Energy efficiency in buildings: how far can they take us in mitigating climate change?

Diana Ürge-Vorsatz
director

IEPEC 2010, Paris
June 10, 2010
Key messages

- Buildings are (the?) key to reaching ambitious mitigation targets…
- …but they can also lock us into high(er) GHG concentration levels for many decades
  - Suboptimal retrofits and new construction are a major climate risk
- EE in buildings may also have the largest co-benefits among mitigation options
- But - since efficiency is unsexy and intangible, measuring and convincingly documenting its performance is crucial for unlocking its potential
- We need to go much further: A suggested evaluation progress agenda
EE in buildings is key to climate change mitigation
The buildings sector offers the largest low-cost potential in all world regions by 2030.
Few sectors can deliver the magnitude of emission reduction needed

- know-how has recently developed that we can build and retrofit buildings to achieve 60 – 90% savings as compared to standard practice in all climate zones (providing similar or increased service levels)
Buildings utilising passive solar construction ("PassivHaus")

Source: Jan Barta, Center for Passive Buildings, www.pasivnidomy.cz
Few sectors can deliver the magnitude of emission reduction needed

- know-how has recently developed that we can build and retrofit buildings to achieve 60 – 90% savings as compared to standard practice in all climate zones (providing similar or increased service levels)
- Novel methods developed for mitigation potential assessment that considers buildings as complex systems rather than independent sums of components
- New scenarios are constructed under the Global Energy Assessment, with co-funding from UNEP SBCI, that reflect this new approach

Photos from Gunter Lang
Final thermal energy consumption in the world’s buildings, 2005-2050

Using state-of-the-art and cost-effective construction know-how

Work in progress – not yet publishable

Watch out for the Global Energy Assessment release in 2011…
Final heating and cooling energy consumption
2005 – 2050, Europe

Western Europe

Eastern Europe

Work in progress – not yet publishable
Watch out for the Global Energy Assessment release in 2011...
CO2 emission reductions until 2050
Heating and cooling, Hungary

CO2 Emissions - Residential and Public Buildings
Including Buildings Built After 2010

85% savings
Opportunity or risk?

The size of the potential lock-in effect
Before SOLANOVA

Renewable Energy
Fossil Energy

-84%
Panelfelújítási programban részt vevő épületek fűtési fajlagos hőfelhasználásának alakulása
(city of Sz in Hungary)

<table>
<thead>
<tr>
<th>H.</th>
<th>H. NY.</th>
<th>H. NY.F.</th>
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<tbody>
<tr>
<td>235,570</td>
<td>230,784</td>
<td>228,894</td>
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<tr>
<td>193,335</td>
<td>171,956</td>
<td>144,538</td>
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<td>-18%</td>
<td>-25%</td>
<td>-36%</td>
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H: Homlokzati hőszigetelés
H: NY: Homlokzati hőszigetelés, nyílászáró csere
H: NY. F: Homlokzati hőszigetelés, nyílászáró csere, fűtéskorszerűsítés

The lock-in effect

Final world thermal energy consumption
State-of-the-art vs. suboptimal retrofits

Work in progress – not yet publishable
Watch out for the Global Energy Assessment release in 2011...
85% of emissions are saved in deep scenarios

45% of emissions remain locked-in by the suboptimal scenario
Final heating and cooling energy consumption
2005 – 2050, Western Europe

State-of-the-Art Scenario  Sub-Optimal Scenario

Work in progress – not yet publishable
Watch out for the Global Energy Assessment release in 2011…
Co-benefits - the entry points to policy-making?

