EBC
Energy in Buildings and Communities Programme

IEA EBC Annex 80 - Resilient Cooling

Webinar 2: Future weather data and heatwaves

AIVC venticool INIVE Institute of Building Research & Innovation ZT-GmbH iea Energy Technology Network

31/05/2022

EBC
Energy in Buildings and Communities Programme

IEA EBC Annex 80 - Resilient Cooling

Webinar 2: Future weather data and heatwaves

Peter Holzer

Operating Agent EBC Annex 80
Institute of Building Research & Innovation
Vienna, Austria

Institute of Building Research & Innovation ZT-GmbH

Federal Ministry
Republic of Austria
Climate Action, Environment, Energy, Mobility, Innovation and Technology

iea Energy Technology Network

31/05/2022

IEA EBC Annex 80

EBC Energy in Buildings and Communities Programme

Series of webinars in cooperation with AIVC & venticool

1. Indicators to assess resilience of cooling in buildings [May 10, 15:00-16:15 CEST]
2. **Future weather data and heatwaves [May 31, 16:00-17:15 CEST]**
3. Examples of resilient cooling solutions [September 13, 15:00-16:15 CEST]
4. Case studies and policy recommendations [September 20, 15:00-16:15 CEST]

https://annex80.iea-ebc.org/

AIVC venticool the platform for resilient ventilative cooling INIVE

Today's Programme

Programme (Brussels time)

16:00	**Introduction to Annex 80, AIVC & venticool** Peter Holzer, Operating Agent EBC Annex 80, Institute of Building Research & Innovation, AT
16:05	**Motivation & determination of world-wide future weather data and heatwaves** Agnese Salvati, UPC, ES
16:25	**Practical Applications 1: Mitigation and adaptation strategies in building design** Anaïs Machard, University of La Rochelle, FR
16:40	**Practical Applications 2: Evaluation and sizing of cooling technologies in future climates** Ronnen Levinson & Sang Hoon Lee, LBNL, US
16:55	Questions and answers
17:15	End of the webinar

IEA EBC Annex 80

- **Participants**

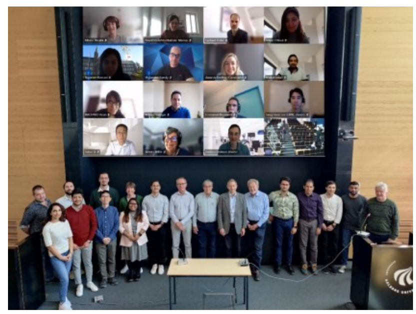
  36 institutions from 16 countries (Americas, Europe, Asia, Australia)

- **Guests** (not part of EBC yet)

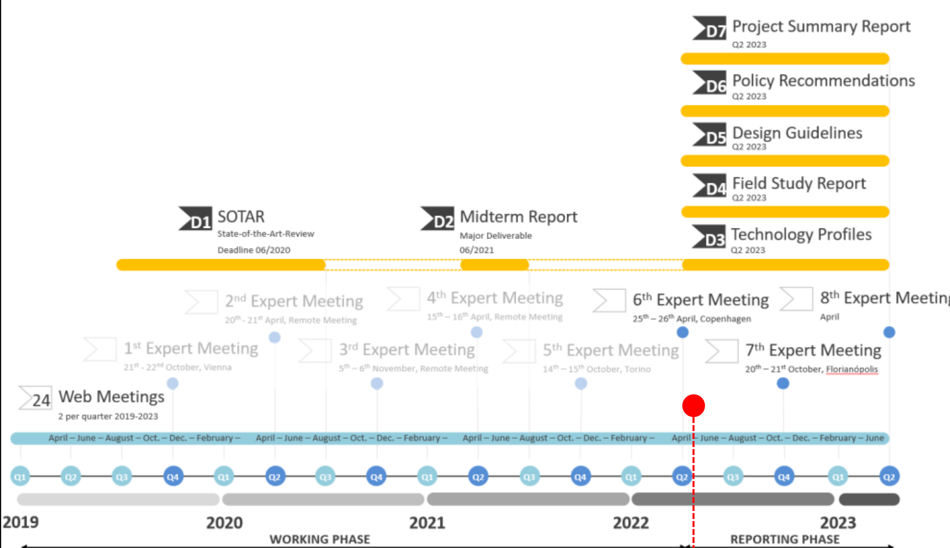
  Mexico, **José Roberto Garcia Chavez**, Metropolitan Autonomous University Mexico City

  India, **Rajan Rawal**, CEPT University, CARBSE

1. Preparation Phase (1 year)
   June 2018 – June 2019
2. Working Phase (3 years)
   June 2019 – June 2022
3. Reporting Phase (1 year)
   June 2022 – June 2023



Annex 80 Roadmap



Annex 80 Objectives

"Support a transition to an environment where ***affordable low energy*** *and* ***low carbon*** *cooling systems are the mainstream and preferred solutions for cooling and overheating issues in buildings."*

A Assess benefits, potentials and performance indicators. Provide guidance on design, performance calculation and system integration.

B Research towards implementation of emerging technologies. Extend boundaries of existing solutions.

C Evaluate the real performance of resilient cooling solutions.

D Develop recommendations for policy actions.

Definition of Resilient Cooling

"Affordable low energy and low carbon cooling solutions, strengthening the ability of individuals and communities to withstand and prevent the thermal - and other - **impacts of changes in global and local climates."**

Annex 80 Deliverables

D1	State-of-the-Art-Report	▪ Research community and associates ▪ Real Estate developers ▪ Urban planning experts ▪ Policy makers	OA, STA, STB, STC, STD
D2	Midterm Report	▪ Research community and associates ▪ IEA and EBC Programme	OA, STA, STB, STC, STD
D3	**Technology Profiles**	▪ Building component developers and manufacturers ▪ Architects and design agencies ▪ Engineering offices and consultants	STB
D4	**Field Studies**	▪ Building component developers and manufacturers ▪ Architects and design agencies ▪ Engineering offices and consultants ▪ Real Estate developers	STC
D5	**Design and Operation Guidelines**	▪ Architects and design agencies ▪ Engineering offices and consultants ▪ Real Estate developers	STA, STB, STC
D6	**Recommendations for policy actions, legislation and standards**	▪ Policy makers ▪ Legal interest groups ▪ Experts involved in building energy performance standards and regulation	STD
D7	**Project Summary Report**	▪ Research community and associates ▪ IEA and EBC Programme ▪ Real Estate developers ▪ Policy makers	OA, STA, STB, STC, STD

Annex 80 Publications

1. "**Developing an understanding of resilient cooling**: a socio-technical approach City and Environment Interactions" (Wendy Miller et al; published in Elsevier City and Environment 2021) https://doi.org/10.1016/j.cacint.2021.100065
2. "**Resilient cooling of buildings to protect against heat waves and power outages**: key concepts and definition" (Shady Attia et al; published in Energy and Buildings 2021) https://doi.org/10.1016/j.enbuild.2021.110869
3. "**Resilient cooling strategies - a critical review and qualitative assessment**" (Chen Zhang et al; published in Energy and Buildings 2021) https://doi.org/10.1016/j.enbuild.2021.111312
4. Report of Thermal Conditions Task Group "**Framework to evaluate the resilience of different cooling technologies**" (Shady Attia et al; published) http://dx.doi.org/10.13140/RG.2.2.33998.59208




Next:

Dr. Agnese Salvati

Universidad Politécnica de Cataluña, Barcelona Tech

Spain

Webinar : Future weather data and heatwaves | 31 May 2022

Motivation & determination of world-wide future weather data and heatwaves

Dr Agnese Salvati

AiEM - Architecture and Energy Research group
Barcelona School of Architecture | ETSAB UPC

UNIVERSITAT POLITÈCNICA DE CATALUNYA BARCELONATECH

On behalf of:

IEA EBC Annex 80 Weather Data Task Force leaders:
Anaïs Machard, Mamak P.Tootkaboni, Agnese Salvati, Abhishek Gaur

1

Future weather data and heatwaves: structure of the presentation

- **Purpose** of the future Weather datatsets generated for the Annex 80
- **Methodology**: selected cities, data source, validation
- **Results**
  - Expected changes in "*Typical Metheorological Years*"
  - Future *heatwaves* (Anaïs Machard – following presentation)

2

Future weather data and heatwaves: motivation

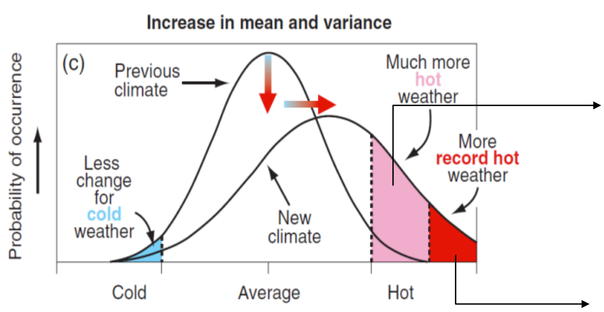
*The world is facing a rapid **increase of air conditioning** of buildings. This is driven by multiple factors, such as **urban growth and climate change.***

It is the motivation** of the Annex 80 **to develop, assess and communicate solutions of resilient cooling and overheating protection** (…) to withstand, and also prevent, **thermal stress** and **building cooling demand increase** due **to higher ambient temperatures** and increased frequency and severity of **heat wave events.

