Aalto University
School of Engineering

Summertime overheating in existing building stock

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Juha Jokisalo, Azin Farahani, Risto Kosonen,
Aalto University

Research questions

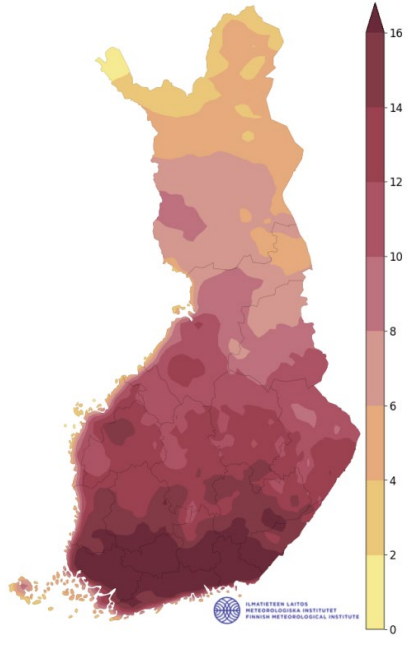
- How high are the actual room temperatures in summer in Finnish apartment buildings today?
- How significant is the proportion of apartments that overheat?
- Does the year of construction or the size of the apartment have an effect on the actual room temperatures?

Four climate zones in Finland

- This study focuses on overheating of apartment buildings located in Helsinki region in climate zone 1.

- Representative weather stations:
  - I: Vantaa
  - II Jokioinen
  - III: Jyväskylä
  - IV: Sodankylä

