Overheating control needed in Nordic dwellings

-SCANVAC webinar

AARHUS
UNIVERSITY
DEPARTMENT OF CIVIL AND ARCHITECTURAL ENGINEERING

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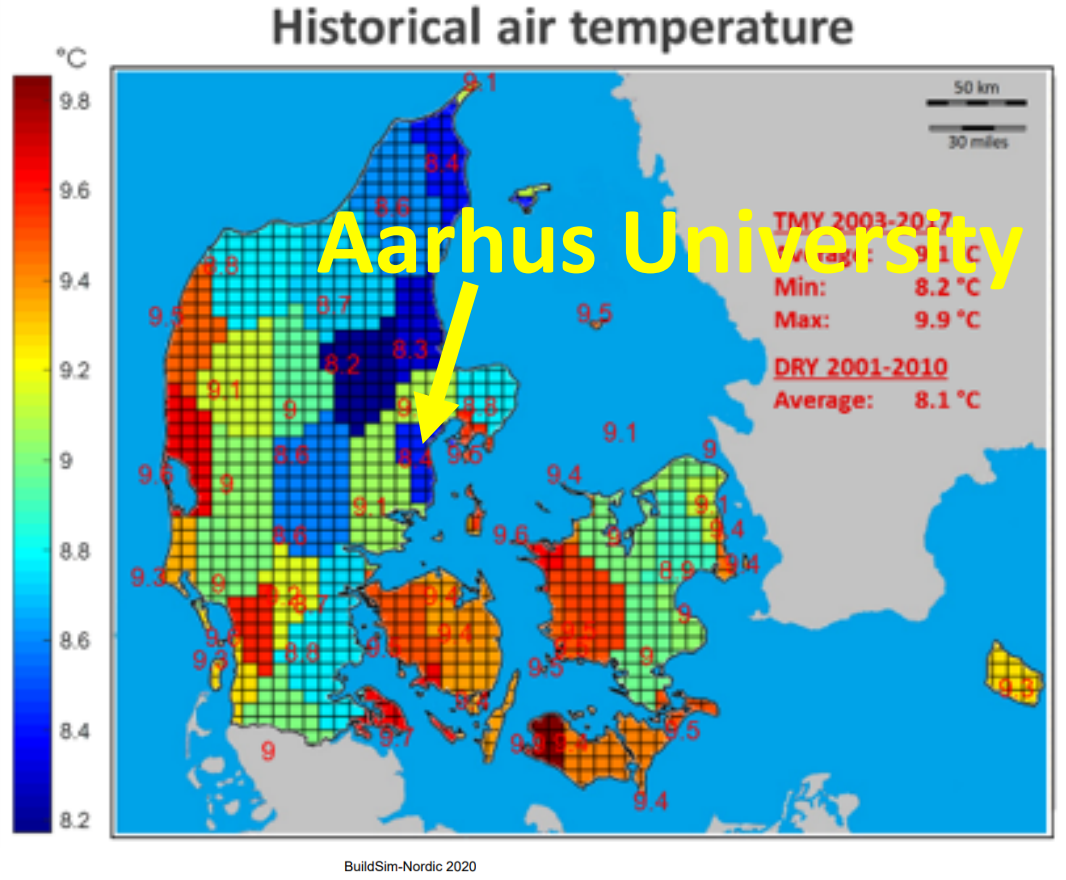
BUILDING SIMULATION 2025 24–27 AUG BRISBANE
CARBON AND CLIMATE RESPONSIVE

FUTURE OVERHEATING RISKS IN BUILDINGS COMPLYING WITH CURRENT BUILDING CODE

Oral presentation

THERMAL INDOOR ENVIRONMENT REQUIREMENT IN DENMARK

- **Danish Building Code**
  - "In rooms where people stay for a longer period of time, it must be ensured that a thermal indoor climate that is satisfactory in terms of health and comfort can be maintained during the intended use and activity."
- **Guideline**
  - Operative temperatures must not exceed 27 C for more than 100 hours and 28 C for more than 25 hours during the Danish Reference Year.



BuildSim-Nordic 2020

The Effect of Local Climate Data and Climate Change Scenarios on the Thermal Design of Office Buildings in Denmark

