Reducing Energy by a Factor of Ten: Sustainable Housing Approaches in Europe

ACI Home Performance Conference 2007
Keynote, Dr. Bernd Steinmüller, BSMC, April 24th 2007

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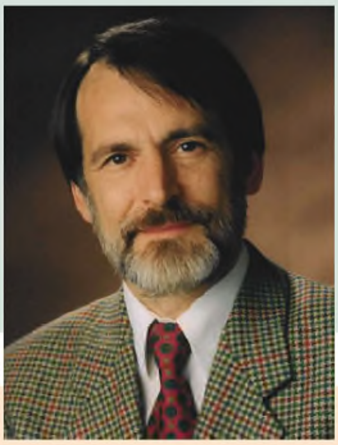
Keynote Speaker - Bernd Steinmüller



Bernd Steinmüller entered the field of energy and buildings at Philips Research in 1977. He pioneered advanced energy and housing concepts in U.S. and European climates fundamental to the passive house approach of the Institute for Housing and Environment (IHE). As a head of IHE and many initiatives, Bernd advanced passive housing and "Factor-10" retrofit applications. In 2000, he founded "Dr. Bernd Steinmüller Sustainability Management Consulting" promoting sustainability concepts worldwide.

Tuesday, April 24, 8:30 AM, Keynote Address

Reducing Energy by a Factor of Ten: Sustainable Housing Approaches in Europe

Developed in Germany during the 90's, the "Passive House" performance standard of 15 kWh per meter^2 annual heating requirement of 1 Watt per square foot maximum heat load was designed for new construction. This is achieved by a highly efficient building envelope with optimized windows and highly efficient air / energy supply. Thousands of new buildings have been built and certified, and cost-effectiveness and practicality demonstrated. More recently, passive house technologies have successfully been introduced for retrofitting old buildings. This way substantial energy savings along with considerable improvements on comfort, health, and "sustainable life" can be achieved.

Explore the concept, its impact on building system innovation, and the implications for existing (and new) homes in North America.

This paper outlines the keynote given by Dr. Bernd Steinmüller at the 21st North American ACI Conference, 23 – 27 April 2007 in Cleveland, Ohio, US. Copies of the corresponding slides and more information are available on the homepages of ACI (www.affordablecomfort.org), BSMC (www.bsmc.de)

1 Introduction

"**Reducing Energy by a factor of 10**" - i.e. not by a mere 5, 10 or 20% - but by 90% and more, is a great challenge. The challenge does not consist in just reducing energy, but to do this in an economic, ecological and socially responsible manner.

In the next 40 minutes I shall outline, which **sustainable housing approaches** have been taken in Europe and Germany in particular. I shall also take a glance at the States. In fact, when tracking back history, you'll find that many roots lie in the US. Thus, I am also looking forward to learning from you about recent developments here and discuss, how we can make more progress together.

Sustainability (**slide 2**) can be seen as the most fundamental notion and global challenge of the 21st century. In Germany, it is closely linked to a fundamental principle of forestry, which says that you should not cut in more wood than you grow again. Generalized to all our other natural resources, this picture very nicely catches the essentials of sustainability - which were confirmed in Rio 1992 in an integral manner including the social and economic dimensions of the global challenge.

The challenge is augmented by the fact that we have reached and already transgressed the natural limits of our globe, whereby the global population growth towards 10 bill. people by the mid of this century and world-wide inequalities built up additional pressure. The situation is characterized by the fact that just 20% of the population demand about 80% of the resources, whereby the 500 Mill. people in Europe belong to the "high-end" consumers together with the 300 Mill. US inhabitants even topping the European demand. At the same time much bigger countries like China and India (2500 Mill. People) with a lower consumption ask their share.

While energy almost has been the synonym for progress and wealth in the last century, it is clear that is has become one of the most critical natural resources ecologically, politically and economically. Fossil deposits are limited with insecure access in unstable countries, but the sinks – in particular our atmosphere – have already reached their limits as indicated by the increasing global warming problem. In short: our energy consumption is far from being sustainable!

In fact, it has been almost universally agreed (**slide 3**) that the **global limit for energy-related CO_2-emissions** is about 10 bill. tons per year, a limit which has already been missed by a factor of 2 in 1990 with a much lower population. Taking into account that the global population will reach about 10 bill. people by the mid of this century, this implies that we have to strive for a maximum emission rate of about 1 ton per person and year.

Looking at the **distribution of CO_2-emissions across the world** (**slide 4**), it can be seen that we are surpassing this limit by more than a factor of 20 in North America, Arabia and Australia … and by a factor of 10 in Europe. Thus (**slide 5**) - in order to become sustainable - it will be necessary, to reduce energy-related CO_2-emissions by at least a **factor of 10 in the western world**.

This holds for all sectors in particular for **housing** (**slide 6**), which typically consumes about 1/3 of fossil energy in western countries. Adding residential and commercial buildings, even a

40% share is met in the US and Europe, whereby heating (with hot water) accounts for about 50% of the share in the US and more than 80% in Europe, with the remaining part to be attributed to household appliances and cooling. At the same time this sector offers enormous "non-regret" saving potentials for energy and CO_2-emissions, dramatically reducing the load on ecology, while decisively improving comfort, health and living conditions for attractive overall life cycle costs. Thus, it offers unique possibilities to redirect our way and style of living towards sustainability.

Before going into more detail, let us ask in how far renewables can contribute to solving the energy problem (**slide 6**) and take a look at European strategies.

2 The Role of Renewables – Global Perspective and European Approaches

2.1. World

Global energy consumption (**slide 7**) has almost doubled since 1971 in spite of several supply crisis in between. This reflects the growing world population, but also our addiction to the energy drug and the neglect of effective energy conservation measures - which are urgently needed, if we want to stop and reverse the consumption growth. As shown by the graph, even as recent as 2004 about 80% of the primary energy consumption was covered by fossil resources, and only 13 – 14 % by renewables. Thereby "renewables" predominantly mean rather "traditional" renewables like biomass and water, the use of which has crossed the sustainability limits in many of the developing countries, while exploitation limits are in sight in many developed countries. The "new" renewables like geothermal, wind and solar energy only have reached 0,5% of the global contribution strongly indicating further growth potential, which however, will only become effective, if overall growth of consumption is stopped and reversed.

