WHEN TRUST MATTERS

Hours of Use Analysis for Michigan Commercial and Industrial Buildings

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Introductions

Derek Decker, CEM, CMVP

Senior Energy Engineer

APS – Manager Technical Operations

6 years with DNV, 22 years in energy efficiency

DTE, CE Pilots, APS

Specialties include:

Energy Savings Measurement & Verification

Program development and design

Measure development and design

Energy program management

Bill Kosik, PE, CEM, BEMP

Senior Energy Engineer

Energy Use Services (EUS)

4 years with DNV, 25+ in engineering and energy analysis

Data Center Expert

45+ articles published

Measure development and design

Agenda

- Why we did the study
- The application of AMI data in HOU analysis
- DNV analysis methodology
- Normalization of DNV results
- Study results and recommendations
- Questions

Why we did the study

- DNV – Consumers Energy tech demo partnership
- Review emerging technology and existing measures
- Existing measure review
  - State TRM comparisons
  - Baseline efficiencies
  - Proposed efficiencies
  - Other variables used (ex: hours of use)
  - Code changes
- Non-weather sensitive measures
- Focused on measures that are older or vary significantly for other TRMs / industry references

Why we did the study

- MEMD lighting hours of use review
- Reviewed existing method
  - Michigan Statewide Commercial and Industrial Lighting Hours-of-Use Study (June 2014)
  - Small sample size
- Multiple approaches considered – AMI data chosen

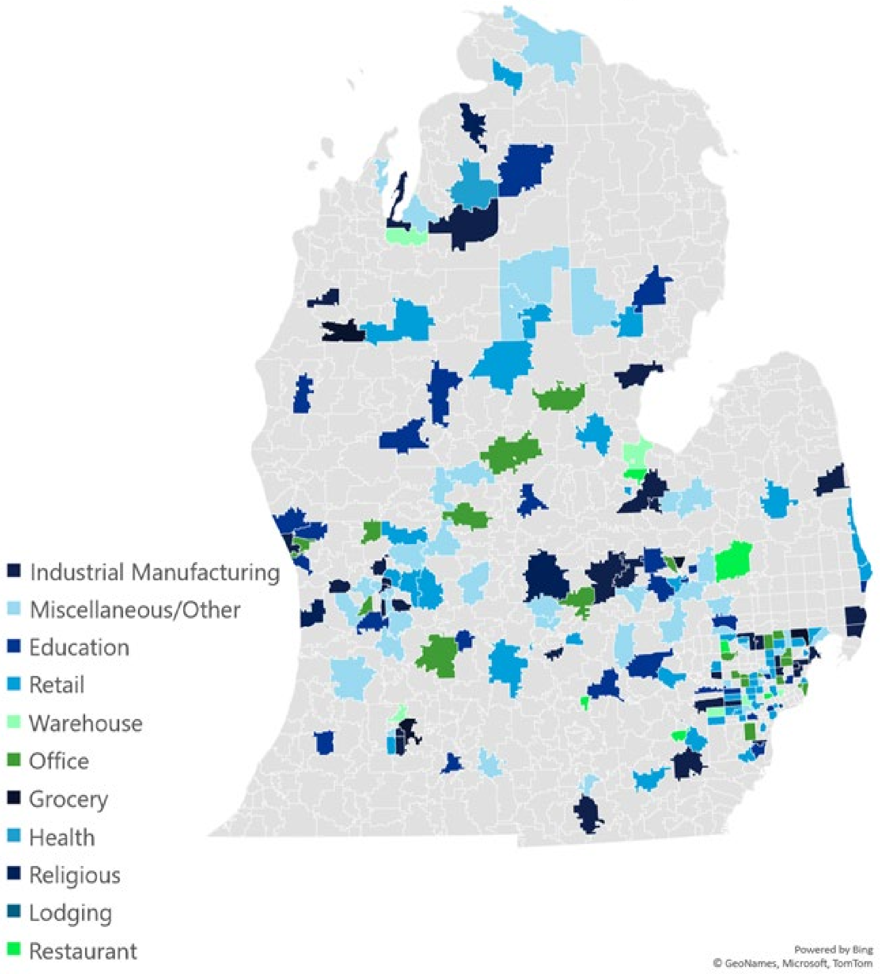
The Application of AMI Data in HOU Analysis

Basics of AMI Data Files

Overview

- Each file contains electrical use data for one customer account
- Consumers Energy – 170 accounts; DTE – 155 accounts
- Data in 15-minute increments (kW)
- Period of meter data
  - Start: January 1, 2018, 1:00 AM
  - End: June 4, 2021, 11:00 PM
- 29,000 data points per customer account
- Data spans 3.5 calendar years, total of 14 seasons

Business Type Sample



Building Type	Facility Count
Education	36
Grocery	8
Health	5
Industrial Manufacturing	41
Lodging	3
Miscellaneous/Other	65
Office	55
Religious	3
Restaurant	13
Retail	79
Warehouse	15
Total	**325**

Combined CE and DTE facility types used in DNV study

Testing AMI Data as a Proxy for Building Occupancy

AMI Data Sets are Foundational to DNV Study

- AMI framework provides automated communication between a utility and consumer
- The data used in the DNV study is a result of the recording, collection, and analysis by the AMI framework
- The energy use patterns extracted from the AMI data is especially important for this study
- Irregular load shapes and missing data were replaced with another random sample

