Climate change mitigation in the buildings sector: the findings of the 4th Assessment Report of the IPCC

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and

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Center for Climate Change and Sustainable Energy
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Outline

- Mitigation in the buildings sector: global and regional importance
  - Potential and costs of GHG mitigation in buildings
- Co-benefits of GHG mitigation in bldgs
- Policies to foster carbon-efficiency buildings
- Conclusions
Mitigation in the buildings sector: global and regional importance
Building sector: global importance

In 2004, in buildings were responsible for app. 1/3rd of global energy-related CO$_2$ (incl. indirect) and 3/5th of halocarbon emissions.

GHG emissions from buildings in 2004 (in Gt CO2 equivalent)

- Total energy-related CO$_2$, 8.6 Gt, 81%
- Energy-related direct CO$_2$, 3 Gt, 28%
- Electricity-related indirect CO$_2$, 5.6 Gt, 53%
- CH$_4$, 0.4 Gt, 4%
- N$_2$O, 0.1 Gt, 1%
- Halocarbons, 1.5 Gt, 14%
The buildings sector offers the largest low-cost potential in all world regions by 2030.
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 supply sectors, the potential is split into two categories: at costs below 20 US$/tCO2 and at 20-100 US$/tCO2.
Estimated potential for GHG mitigation at a sectoral level in 2030 in different cost categories in developing countries

Cost categories (US$/tCO2eq)

- <20
- <0
- 0-20
- 20-100

Builtlings | Industry | Agriculture | Energy supply | Forestry | Waste | Transport

Gton CO2eq.

Constructed based on Chapter 11 results
Mitigation in the buildings sector: opportunities

- Globally app. 30% of all buildings-related CO2 emissions can be avoided at a net benefit by 2020
- New buildings can achieve the largest savings
  - As much as 80% of the operational costs of standard new buildings can be saved through integrated design principles
  - Often at no or little extra cost
Buildings utilising passive solar construction
examples
Mitigation in the buildings sector: opportunities

- Globally app. 30% of all buildings-related CO2 emissions can be avoided at a net benefit by 2020
- New buildings can achieve the largest savings
  - As much as 80% of the operational costs of standard new buildings can be saved through integrated design principles
  - Often at no or little extra cost
- Hi-efficiency renovation is more costly, but possible
Case study:
Solanova in Hungary

www.solanova.eu, not in IPCC report
Case study: savings by reconstruction, Germany

Before reconstruction

Reconstruction according to the passive house principle

-90%

over 150 kWh/(m²a) // 15 kWh/(m²a)
Mitigation in the buildings sector: opportunities

- Globally app. 30% of all buildings-related CO2 emissions can be avoided at a net benefit by 2020
- New buildings can achieve the largest savings
  - As much as 80% of the operational costs of standard new buildings can be saved through integrated design principles
  - Often at no or little extra cost
  - Hi-efficiency renovation is more costly, but possible
- The majority of technologies and know-how are widely available
- Net zero energy/emission, or even negative energy buildings are dynamically growing
Low and zero-net energy buildings already exist
WBCSD: “Our vision
A world where buildings consume zero net energy
Energy Efficiency in Buildings”

WBCSD: “Our target is all buildings, everywhere
The EEB project will map out the transition to a 2050 world in which buildings use zero net energy. They must also be aesthetically pleasing and meet other sustainability criteria, especially for air quality, water use and economic viability.” (not in IPCC report)
Co-benefits of GHG mitigation in buildings
Co-benefits of GHG mitigation in buildings 1.

- Co-benefits are often not quantified, monetized, or identified
- Overall value of co-benefits may be higher than value of energy savings
- A wide range of co-benefits, including:
  - Reduced morbidity and mortality
    - App. 2.2 million deaths attributable to indoor air pollution each year from biomass (wood, charcoal, crop residues and dung) and coal burning for household cooking and heating, in addition to acute respiratory infections in young children and chronic pulmonary disease in adults
    - Gender benefits: women and children also collect biomass fuel, they can work or go to school instead
Co-benefits of GHG mitigation in buildings 2.

