 %	0,45	1,2	5,5
D : 24000 –36000	1,2	63,2	0,40	1,3	4,4
E : 36000 – 63000	1,5	68,0	0,49	1,3	4,4
F : 63000 – 100000	1,70	67,0	0,53	1,3	4,5
G : > 100000	2,15	69,0	0,74	1,6	6,2

Although it is clear that higher income groups use more air conditioning units, the ratio of installed air conditioners per square meter and person, is much higher for the lower income people. As shown in Table 7, the density of installed air conditioners per person is much higher for the lower income group than for the middle ones and is comparative to the figure of the richest group. However, the density of installed air conditioners per square meter is much higher for the lower income people that for all other groups. The same is observed when the ratio of installed air conditioners per square meter and person is calculated, Table 7. Thus, although middle and high income people use more air conditioning, the relative cost of comfort during the summer period is much higher for the lower income people. This can be explained as low income people lives in buildings with limited thermal protection and also because low income housing is located in areas of Athens where heat island gets its maximum intensity.

The same conclusions have been drawn, when the cost of air conditioning has been assessed. To evaluate the impact of air conditioning on the electricity expenses of each income group, the specific electricity cost for all families having or not at least one air conditioner installed, has been calculated, (Santamouris et al, 2007). The obtained annual cost per income group is given in Figure 2.9. As shown, the use of air conditioning increases considerably the annual electricity expenses especially in the low income groups. As a mean value, the use of air conditioning increases the annual expenses to about 100 Euros per household, or 0,6 Euros/m², or 12.5 Euros per person. The increase is much higher for the low income groups, where the relative increase of the cost because of the air conditioning use is close to 195 Euros/household, or 1.2 Euros/m², or 87 Euros/person. Thus, the findings on the use of air conditioning that although middle and high income people use more air conditioning, the relative cost of comfort during the summer period is much higher for the lower income people, is verified. As already mentioned, this may be explained by the fact that low income people lives in buildings with limited thermal protection and also because low income housing is located in areas of Athens where heat island gets its maximum intensity.

