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Impact of interactions between buildings and their outdoor conditions on the calibration of an urban building energy model

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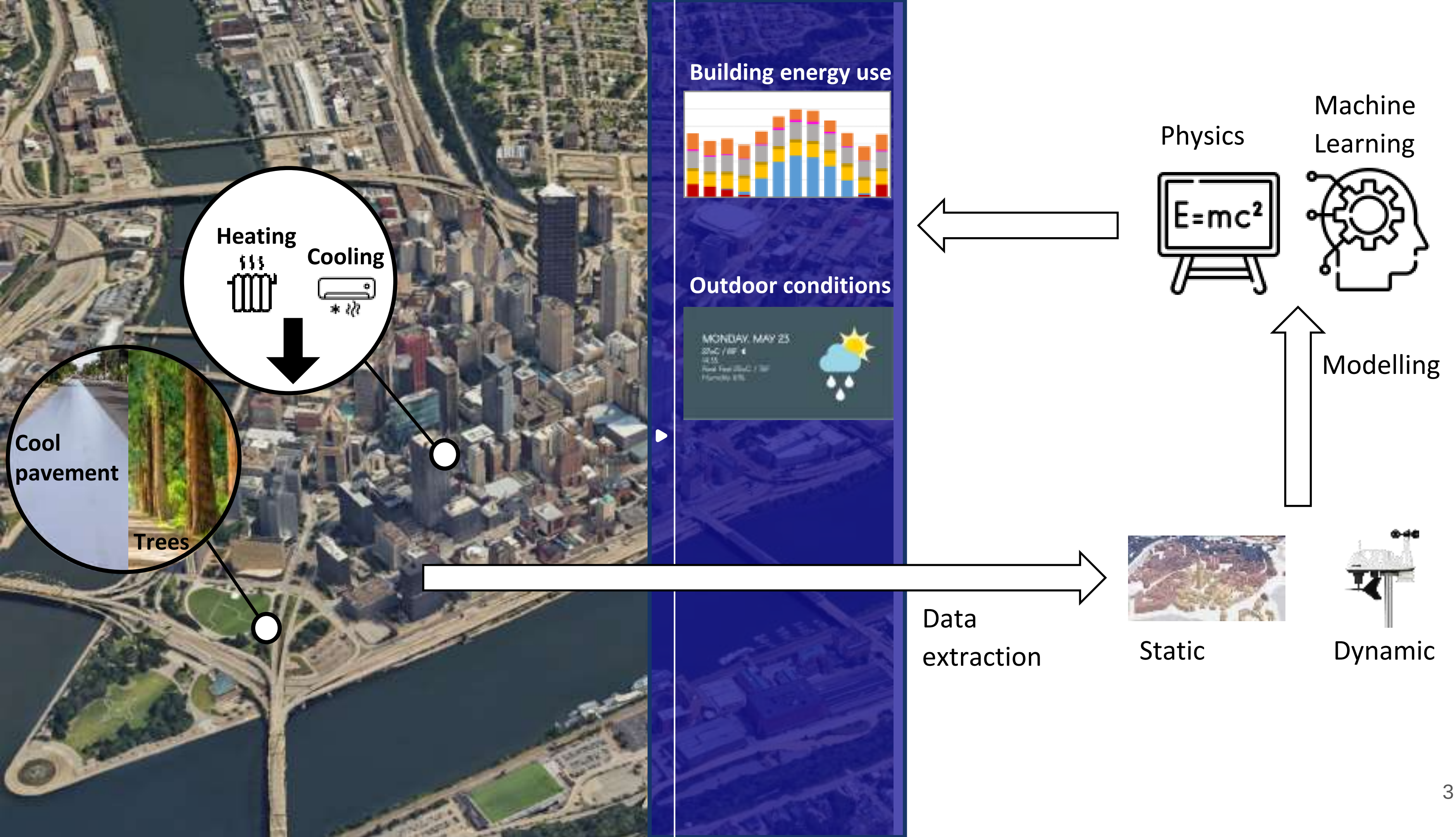
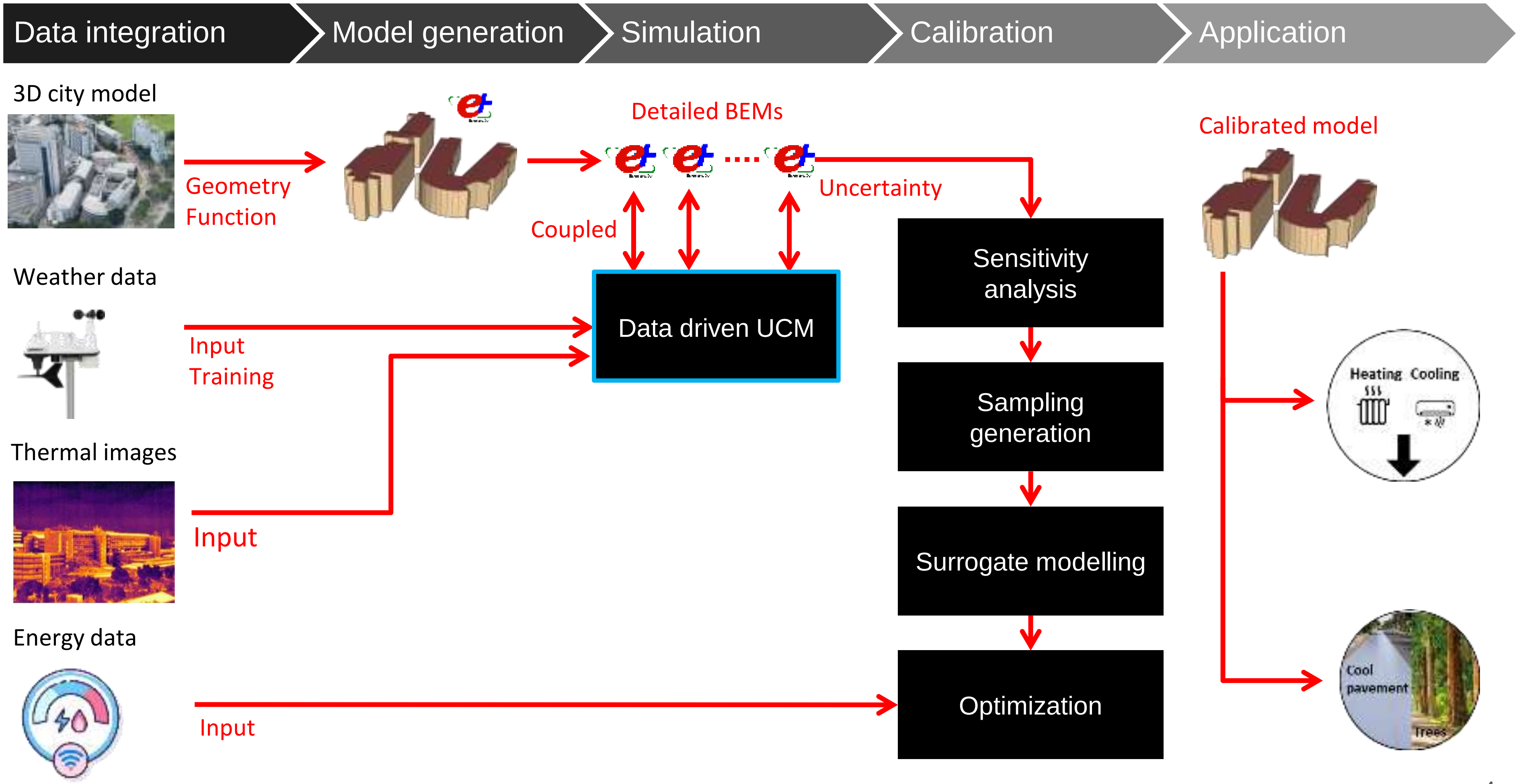
in collabortion with Carnegie Mellon University