2.2. Europe

So, how is the situation in Europe, or more specifically in the European Union EU-27 (**slide 9**). The EU-27 covers 27 countries with fairly heterogeneous climate conditions. As far as politics is concerned, the main responsibilities still reside with the individual nations, whereby the EU supplies the political framework, which has to be filled in and detailed by the nations. As far as energy is concerned, there has been increasing awareness that the great challenge ahead can only be met together. In particular there is the danger that the high degree of energy dependency of about 50% will increase towards 70% by 2030, if no measures are taken - with drastic implications on political independence and economic competitiveness. Besides, the economic implication, the ecological and social dimension of challenge are more and more recognized. Renewable energies only have a 6% share, while CO_2-Emissions are a factor of 8 beyond the sustainability limit.
The official near term goal is to reduce CO_2-Emissions by 8% in line with the Kyoto protocol and to increase the share of renewables up to 12%. These goals will be difficult to achieve, and it has been recognized that especially efficiency needs much more attention in the future. As far as mid-/long term goals are concerned, 20% -30% CO_2 reduction targets are being set for 2020 and 60 – 80% targets proposed for 2050, whereby the latter still is below the 90% target required.

If we look at the use of **renewable energies** in EU-countries (**slide 10**), the share of traditional resources as water and biomass is dominant as well. However, in some countries – as in Germany, Spain, Italy and Denmark the "new renewables" have gained a sizable share. Especially with respect to wind (**slide 11**) quite an exponential growth set in during the last decade, which has put Germany into a world-wide leading position only recently being taken over by the US.

Summing up renewables, it turns out, that they account for almost 10% of the CO_2-reduction with respect to the baseline year 1990 in Germany. There are different scenarios, how this can be extrapolated into the future - an example of which is shown in the following slide with the renewables shown in yellow (**slide 12**). All scenarios assume a drastic reduction of the overall consumption so that the contribution of renewables could reach a 50% share by 2050 with CO_2-emissions reduced by 80% in total – This would be fine, but still another factor 2 is necessary, if we want to achieve the 1 ton p.p. p.y. goal.
Thus, we have to look at the demand side more closely, an in particular into the sector, where most energy is used: housing.

3 Energy efficient housing –

3.1. Basics, Philips Experimental House

From what has been said, it is clear that we have to improve energy performance of houses by a factor of 10 (**slide 14**) with a focus on the heating demand. Of course, we should also look at appliances and hot water, whereby the overall consumption of non-renewable primary energy sources is what finally matters. But in order to be successful, we have to start at the source, where the overall consumption is evoked, i.e. at the demand side, and start with the biggest component, i.e. heating, which in German residential buildings causes an average demand of about 150 kWh/m^2a.

Corresponding fundamental research in Germany was triggered by the first oil crisis in 1973 and inspired by Scandinavian work on low energy housing as well as by American work on passive solar buildings and renewables. As early as 1974, Philips - as a total outsider in the buildings sector - built the first ultra-low energy house in Germany (**slide 15**) in order to study the potential of renewable energies and supply devices such as vacuum collectors, heat pumps etc. in buildings. The building was an off-the shelf prefabricated wooden frame house upgraded with super insulation, the best obtainable windows, controlled ventilation with 90% heat recovery and a soil heat exchanger leading to an overall heating demand of 20 – 30 kWh/m^2a, which was about a factor of 15 below the demand of normal houses at that time and already close to what a German passive house would need today. In fact – apart from the windows, which were not available at that time – it showed all of the properties a modern passive house is known for. The small remaining energy requirements were largely covered by renewable energies, such as solar thermal energy supplied by own experimental vacuum collectors and heat pumps in the cellar.

The overall goal was to use the Philips Experimental House as a test bed in order understand the parameters of the overall system and derive models for analysing the relevance of the different parameters under a wide set of possible boundary conditions. Thus, extensive studies including the US & Europe where performed (**slide 16**). From these simulations it **appeared that it was possible to reduce the heating requirement by more than a factor of 10 in all**

climates simply by increasing the **insulation standard**. In fact, it appeared that these efficiency measures are much more effective than measures on the supply side so that the paradoxical result for a company - which set out to exploit the supply side potential - was that demand side measures should receive top priorities.

Of course many more studies were done, e.g. prospecting the potential of **window systems** in various climates (**slide 17**), which showed the large potential of passive solar heating climates as in Albuquerque … pointing however at the same time at the limits in Europe, where in good houses window areas beyond 30 – 50% in south do not lead to additional gains. Here, the improvement of the U-Value of a window is of prime importance.

Though this knowledge has been around for about thirty years, progress in the building sector takes some time … Unfortunately, in this important sector the typical time scale is given by decades in comparison to the electronics industries – which I also worked for - where the innovation cycle is counted in fractions of a year. Thus, it will be an important task to drastically accelerate cycle-times in the building sector.

3.2. Passive Houses

One of the driving motors in Germany is Wolfgang Feist, who – inspired by Swedish research and some of the research we did – developed the well-defined "Passive House Standard" (**slide 19**). Accordingly, a passive house is a house, whose maximum heating load at climate extreme[1] does not exceed 10 W/m^2, which is equivalent to about 1 W/ ft^2 needed on site. As suggested by Marko Spiegel, who detailed upon passive houses yesterday, a passive house may therefore even be called a 1 Watt house, as this term most precisely says what a passive house all is about and it prevents confusion with the vague concept of passive Solar Buildings. Thus, a 2000 ft^2 house can be heated by 20 light bulbs at the extreme heating days of the year or even better by equivalent renewable energy devices. The essential idea is that for such a low maximum demand you can go without a traditional expensive heating system, but rather use the savings for better insulation and controlled efficient air supply.

Under central European climate conditions, in an optimized south-oriented building such a low heating load is equivalent to an annual heating demand of 15 kWh/m^{2}a, which therefore has become a central characteristics of the passive house standard. **In fact 15 kWh/ m^{2}a is exactly a factor 10 below the overall average of existing old and new houses in Germany** and thus fulfils our reduction target on the point. In extreme climates it may have to be adapted, whereby the savings of good insulation usually will be even higher.

Finally, in order to prevent that a low heating demand is wastefully obtained with heat-producing household appliances or inefficient heating, a limit for the overall primary energy consumption including household appliances has been set at 120 kWh/ m^{2}a. In practice it is possible to stay well below this limit, which therefore should be lowered in the future.

