Impact Assessment of Climate Change on the Hygrothermal Perfromance of Buildings

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5th assessment report of the state of the global climate by the Intergovernmental Panel on Climate Change (IPCC) climate change will accelerate.

Depending on greenhouse gas emissions an increase of 0.8 to 2.4°C by 2050 is expected in the global temperature compared to 1990.

- Increase in climate variability
- Increase in extreme events

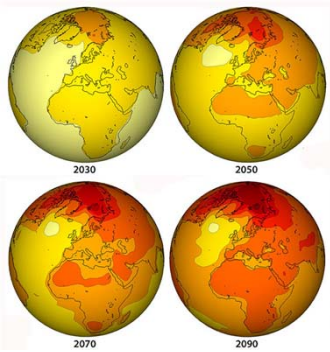
2

Extreme floods in southern Sweden

wind-driven rain

What to do to prevent/decrease?

Climate Change Mitigation



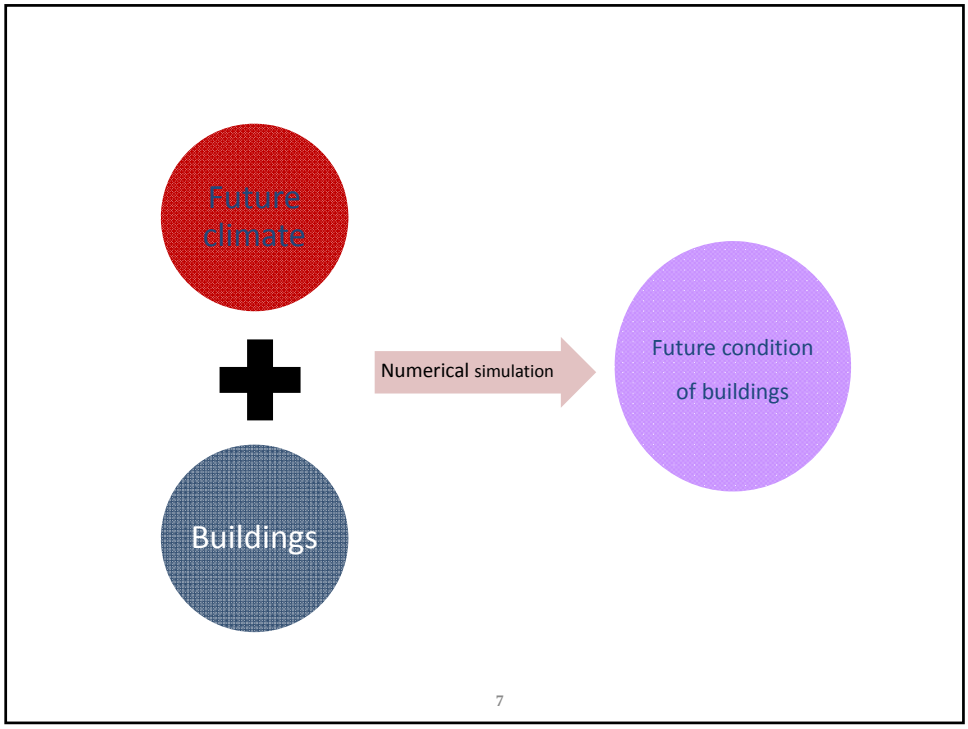
How to face it?
How to decrease future risks?

Impact Assessment

5

What are the future conditions for buildings in Sweden?

6


Future climate
Buildings
Numerical simulation
Future condition of buildings
7

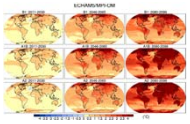

SMHI
Swedish Meteorological and Hydrological Institute
Rossby Centre
8
Norwegian Sea
Östersund
Norway
Finland
Sweden
Stockholm
Baltic Sea
Gothenburg
Lund

Global Climate Models (GCMs)

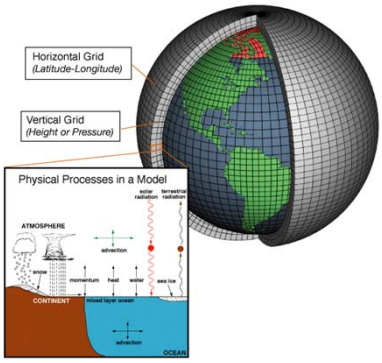
1. CCSM3
2. CNRM
3. ECHAM5
4. HadCM3
5. IPSL

Future Climate

Emissions Scenarios



1. A2
2. A1B
3. B1



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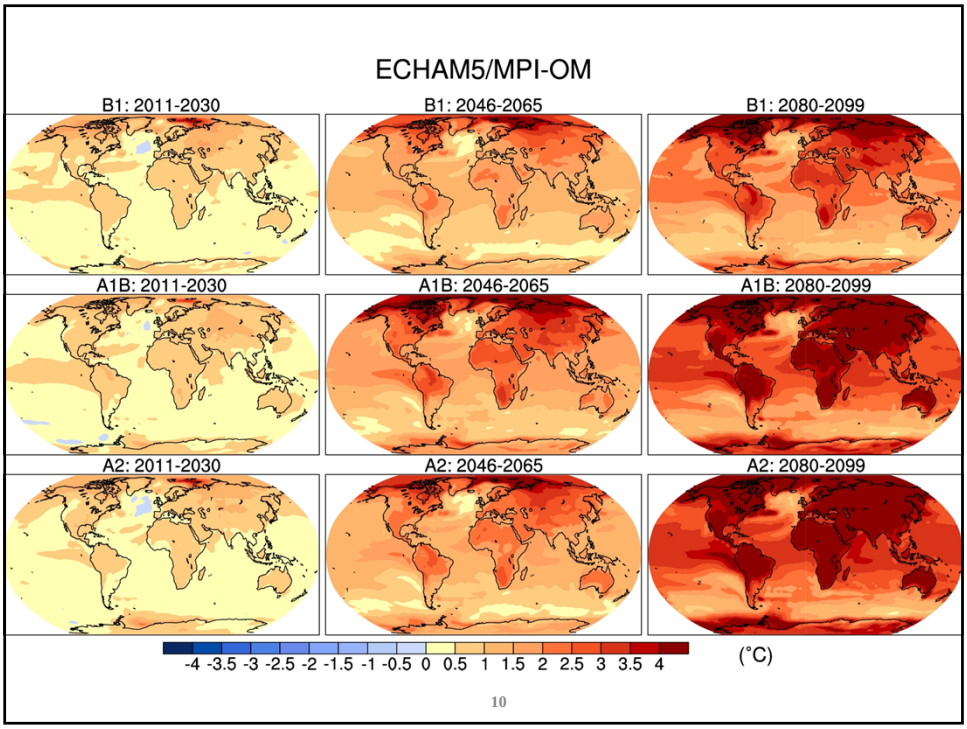

10

Global Climate Models (GCMs)

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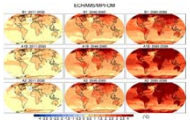
Future Climate

Emissions Scenarios



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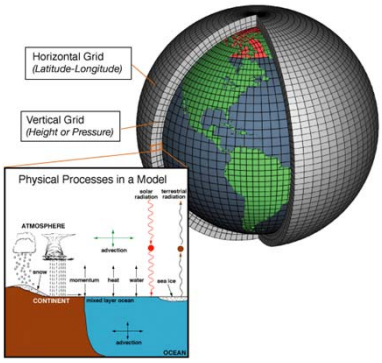


