Global climate change and building cooling

September 2020

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CLA Buildings chapter IPCC AR6

Introduction

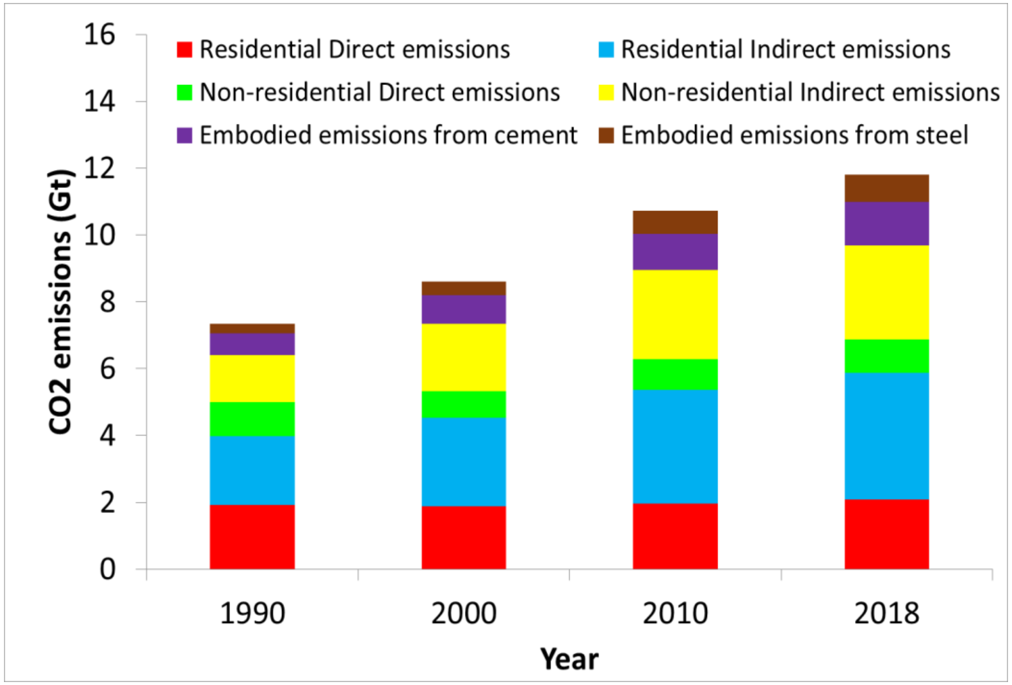
- Over the period 2010-2018, global cooling energy consumption experienced an increase of 40% in residential buildings
- This increase ranges from more than 90% in emerging and developing countries to 24% in Europe and 10% in Asia Pacific
- This increase of cooling energy consumption stems from warming global temperatures and an increasing affordability of and access to low efficient cooling appliances, especially in emerging economies

Introduction

- Consequently, ownership of room air conditioners:
  - Increased by 32% in the region of South and South East Asia and 21% in Latin America and Caribbean countries
  - In North America and Middle East, two air conditioners' saturated markets, experienced the lowest increases with 8% and 1% each
- Cooling consumption is projected to be one of the largest causes for increases in global energy use

Global building emission trends

- Total CO_2 emissions in the building sector reached 11.81 Gt in 2018
  - 56% were indirect emissions resulting from the use of carbonized electricity and heat
  - 26% were direct emissions
  - 18% were emissions resulting from the use of cement and steel for the construction and/or refurbishment of buildings



Regional CO_2 emissions trends

- The building stock in the developed world experienced a decrease of its direct and indirect emissions except in North America where an increase of a 3% was observed in residential buildings and almost no changes were experienced in direct emissions in non-residential buildings in this region over the period 2010-2018
- The highest decrease of direct emissions was observed in residential buildings in Europe with 19% decrease, followed by non-residential in Europe with 10% decrease while in developed Asia-Pacific the decrease of direct emissions was at 3% in residential buildings and 3.6% in non-residential ones

