ANN BASED THERMAL MODELING OF BUILDINGS

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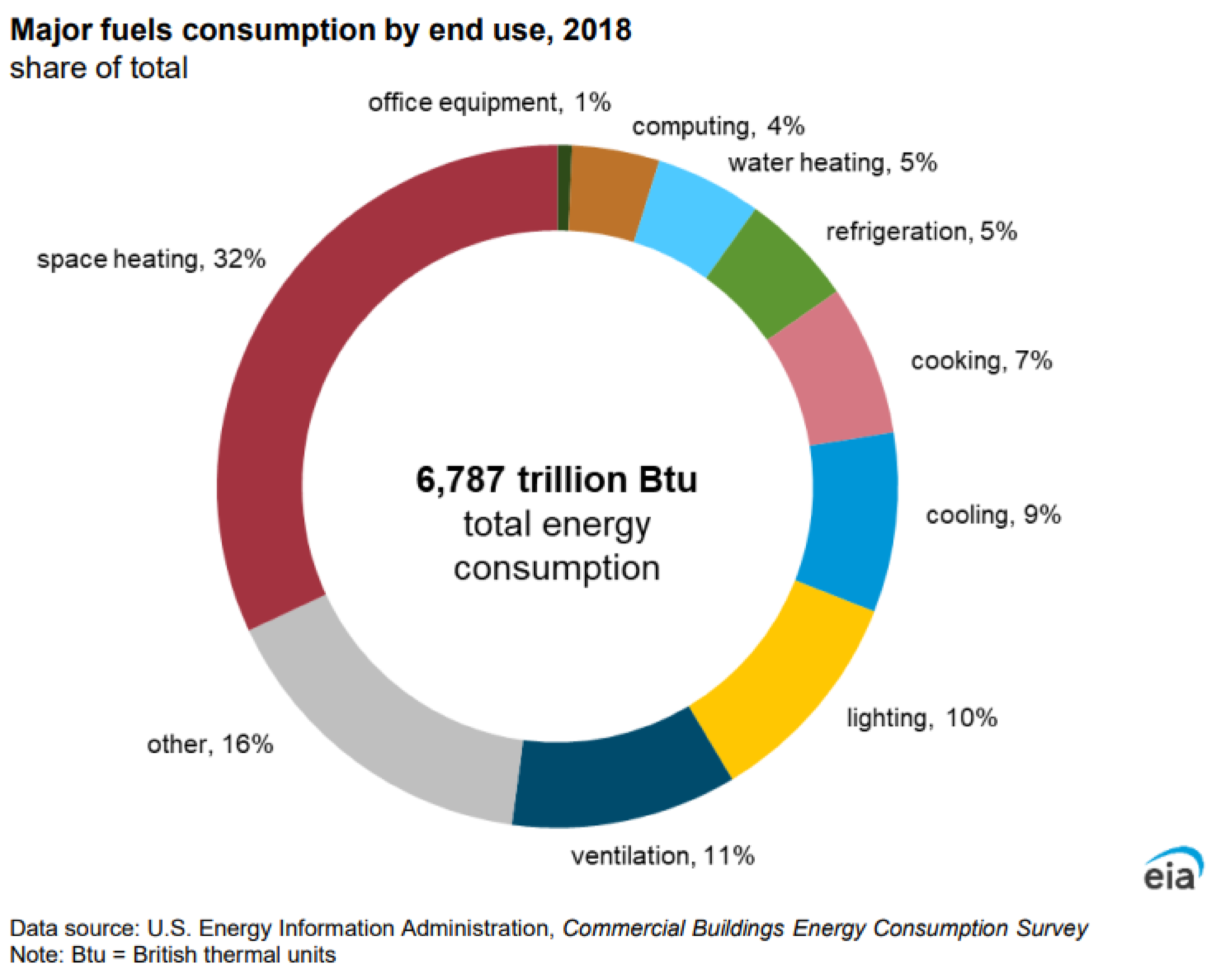
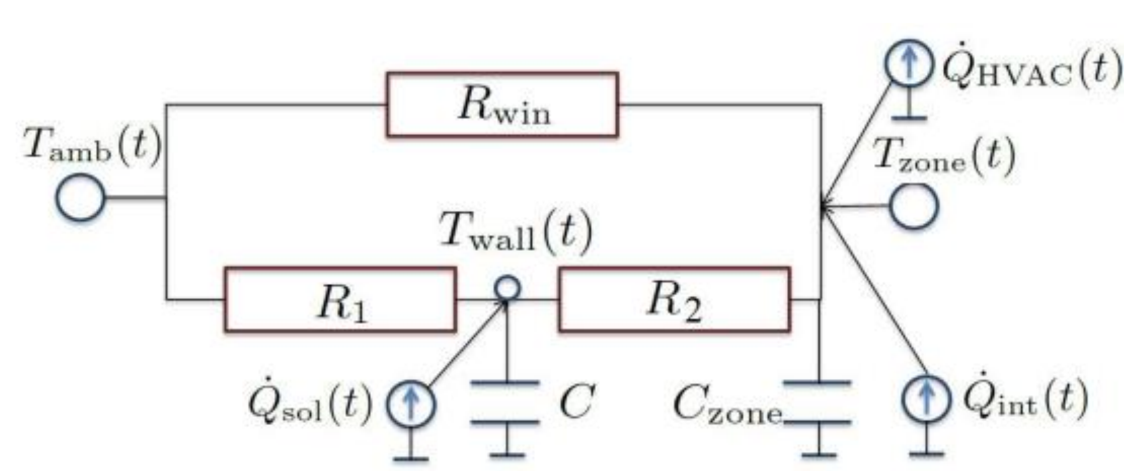
1. BACKGROUND AND MOTIVATION