- **Improved social welfare**
  - Fuel poverty: In the UK, about 20% of all households live in fuel poverty. The number of annual excess winter deaths is estimated at around 30 thousand annually in the UK alone.
  - Energy-efficient household equipment and low-energy building design helps households cope with increasing energy tariffs

- **Employment creation**
  - “producing” energy through energy efficiency or renewables is more employment intensive than through traditional ways
  - A 20% reduction in EU energy consumption by 2020 can potentially create 1 mil new jobs in Europe

- **new business opportunities**
  - A market opportunity of € 5–10 billion in energy service markets in Europe

- **Reduced energy costs will make businesses more competitive**

- **Others:**
  - Improved energy security, reduced burden of constrained generation capacities, Increased value for real estate, Improved energy services (lighting, thermal comfort, etc) can improve productivity, Improved outdoor air quality
Although improving building efficiency is often profitable, investments are hindered by barriers

- Although there are large cost-effective investments to be made, market barriers often hinder that they are captured by market forces
  - Including misplaced incentives, distorted energy price/tax regimes, fragmented industry and building design process, limited access to financing, lack of information and awareness (of the benefits), regulatory failures, etc.

- These barriers are perhaps the most numerous and strongest in the buildings sector

- Therefore, only strong and diverse policies can overcome them to kick-start and catalise markets in capturing the potentially cost-effective investments
Policies to foster carbon-efficiency buildings
Method: global review of ex-post policy evaluations

- Over 80 ex-post policy evaluation studies were reviewed from over 52 countries
- 20 policy instruments analysed
## The impact and effectiveness of various policy instruments

### Part 1: Control and regulatory mechanisms - normative instruments

<table>
<thead>
<tr>
<th>Policy instrument</th>
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<th>Cost of GHG emission reduction for selected best practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appliance standards</td>
<td>EU, US, JP, AUS, Br, Cn</td>
<td>High</td>
<td>Jp: 31 M tCO₂ in 2010; Cn: 250 Mt CO₂ in 10 yrs; US: 1990-1997: 108 Mt CO₂eq, in 2000: 65 Mt CO₂ = 2.5% of el. use; Can: 8 Mt CO₂ in total by 2010; Br: 0.38 Mt CO₂/yr; AUS: 7.9 Mt CO₂ by 2010</td>
<td>High</td>
<td>AUS: -52 $/tCO₂ in 2020, US: -65 $/tCO₂ in 2020; EU: -194 $/tCO₂ in 2020 Mar: 0.008 $/kWh</td>
</tr>
<tr>
<td>Building codes</td>
<td>SG, Phil, Alg, Egy, US, UK, Cn, EU</td>
<td>High</td>
<td>HKG: 1% of total el. saved; US: 79.6 M tCO₂ in 2000; EU: 35-45 Mt CO₂, up to 60% savings for new bdgs; UK: 2.88 Mt CO₂ by 2010, 7% less en use in houses 14% with grants &amp; labelling; Cn: 15-20% of energy saved in urban regions</td>
<td>Medium</td>
<td>NL: from -189 $/tCO₂ to -5 $/tCO₂, for end-users, 46-109 $/tCO₂ for Society</td>
</tr>
<tr>
<td>Procurement regulations</td>
<td>US, EU, Cn, Mex, Kor, Jp</td>
<td>High</td>
<td>Mex: 4 cities saved 3.3 ktCO₂eq. in 1 year; Ch: 3.6 Mt CO₂ expected; EU: 20-44 Mt CO₂ potential; US: 9-31 Mt CO₂ in 2010</td>
<td>High/ Medium</td>
<td>Mex: $1 Million in purchases saves $726,000/year; EU: &lt;21 $/tCO₂</td>
</tr>
<tr>
<td>Energy efficiency obligations and quotas</td>
<td>UK, Be, Fr, I, Dk, Ir</td>
<td>High</td>
<td>UK: 2.6 M tCO₂/yr</td>
<td>High</td>
<td>Flanders: -216 $/tCO₂ for households, -60 $/tCO₂ for other sector in 2003. UK: -139 $/tCO₂</td>
</tr>
</tbody>
</table>
The impact and effectiveness of various policy instruments
Part 2: Regulatory- informative instruments

