

# End-Use Load Shape Development

*As a Foundation for Utility Planning*

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2019 IRP Contemporary Issues Technical Conference

*IURC, Indianapolis, IN*

*April 15, 2019*

    
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# Exploring Technology and Analytics for Load Data Development

## Challenge

- Capturing end-use data is complex, intrusive and expensive.
- Strategizing utility use cases for end-use and whole premise load data
- Empirical versus Engineering Model?

## Current Landscape

- New metering technologies, interfaces, communication
- Access to interval data

## EPRI Focus

Assessing four areas of load data technologies and analytics for cost, accuracy and utility application:

- Direct Measurement
- Non-Intrusive Load Monitoring Devices (NILM)
- Statistical Methods- Conditional Demand Analysis (CDA)
- Advanced Direct Measurement (Sensors, EMCB, Neural Networks)
- Data Repository (Load Shape Library)



**Leveraging AMI data for End Use Load Data Development & Analytics**

# Do We Really Need End-Use Load Shapes?

I don't know, but...

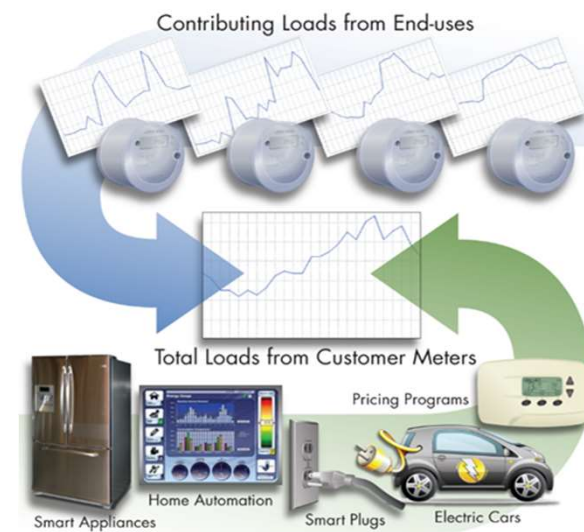
There are two main drivers of system peaks:

- A. HVAC
- B. Water Heating

- ✓ For Regulated Utilities: The peaks are used to allocate fixed costs of \$1.2T in the U.S. among customer classes and forecast system peaks
- ✓ For Competitive Market Generators: System reliability and stability
- ✓ For Load Serving Entities (LSE's) – Network operation and management
- ✓ For Retail Electric Providers (REP's) – Customer portfolio management

But... the cost of collecting end-use load data has dropped dramatically:

- Increased availability of AMI
- Sub-metering costs have declined
- Communication technology is now low cost



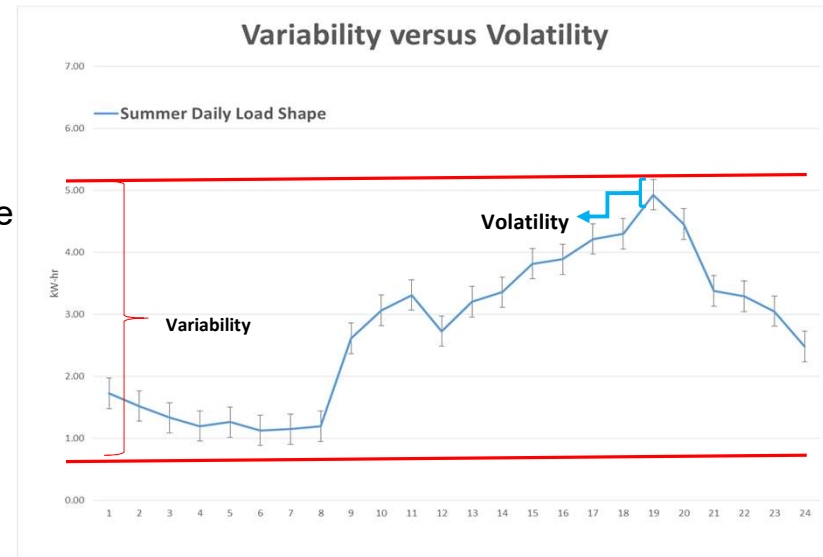
# Sample REP Pricing in Competitive Markets