In order to build a passive house, a set of **typical properties** must be achieved (**slide 20**), which extrapolate the basic features known from the Philips Experimental House. In particular, a high overall insulation standard must be secured by highly insulated components,

[1] Not necessarily the coldest sequence of days – as these are often sunny!

avoidance of thermal bridges, energy efficient triple pane windows supplemented by a highly efficient air and heat supply.

If we compare a passive or 1 Watt house with the **current average buildings** (**slide 21**), we can see that in terms of on site energy ratings, the heating requirement is cut down by more than a factor of 10. Including hot water and currently obtainable household appliances the reduction still is a factor of 7. If we compare it to the low energy standard, which is the current German norm for new buildings, the passive house still excels by a factor of 4.

Looking at the specific energy ratings of average buildings in the US, similar orders of magnitude are found, whereby, however, the proportion of household electricity is much higher. This means that

a) the "true" heating demand is higher than depicted, as there is an implicit "electric contribution" provided via the waste-heat of household appliances in inefficient, uncontrolled manner.
b) these appliances also add to the cooling demand in summer.
c) appliances represent a large additional saving potential – in direct and indirect terms

Note that the numbers are per unit area. As space consumption per person is about 70% higher in the US than in Mid-Europe, the US numbers per person have to be increased. The growth of floor area is a problem in Europe too. Hence, besides observing "efficiency" we have to make sure that "re-bound" effects do not eat up efficiency gains. Thus, "sufficiency" is an issue as well….

In order to show that his concepts worked, Wolfgang Feist during his time at the Institute for Housing and Environment (IWU) built **the first passive house** in Germany in 1991 (**slide 22**). It is a house in the row for 4 families, which fulfilled all expectations. The heating and especially the primary energy demand actually were much lower than required.

Only a few years later, the **first settlement of passive and low energy houses** was built in Germany (**slide 23**) , which allowed a direct comparison of the two house types in practice. The results were fully convincing. Not only were all design goals met, but the inhabitants were highly satisfied with the dwelling conditions and the low building cost of about 100 €/ft^2. Thus, passive or 1 Watt houses enable sustainable dwelling and living in all aspects and hence should be considered as a key dwelling form of the future.

Meanwhile, all sort of passive houses have been built (**slide 24**) including fancy and traditional style of single family homes, office buildings, mixed living and office buildings as well as multi-family homes and schools. The number of units built (**slide 25**) has grown exponentially at a rate of about 100% with 3000 units reached in 2002 and about 10 000 units in 2007 …. In spite of these impressive numbers, it can be seen that it took another decade from finalization of the first passive house to a real uptake by the building industry...

This development has been accompanied by a step-wise move from hand-craft towards series-production. This is mirrored by a corresponding learning curve, which in the following slide (**slide 26**) is depicted for houses in a row. Accordingly, the additional investment for a passive house with respect to a standard low energy house has come down to less than 80 €/m^2 or 10 $/ ft^2, i.e. less than 7% of typical building cost. As to multi-family homes, the additional cost has fallen to 3 – 5% - while for free standing single family homes 5 - 10% may be reached.

Comparing these figures to the net present value of energy savings expected (**slide 27**)[2] , it turns out that for most cases the mere energy savings already outweigh the additional cost, while higher building quality and comfort, lower maintenance cost and risk will substantially add to the advantage a passive house offers. Putting these things together, it therefore can be concluded that building a passive house instead of a standard low energy one not only saves a factor of 4 in energy terms. Rather, it also is an economically and socially backed decision. As a consequence, the German city of Frankfurt has recently decided that all their public buildings should follow this standard, while its largest housing company has adopted this standard for all its new housing projects.

In spite of these good signs, we have to be aware of the fact that by no means all new houses are built this way so that every day large saving potentials are lost. They are lost for many decades, because errors in the building construction can only be efficiently corrected, when houses reach their next fundamental maintenance milestone after several decades of lifetime – if at all. This means that more than 95% of new houses in Germany are a factor of 4 below the state-of-the-art and add 300% of additional energy and emissions to our joint environmental bill.[3]

3.3. Old Buildings

In order to reach our overall targets, it is necessary to look at old buildings as well, which span a broad **spectrum of building styles and ages**, a selection of which is shown on this slide (**slide 29**). A cost-effective exploitation of the inherent saving potentials is only possible, if we synchronize with the individual renovation cycles and apply the most efficient and effective measures preferably at a time, when basic renovation measures have to be undertaken anyway.

A detailed analysis of the building stock, renovation cycles and applicable measures shows how the **heat saving potential in old and new German dwellings** (**slide 30**) can be stepwise exploited over time. It turns out that - with the application of standard measures typical for the conventional low energy standard - it is possible to reduce the heating demand of the whole building stock by a factor of 2 until 2050. If advanced measures reflecting the passive house technologies are applied, even a factor of 5 seems possible. Thereby it has to be taken into account that not all buildings can be improved by this factors so that well-suited buildings have to make up for the worse-suited ones. In order to reach a factor of 10 for the overall primary energy supply, the potential of renewable energy supply has be exploited, which can render a factor of 2 and more.

The technical potential is even higher of course, and will increase over time as indicated by the lower line. The overall economic potential is also higher at a given point in time, however it can only be exploited step by step due to the observation of renovation cycles.

3.4. Progress in Modernization of Old Buildings

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[2] Note: the figure does not make any statement about "pay back times", but about the net present value of energy savings, which is the fundamental parameter to be considered in energy economy. The payback time can be much lower than the "savings period".

[3] This of course holds all over the world, and I was shattered, how much is lost also in the US. Together with Marko Spiegel, CTI International, I looked at large new luxury houses under construction, which are already outdated before being finished.

Current progress and current best practice have recently been unveiled by a number of competitions on federal state and regional level (**slide 32**). It could be shown that even buildings from former centuries can overtop the low energy level without changing the character of the building. On the other hand, interesting architectural solutions turned up, where originally face-less houses obtained a new, appealing appearance.