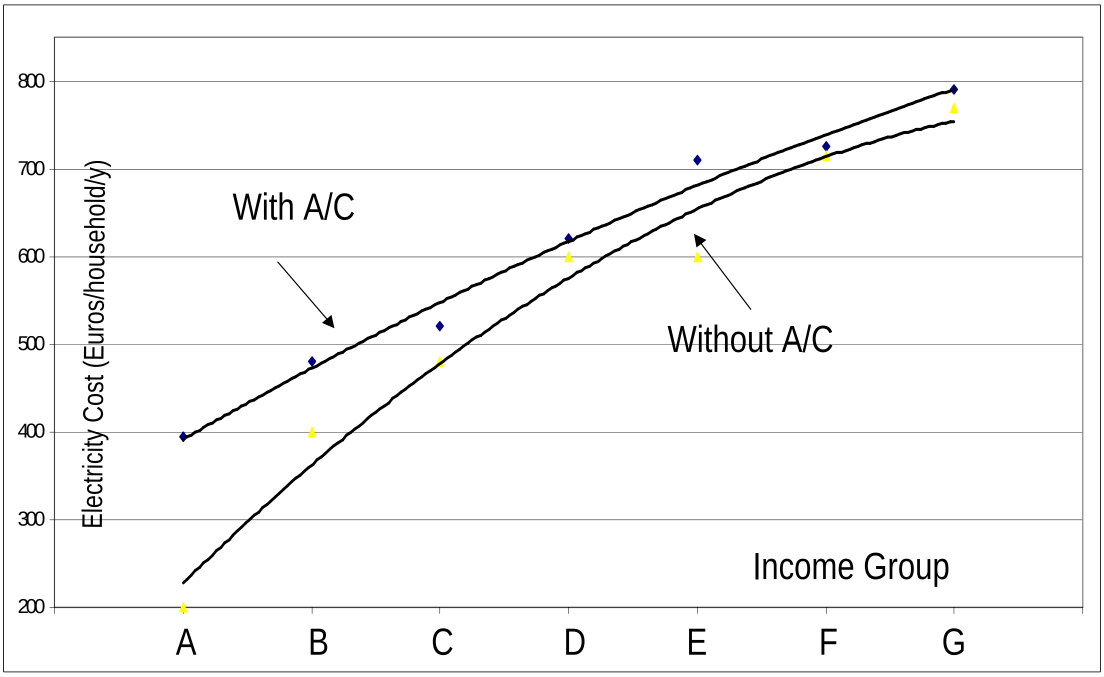

Figure 2.9 - Variation of the Annual Median Electric Energy Cost per household for families with and without air conditioning for all income groups, Data are from the Greek study on energy and poverty and refer to the Greek residential stock, Santamouris et al, 2007

Increased use of air conditioning creates a serious peak electricity load problem to utilities and increases the cost of electricity. According to OFFER and National Audit Office, (1998, 2003), the mean European cost of a kWh out of peak is close to 3,9 cents, while the mean cost during peak is 10,2 cents. In parallel, the average cost of a saved kWh is 2.6 cents. In addition, strength increases highly during heat weaves. As reported, during the July 2006 heat wave in California, the average homeowner used about 28 percent more electricity, (San Jose News, 2006). It is evident that proper and alternative conditioning techniques as well as appropriate ventilation techniques have to be used to improve indoor environmental conditions and diminish the impact of thermal stress.

3 Bringing solutions and presenting good examples

It is evident that the nature of the problem is completely different in the developed and the developing world. Completely different political procedures, technologies and implementation plans have to employed in both cases.

3.1 Discussing solutions for the developed world

In the developed world the aim should be to enhance indoor comfort conditions and when possible reduce or increase indoor temperatures up to a comfortable level.

Alternative energy and environmental solutions have to be adopted to improve the environmental conditions of low income households. The idea is not to maintain temperatures within the ASHRAE-defined comfort zone of (20–27 °C) using energy driven systems, but to create buildings that will not threaten the lives of their occupants under adverse ambient conditions and even when if power is lost or citizens can not afford to pay for it, (Wilson, 2005).

It is not in the scopes of the present document to discuss the whole series of measures to protect low income and vulnerable people. Several programs have been developed and applied on this purpose. Some of the more important and efficient techniques are mentioned below.

As it concerns protection during the winter period, existing programs in UK have shown that adoption of energy efficient measures, for example additional insulation, can exacerbate the problem, however have to accompanied by additional ventilation measures. It has to be understood that increasing the temperature of damp houses without increasing the ventilation rate will create a warm humid environment and will enhance the growth of house dust mites. Guidelines to improve the ventilation and avoid condensation in existing households have been prepared and are easily available, (Good Practice Guides 155 and 268). Several techniques like trickle vents, extract fans, passive stack ventilation and whole house mechanical ventilation systems with heat recovery are proposed. It is evident that low income citizens can afford a high capital or running cost, thus the measured to be selected should present the lower cost together with the maximum possible efficiency.

A recent program in UK, has studied the necessary household improvements for existing social housing to improve the health of asthmatics, (Baker 2001). Additional ventilation, conditioning and energy efficient measures have been implemented and their impact on health, comfort, energy use and dust mites has been monitored. It is found that modifications contributed to improve the perceived health by 12%; effectiveness of lungs of 4 asthmatics improved by mean of 20%; medication or symptoms reduced for 3 out of the 4 asthmatics where this was recorded.