Initial Conditions

1
2
3

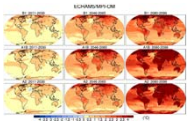
11

Global Climate Model (GCM)

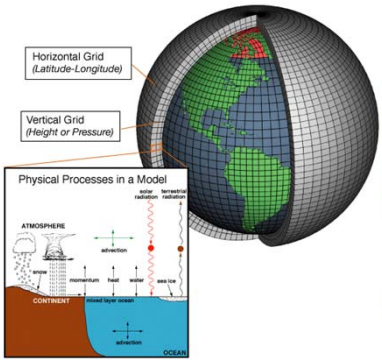
1. CCSM3
2. CNRM
3. ECHAM5
4. HadCM3
5. IPSL

Future Climate

Emissions Scenario

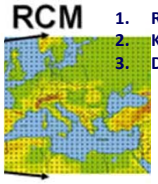


1. A2
2. A1B
3. B1



l Climate Model

RCM



1. RCA3
2. KNMI-RACMO2
3. DMI-HIRHAM5

tial Resolution

1. 50 km X 50 km
2. 25 km X 25 km

Initial Conditions

1
2
3

13

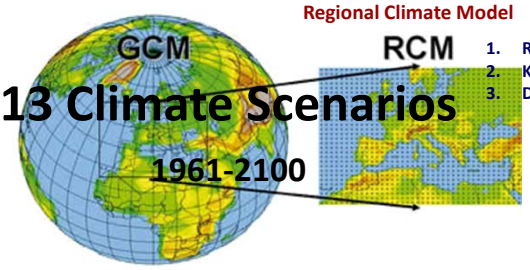
Global Climate Model (GCM)

1. CCSM3
2. CNRM
3. ECHAM5
4. HadCM3
5. IPSL

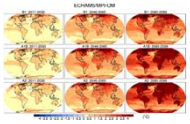
Future climate

Regional Climate Model

1. RCA3
2. KNMI-RACMO2
3. DMI-HIRHAM5



Emissions Scenario



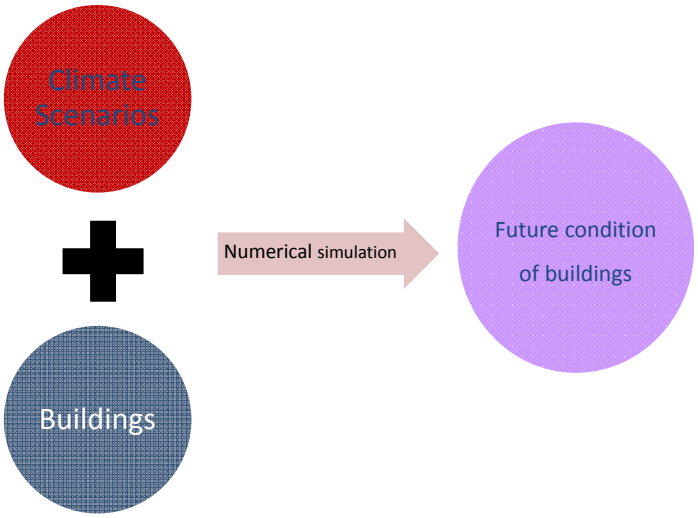
1. A2
2. A1B
3. B1

Spatial Resolution

1. 50 km X 50 km
2. 25 km X 25 km

Initial Conditions 1 2 3

14



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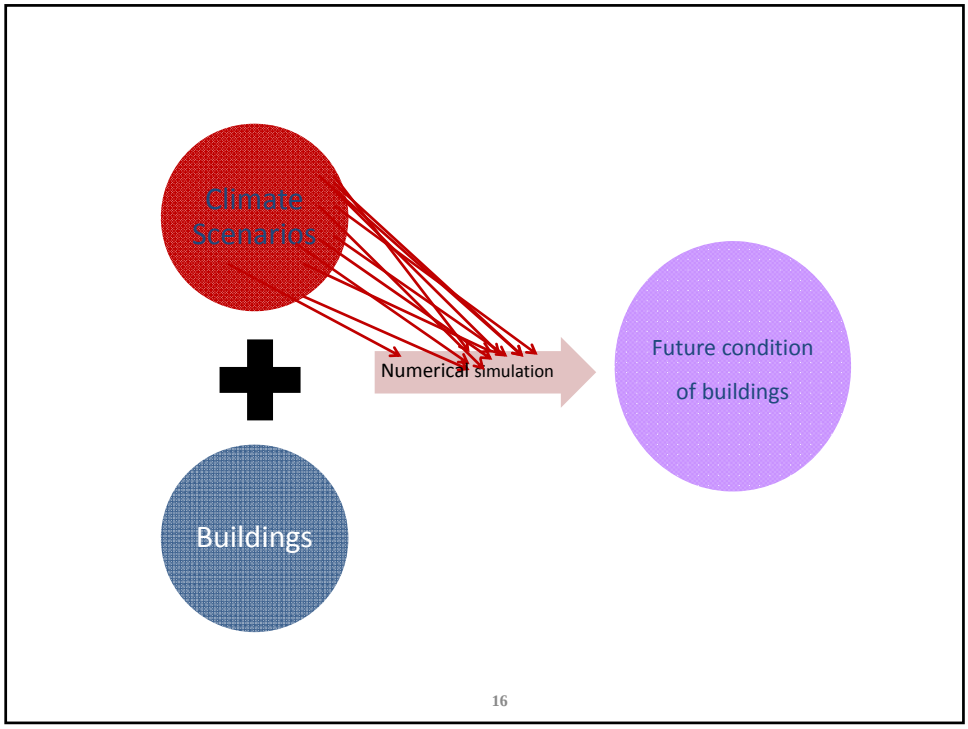
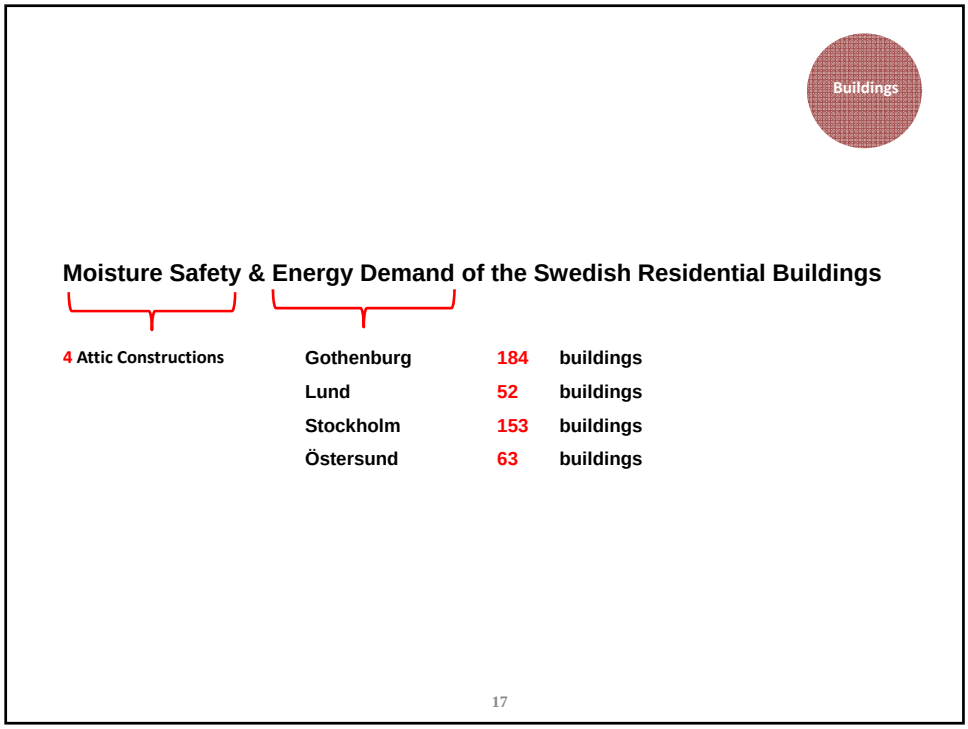
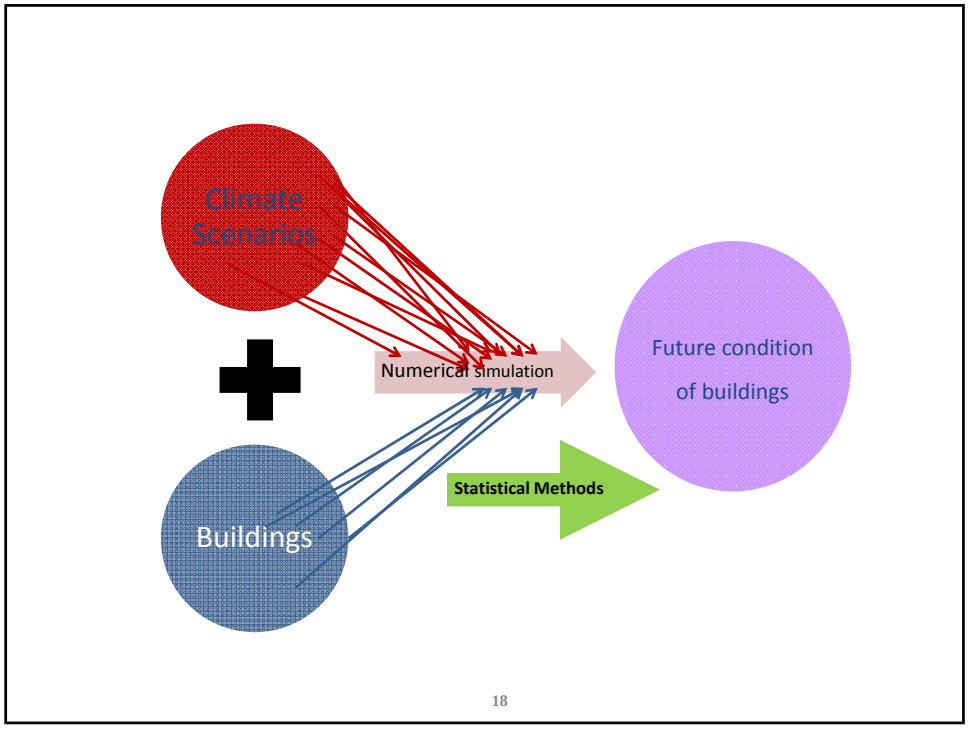