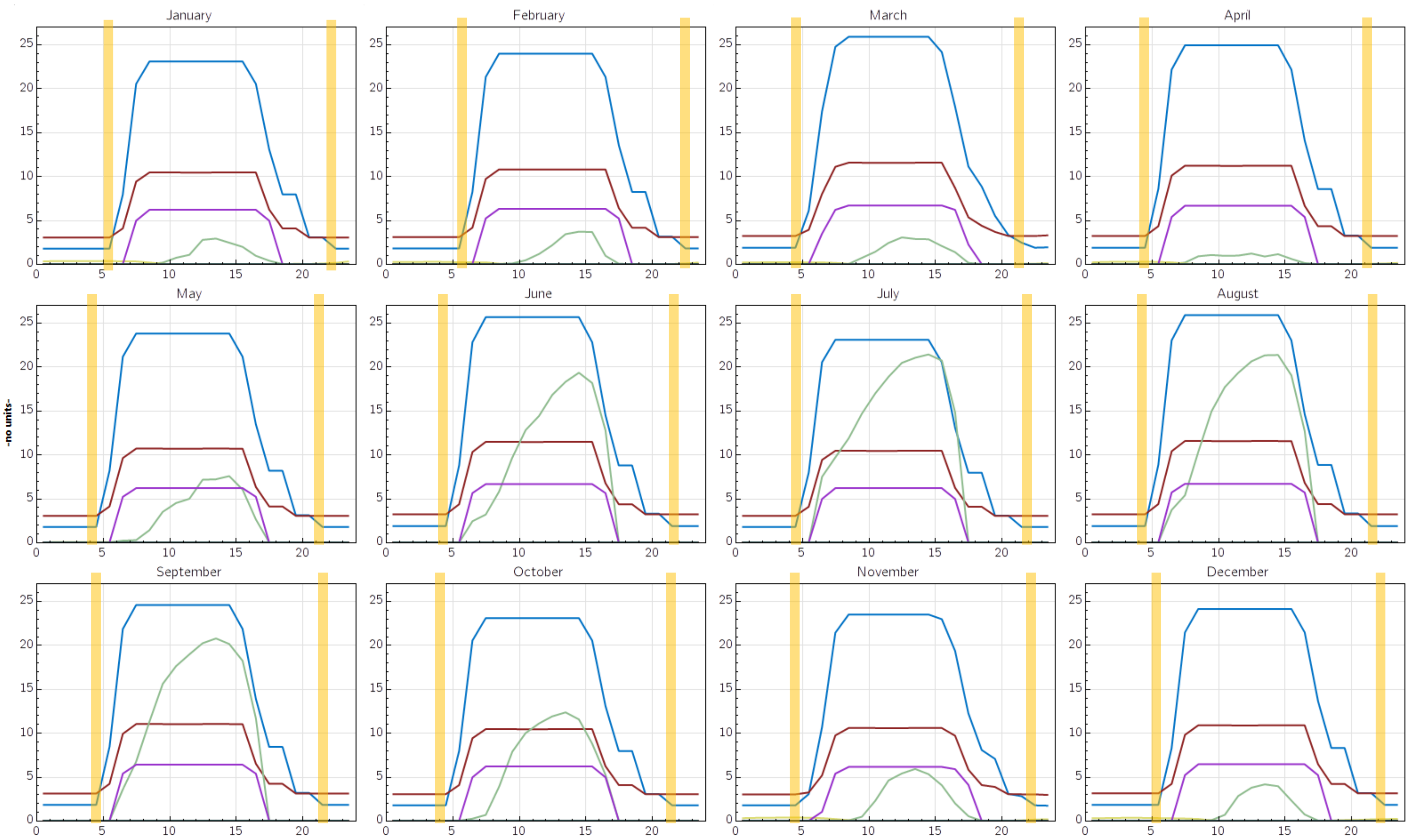
AMI Data Had to Meet Certain Conditions to be Used in Study

- The daily electricity use curve must show a clear maximum and minimum
- By observation, when the electricity use is at a minimum, the facility is unoccupied*
- Conversely, it is assumed when the electricity use is at a maximum, the facility is occupied*

*These assumptions are applicable to the AMI data used in the DNV study: all the facilities are commercial buildings with no special processes or heavy manufacturing.

DNV

Example HOU Profiles for Office Building



- The lines indicate the minimum electricity consumption for the lighting system, at building opening and closing.
- The other building systems are shown for comparison.
- The lighting hours in a commercial building will equal (or exceed) general building hours of occupancy.

LIGHTING

PLUG LOAD

VENTILATION

COOLING

DNV

DNV Analysis Methodology

DNV

DNV Analysis Methodology - Overview

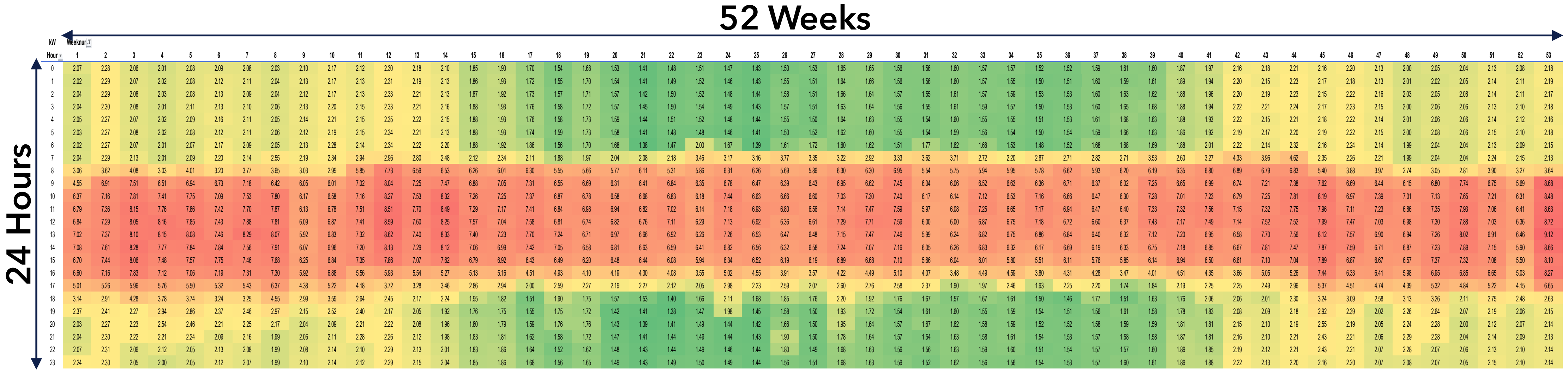
Overview

- Developed an automated routine to extract data from each AMI file, such as building type, facility location, and account number
- Time stamp for 15-minute interval electricity use was validated; non-conformers were replaced
- Data from each customer account was then used in algorithms to calculate hours of use
- DNV ran two independent analyses on the data (Approach A and Approach B)
- Approach A and Approach B were tested statistically using the mean bias error (MBE) test and the coefficient of variation of the root mean squared error (CV(RMSE))
- The MBE and CV(RSME) testing showed compliance to generally accepted modeling techniques[1,2]

[1]Kreider and Haberl 1994a, 1994b ; Haberl and Thamilseran 1996
[2]ASHRAE Guideline 14 - Measurement of Energy and Demand Savings