The **WEATHER DATA TASK FORCE** of the **IEA EBC Annex80** was created to agree on a common and scientifically robust methodology to **produce sets of weather data** of **characteristics climate zones worldwide.**

The **purpose** of the data is to carry out **building performance simulations** to **assess thermal stress** and **building cooling demand** in **present and future periods**

Future weather data and heatwaves: what kind of future weather data?



Increase in building cooling demand

Increase in thermal stress and risk of power outages

Source: (IPCC). Climate Change 2001: The scientific basis. Contribution of Working Group I

Two kinds of weather files are needed :

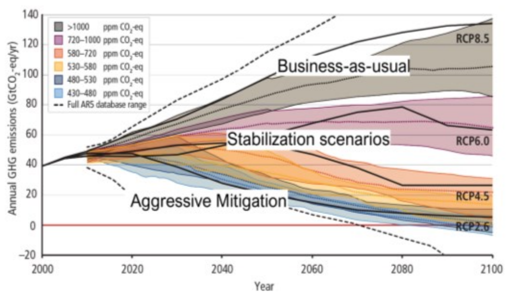
1) **Typical Meteorological Years**
2) **Weather files including heatwaves**

For **present** and **future** periods

For **representative climate zones**

Future weather data and heatwaves: climate projections and emission scenarios

- The analysis of future climate is based on **projections of climate models**
- Assumptions for climate models are the **green house gas concentration** scenarios developed by the **Intergovernmental Panel for Climate Change's (IPCC)** assessment reports (AR)
- 5th AR, released four Representative Concentration Pathways (RCPs) in 2014, which are identified by their associated warming effect (radiative forcing) in the year 2100 .



Selected RCP:
RCP8.5: Assumes a '*business-as-usual*' approach (worse case scenario)

Selected periods

- Historical **2010s**: (2001-2020)
- Future med-term **2050s**: (2041-2060)
- Future long term **2090s**: (2081-2100)

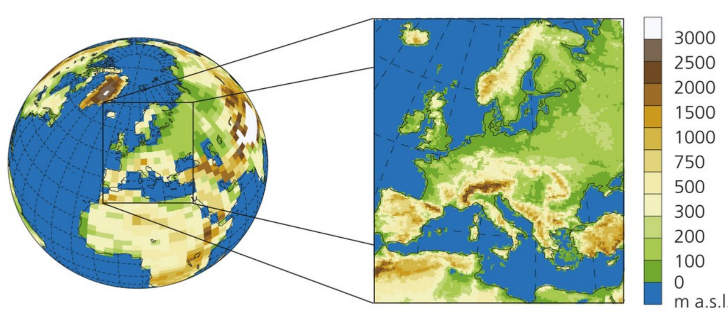
! **20-years** : minimum recommended length of time for climate change impact assessment studies.

Future weather data and heatwaves: what methodology?

Need downscaling:
To obtain higher resolution data

Statistical downscaling (Morphing Method) → using Future mean value (GCMs) to modify observed weather data

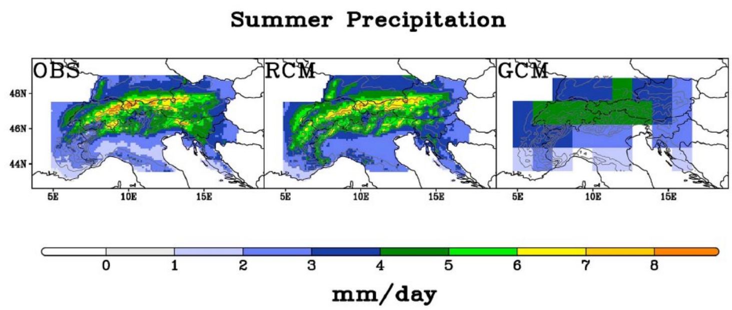
Dynamical downscaling → Using **RCM**s models forced by boundary conditions from a GCM model



General Circulation Models - GCM
Spatial resolution: 150–600 km

Regional Climate Models - RCM
Spatial resolution: down to 2.5 km

Future weather data and heatwaves: advantages of dynamical downscaling using RCMs



Source: Giorgi, F. Thirty Years of Regional Climate Modeling: Where Are We and Where Are We Going next? J. Geophys. Res. Atmos. **2019**, 124, 5696–5723.

RCMs allow representation of extreme events such as **heatwaves,** which is not possible with other weather generators based on statistical downscaling (i.e. METENORM).

Future weather data and heatwaves: CORDEX datasets

CORDEX: COrdinated **R**egional **D**ownscaling **EX**periment
Project sponsored by World Climate Research Program (WCRP) to provide **regional-scale** climate projections for **impact assessment** and **adaptation studies**

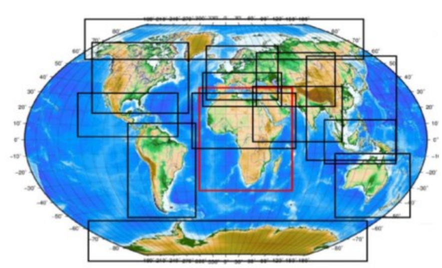
Several climate models and socio-economic projections worldwide, within the IPCC AR5 timeline

Specifications of the CORDEX data used:

GCM-RCM models: *MPI-ESM-LR/REMO*
Model combination that is closer to the median temperature of all climate models projections.

Data resolution:
- Minimum 3h temporal frequency
- Minimum 25 km spatial resolution

Variables:
- Dry-bulb air Temp
- Relative humidity
- Global horizontal irradiation
- Wind Speed
- Atmospheric pressure



Future weather data and heatwaves: bias-correction of RCM data

Goal : to reduce long term bias associated with climate model data

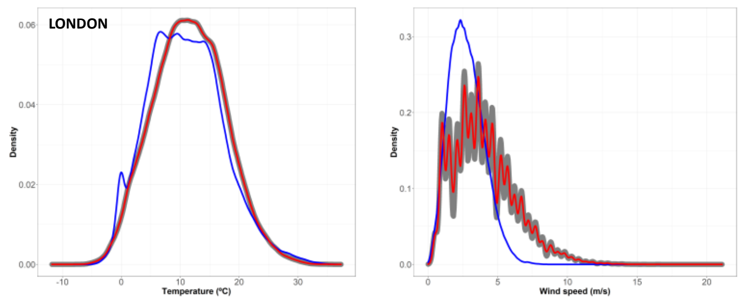
Hourly **historical observations**
(20-years ideally, 5 years minimum)

Hourly **CORDEX climate data**
(same period for which observations are available)

Bias-correction methods:
1) Solar Irradiation:
Quantile delta mapping (QDM
(Cannon et al., 2015)

2) Rest of climate variables:
Multivariate Bias Correction (MBC)
(Cannon, 2018)

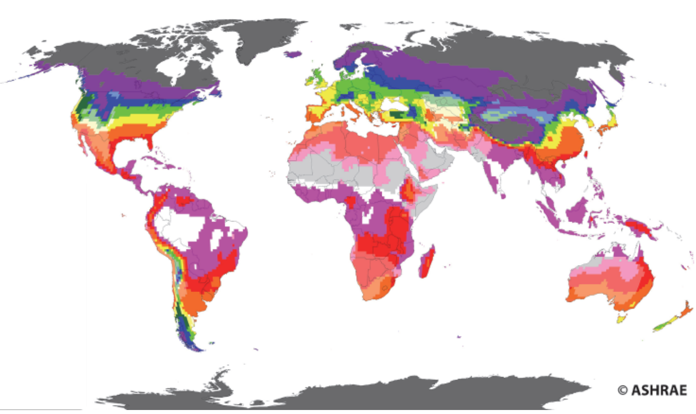
RCM
Observations
Bias-corrected RCM



Future weather data and heatwaves: Selecting representative cities

Criteria:
1. At least **one city for climate zones** considering the ASHRAE classification

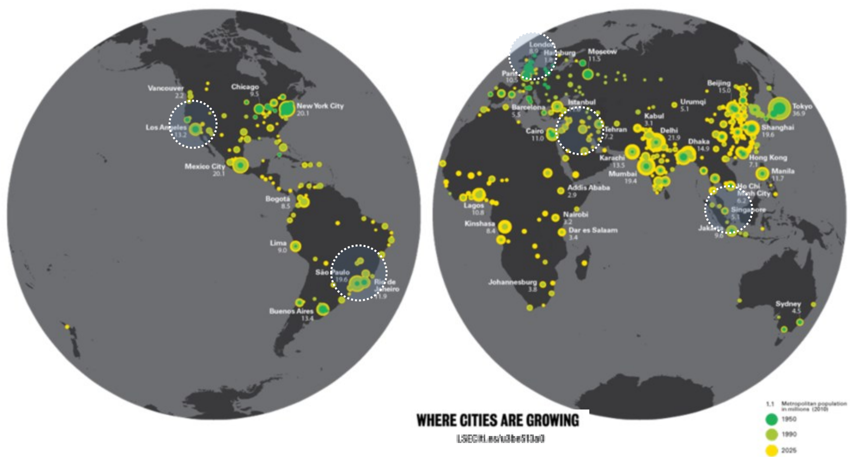
CZ	Description
0A	Extremely Hot Humid
0B	Extremely Hot Dry
1A	Very Hot Humid
1B	Very Hot Dry
2A	Hot Humid
2B	Hot Dry
3A	Warm Humid
3B	Warm Dry
3C	Warm Marine
4A	Mixed Humid
4B	Mixed Dry
4C	Mixed Marine
5A	Cold Humid
5B	Cold Dry
5C	Cool Marine
6A	Cold Humid
6B	Cold Dry