Climate Scenarios
Numerical simulation
Future condition of buildings
Buildings
16


Buildings
Moisture Safety & Energy Demand of the Swedish Residential Buildings
4 Attic Constructions
Gothenburg 184 buildings
Lund 52 buildings
Stockholm 153 buildings
Östersund 63 buildings
17


Climate Scenarios
Numerical simulation
Future condition of buildings
Buildings
Statistical Methods
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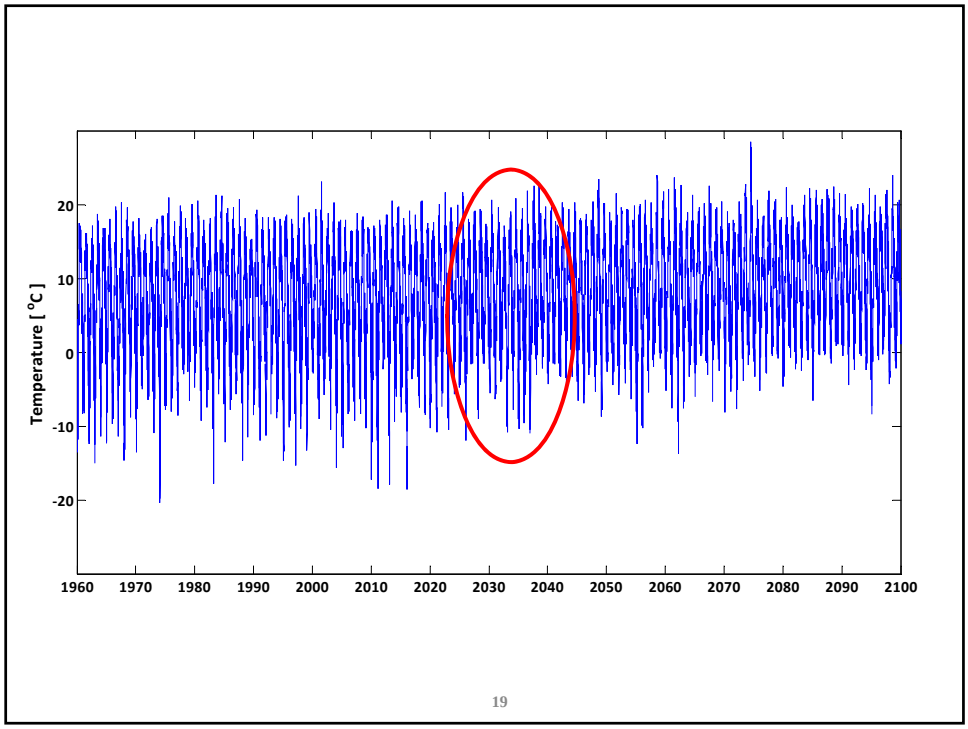
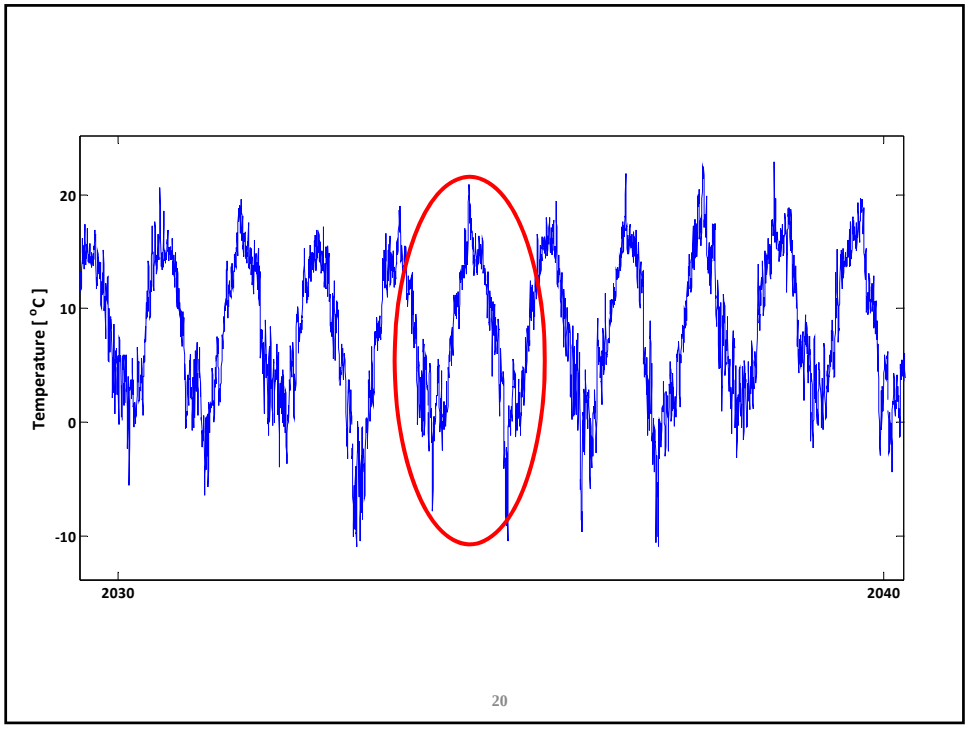
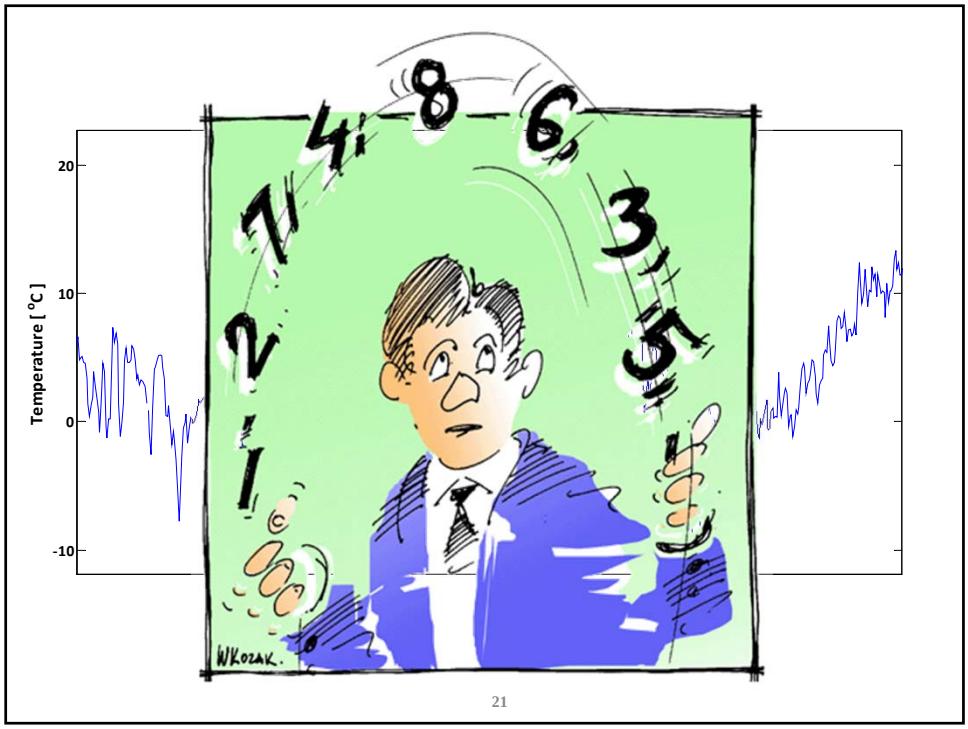
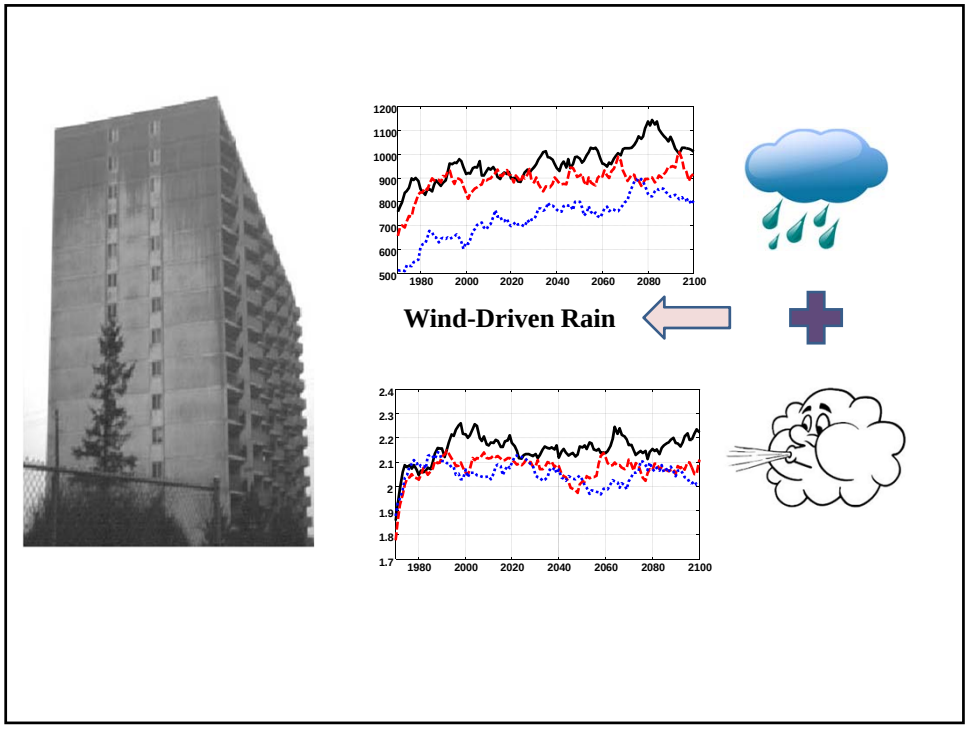
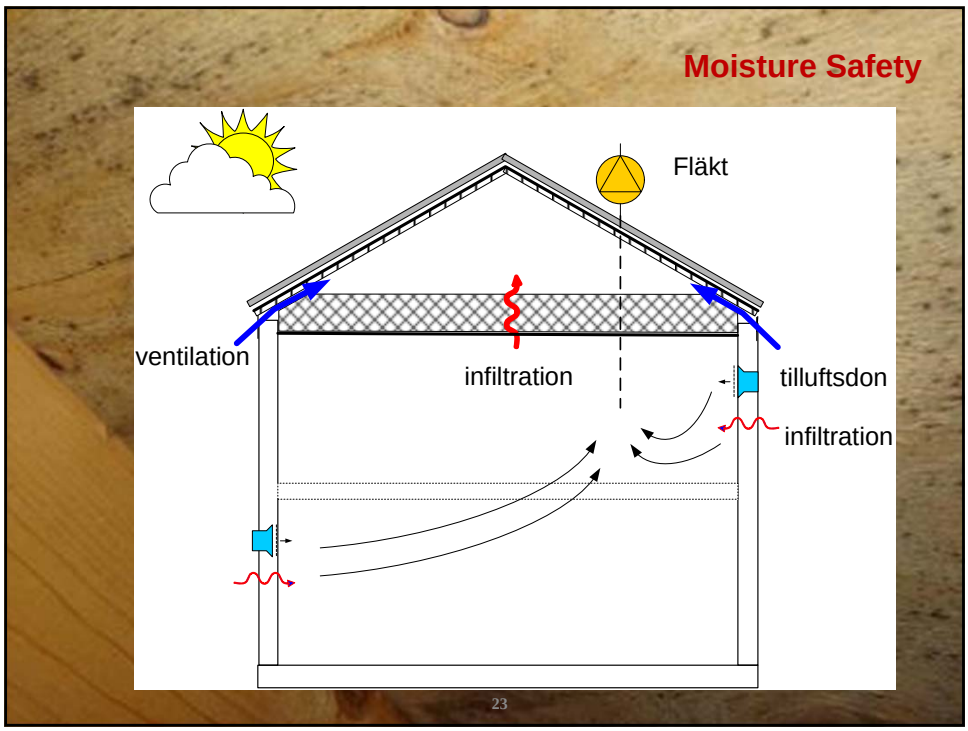