DNV Analysis Methodology – Approach A

Analysis using data binning and heat maps to determine HOU



Hour	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0	2.07	2.28	2.06	2.01	2.08	2.09	2.08	2.03	2.10	2.17	2.12	2.30	2.18	2.10
1	2.02	2.29	2.07	2.02	2.08	2.12	2.11	2.04	2.13	2.17	2.13	2.31	2.19	2.13
2	2.04	2.29	2.08	2.03	2.08	2.13	2.09	2.04	2.12	2.17	2.13	2.33	2.21	2.13
3	2.04	2.30	2.08	2.01	2.11	2.13	2.10	2.06	2.13	2.20	2.15	2.33	2.21	2.16
4	2.05	2.27	2.07	2.02	2.09	2.16	2.11	2.05	2.14	2.21	2.15	2.35	2.22	2.15
5	2.03	2.27	2.08	2.02	2.08	2.12	2.11	2.06	2.12	2.19	2.15	2.34	2.21	2.13
6	2.02	2.27	2.07	2.01	2.07	2.17	2.09	2.05	2.13	2.28	2.14	2.34	2.22	2.20
7	2.04	2.29	2.13	2.01	2.09	2.20	2.14	2.55	2.19	2.34	2.94	2.96	2.80	2.48
8	3.06	3.62	4.08	3.03	4.01	3.20	3.77	3.65	3.03	2.99	5.85	7.73	6.59	6.53
9	4.55	6.91	7.51	6.51	6.94	6.73	7.18	6.42	6.05	6.01	7.02	8.04	7.25	7.47
10	6.37	7.16	7.81	7.41	7.75	7.09	7.53	7.80	6.17	6.58	7.16	8.27	7.53	8.32
11	6.79	7.36	8.15	7.76	7.86	7.42	7.70	7.87	6.13	6.78	7.51	8.51	7.70	8.49
12	6.84	7.29	8.05	8.16	7.85	7.43	7.88	7.81	6.09	6.87	7.41	8.59	7.60	8.25
13	7.02	7.37	8.10	8.15	8.08	7.46	8.29	8.07	5.92	6.83	7.32	8.62	7.40	8.33
14	7.08	7.61	8.28	7.77	7.84	7.84	7.56	7.91	6.07	6.96	7.20	8.13	7.29	8.12
15	6.70	7.44	8.06	7.48	7.57	7.75	7.46	7.68	6.25	6.84	7.35	7.86	7.07	7.62
16	6.60	7.16	7.83	7.12	7.06	7.19	7.31	7.30	5.92	6.88	5.56	5.93	5.54	5.27
17	5.01	5.26	5.96	5.76	5.50	5.32	5.43	6.37	4.38	5.22	4.18	3.72	3.28	3.46
18	3.14	2.91	4.28	3.78	3.74	3.24	3.25	4.55	2.99	3.59	2.94	2.45	2.17	2.24
19	2.37	2.41	2.27	2.94	2.86	2.37	2.46	2.97	2.15	2.52	2.40	2.17	2.05	1.92
20	2.03	2.27	2.23	2.54	2.46	2.21	2.25	2.17	2.04	2.09	2.21	2.22	2.08	1.96
21	2.04	2.30	2.22	2.21	2.24	2.09	2.16	1.99	2.06	2.11	2.28	2.26	2.12	1.98
22	2.07	2.31	2.06	2.12	2.05	2.13	2.08	1.99	2.08	2.14	2.10	2.29	2.13	2.01
23	2.24	2.30	2.05	2.00	2.05	2.12	2.07	1.99	2.10	2.14	2.12	2.29	2.15	2.04

Hour	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
0	1.85	1.90	1.70	1.54	1.68	1.53	1.41	1.48	1.51	1.47	1.43	1.50	1.53	1.65	1.65	1.56
1	1.86	1.93	1.72	1.55	1.70	1.54	1.41	1.49	1.52	1.46	1.43	1.55	1.51	1.64	1.66	1.56
2	1.87	1.92	1.73	1.57	1.71	1.57	1.42	1.50	1.52	1.48	1.44	1.58	1.51	1.66	1.64	1.57
3	1.88	1.93	1.76	1.58	1.72	1.57	1.45	1.50	1.54	1.49	1.43	1.57	1.51	1.63	1.64	1.56
4	1.88	1.93	1.76	1.58	1.73	1.59	1.44	1.51	1.52	1.48	1.44	1.55	1.50	1.64	1.63	1.55
5	1.88	1.93	1.74	1.59	1.73	1.58	1.41	1.48	1.48	1.46	1.41	1.50	1.52	1.62	1.60	1.55
6	1.88	1.92	1.86	1.56	1.70	1.68	1.38	1.47	2.00	1.67	1.39	1.61	1.72	1.60	1.62	1.51
7	2.12	2.34	2.11	1.88	1.97	2.04	2.08	2.18	3.46	3.17	3.16	3.77	3.35	3.22	2.92	3.33
8	6.26	6.01	6.30	5.55	5.66	5.77	6.11	5.31	5.86	6.31	6.26	5.69	5.86	6.30	6.30	6.95
9	6.88	7.05	7.31	6.55	6.69	6.31	6.41	6.84	6.35	6.78	6.47	6.39	6.43	6.95	6.62	7.45
10	7.26	7.25	7.37	6.87	6.78	6.58	6.68	6.83	6.18	7.44	6.63	6.66	6.60	7.03	7.30	7.40
11	7.29	7.17	7.41	6.84	6.98	6.94	6.82	7.02	6.14	7.18	6.93	6.80	6.56	7.14	7.47	7.59
12	7.57	7.04	7.58	6.81	6.74	6.82	6.76	7.11	6.29	7.13	6.92	6.36	6.61	7.29	7.71	7.59
13	7.40	7.23	7.70	7.24	6.71	6.97	6.66	6.92	6.26	7.26	6.53	6.47	6.48	7.15	7.47	7.46
14	7.06	6.99	7.42	7.05	6.58	6.81	6.63	6.59	6.41	6.82	6.56	6.32	6.58	7.24	7.07	7.16
15	6.79	6.92	6.43	6.49	6.20	6.48	6.44	6.08	5.94	6.34	6.52	6.19	6.19	6.89	6.68	7.10
16	5.13	5.16	4.51	4.93	4.10	4.19	4.30	4.08	3.55	5.02	4.55	3.91	3.57	4.22	4.49	5.10
17	2.86	2.94	2.00	2.59	2.27	2.19	2.27	2.12	2.05	2.98	2.23	2.59	2.07	2.60	2.76	2.58
18	1.95	1.82	1.51	1.90	1.75	1.57	1.53	1.40	1.66	2.11	1.68	1.85	1.76	2.20	1.92	1.76
19	1.76	1.75	1.55	1.75	1.72	1.42	1.41	1.38	1.47	1.98	1.45	1.58	1.50	1.93	1.72	1.54
20	1.80	1.79	1.59	1.76	1.76	1.43	1.39	1.41	1.49	1.44	1.42	1.66	1.50	1.95	1.64	1.57
21	1.83	1.81	1.62	1.58	1.72	1.47	1.41	1.44	1.49	1.44	1.43	1.90	1.50	1.78	1.64	1.57
22	1.83	1.86	1.64	1.52	1.62	1.48	1.43	1.44	1.49	1.46	1.44	1.80	1.49	1.68	1.63	1.56
23	1.85	1.86	1.68	1.56	1.65	1.49	1.43	1.49	1.50	1.49	1.44	1.56	1.51	1.68	1.63	1.59

