ELECTRIC DRYER BASELINE RESEARCH
EMERGING TECHNOLOGIES PROGRAM

NORTHEAST ENERGY EFFICIENCY PARTNERSHIPS
FACILITATING PARTNERSHIPS TO ADVANCE ENERGY EFFICIENCY

energy & resource solutions

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PRESENTATION OVERVIEW

- Study goals
- Summary of key findings
- Study methodology
- Clothes dryer primer
- Site data
- Metered data
- Data analysis
- Secondary data - comparative analysis
- Conclusions

STUDY GOALS

- Establish baseline assumptions for residential electric dryer efficiency measures
  - Monitor and report energy demand and usage
  - Determine average load shape for peak and non-peak demand seasons
  - Measure and report energy impact of venting air to outdoors
  - Develop assumptions for existing dryers and associated washers (type; age; etc.)
  - Characterize homeowner usage patterns
  - Characterize typical installations

SUMMARY OF KEY FINDINGS

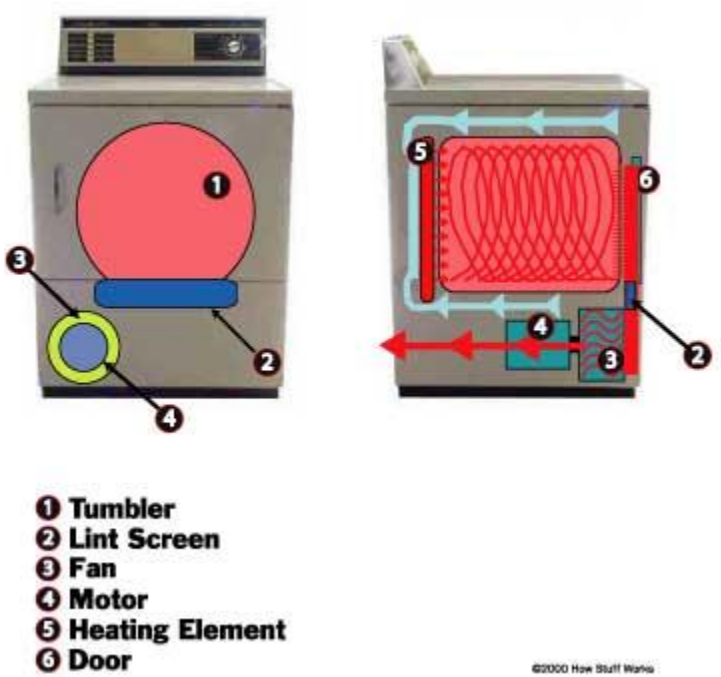
- Average annual estimated electric energy consumption:
  - 993 kWh for an average single family household size of 2.8
  - Energy usage is consistent with other reviewed studies
- Dryer runtimes and energy usage are somewhat higher during cold weather months, due to heavier and/or multi-layer clothing
- Dryer usage is somewhat higher on weekend days
- Weekday load shape is relatively flat between 11 AM and 10 PM, and differs from other reviewed studies
- Dryer standby energy usage is very small:
  - Dryers with electronic controls; ≅1.5 kWh per dryer per year (actual measured amperage is below meter accuracy range)
  - Dryers with electro-mechanical controls have 0 standby usage
- For New England, the most common dryer location is in a heated or semi-heated (thermally coupled) basement
- All surveyed sites had proper venting to the outdoors
- Volume of exhausted air produces energy penalty of ≅12% of dryer usage

SUMMARY OF METHODOLOGY

- Perform limited secondary research
  - Relevant studies
  - Market data
- Develop target laundry configurations for M&V
  - Household demographics
  - Washer/dryer
- Monitor dryer usage for 8-9 months
  - Usage patterns; drying times
  - Energy demand and usage
- Meter
  - Dryer air exhaust CFM (utilizing velocity measurements)
  - Standby dryer usage
- Homeowner interviews and home surveys
  - Laundry usage patterns
  - Home size and dryer location
  - Heating and air conditioning systems

Residential Electric Clothes Dryer Operation

- Motor and controls operate on 120v
- Resistance coils operate on 240v
- Coil(s) are cycled on/off depending on temperature settings and sensors
  - Some dryers have two coils that are controlled separately
- One motor drives both the fan and the tumbler through pulley actuators
  - The fan draws air across the heating coils and forces it through the tumbler drum
- Older dryers with electro-mechanical controls have no standby energy usage
- Dryers with electronic controls have small standby energy usage – typically less than 1 watt



SAMPLE SELECTION

23 residential sites recruited

- Single family homes
- Year-round occupancy
- Maine, Massachusetts, Vermont, New Hampshire
- 2 – 4 occupants
- Recent electric dryer models (target ≤ 5 years)
- Washing machines include modern front load
- Variety of dryer install locations

21 sites produced usable data

MONITORED SITES

ID	State	City	Dryer Make	Dryer Model #	Dryer Age	Washer Make	Washer Type	Washer Age	Dryer Location	Heated Space	Family Size	Heat Source	Cooling	# Floors	Square Footage
V1	VT	MIDDLEBURY	Kenmore	796.4117221	1	Kenmore	Front Load	1	Utility Room	Yes	2 Adults	40%/60% oil/wood	None	2	3,800
V2	VT	WALTHAM	Kenmore	110.6002201	3	Kenmore	Front Load	3	Utility Room	Yes	2 Adults	Passive solar/wood/electric backup	Ductless heatpump	2	2,100
V3	VT	CHARLOTTE	Whirlpool	WED70HEBWO	1	Whirlpool	Front Load	1	Utility Room	Yes	2 Adults, 2 Children	Propane/wood	None	2	2,200
V4	VT	BRANDON	Samsung	DV400EWHDR/AA	1	Samsung	Front Load	3	Utility Room	Yes	2 Adults, 2 Children	65%/35% oil/wood	3 Window units	2	2,100
V5	VT	UNDERHILL	NA	NA	1	NA	NA	1	Basement	Yes	2 Adults	50%/50% oil/wood	None	2	1,600
V6	VT	SHELBURNE	Sears	417.82042101	NA	Sears	Front Load	NA	Garage	Yes	2 Adults, 2 Children	100% NG furnance	None	2	2,800
V7	VT	SOUTH BURLINGTON	LG	DLE2516W	2	NA	Front Load	2	Basement	Yes	3 Adults	100% NG furnance	None	1	1,100
V8	VT	MIDDLEBURY	Maytag	MEDX500XW1	1	Maytag	Top Load	1	Basement	Yes	2 Adults	100% Propane	None	1	900
V9	VT	VERGENNES	GE	DWSR463EG6WW	6+	Frigidaire	Front Load	3	Utility Room	Yes	2 Adults, 2 Children	60%/40% oil/wood	None	2	2,200
V10	VT	VERGENNES	Whirlpool	WED8200YWO	5	Whirlpool	Front Load	5	Utility Room	Yes	2 Adults, 1 Child	50%/50% oil/wood	None	2	2,300
V11	VT	BRISTOL	Kenmore	NA	2	Kenmore	Front Load		Utility Room	Yes	2 Adults	80%/20% oil/wood	None	2	1,600
ME1	ME	YORK	NA	NA	1	NA	Top Load	1	Utility Room	Yes	1 Adult	Propane	None	1	900
ME2	ME	YORK	Maytag	MDE6800AYW	7	Whirlpool	Top Load	7	Basement	No	2 Adults	100% Oil	None	2	1,200
ME3	ME	YORK	Samsung	DV457EVGSGR/A1	1	Samsung	Front Load	1	Basement	No	2 Adults	100% Oil	None	2	1,400
ME4	ME	YORK	Kenmore	110.87561603	5	Kenmore	Front Load	5	Basement	No	3 Adults	100% Oil	None	2	1,638
ME5	ME	YORK	GE	DWSR405EB2WW	5+	GE	Top Load	10	First floor	No	2 Adults,2 Children	100% Oil	None	2	1,800
ME6	ME	YORK	Maytag	MDE5500AYQ	5	Whirlpool	Front Load	5	Basement	No	4 Adults	100% Oil	None	2	1,938
MA1	MA	LEOMINSTER	Kenmore	110.84821301	2	Kenmore	Front Load	2	Basement	Yes	3 Adults	100% Oil	None	2	1,500
MA2	MA	LUNENBURG	Whirlpool	LER5636EQ3	1	Whirlpool	Top Load	7	Basement	Yes	4 Adults	60%wood/40% Oil	None	2	1,600
MA3	MA	LEOMINSTER	Whirlpool	LE7685XPW0	5	Whirlpool	Top Load	10	Basement	No	3 Adults	100% Oil	None	1	1,300
MA4	MA	LEOMINSTER	Kenmore	110.668625	3	GE	Top Load	10	First floor	Yes	3 Adults, 1 Child	100% NG furnance	None	2	3,000
NH1	NH	BROOKLINE	Maytag	MEDC400VW0	4	Kenmore	Top Load	5	Second floor	Yes	2 Adults, 1 Child	80%/20% oil/wood	Central AC	2	2,600

