

Determination of Buildings' Thermo-Physical Characteristics Through Inverse Modelling

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Digital Twins for
Performance Prediction
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Building Energy Epidemiology

Introduction:

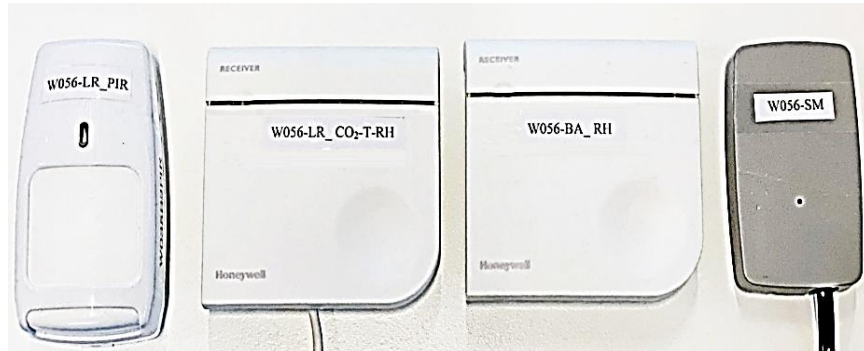
The Study

- A measurement campaign of 100 houses has been carried out: OPSCHALER project
- The data is analyzed for 1 sample apartment (1 year measurement).
- A lumped RC circuit is used for inverse modelling.

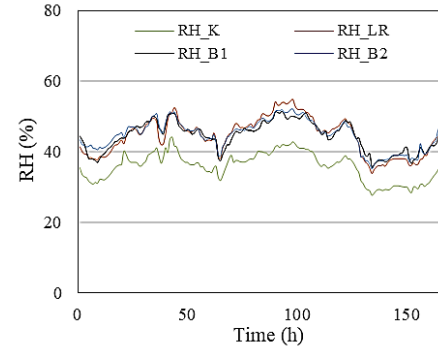
Aim: finding the global thermo-physical characteristics of the building in order to diagnose