Temperature [°C]
20
10
0
-10
-20
1960
1970
1980
1990
2000
2010
2020
2030
2040
2050
2060
2070
2080
2090
2100
19


Temperature [°C]
20
10
0
-10
2030
2040
20


Temperature [°C]
20
10
0
-10
WKozak
21


Wind-Driven Rain


Moisture Safety
Fläkt
ventilation
infiltration
tilluftsdon
infiltration
23

mean values – GCMs – outdoor climate

	CTL period (1961-1990)					SCN period (2071-2100)			
	ERA40	CCSM3	CNRM	ECHAM5	HADCM3	CCSM3	CNRM	ECHAM5	HADCM3
30-year mean (Summer)									
$\overline{T}$	11.96	10	12.3	11.47	12.08	11.9	13.82	13.5	14.7
$\overline{RH}$	0.83	0.83	0.84	0.85	0.85	0.86	0.87	0.88	0.89
$\overline{GR}$	169	165	163	157	161	149	146	137	137
Seasonal mean (Summer)									
$\overline{T}+T_y'$	11.46	10.2	13.45	12.57	11.3	11.76	14.3	12.65	14.5
$\overline{RH}+RH_y'$	0.82	0.84	0.83	0.82	0.85	0.88	0.89	0.87	0.91
$\overline{GR}+GR_y'$	177	155	175	174	158	141	137	142	119

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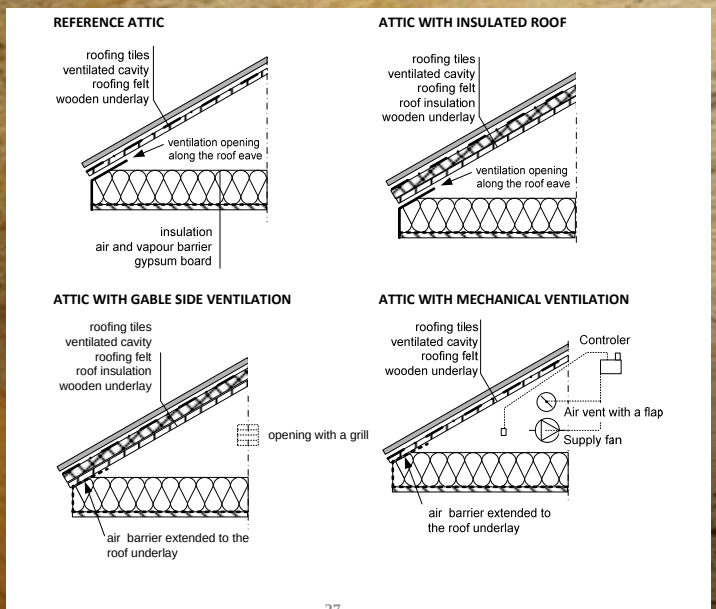
Moisture Safety



