W'ALL IN ONE: MODA

Modeling on an envelope scale

OVERVIEW of the simulation			
1	**User Case**	Heat and moisture transfer modeling on system (wall envelope) level to assess the thermal and moisture performance of such systems in different boundary conditions. to analyze the impact of the newly developed systems on 1D heat losses, on thermal bridge (2D) heat losses, and on inner surface temperature with a condensation and mould growth risk assessment.	
2	**Chain of Models**	**Model 1**	Heat transport: continuum model conservation of energy equation (1st law of thermodynamics) • Heat transfer due to conduction (diffusion) • Heat transfer due to convection • Heat transfer due to radiation • Fourier's law (conductive flow) • Newton's law of cooling (convective flow) • Stefan Boltzmann's law (radiative flow)
		Model 2	Moisture transport: continuum model conservation of mass (moisture transfer) • Fick's first law (vapour flow) • Darcy's law (liquid flow)
3	**Publication on the simulation**		
4	**Access conditions**	bought software license *(for WUFI or Delphin)*	

1	**Aspect of the User Case/System to be Simulated**
1.1	**Aspect of the User Case to be simulated and how it forms a part of the total user case**	Analyze the impact of adding the newly developed system at the interior surface of historical brick walls (taken as an e.g.) on the heat losses, and on inner surface temperature with a condensation and mould growth risk assessment
1.2	**Material**	e.g.: Brick with Aerogel blanket layer and plaster on the interior
1.3	**Geometry**	Cartesian (1D)
1.4	**Time Lapse**	5 years
1.5	**Manufacturing process or in-service conditions**	External forces : heat (for e.g. solar radiation) and moisture (for e.g. rain) (the source is the weather data)
1.6	**Publication on this one simulation**	

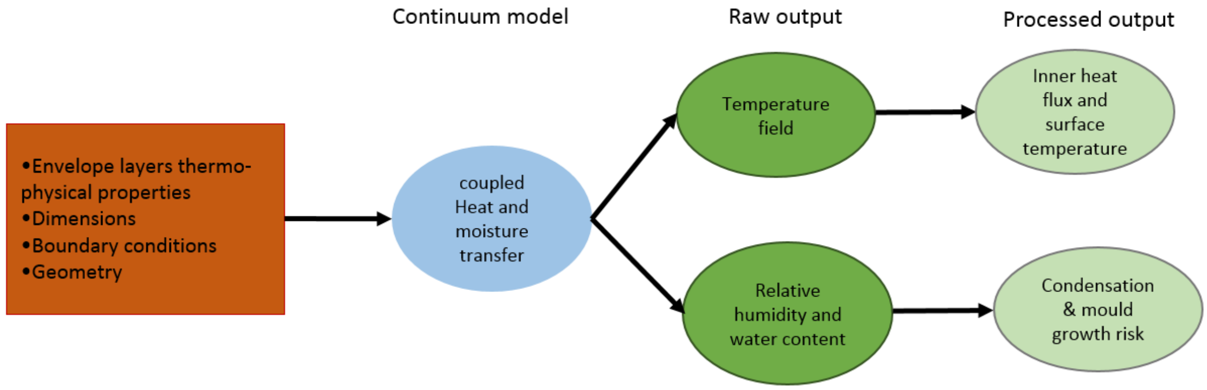
2	**Generic Physics Of The Model Equation**		
2.0	**Model type and name**	Tightly coupled equations: Heat transport: continuum model Moisture transport: continuum model	
2.1	**Model entity**	finite volumes	
2.2	**Model Physics/**	**Equations**	PE1: $\frac{dH}{dT}\frac{\partial T}{\partial t} = \nabla(\lambda \nabla T) + h_v \nabla(\delta_p \nabla(\varphi P_{sat}))$

	CHEMISTRY EQUATION PE’S		PE2: $\frac{dw}{d\varphi}\frac{\partial\varphi}{\partial t} = \nabla(D_{\varphi}\nabla\varphi + \delta_p\nabla(\varphi P_{sat}))$
		Physical quantities for each equation	PE1: Physical quantities H=enthalpy (J) T = temperature (K) φ = relative humidity (-) λ = thermal conductivity (W/(mK)) t = time (s) δ_p = water vapour permeability (kg/(msPa)) hv = evaporation enthalpy (J/kg) $Psat$ = water vapour saturation pressure (Pa) PE2: Physical quantities w = water content (kg/m3) φ = relative humidity (-) D_{φ} = liquid conduction coefficient (kg/(ms)) t = time (s) δ_p = water vapour permeability (kg/(msPa)) $Psat$ = water vapour saturation pressure (Pa)
2.3. MATERIALS RELATIONS			1. The material’s thermal conductivity as a function of temperature (for PE1) 2. The material’s thermal conductivity as a function of moisture content (for PE1) 3. The material’s specific heat capacity (for PE1) 4. water vapour permeability or water vapour diffusion resistance factor (for PE1 and PE2) 5. the material’s liquid conduction coefficient or liquid absorption coefficient (for PE2) 6. The sorption isotherm curve (for PE2) *(all the above are the results of experimental measurments)*
2.4	**SIMULATED INPUT**		NA