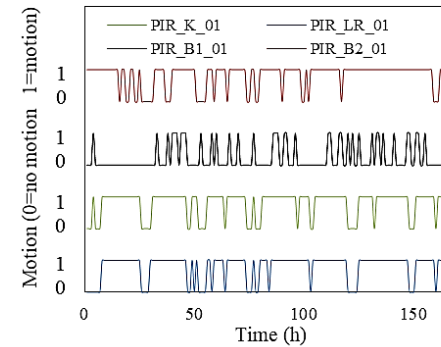
Data Preparation: Indoor Air Data



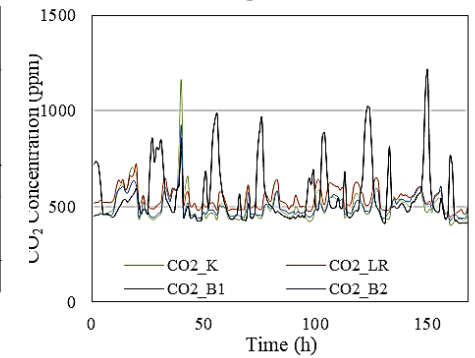
C: Average Room Relative Humidity



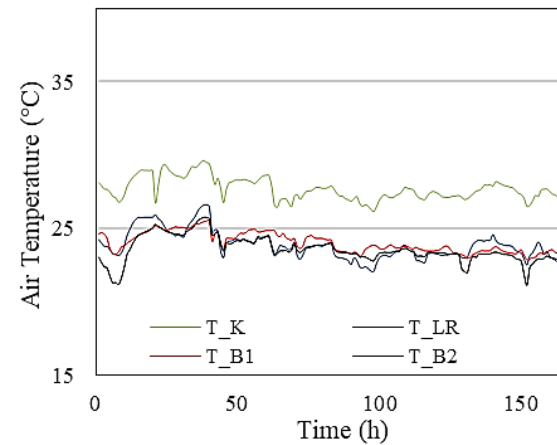
D: Motion



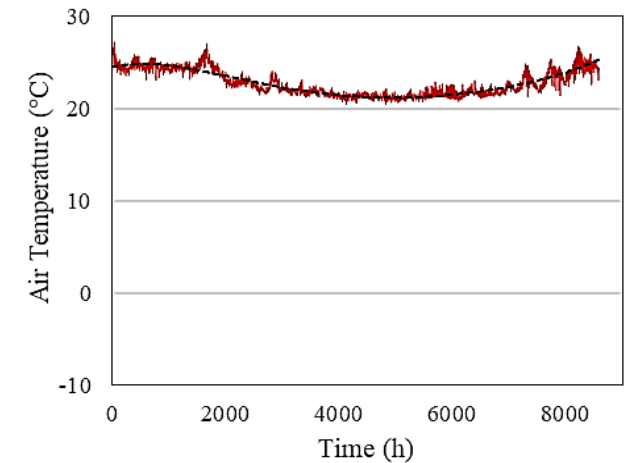
B: Room CO₂ Concentration



A: Average Room Air Temperature



Average Indoor Temperature



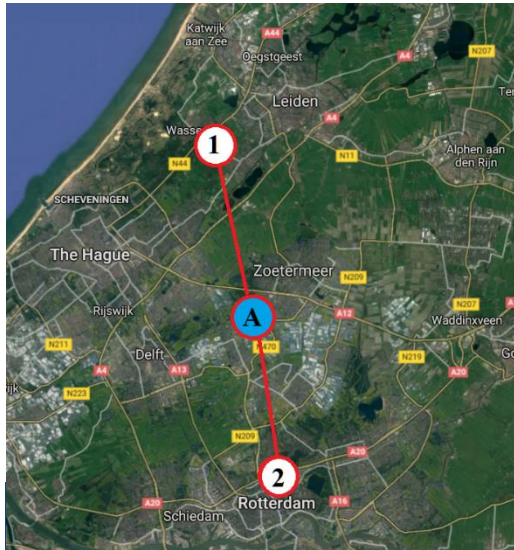
- Data preparation:
- Time Stamp Synchronization
 - Sensor Calibration and Correction
 - Dealing with Missing data
 - Data Aggregation

$$T_K \quad T_{LR} \quad T_{B1} \quad T_{B2} \quad \longrightarrow \quad T_{in}^{\infty}$$

