Occupancy-Based Adaptive Thermostat for Increased Energy Efficiency

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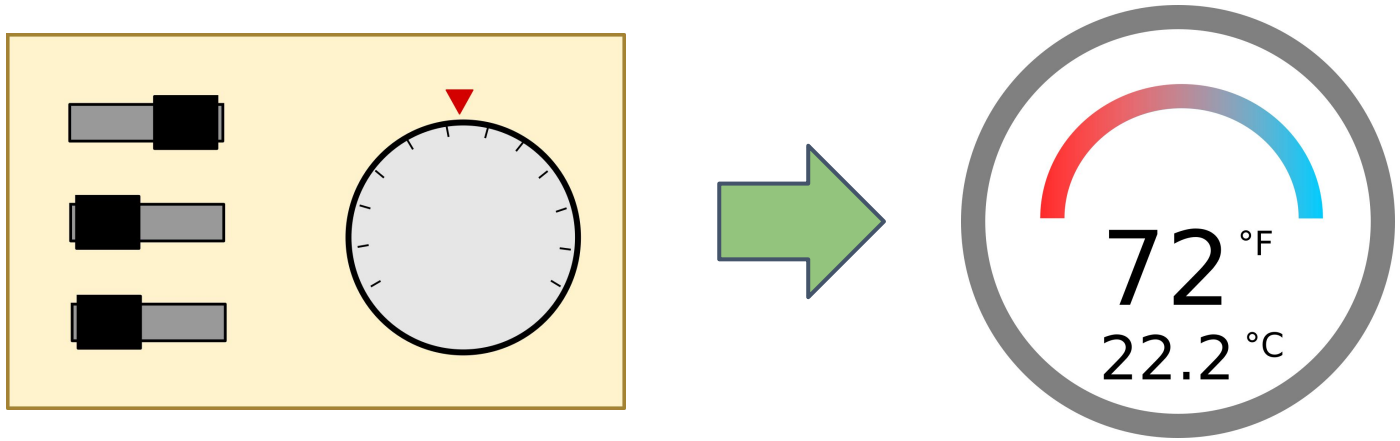
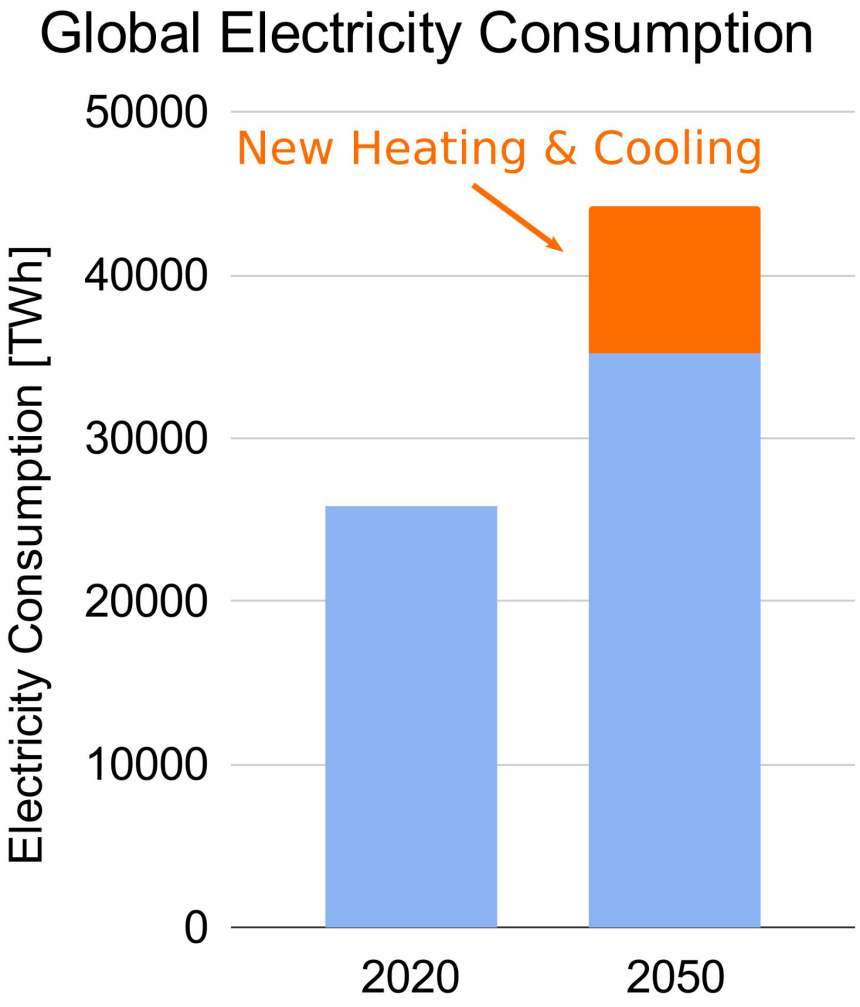
Heating, Air Conditioning & Electricity

- Heating & cooling is projected to cause nearly 50% of global electricity demand growth over next 29 years [1]
- Heating and cooling use around 30% of energy in a typical American home [3]
- Expensive to replace air conditioning & heating systems

