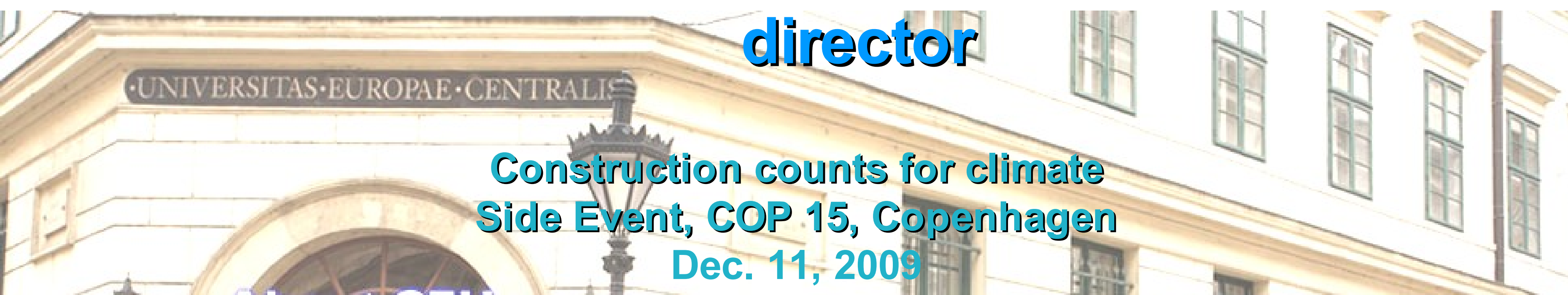
Buildings: how far can they take us in mitigating climate change?

CENTER FOR CLIMATE CHANGE AND SUSTAINABLE ENERGY POLICY

CENTRAL EUROPEAN UNIVERSITY

Diana Ürge-Vorsatz

director



Construction counts for climate
Side Event, COP 15, Copenhagen
Dec. 11, 2009

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
  - more focus on retrofit is needed
  - Suboptimal retrofits (and new construction) are a major climate risk
- Building enegy-efficiency may also have the largest co-benefits among mitigation options

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Buildings are key in climate change mitigation

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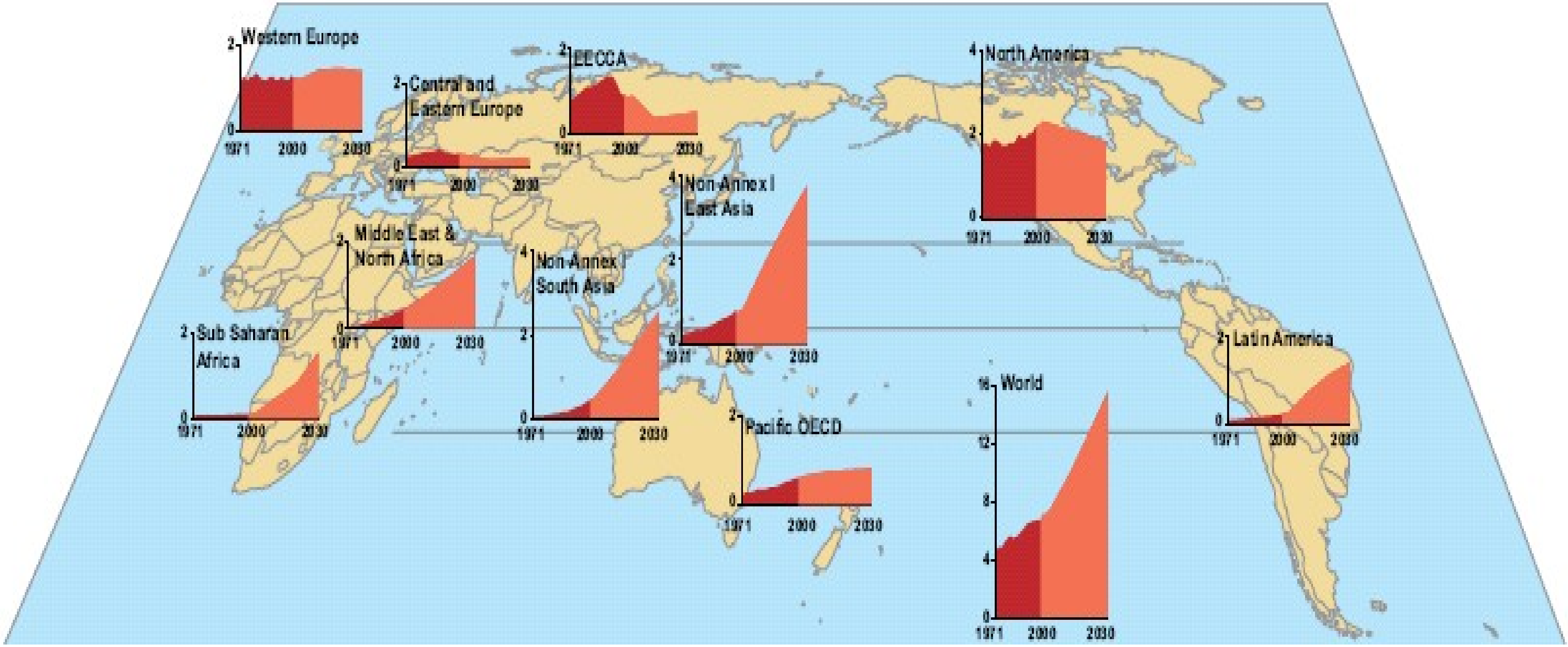
Buildings sector: regional importance

In 2030: the share of building-related emissions in global will stay at approximately 1/3 of energy-related CO2



CO2 emissions including through the use of electricity, A1B scenario

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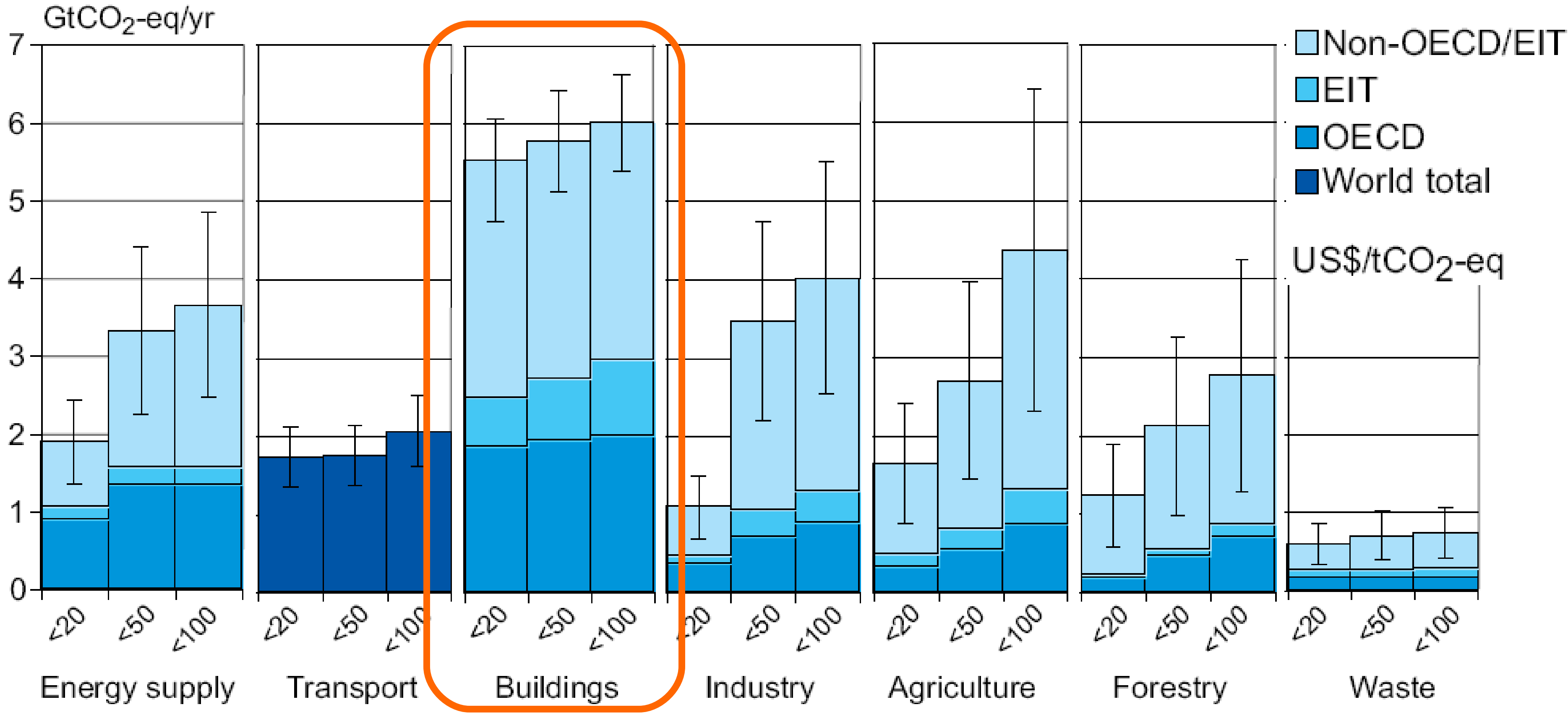
The buildings sector offers the largest low-cost potential in all world regions by 2030