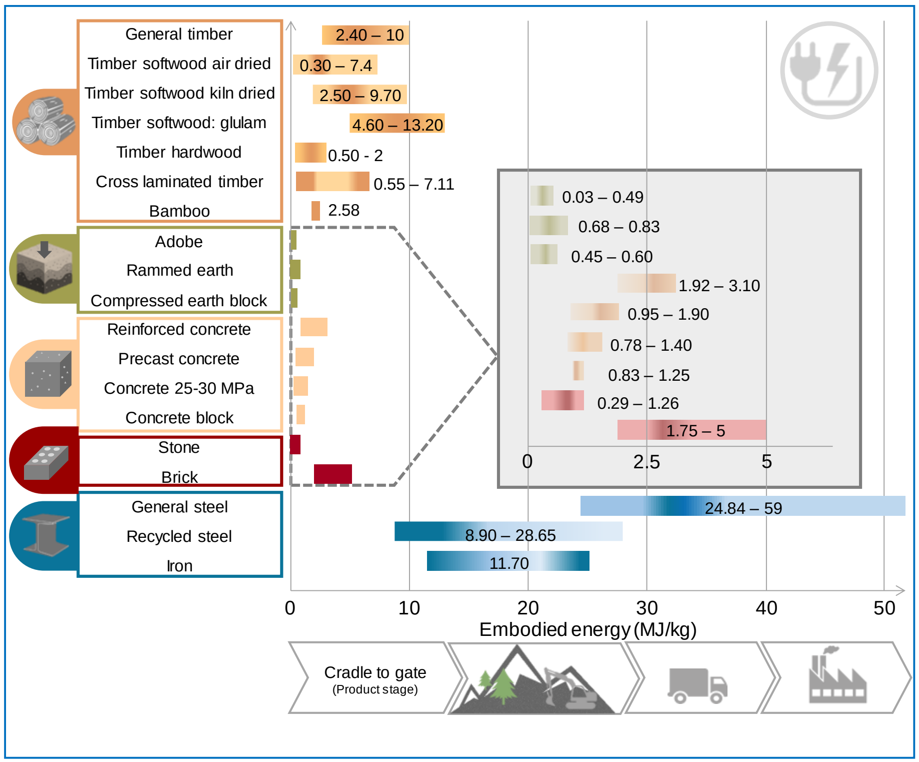
Regional CO_2 emissions trends

- Trends in regional direct, indirect and embodied CO_2 emissions in the building sector over the period 2010-2018

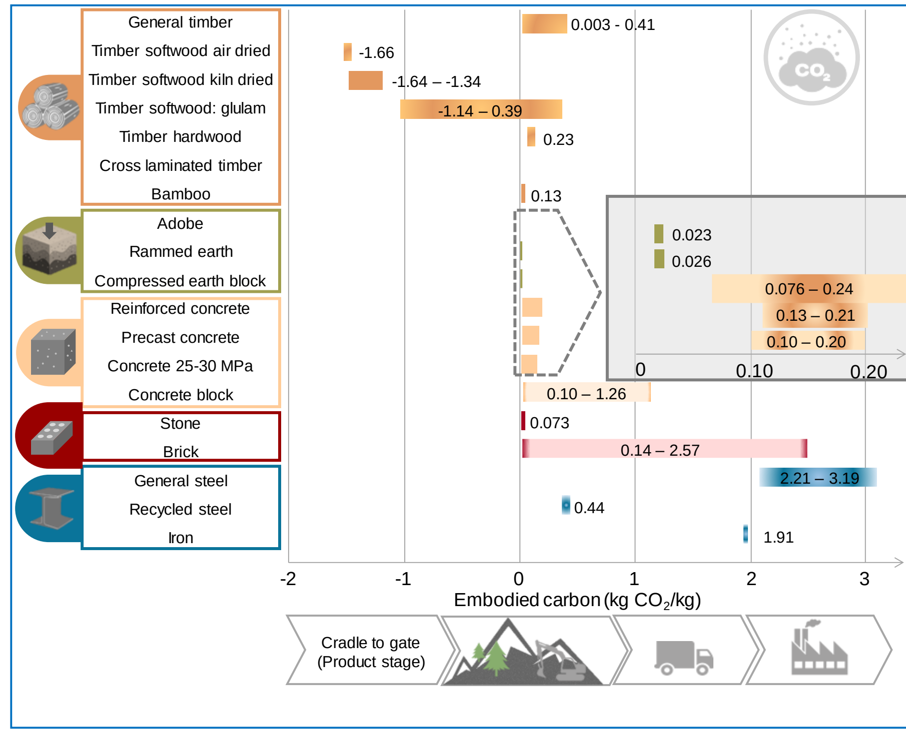
Region	Direct		Indirect		Embodied[1]	
	Residential	Non-residential	Residential	Non-residential	Cement	Steel
North America	+3%	-0.4%	-23%	-19%	+8%	+2%
Europe	-19%	-10%	-20%	-18%	+6%	+8%
Asia-Pacific Developed	-3%	-3.6%	-4.2%	+4%	-10%	-12%
Latin America and Caribbean	+8.6%	+8.2%	+19.4%	+19.5%	+1%	Not available
Africa	+44%	+52%	+25%	+21%	+29%	+15%
Middle East	+4.4%	Not available	+28%	+33%	+26%	+12%
Eurasia	+44%	-13%	-14%	-9%	+30%	+42%
Eastern Asia	+25%	+17.5%	+62%	+66%	+7%	+13%
South and South-East Asia and developing Pacific	+20%	+18%	+53%	+43%	+67%	+54%