CO2


HORIZON
EUROPE


Now
2030
2050
100 cities
in Europe
All cities
in Europe

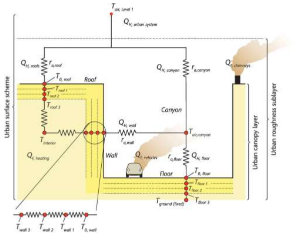

Building energy use
Outdoor conditions
MONDAY, MAY 23
Heating
Cooling
Cool
pavement
Trees
Physics
Machine
Learning
E=mc²
Modelling
Data
extraction
Static
Dynamic



Data integration
Model generation
Simulation
Calibration
Application
3D city model
Geometry
Function
Detailed BEMs
Coupled
Uncertainty
Calibrated model
Weather data
Input
Training
Data driven UCM
Sensitivity analysis
Sampling generation
Surrogate modelling
Optimization
Heating Cooling
Thermal images
Input
Energy data
Input
Cool pavement
Trees

Physically-based approach

Energy and mass balance



Oke et al. (2017)

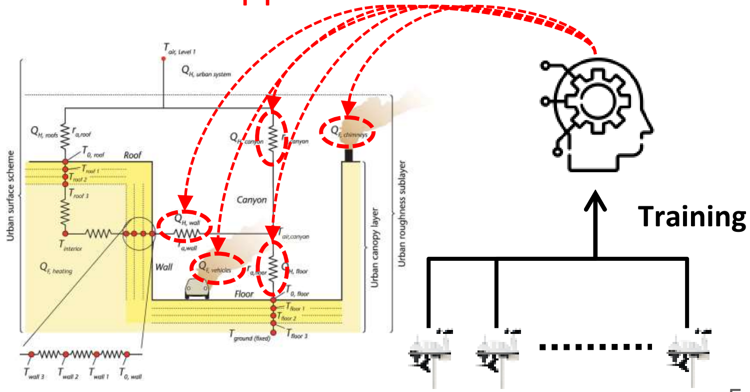
Low level of detail

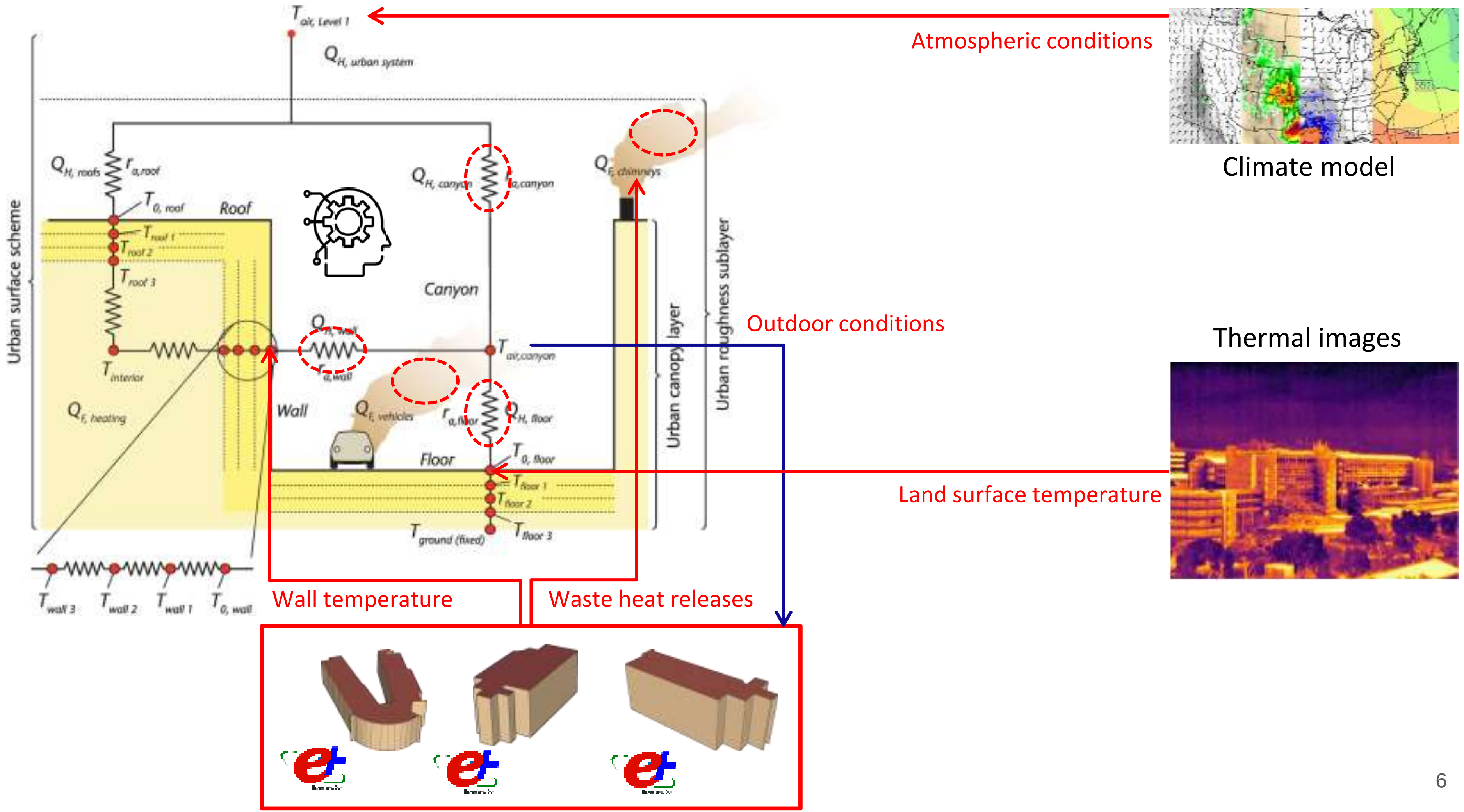
CFD

Yap (2021)