MONITORED SITES – REPORTED USAGE

Participant reported dryer usage

- Surveyed at time of meter install and/or retrieval

Average # of loads per week	5.25
Average % of loads dried in electric dryer	79%
Average % of loads moisture or air temperature sensor terminated[1]	75%
Average % of loads timer terminated	25%
Average % of loads receiving extra or extended ("ultra") spin cycle	33%

MONITORING PROCEDURE

- Monitoring period:
  - Early April – Mid November 2014
  - 3 dryers continued monitoring through December
- Install data loggers to collect:
  - kW
  - kWh
  - Dryer run times
  - Both resistance coil and auxiliary power (tumble motor/controls) - metered both legs of 220 circuit
- Interview homeowners
- Survey installations

SITE SUMMARY – METERED DATA

ID	Date Start	Date End	Days Metered	# Loads	Avg Load Time (mins)	Average Demand During Operation (kW)
V1	4/24/2014	11/3/2014	193	101	35	3.0
V2	4/23/2014	11/3/2014	194	178	63	2.4
V3	4/22/2014	11/3/2014	195	147	43	3.8
V4	4/24/2014	11/3/2014	193	337	67	2.5
V5	4/24/2014	11/4/2014	194	283	35	2.8
V6	4/22/2014	10/27/2014	188	228	26	2.7
V7	4/23/2014	11/3/2014	194	168	41	3.1
V8	4/23/2014	10/15/2014	175	128	25	3.8
V9	4/22/2014	11/3/2014	195	196	46	2.9
V10	4/23/2014	12/4/2014	225	218	64	3.1
V11*	NA	NA	NA	NA	NA	NA
ME1**	4/2/2014	8/12/2014	132	418	25	1.8
ME2***	5/18/2014	6/30/2014	43	35	40	4.0
ME3	5/18/2014	12/12/2014	208	262	39	3.1
ME4	3/31/2014	12/11/2014	255	132	96	2.3
ME5	5/19/2014	1/9/2015	235	312	34	3.1
ME6	3/25/2014	5/16/2014	52	35	51	3.4
ME6****	12/14/2014	1/11/2015	28	31	30	4.9
MA1	3/26/2014	11/7/2014	226	348	110	1.3
MA2	3/30/2014	12/14/2014	259	665	42	3.8
MA3	3/29/2014	11/6/2014	222	345	33	2.9
MA4	3/26/2014	11/3/2014	222	118	82	2.3
NH1	4/1/2014	1/15/2015	289	292	40	3.2
Average			**187**	**226**	**48**	**3.0**

*** Data corrupt**

**** Customer moved in August**

***** Logger failure**

****** Gap in metered data**

MONTHLY ENERGY USAGE APR – NOV (ME, MA, NH)
PARTIAL MONTHS EXTRAPOLATED TO FULL MONTHS

Site ID	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan-15	Annual Standby kWh	Daily Average kWh
V1	NM	NM	NM	32	32	19	30	23	33	34	NM	NM	NM	1.1	1.0
V2	NM	NM	NM	27	31	33	20	31	34	165	131	NM	NM	1.1	1.9
V3	NM	NM	NM	56	62	65	51	80	54	65	142	NM	NM	1.1	2.4
V4	NM	NM	NM	190	262	117	47	68	185	199	256	NM	NM	1.1	5.4
V5	NM	NM	NM	85	93	80	64	61	62	67	92	NM	NM	1.1	2.5
V6	NM	NM	NM	57	58	28	41	38	38	52	NM	NM	NM	1.1	1.5
V7	NM	NM	NM	16	49	71	46	78	50	56	68	NM	NM	1.1	2.0
V8	NM	NM	NM	40	36	40	27	30	32	55	NM	NM	NM	1.0	1.2
V9	NM	NM	NM	118	87	52	51	59	56	76	149	NM	NM	1.1	2.7
V10	NM	NM	NM	74	118	91	82	92	88	104	108	NM	NM	1.3	3.1
ME1	NM	NM	NM	49	72	96	79	54	NM	NM	NM	NM	NM	0.7	2.3
ME3	NM	NM	NM	NM	104	102	90	74	69	56	56	106	NM	1.2	2.7
ME4	NM	NM	NM	76	49	63	46	55	47	54	71	72	NM	1.5	1.9
ME5	NM	NM	NM	NM	89	62	55	60	60	74	88	74	117	1.4	2.5
ME6	NM	NM	NM	75	50	NM	NM	NM	NM	NM	NM	88	65	1.0	2.3
MA1	NM	NM	NM	92	85	152	156	85	110	25	90	NM	NM	1.2	3.3
MA2	NM	NM	NM	101	222	217	199	217	183	244	248	252	NM	1.4	6.8
MA3	NM	NM	NM	72	96	68	67	73	72	68	90	NM	NM	1.3	2.5
MA4	NM	NM	NM	38	30	54	61	43	38	78	35	NM	NM	1.3	1.5
NH1	NM	NM	NM	64	65	82	69	59	59	82	59	61	53	1.7	2.1
Average														1.2	2.6