(potential at <US$100/ tCO_2-eq: 2.4 - 4.7 Gt CO_2-eq/yr)	*(potential at <US$100/ tCO_2-eq: 1.6 - 2.5 Gt CO_2-eq/yr)*	*(potential at <US$100/ tCO_2-eq: 5.3 -6.7 Gt CO_2-eq/yr)*	*(potential at <US$100/ tCO_2-eq: 2.5 - 5.5 Gt CO_2-eq/yr)*	*(potential at <US$100/ tCO_2-eq: 2.3 -6.4 Gt CO_2-eq/yr)*	*(potential at <US$100/ tCO_2-eq: 1.3 - 4.2 Gt CO_2-eq/yr)*	*(potential at <US$100/ tCO_2-eq: 0.4 - 1 Gt CO_2-eq/yr)*

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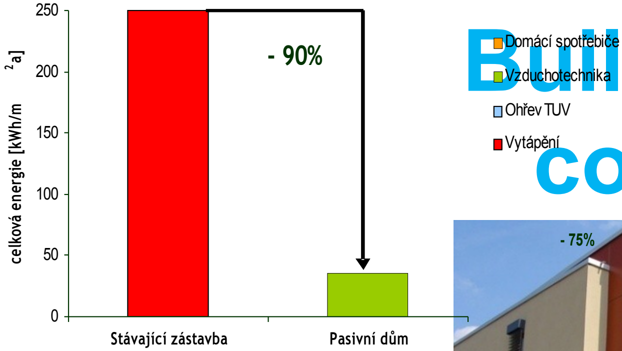
How far can buildings take us? Recent research advances

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

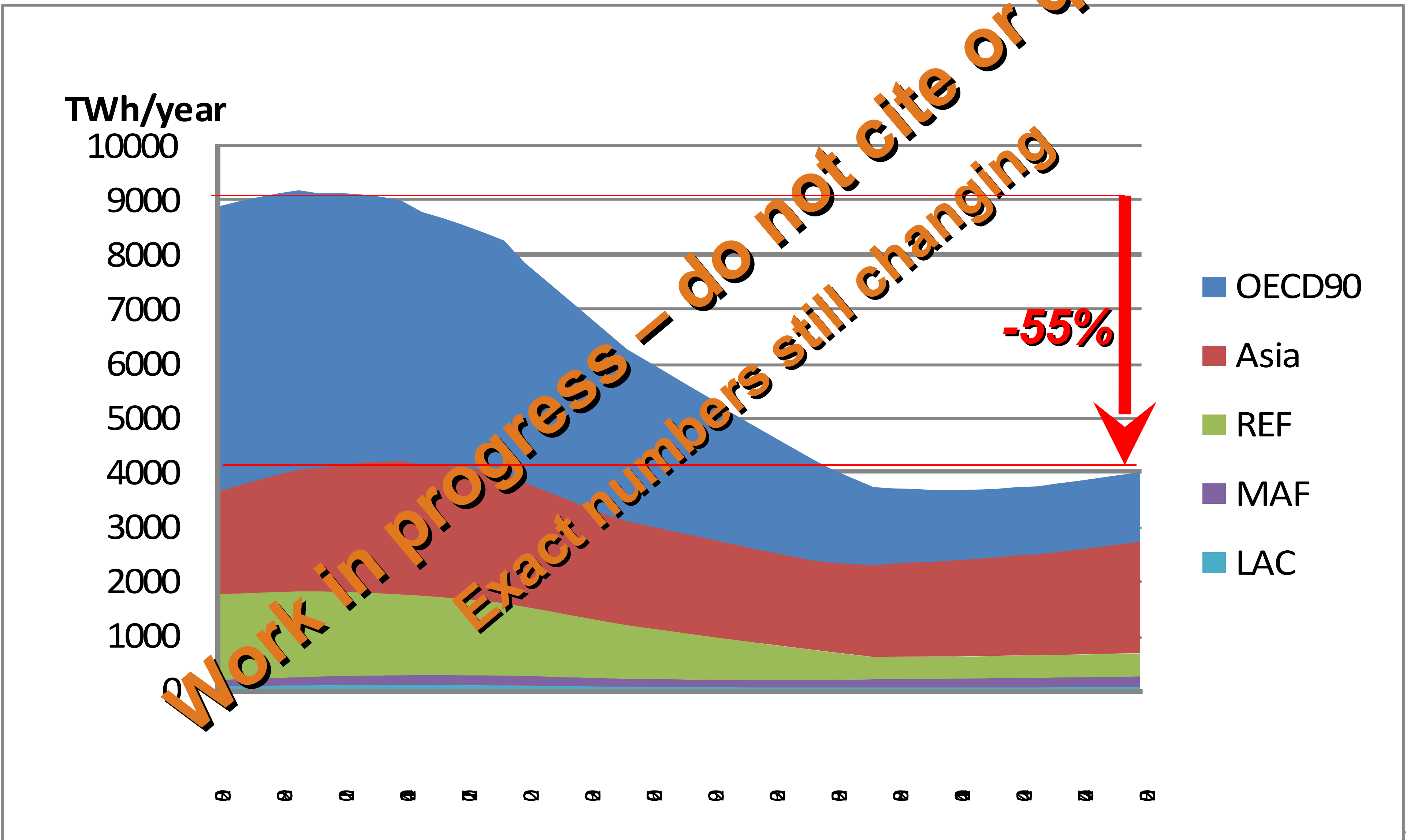
Few sectors can deliver the magnitude of emission reduction needed

- 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



Opportunity or risk?

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The size of the potential lock-in effect

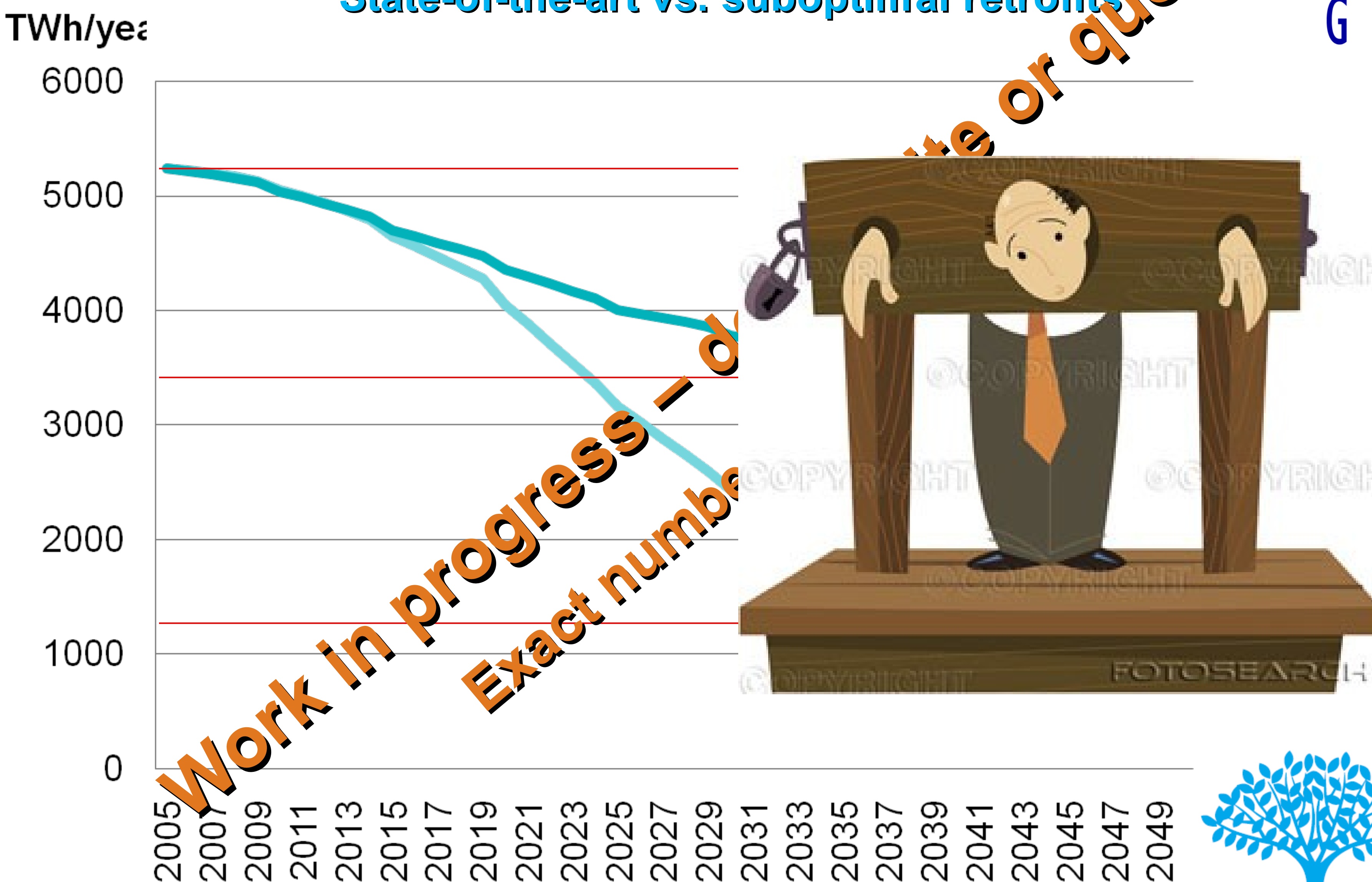

300
250
200
150
100
50
0
kWh/m2
-84%
Renewable Energy
Fossile Energy
Before
SOLANOVA

