Intelligent Residential Air-Conditioning System with Smart Grid Functionality

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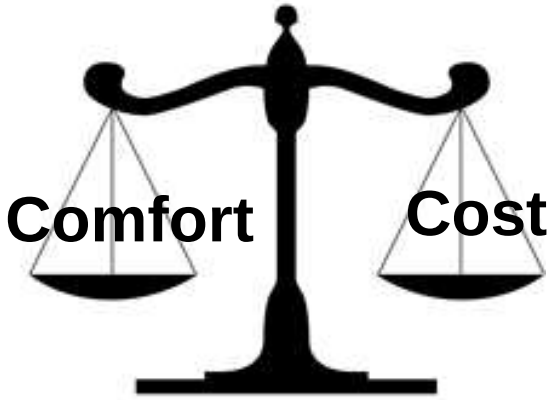
Auswin G. Thomas, Pedram Jahangiri, Di Wu, Chengrui Cai, Huan Zhao, Dionysios C. Aliprantis, and Leigh Tesfatsion, “Intelligent Residential Air-Conditioning System with Smart Grid Functionality,” *IEEE Transactions on Smart Grid,* Vol. 3, No. 4, 2012, 2240-2251

Paper Summary

- A novel intelligent A/C system controller is developed for a household resident
- Solves for optimal 24-hour comfort/cost tradeoffs, given anticipated prices & environmental conditions
- A test case is developed to study energy usage under alternative household attribute settings
- Simulation outcomes are reported

Intelligent A/C Controller



Prices
Household Preferences

House Thermal Dynamics (ETP model)

Environmental conditions

(to A/C motor)

On/Off

Air Temp.

Forecast of environmental conditions

Retail price sequence

Scheduling (on remote or local server)

Control Map

Estimator for Mass Temp.

Wall Control Unit

User-defined preferences (entered via a user-friendly graphical interface)

Equivalent Thermal Parameter (ETP) Model

$$\frac{dT^a}{dt} = \frac{1}{C^a}\left[(T^o - T^a)U^a + (T^m - T^a)U^m + \dot{Q} + \dot{Q}^a\right]$$