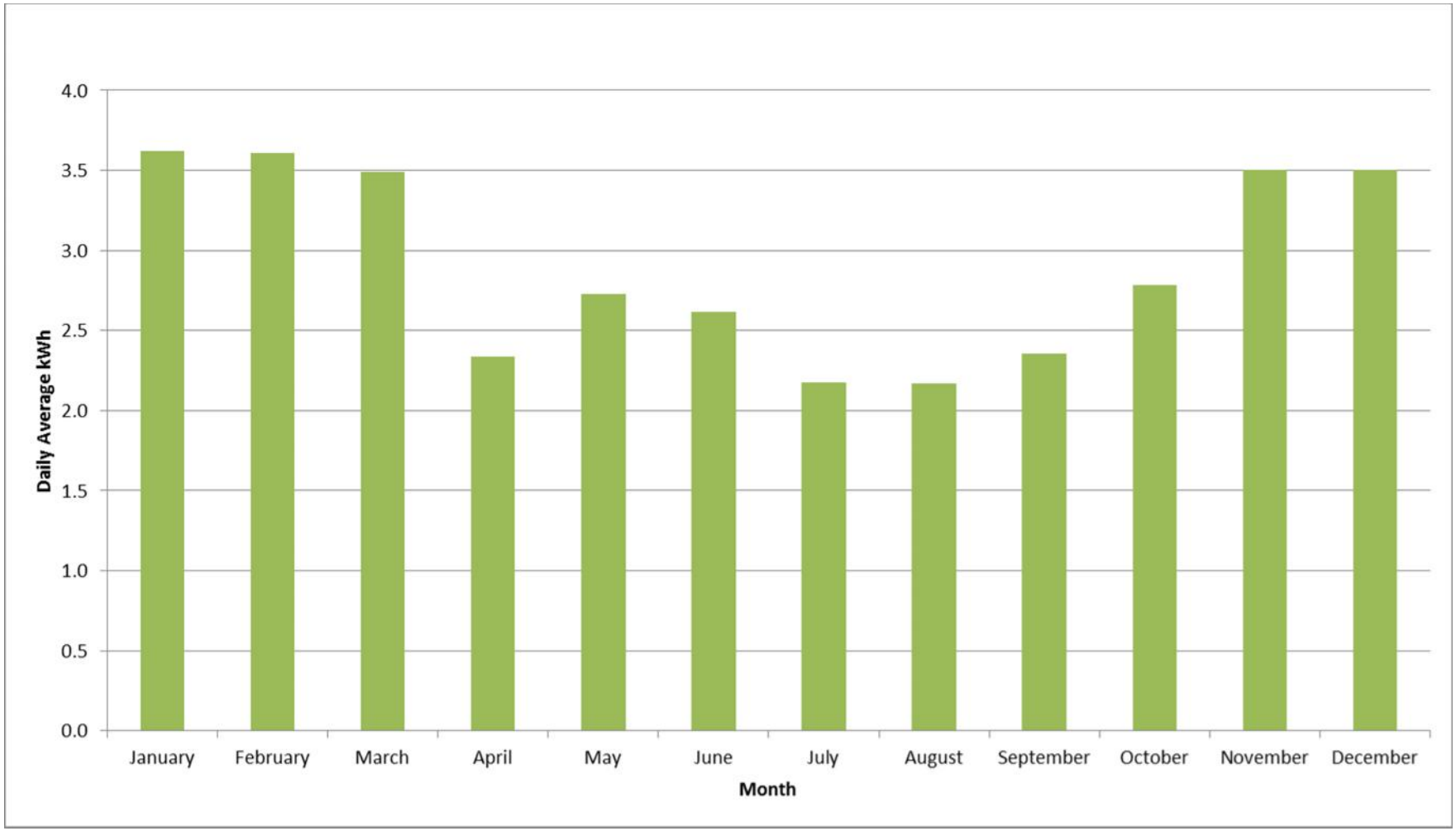
NM – Not Metered During Time Period

EXTRAPOLATION METHODOLOGY

In order to estimate annual usage, metered data was extrapolated:

- Partial month metered data for each site was extrapolated to full month usage
- For Jan, Feb, March – data metered during October, November, December, January 2015 (limited to 3 sites for 2 weeks) and April, was used to plot a projection for estimated usage
- Projected data was compared with NEEA metered monthly data for consistency with usage changes associated with colder weather periods

EXTRAPOLATED 12 MONTH AVERAGE DAILY ENERGY USAGE



Annual Energy Usage Normalized for Household Size

2010 U.S. Census:

- 60% of homes are single unit homes
- Average household size for all housing types; 2.58 occupants
- Average household size for single unit homes; 2.81 occupants
- Average household size for this study; 3.00 occupants
- Average annual metered energy usage
  - 1,060 kWh
- Average annual energy usage normalized to 2.8 occupants
  - 993 kWh