Co-benefits of energy-efficiency in buildings
# Quantified non-energy benefits of building energy-efficiency programs (1/5)

<table>
<thead>
<tr>
<th>Co-benefits</th>
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<td>Physical indicator</td>
<td>Monetary indicator</td>
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<td>USA: A drop of concentration of the smallest airborne particles by 94% resulted in a decrease of the confusion scale by 3.7%, fatigue scale by 2.5%. The feeling of “stuffy” air 5.3%, of “too humid” by 7.0%, of “too cold” by 5.5% and “too warm” by 3.5%. USA: Cooler temperatures within the recommended comfort range resulted in a decrease of the chest tightness by 23.4% per each 1°C decrease. Denmark: Better thermal air quality led to better concentration of 15% of respondents and a 34% decrease “sick building syndrome” cases.</td>
<td>USA: Improved ventilation may result in net savings of EUR 302/employee-yr. that on a national scale represents productivity gain of EUR 17 billion/yr. USA: NPV over the lifetime of improved ventilation can reach up to EUR 1.653/bhp. USA: Better ventilation and indoor air quality reduce influenza and cold by 9-20% (ca 16-37 million cases) that translates into savings of EUR 4.5-10.6 billion/yr. New Zealand: Health benefits due to a weatherization program amount to EUR 35/hh-yr. or 18.5% of the total annual energy savings of a household.</td>
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<td></td>
<td>USA, New Zealand, Denmark</td>
<td>• A double-blind, multiple crossover intervention</td>
<td>Man-Indoor Environment Relationship (MIR)</td>
<td>Mendell et al. 2002; Milton et al. 2000; Schweitzer and Tonn 2002; Wyon 1994; Stoecklein and Scumatz 2007; Fisk 1999; Fisk 2000a</td>
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<td></td>
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<td>• Initial self-completed background questionnaires; then shorter weekly questionnaires assessing the outcomes</td>
<td>Man-Indoor Environment Relationship (MIR)</td>
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<td>• Environmental measurements</td>
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<td></td>
<td>• Cost-benefit analysis</td>
<td>Man-Indoor Environment Relationship (MIR)</td>
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<td>• Literature review</td>
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<td></td>
<td>• Authors’ adjustment/estimates</td>
<td>Man-Indoor Environment Relationship (MIR)</td>
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<tr>
<td>Mortality reduction</td>
<td>Hungary; USA, Ireland, Norway</td>
<td>• Bottom-up study (with Monte Carlo simulation)</td>
<td>USA: Every 10 g/m³ increase in ambient particulate matter (the day before deaths occur brings a 0.5% increase in the overall mortality. Ireland, Norway: The share of excess winter mortality attributable to poor thermal housing standards is 50% for cardiovascular disease and 57% for respiratory disease.</td>
<td>Hungary: Energy saving program resulted in the total health benefit of EUR 485 million/yr. due to a decrease of chronic respiratory diseases and premature mortality. Ireland, Norway: A total mortality benefit of a hypothetical thermal-improving program is EUR 1.5 billion (undiscounted) for a study in the left column.</td>
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## Quantified non-energy benefits of building energy-efficiency programs (2/5)