UNEP SBCI
Sustainable Buildings & Climate Initiative

GEA

The lock-in effect

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



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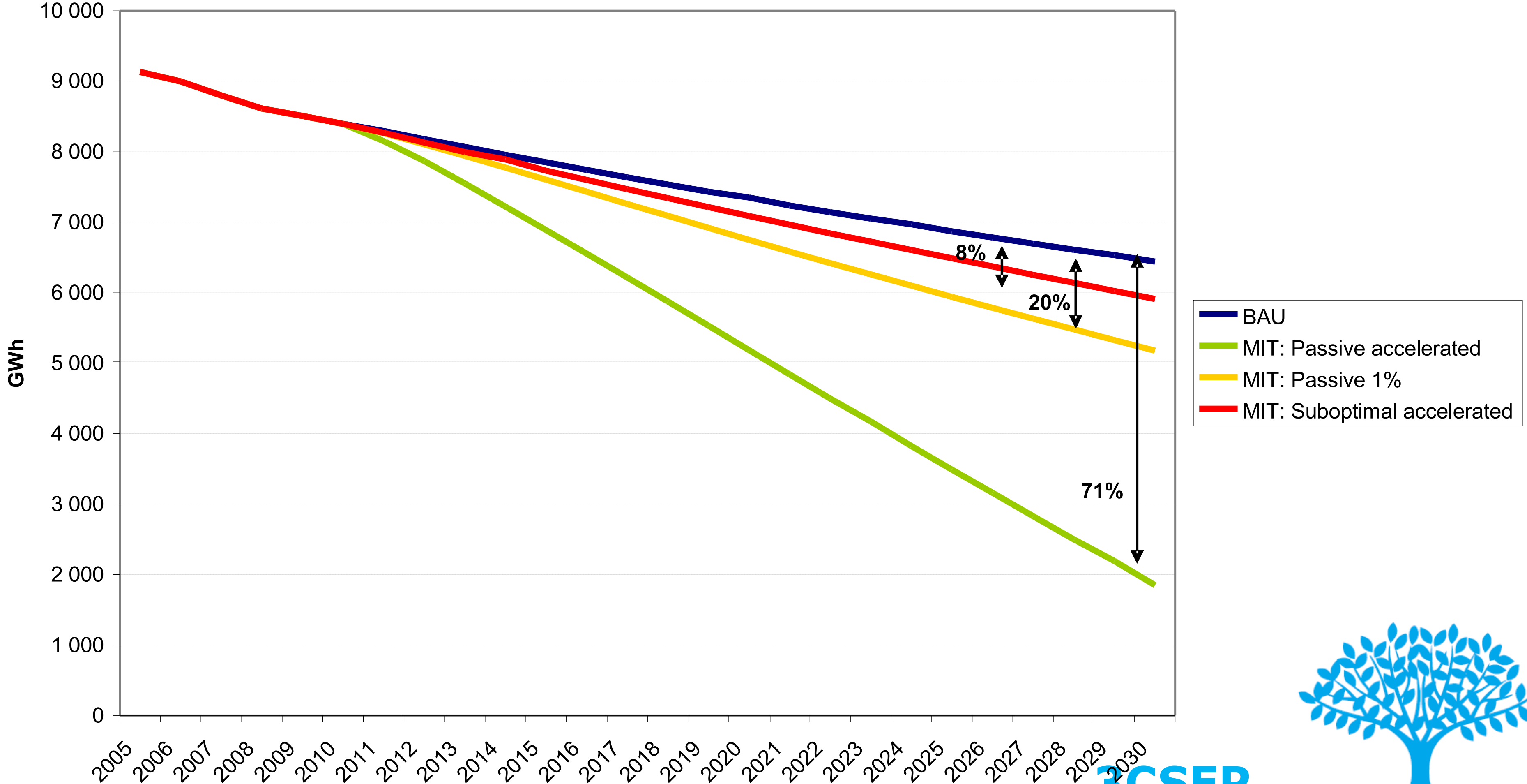
The lock-in effect, case study

Heating energy use in Hungarian public buildings

Source: Katarina Korytarova, draft dissertation, 2009



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Perhaps the largest co-benefits among mitigation options

selected highlights

- (local) job creation: Danish study finds twice higher employment intensity than for other mitigation options
- Health: up to 2 million die due to poor indoor air quality
- Health: better buildings reduce flu by up to 20%, resulting in EUR 10 bln/yr savings in US alone

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“From today, each new building constructed in an energy-wasting manner or retrofited to a suboptimal level will lock us into a high climate-footprint future”

Thank you for your attention

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a world in which global efforts to combat

Diana Ürge-Vorsatz Diana

Center for Climate Change and Sustainable Energy Policy (3CSEP), CEU

http://3csep.ceu.hu   www.globalenergyassessment.org

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Supplementary slides

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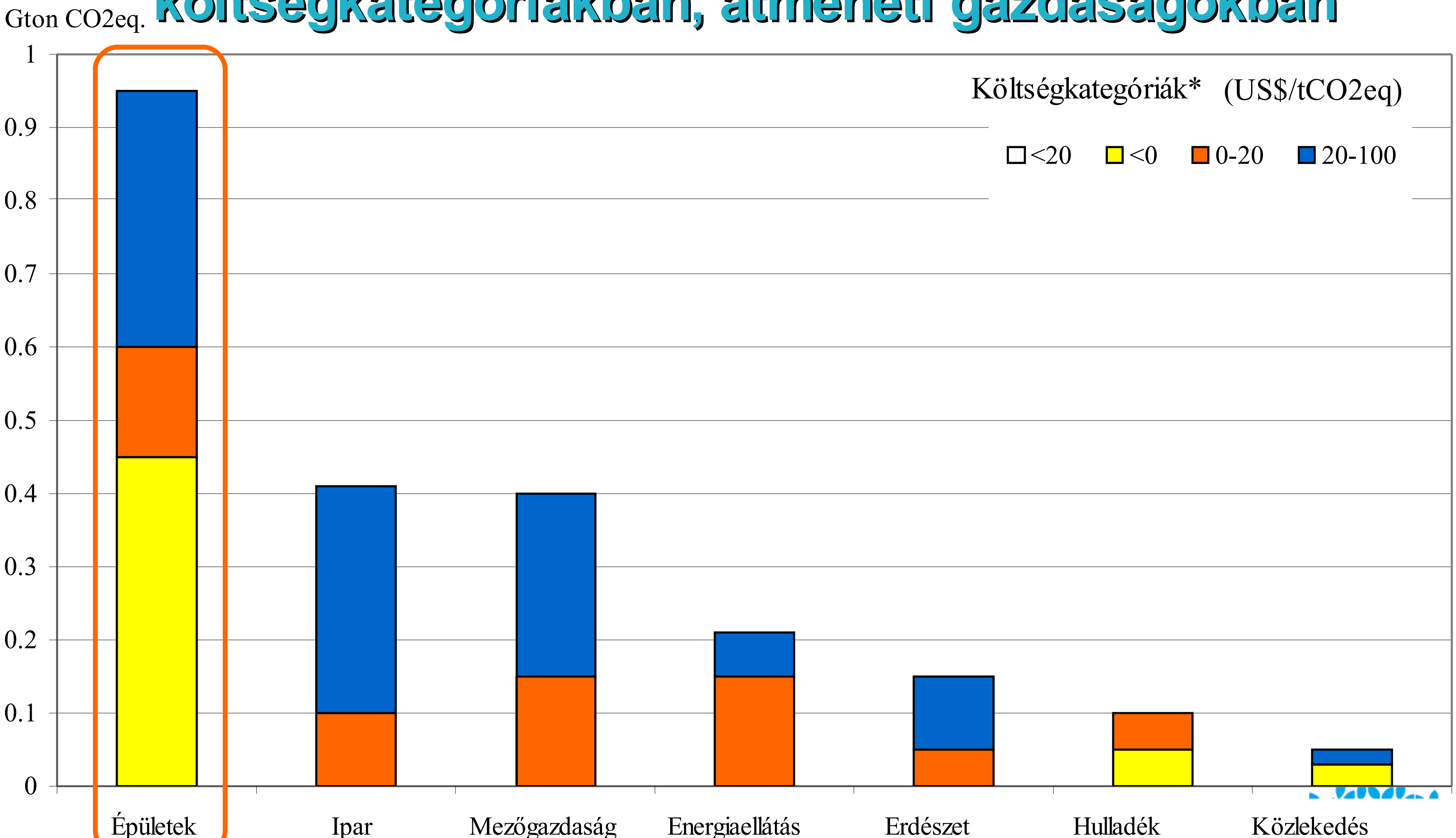
world in which global efforts to combat

Az üvegházhatású gázok mérséklésének 2030-ra becsült szektoronkénti potenciálja különböző költségkategóriákban, átmeneti gazdaságokban



* Az épületek, erdészet, hulladék és közlekedés területein 3 kategóriába van osztva a potenciál: negatív nettó költség, 0-20 US$/t$CO_2$ és 20-100 US$/t$CO_2$. Az ipar, mezőgazdaság és energiaellátás területein 2 kategóriába van osztva: 20 US$/t$CO_2$ alatt és 20-100 US$/t$CO_2$.