- The break-even price for a full requirements product is:

$$P_{fts} = RF (1/T) \int_0^T e^{\delta \sigma_p \sigma_l}$$

Where:

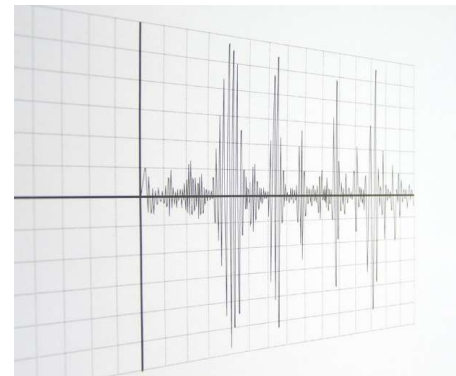
- RF is the load weighted forward price
- T is the contract duration
- $\delta$  is the covariance between wholesale and customer loads
- $\sigma_p$  is the wholesale price volatility
- $\sigma_l$  is the customer load volatility



Source: "Pricing Retail Electricity: Making Money Selling a Commodity", Pricing in Competitive Market, Eakin and Faruqui, Klower Academic Publishers, 2000

# End-Use Load Measurement: Direct vs. Indirect Methods

- **Direct Measurement**
  - Sensor Installed at Appliance or Circuit Breaker
  
- **Pattern Recognition (No sensor, usage data)**
  - Total Usage
  - Minimum & Excess usage
  
- **Cluster/Event-based Analysis (NILM, Disaggregation)**
  - Isolates loads on electrical characteristics
  - Edge data clustering
  
- **Statistical**
  - Statistically Adjusted Engineering Estimates (SAE) (single site approach)
  - Proportional Fitting: Adjust end-use loads to known totals
  - Hourly (CDA): Regression method that uses variance in appliance presence to estimate aggregate customer or class load shapes
  - Hybrid: CDA with addition of NILM or engineering estimates
  
- **High Frequency Signal Analysis Methods (NILM)**
  - Harmonic frequency analysis
  - Modified Fourier transform



# Hourly CDA Approach: (Class) Diversified Load Shapes

- Relies on the *variation* of end-use appliance presence for statistically inferring the *components* of customers' hourly load profiles
- Modified Regression applied to hourly *load* data, using variables from *survey* information
- Conditioned on other causal variables to allocate total load to end uses
  - Comparing total loads of two identical houses, where only one has electric water heater; difference between loads is load of water heater
  - Regression analysis makes those comparisons across hundreds of customers & all included end uses
  - Result produces a “diversified end use load shape”

**CDA provides a low cost method to collect End-Use Load Data that provides quantifiable accuracy at low cost**

# Joint EPRI/NREL End-Use Load Profile Development for Baseline Loads

## Scope

- Baseline end-use load shape development for Residential & Commercial building stock
- Leverage utility meter data by region, to cover building types and climate zones.

## Leverage

- Knowledge base, expertise under EPRI Energy Analytics and Market Insights in which End Use Load Research resides
- EPRI Public Product: Load Shape Library  
[loadshape.epri.com](http://loadshape.epri.com)

## Value

- Statistically significant, baseline end-use profile by building type
- Web accessible data and visualization
- Utility representation across the U.S



# Proposed Approach

- Res.& Comm. end-use load shapes by climate zone, building type
- Leverage customer AMI data, customer survey information, building characteristics and other public data
- Statistical analysis: Better accuracy by class, building type
- Basic and enhanced project options
  - Additional sampling domains such as age and size of structures, occupancy, program participation, etc.
- Data made available through EPRI's web product Load Shape Library: public database, user interface