Embodied energy in building materials

- Cradle to gate coefficients reported in the literature



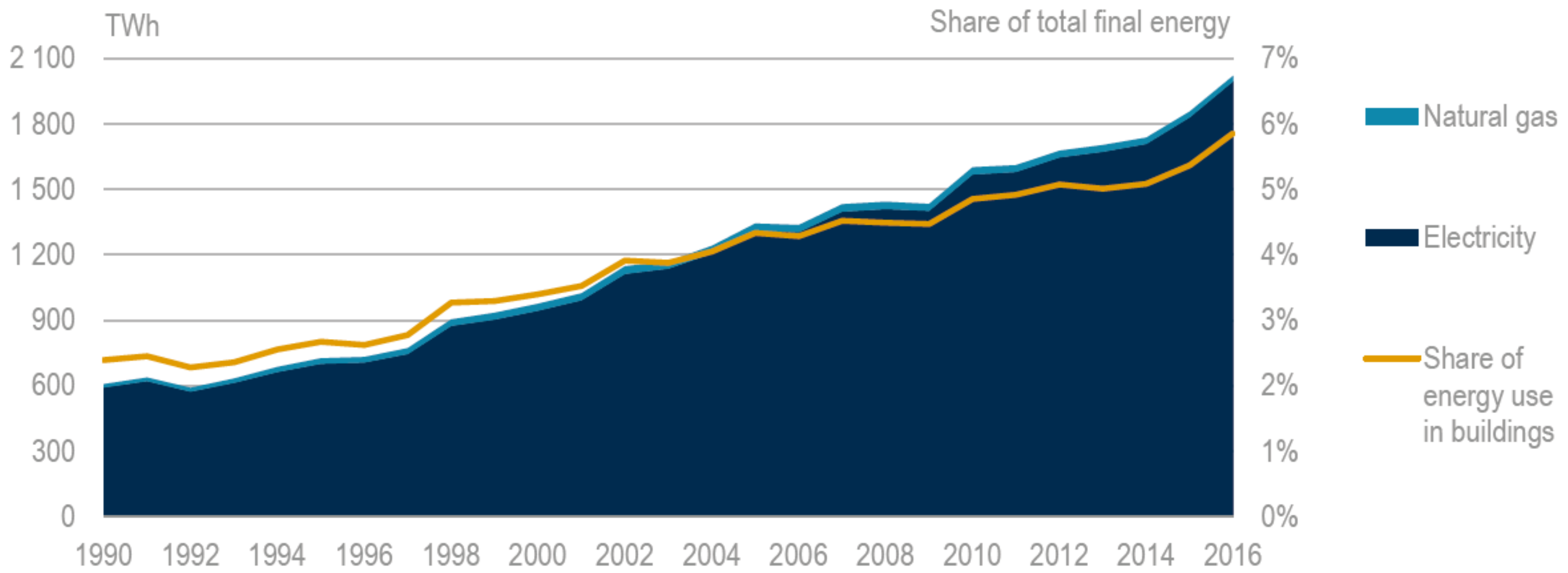
Embodied energy



Embodied carbon

Building cooling energy trends

- Space cooling is the fastest-growing use of energy in buildings, both in hot and humid emerging economies where incomes are rising



Buildings cooling halocarbon emissions

- The buildings sector halocarbon emissions exceeded those of industry production process and became in 2017 the dominant source of HFCs emission

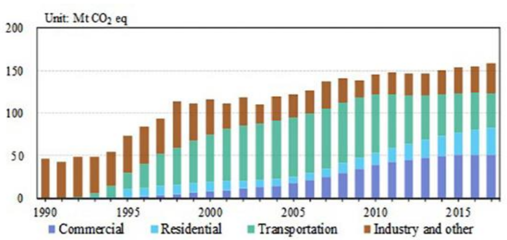


Fig. 8. Sectorial share of total US HFC emissions (1990–2017). Data source: USA GHG inventory 2019 [24].