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Quantified non-energy benefits of building energy-efficiency programs (1/5)

Co-benefits	Country/ region	Methodology	Impact of CO_2 emission reduction		References
			Physical indicator	Monetary indicator	
Quantifiable health effects					
Morbidity reduction	USA, New Zealand, Denmark	• A double-blind, multiple crossover intervention • Initial self-completed background questionnaires; then shorter weekly questionnaires assessing the outcomes • Environmental measurements • Statistical analysis • Cost-benefit analysis • Literature review • Authors' adjustment/estimates	USA: A drop of concentration of the smallest airborne particles by 94% resulted a decrease of 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.	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 as hight as EUR 1,652/hh 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.	Mendell et al. 2002; Milton et al. 2000; Schweitzer and Tonn 2002; Wyon 1994; Stoecklein and Scumatz 2007; Fisk 1999; Fisk 2000a
Mortality reduction	Hungary; USA, Ireland, Norway	• Bottom-up study (with Monte Carlo simulation) • Statistic time-series analysis: semi-parametric log-linear model, a weighted 2-stage regression • Analysis of mortality statistics with a population of a similar country as the control group	USA: Every 10 g/m^3 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.	Hungary: Energy saving program resulted in the total health benefit of EUR 489 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.	Aunan et al. 2000; Samet et al. 2000; Clinch and Healy 1999

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Quantified non-energy benefits of building energy-efficiency programs (2/5)

Co-benefits	Country/ region	Methodology	Impact of CO_2 emission reduction		References
			Physical indicator	Monetary indicator	
Environmental (ecological) co-benefits					
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 expenditures saved		Stoecklein 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 lease 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 NO_x , 590 kg of SO_2, 265 tonnes of CO_2, 68 kg of coarse particulate matter (PM10) less in comparison with the average practice	USA: The study in the left column results in NPV EUR 0.4/ft^2 (~EUR 0.037/m^2) over 20 yr. USA: NPV of air emission reduction (CO_2, SO_x, NO_x, CO, CH_4, PM) over lifetime of the measures is (all in thousand EUR/hh.: a) from natural gas burning 30.2 - 37.7; b) from electricity consumption EUR 118-185; c) air emissions of heavy metals is 0.75-12.8	Schweitzer and Tonn 2002; Kats 2005; Kats 2006

Quantified non-energy benefits of building energy-efficiency programs (3/5)

Co-benefits	Country/ region	Methodology	Impact of CO_2 emission reduction		References
			Physical indicator	Monetary indicator	
Economic co-benefits and ancillary financial impacts					
Indirect secondary impact from reduced overall market demand and resulting lower energy prices market-wide	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/m^2 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	USA : if the cost of teacher loss is 50% of salary, the left column tops study equals to a saving of EUR 0.28/m^2 if ~214 m^2/teacher is assumed USA/The State of Washington (left column): Savings of USD 160 thousand/yr. during 20 years (not discounted) Ireland: The annual value of the morbidity benefits of the energy efficiency program is EUR 58 million excl. reduced-activity days and EUR 66.6 million incl. them	Buckley et al. 2005; Kats 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% - 34%/each control type. A 1% increase in productivity (~ ca 5 minutes/day) is equal to EUR 452 – 528/employee-yr. or EUR 0.21/m^2-yr.; a 1.5 % increase in productivity (~ ca 7	Lovins 2005; Fisk 2000a; Fisk 2000b; Heschong Mahone Group 1999; Federspiel 2002; Menzies

Quantified non-energy benefits of building energy-efficiency programs (4/5)

Co-benefits	Country/ region	Methodology	Impact of CO_2 emission reduction		References
			Physical indicator	Monetary indicator	
		analysis of student perfromance data • Log-linear regression model • Statistical analysis • Questionnaire • NPV analysis with a 7% DR over 20 years	outdoor air and temperature higher than 25.4°C result in lower work performance Canada: A new ventilation system improved the productivity of co-workers by 11% versus reduced productivity by 4% in a control group USA: After building retrofitting, absenteeism rates dropped by 40% and productivity increased by more than 5%; after moving to a retrofitted facility two business units monitored 83% and 57% reductions in voluntary terminations versus a c control group with 11% reduction in voluntary termination of employment	minutes/day) is equal to ~EUR 754/employee-yr. or EUR 0.35/m^2-yr. USA: More comfortable temperature and lighting results in productivity increase by 0.5% - 5%; considering only U.S. office workers, such a change translates into an annual productivity increase of roughly EUR 15 – 121 billion.	1997; Kats 2003; Pape 1998; Shades of Green 2002
Avoided unemployment	USA	• Literature review • Authors' adjustment and calculations	NPV of avoided unemployment over the lifetime of weatherization measures is EUR 0 – 137.9/hh.		Schweitzer and Tonn 2002
Lower bad debt write-off	USA	• Literature review • Authors' adjustment/estimates	NPV of lower bad debt write-off over the lifetime of weatherization measures is EUR 11.3 – 2,610 /hh.		Schweitzer and Tonn 2002
Employment creation	USA	• NPV analysis with a 7% DR over 20 years • Literature review • Authors' adjustment/estimates • Statistical assessment of the 5- year the energy efficiency programs	USA: Green schools create more jobs than conventional schools: the long-term employment impact of increased energy efficiency may provide EUR 0.21/m^2 of benefits USA: NPV of direct and indirect employment creation over the lifetime of the measures is EUR 86.7 – 3.2 thousand/hh. (note: this benefit occurs only one time in year weatherization is performed) 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 104.8 million to the gross state product, including EUR 48.2 million in disposable income (in 2002 in Massachusetts)		Kats 2005; Schweitzer and Tonn 2002; O'Connor 2004; Kats 2005
Rate subsidies avoided	USA	• Literature review • Authors' adjustment/estimates	NPV of avoided rate-subsidies over the lifetime of weatherization measures is EUR 4.5 – 52.8 /hh.		Schweitzer and Tonn 2002
National energy security	USA	• Literature review • Authors' adjustment/estimates	NPV of enhanced national energy security over the lifetime of weatherization measures is EUR 56.5 – 2,488/hh.		Schweitzer and Tonn 2002

Quantified non-energy benefits of building energy-efficiency programs (5/5)

Co-benefits	Country/ region	Methodology	Impact of CO_2 emission reduction: Physical indicator	Impact of CO_2 emission reduction: Monetary indicator	References
Service provision benefits					
Transmission and distribution loss reduction	USA	• Literature review • Authors' adjustment/estimates	USA: NPV over the lifetime of weatherization measures installed ranges EUR 24.9 – 60.3/hh.		Schweitzer and Tonn 2002
Fewer emergency gas service calls	USA	• Literature review • Authors' adjustment/estimates	USA: NPV of fewer emergency gas service calls over the lifetime of weatherization measures is EUR 29.4 – 151.5/hh.		Schweitzer and Tonn 2002
Utilities' insurance savings	USA	• Literature review • Authors' adjustment/estimates	USA: NPV of utilities insurance cost reduction over the lifetime of weatherization measures is EUR 0 – 1.5/hh.		Schweitzer and Tonn 2002
Decreased number of bill-related calls	New Zealand	• Direct computation • Willingness to pay, willingness to accept, contingent valuation and other survey-based methods	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		Stoecklein and Scumatz 2007
Social co-benefits					
Improved social welfare and poverty alleviation	UK	• Survey monitoring the impact of energy company schemes which were set up to fuel poverty	UK: Energy efficiency schemes applied to 6 million households in January-December 2003 resulted in the average benefit of EUR 12.7/hh-yr.		DEFRA 2005
Safety increase: fewer fires	USA	• Literature review • Authors' adjustment/estimates	USA: NPV over the lifetime of the measures installed is EUR 0 - 418 /hh.		Schweitzer and Tonn 2002
Increased comfort	Ireland; New Zealand	• A computer-simulation energy-assessment model • Direct computation • Willingness to pay, willingness to accept, contingent valuation and other survey-based methods	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.	Ireland: The total comfort benefits of the program for households (described in the left column) amount to EUR 473 million discounted at 5% over 20 years; New Zealand: Comfort (incl. noise reduction) benefits after the weatherization program estimated as EUR 103/hh.-yr. that is 43% of the saved energy costs	Clinch and Healy 2003; Stoecklein and Scumatz 2007.

Example of savings by reconstruction

Before reconstruction

over 150 kWh/(m²a)

-90%

Reconstruction according to the passive house principle

15 kWh/(m²a)

Source: Jan Barta, Center for Passive Buildings, www.pasivnidomy.cz, EEBW2006

What is a sustainable level of retrofit?