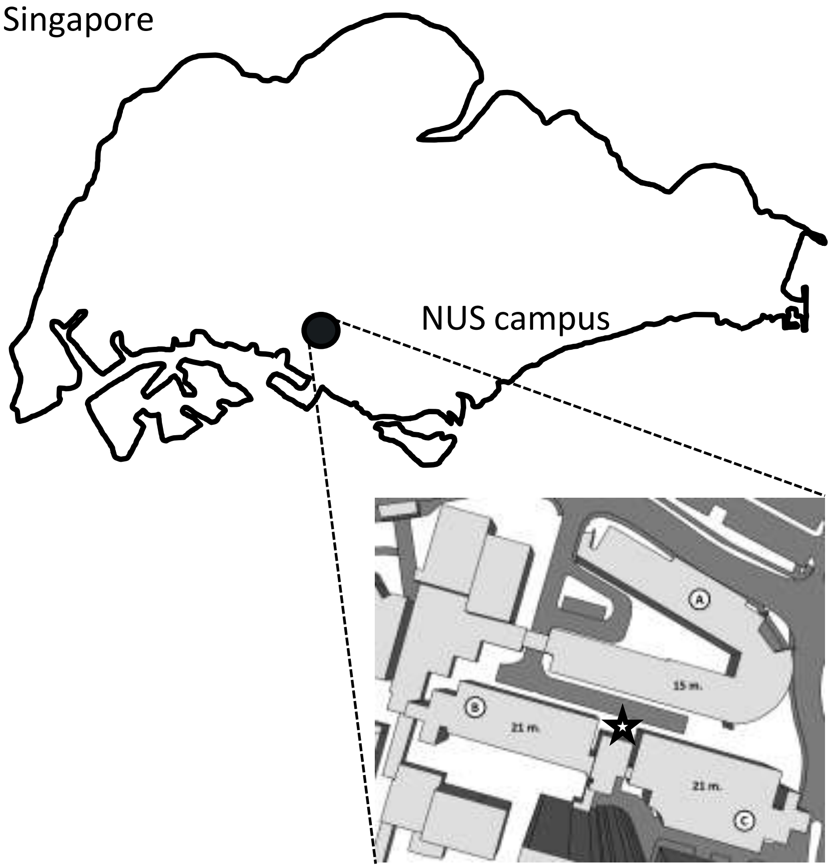
High computational cost

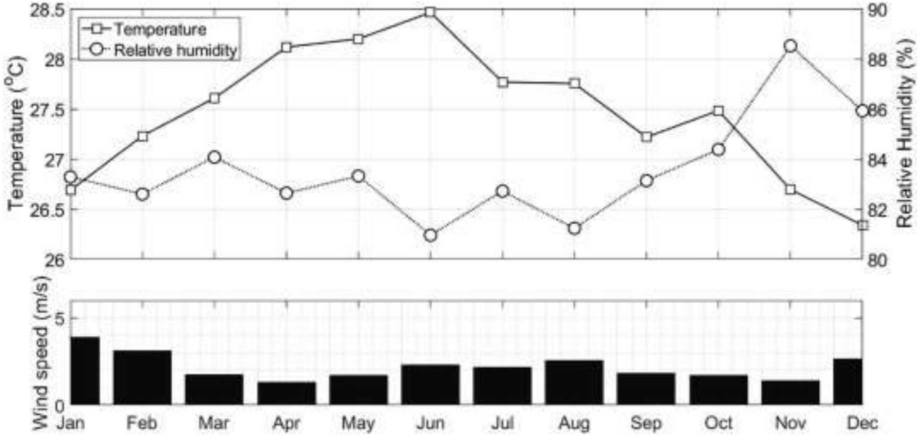
Data driven approach



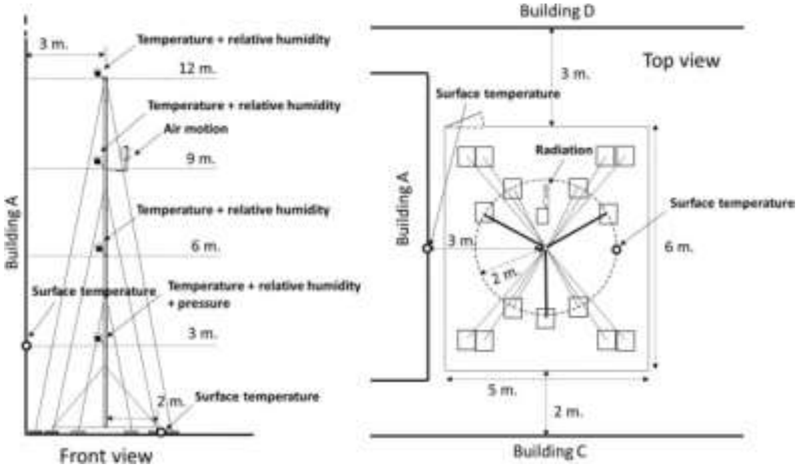


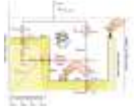
Atmospheric conditions
Climate model
Outdoor conditions
Thermal images
Land surface temperature
Wall temperature
Waste heat releases
Urban surface scheme
Urban canopy layer
Urban roughness sublayer
Roof
Canyon
Wall
Floor
T air, Level 1
Q H, urban system
Q H, roofs
r a,roof
T 0, roof
T roof 1
T roof 2
T roof 3
T interior
Q F, heating
Q H, canyon
r a,canyon
Q F, chimneys
Q H, wall
r a,wall
T air,canyon
Q F, vehicles
r a,floor
Q H, floor
T 0, floor
T floor 1
T floor 2
T floor 3
T ground (fixed)
T wall 3
T wall 2
T wall 1
T 0, wall





Miguel et al. (2021)