Hour	31	32	33	34	35	36	37	38	39	40	41	42	43
0	1.56	1.60	1.57	1.57	1.52	1.52	1.59	1.61	1.60	1.87	1.97	2.16	2.18
1	1.56	1.60	1.57	1.55	1.50	1.51	1.60	1.59	1.61	1.89	1.94	2.20	2.15
2	1.55	1.61	1.57	1.59	1.53	1.53	1.60	1.63	1.62	1.88	1.96	2.20	2.19
3	1.55	1.61	1.59	1.57	1.50	1.53	1.60	1.65	1.68	1.88	1.94	2.22	2.21
4	1.54	1.60	1.55	1.55	1.51	1.53	1.61	1.68	1.63	1.88	1.93	2.22	2.15
5	1.54	1.59	1.56	1.54	1.50	1.54	1.59	1.66	1.63	1.86	1.92	2.19	2.17
6	1.77	1.62	1.68	1.53	1.48	1.52	1.68	1.68	1.69	1.88	2.01	2.22	2.14
7	3.62	3.71	2.72	2.20	2.87	2.71	2.82	2.71	3.53	2.60	3.27	4.33	3.96
8	5.54	5.75	5.94	5.95	5.78	6.62	5.93	6.20	6.19	6.35	6.80	6.89	6.79
9	6.04	6.06	6.52	6.63	6.36	6.71	6.37	6.02	7.25	6.65	6.99	6.74	7.21
10	6.17	6.14	7.12	6.53	7.16	6.66	6.47	6.30	7.28	7.01	7.23	6.79	7.25
11	5.97	6.08	7.25	6.65	7.17	6.94	6.47	6.40	7.33	7.32	7.56	7.15	7.32
12	6.00	6.00	6.87	6.75	7.18	6.72	6.60	6.37	7.43	7.17	7.49	7.14	7.52
13	5.99	6.24	6.82	6.75	6.86	6.84	6.40	6.32	7.12	7.20	6.95	6.58	7.70
14	6.05	6.26	6.83	6.32	6.17	6.69	6.19	6.33	6.75	7.18	6.85	6.67	7.81
15	5.66	6.04	6.01	5.80	5.51	6.11	5.76	5.85	6.14	6.94	6.50	6.61	7.10
16	4.07	3.48	4.49	4.59	3.80	4.31	4.28	3.47	4.01	4.51	4.35	3.66	5.05
17	2.37	1.90	1.97	2.46	1.93	2.25	2.20	1.74	1.84	2.19	2.25	2.25	2.49
18	1.67	1.57	1.67	1.61	1.50	1.46	1.77	1.51	1.63	1.76	2.06	2.06	2.01
19	1.61	1.60	1.55	1.59	1.54	1.51	1.56	1.61	1.58	1.78	1.83	2.08	2.09
20	1.67	1.62	1.58	1.59	1.52	1.52	1.58	1.59	1.59	1.81	1.81	2.15	2.10
21	1.54	1.63	1.58	1.61	1.54	1.53	1.57	1.58	1.58	1.87	1.81	2.16	2.10
22	1.56	1.63	1.59	1.60	1.51	1.54	1.57	1.57	1.60	1.89	1.85	2.19	2.12
23	1.52	1.62	1.56	1.56	1.54	1.53	1.57	1.60	1.61	1.89	1.88	2.22	2.13

Hour	44	45	46	47	48	49	50	51	52	53
0	2.21	2.16	2.20	2.13	2.00	2.05	2.04	2.13	2.08	2.18
1	2.23	2.17	2.18	2.13	2.01	2.02	2.05	2.14	2.11	2.19
2	2.23	2.15	2.22	2.16	2.03	2.05	2.08	2.14	2.11	2.17
3	2.24	2.17	2.23	2.15	2.00	2.06	2.06	2.13	2.10	2.18
4	2.21	2.18	2.22	2.14	2.01	2.06	2.06	2.14	2.12	2.16
5	2.20	2.19	2.22	2.15	2.00	2.08	2.06	2.15	2.10	2.18
6	2.32	2.16	2.24	2.14	1.99	2.04	2.04	2.13	2.09	2.15
7	4.62	2.35	2.26	2.21	1.99	2.04	2.04	2.24	2.15	2.13
8	6.83	5.40	3.88	3.97	2.74	3.05	2.81	3.90	3.27	3.64
9	7.38	7.62	6.69	6.44	6.15	6.80	7.74	6.75	5.69	8.68
10	7.81	8.19	6.97	7.39	7.01	7.13	7.65	7.21	6.31	8.48
11	7.75	7.96	7.11	7.23	6.86	7.35	7.93	7.06	6.41	8.63
12	7.52	7.99	7.47	7.03	6.98	7.30	7.88	7.03	6.36	8.72
13	7.56	8.12	7.57	6.90	6.94	7.26	8.02	6.91	6.46	9.12
14	7.47	7.87	7.59	6.71	6.87	7.23	7.89	7.15	5.90	8.66
15	7.04	7.89	6.87	6.67	6.57	7.37	7.32	7.08	5.50	8.10
16	5.26	7.44	6.33	6.41	5.98	6.95	6.85	6.65	5.03	8.27
17	2.96	5.37	4.51	4.74	4.39	5.32	4.84	5.22	4.15	6.65
18	2.30	3.24	3.09	2.58	3.13	3.26	2.11	2.75	2.48	2.63
19	2.18	2.92	2.39	2.02	2.26	2.64	2.07	2.19	2.06	2.15
20	2.19	2.55	2.19	2.05	2.24	2.28	2.00	2.12	2.07	2.14
21	2.21	2.43	2.21	2.06	2.29	2.28	2.04	2.14	2.09	2.13
22	2.21	2.43	2.21	2.07	2.28	2.07	2.06	2.13	2.10	2.14
23	2.20	2.16	2.20	2.07	2.08	2.07	2.05	2.15	2.10	2.14

Power Use of a Facility – Visual Analysis Using Heat Map (24 hours x 52 weeks)

24-hour Period Segmentation Used in Approach A

- Midnight – 07:00 (unoccupied)
- 07:00 – 09:00 (partial occupancy, increasing)
- 09:00 – 17:00 (fully occupied, constant)
- 17 17:00 – 19:00 (partial occupancy, decreasing)
- 19:00 – Midnight (unoccupied)