- Ecofys (Hermelink:
  How deep to go?) 2009 finds:
- For new buildings a primary energy level of appr. 140 kWh/m2a for space heat, DHW, household electricity and embodied energy,
  - ~ the primary energy requirement for passive houses.
- From an energy life-cycle perspective [Hermelink 2006] analyses which renovation level should be achieved in order to be better than a rebuild option. He conclude**s** that “taking sustainability seriously, a space heat consumption between 25 and 40 kWh/m2a should be aimed at” in renovation.
- = savings of 80% - 90%.

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Characteristics of stabilisation scenarios and the emission reduction needs

Category	Radiative forcing (W/m²)	CO_2 concentration[c)] (ppm)	CO_2-eq concentration[c)] (ppm)	Global mean temperature increase above pre-industrial at equilibrium, using "best estimate" climate sensitivity[b), c)] (°C)	Peaking year for CO_2 emissions[d)]	Change in global CO_2 emissions in 2050 (% of 2000 emissions)[d)]
I	2.5-3.0	350-400	445-490	2.0-2.4	2000-2015	-85 to -50
II	3.0-3.5	400-440	490-535	2.4-2.8	2000-2020	-60 to -30
III	3.5-4.0	440-485	535-590	2.8-3.2	2010-2030	-30 to +5
IV	4.0-5.0	485-570	590-710	3.2-4.0	2020-2060	+10 to +60
V	5.0-6.0	570-660	710-855	4.0-4.9	2050-2080	+25 to +85
VI	6.0-7.5	660-790	855-1130	4.9-6.1	2060-2090	+90 to +140
						Total

Source: IPCC AR4, WGIII, Table SPM5

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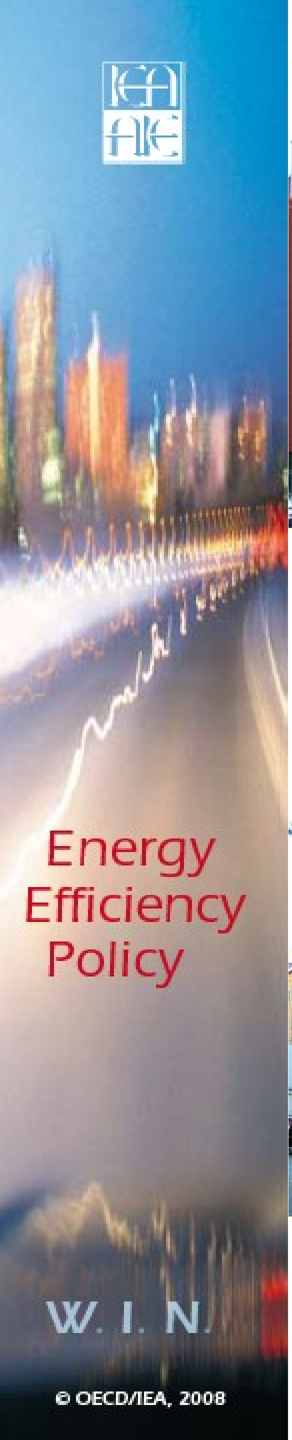

Frankfurt/M Germany Sophienhof
FAAG/ABG Frankfurt Architect Fuessler

Blocks of Flats

160 dwellings
14 767 m²
Passive House Technology
15 kwh / m² per year

Extra costs
= 3-5% of the total costs

Payback = 9 – 10 years

Can we afford this ?

Source: Jens Lausten, IEA

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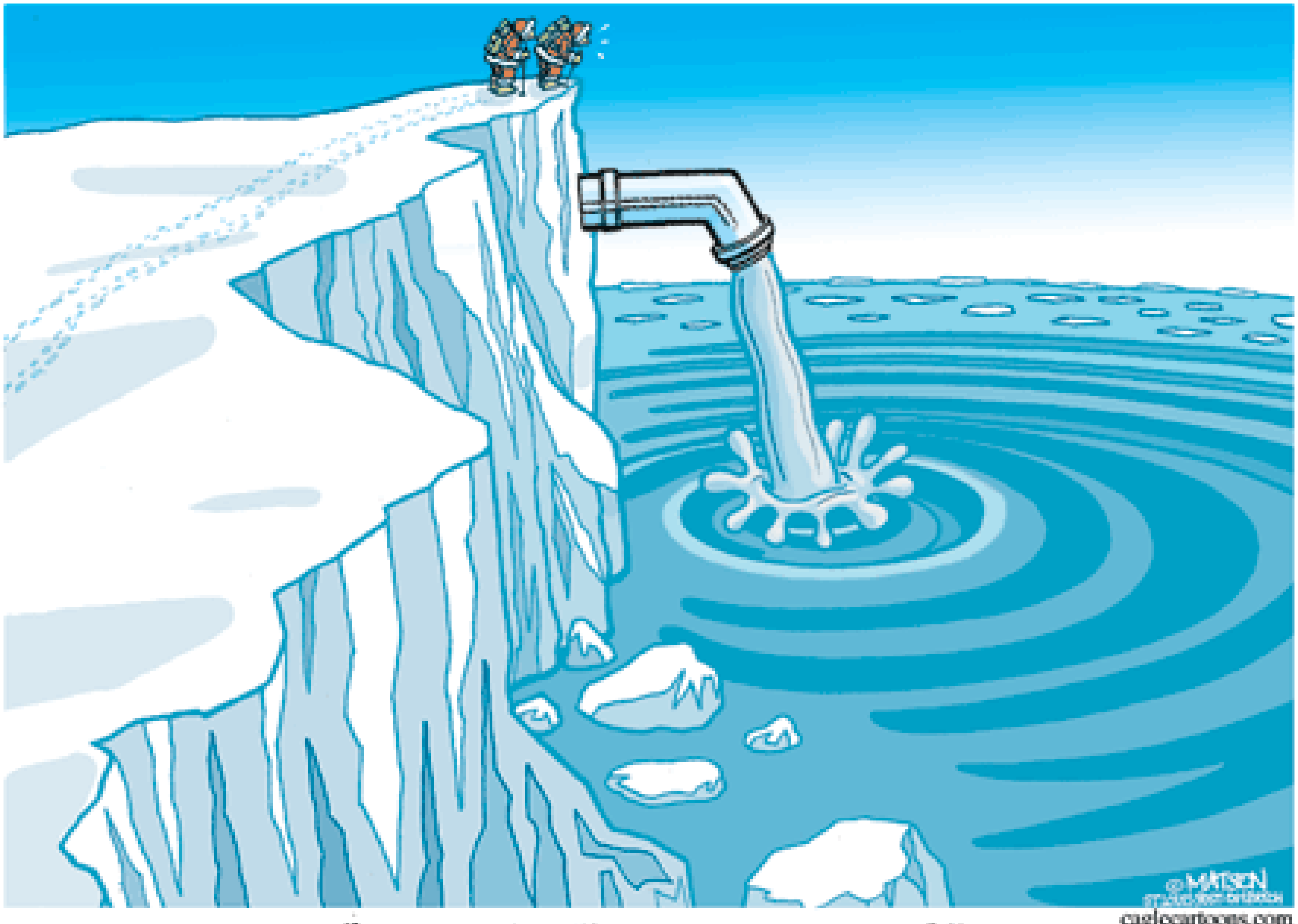
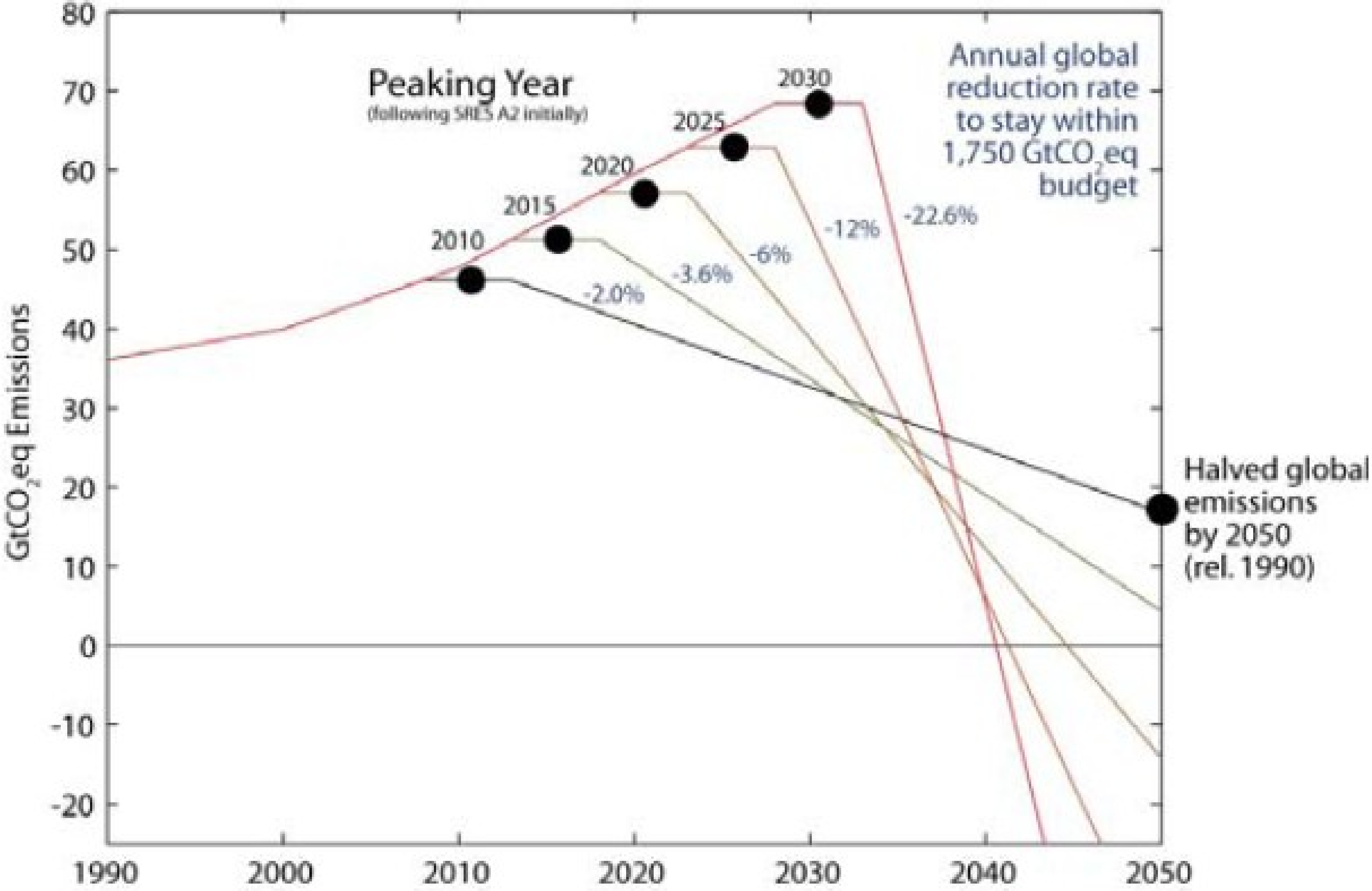
The climate change mitigation challenge