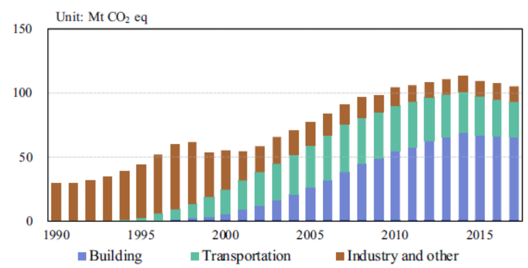


Fig. 9. Sectorial share of total EU HFC emissions (1990–2017). Data source: EU GHG inventory [18].

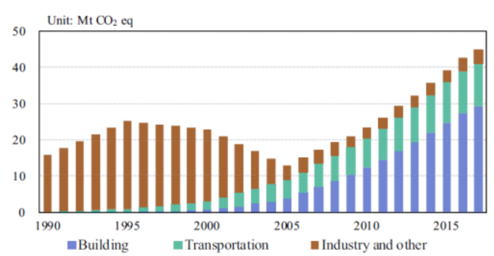


Fig. 10. Sectorial share of total Japanese HFC emissions (1990–2017). Data source: Japan GHG inventory [26].

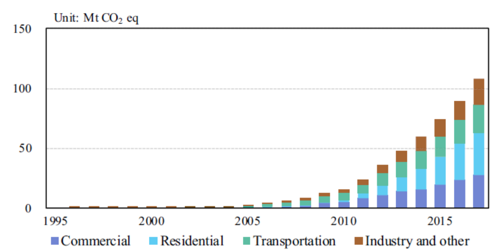


Fig. 11. Sectorial share of China's total HFC emissions (1995–2017). Data source: Estimated from Li et al. (2019) [34].

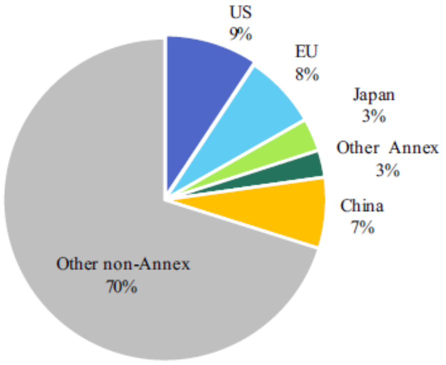


Fig. 14. Regional share of global buildings sector HFC emissions in 2017. Data source: Estimations performed in this study.

Buildings cooling halocarbon emissions

- Space cooling related non-CO_2 emission are approaching CO_2 emission
- Non-Annex parties were a larger contributor to buildings-sector HFC emissions than Annex parties

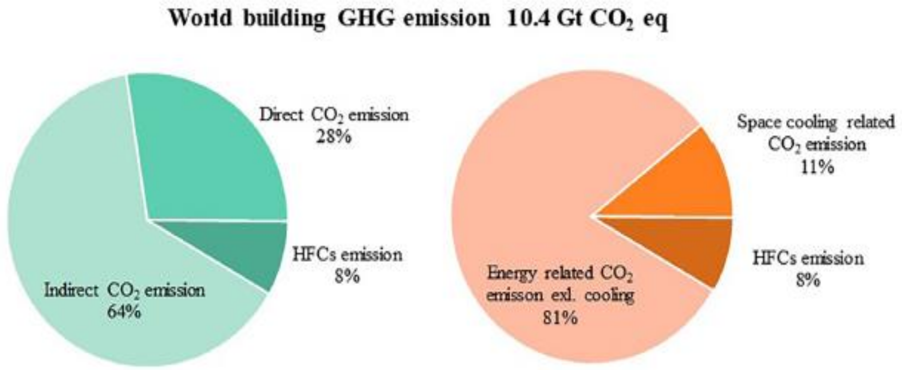


Fig. 15. Global buildings-sector GHG emissions in 2017. Data source: IEA [35,37] and estimations performed in this study.