AVERAGE HOUSEHOLD

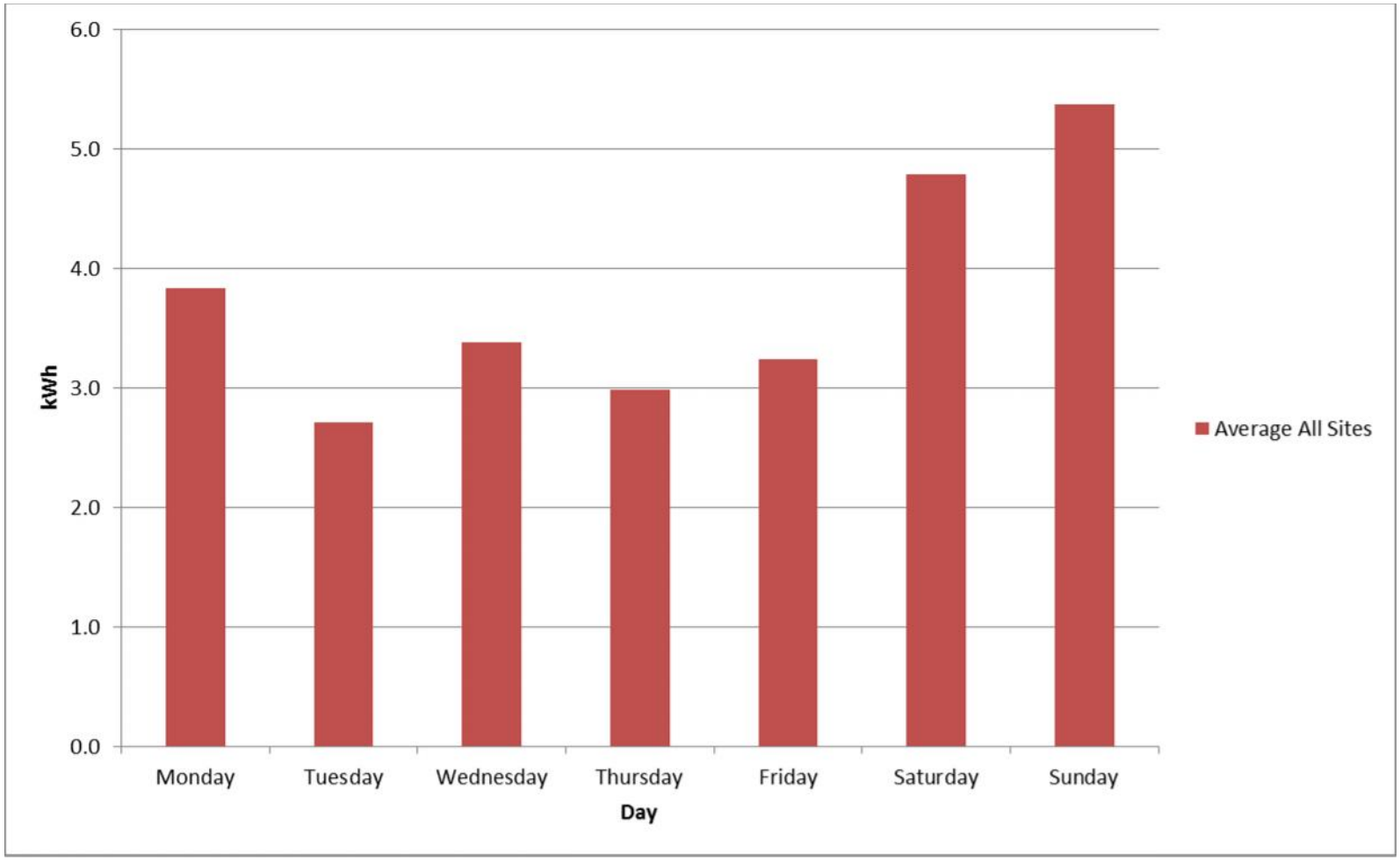
ID	# Adults	# Children	Total
V1	2	0	2
V2	2	0	2
V3	2	2	4
V4	2	2	4
V5	2	0	2
V6	2	2	4
V7	3	0	3
V8	2	0	2
V9	2	2	4
V10	2	1	3
ME1	1	0	1
ME2	2	0	2
ME3	2	0	2
ME4	3	0	3
ME5	2	2	4
ME6	4	0	4
MA1	3	0	3
MA2	4	0	4
MA3	3	0	3
MA4	3	1	4
NH1	2	1	3
Average	**2.4**	**0.6**	**3.0**

EXTRAPOLATED 12 MONTH ENERGY USAGE

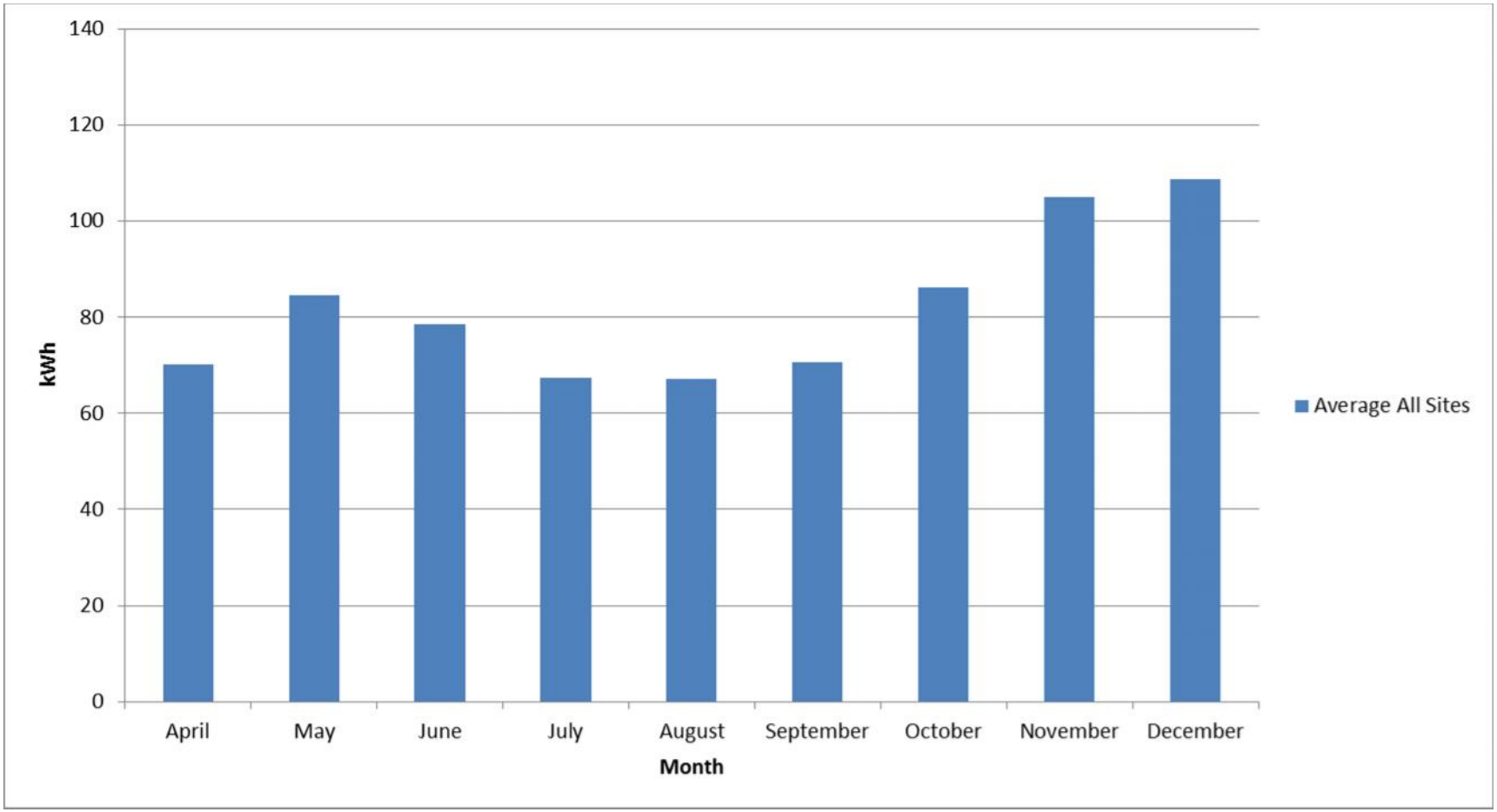
	kWh	
Month	Monthly Average All Sites	Daily Average All Sites
January*	112	3.6
February *	101	3.6
March *	108	3.5
April	70	2.3
May	85	2.7
June	78	2.6
July	67	2.2
August	67	2.2
September	71	2.4
October	86	2.8
November	105	3.5
December	109	3.5
Total Annual kWh; all Sites	**1,060**	
Normalized for 2.8 Occupants per Household	**993**	