Average number of hot days* between 1991-2020

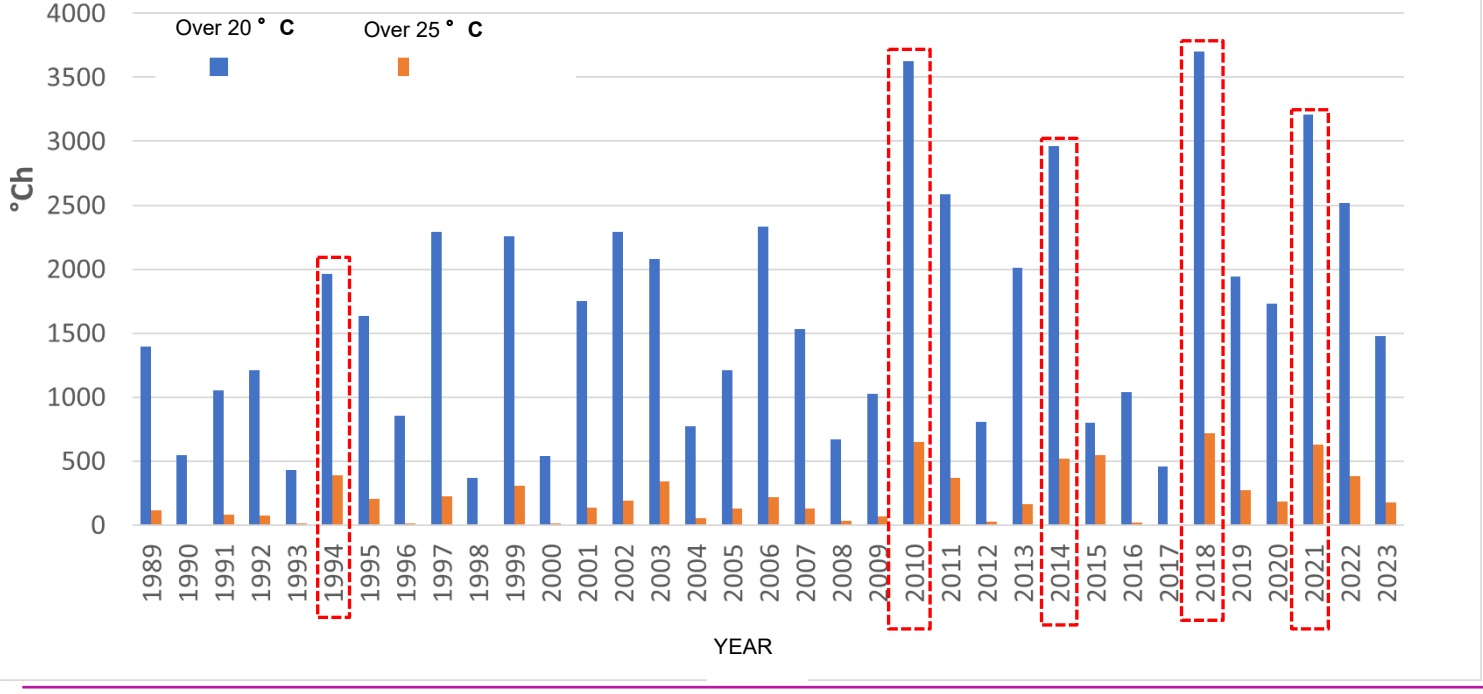


**Hot day = daily temperature exceeds 25°C*

→ The average risk of overheating in buildings is highest in climate zone I.

Summers are getting warmer and long heat waves are becoming more common

- **Degree hours over 20 and 25 °C during 35 years in Climate zone 1 (Vantaa)**



- Summers have become warmer
- TOP 5: longest heatwaves:

1. 25 days (2018)
2. 20 days (2010)
3. 16 days (2021)
4. 14 days (2014)
5. 10 days (1994)

***Used definition**: Heat wave = A period of consecutive hot days*

Extensive indoor temperature measurement data for apartment buildings

- **Hourly indoor temperature of apartment buildings in Helsinki region for**
  - Normal summer 2020 (16 hot days in total)
  - Hot summer 2021 (30 hot days in total)
- **Number of measured buildings / apartments:**
  - Normal 2020: 578 buildings / 6974 apartments
  - Hot 2021: 560 buildings / 6057 apartments
- **Construction year of the buildings: 1902-2016**
- **Floor area of apartments: 20-232 m²**

Indoor temperature measurements

- **IoT sensors (1/apartment) installed in an entrance hall of each apartment in a shady place**

  → *Measured temperature describes the average temperature of the apartment*

- **We know:**
  - Location, year of constriction, size of apartments
  - There are no permanently installed cooling devices
- **We don't know:**
  - Orientation, window areas, number of occupants, etc.
  - Are there portable cooling devices in use?

Grouping the apartmens by the design year

1. Designed before 1977

- Time before the Finnish building code
- Type of ventilation: Mechanical exhaust or passive stack ventilation (natural ventilation)

2. Designed between 1977-2003

- Requirements for thermal insulation level of buildings came into force
- Type of ventilation: Mechanical exhaust ventilation

3. Designed between 2004-2009

- Requirements for the thermal insulation level of windows were tightened (U-value: 2.1→1.4W/m^2,K)
  → Use of the low-emissivity windows became a standard solution
- Requirements for ventilation heat recovery came into force
  →Type of ventilation: Mec. balanced ventilation with heat recovery

4. Designed between 2010-2011

- Tighter envelope U-value requirements were in force.

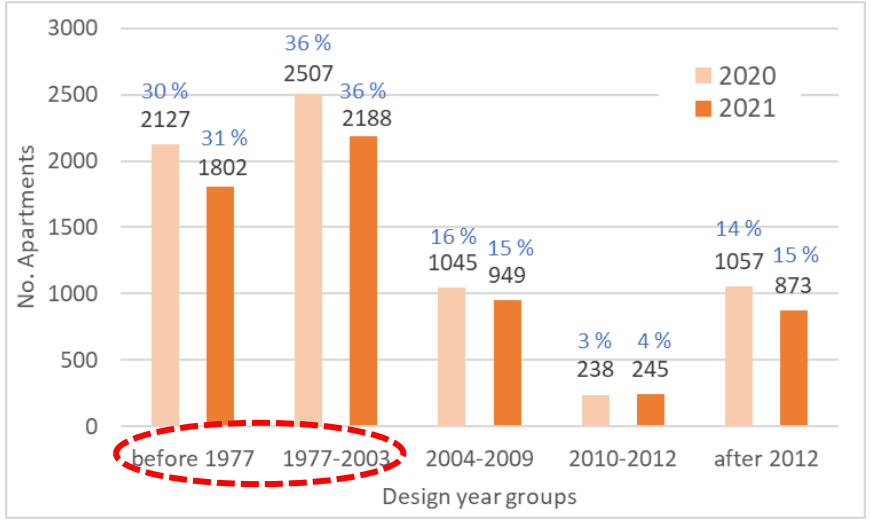
5. Designed after 2012

- Simulated indoor temperature during the summer period (1.6-31.8) cannot exceed 27°C more than 150 degree hours.
- Type of ventilation: Mec. balanced ventilation with heat recovery