As it concerns protection from high indoor temperatures, ventilation and increased air movement is associated with increased heat stress when the ambient temperature exceeds 37-38 °C. Therefore, increased ventilation rates have to be used only at temperatures lower than 32.2 °C and humidity lower than 35-40 %. Above these limits the use of fans is not protective. In low humidity zones, low cost fans associated with direct evaporative systems may be used. However, the levels of indoor humidity, has to be controlled. Indirect evaporative systems may increase the air flow and decrease the indoor temperature without increasing the indoor humidity content. Such a system is quite more expensive than simple fans or direct evaporative systems but much chipper than conventional air conditioners. As mentioned by Kilbourne et al, (1982), the use of air conditioning reduces the risk for heatstroke and heat-related illness, even if it is available for only part of the day. However, as air conditioning is a protective factor, poverty is a risk factor for heat-related illness.

The City of Philadelphia's, USA, runs the "Cool Homes Program" for elderly low-income residents. The program provides non-mechanical cooling measures that save energy and lower costs. The aims of the program involve the reduction of the indoor temperatures to a comfortable level, minimisation of health risks, stabilisation of the energy consumption and provision of social interaction. At the initial phase of the program, 100 households at the area of the city presenting the highest incidence of heat related mortality have been were selected. Then the program has been extended to 400 additional residences. The program has provided to all houses, a window mounted whole house fan, interior air sealing, and an elastomeric roof coating to decrease the roof temperature. It has been found that the employed measures lower the solar gains by 80 % and reduces the bedroom indoor temperatures by 2.5 °C. The estimated energy offer was equivalent to the energy delivered by a conventional air conditioner of 8 kBtu/h (2.3 kW), running for four hours per day.

Recent developments in passive cooling technologies permit improvements in the indoor environmental quality of low income households. High reflective coatings for buildings, present low cost, are easily accessible and when used may reduce substantially indoor temperatures and enhance comfort in most of the warm zones of the planet. In parallel, recent knowledge and developments on ventilation technologies permit to better design and position openings in urban buildings, enhance indoor air speed, improve indoor comfort and decrease indoor pollutants concentration.

The use of reflective roofs can improve considerably comfort levels in low income households and protect people. Santamouris et al, (2007), has reported the expected reduction of the cooling needs of low income housing for 29 locations in the planet (Table 3.1). As shown the expected absolute reduction of the cooling load varies between 5 to 70 kWh/m², as a function of the local climate characteristics. Lower absolute contributions correspond to small cooling loads but represent a high percentage of the load, up to 70 %, while high absolute contributions correspond to high cooling loads and a lower relative reduction of the load, (> 20 %). As a mean value, the use of reflective coatings in the roof of this type of buildings in the selected areas may decrease their cooling load up to 30-35 %.

In parallel, Table 3.2 gives the calculated number of hours with an indoor temperature above 30 °C, 27.5 °C and 26 °C when reflective roofs are used. Results show that for all temperature bases, a very important improvement of indoor comfort may be achieved by using reflective roofs. The specific reduction of the hours above a threshold temperature depends highly on the distribution of the ambient temperature during the day, and the overall climatic conditions. As expected the higher the temperature base the higher the benefits. For the temperature base of 30 °C, the 50 % of the calculated cumulative distribution corresponds to 3400 h and 1700 for the conventional and the reflective roof building respectively. The corresponding values for the temperature base of 27.5 °C are 6400 and 4400, while for the base of 26 °C the corresponding values are 7400 and 5800 respectively.

Table 3.1 - The calculated cooling load for both scenarios and the expected energy savings