# Sample Commercial Load Shape Measurement (Segmentation)

**U.S. Commercial Energy Utilization Indices (EUI) End-Use by Building Activity (kWh/ft2)**

<u>End-Use (%)</u>	<u>Building Activity</u>	<u>Percent of U.S. Commercial Electric Consumption</u>
Space Heating (4.7%)	Education	8.2%
Cooling (13.5%)	Food sales	4.6%
Ventilation (12.3%)	Food service	4.8%
Water Heating (2.5%)	Health care	5.5%
Lighting (37.7%)	Inpatient	3.9%
Cooking(0.7%)	Outpatient	1.6%
Refrigeration (10.7%)	Lodging	5.2%
Office Equip. (1.9%)	Mercantile	16.1%
Computers (4.4%)	Retail (other than malls)	4.6%
Other (11.7%)	Enclosed and strip malls	11.5%
	Office	15.8%
	Public assembly	3.7%
	Public order and safety	1.3%
	Religious worship	1.4%
	Service	3.3%
	Warehouse and storage	5.4%
	Other	2.9%

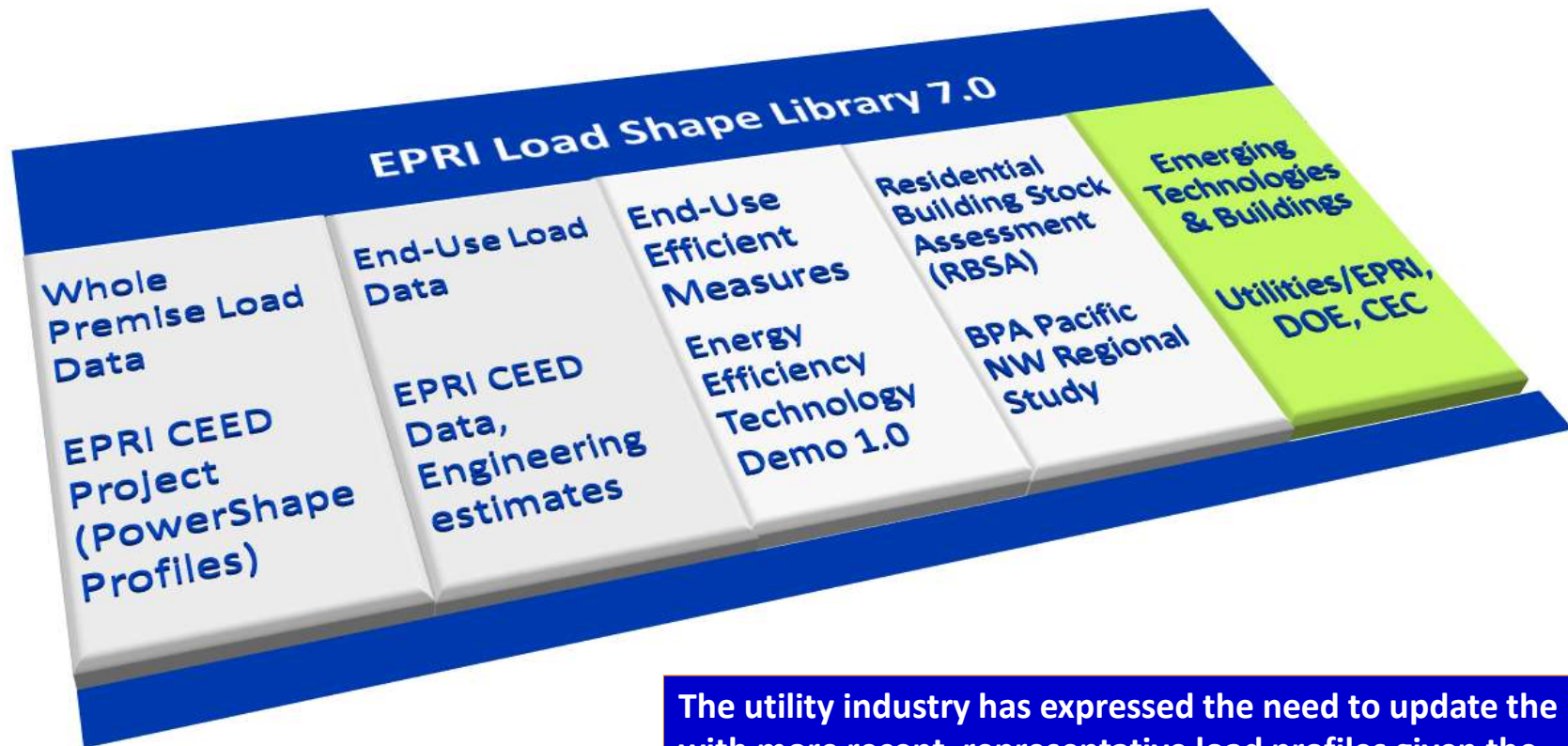
Source: Energy Information Administration, Table E3a, Energy Consumption by Building and End-Use, 2003.