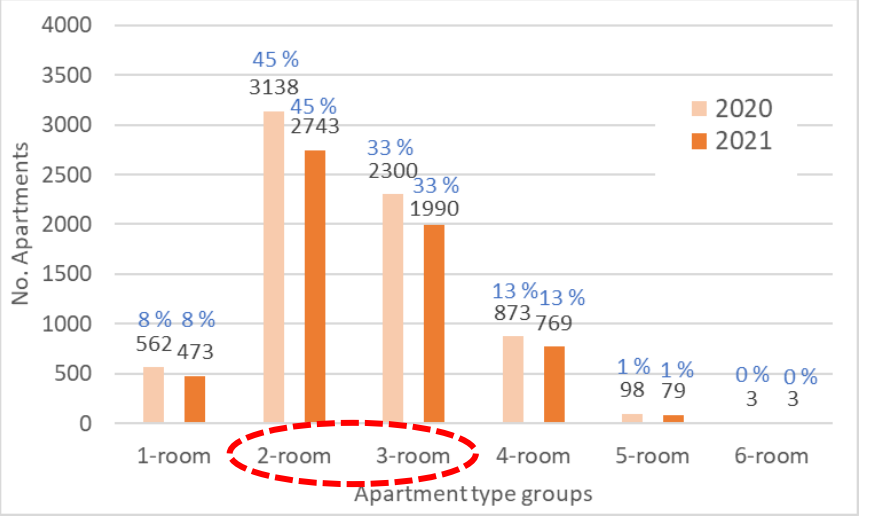
Number of apartments analyzed by the design year and size

- Apartments after the pre-processing and cleaning the dataset:

Design year groups



Apartment type groups



Finnish requirements for indoor temperature

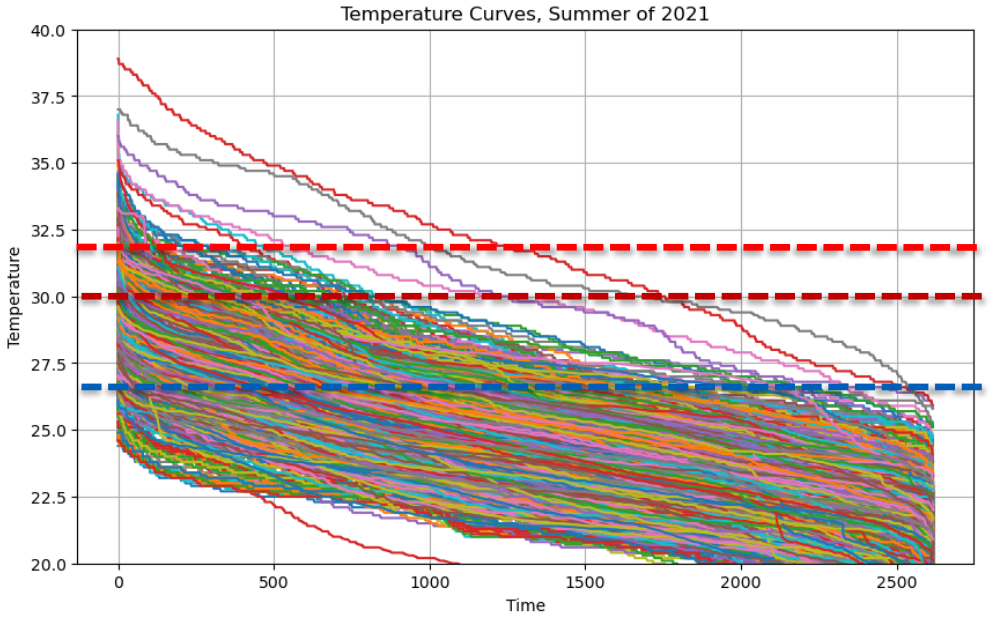
- Housing health decree of the Ministry of Social Affairs and Health (545/2015) (6§): The indoor air temperature outside the heating season must remain within the action limits of *+18* – *+32°C* (special groups 30°C).

- Decree of the Ministry of the Environment (1009/2017) on the indoor climate and ventilation of new buildings (4§): In designs for room temperature control of new buildings, room temperature may fluctuate between 20°C and 27°C outside the heating season.
- Decree of the Ministry of the Environment (1010/2017) on the energy efficiency of new buildings (29§): The simulated indoor temperature must not exceed 27°C in an apartment building by more than 150 degree hours between 1st of June and 31st of August using the average test reference year weather data (TRY 2012) of climate zone I.