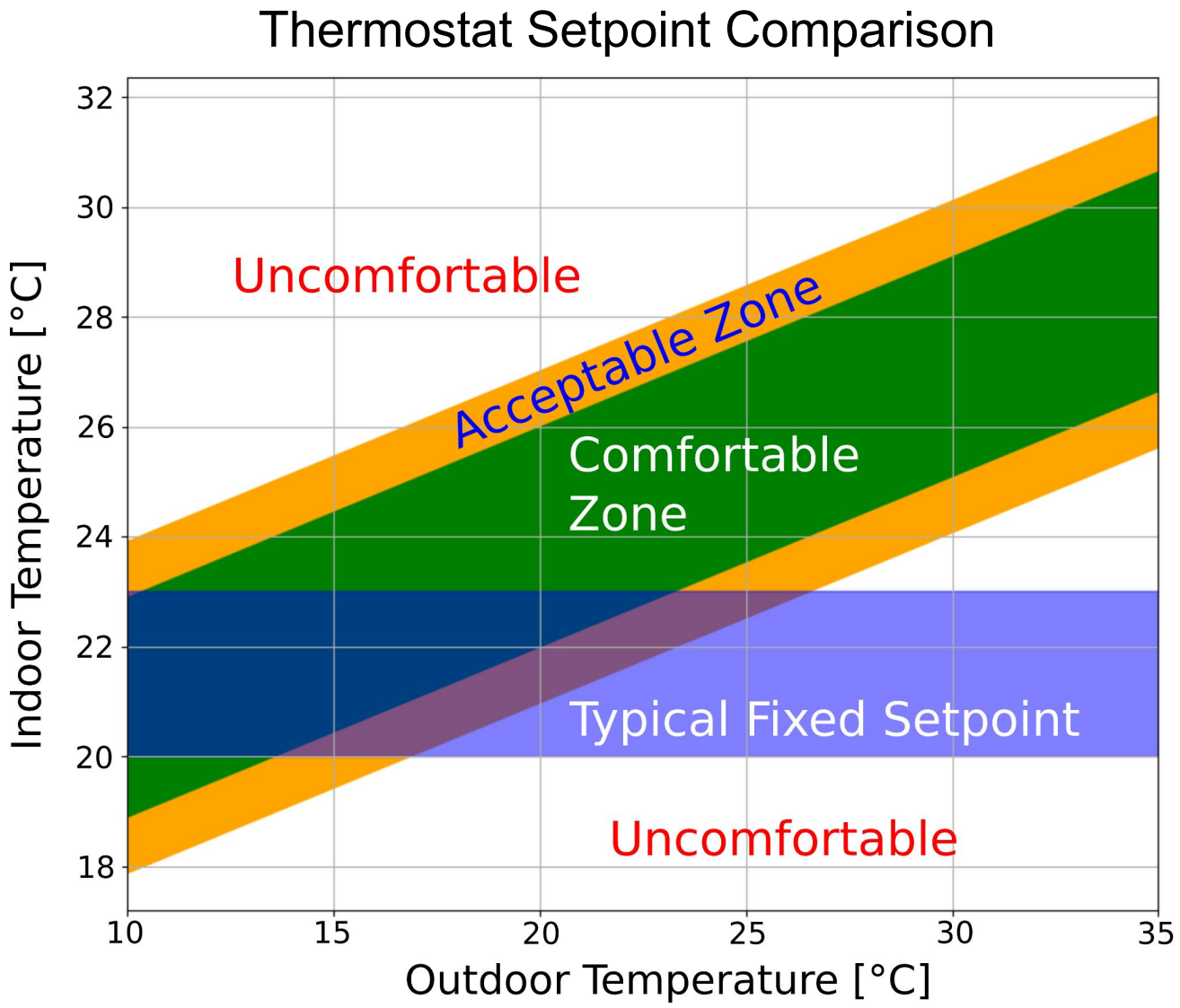




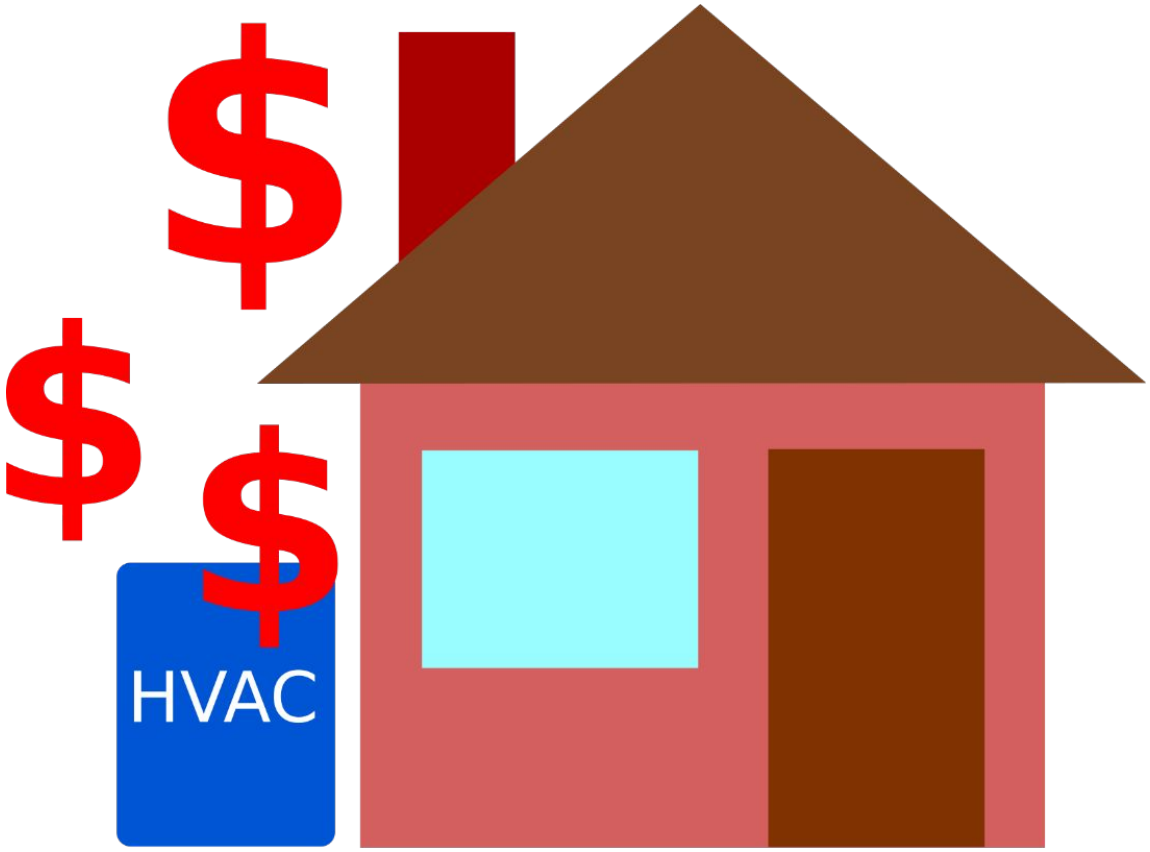
Source data [1][2]

Adaptive

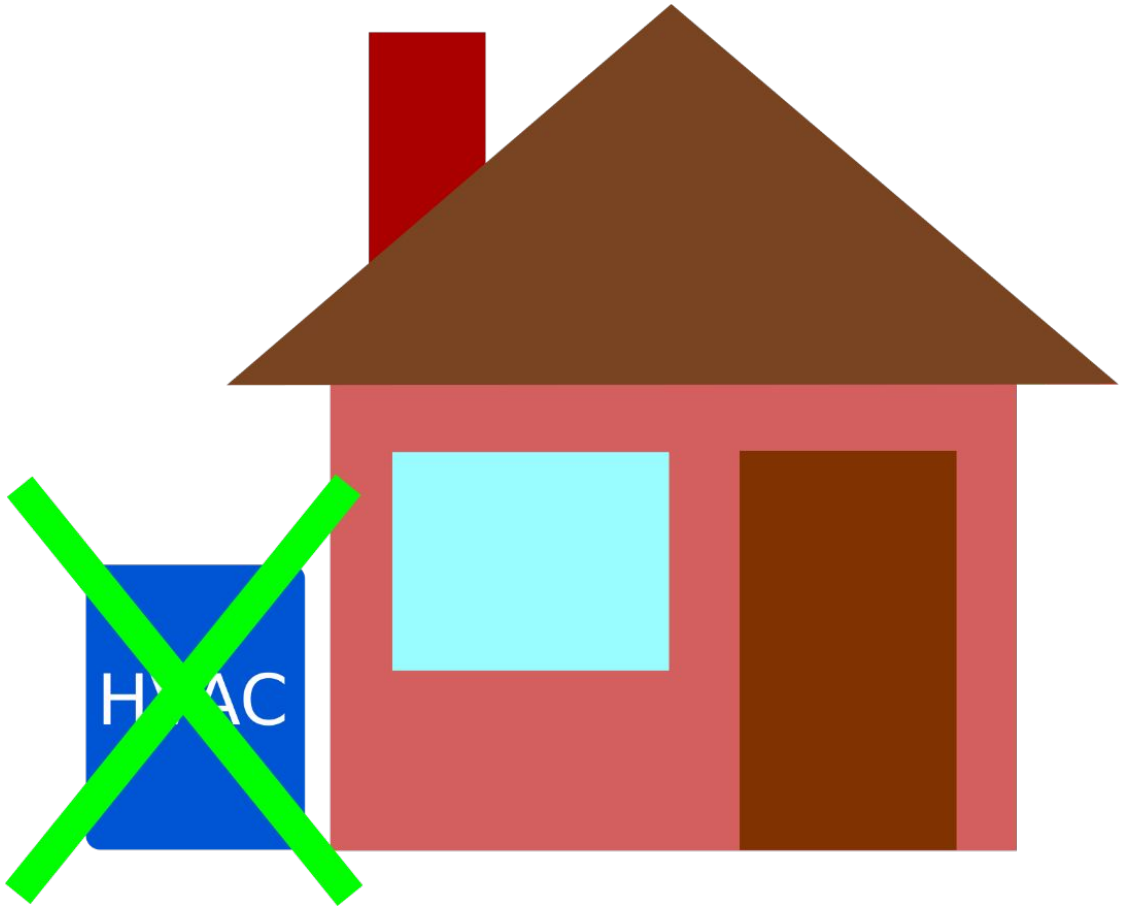
- Conventional thermostats cannot match conditions
- “Adaptive” follows range where 90% of people feel comfortable [4][5]