Encouraged by this type of findings and triggered by the national German Sustainability council, the German Energy Agency DENA set-up an **advanced retrofit program** in 2002 in order to initiate nation-wide advancement and proliferation of best practice - targeting at levels beyond the low energy standard (**slide 33**). In pilot phase 1 (which was finished last year, and which my consultancy office has taken part in with a building in Bielefeld) 33 multi-family buildings were covered, while in phase 2 more than 100 multi- and single-family houses are included. Phase 3 has just started…

As an **example** for the results of phase 1, I would like to shortly outline the DENA-Project in Bielefeld (**slide 34**). The approach was defined by sustainability principles focussing on life-cycle instead of short-term optimization of components striving for long-term economy, usability and adaptability to different life-age conditions. As far as insulation is concerned, it **was found that standards typical for new passive houses were economically optimum for retrofit as well** leading to an addition of 15 inch cellulose insulation on the upper ceiling, 8 inches high quality insulation on the walls and 4 inches special high performance insulation under ceiling of the cellar where height restrictions had to be observed. The theoretical optimum under roof with celluloses actually amounts to 20 inches and more, which, however, were not realized because of practical height and stair flight restrictions. Thermal bridges could be reduced by a factor of 2 to 10 with optimized solutions. Passive house windows were applied as the most economical solution of the future. A highly efficient ventilation system could be elegantly installed under the thick layer of celluloses on the top ceiling and in the unused vertical chimneys. A solar-assisted condensing gas burner provides the small amount of rest heat downsized by a factor of 10. The maximum heating load of the building dropped to about 2 Watt/m^2, i.e. close to the requirements of a passive house.

In order to give you a rough visual impression, I'll quickly run you through a couple of slides, which partially speak for themselves, thus I shall only give a few comments (**slide 35 – slide 81**) **…**

… Now, looking at the **overall results of phase 1 of the advanced retrofit program**, (**slide 82**) energy savings of a factor of 10 turned out to be the rule for all buildings rather than the exception: Primary energy consumption was lowered by 87% from 336 kWh/m^{2}a to 44 kWh/m^{2}a on the average, which tops the low energy standard for corresponding new buildings by more than a factor of 2, i.e. the renovated buildings had ½ of the energy use of new buildings built to our "low energy standard". Thus, it was shown that by use of passive house technologies the required substantial energy reductions can be reached also in retrofit sector.

Let us now take a look at the situation in other parts of Europe (**slide 83**)

3.5. Passive Houses in Europe … and the World

While passive houses showed an exponential growth in Germany, considerable progress is found in other European countries too.

In fact, as early as 1998 (**slide 84**) a first trans-national project called "CEPHEUS" was started under the umbrella of the European Joule-Thermie program. CEPHEUS stands for "**Cost Effective Passive Houses as European Standard**". It features the erection and scientific evaluation of about 250 passive housing units in 5 European countries creating the preconditions for further market penetration. The picture on the left hand side shows that a broad spectrum of building types and locations was involved. Central results were presented on the world Exposition EXPO 2000 in Hannover, where a whole settlement of highly energy and cost-efficient passive houses was erected presenting a full primary-energy and climate-neutral approach by inclusion of renewable energies. The project shows how energy efficiency and renewable energy can ideally supplement each other. The zero energy level can only be reached as an annual average value. Seasonal or temporary energy surpluses are delivered to third parties and balanced against energy needs under unfavourable weather conditions.

The highest growth rates are currently found in Austria (**slide 85**). With an original time lag of about 3 to 5 years, Austria has already passed Germany by the number of passive house units per person … heading for 10 000 objects in 2008/2009. At the same time a strong passive house movement has started in North Italy as well as in Norway, where 1000 passive house units are projected (**slide 86**).

The last International Passive House Conference in Hannover 2006 and Bregenz 2007 (**slide 87**) signalled further spread-out of the passive house ideas throughout and beyond Europe. Meanwhile, there are passive house projects under way in almost each European country. As the map shows, passive house interest groups have formed all over Europe. Completed passive house projects confirm that the passive house concept is applicable to a broad spectrum of climate conditions and building types in and outside the residential sector. In particular, passive house technology is increasingly applied to old buildings as well.

Moreover, increasing interest from outside Europe showed up on the conference with passive house projects now under way in Asia and America.

In fact, first houses are built in the US: single-family houses (**slide 89**) as well as mixed school/residential buildings (**slide 90**) … Currently, a mixed retrofit/new construction project is under way at Berkeley. The special conditions of the southern US are being evaluated and it appears that - in spite of the special challenge of cooling and humidity - with corresponding adaptations the passive house concept also makes sense down there, reducing energy demand and adding to sustainable life comfort.

4 Conclusions

Sustainable energy and housing is a large, intriguing subject which can be hardly covered in a talk of 40 minutes. As you have seen, it offers enormous chances for the individual, for society as a whole and our joint environment.

Concluding my talk (**slide 92**), I want to point out again that the boundary conditions set-up by the environment imply that we have to reduce non-renewable energy consumption by more than a factor of 2 world wide and a factor of 10 in the western world at least. This can only be achieved by intelligently combining drastic energy efficiency and saving measures – which as I have shown can render gains of a factor 5 and more – together with renewable energies –

which can yield a factor of 2 at least. This, in principle, has to be done in all sectors: industry, traffic and housing.

The housing & building sector is of special importance, as it causes about 40% of the energy consumption in Europe and the US, offering large “no-regret” potentials and huge quality of life improvements with proven, promising technologies waiting for local application.

Hence: **sustainability starts at home** (**slide 93**) …
Thus, join in with your neighbours.

Thank you! (**slide 94**)

Appendix

Summary of figures/slides: see following pages

Reducing Energy by a Factor of 10 - Sustainable Housing Approaches in Europe

BSMC
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Sustainability Management Consulting
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ACI – Home Performance Conference

Cleveland, Ohio, April 2007

Sustainability

- "Do not cut more wood than you grow again! …"
- Rio 1992 social, economic, ecological dimensions -> Agenda 21st Century
- Global Challenge
  - Reached and transgressed natural limits during last decades
  - Continued population growth and inequalities built up additional pressure
    - 20% of population use about 80% of the global resources
    - 500 Mill. people in Europe "EU-27" high end consumers … (Germany 80 Mill. largest country)
    - 300 Mill. people in the US … highest load
    - Developing countries (China, India 2500 Mill.) … asking their share
- Factor Energy most critical
  - Resources limited … in unstable countries
  - Sinks limited … climate problem
  - Production & usage … not sustainable

Sustainability Limit

for Energy Related CO_2-Emissions

Global limit
10 billion tons per year

means

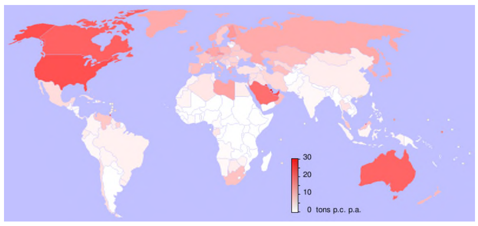
max. 1 ton

per capita and year

Population 2050:
10 billion people

The Situation

CO_2-Emissions in tons p. p. and yr. across the world



The Implication

Energy-related CO_2-emissions have to be reduced

by at least a factor of 10 in the western world!