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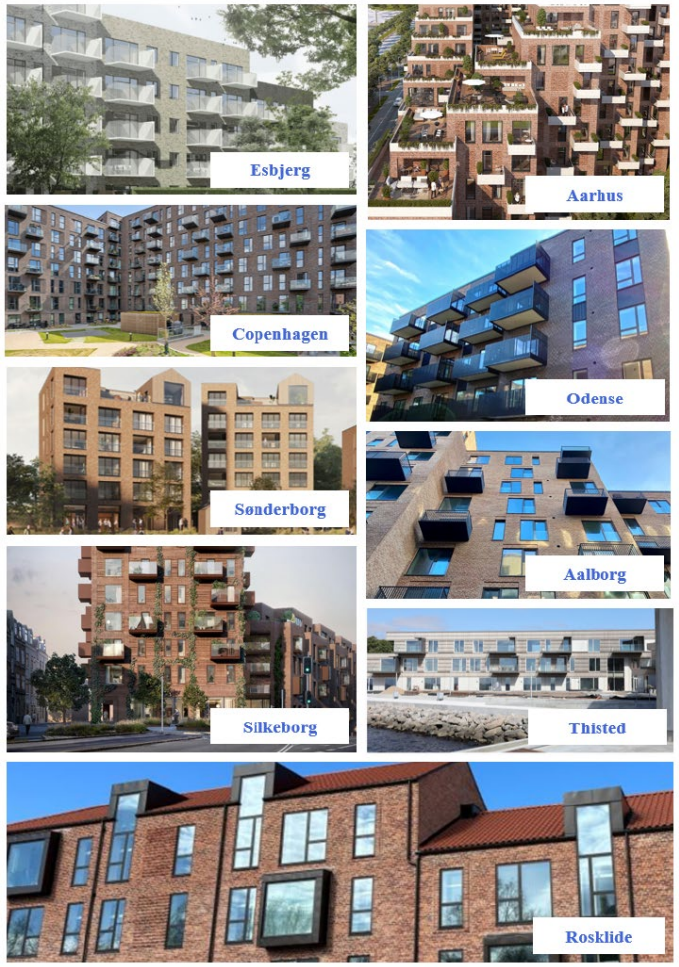
CURRENT BUILDING DESIGNS IN DENMARK