Visual Analysis of Heat Map

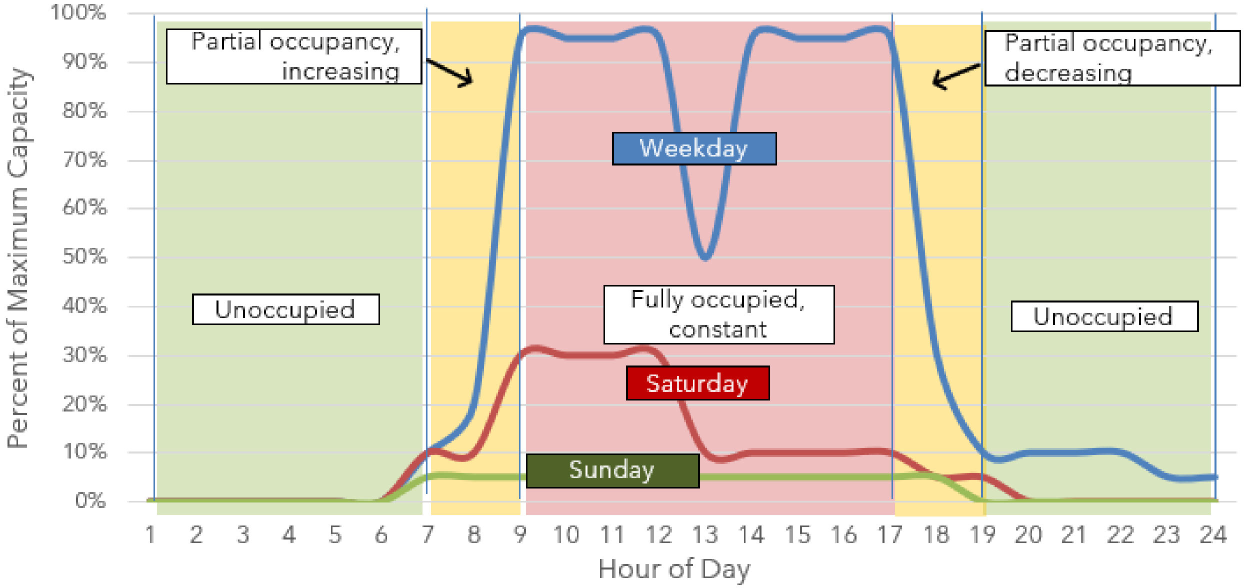
- The heat map informs us on the low, middle, and high frequency bins for a given facility.
- The lowest usage values are in the first bin and represent unoccupied hours
- The first bin (unoccupied hours) is shown in green (or shades of green)
- The remainder of the values which have been captured in subsequent bins have been considered as occupied hours.

DNV Analysis Methodology – Approach B

Algorithmic method to calculate HOU

Segment	Full Date	Year	Month	Day	Hour	Usage
SEGMENT 1	2018-01-01	2018	01	01	0:00	6.4
	2018-01-01	2018	01	01	1:00	6.4
	2018-01-01	2018	01	01	2:00	6.4
	2018-01-01	2018	01	01	3:00	6.4
	2018-01-01	2018	01	01	4:00	6.4
	2018-01-01	2018	01	01	5:00	6.2
	2018-01-01	2018	01	01	6:00	6.4
	2018-01-01	2018	01	01	7:00	6.3
SEGMENT 2	2018-01-01	2018	01	01	8:00	6.3
	2018-01-01	2018	01	01	9:00	6.3
	2018-01-01	2018	01	01	10:00	6.2
	2018-01-01	2018	01	01	11:00	6.4
	2018-01-01	2018	01	01	12:00	6.3
	2018-01-01	2018	01	01	13:00	6.0
	2018-01-01	2018	01	01	14:00	5.7
	2018-01-01	2018	01	01	15:00	5.5
SEGMENT 3	2018-01-01	2018	01	01	16:00	5.5
	2018-01-01	2018	01	01	17:00	5.3
	2018-01-01	2018	01	01	18:00	5.4
	2018-01-01	2018	01	01	19:00	4.9
	2018-01-01	2018	01	01	20:00	5.6
	2018-01-01	2018	01	01	21:00	5.8
	2018-01-01	2018	01	01	22:00	6.1
	2018-01-01	2018	01	01	23:00	6.0

Segment	Average	Standard deviation
SEGMENT 1	6.3	0.048
SEGMENT 2	6.1	0.311
SEGMENT 3	5.6	0.379



Finalizing Results of Approach B Analysis Method

- When the calculations are complete, each eight-hour segment will be represented by numerical values, one (occupied) and zero (unoccupied).
- The total of the values for each segment is determined, The total is then multiplied by eight, resulting in the estimated annual hours of use.
- Finally, the totals are divided into the corresponding year of power use readings (2018, 2019, 2020, 2021).

First segment

- Increasing power from 7:00 AM to 11:00 AM (4 hours)
- Stable power demand from 11:00 AM to 3:00 PM (4 hours)

Second segment

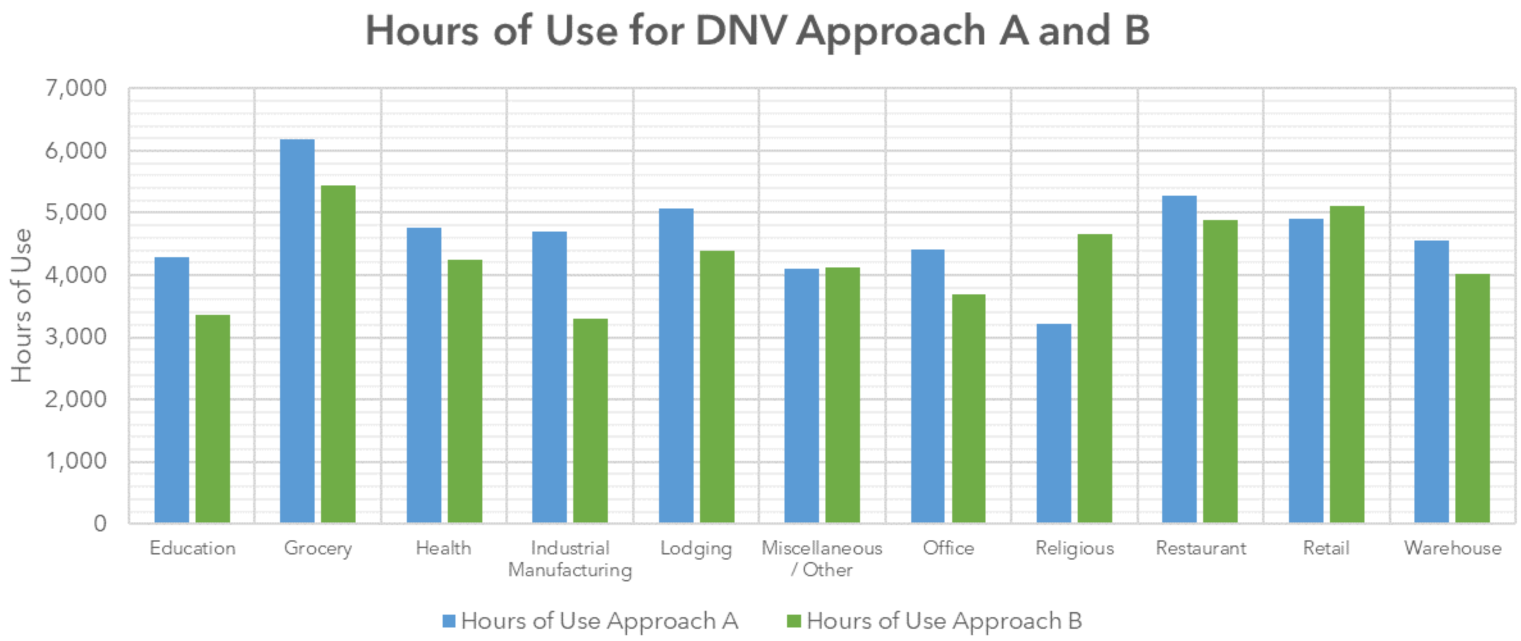
- Decreasing power demand from 4:00 PM to 12:00 midnight (8 hours)