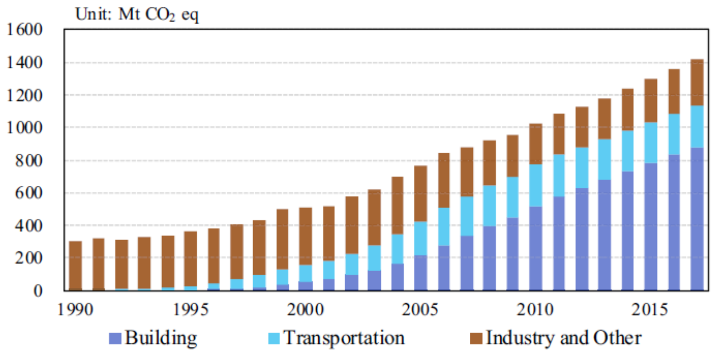


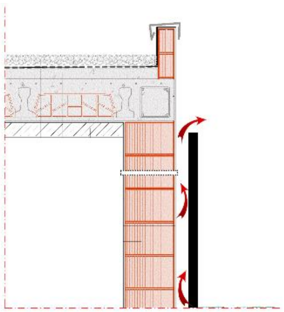
Fig. 13. Global HFC emissions by sector (1990–2017). Data source: Estimations performed in this study.

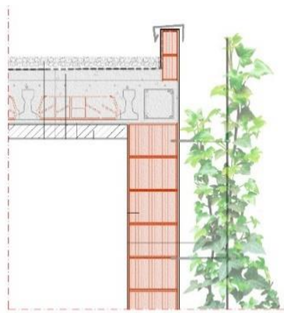
Technology progress

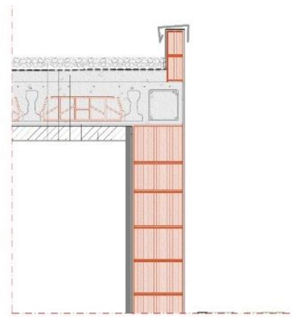
- There are many technologies that can reduce energy use in buildings
- Other technologies that can contribute in achieving carbon zero buildings are less present in the literature
- Technologies have a wide range of applications in buildings and the built environment:
  - Heating and cooling
  - Appliances
  - Lighting
  - Cooking
  - etc.

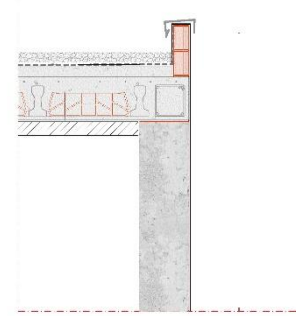
Technology strategies

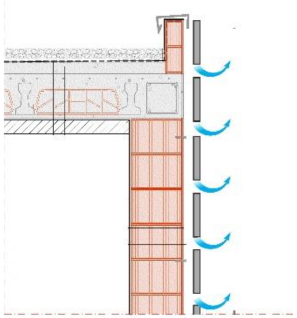
- Technologies contributing to sufficiency aspects: energy savings potential

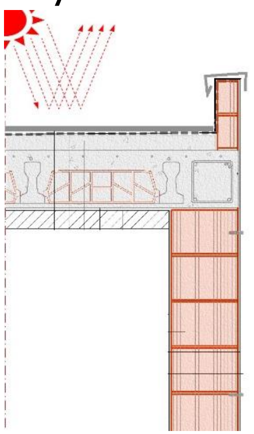

Trombe wall – 20%

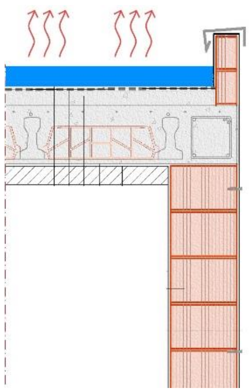

Vertical greenery systems – 35-60%

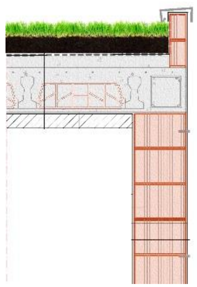

PCM wall systems – 10-30%


AAC walls – 7%


Double skin walls – 10-50%


Cool roofs – 0-30%


Roof ponds – 30%


Green roofs – 5-15%

Technology strategies

- Technologies contributing to efficiency aspects: energy savings potential
  - Thermally activated building systems (TABS) – 15-25%
  - Heat pumps – 10-60%
  - Organic Rankine cycles (ORC) – 9-60%
  - Evaporative condensers – 15-60%
  - Smart ventilation – up to 60%
  - Heat recovery systems – 10-60%
  - Fuel cells – 15-35%
  - Thermal energy storage – 12-50%