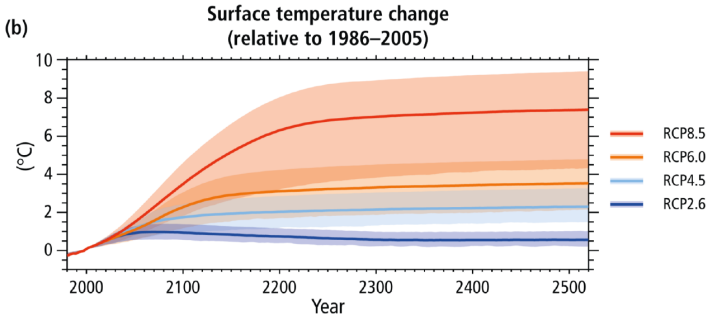
Apartments

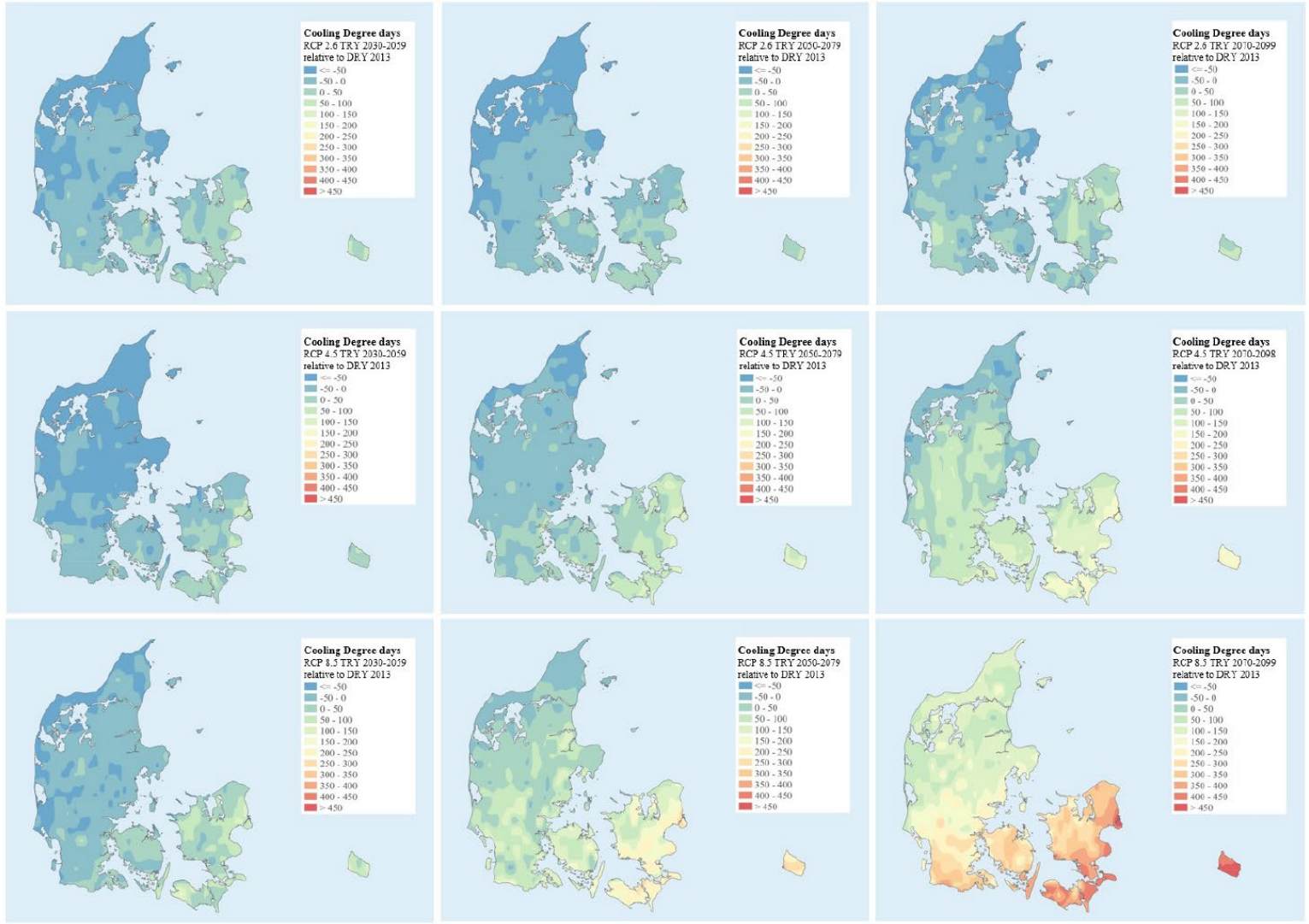


Single-family homes

CLIMATE CHANGE

- Climate projections according to RCPs





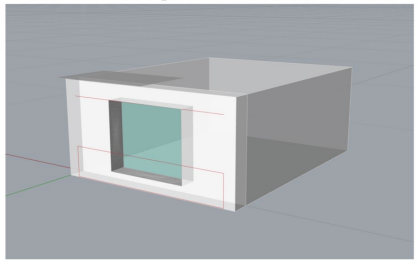
RESEARCH QUESTION

Are Danish dwellings built today resilient to the risk of overheating assuming different climate change scenarios?

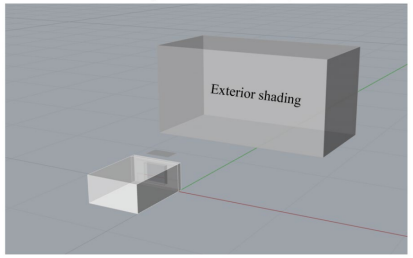
METHOD

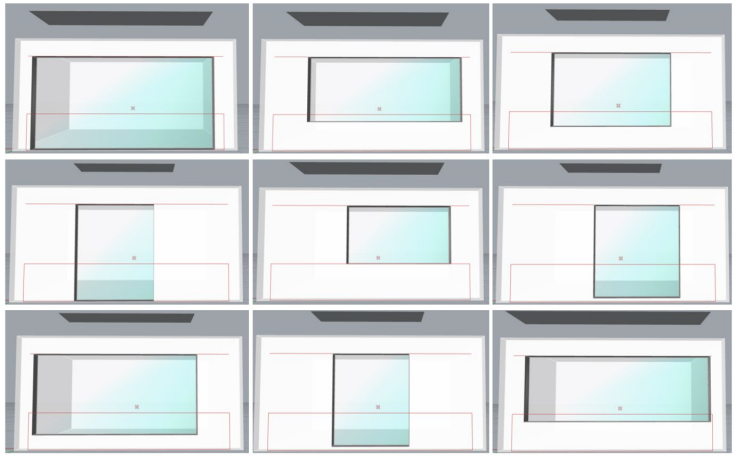
- Parametric model of a living room in a dwelling
- Galapagos was used to generate 11 086 variations
- Simulated in ICEbear
- A total of 4 115 passed the overheating criteria -> 321 models were manually chosen as representative to this sample

Perspective view (front)



Perspective view (back)