"HOW ON EARTH DO WE TURN IT OFF?"

The later emissions peak, the more ambitious reductions needed



Source: Meinshausen et al 2009

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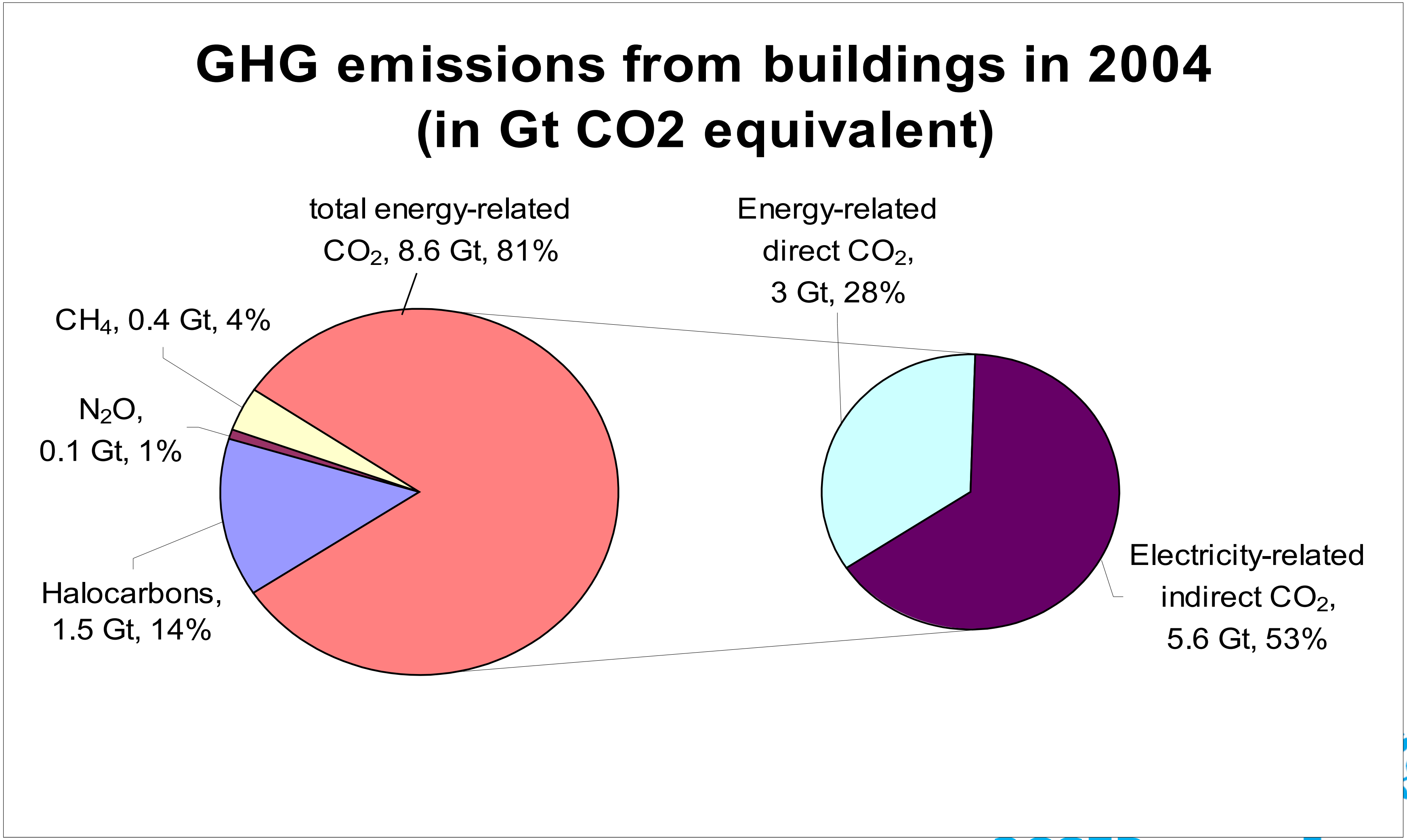
Building sector: global importance

In 2004, in buildings were responsible for app. 1/3 of global energy-related CO_2 (incl. indirect) and 2/3 of halocarbon emissions



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The Global Energy Assessment: Background and purpose

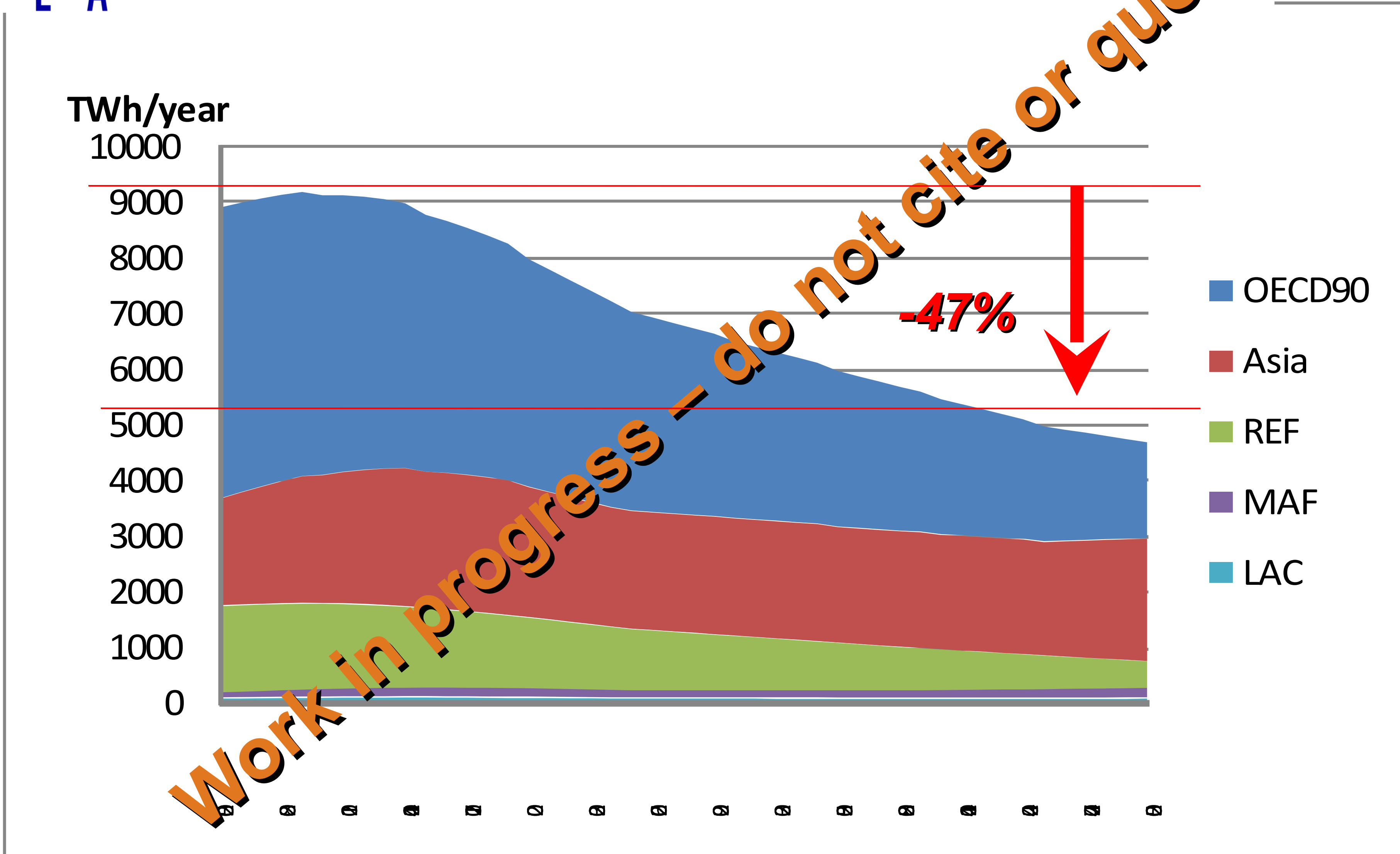
- The Global Energy Assessment aims at providing (a) blueprint(s) for the world how energy-related social, environmental, geopolitical and other challenges can be addressed this century
- We all know that buildings are the key pillar to such a future, but **how much?**
- GEA constructs new scenarios (complementing IPCC-type scenarios) that attempt to take advantage of the really large and novel opportunities in buildings, hard-to-model by existing modeling frameworks
- UNEP SBCI is a partner to further GEA efforts in the buildings scenarios (and WB is partner in GEA)