Future weather data and heatwaves: Selecting representative cities

Criteria:

1. At least **one city for climate zones** considering the ASHRAE classification
2. Cities with high **population and growth**

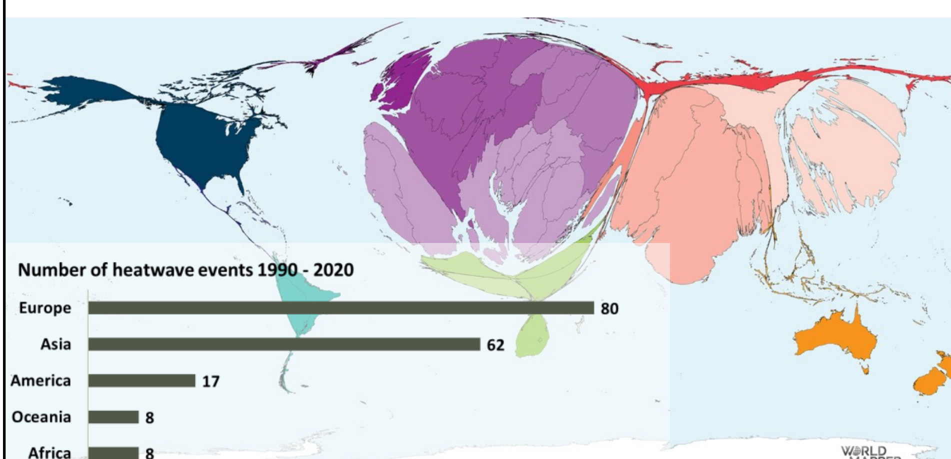


Source: Urban Age project, LSE Cities (2013)

Future weather data and heatwaves: Selecting representative cities

Criteria:

1. At least **one city for climate zones** considering the ASHRAE classification
2. Cities with high **population and growth**
3. Cities in **different continents**



Source: Source: EM-Dat International disaster database, Centre for Research on the Epidemiology of Disasters (CRED), https://www.emdat.be/

Future weather data and heatwaves: Selected cities

CLIMATE ZONE	City	Population 2022	Change % (since 2021)	Country	Continent
0A	Singapore	6,039,577	0.80%	Singapore	Asia
0B	Abu Dhabi	1,539,830	1.86%	UAE	Asia
1A	Guayaquil	3,092,355	1.62%	Ecuador	South America
2A	Sao Paulo	22,429,800	0.86%	Brazil	South America
3A	Buenos Aires	15,369,919	0.74%	Argentina	South America
3A	Rome	4297877	0.46%	Italy	Europe
3B	Los Angeles	3,985,516	0.05%	California	North America
4A	Brussels	2,109,631	0.67%	Belgium	Europe
4A	Gent	n/a	n/a	Belgium	Europe
4A	London	9,540,576	1.22%	UK	Europe
4C	Vancouver	2,631,690	0.97%	Canada	North America
5A	Toronto	6,312,974	0.93%	Canada	North America
5A	Copenhagen	1,370,131	0.85%	Denmark	Europe
5A	Vienna	1.960.023	0.78%	Austria	Europe
6A	Montreal	4,276,526	0.68%	Canada	North America
6A	Stockholm	1,679,050	1.36%	Sweden	Europe

Future weather data and heatwaves: Summary of methods and outputs

RCM projections (CORDEX) + Bias-adjustment (Using Observations)

Hourly bias-adjusted datasets of:

- Dry-bulb air Temp
- Relative humidity
- Global horizontal irradiation
- Wind Speed
- Atmospheric pressure

For 20-years periods:

- Historical: (2001-2020)
- Future medium term (2041-2060)
- Future long term (2081-2100)

Statistical analysis of the 20-years periods

OUTPUT 1:

Typical Meteorological Years (TMYs)

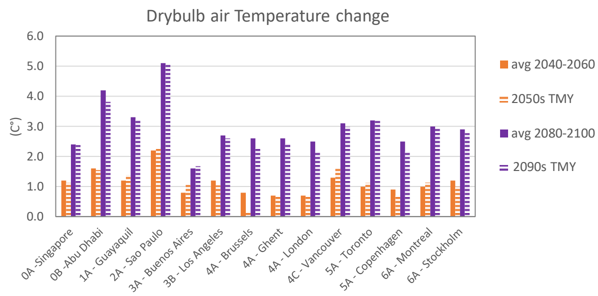
Method: EN ISO 15927-4:2005 standard
TMYs are constructed from the 12 most representative months ("Best months") from the multi-year period.

OUTPUT 2:

Weather files including heatwaves (HWs)

Method: Ouzeau et al., 2016
Based on relative temperature thresholds to detect heatwaves

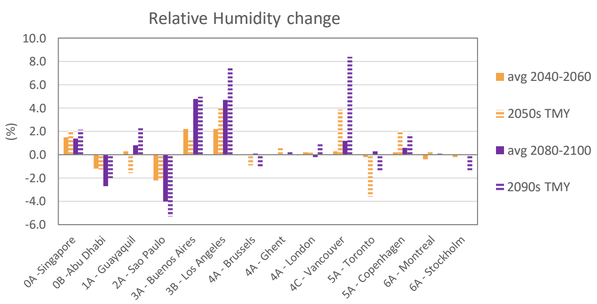
Future weather data : Projected changes in climate variables



TMYs well represent the 20-year period trend.

The **air temperature is consistently higher in the future for all the cities**.

Higher increase in the long term that in the mid-term TMY

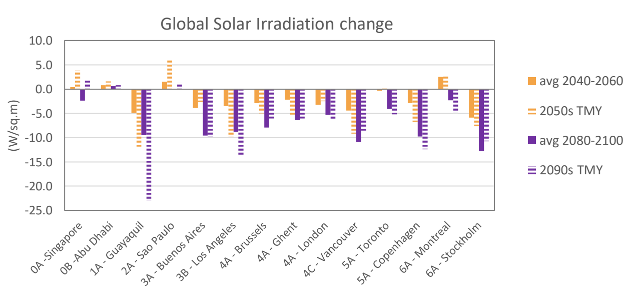


High variability in the sign of **future changes in relative humidity**.

Increasing RH:
Singapore (CZ: Extremely Hot Humid)
Guayaquil (CZ: Very Hot Humid)
Buenos Aires (CZ: Warm Humid)
Los Angeles (CZ: Warm Dry)
Vancouver (CZ: Mixed Marine).

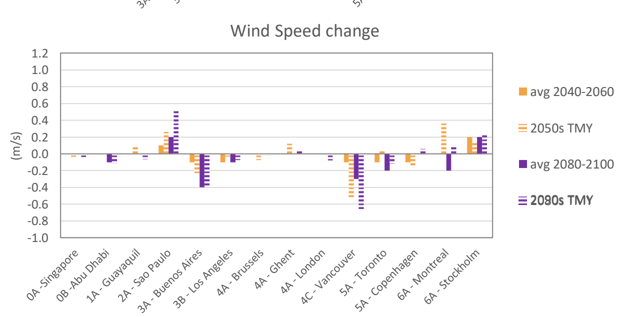
Decreasing RH:
Sao Paulo (CZ: Hot Humid)
Abu Dhabi (CZ: Extremely Hot Dry)

Future weather data : Projected changes in climate variables



Global solar radiation is **reduced in the future TMYs of the majority of the cities**.
This is in agreement with the 20-years projections.

Same results found in other studies. It can be explained by increasing aerosol concentrations and increasing cloudiness



The **changes in wind speed are minimal** for most of the cities.

The 2090s-TMY of Vancouver (CZ: Mixed Marine) has the largest decreases in mean wind speeds of 0.7 m/s.

Future weather data : References and data availablity

The outcomes of this work will be made soon available through a **data paper** (in progress).