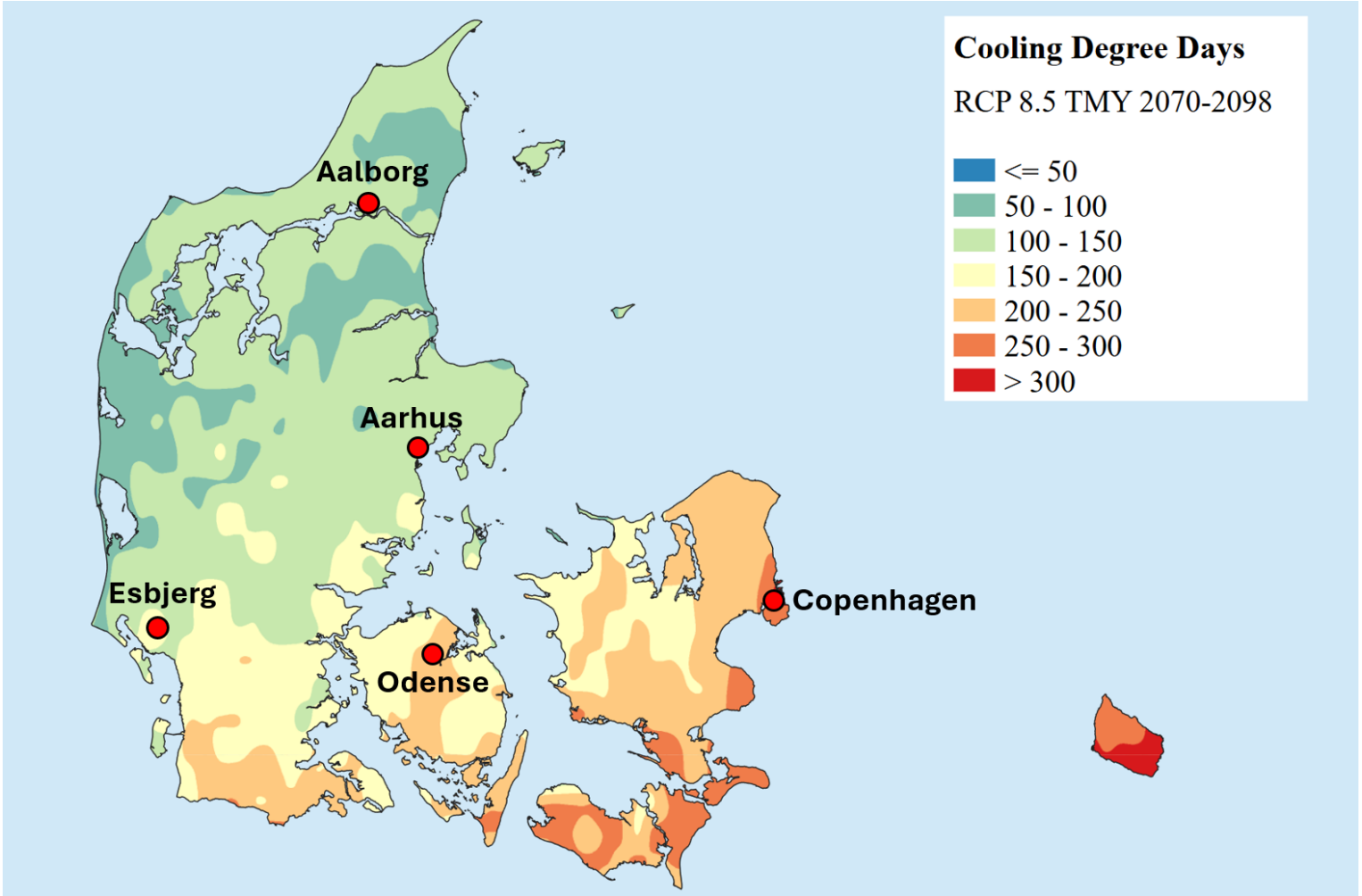




Variable	Range
Horizontal window placement	[0%; 100%]
Window width	[0%; 100%]
Windowsill height	[0 m; 1.1 m]
Window overhang depth	None or [1.0 m; 2.0 m]
Window overhang width	None or [2.0 m; 4.0 m]
Facade orientation	North or south
Glazing type	If north: Double layer (LT: 0.81, g: 0.60, U: 1.16) or triple layer (LT: 0.73, g: 0.49, U: 0.59) If south: Double layer (LT: 0.70, g: 0.35, U: 1.10) or triple layer (LT: 0.63, g: 0.32, U: 0.57).
Heat capacity	28, 46 or 72 Wh/(K·m²)
Shading from surroundings	None or shading
Wall thickness & U-value	0.358 m & 0.20 W/(m²K) or 0.408 m & 0.16 W/(m²K) or 0.458 m & 0.13 W/(m²K) or or 0.508 m & 0.11 W/(m²K)