Main philosophy and assumptions

- Assumes that the world's building stock will transform over to today's known (and built) cutting edge in architecture
  - At the most affordable cost
  - At the natural rate of building construction and retrofit
  - Taking into account capacity and other limitations, but assuming ambitious and supportive (not financially but legally) policy environment.
- The main pillars of the model are existing best practices
  - Best practice from and energy and INVESTMENT COST perspective as well
- The world's building stock is broken down by regions, climate zones and 3 building types
- Model eradicates energy poverty well before 2050, i.e. everyone has appropriate thermal comfort energy services by 2050
- several scenarios planned:
  - Very high efficiency with different modalities; +building-integrated renewables; +behavioural change

Final thermal energy consumption in the world's buildings by region, 2005-2050

1.4%/yr retrofit rate



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Conclusions

- Buildings are key to climate change mitigation in each world region
- Substantial opportunities exist; as much as 77% of 2005 final thermal energy consumption can be eliminated by 2050 by building codes, while living standards increase as BAU and energy poverty eliminated
- To reach ambitious values:
  - Building codes need to be universal and fully implemented
  - Most advanced (low-cost) know-how needs to be mandated
  - Construction industry needs to gear up soon (in app. a decade)
  - **Codes need to cover major retrofit as well**, not only newbuild
  - 2050 emissions extremely sensitive to retrofit rate: 77% energy savings for 3% retrofit rate drops to 37% for 1.4% rate!!
- Major lock-in risks exist
  - Suboptimal retrofit represents major climate lock-in risk
  - Present trends can **lock in 23% – 35% of all 2005 emissions** (increasing achievable low levels by **37 - 152%!)** for many decades
- Suboptimal retrofits should not be supported; rather wait if complex, deep retrofit is not possible yet

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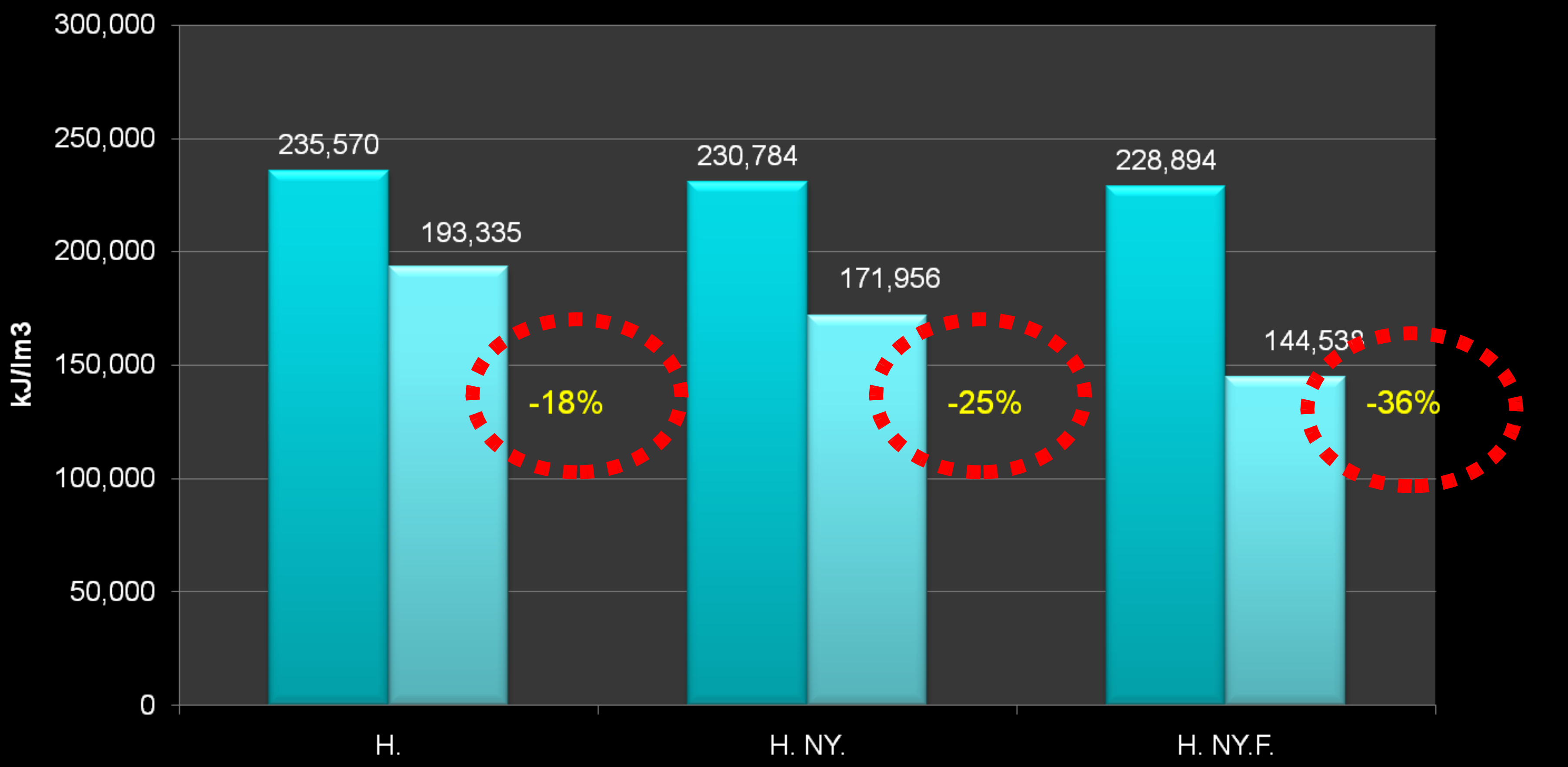
Panelfelújítási programban részt vevő épületek fűtési fajlagos hőfelhasználásának alakulása
Székesfehérvár

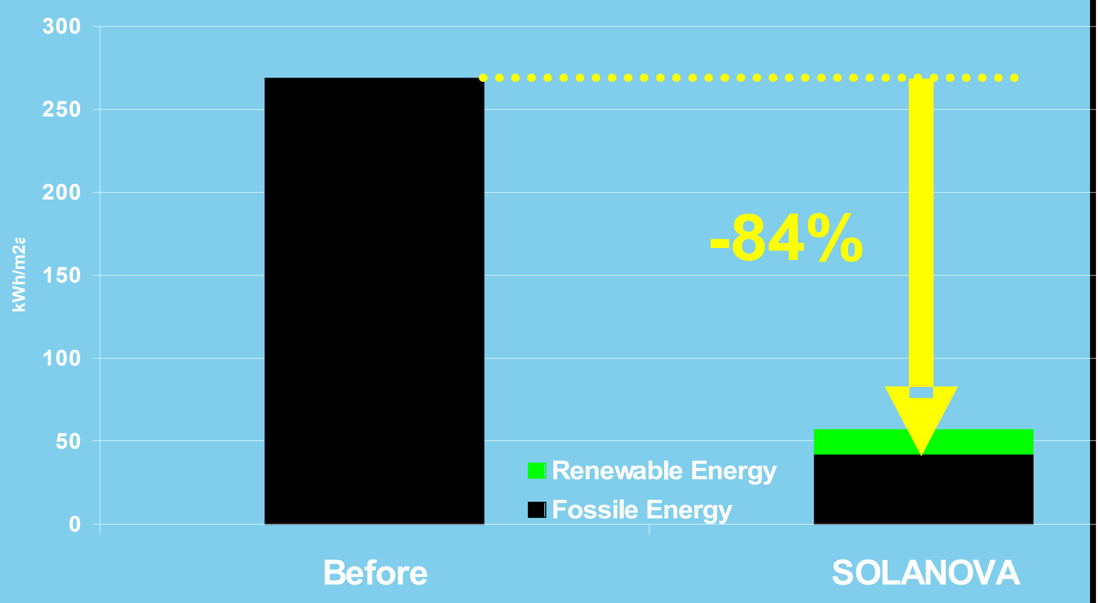


H: Homlokzati hőszigetelés
H: NY. Homlokzati hőszigetelés, nyílászáró csere
H: NY. F. Homlokzati hőszigetelés, nyílászáró csere, fűtéskorszerűsítés

Source: Pájer Sándor, SZÉPHŐ Zrt., KLÍMAVÁLTOZÁS - ENERGIATUDATOSSÁG –ENERGIAHATÉKONYSÁG. V. Nemzetközi Konferencia, SZEGED, 2009. április 16-17.