*** Extrapolated data**

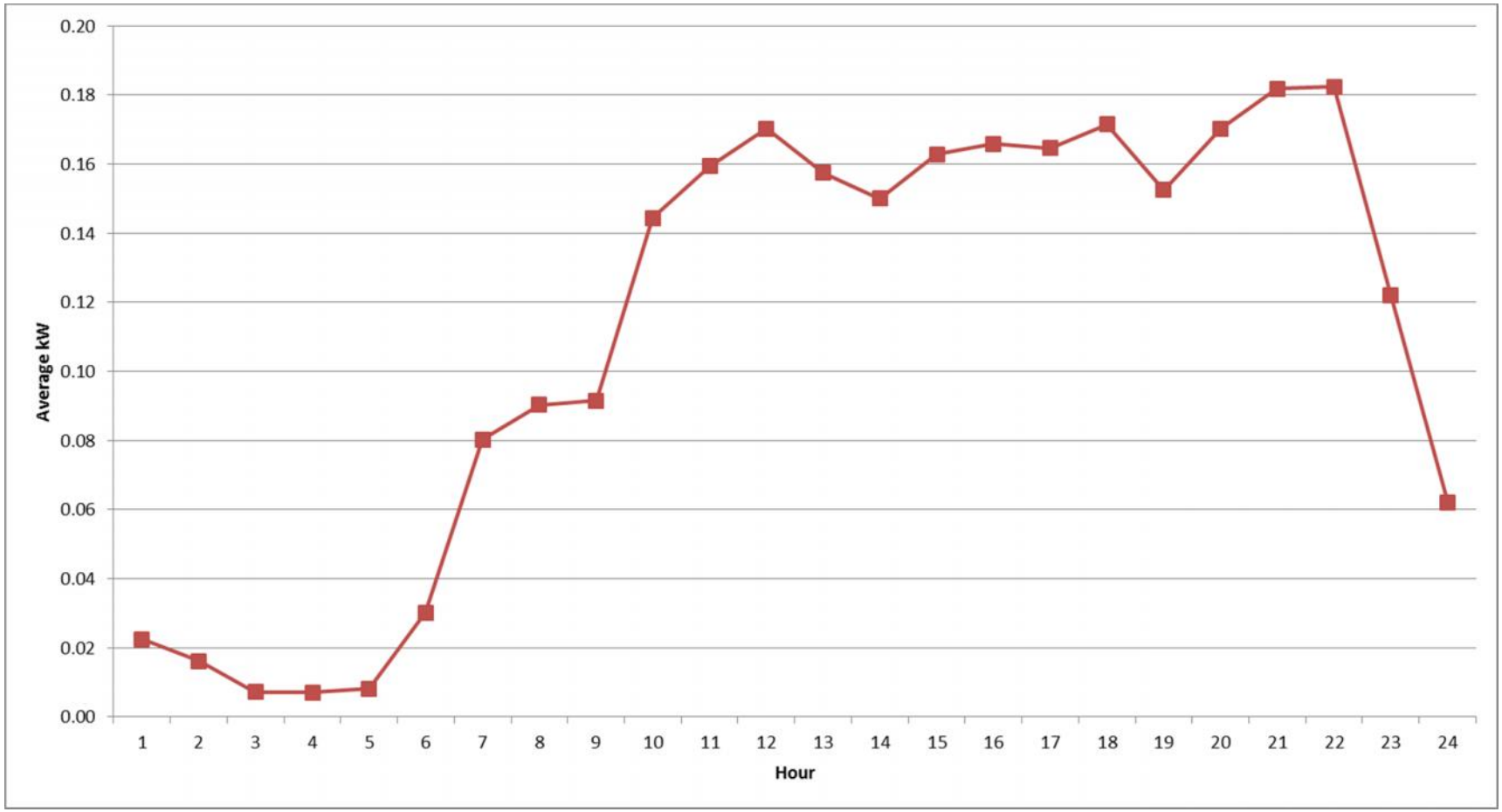
AVERAGE DAILY ENERGY USAGE MAR – DEC



AVERAGE MONTHLY ENERGY USAGE APR – DEC

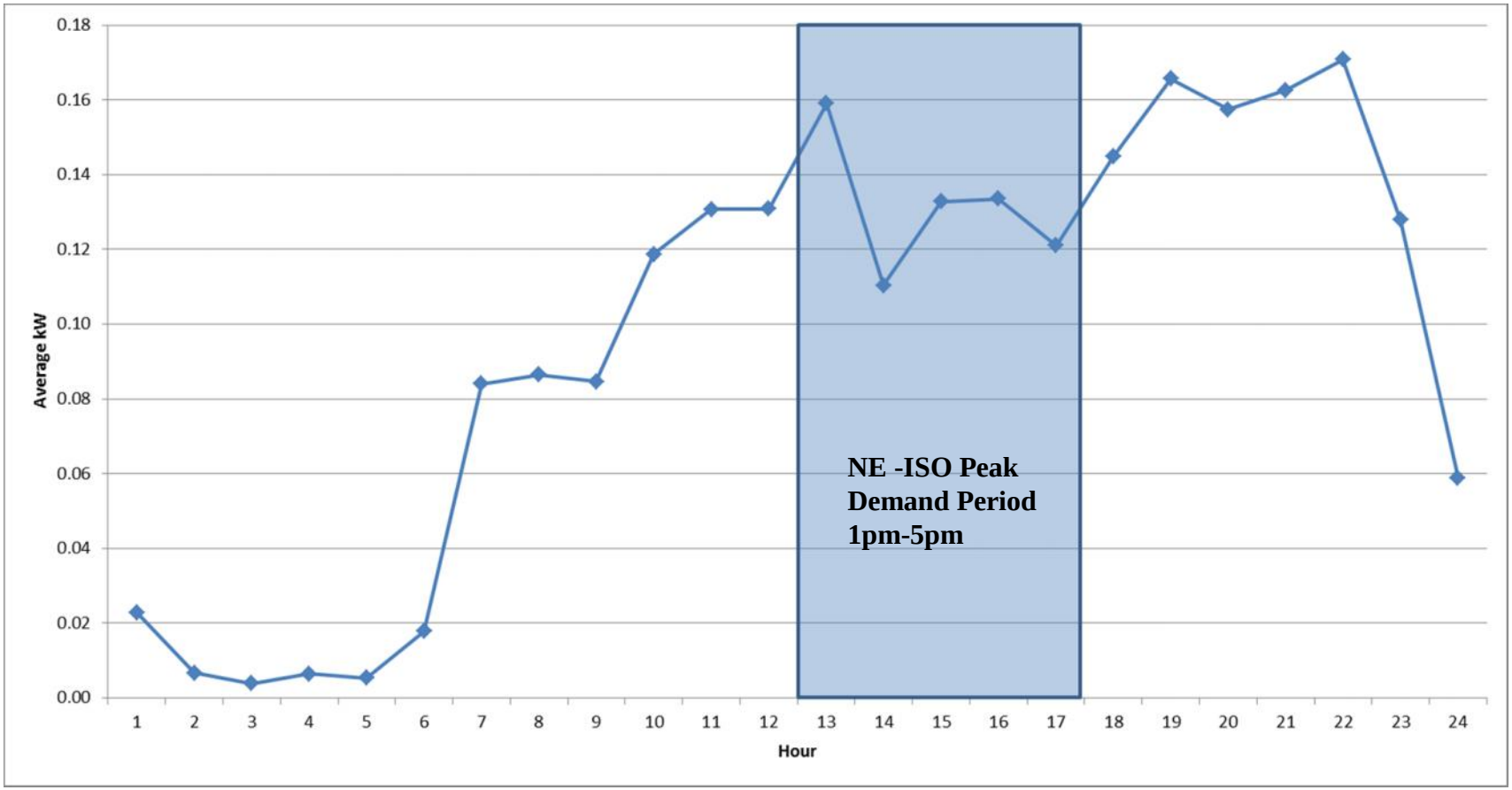


AVERAGE LOAD SHAPE APR - DEC



AVERAGE LOAD SHAPE WEEKDAY JUNE, JULY, AUGUST

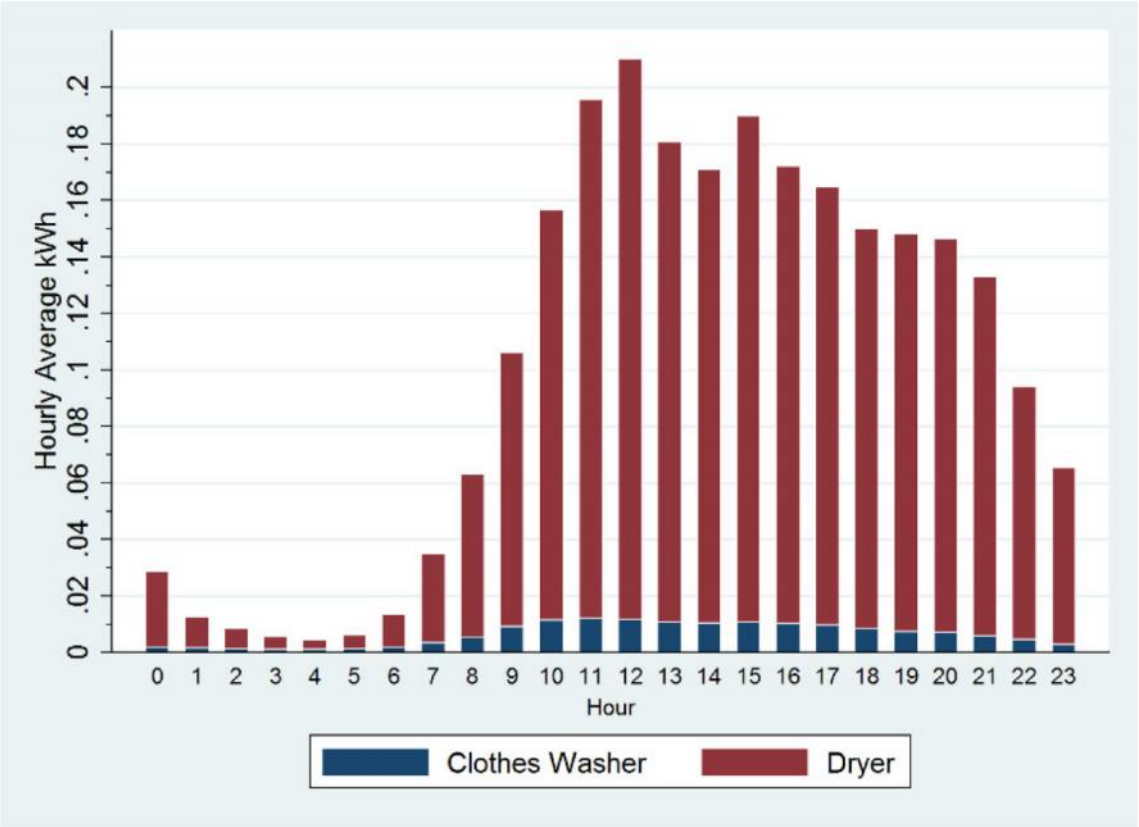