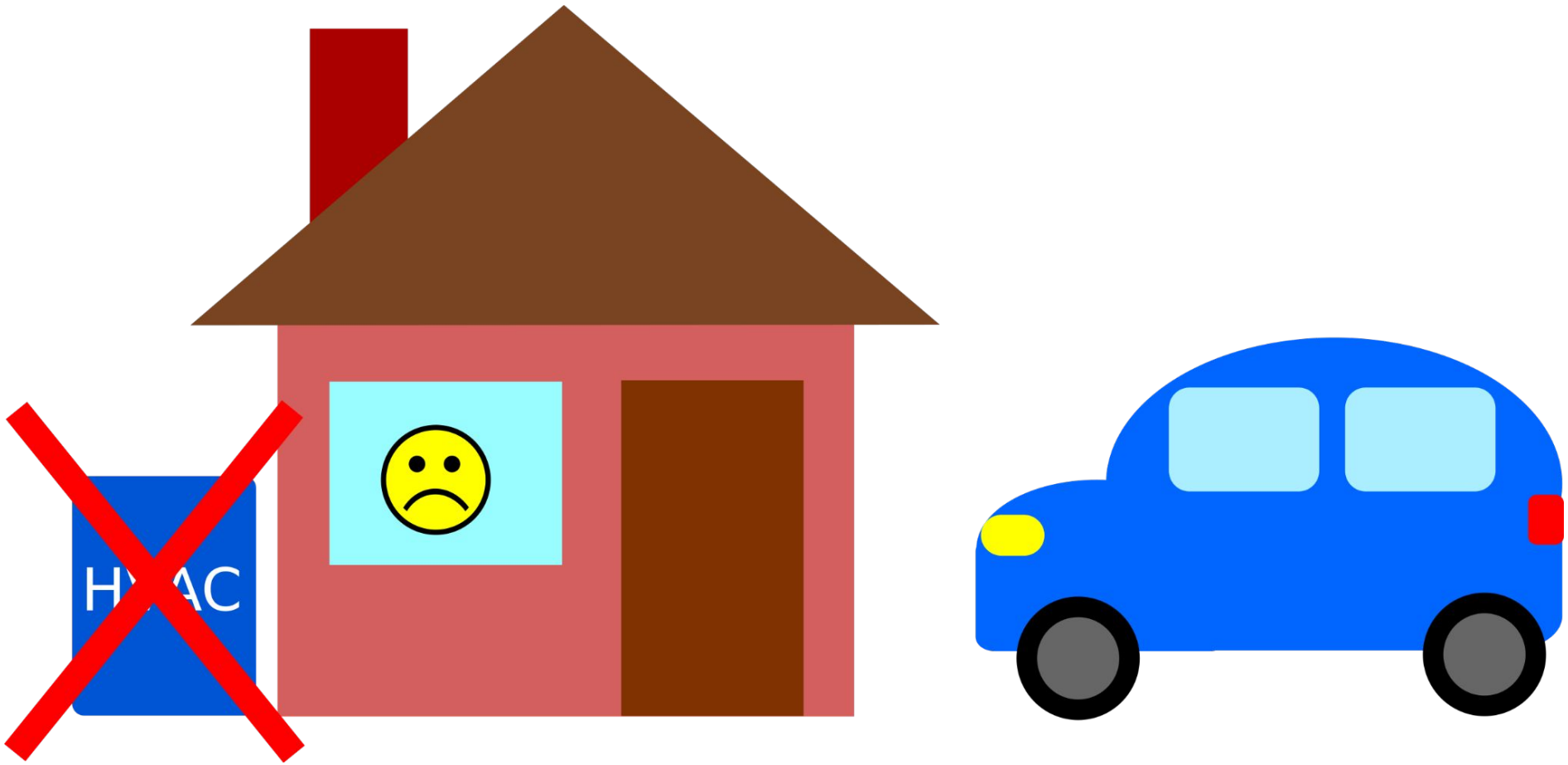
No Occupancy: Wasteful



Occupancy Energy Savings

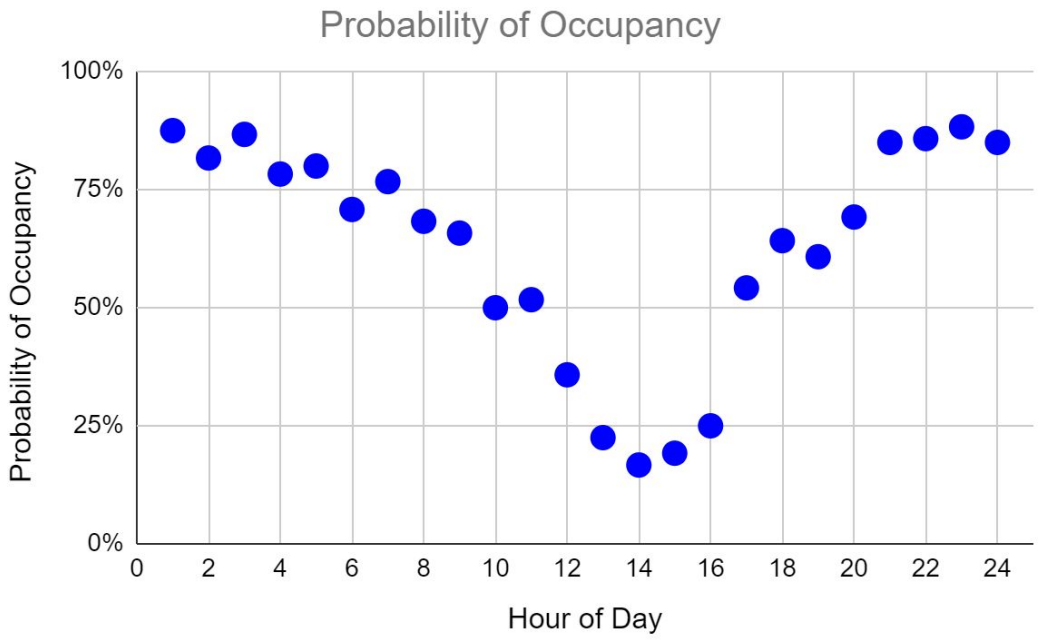


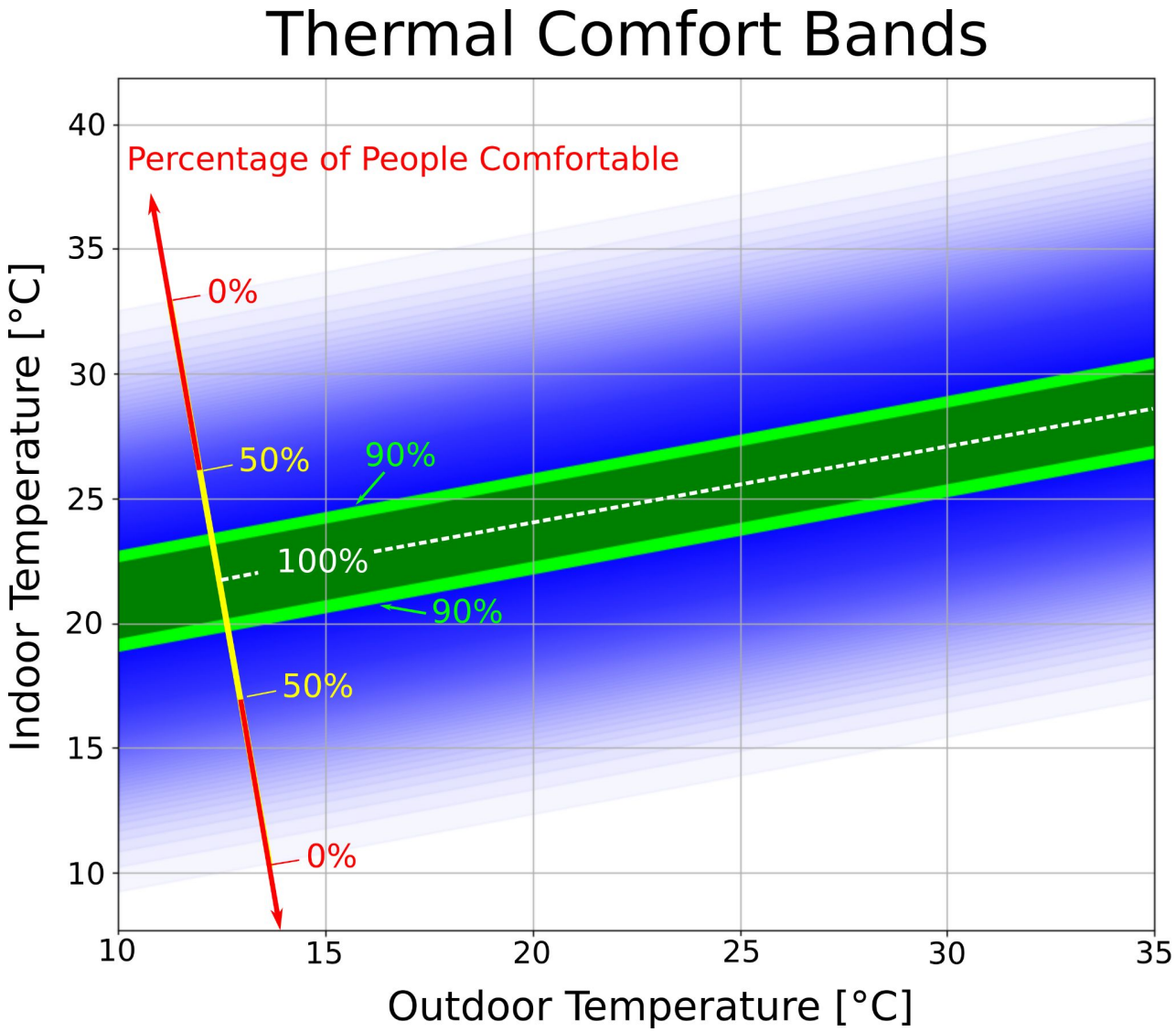
Challenge With Occupancy Control



Occupancy Probability

- Probability of occupancy determines how far to set back
- Nearly comfortable when people likely to return [6]





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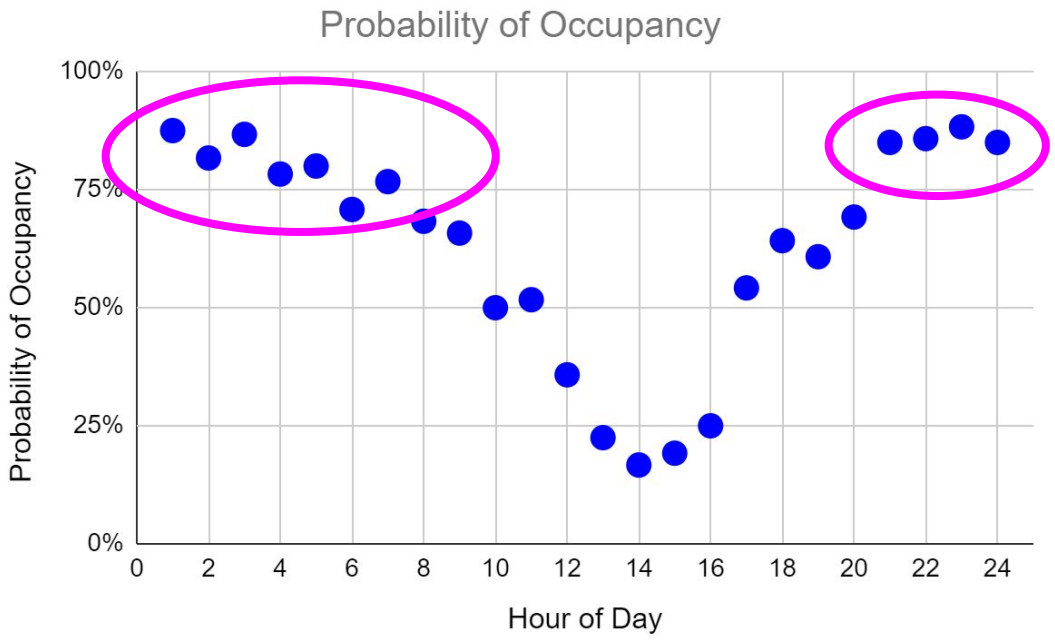