SN	Station	Cooling load (kWh/m²)			Percentage (B – A) / A
		conventional	high refl. Roof	difference (B – A)	
1	Abu Dhabi	265.4	212.0	-53.4	-20.1%
2	Aden	287.1	222.3	-64.9	-22.6%
3	Alexandria (Nouzha)	69.4	34.5	-34.9	-50.3%
4	Bagdad	142.3	105.3	-37.0	-26.0%
5	Baku	44.4	23.6	-20.9	-46.9%
6	Bamaco	211.5	145.4	-66.1	-31.3%
7	Bangui	141.9	87.3	-54.6	-38.5%
8	Basrah	193.5	151.8	-41.8	-21.6%
9	Belem	146.0	92.4	-53.6	-36.7%
10	Belo Horizonte	26.1	6.1	-20.0	-76.7%
11	Brazzaville	117.0	69.1	-47.9	-40.9%
12	Cairo	106.2	63.0	-43.2	-40.7%
13	Casablanca	30.4	8.7	-21.6	-71.2%
14	Dakar	122.6	62.8	-59.7	-48.7%
15	Damascus (Kharabo)	65.3	32.7	-32.6	-49.9%
16	Khartoom	285.3	212.8	-72.5	-25.4%
17	Mogadiscio	256.5	194.8	-61.8	-24.1%
18	Monrovia	160.0	103.5	-56.6	-35.3%
19	Muscat	198.4	145.8	-52.6	-26.5%
20	Ndjamena (Fort Lamy)	258.4	187.9	-70.5	-27.3%
21	Paramaribo	148.3	94.0	-54.3	-36.6%
22	Port Soudan	263.6	198.0	-65.6	-24.9%
23	Pretoria	24.0	4.9	-19.1	-79.5%
24	Rabat	29.4	9.5	-19.9	-67.7%
25	Sanaa	26.8	7.6	-19.2	-71.7%
26	Sao Paulo	6.1	0.8	-5.3	-86.2%
27	Tabriz	34.7	15.8	-18.8	-54.4%
28	Teheran	85.3	54.8	-30.5	-35.7%
29	Walvis Bay	256.6	190.5	-66.1	-25.8%

Table 3.2 - Reduction of the hours with indoor temperature above 30, 27.5 and 26 °C, for the conventional and the building with the reflective roof

SN	Place	Hours Above the following Indoor Temperature								
		30ºC			27.5ºC			26ºC		
		Conventional	Reflective Roof	Reduction of discomfort hours	Conventional	Reflective Roof	Reduction of discomfort hours	Conventional	Reflective Roof	Reduction of discomfort hours
1	Abu Dhabi	5987	5349	10,7%	6968	6255	10,2%	7516	6849	8,9%
2	Aden	7818	6778	13,3%	8521	8006	6,0%	8661	8456	2,4%
3	Alexandria (Nouzha)	1996	691	65,4%	3295	1970	40,2%	4003	2789	30,3%
4	Bagdad	3467	2822	18,6%	4041	3544	12,3%	4384	3913	10,7%
5	Baku	1222	513	58,0%	2061	1275	38,1%	2540	1829	28,0%
6	Bamaco	6452	4310	33,2%	8058	6952	13,7%	8496	7935	6,6%
7	Bangui	4393	1575	64,1%	7594	5561	26,8%	8373	7513	10,3%
8	Basrah	4251	3765	11,4%	4906	4407	10,2%	5221	4832	7,5%
9	Belem	4536	2022	55,4%	7287	5412	25,7%	8230	7303	11,3%
10	Belo Horizonte	196	0	100,0%	1342	245	81,7%	2776	923	66,8%
11	Brazzaville	3314	1037	68,7%	6450	4414	31,6%	7602	6497	14,5%
12	Cairo	3190	1688	47,1%	4279	3207	25,1%	4753	3979	16,3%
13	Casablanca	462	34	92,6%	1501	402	73,2%	2362	996	57,8%
14	Dakar	3210	764	76,2%	6487	3603	44,5%	7749	5744	25,9%
15	Damascus (Kharabo)	1847	740	59,9%	2735	1743	36,3%	3218	2296	28,7%
16	Khartoom	7228	6167	14,7%	8089	7308	9,7%	8467	7885	6,9%
17	Mogadiscio	8201	6981	14,9%	8732	8623	1,2%	8750	8747	0,0%
18	Monrovia	5312	2816	47,0%	7666	6271	18,2%	8267	7655	7,4%
19	Muscat	5583	4617	17,3%	6749	5896	12,6%	7460	6653	10,8%
20	Ndjamena (Fort Lamy)	7269	5822	19,9%	8214	7454	9,3%	8539	8049	5,7%
21	Paramaribo	4724	2429	48,6%	7228	5569	23,0%	8232	7312	11,2%
22	Port Soudan	6769	5592	17,4%	7883	6956	11,8%	8340	7704	7,6%
23	Pretoria	239	6	97,5%	1162	176	84,9%	2060	620	69,9%
24	Rabat	518	25	95,2%	1511	431	71,5%	2299	1035	55,0%
25	Sanaa	327	7	97,9%	1474	343	76,7%	2469	1012	59,0%
26	Sao Paulo	19	0	100,0%	280	24	91,4%	733	140	80,9%
27	Tabriz	874	239	72,7%	1670	881	47,2%	2173	1354	37,7%
28	Teheran	2417	1638	32,2%	3071	2453	20,1%	3388	2843	16,1%