# Potential Utility Data Collection Sites – Residential & Commercial



- a) CDA for Utilities with both interval data and metadata
- b) CDA for Utilities with interval data but no metadata, and...
- c) Low cost direct metering for Utilities with neither

# EPRI Public Product: Load Shape Library



The utility industry has expressed the need to update the Library with more recent, representative load profiles given the availability of AMI data

# End-Use & Whole Premise Databases (EPRI CEED PowerShape™, Model + Limited Field Validated)

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Load Shape Library

Home End Use Whole Premise About Help

You Are Here: Load Shape Library > Whole Premise Load Shapes

Whole Premise Load Shapes

Add Load Shape(s)

Country: USA

City, State: Los Angeles, CA

Heating Type:  Electric  Fossil Fuel

Date Range: From: 01/01/2001 To: 12/31/2001

Building Type:  Commercial  Residential

Commercial:  Grocery, Supermarket  Hospital - Non Profit  Hotel  Office, Small  Office, Medium  Office, Large  Office, Small, Bank  Restaurant, Fast Food  Restaurant, Full Service  Restaurant, Sit-Down  Retail, Mail  Retail, Large  Retail, Small  Transport-Public Utility  Warehouse

Residential:  Office, Large  Office, Small, Bank  Restaurant, Fast Food  Restaurant, Full Service  Restaurant, Sit-Down  Retail, Mail  Retail, Large  Retail, Small  Transport-Public Utility  Warehouse



2008 NERC Regional Distinctions

Sectors and End Uses

Unitized end use load shapes

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Load Shape Library

Home End Use Whole Premise About Help

You Are Here: Load Shape Library > Whole Premise Load Shapes

Whole Premise Load Shapes

Add Load Shape(s)

Country: USA

City, State: Austin, TX

Heating Type:  Electric  Fossil Fuel

Date Range: From: 1/1/2001 To: 12/31/2001

Building Type:  Commercial  Residential

Commercial:  Office, Large  Office, Small, Bank  Restaurant, Fast Food  Restaurant, Full Service  Restaurant, Sit-Down  Retail, Mail  Retail, Large  Retail, Small  Transport-Public Utility  Warehouse

Residential:  Office, Large  Office, Small, Bank  Restaurant, Fast Food  Restaurant, Full Service  Restaurant, Sit-Down  Retail, Mail  Retail, Large  Retail, Small  Transport-Public Utility  Warehouse



Options to allow day and selections such as peak day, summer, winter, shoulder etc.