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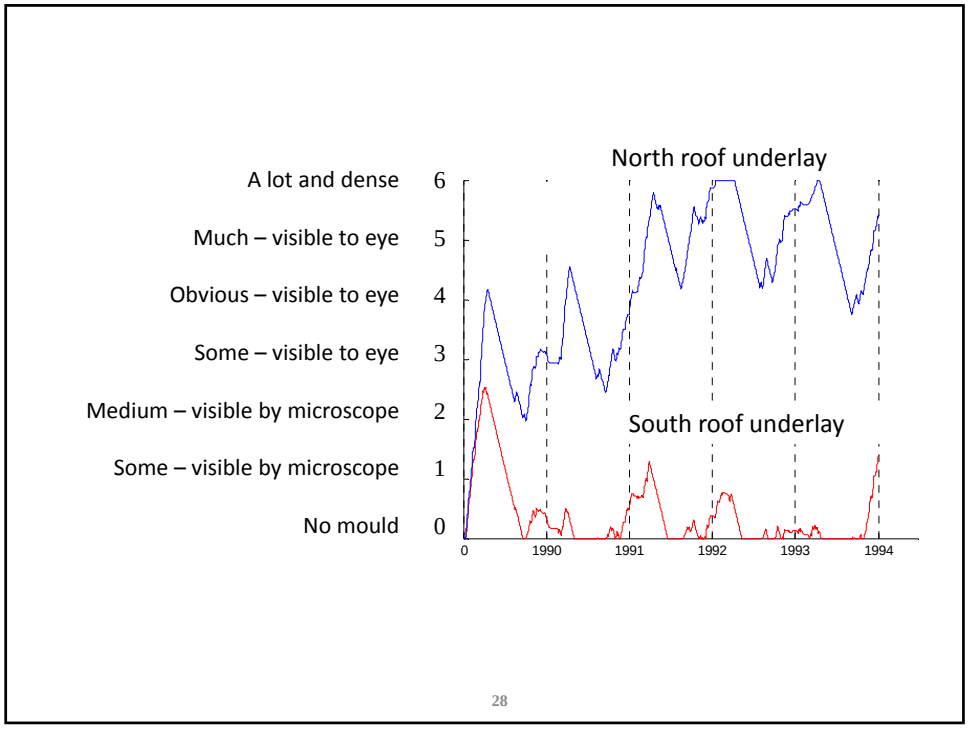
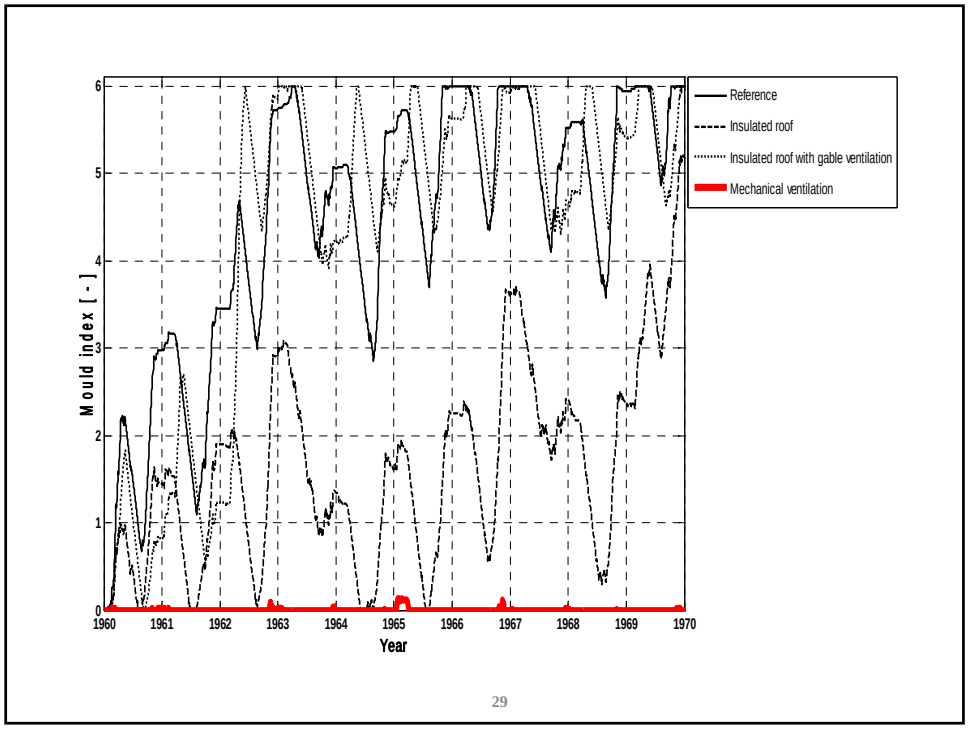
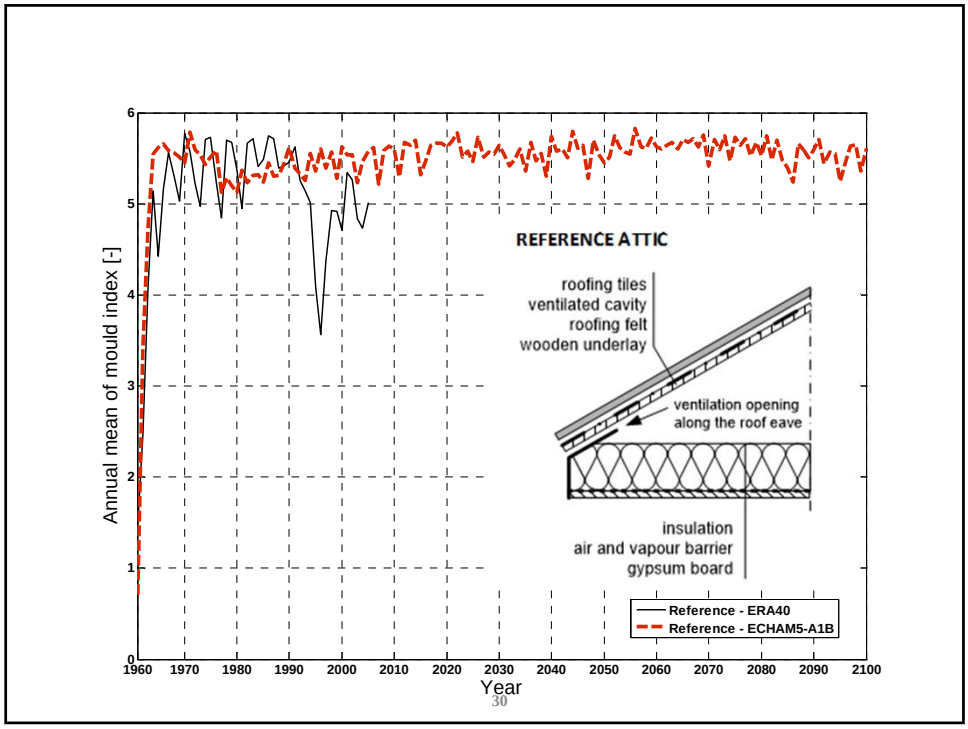
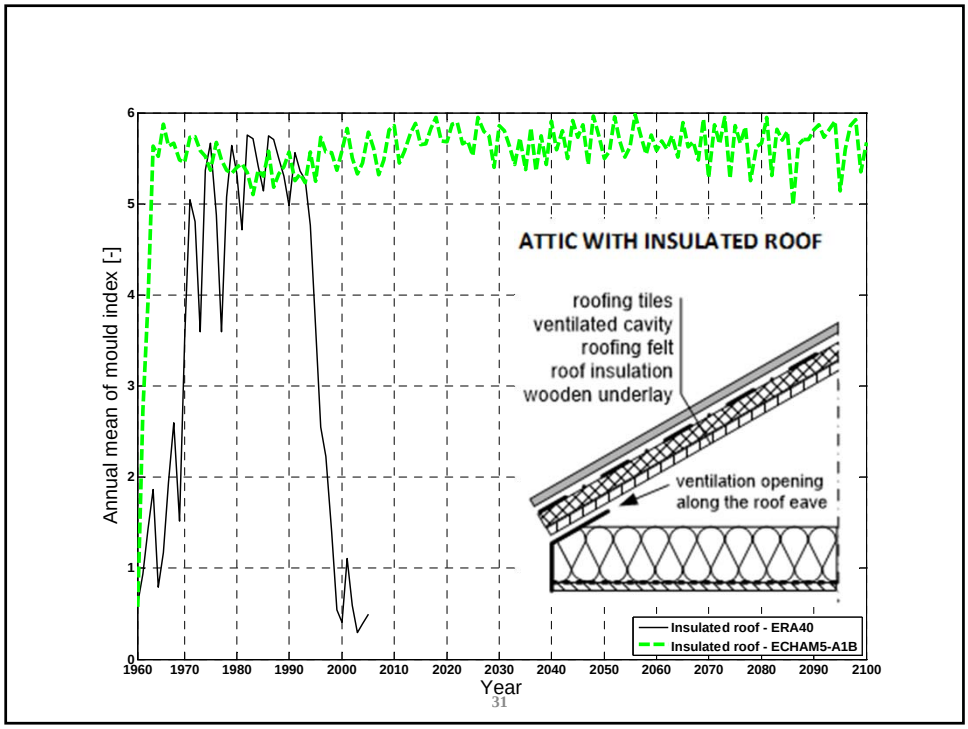

A lot and dense
Much – visible to eye
Obvious – visible to eye
Some – visible to eye
Medium – visible by microscope
Some – visible by microscope
No mould
6
5
4
3
2
1
0
North roof underlay
South roof underlay
0
1990
1991
1992
1993
1994
28


Reference
Insulated roof
Insulated roof with gable ventilation
Mechanical ventilation
Mould index [-]
Year
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
29


Annual mean of mould index [-]
Year
REFERENCE ATTIC
roofing tiles
ventilated cavity
roofing felt
wooden underlay