  → TRY 2012 has been done for heating energy calculation, and it has only 7 hot days in climate zone I.

Results

How significant is overheating in apartments during hot summer of 2021?



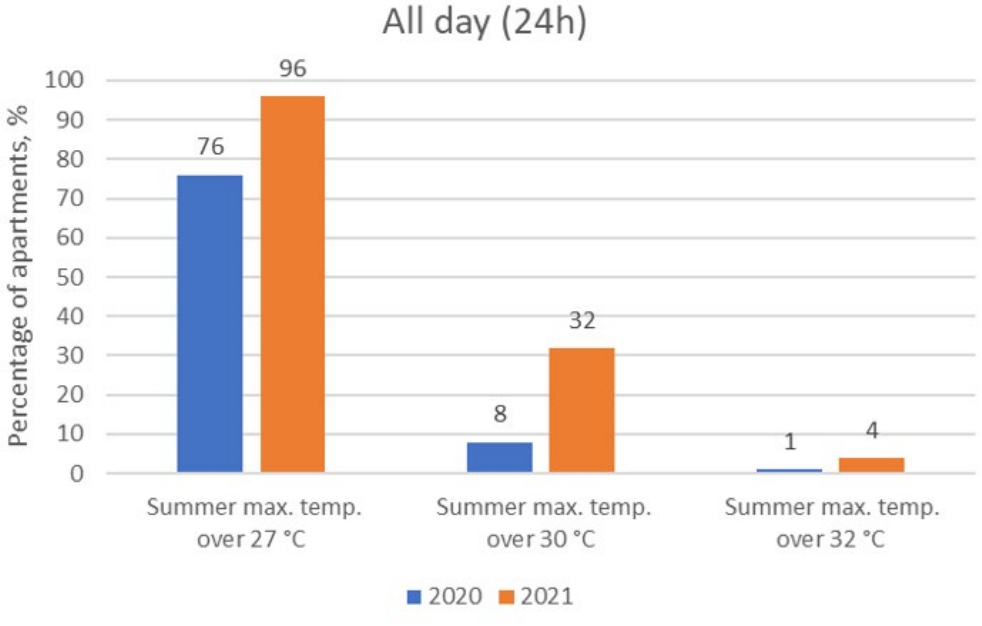
→ The action limits of Housing health decree:

- 32°C is exceeded in 4% of the apartments.
- 30°C is exceeded in 32% of the apartments.

- The 27°C design criteria for new buildings is exceeded 96 % of the apartments.