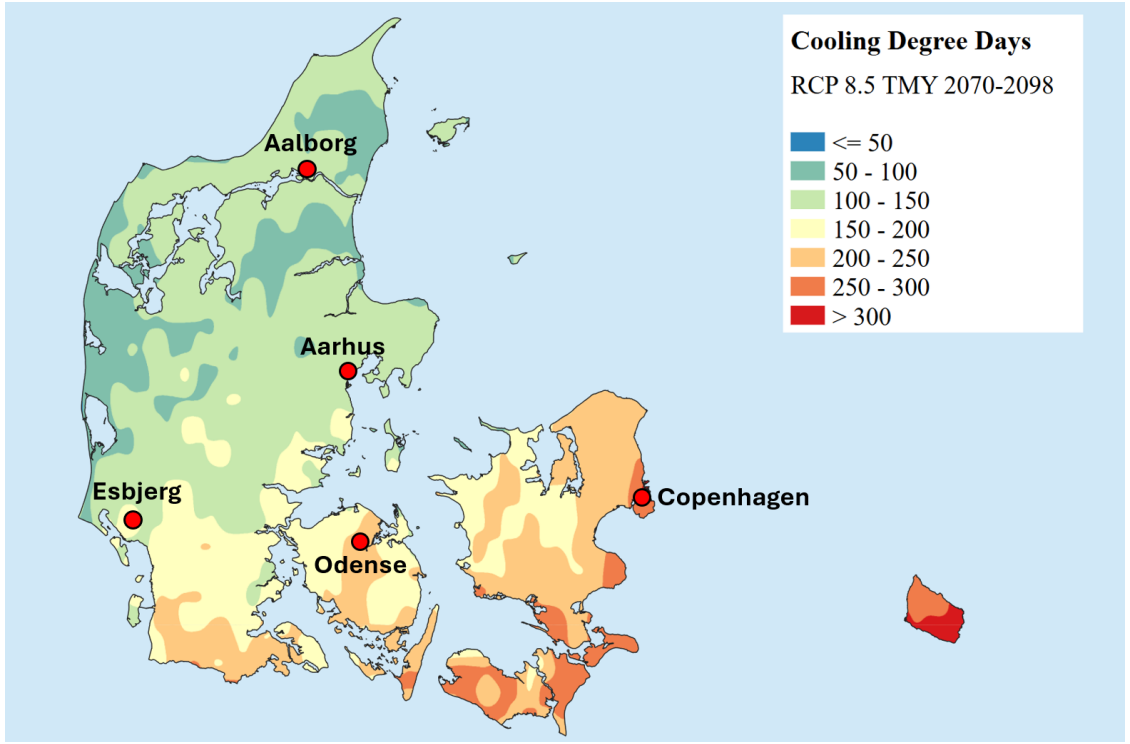
METHOD

- The overheating performance were evaluated for the 321 models subject to the three RCP scenarios for five different locations
- How many models **passed** the guideline for overheating?



RESULTS - OVERALL

City	RCP	2030-2059	2050-2079	2070-2099
Copenhagen	2.6	5	89	174
	4.5	66	191	1
	8.5	249	0	0
Aarhus	2.6	321	321	321
	4.5	321	321	321
	8.5	321	108	1
Odense	2.6	301	251	120
	4.5	321	122	2
	8.5	125	106	0
Aalborg	2.6	321	321	321
	4.5	321	321	28
	8.5	321	301	6
Esbjerg	2.6	321	321	321
	4.5	321	50	0
	8.5	321	0	0



RESULTS – IMPORTANCE OF VARIABLES

Table 3: Number of complying designs out of 321 sorted by heat capacity (28/46/72 Wh/(K·m²)).

City	RCP	2030-2059	2050-2079	2070-2099
Copenhagen	2.6	1/1/3	5/29/55	47/62/66
	4.5	5/12/49	51/61/79	0/0/1
	8.5	44/78/127	0/0/0	0/0/0
Aarhus	2.6	68/109/144	68/109/144	68/109/144
	4.5	68/109/144	68/109/144	68/109/144
	8.5	68/109/144	7/29/72	0/0/1
Odense	2.6	65/96/140	52/71/128	19/29/72
	4.5	68/109/144	11/40/71	0/1/1
	8.5	12/34/72	7/33/66	0/0/0
Aalborg	2.6	68/109/144	68/109/144	68/109/144
	4.5	68/109/144	68/109/144	5/4/19
	8.5	68/109/144	61/46/144	0/1/5
Esbjerg	2.6	68/109/144	68/109/144	68/109/144
	4.5	68/109/144	0/2/48	0/0/0
	8.5	68/109/144	0/0/0	0/0/0

Table 4. Number of complying designs out of 321 without or with window overhang (without/with).

City	RCP	2030-2059	2050-2079	2070-2099
Copenhagen	2.6	0/5	24/65	30/144
	4.5	8/58	56/135	0/1
	8.5	76/173	0/0	0/0
Aarhus	2.6	121/200	121/200	121/200
	4.5	121/200	121/200	121/200
	8.5	121/200	21/87	0/1
Odense	2.6	105/197	77/174	23/97
	4.5	121/200	37/85	0/2
	8.5	24/101	32/74	0/0
Aalborg	2.6	121/200	121/200	121/200
	4.5	121/200	121/200	0/28
	8.5	121/200	104/197	0/6
Esbjerg	2.6	121/200	121/200	121/200
	4.5	121/200	13/37	0/0
	8.5	121/200	0/0	0/0

RESULTS – IMPORTANCE OF VARIABLES

Table 5: Number of complying designs out of 321 with or without shading from surroundings (without/with).