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Load Shape Library

Home End Use Whole Premise About Help

You Are Here: Load Shape Library > One Use Load Shapes

End Use Load Shapes

Add Load Shape(s)

Country: USA

Region: ECAR

Season and Day Type:  Peak Season, Peak weekday  Peak Season, Average weekday  Peak Season, Average weekend  Off Peak Season, Peak weekday  Off Peak Season, Average weekday  Off Peak Season, Average weekend

Sector and End Use:  Commercial  Residential  Industrial

Cooling  Heating  Lighting, General 'All Regions' only  Lighting, Internal  Office Equipment  Refrigeration  Ventilation  Water Heating

6 End Use Load Shapes plotted.

Scaling

Region	Selected Use	Peak kW	Annual kWh
ECAR	Com. Cooling	1.0	1418.1176

Load Shapes

Region	Season	Day Type	Selected Use
ECAR	Peak	Average weekday	Com. Cooling
ECAR	Off Peak	Peak weekday	Com. Cooling
ECAR	Peak	Peak weekday	Com. Cooling
ECAR	Peak	Peak weekend	Com. Cooling
ECAR	Off Peak	Average weekend	Com. Cooling
ECAR	Off Peak	Average weekday	Com. Cooling

Scaling Factors to convert unitized values to kW or kWh

Scaling Factors to convert unitized values to kW or kWh

# Technology Measures & RBSA Databases

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Home End Use Whole Premise **Technology Measures** Pacific Northwest RBSA About Help

You Are Here: Load Shape Library 3.0 > Technology Measures Load Shapes

### Technology Measures Load Shapes

**Add Load Shape(s):**

Country: USA

City, State: Cantonment, FL

Utility: Choose a Utility ...

Climate Zone: Choose a Climate Zone

**Technology Type:**

- Water Heater, Unconditioned
- Water Heater, Conditioned
- Appliances
- Up to 50 Gallon
  - Conventional Water Heaters
  - Manufacturer & Heat Pump Water Heaters

**Day Type and Date Range:**

Weekdays, Weekends

Weekday Weekend Weekdays and Weekends

Date Range: Date Range1: Date Range2:

**Technology Measures Load Shape Plot**

### Residential Building Stock Assessment (RBSA) Load Shapes

**Add Load Shape(s):**

City, State: Choose a City, State

Utility: Choose a Utility ...

Climate Zone: ALL

Fuel Type at Premise: Choose a Fuel Type

**Technology Type:**

- Premise Total & Main End Uses
  - Home Audio
  - Cable Box & DVR
  - Computer
  - Computer & Accessories
  - Lighting and Other
- Appliances
- Electronics, Lighting & Other

**Day Type and Date Range:**

Weekdays, Weekends

Weekday Weekend Weekdays and Weekends

Date Range: Date Range1: Date Range2:

### Technology Measures Load Shape Plots

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Home End Use Whole Premise **Technology Measures** Pacific Northwest RBSA About Us

You Are Here: Load Shape Library 4.0 > Residential Building Stock Assessment (RBSA) Load Shapes

Enter Feedback for More Granular Data

**Residential Building Stock Assessment (RBSA) Load Shapes**

City, State: Choose a City, State

Climate Zone: Choose a Climate Zone

**Technology Type:**

- Premise Total & Main End Uses
  - Premise Total
  - HVAC
  - Water Heater
- Appliances
- Electronics, Lighting & Other

**Day Type and Date Range:**

Weekdays, Weekends

Weekday Weekend Weekdays and Weekends

**Analysis Parameters**

Granularity: Daily Hourly

Date Range: Date Range1: 04/01/2012 - 04/01/2013

**Provide feedback for 15-minute interval data.**

\* 1. Which of the following categories best describes the industry you currently work in?

- Utility
- Utility Contractor/Consultant
- Non-Utility Contractor/Consultant
- Product/Solution Provider
- Academic
- Private Organization/Business
- Government
- Regulator
- Aggregator
- Market Operator
- Utility R&D

Other (please specify):

\* 2. What is the application you plan to use the Load Shape Library data for?

- EE & DR Operations
- Program Design Analytics
- MSV
- Customer Usage Analysis
- EE & DR Operations
- Load Forecasting

**Technology Measures Load Shape Plot**



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