Overheating during the normal and hot summer

Proportion of apartments above different temperature criteria

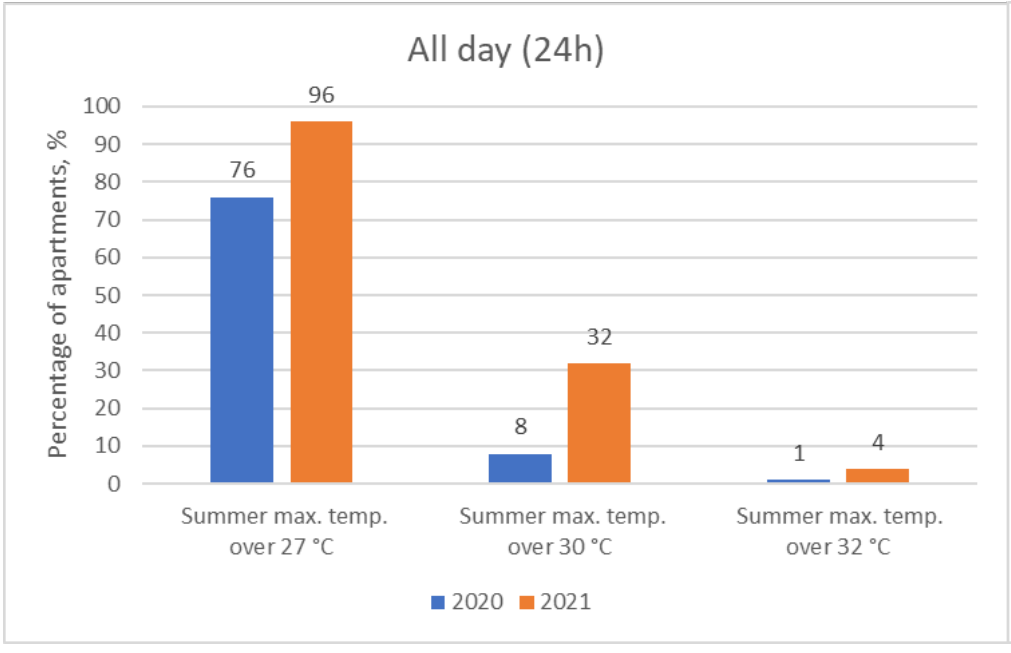


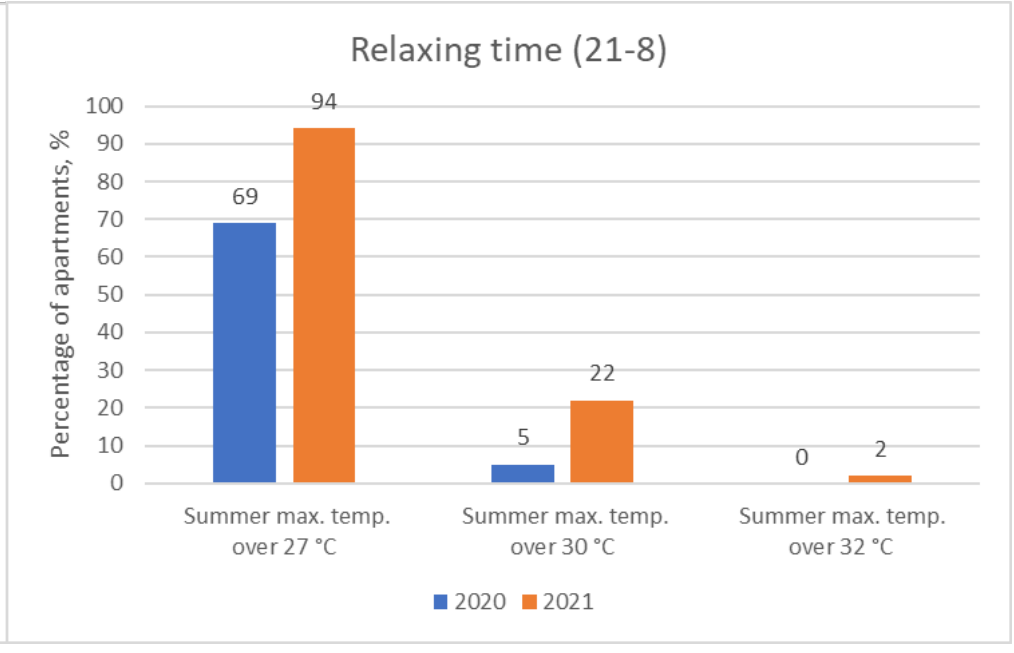
- Most apartments exceed 27°C even during the normal summer.
- The action limits of 30°C and 32°C are also exceeded during the normal summer.
- Applied for whole apartment building stock of Helsinki area (over 0.5 million apartments) 32°C is exceeded in:

→in 5 800 apartments in the normal summer.

→in 23 000 apartments in the hot summer.

Day and nighttime difference in overheating





→ **Only minor difference between the all day and nighttime.**

→ **If apartment buildings with brick or concrete structures warm up, they will stay warm even at night.**

How long will the apartments stay warm?