City	RCP	2030-2059	2050-2079	2070-2099
Copenhagen	2.6	0/5	16/73	42/132
	4.5	12/54	65/126	0/1
	8.5	90/159	0/0	0/0
Aarhus	2.6	146/175	146/175	146/175
	4.5	146/175	146/175	146/175
	8.5	146/175	27/81	0/1
Odense	2.6	127/174	94/157	29/91
	4.5	146/175	26/96	0/2
	8.5	30/95	17/89	0/0
Aalborg	2.6	146/175	146/175	146/175
	4.5	146/175	146/175	2/26
	8.5	146/175	130/171	1/5
Esbjerg	2.6	146/175	146/175	146/175
	4.5	146/175	8/42	0/0
	8.5	146/175	0/0	0/0

Table 6: Number of complying designs out of 321 sorted by orientation (south/north).

City	RCP	2030-2059	2050-2079	2070-2099
Copenhagen	2.6	5/0	30/59	92/82
	4.5	40/26	51/140	1/0
	8.5	132/117	0/0	0/0
Aarhus	2.6	145/176	145/176	145/176
	4.5	145/176	145/176	145/176
	8.5	145/176	53/55	1/0
Odense	2.6	146/156	145/106	86/34
	4.5	145/176	43/79	2/0
	8.5	72/53	24/82	0/0
Aalborg	2.6	145/176	145/176	145/176
	4.5	145/176	145/176	23/5
	8.5	145/176	144/157	6/0
Esbjerg	2.6	145/176	145/176	145/176
	4.5	145/176	17/33	0/0
	8.5	145/176	0/0	0/0

RESULTS – IMPORTANCE OF VARIABLES

Table 7: Number of complying designs out of 321 sorted by orientation and whether the window has two- or thee-layer glazing (two-layer/three-layer)

		North			South		
City	**RCP**	**2030-2059**	**2050-2079**	**2070-2099**	**2030-2059**	**2050-2079**	**2070-2099**
Copenhagen	2.6	4/1	16/14	46/46	0/0	22/37	36/46
	4.5	24/16	25/26	1/0	8/18	59/81	0/0
	8.5	65/67	0/0	0/0	54/63	0/0	0/0
Aarhus	2.6	72/73	72/73	72/73	84/92	84/92	84/92
	4.5	72/73	72/73	72/73	84/92	84/92	84/92
	8.5	72/73	27/26	1/0	84/92	21/34	0/0
Odense	2.6	72/73	72/73	46/40	69/87	46/60	13/21
	4.5	72/73	26/17	2/0	84/92	33/46	0/0
	8.5	36/36	12/12	0/0	19/34	34/48	0/0
Aalborg	2.6	72/73	72/73	72/73	84/92	84/92	84/92
	4.5	72/73	72/73	12/11	84/92	84/92	0/5
	8.5	72/73	72/72	4/2	84/92	72/85	0/0
Esbjerg	2.6	72/73	72/73	72/73	84/92	84/92	84/92
	4.5	72/73	7/10	0/0	84/92	13/20	0/0
	8.5	72/73	0/0	0/0	84/92	0/0	0/0

RESULTS – IMPORTANCE OF VARIABLES

Table 8: Mean glazing area of each scenario by orientation ($\bar{x} \pm s$ $[m^2]$)

		North			South		
City	**RCP**	**2030-2059**	**2050-2079**	**2070-2099**	**2030-2059**	**2050-2079**	**2070-2099**
Copenhagen	2.6	4.47±1.26	4.31±0.98	5.00±1.13	0±0	5.25±1.29	5.17±1.32
	4.5	4.71±1.23	4.66±1.10	5.47±0	4.64±1.18	4.94±1.24	0±0
	8.5	4.78±1.14	0±0	0±0	4.98±1.31	0±0	0±0
Aarhus	2.6	4.74±1.20	4.74±1.20	4.74±1.20	4.76±1.22	4.76±1.22	4.76±1.22
	4.5	4.74±1.20	4.74±1.20	4.74±1.20	4.76±1.22	4.76±1.22	4.76±1.22
	8.5	4.74±1.20	4.80±1.16	5.47±0	4.76±1.22	4.93±1.29	0±0
Odense	2.6	4.74±1.16	4.74±1.16	4.88±1.25	4.82±1.27	4.97±1.33	4.18±1.11
	4.5	4.74±1.20	4.37±0.96	4.40±1.60	4.76±1.22	5.08±1.28	0±0
	8.5	4.82±1.19	4.12±0.89	0±0	4.99±1.31	5.12±1.28	0±0
Aalborg	2.6	4.74±1.20	4.74±1.20	4.74±1.20	4.76±1.22	4.76±1.22	4.76±1.22
	4.5	4.74±1.20	4.74±1.20	4.81±1.22	4.76±1.22	4.76±1.22	4.71±0.92
	8.5	4.74±1.20	4.74±1.20	5.07±1.24	4.76±1.22	4.85±1.25	0±0
Esbjerg	2.6	4.74±1.20	4.74±1.20	4.74±1.20	4.76±1.22	4.76±1.22	4.76±1.22
	4.5	4.74±1.20	4.22±1.13	0±0	4.76±1.22	4.51±1.27	0±0
	8.5	4.74±1.20	0±0	0±0	4.76±1.22	0±0	0±0