- Even though the capacity of Solar and Wind based renewable energy generation is increasing, we still need additional infrastructure of fast-ramping gas-powered generators, utility-scale battery storage and base-load being managed by conventional generators to optimally utilize their potential.
- Soon for a completely decarbonized grid, we will require large installations of utility-scale battery storage which require huge capital investment.
- Modern buildings (residential/commercial) with their solar PVs, battery storage, EV charging and HVAC can be operated in a coordinated manner using intelligent control to act like virtual batteries.
- Here we develop a methodology for developing high-fidelity, computationally inexpensive and controllable building models which will aid in developing these control strategies and performing large-scale simulations



2. GREY-BOX BUILDING THERMAL MODEL

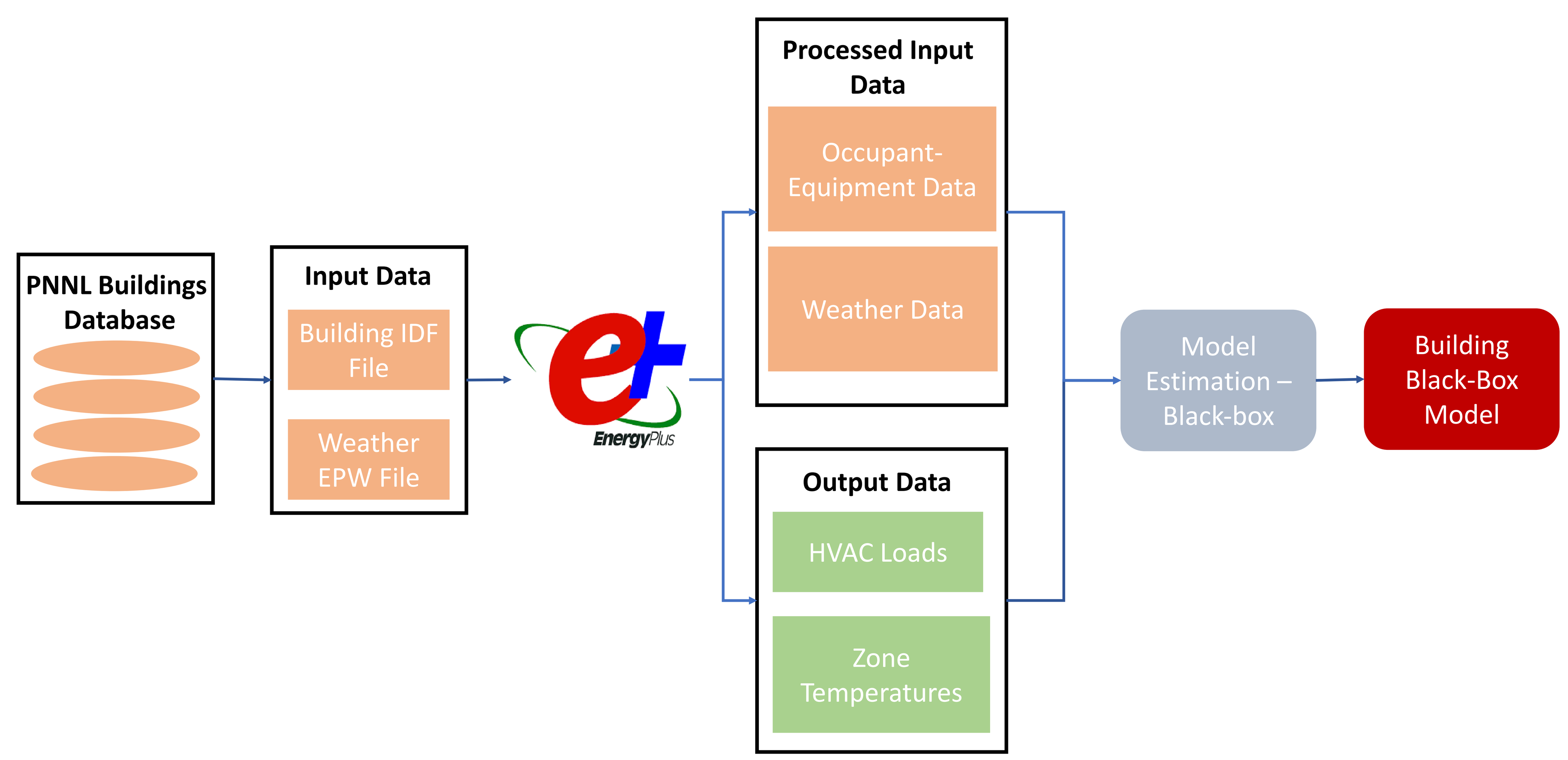


$$\dot{T}_{wall} = \frac{T_{amb} - T_{wall}}{CR_2} + \frac{T_{zone} - T_{wall}}{CR_1} + \frac{\dot{Q}_{sol}}{C}$$

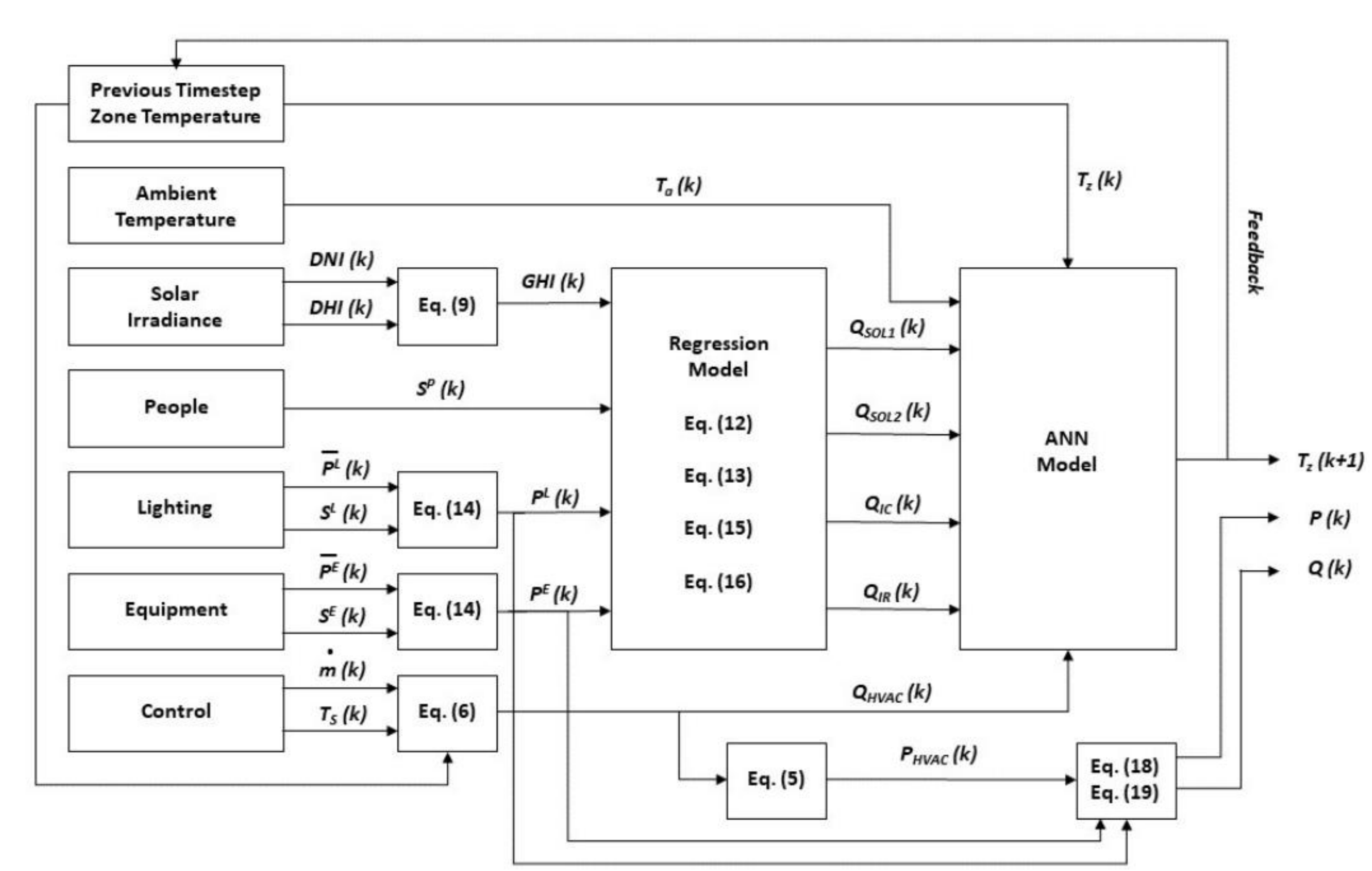
$$\dot{T}_{zone} = \frac{T_{wall} - T_{zone}}{C_{zone}R_1} + \frac{T_{amb} - T_{zone}}{C_{zone}R_{win}} + \frac{\dot{Q}_{int} + \dot{Q}_{HVAC}}{C_{zone}},$$