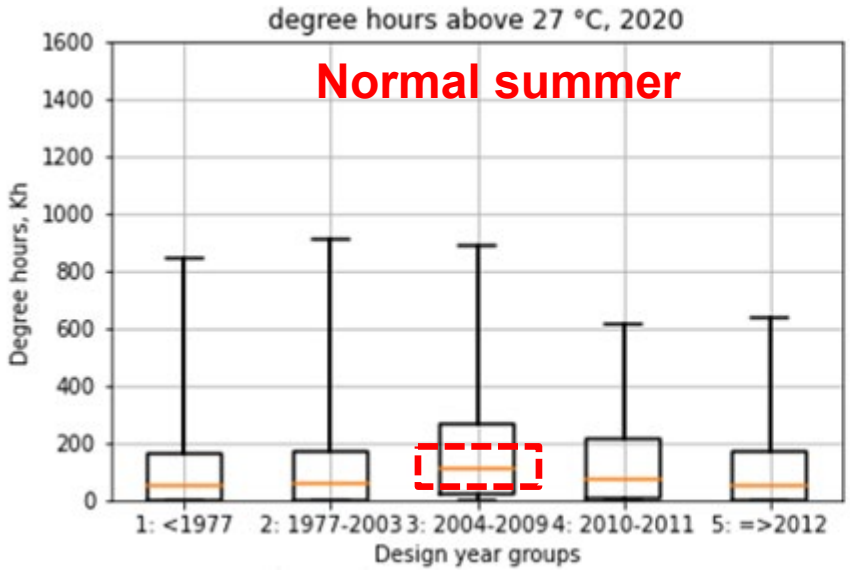
		Percentage (%) of apartments with						
		1 day	2 continous days	3 continous days	4 continous days	5 continous days	6 continous days	7 continous days
Hourly temperature higher than	27 °C	84.8	77.9	69.8	61.0	55.1	50.0	46.8
	28 °C	59.6	48.8	40.2	32.7	26.2	21.5	19.2
	29 °C	28.1	20.9	15.8	11.8	8.8	6.2	5.3
	30 °C	8.3	5.5	3.9	2.8	1.9	1.5	1.2
	31 °C	1.8	1.3	0.9	0.6	0.3	0.2	0.2
	32 °C	0.4	0.3	0.2	0.2	0.1	0.1	0.1
	33 °C	0.1	0.1	0.1	0.1	0.1	0.0	0.0
	34 °C	0.05	0.05	0.05	0.05	0.05	0.0	0.0
	35 °C	0.05	0.03	0.03	0.03	0.03	0.0	0.0

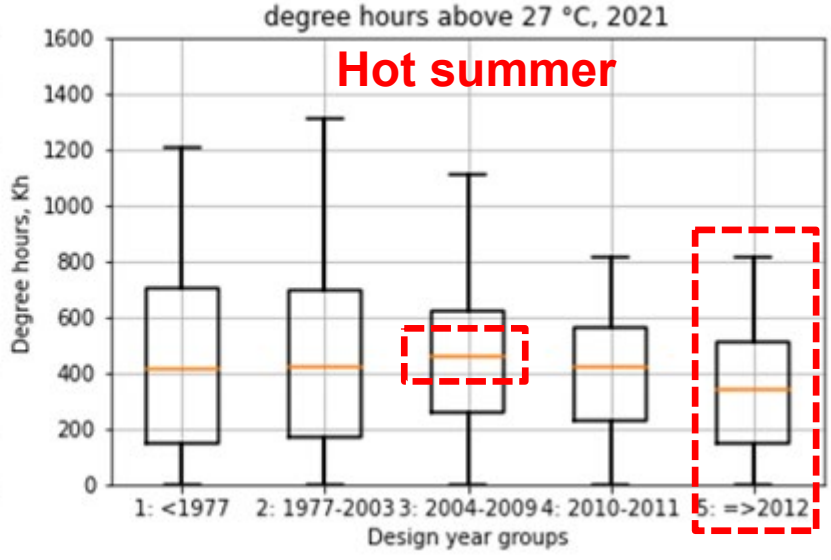
- **Indoor temperature is continuously over e.g. 27°C in the hot summer for:**

→ One day in 85% of the apartments. → Seven days in 47% of the apartments.

→ Once massive apartment buildings warm up, overheating typically takes a long time.