$$\frac{dT^m}{dt} = \frac{1}{C^m}\left[(T^a - T^m)U^m + \dot{Q}^m\right]$$

where

$$\dot{Q}^a = f(\dot{Q}^s, \dot{Q}^i)$$

$$\dot{Q}^m = g(\dot{Q}^s, \dot{Q}^i)$$

T^a , T^m and T^o : Air mass, solid mass, and outside temps

$\dot{Q}^s$ and $\dot{Q}^i$: Solar and internal heat flow rates

C^a, C^m and U^a, U^m : Heat capacity and thermal conductance

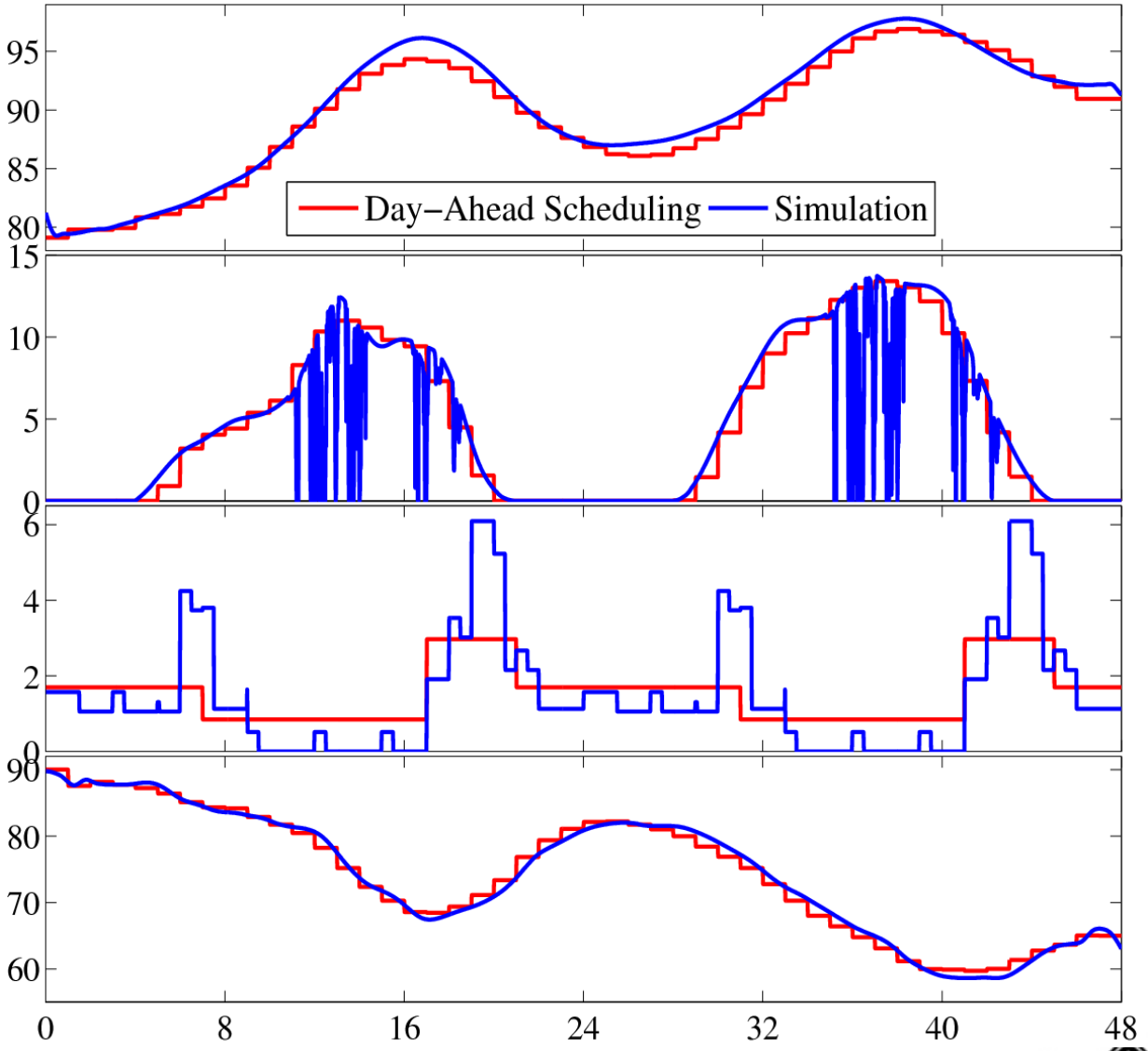
Environmental Forcing Terms

Outside Temperature (^{o}F)

Solar Heat Flow Rate ($^{kBTU}/_{h}$)

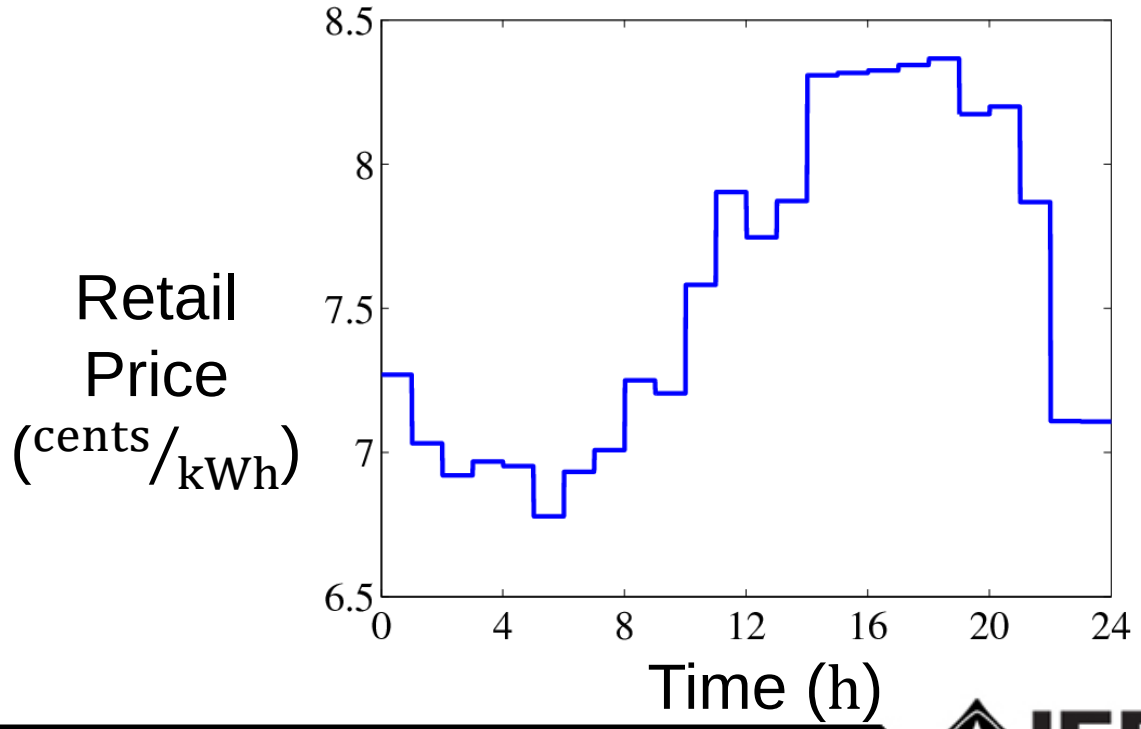
Internal Heat Flow Rate ($^{kBTU}/_{h}$)