ventilation opening
along the roof eave
insulation
air and vapour barrier
gypsum board
Reference - ERA40
Reference - ECHAM5-A1B
30


Annual mean of mould index [-]
Year
ATTIC WITH INSULATED ROOF
roofing tiles
ventilated cavity
roofing felt
roof insulation
wooden underlay
ventilation opening
along the roof eave
Insulated roof - ERA40
Insulated roof - ECHAM5-A1B
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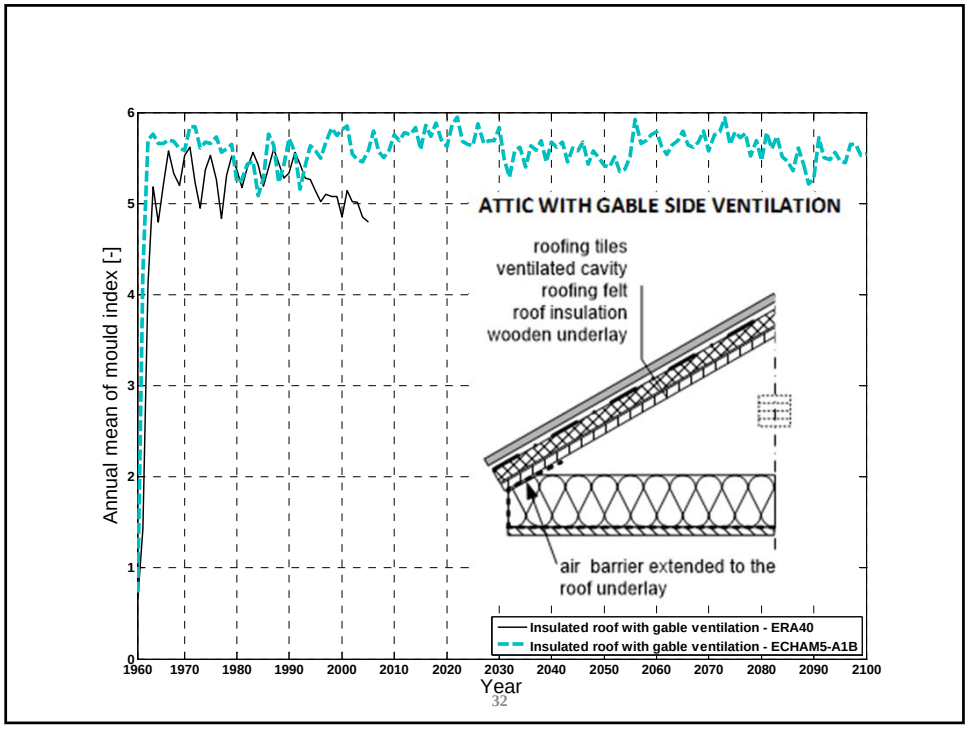
ATTIC WITH GABLE SIDE VENTILATION
roofing tiles
ventilated cavity
roofing felt
roof insulation
wooden underlay
air barrier extended to the roof underlay
Annual mean of mould index [-]
Year
Insulated roof with gable ventilation - ERA40
Insulated roof with gable ventilation - ECHAM5-A1B