Average Demand, NE-ISO Peak Period – 0.13 kW ± 0.014 kW (11%)*



*90% confidence level; ± 11% of metered average

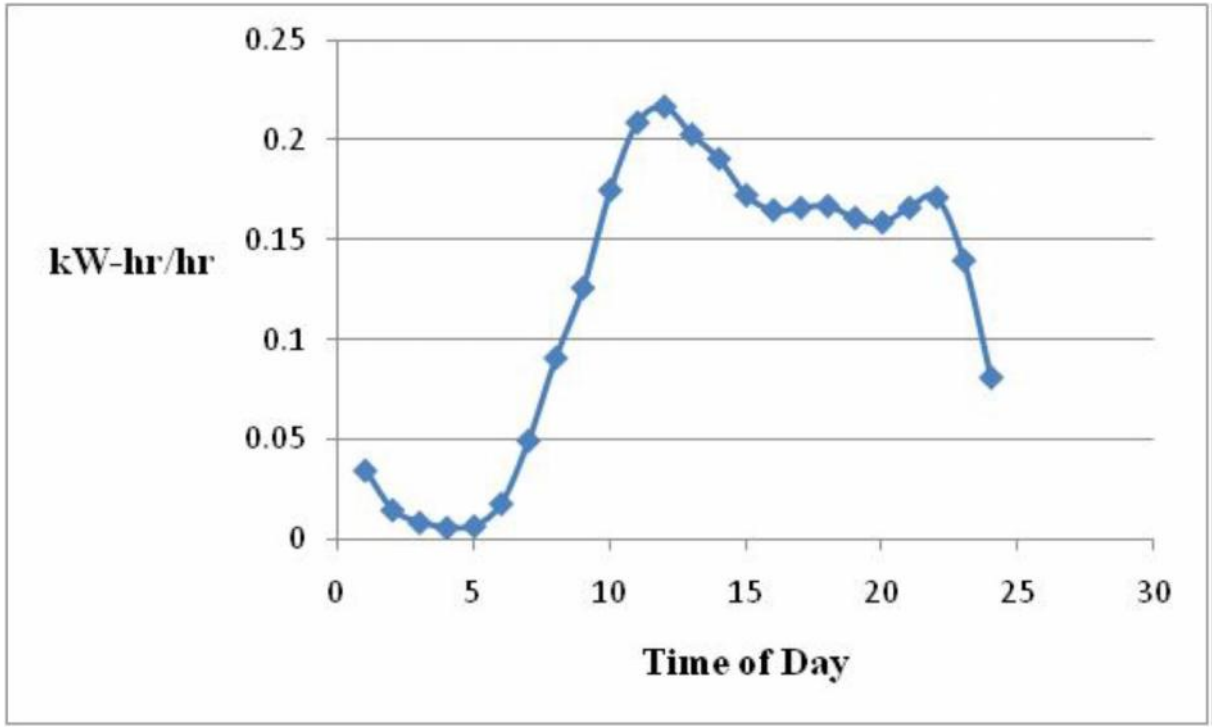
LOAD SHAPES – OTHER JURISDICTIONS

- Ecotope: Residential Baseline Stock Assessment Metering
  - 96 sites – Pacific Northwest