$$\dot{Q}_{HVAC}(t) = \mu_{HVAC}P_{HVAC}(t)$$

3. BUILDING THERMAL MODEL DEVELOPMENT - OVERVIEW



4. BUILDING THERMAL MODEL DEVELOPMENT - SCHEMATIC



HVAC Power Consumption:

$$P_{HVAC_i}(k) = \frac{P_{HVAC}(k)}{n} = f_{HVAC_i}(Q_{HVAC_i}(k)), \quad (5)$$

$$Q_{HVAC_i}(k) = C_a\dot{m}_i(k)(T_{z_i}(k) - T_{s_i}(k)). \quad (6)$$

Solar Irradiance Models:

$$Q_{SOL1_i}(k) = f_{SOL1_i}(GHI(k)), \quad (7)$$

$$Q_{SOL2_i}(k) = f_{SOL2_i}(GHI(k)), \quad (8)$$

$$GHI(k) = DNI(k)|cos(\delta(k))| + DHI(k). \quad (9)$$

Occupant-Equipment Heat Models:

$$Q^m_{IC_i}(k) = f^m_{IC_i}(P^m_i(k)), \; m \in B - \{P\} \quad (12)$$

$$Q^m_{IR_i}(k) = f^m_{IR_i}(P^m_i(k)), \; m \in B - \{P\}, \quad (13)$$

$$P^m_i(k) = \bar{P}^m_i(k) \times S^m_i(k) \quad (14)$$

$$Q^P_{IC_i}(k) = f^P_{IC_i}(S^P_i(k)), \quad (15)$$

$$Q^P_{IR_i}(k) = f^P_{IR_i}(S^P_i(k)), \quad (16)$$

Complete Building Model:

$$\underline{x}_1(k+1) = f(\underline{x}_1(k), \underline{u}(k), \underline{w}(k); \theta), \quad (17)$$

$$P(k) = \sum_i^I P_{HVAC_i}(k) + \sum_m^{B-\{P\}} \sum_i^I P^m_i(k), \quad (18)$$