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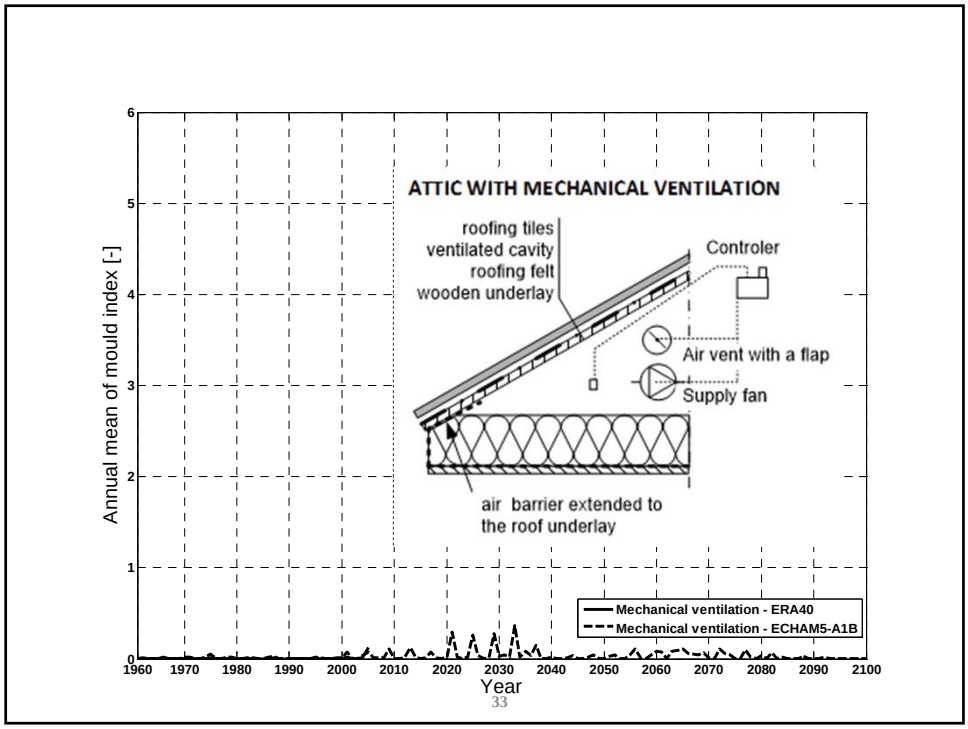
ATTIC WITH MECHANICAL VENTILATION
roofing tiles
ventilated cavity
roofing felt
wooden underlay
Controler
Air vent with a flap
Supply fan
air barrier extended to the roof underlay
Annual mean of mould index [-]
Year
Mechanical ventilation - ERA40
Mechanical ventilation - ECHAM5-A1B

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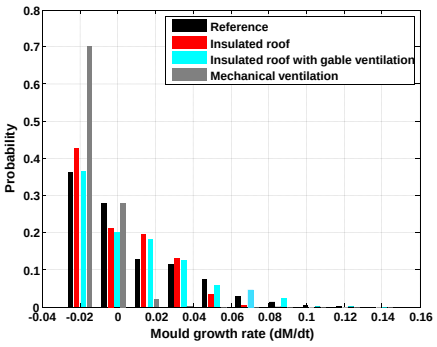