The following datasets will be **available for download from the IEA EBC Annex80 webpage**:

- 20-years hourly datatsets
- TMYs in EPW format
- Weather files including heat waves in EPW format

For each city and time period analaysed

Weather Data Task force : Institutions contributing to the data generation

Politecnico di Torino, Italy
La Rochelle Université & CSTB, France
Brunel University London, United Kingdom
Concordia University, Canada
Natural Research Council of Canada
Fraunhofer Institute for Building Physics IBP, Germany
Lawrence Berkeley National Laboratory, California
CIMEC/ CONICET, Argentina
Federal University of Santa Catarina, Brasil
Institute of Building Research & Innovation, Austria
Belgian Building Research Institute (BBRI), Belgium
University of Liege, Belgium
KU Leuven, Belgium
Aalborg University, Denmark
University of Gävle, Sweden
ENEA, Italy

Future weather data : References

REFERENCES:

Zhang, C., Kazanci, O. B., Attia, S., Levinson, R., Lee, S. H., Holzer, P., Salvatif, A., Machard, A., Pourabdollahtootkaboni, M., Gaur, A., Olesen, B. W., & Heiselberg, P. (2021). *IEA EBC Annex 80 - Dynamic simulation guideline for the performance testing of resilient cooling strategies*. Aalborg University. https://orbit.dtu.dk/files/267004362/Dynamic_simulation_guideline_DCE_report_No.299.pdf

Machard, A., Inard, C., Alessandrini, J.-M., Pelé, C., & Ribéron, J. (2020). A Methodology for Assembling Future Weather Files including Heatwaves for Building Thermal Simulations from the European Coordinated Regional Downscaling Experiment (EURO-CORDEX) Climate Data. *Energies*, *13*, 3424. https://doi.org/doi.org/10.3390/en13133424

Cannon, A. J. (2018). Multivariate quantile mapping bias correction: an N-dimensional probability density function transform for climate model simulations of multiple variables. *Climate Dynamics*, *50*(1–2), 31–49. https://doi.org/10.1007/s00382-017-3580-6

Cannon, A.J., S.R. Sobie, and T.Q. Murdock, 2015. Bias correction of simulated precipitation by quantile mapping: How well do methods preserve relative changes in quantiles and extremes? Journal of Climate, 28:6938-6959. doi:10.1175/JCLI-D-14-00754.1

European Committee for Standardization, EN ISO 15927: Hygrothermal Performance of Buildings – Calculation and Presentation of Climatic Data – Part 4: Hourly Data for Assessing the Annual Energy Use for Heating and Cooling. Brussels: European Committee for Standardization (2005).

Ouzeau, G., Soubeyroux, J. M., Schneider, M., Vautard, R., & Planton, S. (2016). Heat waves analysis over France in present and future climate: Application of a new method on the EURO-CORDEX ensemble. *Climate Services*, *4*, 1–12. https://doi.org/10.1016/j.cliser.2016.09.002

Thank you!

Dr Agnese Salvati
agnese.salvati@upc.edu

AiEM - Architecture and Energy Research group
Barcelona School of Architecture | ETSAB UPC

IEA EBC Annex 80 Weather Data Task Force leaders:
Anaïs Machard, Mamak P.Tootkaboni, Agnese Salvati, Abhishek Gaur

Webinar
Future weather data and heatwaves
31 May 2022

Practical Applications 1:

Mitigation and adaptation strategies in building design

Dr Anaïs MACHARD
CSTB : Scientific and Technical Center, France

Outline of the presentation

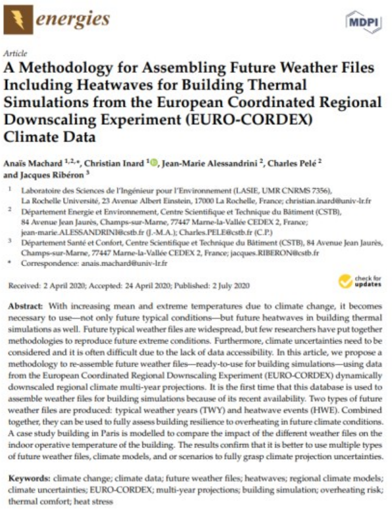
- Future heatwaves weather files developped within Annex 80: Resilient cooling for buildings
- Building design contribution using future heatwave weather files
  - Contribution to building design
  - Mitigation & adaptation strategies : Winter & summer design (example for French climate)
  - Which heatwaves should we use ?
  - Health risk assessment under future heatwaves
- Perspectives

CSTB
le futur en construction

Future heatwaves weather files developped within Annex 80: Resilient cooling for buildings

CSTB
le futur en construction

Assembling future heatwave weather files


energies

MDPI

Article

A Methodology for Assembling Future Weather Files Including Heatwaves for Building Thermal Simulations from the European Coordinated Regional Downscaling Experiment (EURO-CORDEX) Climate Data

Anaïs Machard [1,2,*], Christian Inard [1], Jean-Marie Alessandrini [2], Charles Pelé [2] and Jacques Ribéron [3]

1 Laboratoire des Sciences de l'Ingénieur pour l'Environnement (LASIE, UMR CNRMS 7356), La Rochelle Université, 23 Avenue Albert Einstein, 17000 La Rochelle, France; christian.inard@univ-lr.fr
2 Département Energie et Environnement, Centre Scientifique et Technique du Bâtiment (CSTB), 84 Avenue Jean Jaurès, Champs-sur-Marne, 77447 Marne-la-Vallée CEDEX 2, France; jean-marie.ALESSANDRINI@cstb.fr (J.-M.A.); Charles.PELE@cstb.fr (C.P.)
3 Département Santé et Confort, Centre Scientifique et Technique du Bâtiment (CSTB), 84 Avenue Jean Jaurès, Champs-sur-Marne, 77447 Marne-la-Vallée CEDEX 2, France; jacques.RIBERON@cstb.fr
* Correspondence: anais.machard@univ-lr.fr

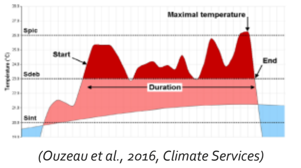
Received: 2 April 2020; Accepted: 24 April 2020; Published: 2 July 2020

Abstract: With increasing mean and extreme temperatures due to climate change, it becomes necessary to use—not only future typical conditions—but future heatwaves in building thermal simulations as well. Future typical weather files are widespread, but few researchers have put together methodologies to reproduce future extreme conditions. Furthermore, climate uncertainties need to be considered and it is often difficult due to the lack of data accessibility. In this article, we propose a methodology to re-assemble future weather files—ready-to-use for building simulations—using data from the European Coordinated Regional Downscaling Experiment (EURO-CORDEX) dynamically downscaled regional climate multi-year projections. It is the first time that this database is used to assemble weather files for building simulations because of its recent availability. Two types of future weather files are produced: typical weather years (TWY) and heatwave events (HWE). Combined together, they can be used to fully assess building resilience to overheating in future climate conditions. A case study building in Paris is modelled to compare the impact of the different weather files on the indoor operative temperature of the building. The results confirm that it is better to use multiple types of future weather files, climate models, and or scenarios to fully grasp climate projection uncertainties.

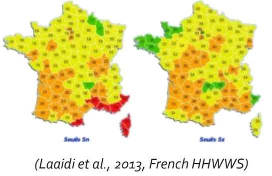
Keywords: climate change; climate data; future weather files; heatwaves; regional climate models; climate uncertainties; EURO-CORDEX; multi-year projections; building simulation; overheating risk; thermal comfort; heat stress

https://doi.org/10.3390/en13133424

Climatologist thresholds to detect heatwaves (extreme hot percentiles over multi-year historical mean daily temperatures) → **depends on outdoor temperatures**



(Ouzeau et al., 2016, Climate Services)

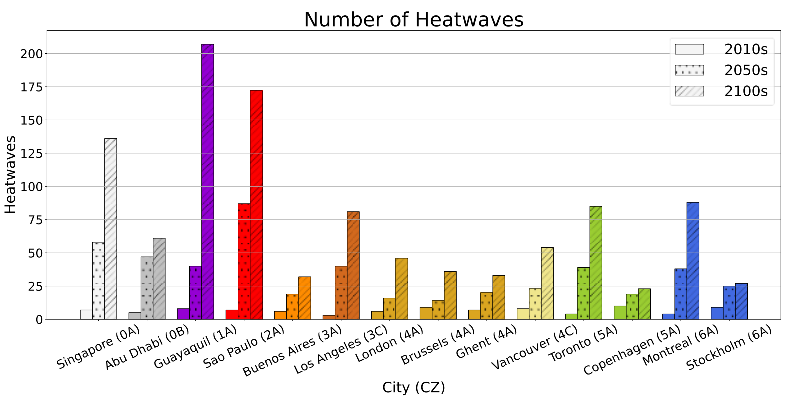


(Laaidi et al., 2013, French HHWWS)

Epidemiologist thresholds to detect heatwaves with potential health risk (exterior hot daytime and nighttime temperatures correlated to mortality data) → **depends on building & people vulnerability**

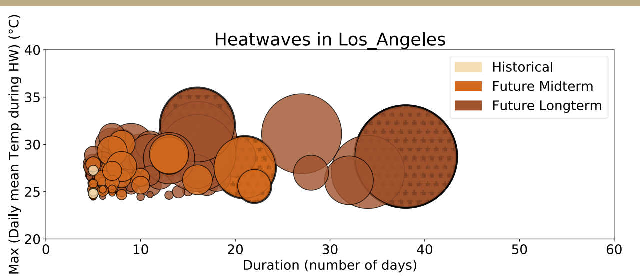
- Because epidemiologist thresholds are country dependent, **only climatologist thresholds are used to detect HW in the context of Annex80** → All ASHRAE climate zones
- More than half future heatwaves detected, in France, are heatwaves with potential health risk

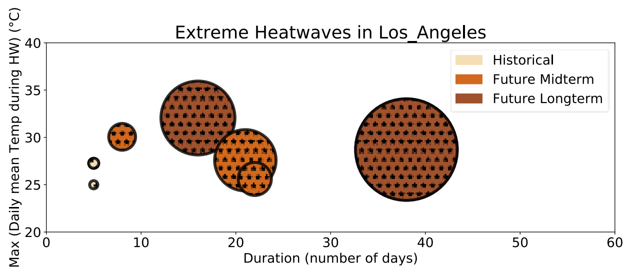
Future weather data: Projected changes in the number of heatwaves