This holds for all sectors

in particular for Buildings & Housing

- Consumption more than 1/3 of energy in most western countries
  - 40% energy share in US and Europe
    - Where heating & hot water accounts for 50% in US, more than 80% in Europe
    - Remaining part: electricity for household appliances and cooling
  - Besides housing is responsible for ~ 50% of all material flows

- Offers enormous "no-regret" potentials
  - Energy savings, reduction of CO_2-emissions
  - Ecological improvements
  - Comfort, health
  - Overall cost reductions
  - Sustainability as a whole

Can Renewable Energies solve the problem? …

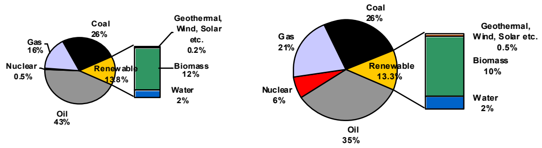
Global Perspective – European Approaches

Global Primary Energy Consumption

doubled since 1971... share renewables constant < 15%

1971: Total: 234 000 PJ (220 btu 10^{15})

2004: Total: 463 000 PJ (440 btu 10^{15})



Source: BMU, IEA

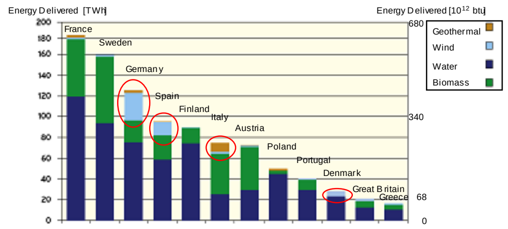
Current Approaches

European Union "EU-27"

- Background
  - 27 countries with heterogeneous conditions
  - Main responsibilities remain with individual nations
  - EU supplies political framework
- Energy Challenge
  - High energy dependency (trend 50 to 70% by 2030), economic dangers
  - Lack of environmental sustainability
- Status Energy and Emissions
  - Renewable energy share 6%
  - CO_2-Emissions 8 t p.yr. p.p.
- Short Term Goals
  - Renewable energy share 12% (2010)
  - CO_2-Reduction 8% (Kyoto 2012)
- Long Term Proposals
  - CO_2-Reduction 20 – 80 % for 2020 - 2050

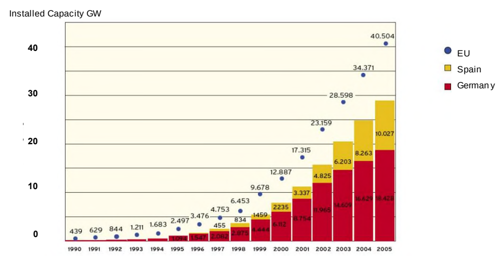
Overview Renewables:

6% share in 2004, "Old Renewables" dominant…
"New Renewables" triggered in Germany, Spain …



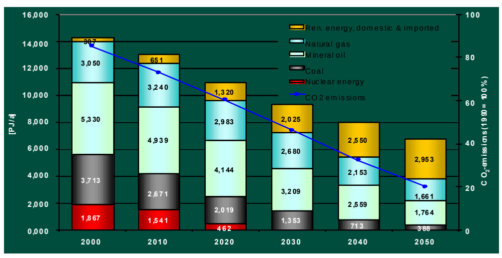
Source: BMU

The Development of Wind Energy – German Success Story



Source: BMU

German Primary Energy and CO_2-Emission Scenario until 2050

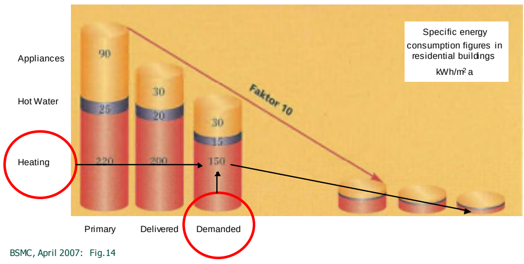


Source: BMU

Housing

Overall boundary conditions imply:

We have to improve energy performance of houses by a factor of 10 … with a focus on heating demand

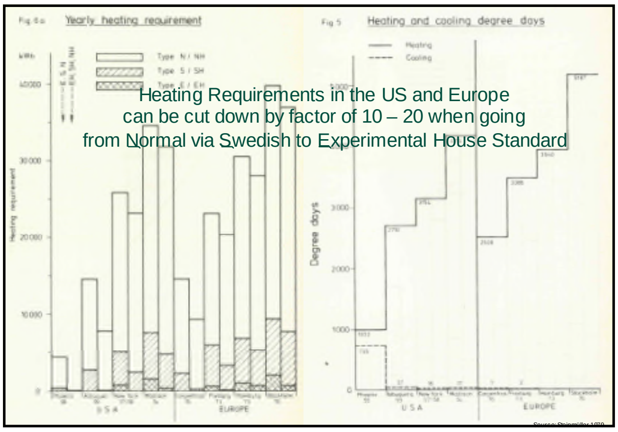


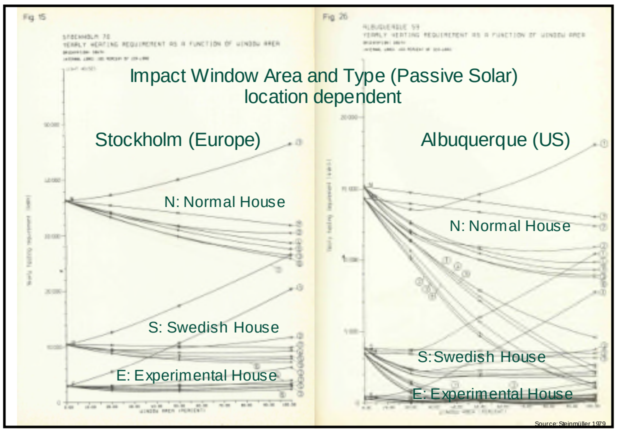
Principles Laid Down in the Seventies

Philips Experimental House -
First (Ultra-)Low-Energy House in Germany, Aachen 1974 ff