Third segment

- Baseline (minimum) power from 12:00 midnight to 7:00 AM (8 hours)

Results of DNV HOU Analysis

Business Type	% of Total	Hours of Use	
		Approach A	Approach B
Education	10%	4,294	3,371
Grocery	2%	6,192	5,433
Health	1%	4,764	4,242
Industrial Manufacturing	12%	4,709	3,301
Lodging	1%	5,065	4,385
Miscellaneous / Other	26%	4,096	4,127
Office	13%	4,412	3,683
Religious	1%	3,222	4,663
Restaurant	3%	5,288	4,895
Retail	25%	4,916	5,123
Warehouse	4%	4,565	4,025



- Approach A and Approach B were tested statistically using the mean bias error (MBE) test and the coefficient of variation of the root mean squared error (CV(RMSE)) test
- The MBE and CV(RSME) testing showed compliance to generally accepted modeling techniques

Normalization of DNV Results Based on Variance of HOU Data per Building Type

Building Performance Database (BPD)
External reference data

- The Building Performance Database (BPD) is the nation's largest dataset of information about the energy-related characteristics of commercial and residential buildings (over 150,000 buildings in database).
- The BPD combines, cleanses and anonymizes data collected by federal, state and local governments, utilities, energy efficiency programs, building owners and private companies, and makes it available to the public.
- The web site allows users to explore the data across real estate sectors and regions and compare various physical and operational characteristics to gain a better understanding of market conditions and trends in energy performance.
- The BPD is sponsored by the U.S. Department of Energy Building Technologies Office. This web application was developed by Lawrence Berkeley National Laboratory and Earth Advantage.

NREL ComStock
External reference data

- ComStock is a highly granular, bottom-up model that uses multiple data sources, statistical sampling methods, and advanced building energy simulations to estimate the annual sub-hourly energy consumption of the commercial building stock across the United States.
- At the most fundamental level, this dataset is the output of approximately 350,000 ComStock building energy models. The output of each building energy model is 1 year of energy consumption in 15-minute intervals, separated into end-use categories.
- The profiles are simulated using ComStock models, which have been calibrated and validated against an array of empirical datasets. This includes anonymous hourly utility meter data, EIA monthly/annual data, and various end-use metered datasets.
- ComStock answers two questions: 1) how is energy used in the U.S. building stock and 2) what are the impacts of energy saving technologies.
- ComStock identifies the impact of efficiency measures: how much energy do efficiency measures save; where, or in what use cases do measures save energy; when, or at what time of day do savings occur; and which building stock segments have the biggest savings potential.

Source: https://comstock.nrel.gov

External Reference Data and Normalization Model

Comparing hours of use for DNV and reference data

Building types:

1. Education
2. Grocery
3. Health
4. Lodging
5. Manufacturing
6. Office
7. Restaurant
8. Retail
9. Warehouse

Reference Data – Codes, Federal Guidelines, Industry Studies:

1. DOE Reference Building Data – 2012
2. National Energy Code of Canada for Buildings - 2017
3. International Energy Conservation Code (IECC) - 2018
4. NYSERDA /NYS Commercial Baseline Study - 2015
5. eQuest Modeling Baseline Assumptions v3.65 - 2018
6. COMNET Energy Modeling Resources - 2016

Reference Data – State and Region TRMs:

1. NY State Approach for Estimating Savings from EEPs - 2022
2. PA PUC Technical Reference Manual - 2021
3. CA DEER TRM
4. Mid-Atlantic TRM Northeast Energy Efficiency Partnerships (NEEP) - 2017

Variance Analysis of Industry References

Certain building types have higher variability in reported HOU values

Building Type and Variance Level (Low variance / High variance)	Miichigan Current MEMD TRM **MEMD TRM**	EMI Consulting Michigan Statewide C&I Lighting HOU Study Study 2014 **EMI**	DOE Reference Building Data 2012 **DOE**	eQuest Modeling Baseline Assumptions v3.65 2018 **eQuest**	COMNET Energy Modeling Resources 2016 **COMNET**	National Energy Code of Canada for Buildings 2017 **NECCB**	International Energy Conservation Code (IECC) 2018 **IECC**	NYSERDA /NYS Commercial Baseline Study 2015 **NYSERDA**	NY State Approach for Estimating Savings from EEPs 2022 **NY State**	PA PUC Technical Reference Manual 2021 **PA PUC TRM**	CA DEER TRM **DEER TRM**	Mid-Atlantic TRM Northeast Energy Efficiency Partnerships (NEEP) 2017 **NEEP TRM**	**Mean of Reference Data**	**Standard Deviation of Reference Data**	**Mean + One Standard Deviation**
Education	2,669	2,239	3,466	2,048	4,107	3,024	3,883	2,964	2,586	2,694	2,310	2,233	2,932	664	3,596
Grocery	2,669	0	3,764	4,368	3,558	4,007	2,555	5,304	2,854	4,110	5,440	-	3,996	917	4,913
Health	2,669	3,222	3,923	-	5,438	0	4,701	5,304	-	-	-	3,817	3,864	1834	5,698
Lodging	2,669	1,515	3,039	-	3,285	2,115	5,013	5,044	3,066	-	5,590	-	3,879	1219	5,098
Manufacturing	2,669	2,575	-	2,340	3,194	2,933	-	-	2,857	3,659	0	4,361	2,763	1276	4,039
Office	2,669	1,974	3,170	2,340	2,856	2,933	2,514	3,588	3,013	2,728	2,520	3,044	2,871	348	3,219
Restaurant	2,669	4,046	1,846	4,368	5,053	5,387	2,953	4,004	2,713	3,921	0	-	3,361	1595	4,955
Retail	2,669	2,830	3,420	5,668	3,558	4,007	2,408	3,172	3,748	3,633	4,110	4,696	3,842	835	4,677
Warehouse	2,669	3,587	2,827	2,340	2,771	2,933	2,394	3,016	4,368	3,332	4,820	-	3,200	804	4,005