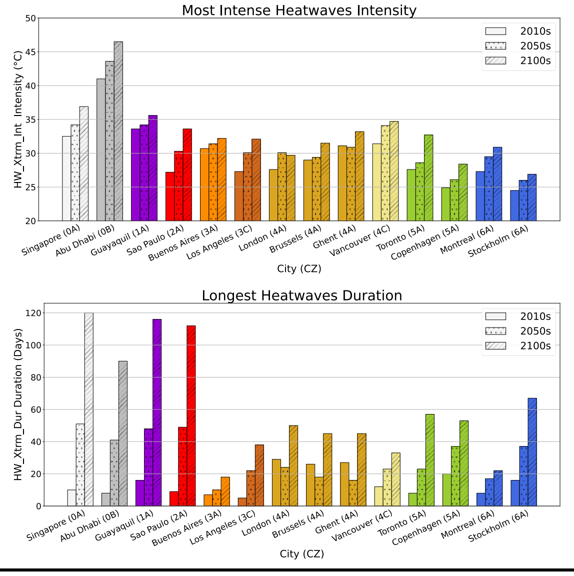
- Contemporary (2010s) : 5 heatwaves max over 30 years
- Mid-century (2050s) : In all cities, at least 15 heatwaves over 30 years (one every two year)
- End of century (2100s): In all cities, at least 25 heatwaves (almost one per year)

Selection of extreme heatwaves: example for Los Angeles





Future weather data: Projected changes in the extreme heatwaves intensity and duration



Extreme heatwave intensity (max daily mean Temp):

- Increase up to 5°C by the end of the century

Extreme heatwave duration :

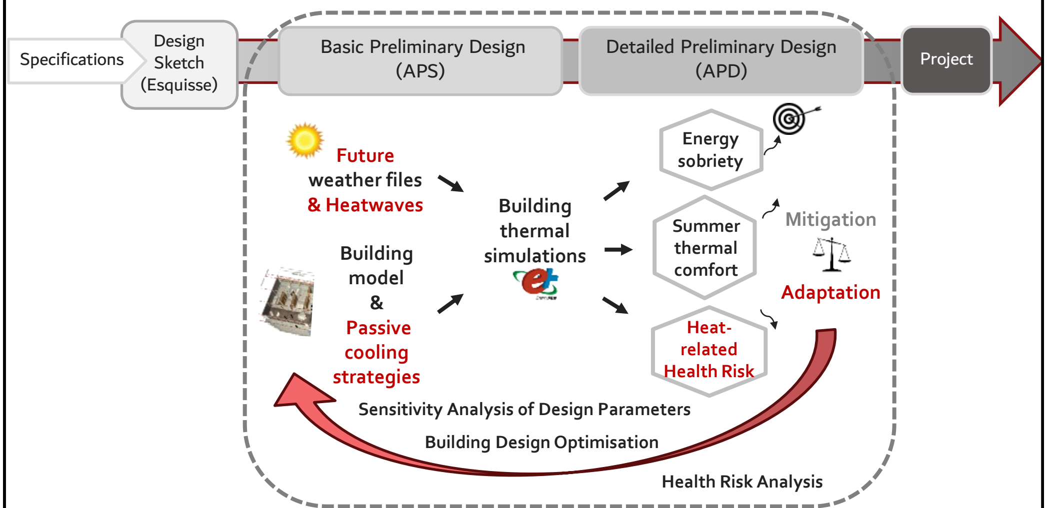
- 3 weeks to 1 month by mid-century
- 1 to 2 months by the end of the century

Data Paper to come with published datasets

Building design using future heatwave weather files

CSTB le futur en construction

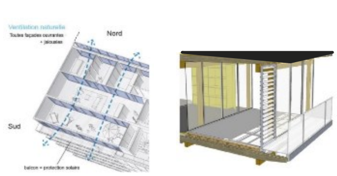
Contribution to building design

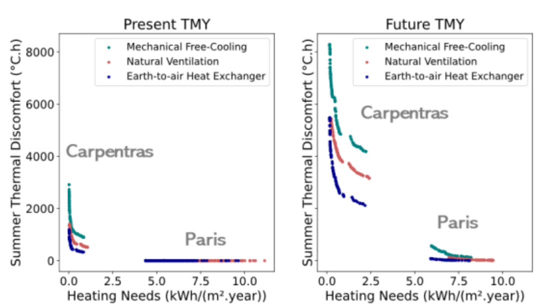


CSTB le futur en construction

Mitigation & Adaptation strategies: Ventilative cooling solutions

Residential case-study building compliant with latest French thermal regulation (RE-2020), cross-ventilation & buffer zones





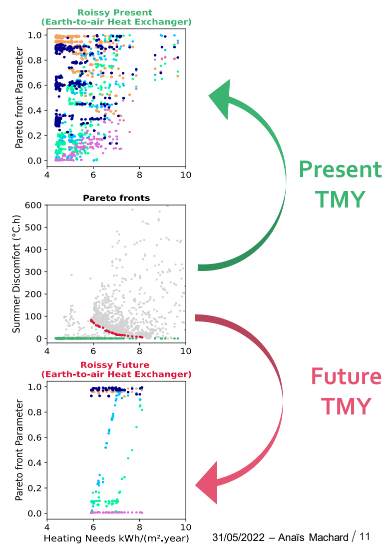
- During the present TMY, in Paris no discomfort, in Carpentras it can be minimized
- During the future TMY, in Paris discomfort is increased, in Carpentras it is very high
- Earth-to-air heat exchanger > Night-cooling natural ventilation > Mechanical free-cooling

Mitigation & Adaptation strategies

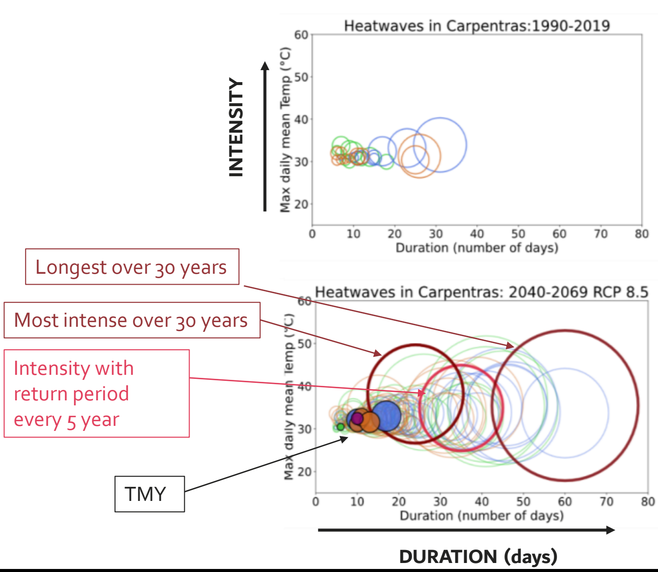
Optimization of building designs (algorithm NSGA-II) after selection of the **most influential parameters** based on sensitivity analysis results

	Parameter	Abbreviation	Min	Max	Unit
Building envelope	Optical properties of exterior coating	Roof α & ε	0.1	0.9	-
	Thermal mass (ceiling, floor & walls)	Thermal Mass	650	2300	kg/m³
Bioclimatic architecture	Overhang length (South)	Overhang L	0	1	m
	Glazing % North & South	Glazing %	35	95	%
Ventilative cooling solution: Earth-to-air heat exchanger	Airflow Rate	Airflow EAHX	0.054	0.270	m³/s

- During the present TMY, different optimized building designs can lead to no thermal discomfort
- During the future TMY, less optimized building design options possible to lead to reduced thermal discomfort



Which heatwave should we use to assess potential health risk ?



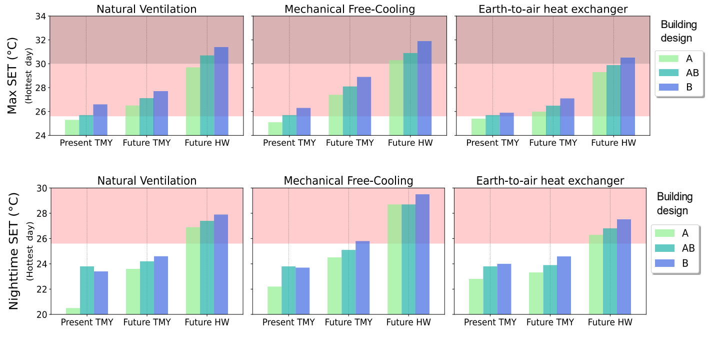
Decision based on risk assessment

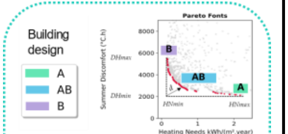
Adaptation ➔ "Typical" HW

?