Relative Humidity (%)



Wholesale Prices Passed Thru to Households

- Retail prices charged to retail energy customers on day D given by DAM LMPs plus profit markup determined on D-1
- Retail prices for day D conveyed by LSEs to households by evening of day D-1

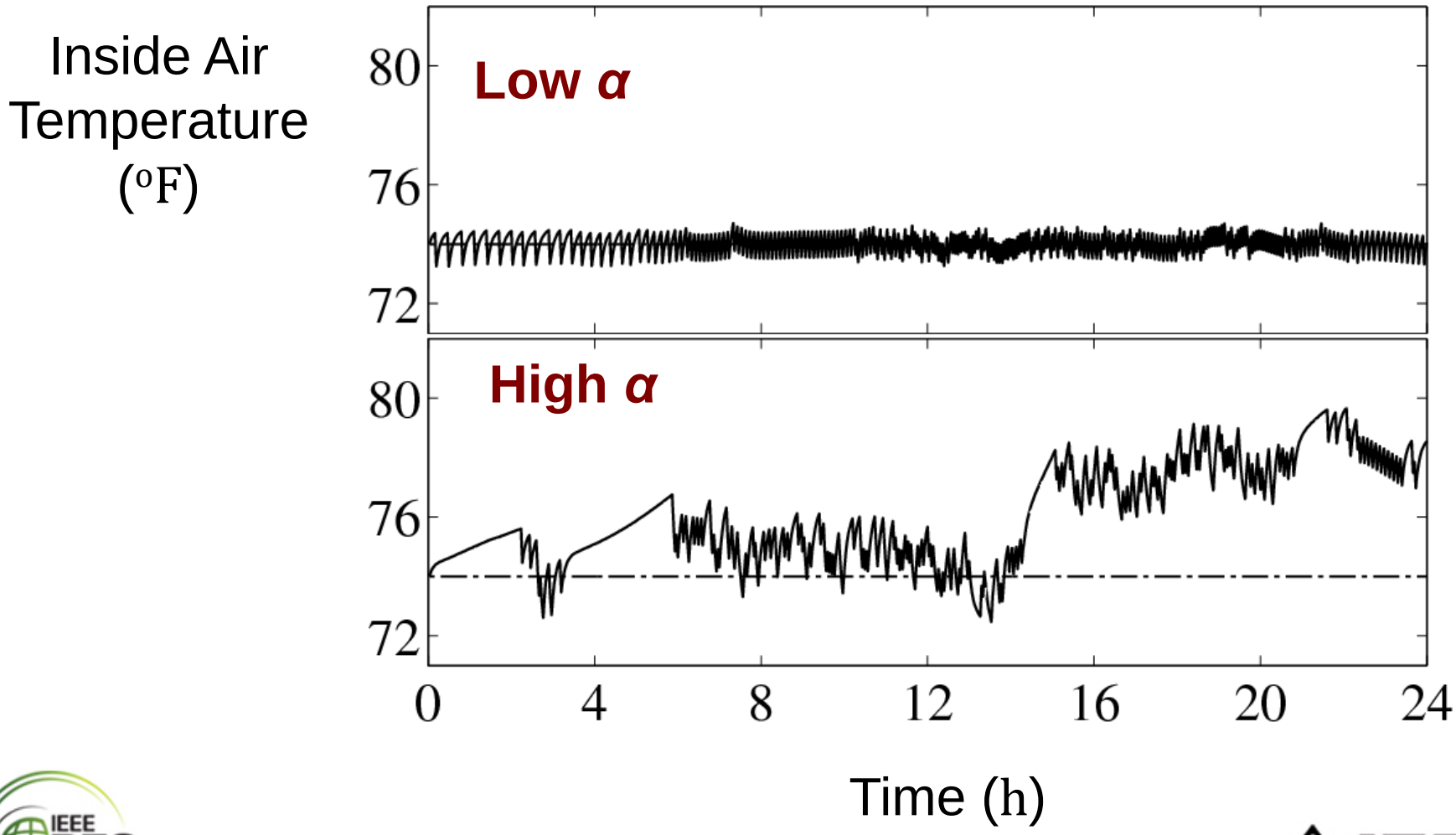


Attributes of Household Residents

- Comfort function (utils) measuring household resident's comfort level as a function of inside air temperature
- Bliss temperature = Inside air temperature providing highest comfort to the at-home resident
- α = Parameter (utils/$) measuring resident's trade-off between thermal comfort and electricity cost (higher α ⟹ higher concern for cost relative to comfort)
- Home-occupancy times of the household resident