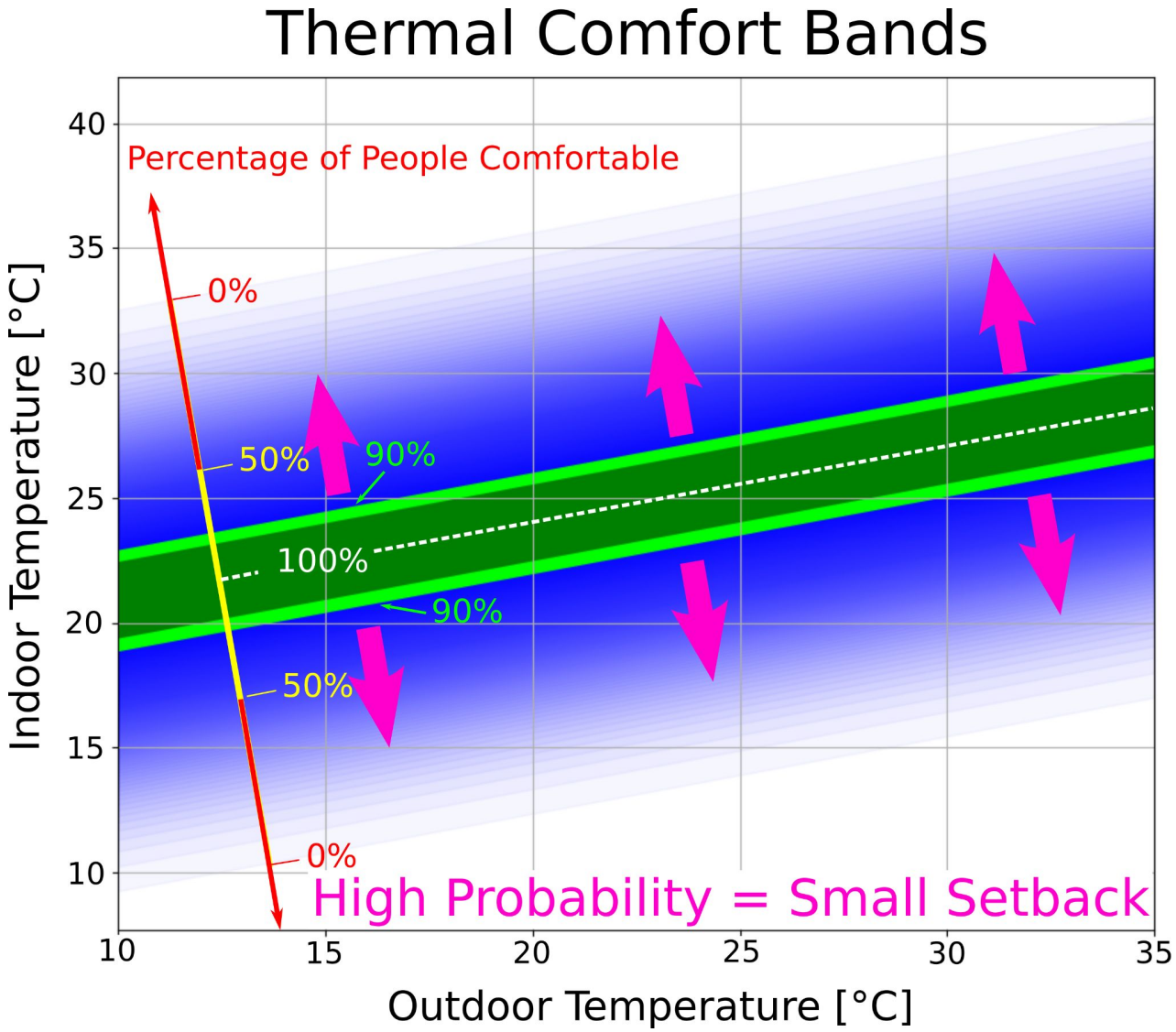

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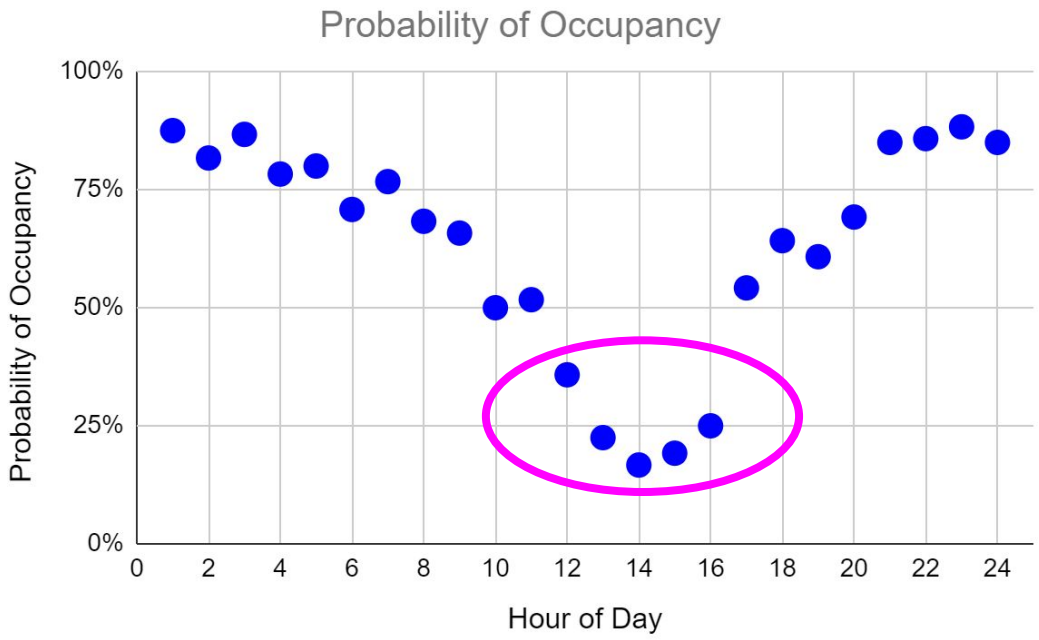
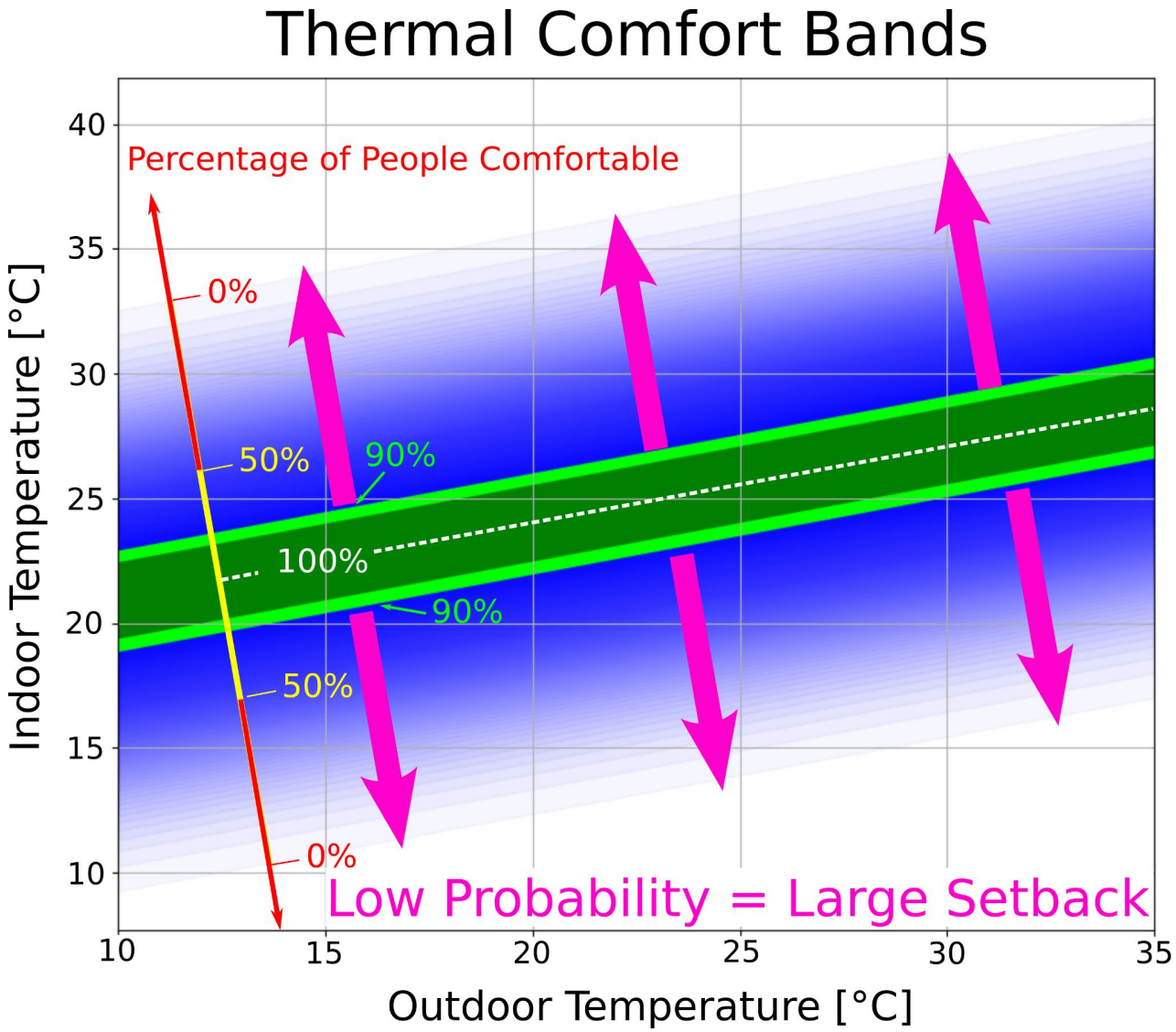
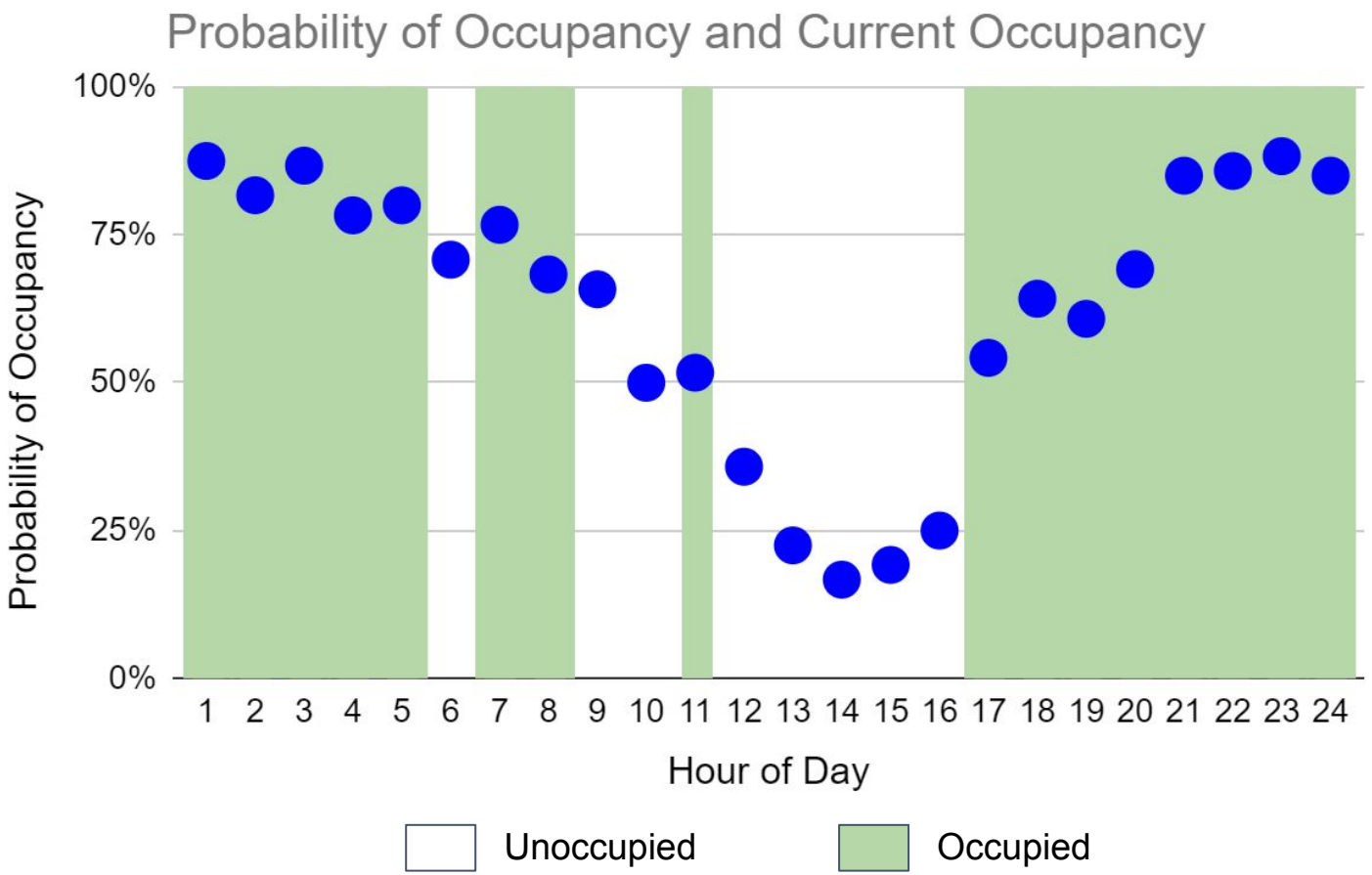