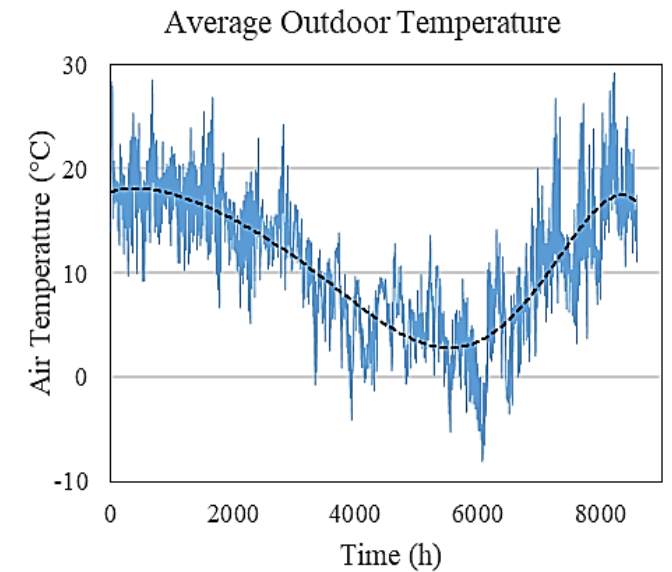
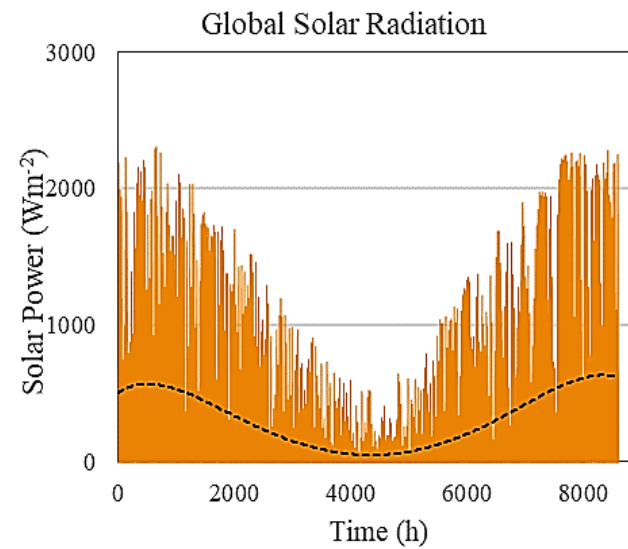
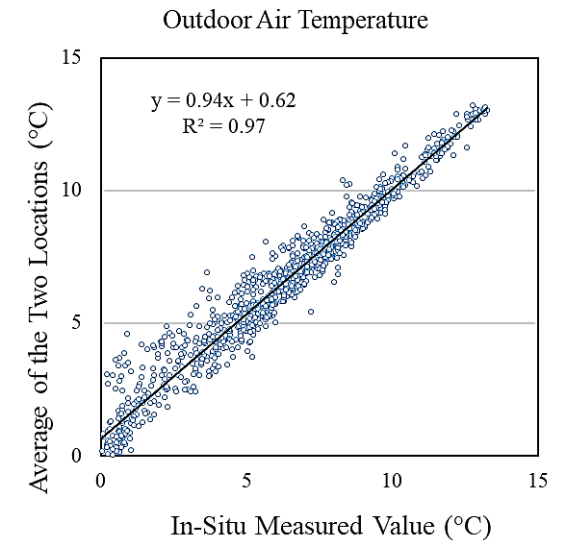
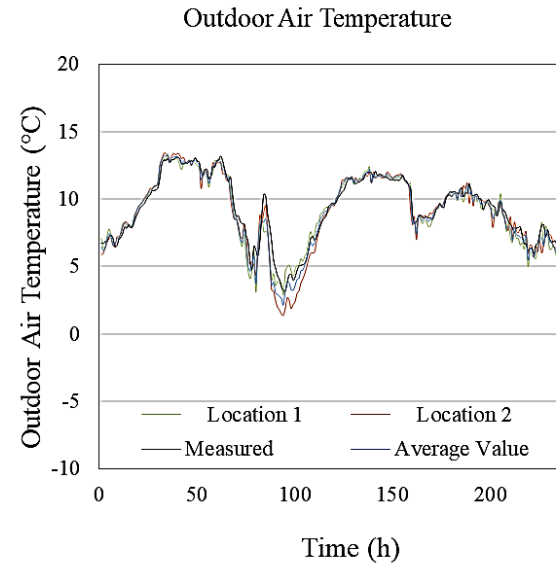
Data Preparation : Meteorological Data

KNMI Data

Weather Station



 Koninklijk Nederlands
Meteorologisch Instituut
Ministerie van Infrastructuur en Waterstaat