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</table>
| General environmental benefits | New Zealand | • Direct computation  
• Willingness to pay to accept, contingent valuation, other survey-based methods | NZ: Benefits to the environment gained after the weatherization program amount to EUR 44/ hh.-yr. in 2007 that accounts for around 18.7% of the total annual energy expenditure saved | Stocklein and Scumatz 2007 |
| Cleaner indoor air | USA | • Literature review  
• Data analysis | US: A sample considered a reduction of concentration of the smallest airborne particles by 94%  
US: The reduction in the emission/yr. of a green school as compared to the average practice:  
- 1,200 pounds of NOₓ - a principal component of smog  
- 1,300 pounds of SO₂ - a principal cause of acid rain  
- 585,000 pounds of CO₂ - GHG and the principal product of combustion  
- 150 pounds of coarse particulate matter (PM10) – a principal cause of respiratory illness and an important contributor to smog. | Mendell et al. 2002; Kats 2005 |
| Fish impingement | USA | • Literature review  
• Authors’ adjustment/estimates | USA: NPV of reduction in fish impingement over the lifetime of weatherization measures is EUR 17.6/ hh. | Schweitzer and Tonn 2002 |
| Waste water and sewage | USA | • Literature review  
• Authors’ adjustment/estimates | USA: NPV of reduction in waste water and sewage over the lifetime of weatherization measures is EUR 2.6 – 495.3/ hh. | Schweitzer and Tonn 2002 |
| Construction and demolition waste benefits | USA | • Statistical analysis  
• NPV analysis with a 7% DR over 20 years | USA: Construction and demolition diversion rates are 50-75% lower in green buildings (with the maximum of 99% in some projects) as compared to an average practice  
USA: A sample of 21 green buildings submitted for certification, 81% of such buildings reduced construction waste by at least 50%, 38% of such buildings reduced construction waste by 75% or more | SBTF 2001; Kats 2005 |
| Reduction in air pollution (indoor & outdoor) | USA | • Literature review  
• Authors’ adjustment/estimates  
• Statistical analysis | USA: A green school emits 544 kg of NOₓ, 590 kg of SO₂, 265 tonnes of CO₂, 68 kg of coarse particulate matter (PM10) less in comparison with the average practice | Schweitzer and Tonn 2002; Kats 2005; Kats 2006 |
Quantified non-energy benefits of building energy-efficiency programs (3/5)

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</table>
| Economic co-benefits and ancillary financial impacts | USA | • NPV analysis with a 7% DR over 20 years  
• Literature review  
• Simplified quantification of the effect of renewable energy/energy efficiency on gas prices and bills  
• Using a range of plausible inverse elasticity estimates | USA: Efficiency-driven reductions in demand results in a in long-term energy price decrease equal to 100% to 200% of direct energy savings; assuming the indirect price impact of 50% over 20 years from an efficient school design, the impact of indirect energy cost reduction for new and retrofitted schools has NPV EUR 0.21/m².  
USA: 1% decrease of the national natural gas demand through energy efficiency and renewable energy measures leads to a long-term wellhead price reduction of 0.8% - 2%; the indirect monetary savings from this price decrease amounted to 90% of the direct monetary savings that it EUR 14.6 million for all customers (cumulative 5-year impact, 1998-2002, over June-September peak hours)  
USA: 1% reduction in natural gas demand result in a 0.75-2.5% reduction in the long-term wellhead prices. | Kats 2006;  
Wiser et al. 2005;  
O'Connor 2004;  
Platts Research & Consulting 2004 |
| Enhanced learning in ‘greened’ buildings | USA | • Review of the financial benefits of education | Better environmental condition lead to enhanced learning abilities, a 3-5% improvement in learning and test scores is equivalent to a 1.4% lifetime annual earnings increase; an increase in test scores from 50% to 84% is associated with a 12% increase in annual earnings. | Hanushek 2005 |
| Employees’ retention: avoided reduced-activity days | USA, The State of Washington, Ireland | • Statistical analysis  
• Literature review  
• Bottom-up model  
• NPV analysis with a 7% DR over 20 years  
• A walk-through assessment of schools  
• Survey | USA: The improved quality of schools increases teacher retention by 3%  
USA/The State of Washington: “Greening” schools could bring 5%yr. of improvement in teacher retention | Buckley et al. 2005;  
Kata 2005;  
Paladino & Company 2005;  
Clinch and Healy 2001 |
| Improved productivity | USA | • Case studies on documented productivity gains  
• Empirical measurements  
• Computer-based literature searches, reviews of conference proceedings, and discussions with researchers  
• Multivariate linear regression | USA: In well-day-lighted buildings: labor productivity rises by about 6-16%, students’ test scores shows ~20–26% faster learning, retail sales rise 40%.  
USA: Students with the most day-lighting show 20% - 26% better results than those with the least day-lighting  
USA: The ventilation rates less than 100%  
USA: The productivity can improve by 7.1%, 1.8%, and 1.2% with lighting, ventilation, and thermal control by a tenant; an average workforce productivity increase is 0.5% - 3% per control type. A 1% increase in productivity (~ ca 5 minutes/day) is equal to EUR 452 - 528/employee-yr. or EUR 0.21/m²-yr.; a 1.5 % increase in productivity (~ ca 7 | Lovins 2005;  
Fisk 2000a;  
Fisk 2000b;  
Heschong Mahone Group 1999;  
Federjspiel 2002; Menzies |
## Quantified non-energy benefits of building energy-efficiency programs (4/5)