CONCLUSIONS

- An urgent need to revise Danish building regulations to account for future climate conditions, as many current dwelling designs will fail to meet overheating criteria.
- Thermal mass, window overhangs and shading from surroundings can mitigate the issue
- Building code should be updated to encourage climate -adaptive design strategies and passive cooling measures
- Update of thermal comfort evaluation method for dwellings

Impact of climate change on building energy demand and seasonal length in Nordic countries

DRAFT PAPER

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[a]Aarhus University, Department of Civil and Architectural Engineering, Inge Lehmanns Gade 10, 8000 Aarhus C, Denmark

Change in cooling and heating degree days from 2030 to 2098

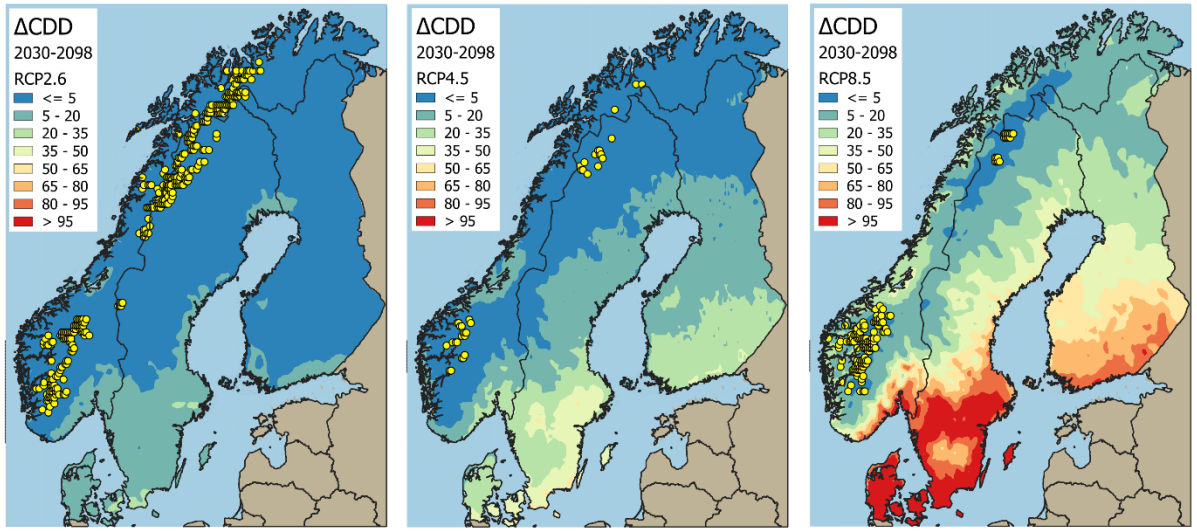

Figure 3 - Absolute difference between CDD estimates for 2030 and 2098 across Denmark, Norway, Sweden, and Finland. The yellow dots mark grid points where CDD=0 in 2030 and CDD>0 in 2098.

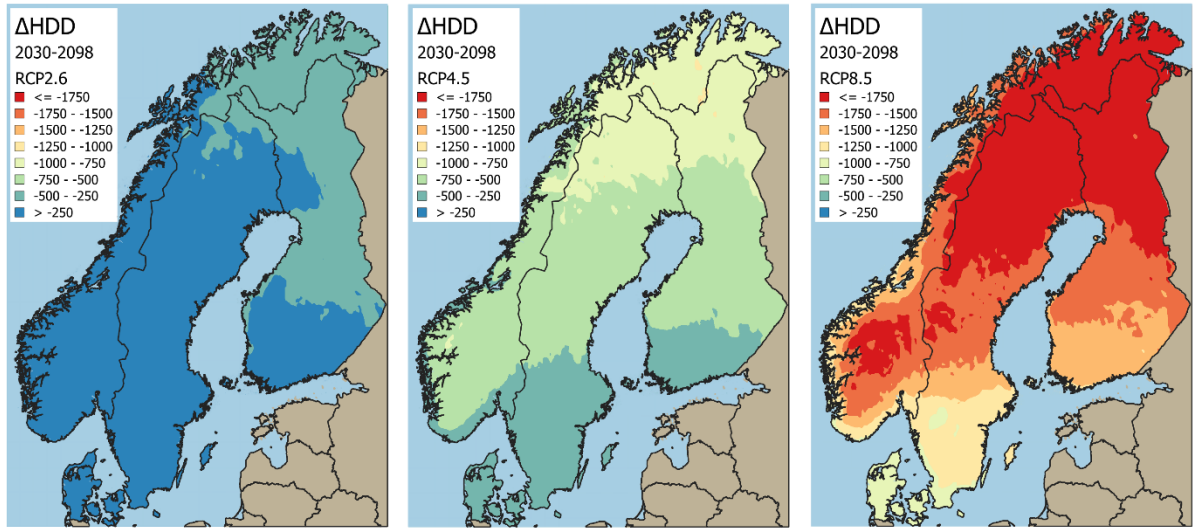

Figure 6 - Absolute difference between HDD estimates for 2030 and 2098 across Denmark, Norway, Sweden, and Finland between.