$$Q(k) = P(k)tan(cos^{-1}(p.f(k))). \quad (19)$$

6. RESULTS

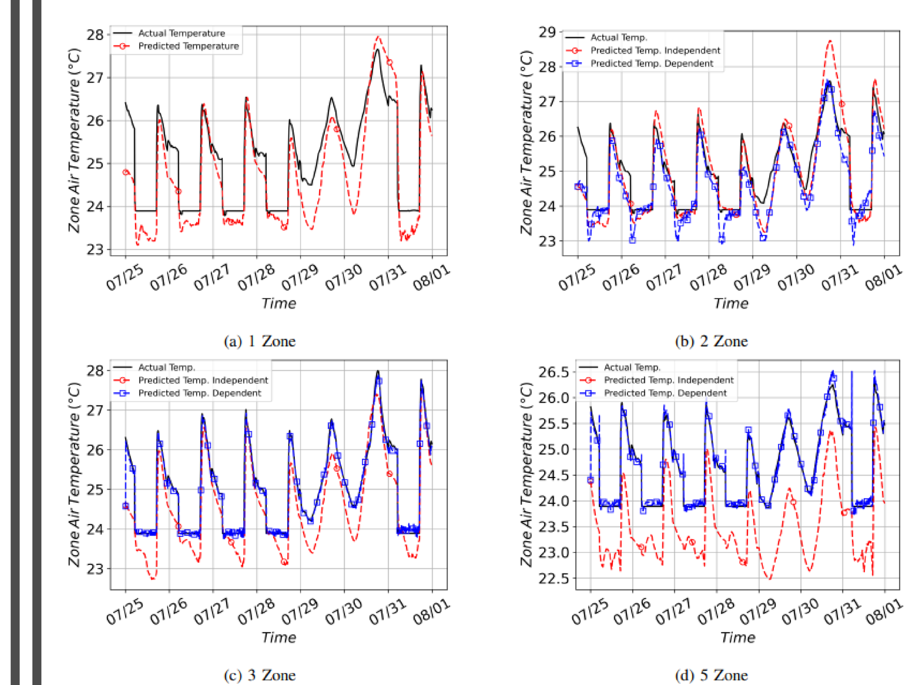


Fig. 3: Actual vs predicted T_{z_i} for different aggregated zone models.

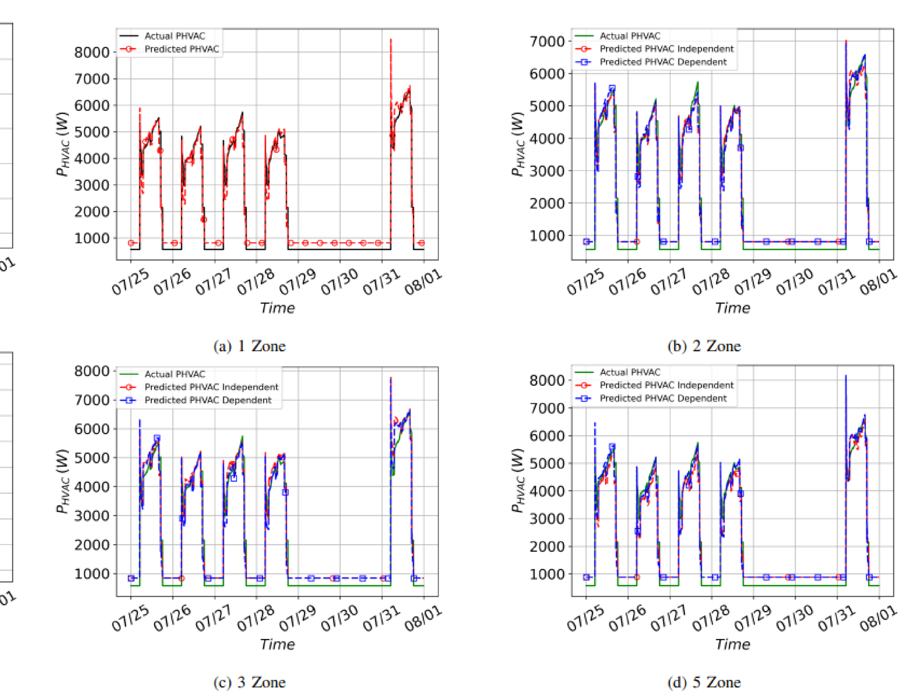


Fig. 5: Actual vs predicted P_{HVAC} for different aggregated zone models.

TABLE II: Average absolute error for T_z prediction

Zone Type	Average Absolute Error (%)		
	Independent	*Dependent*	*Dependent 2*
1Z	3.28	NA	NA
2Z	2.89	2.86	3.59
3Z	6.13	0.54	16.77
5Z	3.61	0.63	2.55

TABLE III: Average absolute error for P_{HVAC} prediction

Zone Type	Average Absolute Error (%)		
	Independent	*Dependent*	*Dependent 2*
1Z	1.05	NA	NA
2Z	1.08	1.78	10.47
3Z	4.55	2.51	8.01
5Z	0.30	2.40	5.60

7. CONCLUSION AND FUTURE WORK

- In this preliminary work, we have developed a principled way of utilizing the structure of a simple RC-Network-based building thermal model to develop ANN-based building thermal models.
- We not only develop an ANN model but also the power consumption model in a form that can be integrated into co-simulation framework along with a power distribution simulator.
- We compute the intermediate heating-cooling gains within the building using linear regression and completely observable data from EnergyPlus.
- Our building model's input mimics that of EnergyPlus making it easier to work with in an intuitive way.
- For future work, we will be comparing the performance of RNN, LSTM, GRU and Neural ODE against the simple MLP used here.
- We will be developing a co-simulation platform using these building models with OpenDSS for large-scale networked building simulations

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