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<th>Cost-effective ness</th>
<th>Cost of GHG emission reduction for selected best practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mandatory labelling and certification programs</td>
<td>US, Jp, CAN, Cn, AUS, Cr, EU, Mex, SA</td>
<td>High</td>
<td>AUS: 5 Mt CO₂ savings 1992-2000, 81 Mt CO₂ 2000-2015, SA: 480 kt/yr, Dk: 3.568 Mt CO₂</td>
<td>High</td>
<td>AUS: -30 $/t CO₂ abated</td>
</tr>
<tr>
<td>Mandatory audit programs</td>
<td>US; Fr, NZL, Egy, AUS, Cz</td>
<td>High, variable</td>
<td>US: Weatherisation program: 22% saved in weatherized households after audits (30% according to IEA)</td>
<td>Medium/High</td>
<td>US Weatherisation program: BC-ratio: 2.4</td>
</tr>
<tr>
<td>Utility demand-side management programs</td>
<td>US, Sw, Dk, Ni, De, Aut</td>
<td>High</td>
<td>US: 36.7 Mt CO₂ in 2000, Jamaica: 13 GWh/ year, 4.9% less el use = 10.8 kt CO₂, Dk: 0.8 Mt CO₂, Tha: 5.2% of annual el sales 1996-2006</td>
<td>High</td>
<td>EU: - 255 $/tCO₂, Dk: -209.3 $/tCO₂, US: Average costs app. -35 $/tCO₂, Tha: 0.013 $/kWh</td>
</tr>
</tbody>
</table>
## The impact and effectiveness of various policy instruments

### Part 3: Economic and market-based instruments

<table>
<thead>
<tr>
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<th>Cost-effectiveness</th>
<th>Cost of GHG emission reduction for selected best practices</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy performance contracting/ESCO support</td>
<td>De, Aut, Fr, Swe, Fi, US, Jp, Hu</td>
<td>High</td>
<td>Fr, S, US, Fi: 20-40% of buildings energy saved; EU: 40-55 MtCO₂ by 2010; US: 3.2 MtCO₂/yr; Cn: 34 MtCO₂</td>
<td>Medium/High</td>
<td>EU: mostly at no cost, rest at &lt;22$/tCO₂; US: Public sector: B/C ratio 1.6, Priv. sector: 2.1</td>
</tr>
<tr>
<td>Cooperative/technology procurement</td>
<td>De, It, Sk, UK, Swe, Aut, Ir, US, Jp</td>
<td>High/Medium</td>
<td>US: 96 ktCO₂; German telecom company: up to 60% energy savings for specific units</td>
<td>Medium/High</td>
<td>US: -118 $/tCO₂; Swe: 0.11$ /kWh (BELOK)</td>
</tr>
<tr>
<td>Energy efficiency certificate schemes</td>
<td>It, Fr</td>
<td>High</td>
<td>I: 1.3 MtCO₂ in 2006, 3.64 Mt CO₂ eq by 2009 expected</td>
<td>High</td>
<td>Fr: 0.011 $/tCO₂ estimated</td>
</tr>
<tr>
<td>Kyoto Protocol flexible mechanisms</td>
<td>Cn, Tha, CEE (JI &amp;AIJ)</td>
<td>Low</td>
<td>CEE: 220 K tCO₂ in 2000; Estonia: 3.8-4.6 kt CO₂ (3 projects); Latvia: 830-1430 tCO₂</td>
<td>Low</td>
<td>CEE: 63 $/tCO₂; Estonia: 41-57$ /tCO₂; Latvia: -10$ /tCO₂</td>
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</tbody>
</table>
Conclusion