The effect of design year on overheating

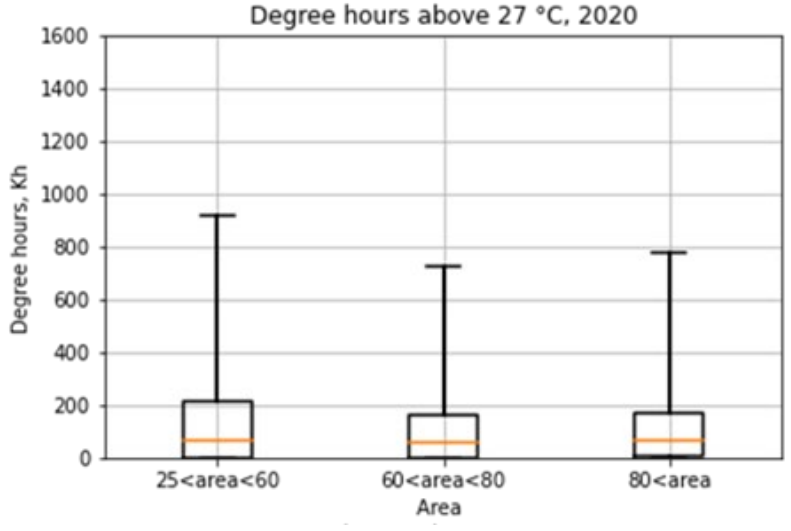


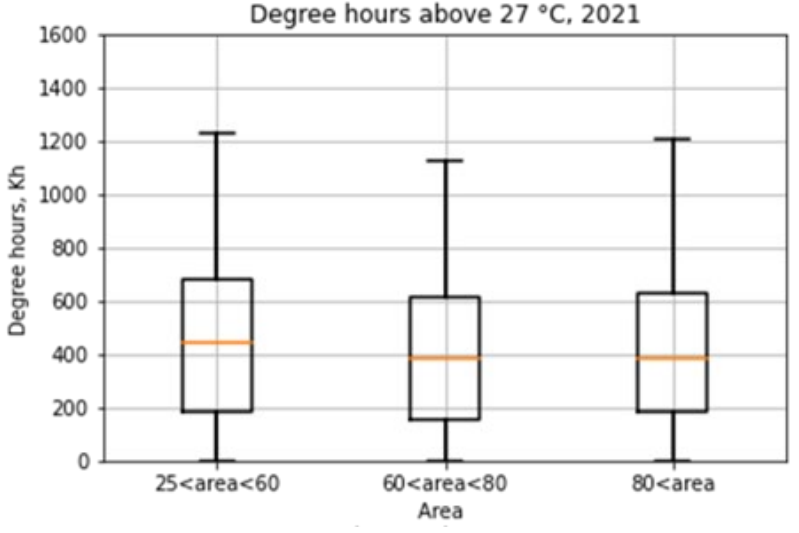


- **The median value of degree hours above 27°C is highest in the 3rd design year group in both normal and hot summer.**
- **The buildings designed 2012 or later are warming less than the older buildings during the hot summer.**
- **But, the summertime indoor temperature requirement is unable to fully prevent overheating.**

The effect of apartment size on overheating

Number of apartments			
year	25<area<60	60<area<80	Area>80
2020	3279	2545	1150
2021	2847	2187	1023





→ **The smaller apartments under 60m^2 are warming slightly more than the others.**

Summary

- Finnish apartments overheat significantly during an extremely hot summer.
- Overheating is a significant challenge in part of the apartments even during a normal summer.
- Once massive apartment buildings warm up, overheating typically takes a long time with minor difference between day and nighttime.
- Summertime indoor temperature requirements for new buildings introduced in 2012 have succeeded in reducing overheating, but not yet enough.
- Stricter regulations are needed to prevent overheating in new buildings, and more attention should be paid to preventing overheating in existing buildings.

More information:

[1] Azin Velashjerdi Farahani, Ilia Kravchenko, Juha Jokisalo, Natalia Korhonen, Kirsti Jylhä, Risto Kosonen. Overheating assessment for apartments during average and hot summers in the Nordic climate. Building Research & Information. 2023. https://doi.org/10.1080/09613218.2023.2253338

[2] Azin Velashjerdi Farahani, Juha Jokisalo, Natalia Korhonen, Kirsti Jylhä, Risto Kosonen. Hot Summers in Nordic Apartments: Exploring the Correlation between Outdoor Weather Conditions and Indoor Temperature. Buildings 14, 1053. 2024. https://doi.org/10.3390/buildings14041053

[3] Azin Velashjerdi Farahani, Matti Leinonen, Laura Ruotsalainen, Juha Jokisalo, Risto Kosonen. Predicting Summer Indoor Temperatures in Nordic Apartments Considering Heatwaves Forecasts. Energy and Buildings. 336 2025. https://doi.org/10.1016/j.enbuild.2025.115630)

[4] Ilia Kravchenko, Azin Velashjerdi Farahani, Risto Kosonen, Simo Kilpeläinen, Olli Saranko, Carl Fortelius. Effect of the urban microenvironment on the indoor air temperature of the residential building stock in the Helsinki region. Building and Environment 246. 2023. https://doi.org/10.1016/j.buildenv.2023.110971

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