Resilience ➔ "Extreme" HW

Health risk assessment under future typical heatwave





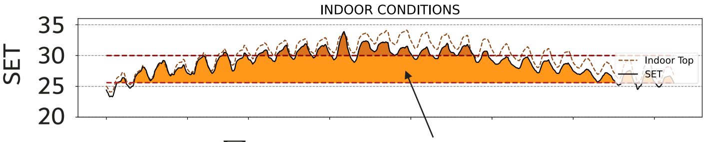
	A	AB	B
Thermal Mass	High	High	High
Glazing %	Low	Low	Low /Medium
Roof A&E	High	Medium/High	Low
Overhang	Yes	No	No
VCS Airflow	Max	Max	Max

SET Scale

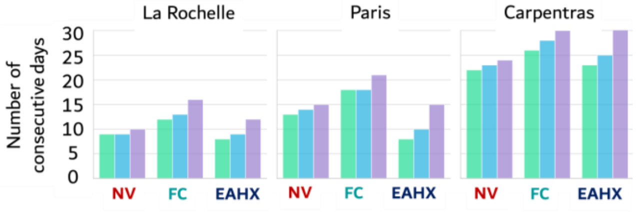
- > 37.5 Very hot (failure of thermoregulation)
- 34.5 – 37.5 Hot (profuse sweating)
- 30 – 34.5 Warm (sweating)
- 25.6 – 30 Slightly warm (slight sweating)

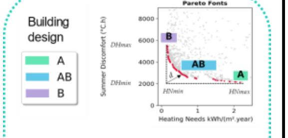
- Daytime and nighttime overheating during future « Typical HW », not noticed with only TMY (UHI effects not included)

Number of consecutive days with potential health risk during future typical heatwave



$$\sum_{N}(\mathrm{SET}_{\mathrm{daytime}}\ AND\ \mathrm{SET}_{\mathrm{nighttime}}) > 25.6\ °C$$



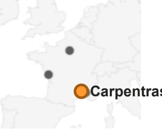


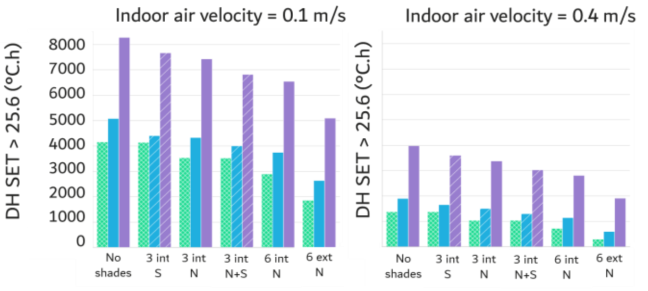
	A	AB	B
Thermal Mass	High	High	High
Glazing %	Low	Low	Low /Medium
Roof A&E	High	Medium/High	Low
Overhang	Yes	No	No
VCS Airflow	Max	Max	Max

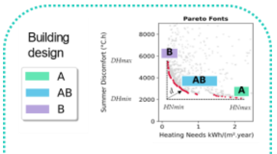
SET Scale

- > 37.5 Very hot (failure of thermoregulation)
- 34.5 – 37.5 Hot (profuse sweating)
- 30 – 34.5 Warm (sweating)
- 25.6 – 30 Slightly warm (slight sweating)

Mitigation & Adaptation strategies: Occupant behavior







	A	AB	B
Thermal Mass	High	High	High
Glazing %	Low	Low	Low /Medium
Roof A&E	High	Medium/High	Low
Overhang	Yes	No	No
VCS Airflow	Max	Max	Max

- Discomfort of optimized building designs 8000 °C.h → 300 °C.h
- Acceptable indoor daylighting levels (300 lux)

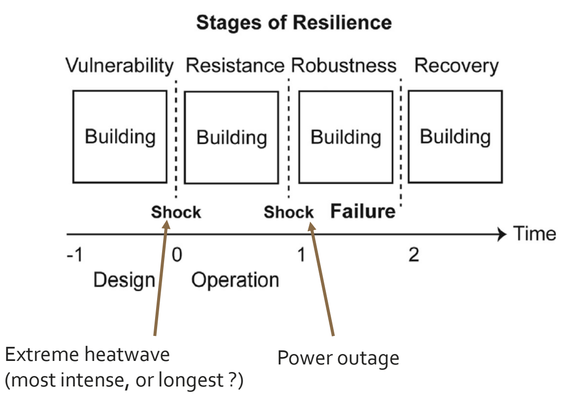
SET Scale

- **> 37.5** Very hot (failure of thermoregulation)
- **34.5 – 37.5** Hot (profuse sweating)
- **30 – 34.5** Warm (sweating)
- **25.6 – 30** Slightly warm (slight sweating)

Illuminance

- > 1000 lux
- 1000 >lux >500
- 500 >lux >300

Perspectives
Annex 80 Resilient Cooling for Buildings



<u>**Questions:**</u>

What are the indoor conditions ?

Is there a health risk ?

How long will the building take to go back to the initial indoor conditions (recovery phase) ?

Conclusions & Perspectives

Conclusions:

- Methodology with new design objective: minimize heat stress risk (different than thermal discomfort!)
- Quantification of potential health risk **indoors** during future heatwaves (datasets will be published)
- **Combination of several mitigation & adaptation strategies needed** to attenuate the risk (ICU mitigation + building envelope + ventilative cooling strategies + behavioral adaptations + active cooling systems might be necessary)

Perspectives (Work within Annex 80):

- Evaluation of the building thermal resilience to indoor overheating and potential health-risk during extreme heatwaves, evaluation of active cooling systems resilience during extreme scenarios with heatwaves + power outages

LA ROCHELLE UNIVERSITÉ

ÉCOLE DOCTORALE EUCLIDE
Laboratoire des Sciences de l'Ingénieur pour l'Environnement
UMR – 7356 CNRS

Towards mitigation and adaptation to climate change:
Contribution to Building Design

Anaïs MACHARD

Thèse soutenue le 21 juillet 2021
pour l'obtention du grade de Docteur de La Rochelle Université
Discipline : Génie Civil
Thèse dirigée par Christian INARD

JURY :		
Christian INARD	Professeur, Université de la Rochelle	Directeur de thèse
Dionysia KOLOKOTSA	Professeur, Technical University of Crete	Rapportrice
Christophe MENEZO	Professeur, Université Savoie Mont Blanc	Président du jury
Mathilde PASCAL	Docteur HDR, Santé Publique France	Examinatrice
Charles PELE	Docteur, Ingénieur CSTB	Examinateur
Mattheos SANTAMOURIS	Professeur, University of New South Wales	Rapporteur
Etienne WURTZ	Directeur de recherche, CEA/LITEN	Examinateur
INVITES :		
Sylvain GASTE	Maitre de conference ENSA Nantes, Architecte, Altersmith	Invité
Jacques RIBERON	Docteur, Chercheur CSTB	Invité

https://www.researchgate.net/publication/360835380_Towards_mitigation_and_adaptation_to_climate_change_Contribution_to_Building_Design

Thank you !

Anaïs Machard
anais.machard@cstb.fr
CSTB : Scientific and Technical Center for Buildings, France
Linkedin, ResearchGate

Lessons learned from Annex 80 simulations of resilient-cooling strategies with future-climate data

Sang Hoon Lee (sanghlee@lbl.gov)
Ronnen Levinson (rmlevinson@lbl.gov)

Lawrence Berkeley National Laboratory, Berkeley, CA, USA

Future weather data and heatwaves (venticool webinar)
Online · May 31, 2022

Simulation method

We modeled eight resilient cooling strategies for medium-office buildings and single-family homes across U.S. climate zones 1 - 5

Cooling strategies

1. Cool roof
2. Cool walls
3. Solar-control windows
4. Fixed exterior shading system
5. Operable window shading system
6. Natural ventilation opening area
7. Natural ventilation operation schedule
8. Ceiling fans

Categories

- Medium-office building
- Single-family home

Vintages

- Oldest: pre-1980
- Older: post-1980
- Current

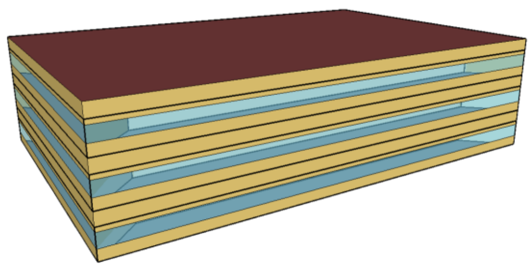
Cities and climate zones

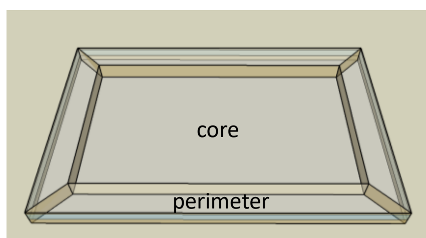
- Miami (CZ 1A)
- Phoenix (CZ 2B)
- Atlanta (CZ 3A)
- Los Angeles (CZ 3B)
- Baltimore (CZ 4A)
- Chicago (CZ 5A)