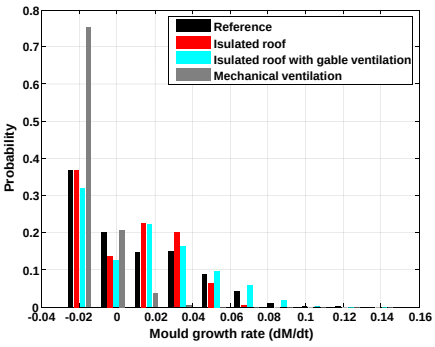

1961-1990

RCA3-ERA40

2071-2100

RCA3-ECHAM5-A1B

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Energy Simulations

1. Gothenburg 184 buildings
2. Lund 52 buildings
3. Stockholm 153 buildings
4. Östersund 63 buildings

a. Heating demand
b. Cooling demand
c. Indoor temperature

Cooling strategies

1. Natural cooling
2. Natural/mechanical cooling
3. Mechanical cooling

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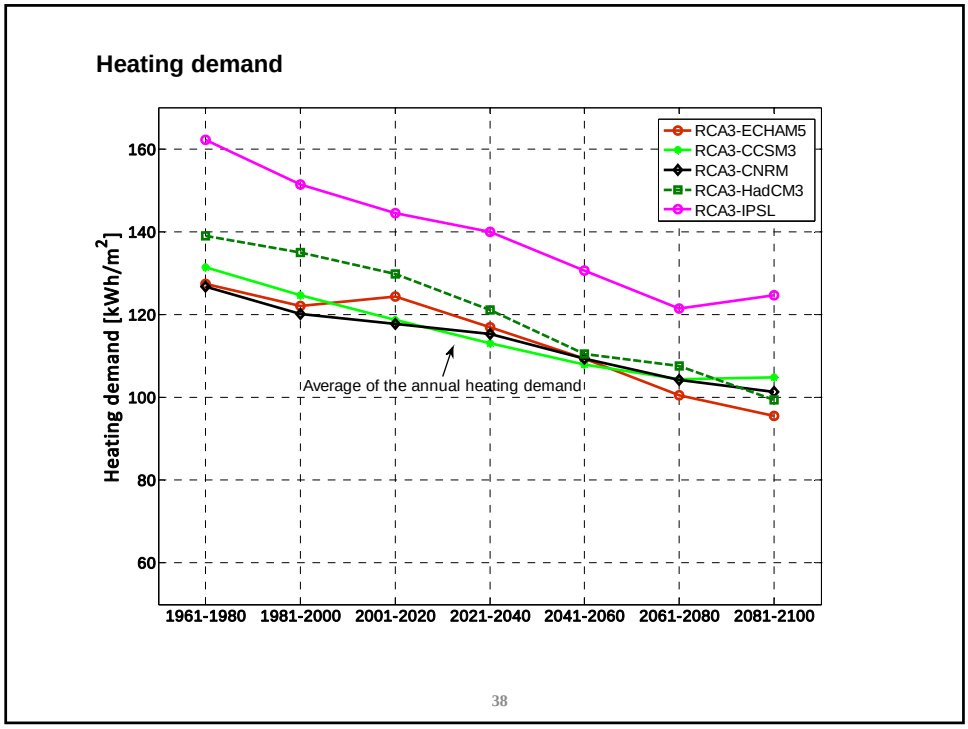
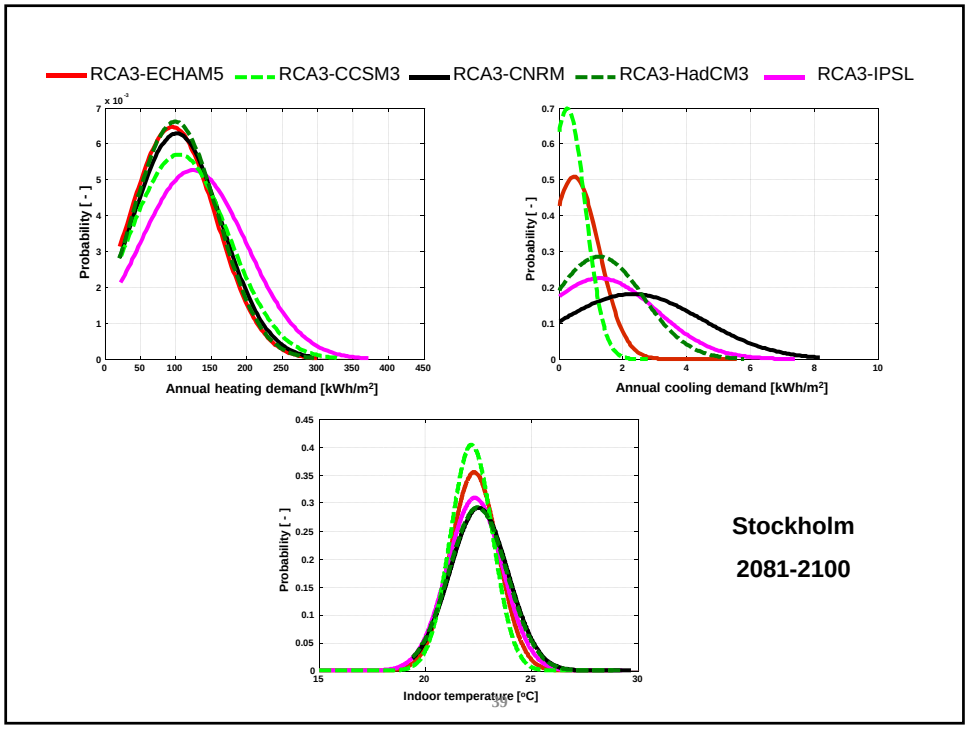
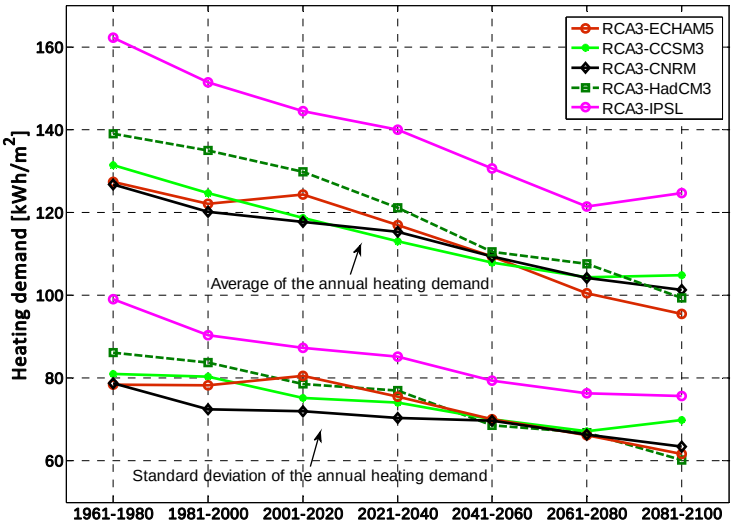

Heating demand
RCA3-ECHAM5
RCA3-CCSM3
RCA3-CNRM
RCA3-HadCM3
RCA3-IPSL
Heating demand [kWh/m2]
160
140
120
100
80
60
Average of the annual heating demand
1961-1980
1981-2000
2001-2020
2021-2040
2041-2060
2061-2080
2081-2100
38

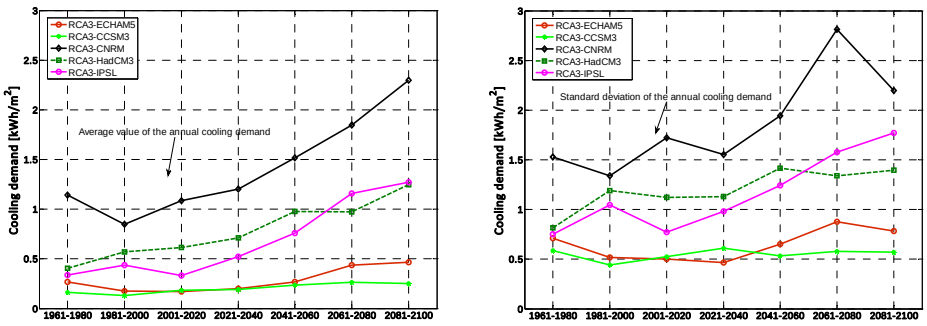

RCA3-ECHAM5
RCA3-CCSM3
RCA3-CNRM
RCA3-HadCM3
RCA3-IPSL
Probability [-]
Annual heating demand [kWh/m2]
Annual cooling demand [kWh/m2]
Indoor temperature [°C]
Stockholm
2081-2100
39

Heating demand



40

Cooling demand



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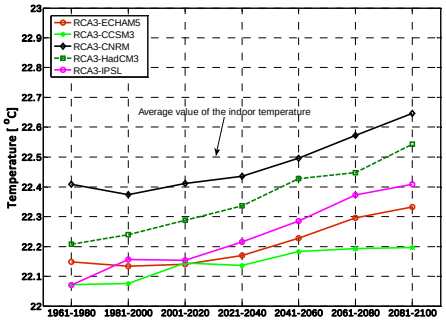
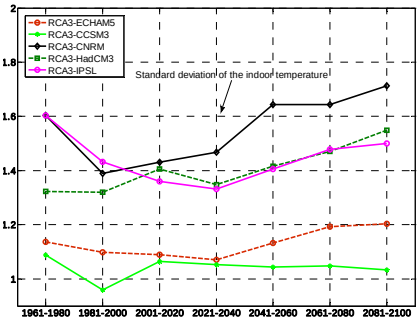
Indoor Temperature





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Formas project – started in 2013

Evaluating the energy retrofitting strategies of the Swedish building stock for the uncertain future climate

Utvärdering av energistrategier vid upprustning av det svenska byggnadsbeståndet inför ett osäkert framtida klimat

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Some points

- Impact analysis of the climate change cannot be based on a few number of climate scenarios.
- Temperature and humidity levels will increase in attics which can increase the risk of mould growth, specifically in attic. Most of the passive strategies won't work in future.
- Heating demand and its variations will decrease in the future. Decrement does not happen with the same rate among the cities and the climate scenarios.

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