- Buildings are responsible for app. 1/3 of energy-related CO2 emissions and 2/3 of halocarbon emissions
- App. 30% of building emissions can be avoided at net benefit by 2020
- Cost-effective mitigation opportunities in all world regions are abundant; technologies and know-how widely available
- In addition to climate change benefits, improved energy-efficiency can advance several development goals as well as strategic economic targets
  - E.g. reducing mortality and morbidity, poverty alleviation, improving social welfare, employment, energy security
- However, due to the numerous barriers public policies are needed to unlock the potentials and to kick-start or catalise markets
- Several instruments have already been achieving large emission reductions at large net societal benefits, often at double or triple negative digit cost figures all over the world
- However, each new building constructed in an energy-wasting manner potentially locks us into high climate-footprint buildings for decades (centuries) – action now is important
**Early investment is important**

*Table 11.17: Observed and estimated lifetimes of major GHG-related capital stock*

<table>
<thead>
<tr>
<th>Typical lifetime of capital stock</th>
<th>Structures with influence &gt; 100 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>less than 30 years</td>
<td>Domestic appliances</td>
</tr>
<tr>
<td></td>
<td>Water heating and HVAC systems</td>
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<tr>
<td></td>
<td>Lighting</td>
</tr>
<tr>
<td></td>
<td>Vehicles</td>
</tr>
<tr>
<td>30-60 years</td>
<td>Agriculture</td>
</tr>
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<td></td>
<td>Mining</td>
</tr>
<tr>
<td></td>
<td>Construction</td>
</tr>
<tr>
<td></td>
<td>Food</td>
</tr>
<tr>
<td></td>
<td>Paper</td>
</tr>
<tr>
<td></td>
<td>Bulk chemicals</td>
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<tr>
<td></td>
<td>Primary aluminium</td>
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<tr>
<td></td>
<td>Other manufacturing</td>
</tr>
<tr>
<td>60-100 years</td>
<td>Glass manufacturing</td>
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<tr>
<td></td>
<td>Cement manufacturing</td>
</tr>
<tr>
<td></td>
<td>Steel manufacturing</td>
</tr>
<tr>
<td></td>
<td>Metals-based durables</td>
</tr>
<tr>
<td></td>
<td>Roads</td>
</tr>
<tr>
<td></td>
<td>Urban infrastructure</td>
</tr>
<tr>
<td></td>
<td>Some buildings</td>
</tr>
</tbody>
</table>
Thank you for your attention

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For more information on AR4: www.ipcc.ch
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Supplementary slides
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
Supply curves of conserved CO2 for buildings in 2020 for different world regions

Source: Figure 6/4. Notes: a) Except for the UK, Thailand and Greece, for which the supply curves are for the residential sector only. b) Except for EU-15 and Greece, for which the target year is 2010 and Hungary, for which the target year is 2030. Each step on the curve represents a type of measure, such as improved lighting or added insulation. The length of a step on the ‘X’ axis shows the abatement potential represented by the measure, while the cost of the measure is indicated by the value of the step on the ‘Y’ axis.
### Table 1. CO2 reduction potential for buildings in 2020 and review of measures(1)