We modeled individual resilient cooling strategies in medium-office buildings

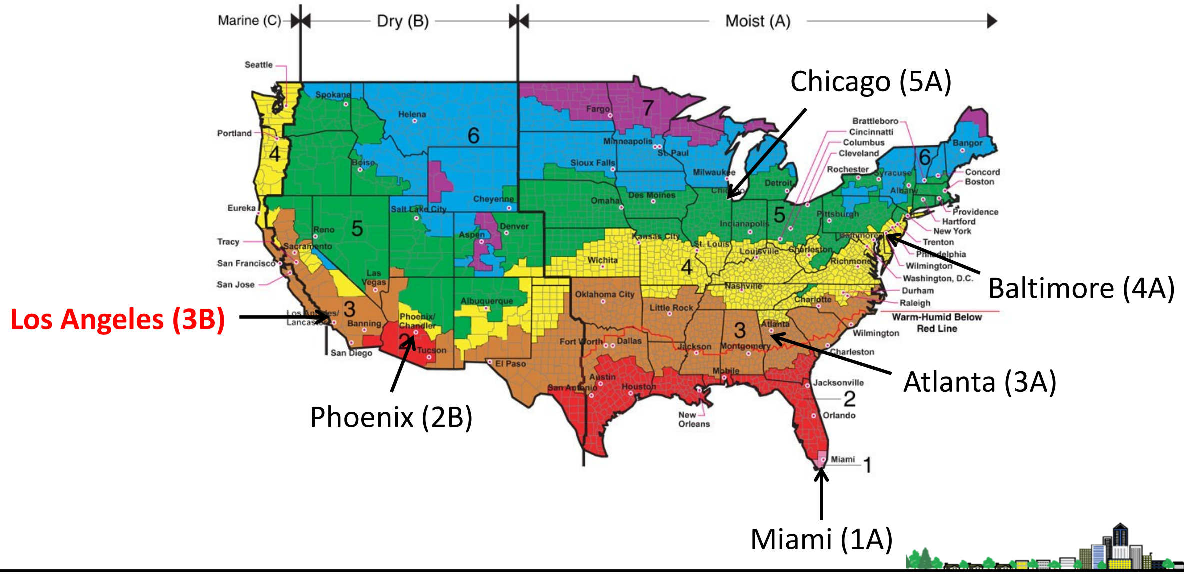
Medium office US DOE reference EnergyPlus model

- Total floor area 4,982 m^2
- 3 floors
- 15 zones
- 1 core and 4 perimeter zones per floor
- Window-to-wall ratio 0.33
- Two-speed DX cooling systems serving each zone
- Gas furnace heating systems serving each zone





We modeled strategies in 6 U.S. climate zones (1A, 2B, 3A, 3B, 4A, and 5A)



We modeled past, present, and future climates in Los Angeles (3B)

- 4 weather files for Los Angeles (LA)
  - TMY3, CORDEX 2010, CORDEX 2050, CORDEX 2090

LA Weather Data	Year coverage	Average temperature {C}	Cooling Degree Days 18C	Cooling Days 18C	Heating Degree Days 18C	Heating Days 18C	Global Horizontal Radiation {Wh/m2}			Direct Normal Radiation {Wh/m2}			Diffuse Horizontal Radiation {Wh/m2}		
							Average	Summer	Winter	Average	Summer	Winter	Average	Summer	Winter
TMY3	1991-2005	16.8	326	138	751	226	208	294	122	201	244	155	80	108	52
CORDEX2010	2001-2020	16.6	395	126	910	237	220	291	138	210	245	162	85	106	63
CORDEX2050	2041-2060	17.8	618	171	705	190	214	276	144	201	223	169	86	108	65
CORDEX2090	2081-2100	19.4	894	230	392	131	203	260	132	187	207	152	85	102	63

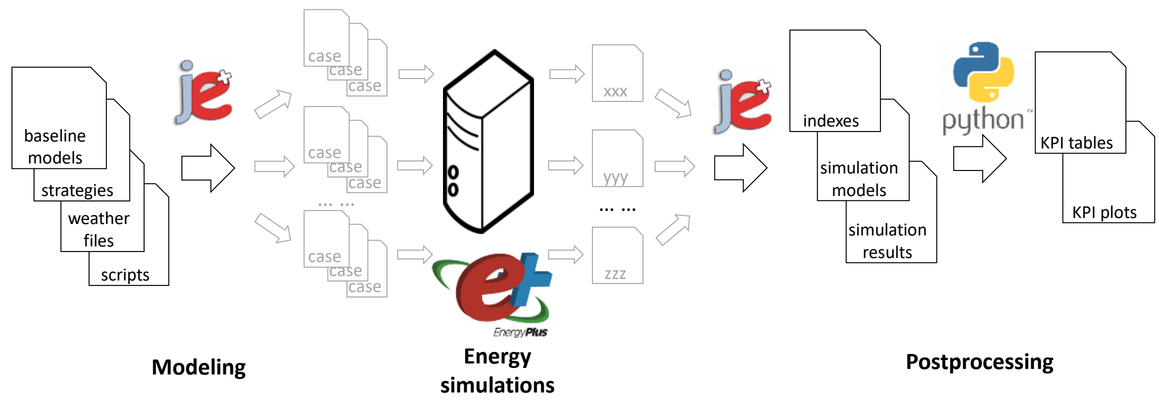
Grayed radiation values were replaced with CORDEX 2010 data

- CORDEX 2010 solar radiation data were used for all weather files
- HVAC system sizing is based on the TMY3 weather file (per Annex 80 guidelines)

We used EnergyPlus, jePlus, and custom Python postprocessing code to simulate buildings

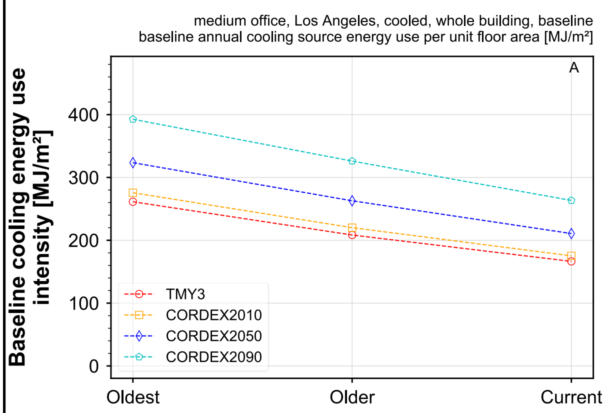
- EnergyPlus 9.6 for building energy simulation
- jePlus 1.2.7 for parametric run

KPI = Key Performance Indicator

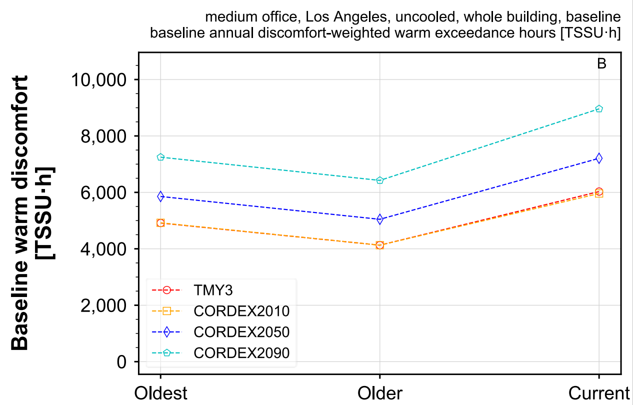


Baseline

Baseline values of energy use intensity (left) and discomfort (right) were evaluated by vintage and weather file (climate year) for the medium-office building in Los Angeles



A: Annual cooling source energy use per unit floor area



B: Annual discomfort-weighted warm exceedance hours

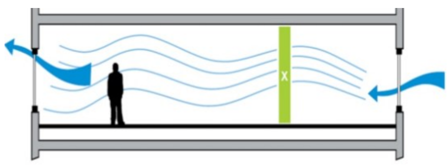
- **Discomfort-weighted warm exceedance hours** is the sum of the positive values of (PMV - 0.7) during occupied hours, where PMV is capped at +4.
- PMV differences have units of TSSU·h (thermal sensation scale unit). For example, PMV 3 – PMV 1 = 2 TSSU

#6: Natural ventilation opening area

We simulated window opening fractions from 0% to 50%

The natural ventilation opening area strategy saves cooling energy and improves thermal comfort by providing cooler air.

- Case 0 = fraction of window area that is operable: 0%
- Case 1 = fraction of window area that is operable: 2.5%
- Case 2 = fraction of window area that is operable: 5%
- Case 3 = fraction of window area that is operable: 10%
- Case 4 = fraction of window area that is operable: 25%
- Case 5 = fraction of window area that is operable: 50%

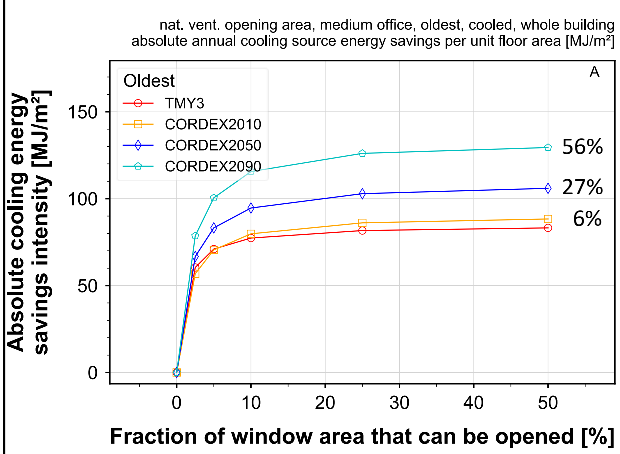


(image courtesy: Chikkalgi 2017)

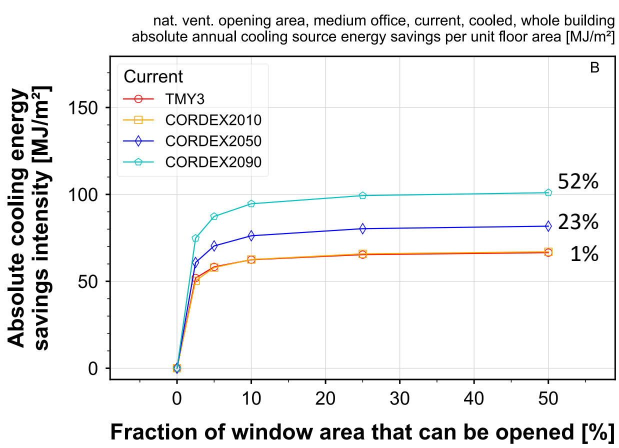
i. Windows are closed when the outdoor air temperature is equal to or lower than the heating set point.
ii. In air-conditioned buildings, windows are closed when the outdoor air temperature is equal to or higher than the occupied-hour cooling set point, and open otherwise.