Occupancy - Current

Simulated occupancy based on probability [7]



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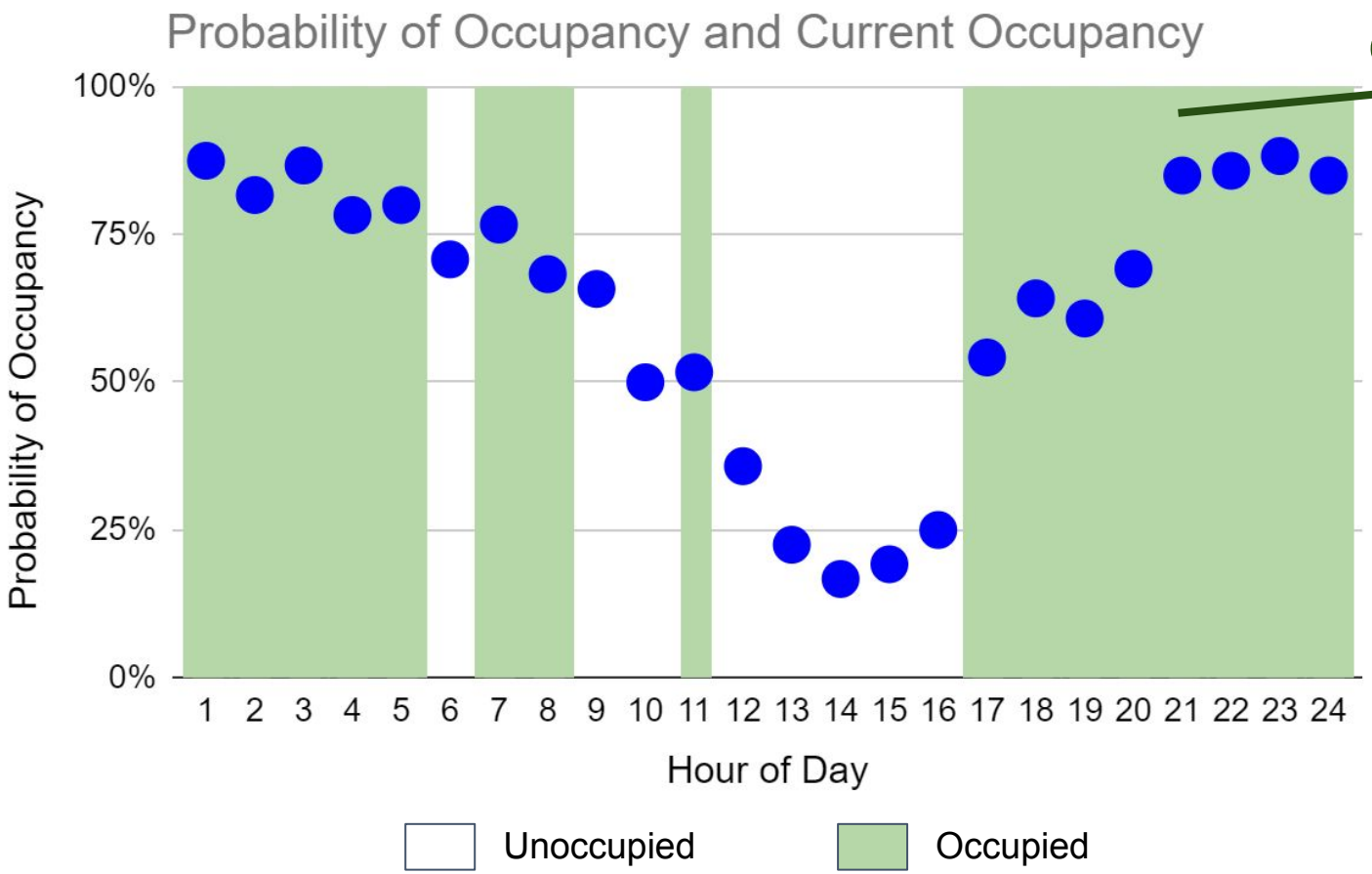
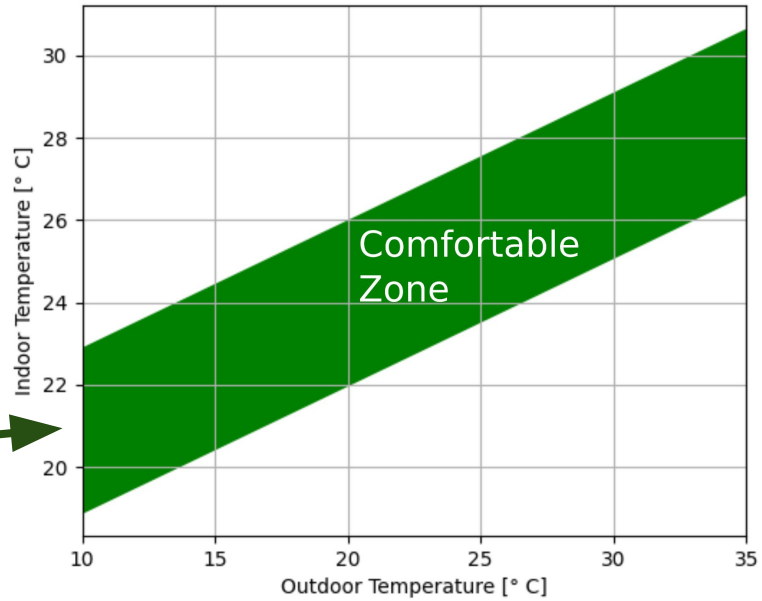