"EU buildings – a goldmine

for CO2 reductions, energy security, job creation and addressing low income population problems"

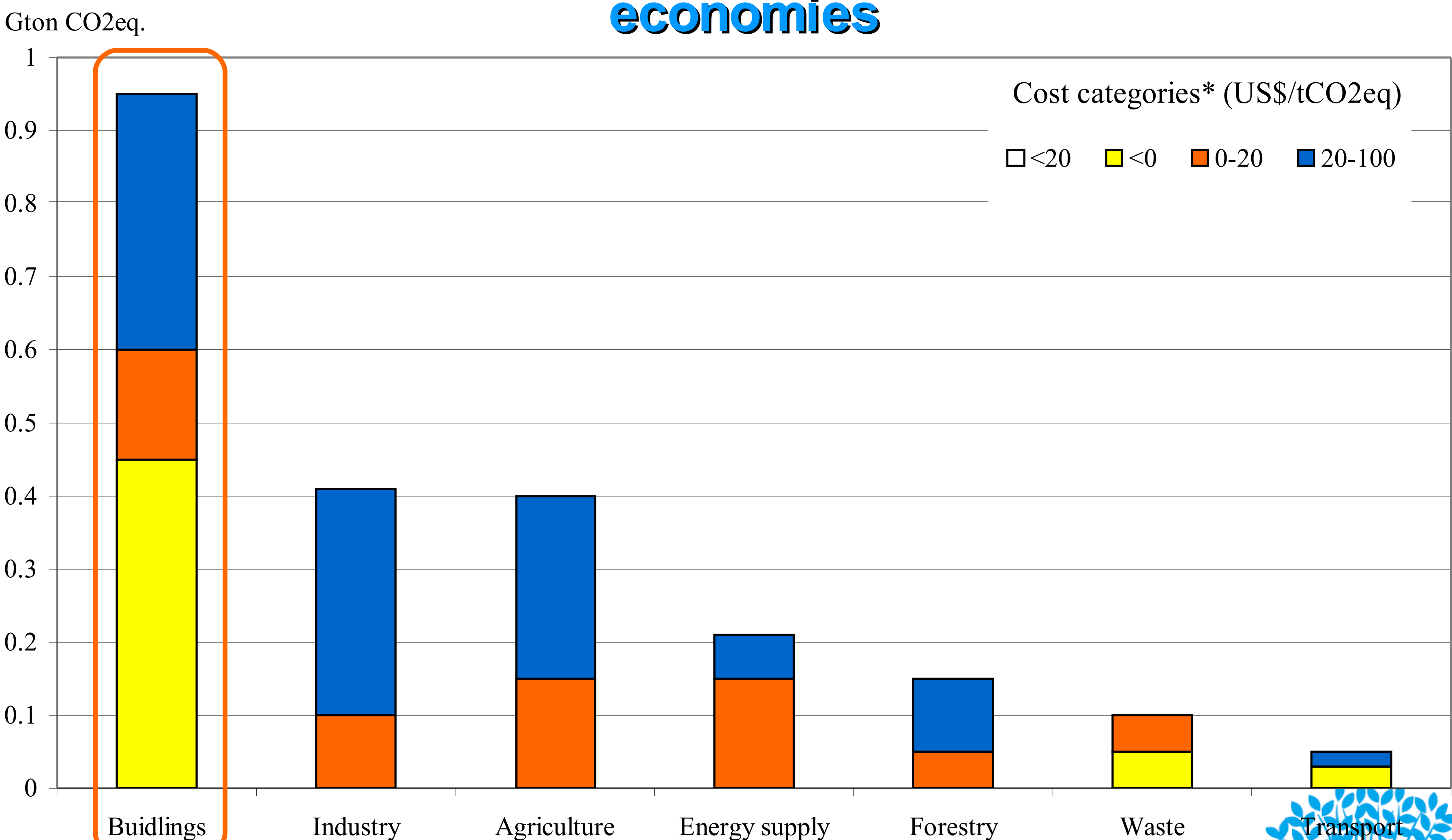


Source: Claude Turmes (MEP), Amsterdam Forum, 2006

More on Solanova: www.solanova.eu

3CSEP

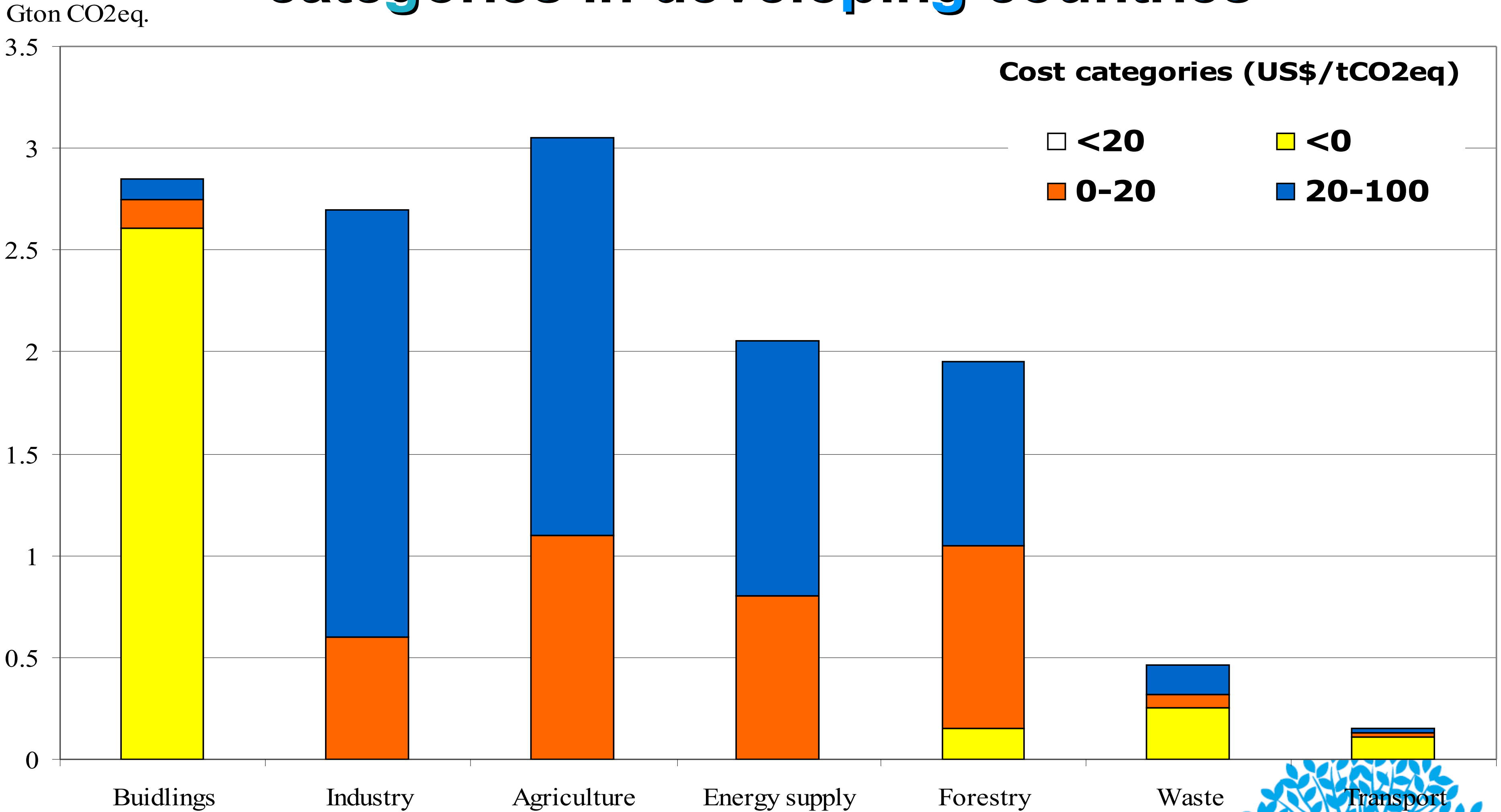
Estimated potential for GHG mitigation at a sectoral level in 2030 in different cost categories , transition economies



* For the buildings, forestry, waste and transport sectors, the potential is split into three cost categories: at net negative costs, at 0-20 US$/tCO2, and 20-100 US$/tCO2. For the industrial, forestry, and energy suppy sectors, the potential is split into two categories: at costs below 20 US$/tCO2 and at 20-100 US$/tCO2.

3CSEP

Estimated potential for GHG mitigation at a sectoral level in 2030 in different cost categories in developing countries



3CSEP

Constructed based on Chapter 11 results