In Los Angeles, natural ventilation saves more cooling energy in the future

Oldest vintage (Pre-1980)

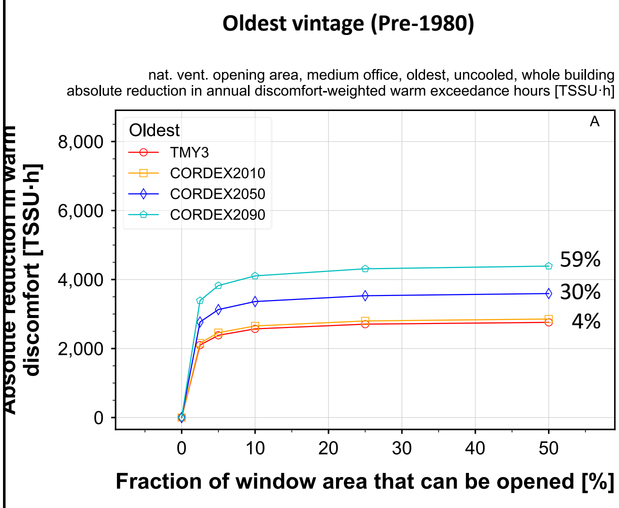


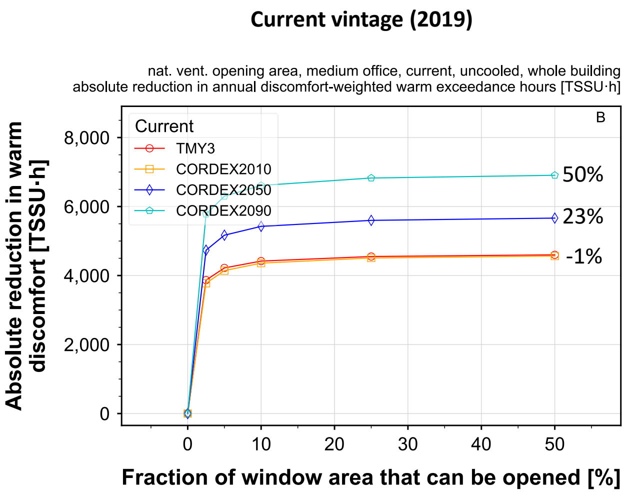
Current vintage (2019)



% improvements are relative to TMY3

In Los Angeles, natural ventilation provides greater discomfort reduction in the future





% improvements are relative to TMY3

#8: Ceiling fans

We simulated ceiling fans corresponding to air speeds of 0.1, 0.4, 0.8, 1.2, and 1.6 m/s

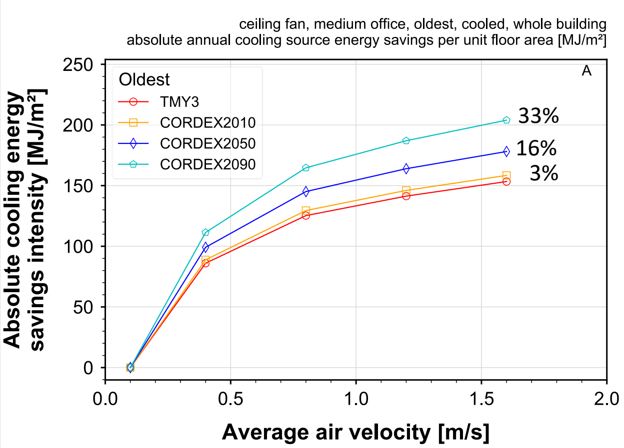
Ceiling fans improve thermal comfort by increasing average air speed (AAS), letting us raise the cooling set point (CSP).

- Case 0 = AAS 0.1 m/s (no fan), CSP 24.9 °C
- Case 1 = AAS 0.4 m/s, CSP 2.0 °C > case 0
- Case 2 = AAS 0.8 m/s, CSP 3.1 °C > case 0
- Case 3 = AAS 1.2 m/s, CSP 3.6 °C > case 0
- Case 4 = AAS 1.6 m/s, CSP 4.0 °C > case 0

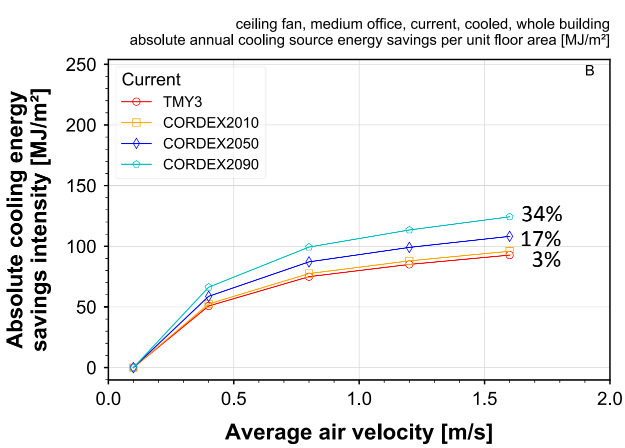
(image courtesy: homewarranty.firstam.com)

In Los Angeles, ceiling fans save more cooling energy in the future

Oldest vintage (Pre-1980)

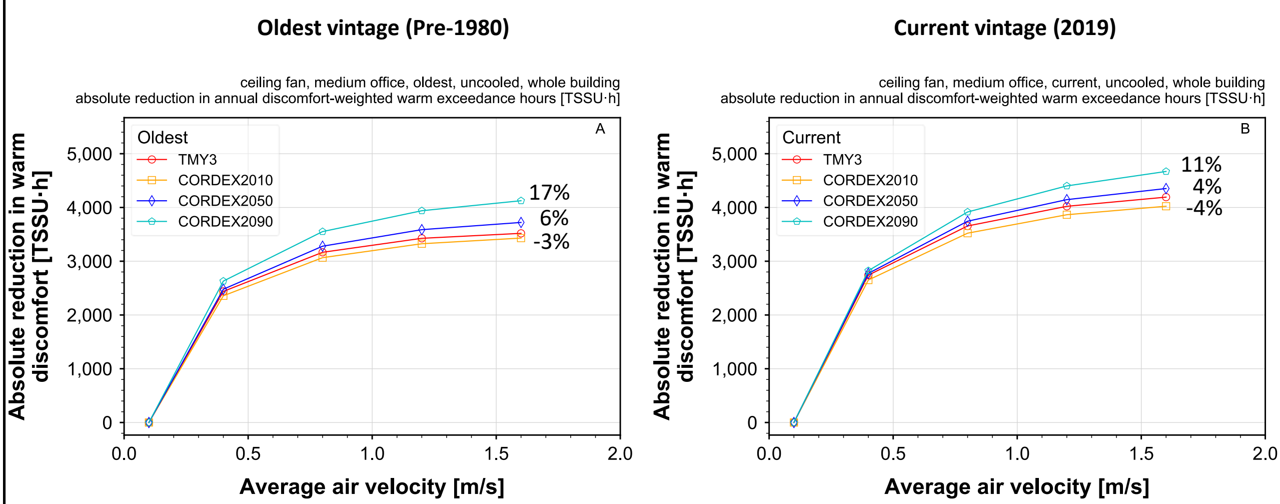


Current vintage (2019)



% improvements are relative to TMY3

In Los Angeles, ceiling fans provide greater discomfort reduction in the future

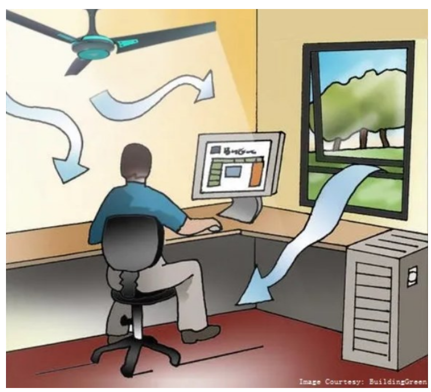


% improvements are relative to TMY3

17

Key takeaways from simulation results

- Future weather matters: in Los Angeles, natural ventilation and ceiling fan strategies provide up to 56% more cooling energy savings and up to 59% more warm-discomfort reduction in future climates
- Fractional increases in cooling energy savings and warm-discomfort reductions were similar for pre-1980 and current medium-office buildings
- Future energy savings and warm-discomfort reductions were greatest in CORDEX 2090



(image source: BuildingGreen)

18

Key takeaways from simulation process

- Look for and resolve unexplained changes in the solar radiation data
- Verify that annual average temperature, annual cooling degree days rise in the future while annual heating degree days decline
- Use latest version of EnergyPlus
- The simulation process is otherwise straightforward

(image source: almanac.com)

Thank you!