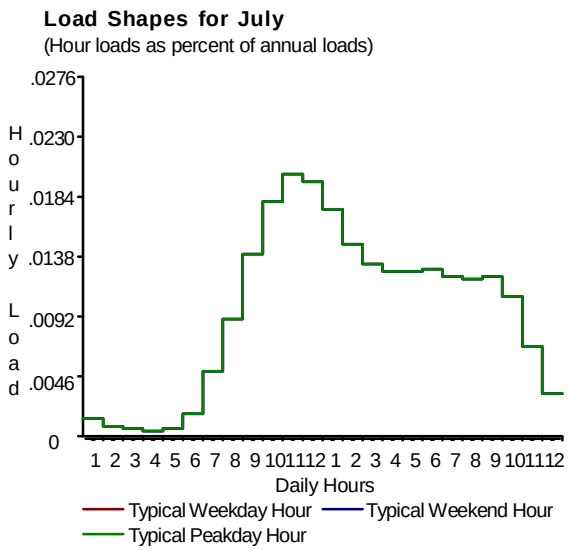
LOAD SHAPES – OTHER JURISDICTIONS

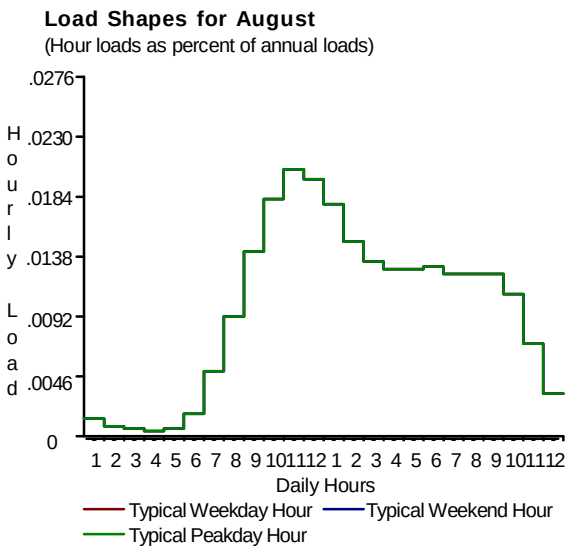
- DOE End-Use Load and Consumer Assessment Program 1989; average annual day

