

# The Sub-metered HVAC Implemented For Demand Response (SHIFDR) Dataset

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### **Demand Response Experiments**



#### Over 5 years of experiments, 17 buildings in MI and NC

- Load shifting experiments
- Open-loop Global Thermostat Adjustment (GTA)
- Fan power submetering data
- Building Automation System (BAS) data
- Whole-building electric load data



#### **Open Access Dataset**

#### https://deepblue.lib.umich.edu/data/collections/vh53ww273?locale=en

#### Michigan data available $\rightarrow$

# North Carolina data forthcoming

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Work Descrip	tion									
tle: SHIFD	R: Michigan Buildings Dataset									
Attribute	Value									
Methodology	Between 2017 and 2021 we have conducted demand response (DR) experiments in 13 commercial buildings located in southeast Michigan through global thermostat adjustment. In each building, we directly sub-metered the heating, cooling, and air conditioning (HVAC) fan power consumption through measuring [more]									
	We have also compiled a subset of the data into an easy to use format with light processing of the data. This subset is labeled '2021 preprocessed data' and encompasses all the testing conducted in the summer of 2021. All the fan power and BAS data from each building experimented on is included as a [more]									
Description	This is a subset of the SHIFDR dataset collection containing data from 14 building found at C <u>https://deep[more]</u>	s in Southeast Michig	;an. The fu	ll dataset coll	ection can be					
	Organization: We include a subfolder for each building, identified by name. All buildings have been renamed after lakes to protect the identity of the building. Within each building subfolder, there is fan power (i.e. current measurements from which fan power can be computed), building automation s [more]									
Creator	<u>Lin, Austin J; Lei, Shunbo; Keskar, Aditya; Hiskens, Ian A; Johnson, Jeremiah X ; Ma</u> Kevin: Flynn [more]	athieu, Johanna L; Ke	<u>ennedy, Tir</u>	n; <u>DeMink, Sc</u>	ott; <u>Morgan</u> ,					

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# What can we learn from this data?



#### Example 1 – Efficiency of Load Shifting DR

• Are buildings inefficient "batteries"?



# What can we learn from this data?



#### **Example 2 – Challenges of Closing the Loop**

- We'd like to close the loop on a power measurement
- Building Automation Systems don't usually capture power
- We can estimate power, but is that good enough for closing the loop?



Lin et al. (in review)

### Value of HVAC Submetering



#### How well can we estimate HVAC fan power?

- Four models:
  - Linear  $p_{est,j}(t) = \alpha_j V_j(t),$ • Quadratic  $p_{est,j}(t) = \beta_j V_j(t)^2,$
  - Quadratic  $p_{est,j}(t) = \beta_j V_j(t)^2$ , Air flow volume, measured by BAS
  - Cubic  $p_{est,j}(t) = \gamma_j V_j(t)^3$ , All measurements by BAS
  - Regression  $p_{est,k}(t) = \chi_k M_{bas,k}(t)$ ,
- → Physics tells us the relationship should be cubic; however, BAS operation and control affect the empirical relationship, which often has a better fit to a linear or quadratic function

#### Value of HVAC Submetering



#### Mean measured + predicted HVAC fan power – 6 Buildings



Down/Up Events

Up/Down Events

Looks OK, right?

# Value of HVAC Submetering Median prediction error

 Often, error spikes when temperature setpoint changes → models don't capture transients

	LRM		Linear		Quadratic		Cubic	
Bulding	Mean	Std	Mean	Std	Mean	Std	Mean	Std
Superior	0.0698	0.0213	0.0807	0.0309	0.0816	0.0368	0.1000	0.0427
Victoria	0.1158	0.0478	0.1139	0.0313	0.0906	0.0247	0.0884	0.0251
Huron	0.0447	0.0135	0.0480	0.0195	0.0380	0.0096	0.0568	0.0334
Michigan	0.0613	0.0356	0.1529	0.3181	0.1803	0.3085	0.2408	0.2883
Caspian	0.1717	0.0662	0.1766	0.0490	0.1083	0.0400	0.2163	0.0650
Aral	0.0555	0.0216	0.0913	0.0284	0.0882	0.0329	0.0939	0.0413



# Value of HVAC Submetering



#### **Simulation Results**

 We see the same issues in simulation, using the Modelica Buildings Library → We need submetering for closed-loop control?



# **Final Thoughts**



- We should do more experiments on real buildings!
  - J. de Chalendar: "While the prevailing method is "model first, experiment second", there is also strong value in "experiment first, model second" and in improving our understanding of a system through experimentation before modeling it."
- We should make our data open access!
- We should accelerate our efforts to use buildings as grid assets!

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