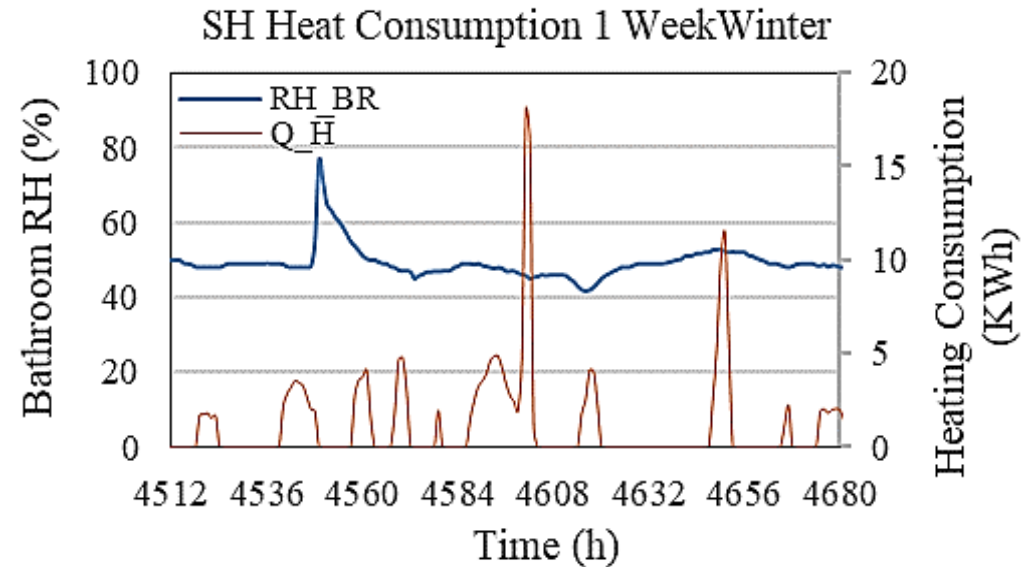
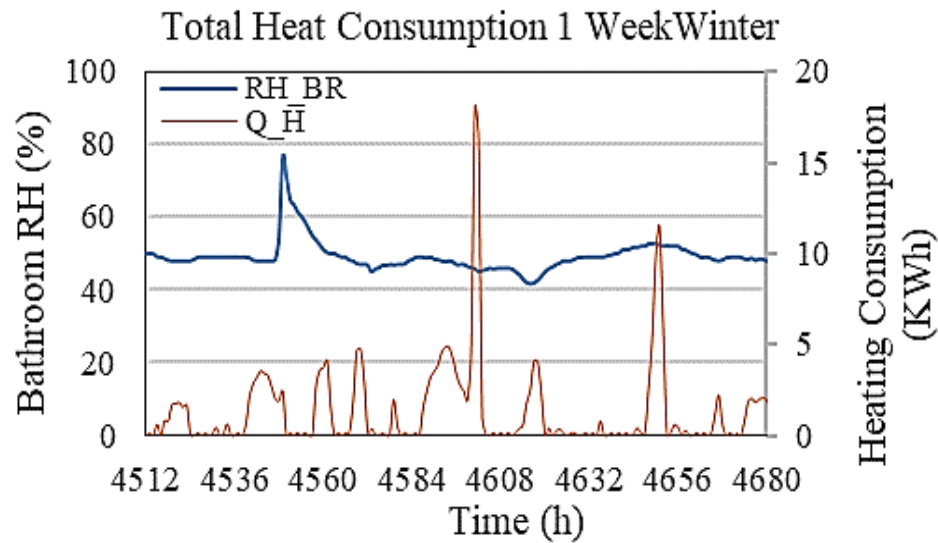
Data Preparation :

Energy Data



Smart Meter Gas Data

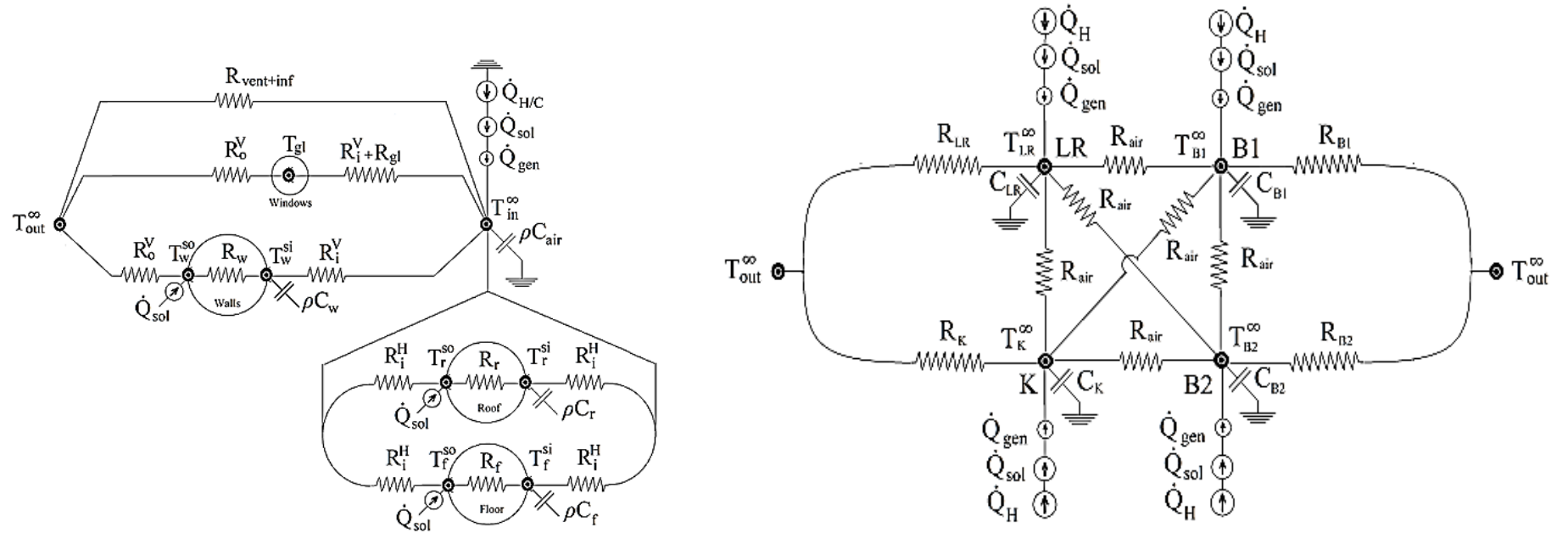
- Space Heating
- Domestic Hot Water
- Cooking and Noise (e.g. boiler set point)