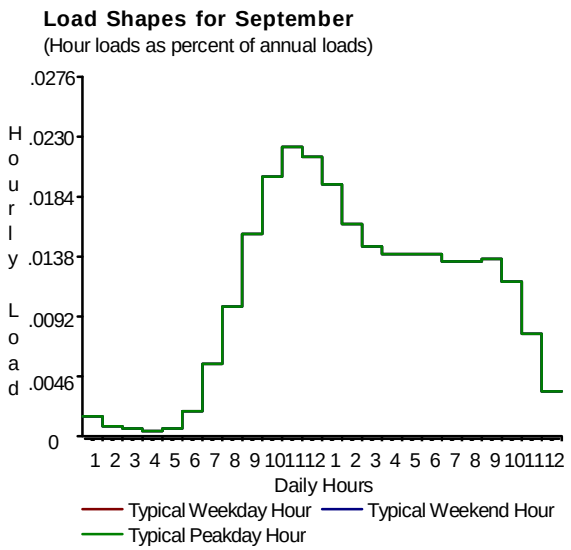


LOAD SHAPES – OTHER JURISDICTIONS

- EPRI RELOAD database; National Energy Modeling System

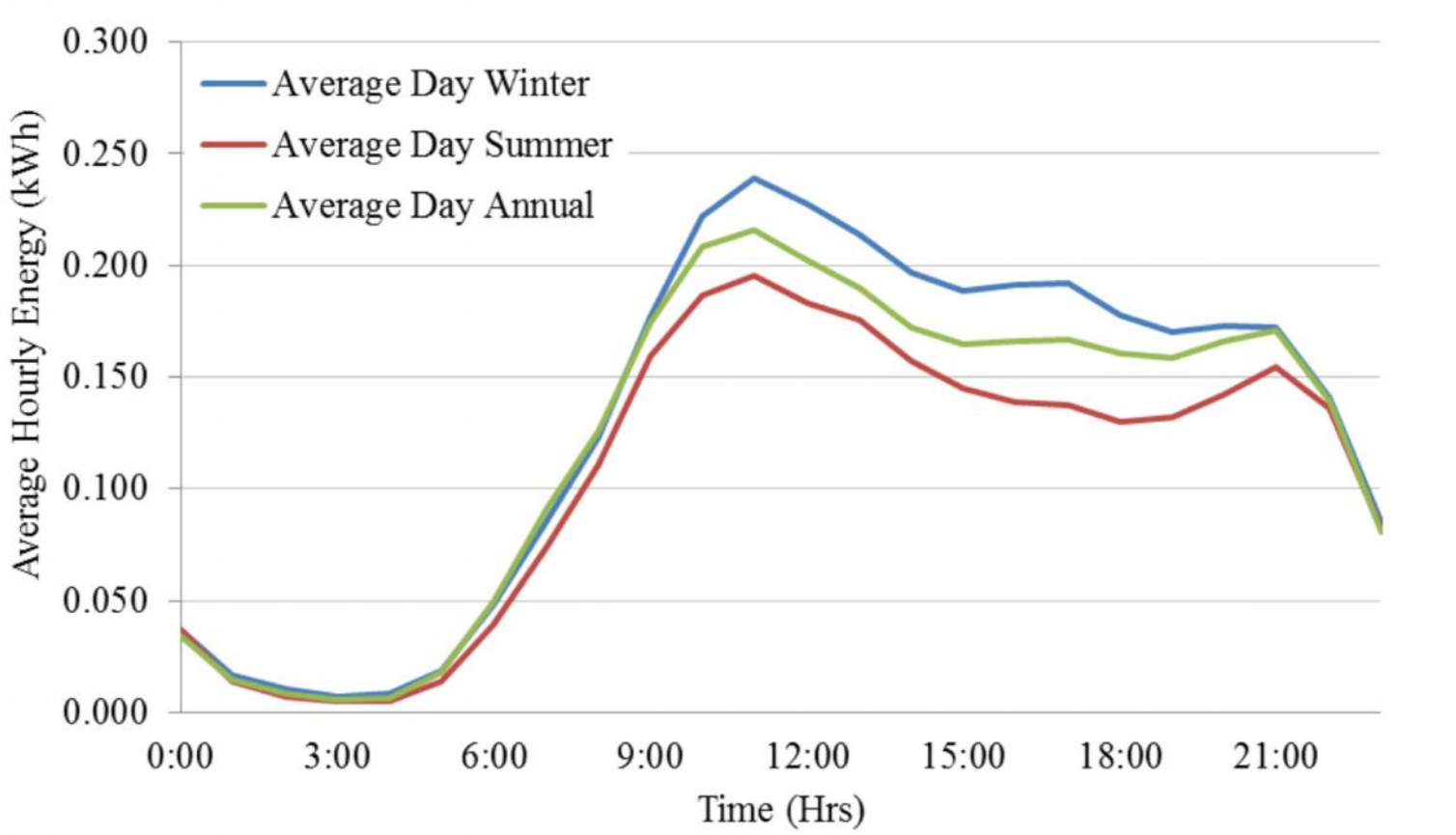






LOAD SHAPES – OTHER JURISDICTIONS

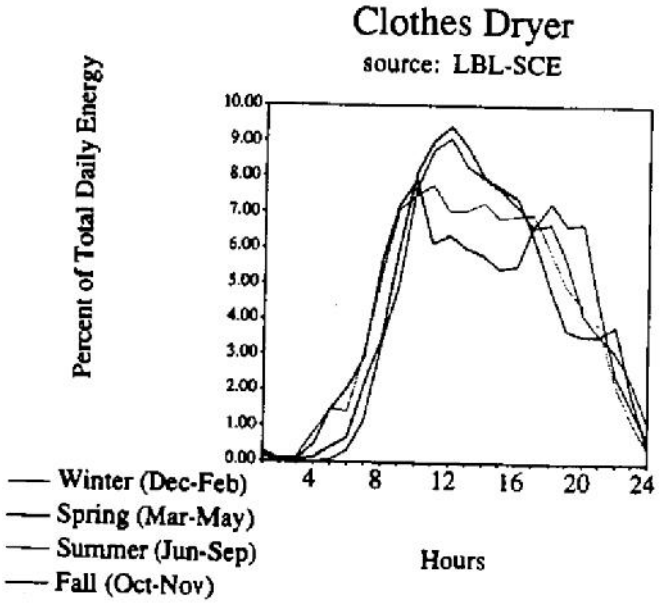
- PNNL - End-Use Load and Consumer Assessment Program Residential Base Study (ELCAP)



LOAD SHAPES – OTHER JURISDICTIONS

- Southern California Edison – 30 metered sites

Figure 10. Daily Load Shape - Clothes Dryer
source: LBL-SCE



MAKE-UP AIR ENERGY CONSUMPTION

Exhausted dryer air introduces additional infiltration

- Introduced air must be conditioned
- Total net effect dependent upon dryer location and tightness of structure
- Exhausted dryer air metered with Dwyer 471 Thermo-Anemometer
- Northeastern U.S. weather data utilized to calculate make-up air heating & cooling
- Accepted engineering practice estimates that for average weather tightness structures the total net effect is approximately 50% of the energy needed to condition the exhausted air volume*
- For tight homes the net make-up energy demand is increased
- For dryers installed in partially thermally coupled space, such as unheated basements, the net make-up energy demand is decreased

* Francisco, P., and L. Palmiter. 1996. "Modeled and Measured Infiltration in Ten Single-Family Homes."

MAKE-UP AIR ENERGY CONSUMPTION

Average Velocity (fps)	Average Flow (cfm)	Heating (Btu/hr)	Cooling (Btu/hr)	Oil Heating Penalty* (gallons)	NG Heating Penalty** (therms)	Electric Heating Penalty*** (kWh)	Cooling Penatly**** (kWh)
1,136	99	3,681	461	4.7	6.4	239.5	3.0

*** #2 Fuel Oil = 138,500 Btu/gallon, Oil @ 78% System Efficiency**
**** NG = 100,000 Btu/therm, NG @ 80% System Efficiency**
***** Electric Resistance Heating @ 100% System Efficiency**
****** Cooling SEER = 13**

Net Penalty - Per standard engineering practice, average net penalty is estimated to be 50% of the above total values: 2.3 gals fuel oil; 3.2 therms NG; 120 kWh electric resistance heating; 1.5 kWh cooling

- Velocity metered at six locations within Maine, Massachusetts and New Hampshire
  - Varied dryer load types and moisture content
- Metered with Dwyer 471 Thermo-Anemometer
- TMY3 Data for Burlington, Pease Air Force Base, Worcester, and Manchester

NEEA & NEEP EM&V Forum Study Key Findings

Key Finding or Factor	NEEA Study	NEEP Study
Average annual energy usage (kWh) per single family household of 2.8[a]	915	993[b]
Average number of dryer loads per year	311	439[b, c]
Average annual dryer runtime (hours)	307	351[b]
Average drying time per load (minutes)	56	48[c]
Reported percentage of washer loads dried in dryer (opposed to hang dry)	93.5%	79%
Increase in drying time for heavy fabrics	13%	N/A[d]
Percentage of medium and high temperature settings selection	50/50%	N/A
Cycle time variation for medium and high temperature settings selection	None	N/A
Average annual standby energy usage (kWh)	1.5	1.1
Energy savings associated with auto-termination versus timed drying	None	N/A
Energy penalty associated with make-up air (kWh, electric resistance heat)	N/A	120
Percentage of horizontal axis (front load)washers in study	23%	62%

[a] NEEA study actual average household size was 2.8 – NEEP study normalized to 2.8 (*note: only annual energy usage is normalized for household size)*

[b] Extrapolated from partial year metered data

[c] Difficult to differentiate distinct loads from "touch-up" loads

[d] Limited metered data demonstrates some increased drying time during winter months

NEEA Study Key Findings

- Dryer energy consumption is approximately 17% higher in December – February compared with June - August consumption

ANNUAL ENERGY USAGE: COMPARISON OTHER JURISDICTIONS

Study	Year Completed	Average Annual Energy Usage (kWh)	Notes
EM&V Forum Study	2015	993	
NEEA - Ecova Field Study	2014	915	Pacific Northwest
DOE - EIA Residential Energy Consumption Survey	2001	1070	
BPA/ELCAP - Exisiting Homes	1986	918	Pacific Northwest
BPA/ELCAP - New Homes	1986	987	Pacific Northwest
Progress Energy	1999	885	Florida
Multi-Housing Laundry Association	2002	993	Average for 3 bedroom home

CONCLUSIONS

- Average annual energy usage for monitored sites – 1,060 kWh
- Average annual energy usage, normalized for avg. household size of 2.8 – 993 kWh ± 129*
- Daily load shape is relatively flat between 11am and 10pm
- Highest average demand occurs on weekends
- Seasonal variations – colder months require more energy for clothes drying
- Dryer runtime average - 48 minutes
- Average number of loads – 439**
- Make-up air energy consumption varies – estimated to be: 120kWh; 2.3 gals fuel oil; 3.2 therms NG, or approximately 12% of dryer energy usage

* Applying a standard 90% confidence interval analysis results in ± 13%, although this statistical analysis is not fully appropriate for the sample and for extrapolated data

** Estimated from metered data – difficult to differentiate distinct individual loads from "touch-up" loads

NEXT STEPS

Project Completion:

- Review and compare Energy Star Data
  - Completed; included in brief summary report
- Retrieve loggers from VT Whirlpool study of efficient dryers and provide data to Efficiency VT

Recommendations for further study:

- Multi-family applications – Baseline studies are needed to determine loadshape and annual usage of dryers in multi-family facilities.
- Washer/dryer combined baseline – Efficient washer/dryer combinations may offer additional savings.

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