<table>
<thead>
<tr>
<th>Country groups</th>
<th>Countries/ country groups reviewed</th>
<th>Potential as bldgs BL % (2)</th>
<th>Measures covering the largest potential</th>
<th>Measures providing the cheapest mitigation options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Developed countries</td>
<td>USA, EU-15, Canada, Greece, Australia, Republic of Korea, UK, Germany, Japan</td>
<td>Technical: 21%-54%[1]</td>
<td>1. Shell retrofit, inc. insulation, esp. windows and walls;</td>
<td>1. Appliances such as efficient TVs and peripheries (both on-mode and standby), refrigerators and freezers, followed by ventilators and AC;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Economic: 12%-25%[2]</td>
<td>2. Space heating systems and standards for them;</td>
<td>2. Water heating equipment;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Market: 15%-37%</td>
<td>3. Efficient lights, esp. shift to CFLs and efficient ballasts.</td>
<td>3. Lighting best practices.</td>
</tr>
<tr>
<td>Economies in Transition</td>
<td>Hungary, Poland, Russia, Croatia, as a group: Lithuania, Malta Latvia, Estonia, Cyprus, Slovakia, Slovenia, Hungary, Poland, the Czech Republic</td>
<td>Technical: 26%-47%[3]</td>
<td>1. Pre- and post- insulation and replacement of building components, esp. windows;</td>
<td>1. Efficient lighting and its controls;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Economic: 13%-37%[4]</td>
<td>2. Efficient lighting, esp. shift to CFLs;</td>
<td>2. Water and space heating control systems;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Market: 14%</td>
<td>3. Efficient appliances such as refrigerators and water heaters.</td>
<td>3. Retrofit and replacement of building components, esp. windows.</td>
</tr>
<tr>
<td>Developing countries</td>
<td>Myanmar, India, Indonesia, Argentine, Brazil, China, Ecuador, Thailand, Pakistan, South Africa</td>
<td>Technical: 18%-41%</td>
<td>1. Efficient lights, esp. shift to CFLs, light retrofit, and kerosene lamps;</td>
<td>1. Improved lights, esp. shift to CFLs light retrofit, &amp; efficient kerosene lamps;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Economic: 13%-52%[5]</td>
<td>2. Various types of improved cook stoves, esp. biomass stoves, followed by LPG &amp; kerosene stoves;</td>
<td>2. Various types of improved cook stoves, esp. biomass based, followed by kerosene stoves;</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Market: 23%</td>
<td>3. Efficient appliances such as air-conditioners and refrigerators.</td>
<td>3. Efficient electric appliances such as refrigerators and air-conditioners.</td>
</tr>
</tbody>
</table>
Problem statement 1: climate change

- Climate change – one of the most formidable challenges of the 21st century
- IPCC’s Fourth Assessment Report showed that:
  - The challenge is Herculean
  - However, many of the solutions exist
  - A large share of these are affordable
  - But significant barriers exist to their adoption
## The impact and effectiveness of various policy instruments
### Part 4: Fiscal instruments and incentives

<table>
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<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>Taxation (on CO2 or household fuels)</td>
<td>Nor, De UK, NL, Dk, Sw</td>
<td>Low/Medium</td>
<td>De: household consumption reduced by 0.9% 2003: 1.5 MtCO2 in total No: 0.1-0.5% 1987-1991 NL: 0.5-0.7 MtCO2 in 2000 Swe: 5% 1991-2005, 3MtCO2</td>
<td>Low</td>
<td>Low</td>
</tr>
<tr>
<td>Tax exemptions/reductions</td>
<td>US, Fr, NI, Kor</td>
<td>High</td>
<td>US: 88 MtCO2 in 2006 FR: 1 Mt CO2 in 2002</td>
<td>High</td>
<td>US: B/C ratio commercial buildings: 5.4 New homes: 1.6</td>
</tr>
<tr>
<td>Public benefit charges</td>
<td>BE, Dk, Fr, NI, US states</td>
<td>Medium/Low</td>
<td>US: 0.1-0.8% of total el. sales saved /yr, 1.3 ktCO2 savings in 12 states NL: 7.4 TWh in 1996 = 2.5 MtCO2 Br: 1954 GWh</td>
<td>High in reported cases</td>
<td>US: From -53$/tCO2 to -17$/tCO2</td>
</tr>
<tr>
<td>Capital subsidies, grants, subsidised loans</td>
<td>Jp, Svn, NL, De, Sw, US, Cn, UK, Ro</td>
<td>High/Medium</td>
<td>Svn: up to 24% energy savings for buildings, BR: 169 ktCO2 UK: 6.48 MtCO2 /year, 100.8 MtCO2 in total Ro: 126 ktCO2/yr</td>
<td>Low sometimes High</td>
<td>Dk: – 20$/tCO2 UK: 29$/tCO2 for soc NL: 41-105$/tCO2 for society</td>
</tr>
</tbody>
</table>
**The impact and effectiveness of various policy instruments**  
*Part 5: Support, information and voluntary action (cont.)*