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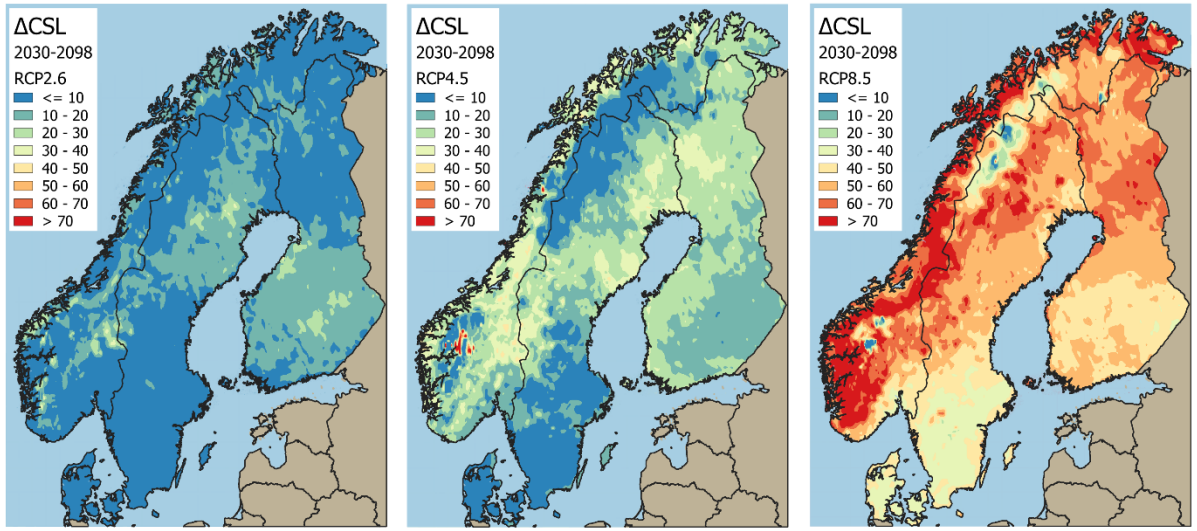

Figure 8 - Absolute difference between estimates of cooling season length (CSL) counted as days for 2030 and 2098 across Denmark, Norway, Sweden, and Finland.

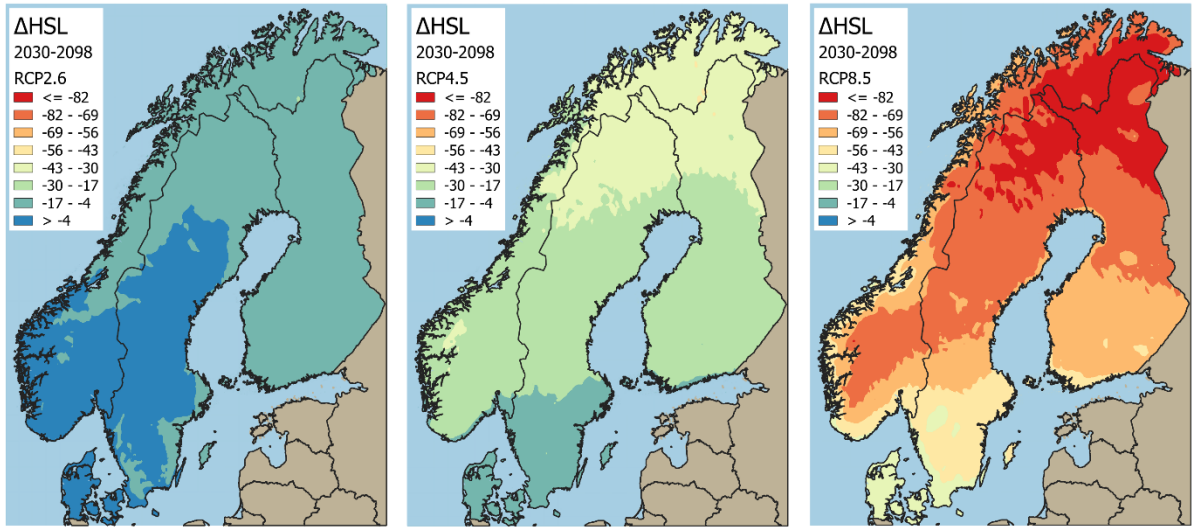

Figure 9 - Absolute differences between estimates of heating season length (HSL) counted as days for 2030 and 2098 across Denmark, Norway, Sweden, and Finland.