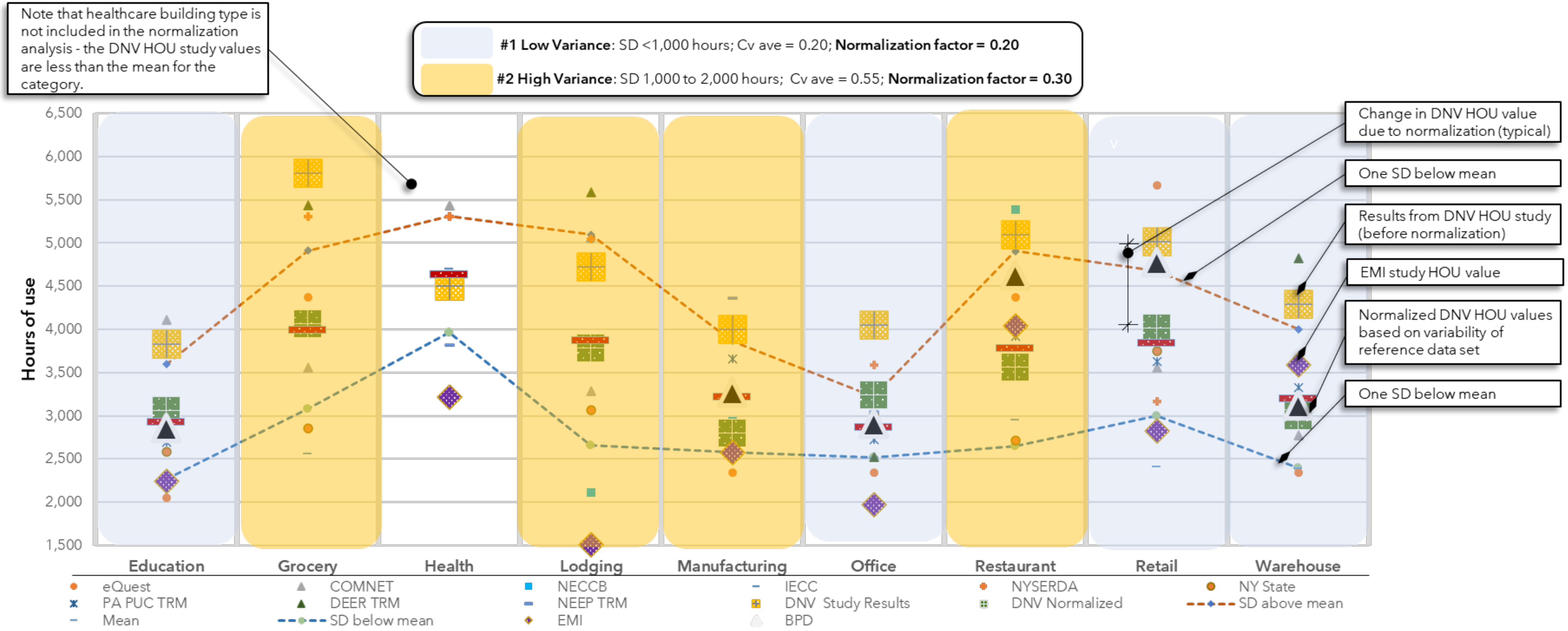
#1 Low Variance: SD <1,000 hours; Cv ave = 0.20; **Normalization factor = 0.20**

#2 High Variance: SD 1,000 to 2,000 hours; Cv ave = 0.55; **Normalization factor = 0.30**

DNV

Normalization Procedure

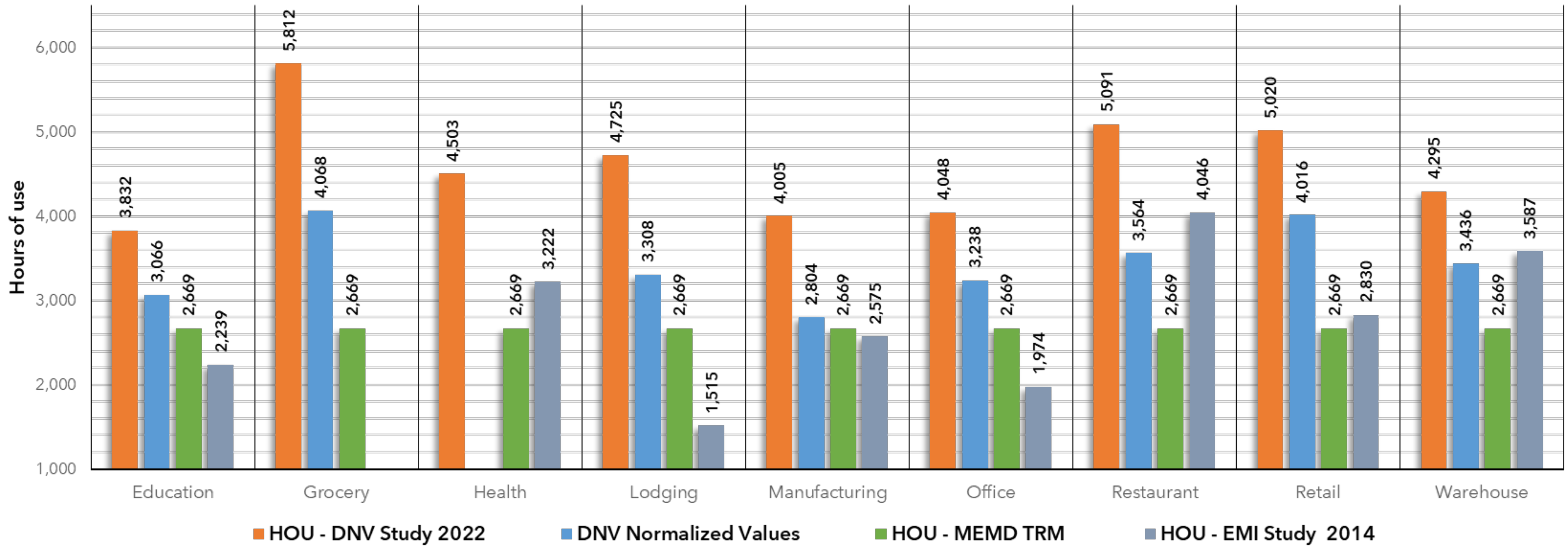
Analysis of reference data to build model