Technology strategies

- Technologies contributing to efficiency aspects: energy savings potential
  - Strategies for cooling:
    - Direct evaporative cooling – 70%
    - Indirect evaporative cooling – 50%
    - Liquid pressure amplification – 25%
    - Ground coupled heat pumps – 50%
    - Chilled ceiling – 10%
    - Desiccant cooling – 75%
    - Ejector cooling – 15%
    - Variable refrigerant flow heat pumps – 15%

Technology strategies

- Technologies contributing to renewables: energy savings potential
  - Geothermal energy or ground source heat pumps – 20-50%
  - Solar energy PV – 12-25%
  - Solar thermal – 30-75%
  - Biomass energy – up to 95%

Technology trends

- Research and industry developments are looking at:
  - New building envelopes to decrease energy demand in buildings
    - Keeping aesthetics
    - Increasing circularity
  - New HVAC systems to increase energy efficiency
  - More efficient appliances and lighting
  - New renewables, including energy storage, to decrease fossil fuels dependency
- The new trends seen in the buildings sector, together with cooling, are:
  - Electrification
  - Digitalisation

Successful cooling policy interventions

- Kigali Amendment to the Montreal Protocol, adopted by almost all countries, is among the most successful global environmental agreements
  - It focuses on reducing greenhouse gas refrigerants and enhancing energy efficiency of cooling equipment

Successful cooling policy interventions

- Minimum Energy performance requirements (MEPS) is another policy tool used effectively to reduce cooling related GHG emissions
  - Nearly 59 countries have proposed or already have minimum energy performance standards (MEPS) for ACs
  - Morocco adopted AC MEPS in June 2018 and Kenya proposed them in October 2018, while in Rwanda new MEPS using United for Efficiency (U4E) model regulations are pending finalization
  - MEPS vary considerably across countries, however, and are generally weakest or absent in hot and humid countries where rapid AC demand growth is expected

Successful cooling policy interventions

- Energy efficiency labelling
  - The policy provides information to users with labels as well as financial incentives to support the market uptake of the most efficient technologies
  - Such policies are already in place in the EU, the US, Australia, China, Tunisia
  - Yet, it is worth noting that MV&E of energy performance is missing in almost all countries.

Successful cooling policy interventions

- In least developed countries, preventing anti-environmental dumping, such as the imports of second-hand cooling equipment, is an effective policy means to avoid the diffusion of inefficient cooling technologies
  - Environment Ministers of African Nations have already laid the foundation for the introduction of anti-environmental dumping at the 17th Conference of African Environment Ministers Conference (AMCEN) in November 2019

Limitations of current cooling policies

- Despite a set of successful policies, cooling energy consumption is expected to increase dramatically as the requirements to reduce cooling demand is largely missing in building energy codes, and nature-based solutions are also not considered
  - French and the Tunisian building energy codes are currently the most advanced in setting requirements at the design stage of buildings to reduce cooling demand

Limitations of current cooling policies

- Existing initiatives and policies currently target the efficiency improvement of vapor compressor technologies which emit GHGs in the use phase
  - However, solar cooling technologies which have very low or no GHG emissions are still very rarely considered in policy design, research programs and financial incentives

Limitations of current cooling policies

- In MEPS, there is a gap between real and rated energy performance
  - Occupant behavior has big impact on cooling energy use and current evaluation standard does not evaluate the equipment efficiency according to real occupant behavior
  - Cooling appliance in the market are designed to adapt intensive usage pattern
  - Therefore, innovative technologies which are designed to adapt less intensive usage pattern, which is real usage pattern are not encouraged by policies and standards

Conclusions

- Cooling energy demand is one of the growing trends that is expected to grow most in the near future
- Technologies are available, although energy performance, efficiency, and costs are still to be improved
- Policies are available, but not widespread as needed

Cooling should be our biggest concern in the near future!

Acknowledgements

This work was partially funded by the Ministerio de Ciencia, Innovación y Universidades de España (RTI2018-093849-B-C31 (FEDER)), the Ministerio de Economia y Competitividad (TIN2015-71799-C2-2-P (MINECO/FEDER)) and the Ministerio de Ciencia, Innovación y Universidades - Agencia Estatal de Investigación (AEI) (RED2018-102431-T).

The authors would like to thank the Catalan Government for the quality accreditation given to their research group (2017 SGR 1537) and the ICREA Catalan institution for awarding the ICREA Academy, for the second consecutive time.

GREiA is certified agent TECNIO in the category of technology developers from the Government of Catalonia.

Acknowledgements

- To the IPCC AR6 Ch 9 Buildings chapter authors
- To my research team

Thank you for your attention!

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