Important research has been carried out recently on appropriate and advanced ventilation techniques, (Santamouris and Wouters, 2006). The main achievements deal with: a) Better understanding of the air flow phenomena and of the expected comfort benefits, in particular in the dense urban environment, and development of efficient and practical procedures to design natural and hybrid ventilation systems and configurations, (Santamouris et al, 2007, Allard et al, 2006), b) Technological developments mainly on the field of hybrid and mechanical ventilation that contribute highly to a more comfortable and healthy indoor environment, (De Gids, 2006)

Extensive experimental and theoretical research to understand better the air flow phenomena in dense urban environments, (Ghiaus et al, 2005), has permitted to develop simple and accurate models to calculate the wind field in the canopy layer, (42, 45), and based on this to develop simple and accurate sizing techniques for windows and other natural ventilation systems, (46) Proper design of windows permits an increase in air speed in households and in comfort by cooling down the human body through the mechanisms of convection, radiation and perspiration. In parallel it permits an increase in air flow rates to achieve lower indoor temperatures, improve indoor air quality and health conditions.

Night ventilation is one of the more efficient passive cooling techniques for low income households. Golneshan and Yaghoubi, (1985,1990), report that the use of 12 ach per hour during night, with one ach during the day, may provide comfortable indoor conditions. Given that the urban environment decreases considerably the cooling potential of night ventilation, (Geros et al 2005, Kolokotroni et al, 2006), appropriate design of openings is very important.

Use of solar chimneys to enhance air flow in buildings is a well known technique that can be easily integrated in low income households. Solar chimneys are natural draft components, using solar energy to build up stack pressure and thus a driving airflow through the chimney channel. Solar chimneys can improve the ventilation rate in naturally ventilated buildings in hot climates, (Bansal, 1993,1994). It is found that the impact of solar chimneys is substantial in inducing natural ventilation for low wind speeds. Recent research has permitted to optimize the design and operation of solar chimneys, (Padki, 1999, Rodrigues et al, 2000, Letan et al, 2003), and thus to improve indoor environmental conditions in overheated houses.

New efficient design of box fans, oscillating or ceiling fans when used can increase the interior air speed and improve comfort at very low cost. Wu et al, (1989), have demonstrated the potential of oscillating fans to extend the comfort zone. It is found that for an air speed of 1.52 m/sec, comfort is achieved at 31 °C at 50 % relative humidity, or at 32 °C at 39 %, or finally at 33 °C at 30 % relative humidity.

Rohles et al, (1983) and Scheatzle et al, (1989), have proven that ceiling fans can extend the comfort zone outside the typical ASHRAE comfort zone. In particular at an air velocity of 1.02 m/sec, comfort may be achieved at 27.7 °C, for 73 % relative humidity, 29.6 °C for 50 % humidity and 31 °C for 39 % relative humidity. Recent research has permitted more efficient ceiling fans. Schmidt and. Patterson, (2001), have designed a new high efficiency ceiling fan that can decrease the power consumption and therefore electricity charges by a factor between two and three, while Parker et al, (1999) have designed a new very efficient ceiling fan of improved aerodynamics blades that presents a much higher airflow performance.