Occupied

Adaptive 90% Comfortable Zone



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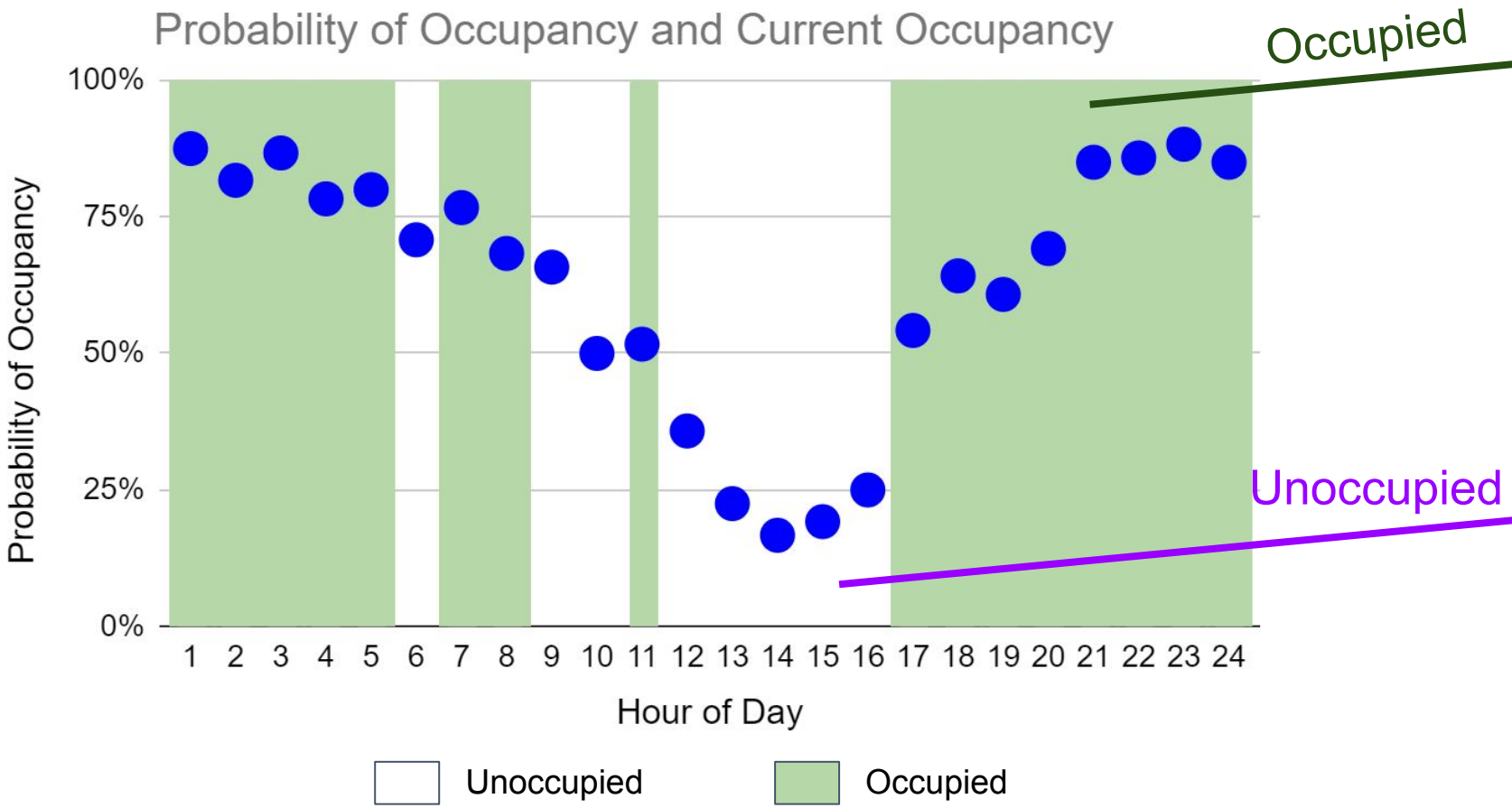
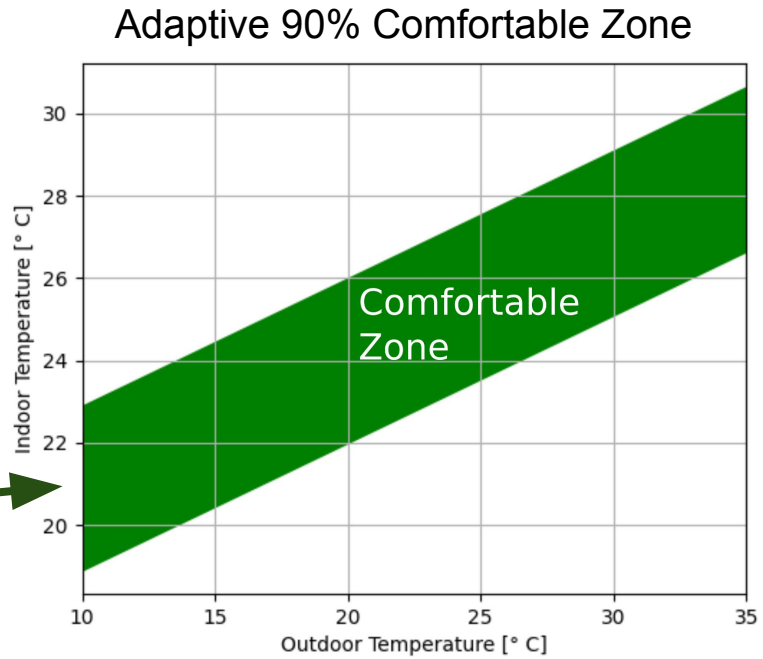
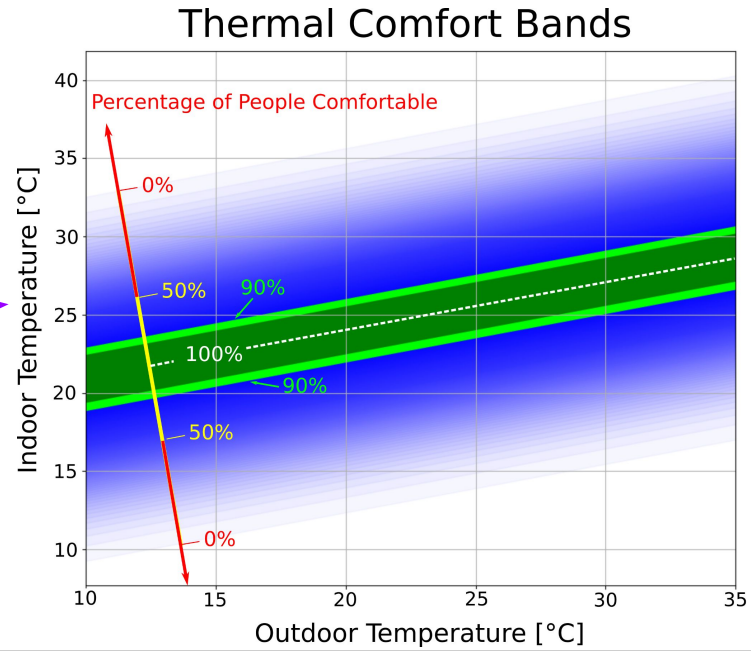