DNV

Study Results and Recommendations

Results of DNV HOU Normalization Analysis



Building Type	HOU - MEMD TRM	HOU - EMI Study 2014	HOU - DNV Study 2022	Normalization Factors	DNV Normalized Values
Education	2,669	2,239	3,832	0.20	3,066
Grocery	2,669		5,812	0.30	4,068
Health	2,669	3,222	4,503		
Lodging	2,669	1,515	4,725	0.30	3,308
Manufacturing	2,669	2,575	4,005	0.30	2,804
Office	2,669	1,974	4,048	0.20	3,238
Restaurant	2,669	4,046	5,091	0.30	3,564
Retail	2,669	2,830	5,020	0.20	4,016
Warehouse	2,669	3,587	4,295	0.20	3,436

DNV

Initial Study Results – Measures Impacted

144 total measures

24 workpapers

33 measures, **12** workpapers currently used

20 unique to CE

8 common to both

5 unique to DTE

Measure Code	File Code	Proposed Technologies for Measures Library
N-CO-LI-000075-E-XX-XX-XX-XX-04	.FESL7	Occupancy Sensors between 150 and 500 sq ft
N-CO-LI-000076-E-XX-XX-XX-XX-03	.FESL7	Occupancy Sensors over 500 sq ft
N-CO-LI-000078-E-XX-XX-XX-XX-03	.FESL10	Central Lighting Control
N-CO-LI-000493-E-XX-XX-XX-XX-03	.FESL12	Daylight Sensor controls
N-CO-LI-000818-E-XX-XX-XX-XX-01	.FESL7	Occupancy Sensor less than 150 sq ft
N-CO-LI-000494-E-XX-XX-XX-XX-03	.FESL3	LED Low Bay (per kW saved)
N-CO-LI-000137-E-XX-XX-XX-XX-04	.FESL6	LED Downlight
N-CO-LI-000153-E-XX-XX-XX-XX-03	.FESL28a	Lighting Power Density - Interior
N-CO-LI-000079-E-XX-XX-XX-XX-04	.FESL11	Switching Controls for Multilevel Lighting
N-CO-LI-000782-E-XX-XX-XX-XX-01	.FESL38	Networked Lighting Controls
N-CO-LI-000490-E-XX-XX-XX-XX-04	.FESL7	Occupancy and Daylight Sensor between 150 and 500 sq ft
N-CO-LI-000491-E-XX-XX-XX-XX-03	.FESL7	Occupancy and Daylight Sensor over 500 sq ft
N-CO-LI-000816-E-XX-XX-XX-XX-01	.FESL7	Occupancy and Daylight Sensors less than 150 sq ft
N-CO-LI-000077-E-XX-XX-XX-XX-03	.FESL7	Occupancy Sensors (connect load base)
N-CO-LI-000492-E-XX-XX-XX-XX-03	.FESL7	Occupancy and Daylight Sensor (connected load base)
N-CO-LI-000139-E-XX-XX-XX-XX-05	.FESL6d	LED PAR/R/BR <= 15.5W
N-CO-LI-000142-E-XX-XX-XX-XX-06	.FESL6d	LED A-line 800-1599 lumen output replacing Incandescent/Halogen
N-CO-LI-000143-E-XX-XX-XX-XX-06	.FESL6d	LED A-line 1600-2600 lumen output replacing Incandescent/Halogen
N-CO-LI-000144-E-XX-XX-XX-XX-05	.FESL6d	LED PAR/R/BR <= 15.5W
N-CO-LI-000655-E-XX-XX-XX-XX-04	.FESL6d	Wi-Fi LED A-line 800-1599 lumen output replacing Incandescent/Halogen
N-CO-LI-000140-E-XX-XX-XX-XX-05	.FESL6d	LED Candelabra <= 5W
N-CO-LI-000141-E-XX-XX-XX-XX-05	.FESL6d	LED Globe <= 8W
N-CO-LI-000750-E-XX-XX-XX-XX-03	.FESL6d	LED A-line 450-799 Lumen output replacing Incandescent/Halogen
N-CO-LI-000751-E-XX-XX-XX-XX-03	.FESL6d	LED A-line 800-1099 Lumen output replacing Incandescent/Halogen
N-CO-LI-000752-E-XX-XX-XX-XX-03	.FESL6d	LED A-line 1100-1599 Lumen output replacing Incandescent/Halogen
N-CO-LI-000753-E-XX-XX-XX-XX-03	.FESL6d	LED A-line 1600-1999 Lumen output replacing Incandescent/Halogen
N-CO-LI-000485-E-XX-XX-XX-XX-05	.FESL31	1L 4' LED Tube replacing T12 1L 4' lamp
N-CO-LI-000486-E-XX-XX-XX-XX-05	.FESL31	1L 4' LED Tube replacing T8 1L 4' lamp
N-CO-LI-000487-E-XX-XX-XX-XX-05	.FESL31	2L 4' LED tube replacing T12 1L 8'
N-CO-LI-000576-E-XX-XX-XX-XX-03	.FESL34	2x2 LED Troffer or Retrofit (2000-3000 lumens)
N-CO-LI-000805-E-XX-XX-XX-XX-01	.FESL34	2x2 LED Troffer or Retrofit (3001-5000 lumens)
N-CO-LI-000807-E-XX-XX-XX-XX-01	.FESL34	2x4 LED Troffer or Retrofit (4501-6000 lumens)
N-CO-LI-000028-E-XX-XX-XX-XX-04	.FESL21	Delamping T12 (per lamp) 8ft

Initial Study Results

2,669 Existing MEMD HOU

4,551 Approach A, **4,200** Approach B

4,376 HOU

Final Summary & Recommendations

2,669 Existing MEMD HOU

4,376 Initial Results

3,378 Normalized Results

Final Summary and Recommendations

- Modify existing value with normalized value
- Phase 2 potential
  - Replace singular value with building specific values
  - Potential opportunity for further HOU validation using building using end use metering, site logging, EMS data, etc.
  - Analysis of other HOU values used in MEMD

dankegon
kudos
mesi
nandri
efharis
danke
merci
děkuji vám
thanks
asante
cheers
gracias

Thank You

grazie
rigato
danke
merci
ďakujem vam
thanks
spasiba
nkosi
waita
hvala

Questions.