3.2 Discussing solutions for the developing world

For developing countries the main aim is simple: remove the air pollution from homes. The means to achieve this goal are even simpler: use of no polluting fuels and adequate ventilation. However, adoption and implementation of even simple solutions has to deal with the specific economic situation. Unfortunately, for the foreseeable future, many poor people will have little option but to cook on low-grade fuels. Compliance with proposed codes and technologies is expensive and thus non affordable to the majority of people, alternative solutions have to be adopted. It is characteristic that in developing countries, official building permits are rarely obtained, (World Bank, 2001). It is estimated that only the 10 % of the more rich households can afford houses that meet the local building codes, (World Bank, 2001).

On the other hand the construction business in developing countries present a very high budget that increases continuously The share of at least the residential sector has increased from 22.2 % to 34.4 % during the decade 1987-1997, (Hardy et al, 2001). Construction activities in less developed countries amount to about $400 billion annually, (UNCHS, 1993), and increases by about 20 billion dollars every year. The estimated percentage of less developed countries in the activities of world construction has increased considerably in recent years, from about 10% in 1965 to about 29% in 1998. Thus, appropriate policies and careful planning may permit the inclusion and implementation of techniques to safely remove the smoke from the households.

The existing experience shows that there is no unique solution for all people in risk. The successful implementation of a technique depends upon the active participation of the concerned families. As mentioned by the UNDP – SL ‘building poor people's capacity to make technology choices is not just "bringing" new technologies to their doorstep, but addressing their organisational, management and marketing skills; opening new channels of information and knowledge and making credit and markets more accessible.’

It is important that any technical changes should involve a high capability of the technology users to continue to use new systems in continuously changing circumstances. Thus, technological capabilities rather than technological options must be the focus of attention.

A number of interventions have been studied by International Help Associations, ITDG, (Bates 2005), and implemented to reduce household exposure to indoor air pollution. Given the high cost of clean fuels like LPG and kerosene, the most promoted techniques involved the use of cooking appliances that remove the smoke from the house through a flue or chimney and in parallel techniques to improve household ventilation.

In many cases, and in particular in dense and polluted urban areas, increasing the household ventilation has some obvious limitations given the polluted outdoor air. As mentioned by (Smith and Akbar, 1999), there are more than 1.5 billion of urban dwellers that are exposed to levels of outdoor air pollution that are above the accepted maximum concentrations, while it is estimated that 400000 additional deaths are attributed every year to outdoor air pollution.

Important real applications aiming to improve indoor air quality in poor households have been designed and implemented by International Help Associations in Sudan, West Kenya and Nepal. In these areas windows are small or poorly positioned with regard to smoke removal and in most of cases were closed off for reasons of security and exclusion of animals. Interventions comprised hoods with flues; larger/more and better positioned windows, large eaves spaces, and in the case of West Kenya, improved stoves.

Monitoring of the applications has shown important reductions to smoke exposure. In Kenya the reduction of the particulates and carbon monoxide was close to 80 %, and the exposure of women was reduced by a quarter. The total time for which the women were exposed to levels of CO greater than 9 ppm was reduced by around 60 % from around 2.5 hours to around 1 hour. In parallel, it is found that the enlarged windows did have benefits, such as improving lighting in the houses, but did not add significantly to the reduction of smoke.

In conclusion, it is evident that by using appropriate policies and implementation plans involving the participation of the local communities, important improvements of the IAQ can be achieved. As reported, the gained experience has indicated that there is no point trying to dictate a solution to a community. Any programme must be based on what is acceptable to the community. There is no point investing massive resources into something that will not be used.

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Air Infiltration and Ventilation Centre
Operating Agent and Management
INIVE EEIG
Boulevard Poincaré 79
B -1060 Brussels - Belgium

www.aivc.org

Tel: +32 2 655 77 11
Fax: +32 2 653 07 29
inive@bbri.be
www.inive.org