Occupied

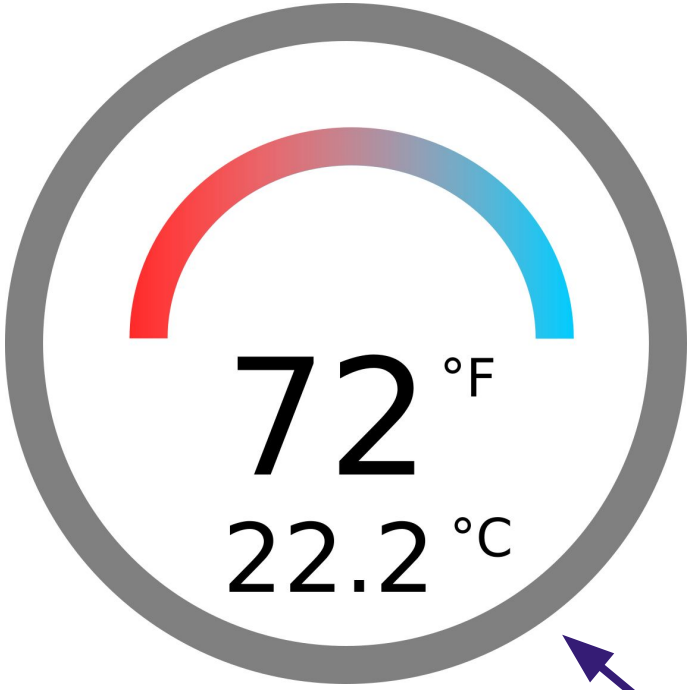
Unoccupied



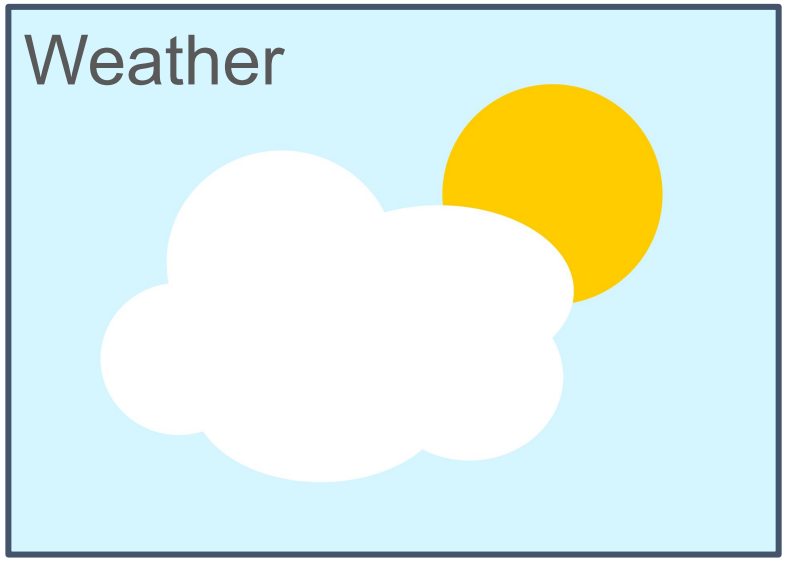


Simulation

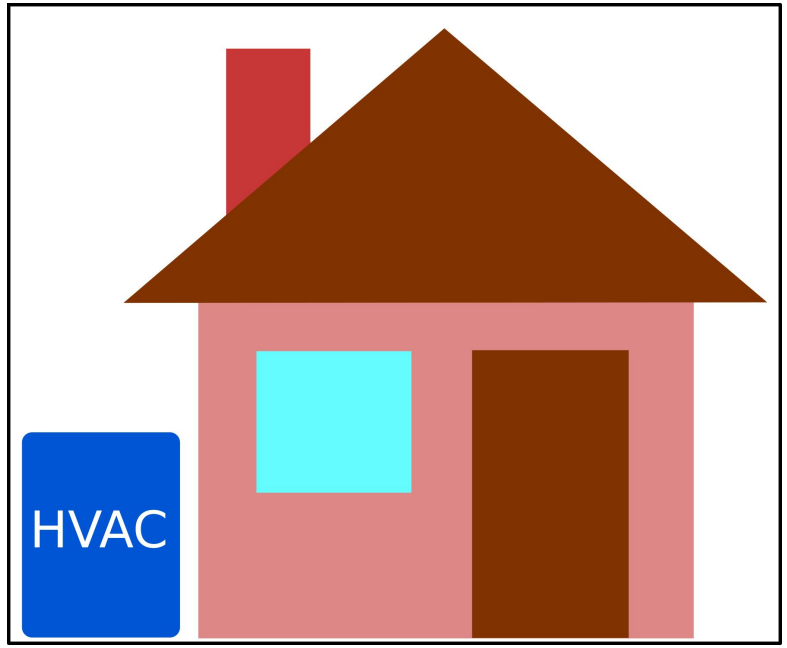
Thermostat

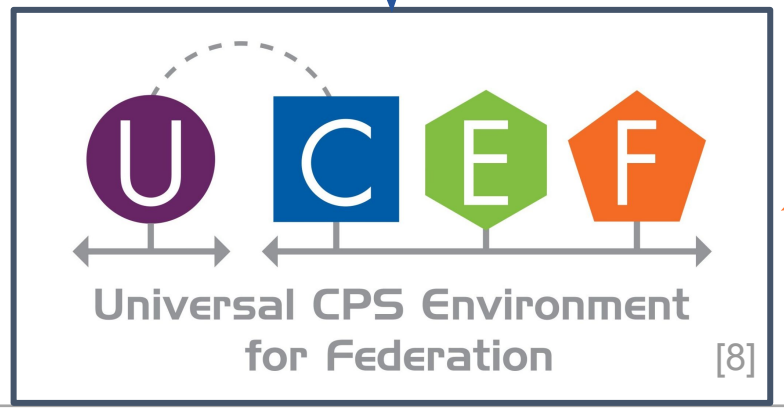


Weather



House Model with HVAC

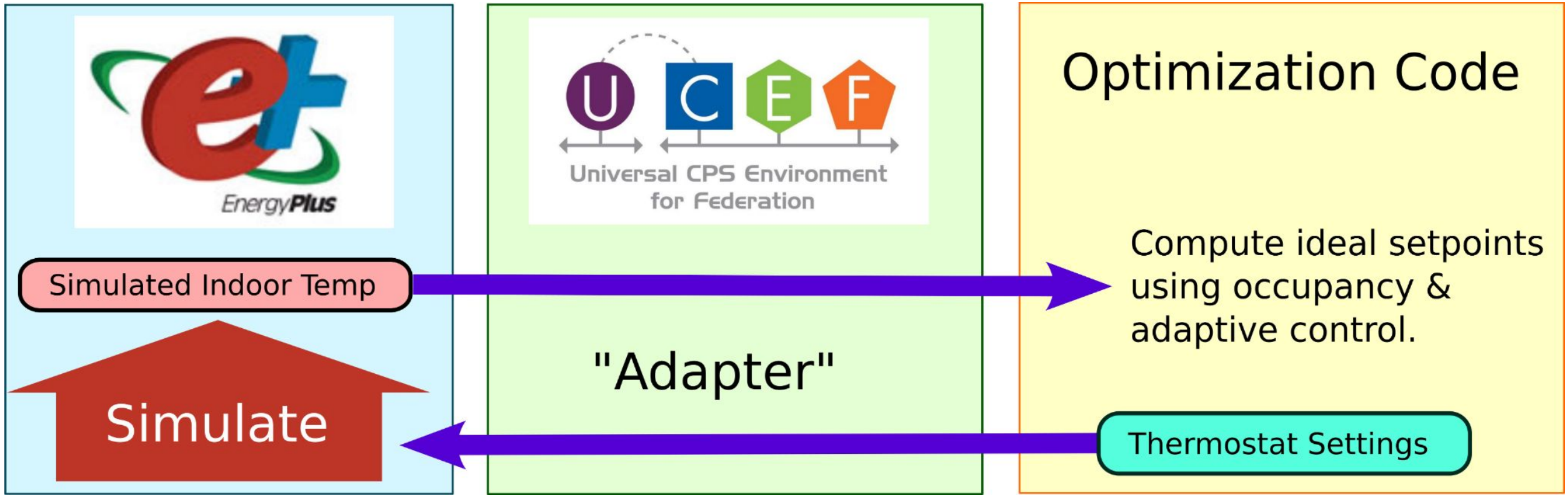




[8]

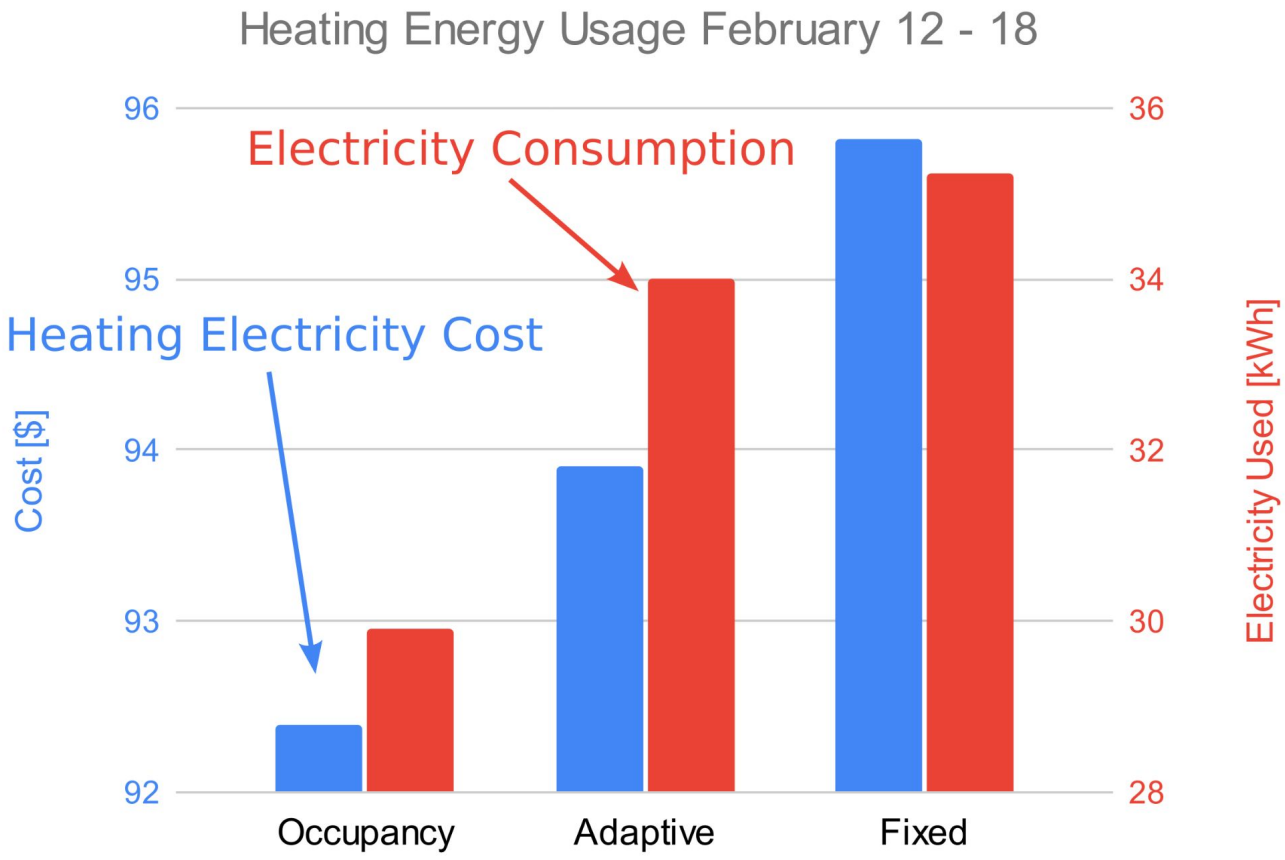
UCEF: Simulation

- NIST Universal CPS Environment for Federation
- “Adapter” between different simulation types