Illustrative Results: Resident Always Home

Bliss temperature 74 °F; Higher α = Higher concern for cost



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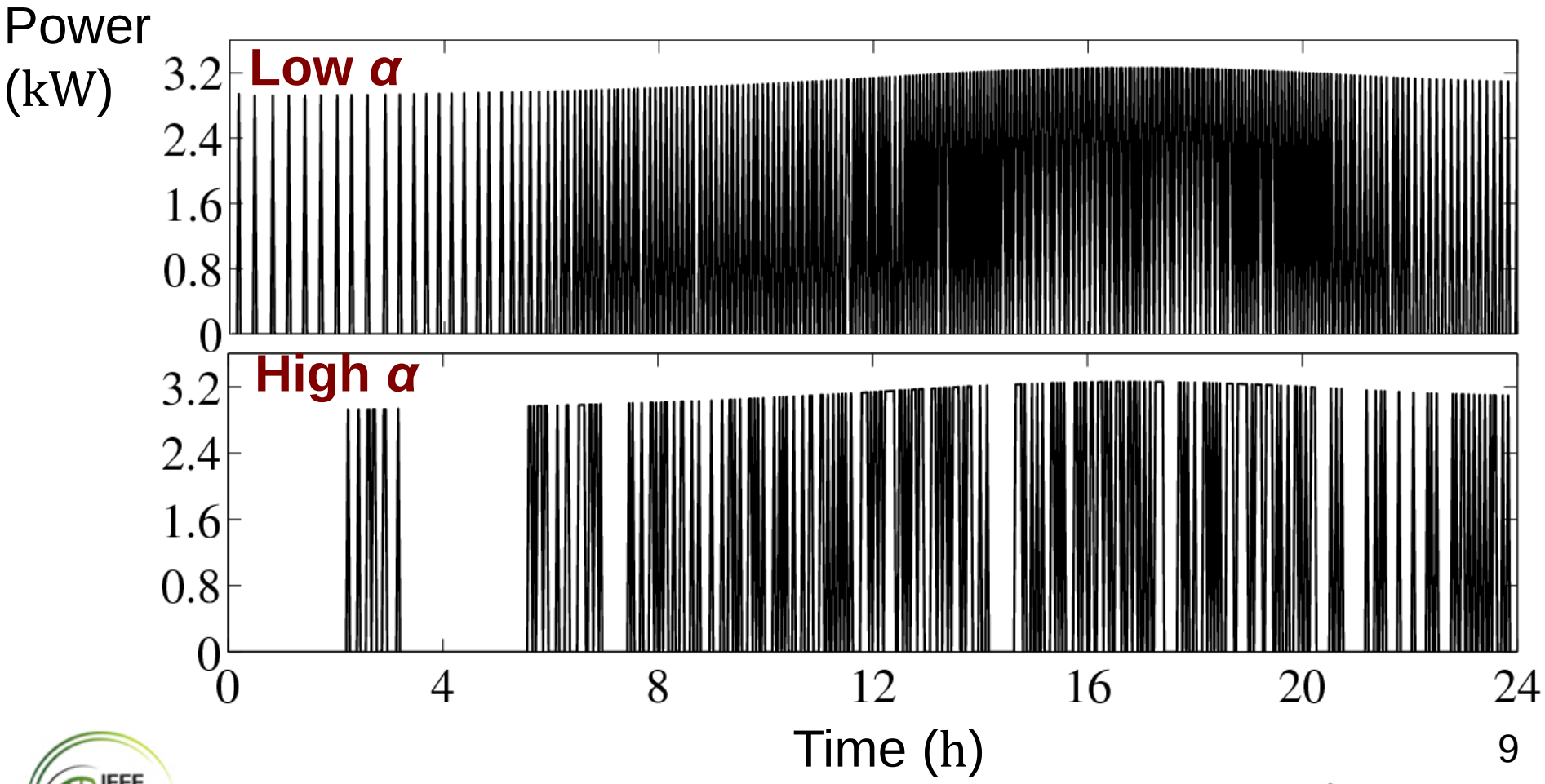
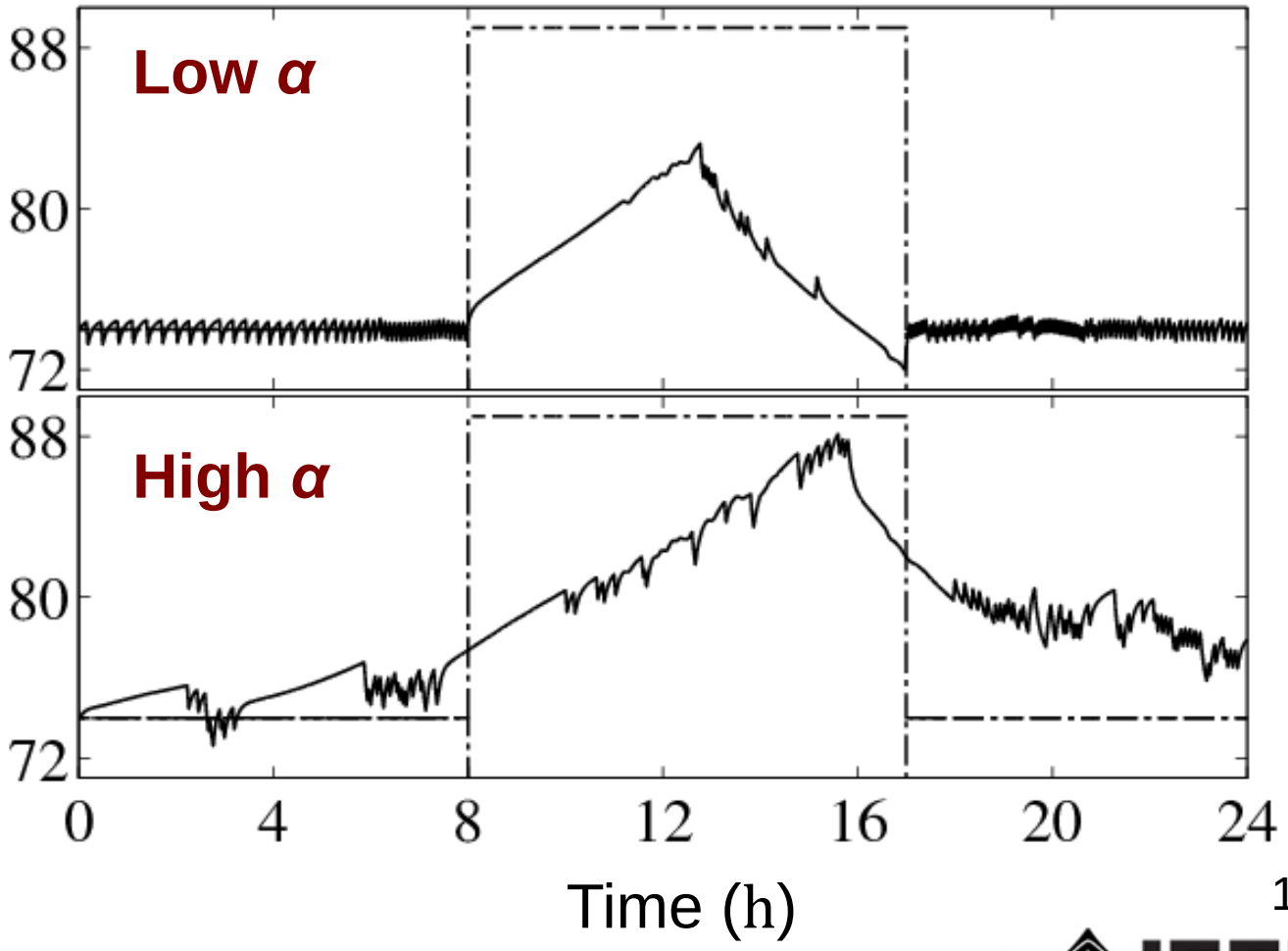


Resident not home between 8am and 5pm

Bliss temperature 74 °F; Higher α = Higher concern for cost

Inside Air Temperature (°F)



Ongoing Research

www.econ.iastate.edu/tesfatsi/irwprojecthome.htm

- Integrated retail & wholesale (IRW) effects of price-responsive demand
- ISO & LSE forecasting of price-responsive demand
- Design of retail energy contracts permitting price-responsive demands
  - Efficiency and fairness concerns
  - System reliability concerns
- Load aggregation & demand response programs