<table>
<thead>
<tr>
<th>Policy instrument</th>
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<th>Cost of GHG emission reduction for selected best practices</th>
</tr>
</thead>
</table>
| **Awareness, education, information** | Dk, US, UK, Fr, CAN, Br, Jp, Swe | Low/Medium | UK: 10.4ktCO₂ annually  
Arg: 25% in 04/05, 355 ktep  
Fr: 40tCO₂/ year  
Br: 2.23kt/yr, 6.5-12.2 MtCO₂/ year with voluntary labeling 1986-2005  
Swe: 3ktCO₂/ year | Medium/High | Br: -66$/tCO₂;  
UK: 8$/tCO₂ (for all programs of Energy Trust)/  
Swe: 0.018$/kWh |
| **Detailed billing & disclosure programs** | Ontario, It, Swe, Fin, Jp, Nor, Aus, Cal, Can | Medium | Max.20% energy savings in households concerned, usually app. 5-10% savings  
UK: 3%  
Nor: 8-10% | Medium | |

**Country name abbreviations:** Alg - Algeria, Arg- Argentina, AUS - Australia, Aut - Austria, Be - Belgium, Br - Brazil, Cal - California, Can - Canada, CEE - Central and Eastern Europe, Cn - China, Cr - Costa Rica, Cz - Czech Republic, De - Germany, Ecu - Ecuador, Egy - Egypt, EU - European Union, Fin - Finland, GB-Great Britain, Hkg-Hong Kong, Hu - Hungary, Ind - India, Ir - Ireland, It - Italy, JP - Japan, Kor - Korea (South), Mar- Morocco, Mex - Mexico, NL - Netherlands, Nor - Norway, Nzl – New Zealand, Phil - Philippines, Pol - Poland, Ro- Romania, SA- South Africa, SG - Singapore, Sk - Slovakia, Svn - Slovenia, Sw - Switzerland, Swe - Sweden, Tha - Thailand, US - United States.
Results of the analysis of studies

- For studies reviewed (see Table 1 on the next slide and Annex I):
  - Estimates of the **technical** potential range:
    - From 18% buildings CO2 emissions in Pakistan in 2020 with a limited number of options
    - To 54% in Greek residences in 2010[1] from a very comprehensive range of measures
  - Estimates of the **economic** potential (assuming zero carbon price) vary:
    - From 12% in EU-15 in 2010[2]
    - To 52% in Ecuador in 2030[3]
  - Estimates of the **market** potential is in the interval:
    - From 14% in Croatia in 2020 focusing on 4 policies only
    - To 37% in USA in 2020 where a wide range of policies were appraised

[1] If the approximate formula of Potential \(2020 = (1 - (1 - \text{Potential}_{2010})^{20/10}\) is used to extrapolate the potential as percentage of the baseline into the future (the year 2000 is assumed as a start year), this corresponds to app. 78% CO\(_2\) savings in 2020.

[2] Corresponds to an app. 22% potential in 2020 if the suggested extrapolation formula is used.

[3] Corresponds to an app. 38% in 2020 if the suggested extrapolation formula is applied to derive the intermediate potential.
Recent developments in Austria

CO$_2$ reductions due to completed/built passive houses

Source: passive-house building database, [www.HAUSderZukunft.at](http://www.HAUSderZukunft.at), not in IPCC report