Grey-Box Modelling:

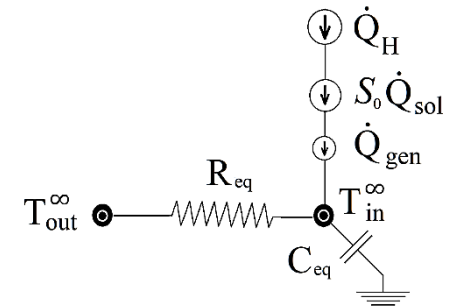
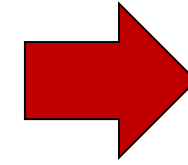
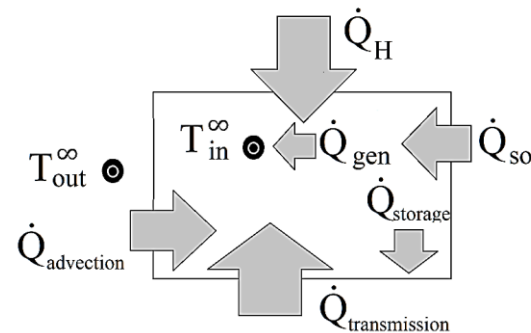
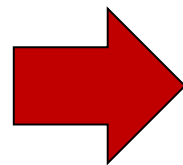
The Choice of Model:

High Resolution
Forward Modelling



Low Resolution

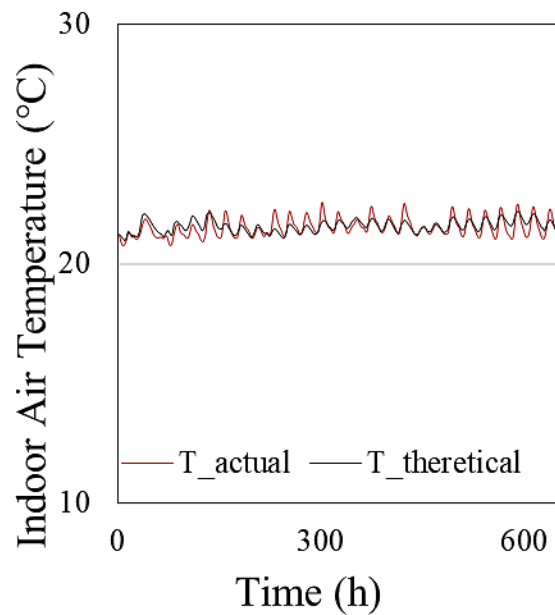
Inverse Modelling



Inverse Modelling:

Period Granularity

- 1 Year
- 1 Season
- 1 Month
- 2 Weeks
- 1 Week
- 1 Day
- Hourly
- Daily
- Weekly



$$\frac{1}{R_{eq}} \left[(\rho c_p \dot{V})_{air} + \sum_{i=1}^4 U_i A_i \right] [T_{out}^{\infty} - T_{in}^{\infty}] - \sum_i \frac{\partial T}{\partial t} (\rho c V)_i + \eta \cdot [\dot{Q}_H] + S_0 \cdot [P_{sol}] + S_1 = 0$$