- Super insulation: U-Value 0.14 W/m²K (R~40)
- Efficient Window Systems: (coated double) + shutters
- Controlled ventilation, 90% air-to-air-heat recovery plus soil heat exchanger
- Heating demand 20 - 30 kWh/(m²a) i.e. 2 – 3 kWh/(ft²a) or 7 – 10 kbtu/(ft²a)
- Renewable Energies
- Theory-Experiment Comparisons
- Parameter Studies US & Europe …

Source: Hörster, Steinmüller (PFA)





Evaluation of experiences and consistent application of principles resulted in "Passive House" Concept

Passive Houses – Formal Definition

Central Requirement:

- Maximum Heating Load at Climate Extreme <= 10 W/m² (~ 1 W/ft²)
  - allows omission of traditional heating system

Secondary Requirements:

- Maximum Annual Heating Demand <= 15 kWh/m²a (~ 5 kBtu/ft²a)
  - for south oriented buildings in Central Europe
- Overall Primary Energy Consumption <= 120 kWh/m²a (~ 40 kBtu/ft²a)
  - Including household appliances
  - To be lowered in the future

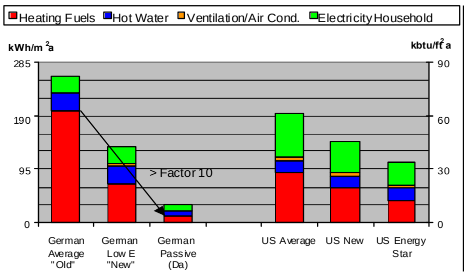
Source: PHI

Passive House – Principles

- Highly Efficient Building Envelope
  - Highly insulated components: U-factors < 0.15 W/(m²K) *(i.e. ~ R40)*, Avoidance of thermal bridges
  - Energy-efficient windows: U-factors < 0.80 W/(m²K) *(~ R7)*, solar heat-gain coefficients ~ 50%, southern orientation (if possible) and shade provisions
  - Air-tightness: infiltration rate < 0.6 per hour in pressure test at 50 Pa *(i.e. CFM50 < 200 ft³/min for a 2000 ft² home)*
  - Compact form
- Highly Efficient Air and Heat Supply
  - No separate traditional heating system necessary
  - Energy-efficient ventilation: Highly efficient heat recovery from exhaust air > 80%
  - Hot water supply using regenerative energy sources
- Energy-saving household appliances

Source: PHI

Passive House – Site Energy Usage
Comparison to Existing and New Buildings in Europe and the US



Source: PHI, J. Krigger ..

Darmstadt-Kranichstein
First Passive House in Europe/Germany 1991

- Super insulated House in a Row
  - Insulation: 10 - 18 inches, U-Value 0.1 bis 0.14 W/(m²K) → R40 to R60
  - Optimized triple panes windows with insulated frames, south oriented
  - Ventilation with heat recovery
- Rest Energy Demand
  - Heating: 12 kWh/(m²a)
  - Hot water: 8 kWh/(m²a)
  - Household appliances: 11 kWh/(m²a)
- Covered by
  - Vacuum collectors
  - Gas condensing furnace

Source: Feist (IWU, PHI)

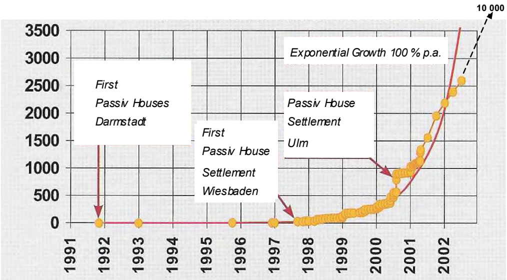
Wiesbaden-Lummerlund
First Passive House & Low Energy-Settlement in Europe 1997

- 46 Houses in a Row,
  - 50% Passive, 50% Low Energy
  - Building cost: 90 - 100 €/ft²
- Scientific Evaluation
  - Inhabitants highly satisfied
  - Passive Houses preferred to low energy ones
- ➢ Passive Houses enable sustainable life-style
  - Energy reduction factor 10
  - Economically attractive
  - Comfortable, healthy indoor climate
  - No sacrifices, but new degrees of freedom

Source: IWU, Rasch

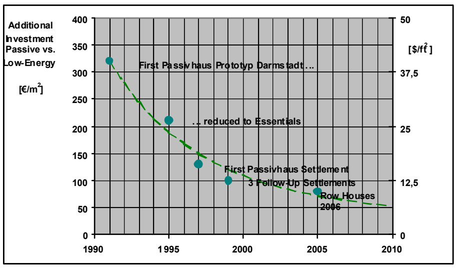
Source: BKI, BSMC, SurTec

Number of Passive House Units Grow …



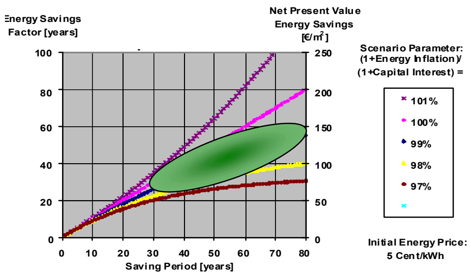
BSMC, April 2007: Fig. 25 Source: PHI

.... Additional Investment Drops → 50 €/m² (6 $/ft2)