3	**SPECIFIC COMPUTATIONAL MODELLING METADATA**		
3.1	**NUMERICAL SOLVER**		Finite volume • Fully implicit for the discretization in time
3.2	**SOFTWARE TOOL**		WUFI or Delphine (https://wufi.de/en/ ; http://bauklimatik dresden.de/delphin/index.php?aLa=en)
3.3	**TIME STEP**		Variable (1h or less)
3.4	**COMPUTATIONAL REPRESENTATION**	**PHYSICS EQUATION, MATERIAL RELATIONS, MATERIAL**	written up for finite volumes
		BOUNDARY CONDITIONS	The physics b.c. are written up for the faces of the outer finite volumes
		ADDITIONAL SOLVER PARAMETERS	

4	**POST PROCESSING**	
4.1	**THE PROCESSED OUTPUT IS CALCULATED FOR**	Temperatures will be used to estimate the thermal losses/gains throughout the envelope Relative humidity will be used to estimate the moisture risks (such as condensation)
4.2	**METHODOLOGIES**	physics definition for loss and gain literature relations for condensations and mould as function of temperature and humidity
4.3	**MARGIN OF ERROR**	

Work flow:



Modeling on a building scale

OVERVIEW of the simulation			
1	**User Case**	Assess the impact of applying the developed internal thermal insulation systems to retrofit an old house on the energy demands and thermal comfort.	
2	**Chain of Models**	**Model 1**	Heat transport: continuum model conservation of energy equation (1st law of thermodynamics) • Heat transfer due to conduction (diffusion) • Heat transfer due to convection • Heat transfer due to radiation • Fourier's law (conductive flow) • Newton's law of cooling (convective flow) • Stefan Boltzmann's law (radiative flow)
3	**Publication on the simulation**		
4	**Access conditions**	Free software *(for EnergyPlus)*	

1	**Aspect of the User Case/System to be Simulated**	
1.1	**Aspect of the User Case to be simulated and how it forms a part of the total user case**	analyze the impact of adding the newly developed system at the interior surface of to retrofit an old house on the heating and/or cooling demands
1.2	**Material**	e.g.: an old brick house with Aerogel blanket layer on the interior
1.3	**Geometry**	Cartesian
1.4	**Time Lapse**	1 year
1.5	**Manufacturing process or in-service conditions**	Statistical weather conditions
1.6	**Publication on this one simulation**	

2	**Generic Physics Of The Model Equation**	
2.0	**Model type and name**	Heat transport: continuum model
2.1	**Model**	Finite volume

	ENTITY		
2.2	**MODEL PHYSICS/ CHEMISTRY EQUATION PE'S**	**Equations**	PE1: $\rho cp \frac{\partial T}{\partial t} = \nabla(\lambda\nabla \mathrm{T})$
		Physical quantities for each equation	PE1: Physical quantities T = temperature (K) λ = thermal conductivity (W/(mK)) t = time (s) ρ = density (kg/m3) cp = specific heat (J/(kg.K))
2.3. MATERIALS RELATIONS			1. The material's thermal conductivity (for PE1) 2. The material's specific heat capacity and density (for PE1) *(all the above are the results of experimental measurements)*
2.4	**SIMULATED INPUT**		

3	**SPECIFIC COMPUTATIONAL MODELLING METADATA**		
3.1	**NUMERICAL SOLVER**	Finite difference Difference scheme: FullyImplicitFirstOrder	
3.2	**SOFTWARE TOOL**	EnergyPlus (https://energyplus.net/)	
3.3	**TIME STEP**	1h or less	
3.4	**COMPUTATIONAL REPRESENTATION**	**PHYSICS EQUATION, MATERIAL RELATIONS, MATERIAL**	written up for finite difference
		BOUNDARY CONDITIONS	Weather data (temperature, radiation, …)
		ADDITIONAL SOLVER PARAMETERS	Inside face temperature convergence criteria: <0.0001

4	**POST PROCESSING**	
4.1	**THE PROCESSED OUTPUT IS CALCULATED FOR**	Temperatures will be used to estimate heating/cooling loads
4.2	**METHODOLOGIES**	physics definition for loss and gain
4.3	**MARGIN OF ERROR**	