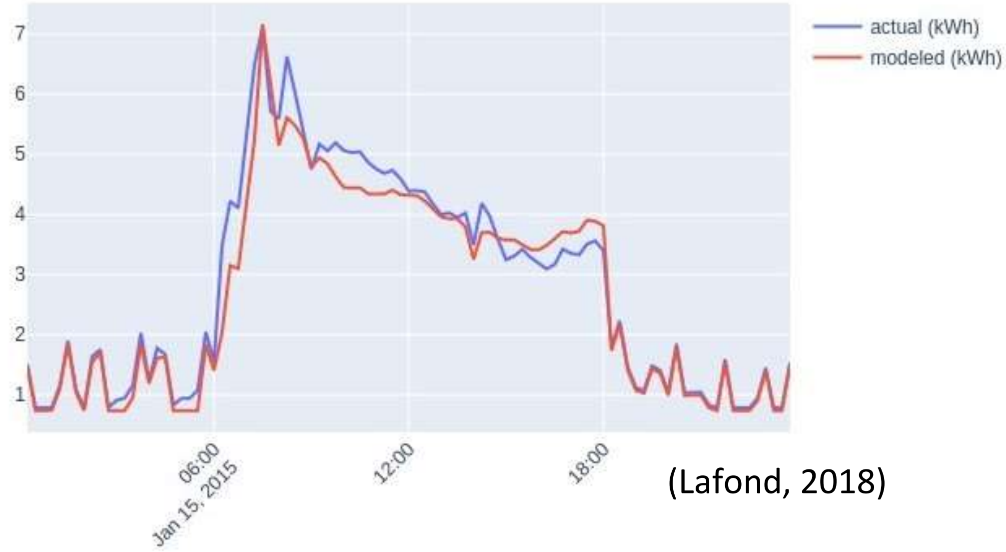
Uncoupled  versus Coupled  

Sensitivity analysis → Sampling generation → Surrogate modelling → Optimization

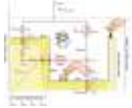
Goodness-of-fit

$$\mathrm{CV(RMSE)} = \frac{1}{\overline{Y}} \sqrt{\frac{\sum_{i=1}^{N} (Y_i - \hat{Y}_i)^2}{N}}$$

Total heating/cooling load



(Lafond, 2018)

Uncoupled  versus Coupled  

Sensitivity analysis

↓

Sampling generation

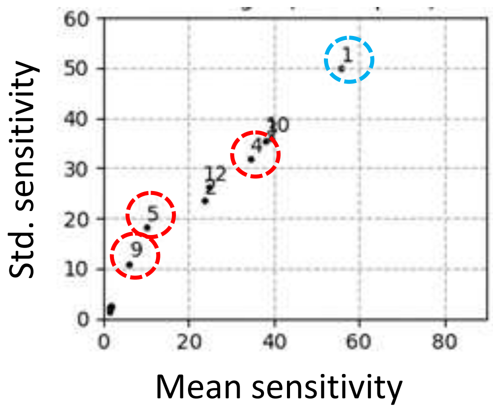
↓

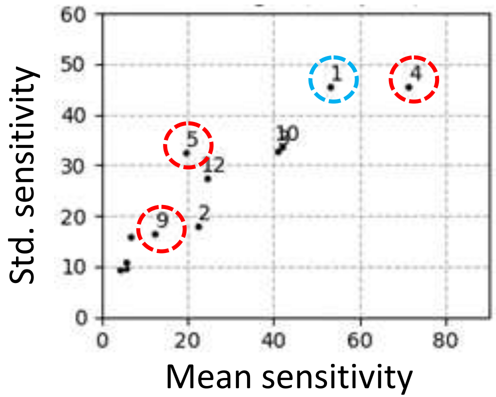
Surrogate modelling

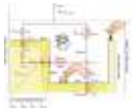
↓

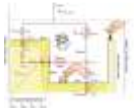
Optimization

θ	Description	θ_l	θ_u
θ_1	Occupancy (in people)	1.21×10^2	3.03×10^3
θ_2	Light intensity (in W)	1.21×10^4	1.21×10^5
θ_3	Equipment intensity (in W)	1.82×10^4	1.82×10^5
θ_4	Infiltration (in m^3/s)	0.01	10.00
θ_5	Wall thermal resistance (in W/m^2-K)	0.05	3.00
θ_6	Wall density (in kg/m^3)	3.00×10^2	1.80×10^3
θ_7	Wall specific heat capacity (in J/kg-K)	4.00×10^2	1.50×10^3
θ_8	Wall thermal emissivity (0-1)	0.01	0.98
θ_9	Wall solar absorptivity (0-1)	0.05	0.90
θ_{10}	Window-to-wall ratio (0-1)	0.01	0.90
θ_{11}	Window thermal resistance (in W/m^2-K)	0.04	1.50
θ_{12}	Window solar heat gain (0-1)	0.20	0.90