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</thead>
<tbody>
<tr>
<td>Avoided unemployment</td>
<td>USA</td>
<td>- Literature review&lt;br&gt;- Authors’ adjustment and calculations</td>
<td>NPV of avoided unemployment over the lifetime of weatherization measures is EUR 0 – 137.9/hh.</td>
<td></td>
<td>Schweitzer and Tonn 2002</td>
</tr>
<tr>
<td>Lower bad debt write-off</td>
<td>USA</td>
<td>- Literature review&lt;br&gt;- Authors’ adjustment/estimates</td>
<td>NPV of lower bad debt write-off over the lifetime of weatherization measures is EUR 11.3 – 2,610/hh.</td>
<td></td>
<td>Schweitzer and Tonn 2002</td>
</tr>
<tr>
<td>Employment creation</td>
<td>USA</td>
<td>- NPV analysis with a 7% DR over 20 years&lt;br&gt;- Literature review&lt;br&gt;- Authors’ adjustment/estimates&lt;br&gt;- Statistical assessment of the 5-year energy efficiency programs</td>
<td>USA: Green schools create more jobs than conventional schools: the long-term employment impact of increased energy efficiency may provide EUR 0.21/m² of benefits&lt;br&gt;USA: NPV of direct and indirect employment creation over the lifetime of the measures is EUR 86.7 – 32 thousand/hh. (note: this benefit occurs only one time in year weatherization is performed)</td>
<td>USA: Energy efficiency investment of EUR 85.2 million in the Massachusetts economy in 2002 created 1780 new short-term jobs; in addition, lowered energy bills for participants and for Massachusetts resulted in additional spending, creating 315 new long-term jobs; energy efficiency jobs added EUR 104.6 million to the gross state product, including EUR 48.2 million in disposable income (in 2002 in Massachusetts)</td>
<td>Kats 2005; Schweitzer and Tonn 2002; O’Connor 2004; Kats 2005</td>
</tr>
<tr>
<td>Rate subsidies avoided</td>
<td>USA</td>
<td>- Literature review&lt;br&gt;- Authors’ adjustment/estimates</td>
<td>NPV of avoided rate-subsidies over the lifetime of weatherization measures is EUR 4.5 – 52.8/hh.</td>
<td></td>
<td>Schweitzer and Tonn 2002</td>
</tr>
<tr>
<td>National energy security</td>
<td>USA</td>
<td>- Literature review&lt;br&gt;- Authors’ adjustment/estimates</td>
<td>NPV of enhanced national energy security over the lifetime of weatherization measures is EUR 56.5 – 2,488/hh.</td>
<td></td>
<td>Schweitzer and Tonn 2002</td>
</tr>
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</table>
## Quantified non-energy benefits of building energy-efficiency programs (5/5)