$$\text{Min}_{\frac{1}{R_{eq}}, C, S_0, S_1} \sqrt{\frac{1}{n} \sum_{i=1}^n \left(\left(\eta \dot{Q}_{H_i} + S_0 \dot{Q}_{sol_i} + S_1 + \frac{1}{R_{eq}} [T_{out}^{\infty}]_i + C_{eq} [T_{in}^{\infty}]_{t-1}^{th} \right) \left(\frac{1}{R_{eq}} + C_{eq} \right)^{-1} - T_i^{ac} \right)^2}$$

s.t. $R_{eq}^{-1} \in [10, 180]$; $C_{eq} \in [1E5, 1E9]$; $S_0 \in [0, 1]$; $S_1 \in [0, 2000]$

Incorporating the dynamic effects:
Fitting T rather than \dot{Q} in the objective function

$$\left[\frac{1}{R_{eq}} \quad C_{eq} \quad S_0 \quad S_1 \right]$$

Evaluation:

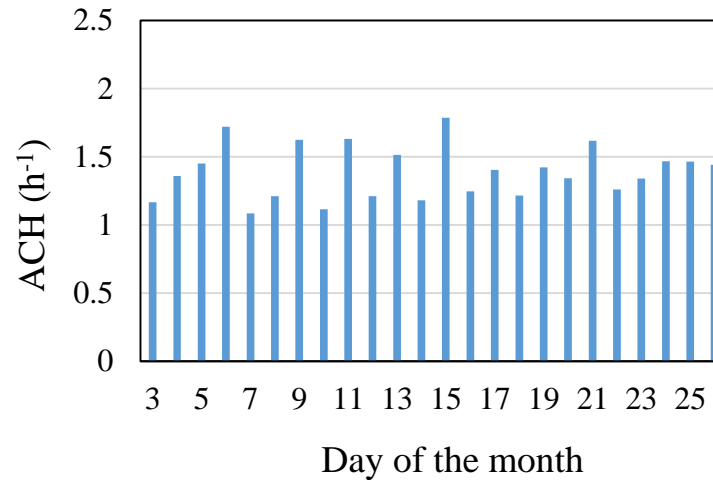
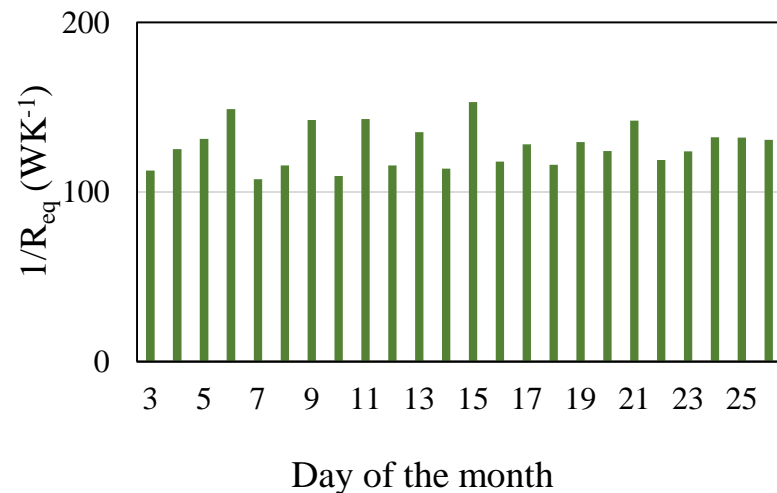
Determination of building's daily heat loss coefficient and airborne heat loss:

Air Change

Transmission

$$\frac{1}{R_{eq}} = (\rho C_p \dot{V})_{air} + \frac{1}{R_f + \alpha_h^{-1}} + \frac{A_r}{\alpha_{h,i}^{-1} + l_r/k_r + \alpha_{h,o}^{-1}} + \frac{A_w}{\alpha_{v,i}^{-1} + l_w/k_w + \alpha_{v,o}^{-1}} + \frac{A_{gl}}{\alpha_{v,i}^{-1} + l_{gl}/k_{gl} + \alpha_{v,o}^{-1}}$$

Construction Report + Inspection + Questionnaire OR In-Situ Measurement



Evaluate ACH:
CO₂ Concentration
Wind Velocity

Thank You !

Questions?