Results - Winter

- Residential house
- San Francisco, CA
- Occupancy control reduces cost by 3.6% & electricity by 15.1% compared to Fixed
- Occupancy 16.3% less comfortable
- Adaptive: smaller savings but maintains comfort

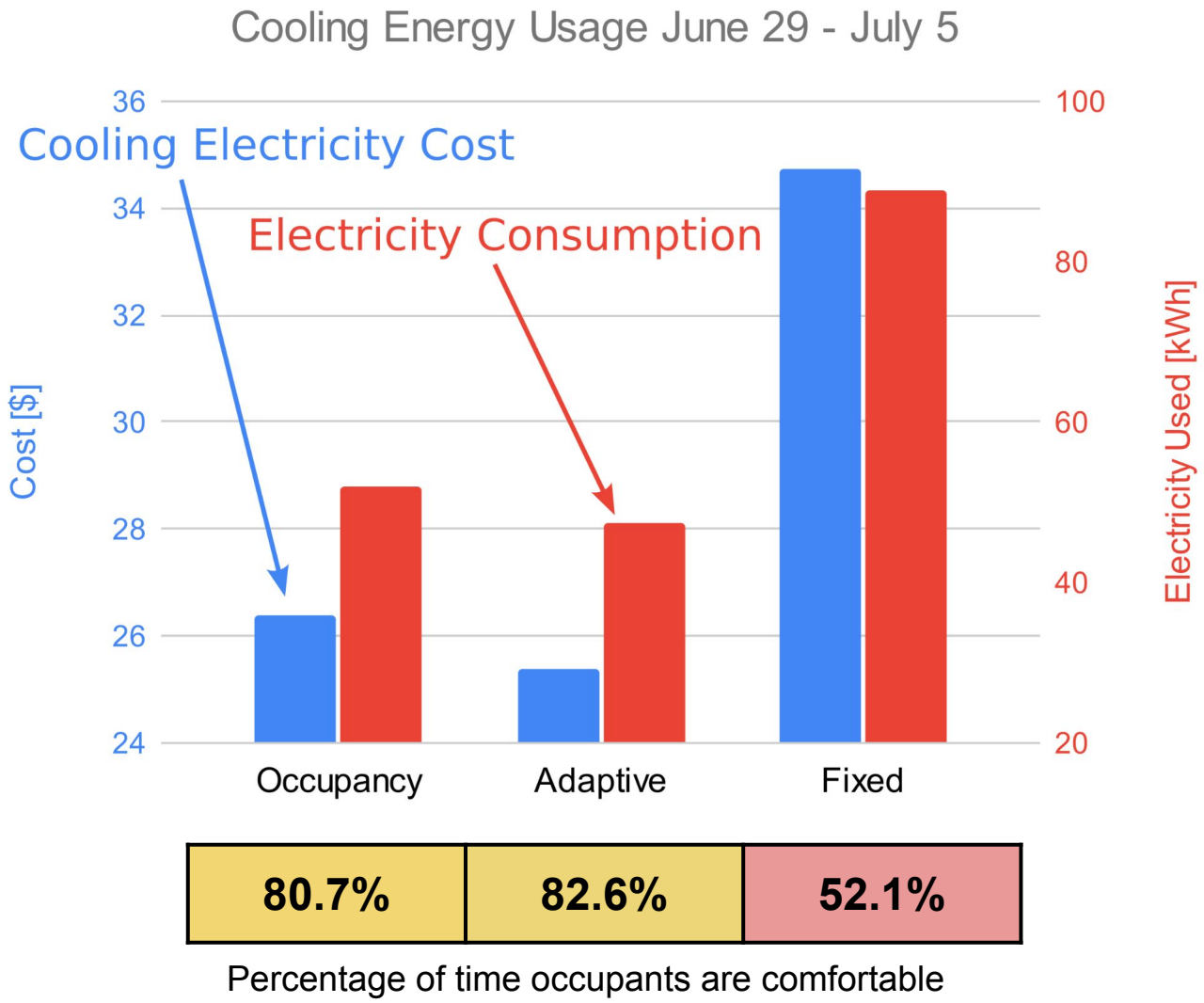


82.7%	99.1%	99.0%

Percentage of time occupants are comfortable

Results - Summer

- Sacramento, CA
- Occupancy saves 24.0% cost and 41.6% electricity over fixed
- Adaptive control better: 26.9% cost & 46.8% electricity reduction
- Fixed setpoints too cold - wasteful & uncomfortable

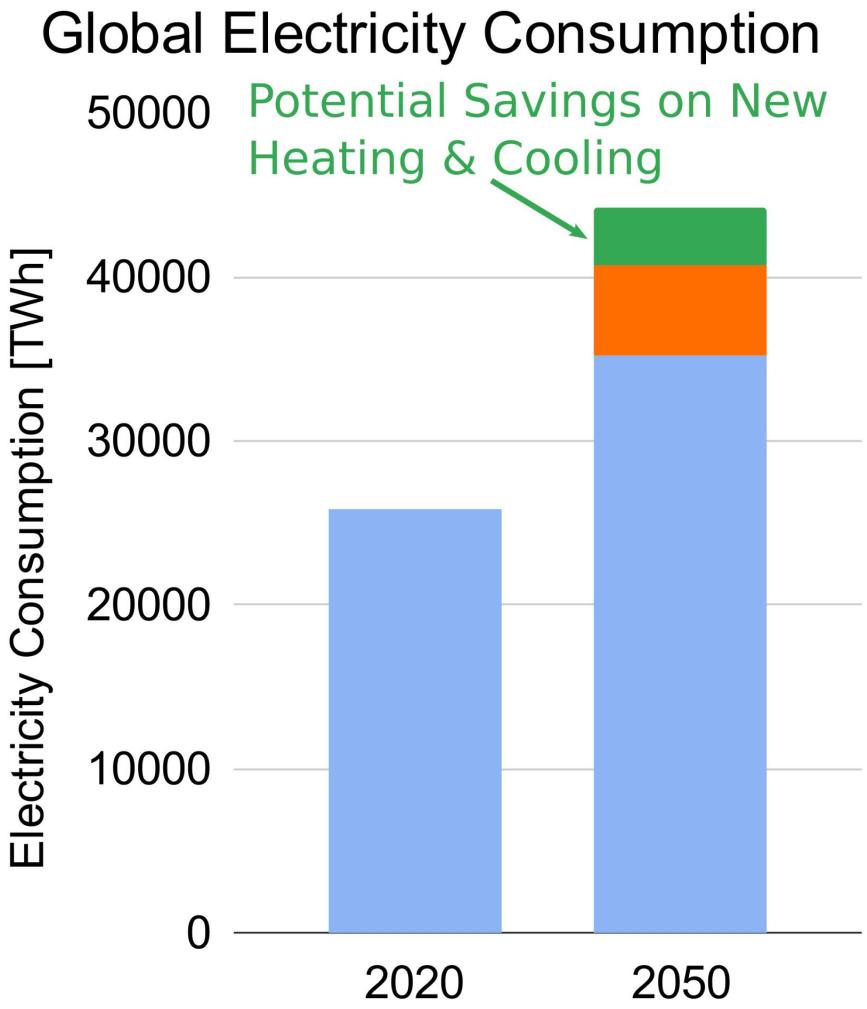


Conclusions

- Occupancy control can reduce energy usage and cost compared to traditional fixed thermostats
- Fixed thermostats are wasteful and can create uncomfortable conditions
- Adaptive may be more practical
  - Easier to implement
  - More cost savings in summer
  - Maintain comfort in winter
- UCEF allows for rapidly testing different simulation combinations

Future Work

- Improve occupancy algorithm
  - Less drastic unoccupied setback points
  - Machine learning
- Different occupancy schedules
  - Consistent schedule
  - Day of week
  - Disruptions
- Longer simulation
- Extreme hot or cold climates
- Implement in real thermostat



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[2] U.S. Energy Information Administration, *International Energy Outlook 2019*, p87, (2019). www.eia.gov/outlooks/archive/ieo19/

[3] U.S. Energy Information Administration, *Annual Energy Outlook 2021*, Table 4, (2021). www.eia.gov/outlooks/aeo/

[4] American Society of Heating Refrigerating and Air-Conditioning Engineers, *ANSI/ASHRAE Standard 55-2013: Thermal Environmental Conditions for Human Occupancy*, 2013 (2013).

[5] T. Parkinson, R. de Dear, G. Brager, *Nudging the adaptive thermal comfort model*, Energy and Buildings. 206 (2020) 109559 ISSN 0378-7788. https://doi.org/10.1016/j.enbuild.2019.109559

[6] U.S. Bureau of Labor Statistics, *American Time Use Survey*. (2015, 2020) www.bls.gov/tus/

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Acknowledgements

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PJ McCurdy
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Erik Mitchell

… and many more!

Thank You!

Question & Answer Session

Continue the conversation...

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