BSMC, April 2007: Fig.26 Source: W.Feist,PHI

Energy Savings > 50€/m² (6$/ft2) ... dependent on scenario

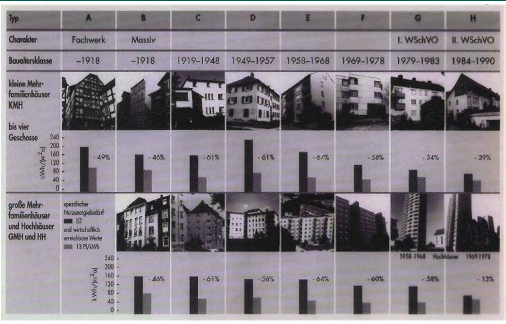


BSMC, April 2007: Fig. 27

Old Buildings

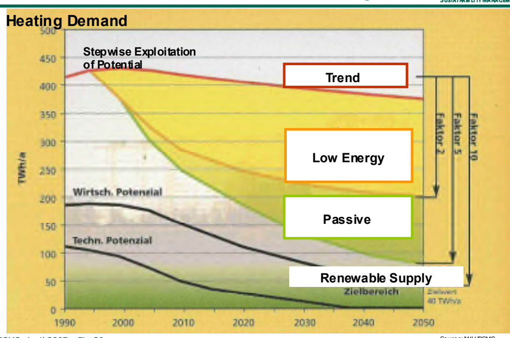
BSMC, April 2007: Fig.28

Old Buildings – Broad Spectrum of Types, Ages



BSMC, April 2007: Fig. 29 Source: IWU

Heat Saving Potential in Old and New German Dwellings



BSMC, April 2007: Fig.30 Source: IWU/BSMC

Progress in Modernization of Old Buildings

Regional Forerunners Identified in Competitions

Source: BSMC, IWU

Systematic National Advances via DENA-Programs

Participants Phase I

- Means
  - Demanding targets exceeding new buildings
    - Quality of building envelope
    - Primary energy consumption
    - Sustainability measures
  - Upgraded government funds
    - special "cheap" loans
    - up to 20 % debt relief
- Phases
  1. 33 Buildings (2003 - 2005) multi-family
  2. > 100 Buildings (2005 - 2007) incl. single-fam.
  3. > 1000 Buildings … just started (incl. KfW)

Source: DENA

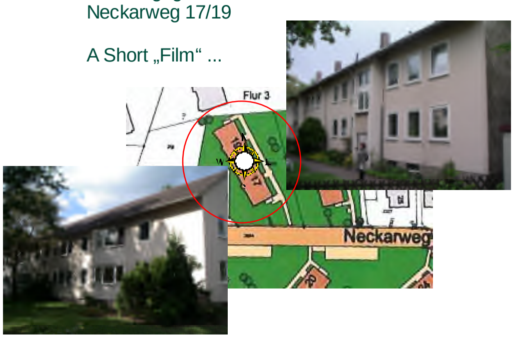
Example: Advanced Retrofit of 8-Family House in Bielefeld

- Sustainability Approach
  - Life-Cycle Optimization Energy and Economy
  - Long-term Usability, Adaptability
- Passive House Technologies
  - Roof 15, Wall 8, Cellar 4 inches additional high performance insulation
  - Reduction of Thermal Bridges
  - Passive House Windows
  - Ventilation 90% heat recovery
  - Solar assisted hot water
- Factor 10 Savings
  - In Energy & CO_2-Emissions
  - Economically "multipliable" and even optimum for most measures

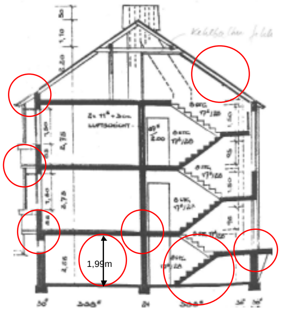
Source: BSMC

Pilot Project Bielefelder Wohnungsgesellschaft BGW Neckarweg 17/19

A Short „Film" ...

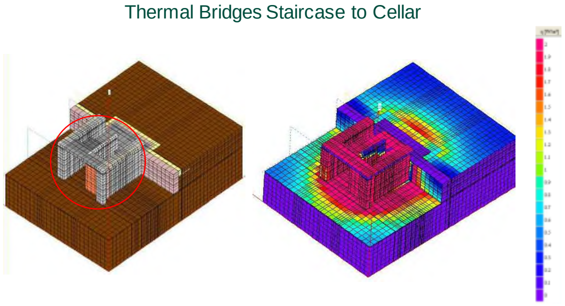


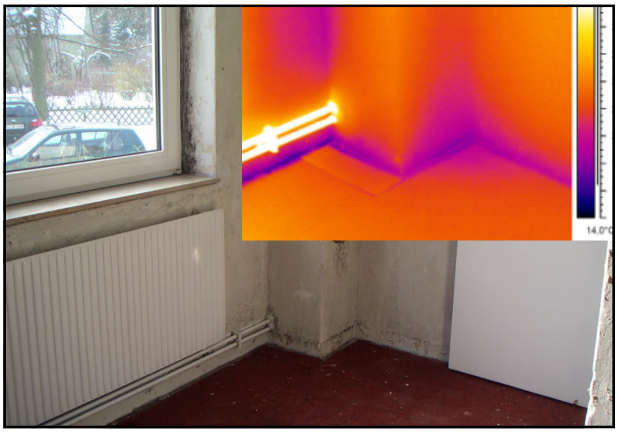
Some Problem Areas

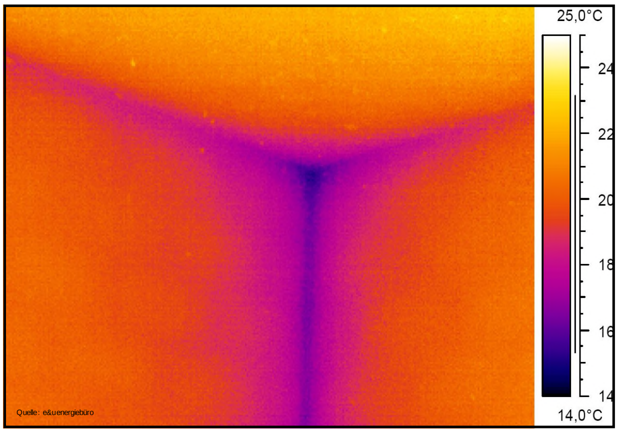


- Lossy Roof
- Lack of Insulation
- Thermal Bridges
- Wrong Window Orientation
- Shading Trees ...
- Low, Lossy Cellar
- Lack of Ventilation, Schimmel
- Lack of Air tightness ...
- Lossy Heating Installation
- ...