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<tbody>
<tr>
<td>Service provision benefits</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Transmission and distribution loss reduction</td>
<td>USA</td>
<td>• Literature review • Authors’ adjustment/estimates</td>
<td>USA: NPV over the lifetime of weatherization measures installed ranges EUR 24.9 – 60.3/hh.</td>
<td>Schweitzer and Tonn 2002</td>
</tr>
<tr>
<td>Fewer emergency gas service calls</td>
<td>USA</td>
<td>• Literature review • Authors’ adjustment/estimates</td>
<td>USA: NPV of fewer emergency gas service calls over the lifetime of weatherization measures is EUR 29.4 – 151.5/hh.</td>
<td>Schweitzer and Tonn 2002</td>
</tr>
<tr>
<td>Utilities’ insurance savings</td>
<td>USA</td>
<td>• Literature review • Authors’ adjustment/estimates</td>
<td>USA: NPV of utilities insurance cost reduction over the lifetime of weatherization measures is EUR 0 – 1.5/hh.</td>
<td>Schweitzer and Tonn 2002</td>
</tr>
<tr>
<td>Decreased number of bill-related calls</td>
<td>New Zealand</td>
<td>• Direct computation • Willingness to pay, willingness to accept, contingent valuation and other survey-based methods</td>
<td>Bill-related calls became less frequent after the implementation of weatherization program, which amounted savings of NZ$30 (~EUR 15.9/hh-yr.) that is 7% of the total saved energy costs</td>
<td>Stoecklein and Scumatz 2007</td>
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<tr>
<td>Social co-benefits</td>
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<td>Improved social welfare and poverty alleviation</td>
<td>UK</td>
<td>• Survey monitoring the impact of energy company schemes which were set up to fuel poverty</td>
<td>UK: Energy efficiency schemes applied to 6 million households in January-December 2003 resulted in the average benefit of EUR 12.7/hh-yr.</td>
<td>DEFRA 2005</td>
</tr>
<tr>
<td>Safety increase: fewer fires</td>
<td>USA</td>
<td>• Literature review • Authors’ adjustment/estimates</td>
<td>USA: NPV over the lifetime of the measures installed is EUR 0 - 413 /hh.</td>
<td>Schweitzer and Tonn 2002</td>
</tr>
<tr>
<td>Increased comfort</td>
<td>Ireland; New Zealand</td>
<td>• A computer-simulation energy-assessment model • Direct computation • Willingness to pay, willingness to accept, contingent valuation and other survey-based methods</td>
<td>Ireland: A household temperature once the energy efficiency program has been completed increased from 14 to 17.7 °C. The analysis showed that comfort benefits peak at year 7 and then decline gradually until year 20.</td>
<td>Clinch and Healy 2003; Stoecklein and Scumatz 2007.</td>
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In many countries, high-performance buildings are not primarily a green, but a social and economic agenda.

- A wide-scale renovation program can create app. 130,000 net jobs in Hu alone (vs. the “1 million” estimated for the whole EU for the 20/20/20 target)
- ...and save 59% of Hungary’s peak (January) natural gas import needs. Fuel poverty is a rising problem in Europe.
- According to a new study, app. 2500 lives are lost in Hungary alone each year.
- By the UK definition, over 80% of Hungarian households are fuel poor.
- A widespread deep (!) building energy retrofit program can eliminate fuel poverty.
However, hard facts, robust numbers needed on ex-post evaluations: energy efficiency has worked!

- while efficiency is often first in rhetoric, it is far from being first when it comes to action
Public Sector Energy R&D in IEA Countries – USD 10 bln/yr

In support of the G8 Plan of Action
However, hard facts, robust numbers needed on ex-post evaluations: energy efficiency works!

- while efficiency is often first in rhetoric, it is far from being first when it comes to action
- Efficiency is not “sexy”, photogenic
- For efficiency to become a market-compatible commodity, standardised MRV is needed
- …just doing it is not enough…
A long-term agenda for progress in energy (program) evaluation

- be honest about ex-post results vs. expected savings (ex-ante)
- Ex-ante: evaluate the lock-in risk
- We need to go beyond measuring direct costs and benefits (savings)
  - quantify/monetise non-energy benefits
    - Ex-post
  - Quantify/monetise transaction costs and other indirect costs/hassles
- Ideally, evaluations should be conducted on a lifecycle basis – going beyond the operational phase
  - If GHGs measured, non-CO2 should also be included
    - (app. 2/3 of F-gas emissions are related to buildings!)
Thank you for your attention

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