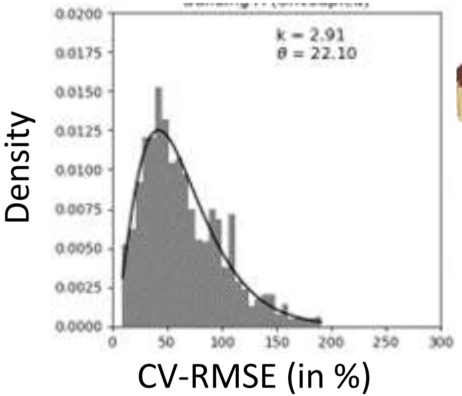


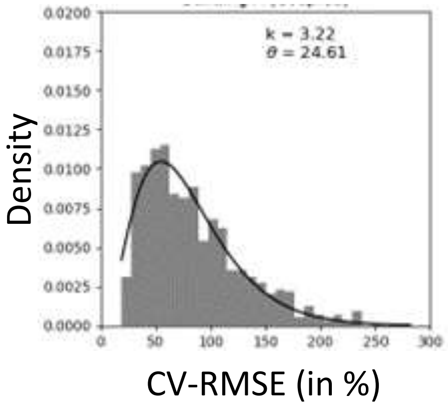


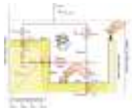



Uncoupled  versus Coupled  

- Sensitivity analysis
- **Sampling generation**
- Surrogate modelling
- Optimization



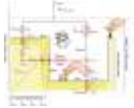




ASHRAE

	Building A		Building B		Building C	
	20%	30%	20%	30%	20%	30%
Uncoupled	7.2	17.2	3.9	13.5	4.4	13.0
Coupled	3.5	9.6	3.7	9.6	3.0	8.6

θ	Building A coeff.	Building A t	Building B coeff.	Building B t	Building C coeff.	Building C t
θ_1	0.0141	27.1	0.0156	35.4	0.0140	28.8
θ_2	0.0001	10.0	0.0001	11.1	0.0001	8.9
θ_3	0.0001	14.7	0.0002	21.3	0.0002	18.4
θ_4	4.1065	27.0	4.7787	37.6	4.2432	29.8
θ_5	-1.6943	-3.4	-1.2795	-2.9	0.0304	0.1
θ_6	-0.0012	-1.1	-0.0007	-0.7	-0.0006	-0.6
θ_7	-0.0052	-3.6	-0.0020	-1.7	-0.0011	-0.8
θ_8	-3.9092	-2.8	-2.3606	-1.7	-0.9580	-0.6
θ_9	3.6317	2.0	11.7867	7.8	14.0499	8.0
θ_{10}	41.6530	24.5	28.1425	20.1	24.8345	16.3
θ_{11}	2.7882	2.7	2.4681	-2.9	3.7907	3.7
θ_{12}	33.4358	15.7	22.3531	12.6	20.9123	10.2
C	20.8267	17.4	21.8236	21.8	18.2139	16.3

Uncoupled  versus Coupled  

Sensitivity analysis

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Sampling generation

↓

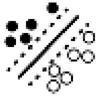
Surrogate modelling

↓

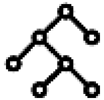
Optimization

LR

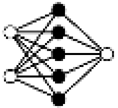
SVM



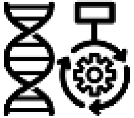
RF



ANN



GA



Conclusions

- Interactions between buildings and their outdoor conditions can be simulated with a high temporal resolution and considering urban morphology with a high fidelity using a coupling between EnergyPlus and a data driven urban canopy model
- It is observed that interactions between buildings and their outdoor conditions have a significant impact on the calibration of an urban building energy model
- A full data driven model could be inferred from a calibrated coupled scheme to assess climate risk over a horizon of 20 or 30 years
- The coupled scheme and full data driven model could easily be integrated into a city digital twin to assist architects and urban planners in their decision making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HOME
PUBLICATIONS
TEACHING
AWARDS
CV
I am a postdoctoral researcher sponsored by the Marie-Curie Global fellowship to contribute to the mission Climate Neutral and Smart Cities in collaboration with the Delft University of Technology and Carnegie Mellon University.

Q&A Session