Thermal Bridges Staircase to Cellar







Solutions

Windows

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Blower Door Tests

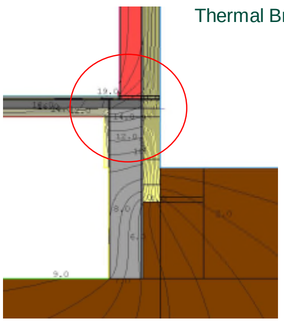
Walls

BSMC, April 2007: Fig. 55

Cellar

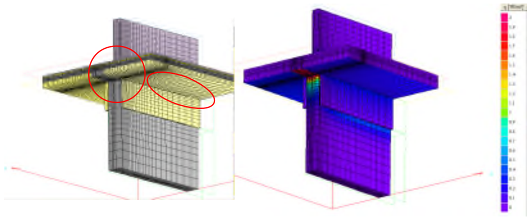
BSMC, April 2007: Fig.58

Thermal Bridge Reduction Outer Walls: Factor 3

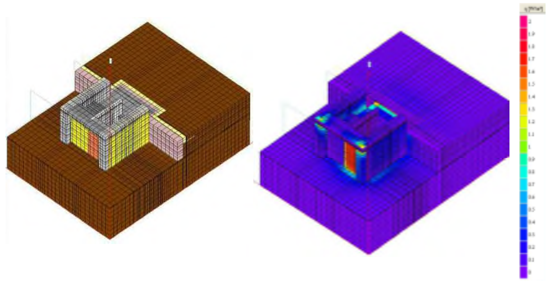


BSMC, April 2007: Fig. 59

Thermal Bridge Reduction Inner Walls: Factor 2

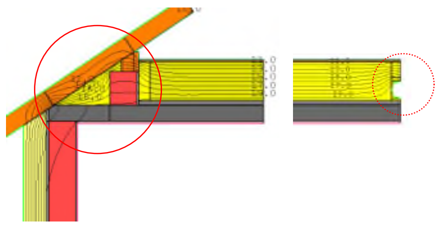


Thermal Bridge Reduction Staircase Footing: Factor 5



Top Floor – Installations and Insulation

Thermal Bridge Reduction Outer Walls and Piping... Factor 10
Insulation of Top Ceililng ... Factor 20



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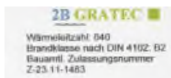
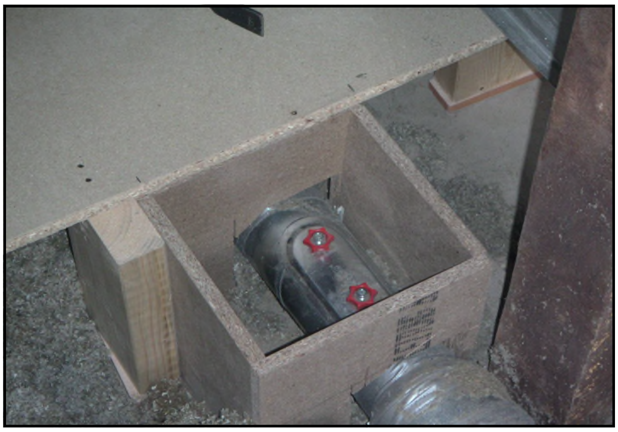
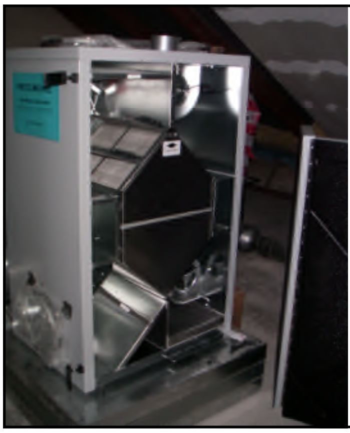
with 15 inches of „Gras“ ...
ecological efficient insulation (celluosis)





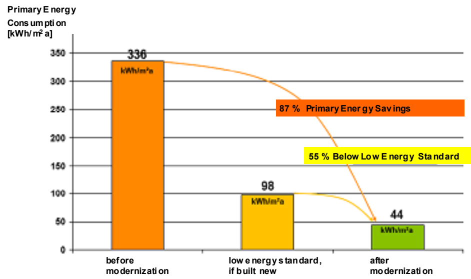


Ventilation Unit

90% Heat Recovery

End of "Film" …

Results Phase I: On the Average 87% Savings for all Buildings



Source: Dena

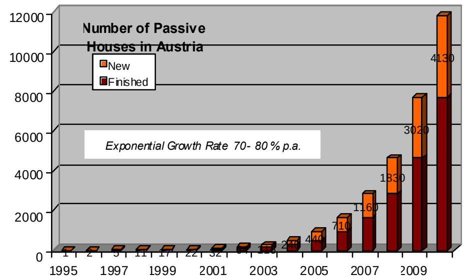
… a glance and outlook at Europe

CEPHEUS Cost Effective Passive Houses as European Standard 1998 - 2001

- First European Research & Development Project, sponsored by the EU-Joule-Thermie Program
- Erection and Scientific Evaluation of about 250 passive houses/living units
- Demonstrating cost-effective passive houses in 5 European countries
- Creating preconditions for market penetration
- Presenting full primary-energy and climate neutral approach combined with use of renewable at the World EXPO 2000

Source: Energieinstitut Vorarlberg

Exponential Growth in Austria …



Source: Lang, IG PH Austria

… similar growth starting in other European countries:

from Norway to Italy …

International Passive House Conferences 2006 & 2007 showed:

- Passive House projects under way in almost each European Country
  - About 10 000 units reached in 2007
  - Applicability to broad spectrum of climate conditions and building types confirmed
  - Passive House Technology is increasingly applied to „old" buildings
- Interest from outside Europe emerging, several projects completed/under way
  - Asia
  - America
  - … and Antarctica!

Source: PHI

… a glance at the US

First Passive House in US, Urbana, Illinois 2003

Source: eco-lab, Klingenberg

First Certified Passive House in the US
Waldsee BioHaus", 2006, Minnesota
Climate Zone 7, 5700 hdd

Source: Waldseebiohaus.com

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… retrofit projects under way

… projects for hot climates under planning

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Conclusions

- Non-renewable energy consumption has to be reduced by a
  - factor of 2 world wide
  - factor of 10 in the western world …. at least
- This can only be achieved by combining
  - Drastic energy efficiency & saving measures (factor 5 and more)
  - Promotion of renewable energies (factor 2 at least)
  - In all sectors: industry, traffic and housing
- The housing & building sector is of special importance
  - Causing 40% of energy consumption in Europe and the US
  - Offering large "no-regret" saving potentials and huge quality of life with proven, promising technologies waiting for local application
- Sustainability starts at home …