End-Use Load Shape Development

As a Foundation for Utility Planning

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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)

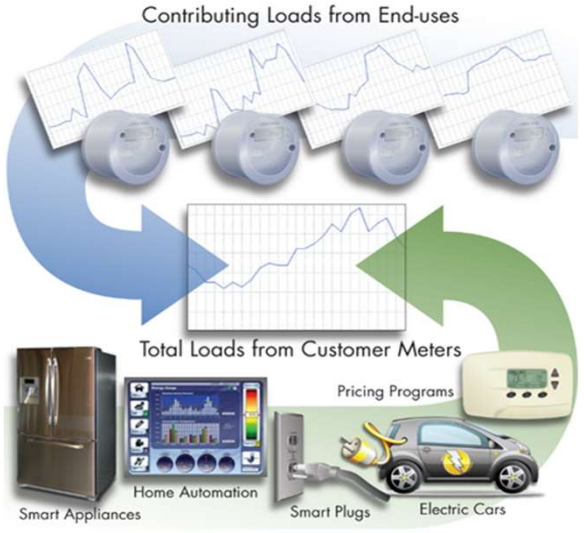
Leveraging AMI data for End Use Load Data Development & Analytics

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 to 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

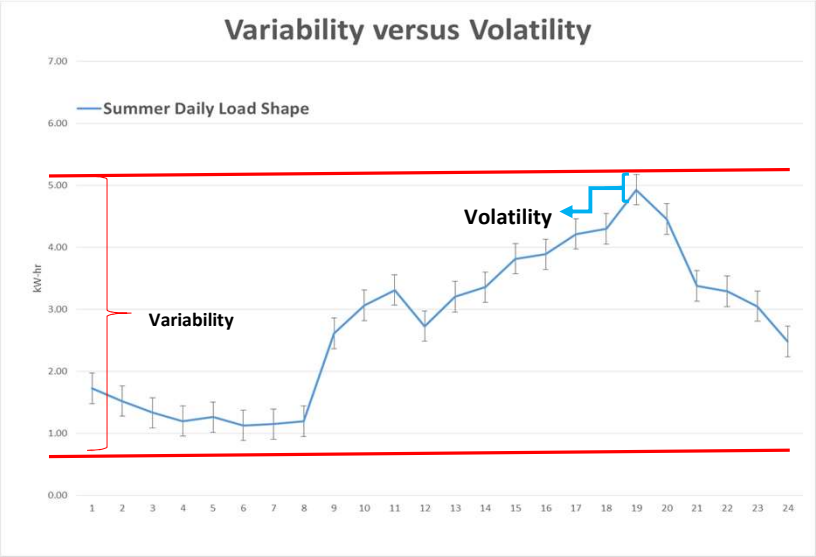
Sample REP Pricing in Competitive Markets

- 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:

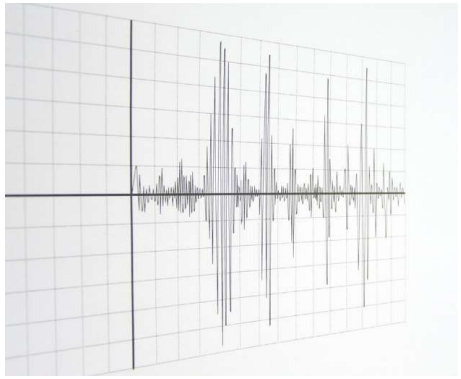
- RF is the load weighted forward price
- T is the contract duration
- δ is the covariance between wholesale and customer loads
- σ_p is the wholesale price volatility
- σ_l is the customer load volatility



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

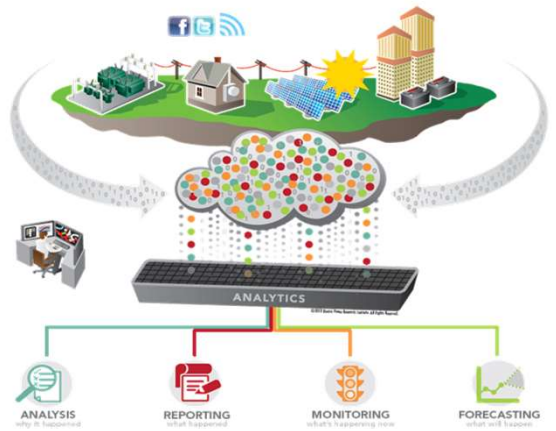
- Knowledge base, expertise under EPRI Energy Analytics and Market Insights in which End Use Load Research resides
- EPRI Public Product: Load Shape Library loadshape.epri.com

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



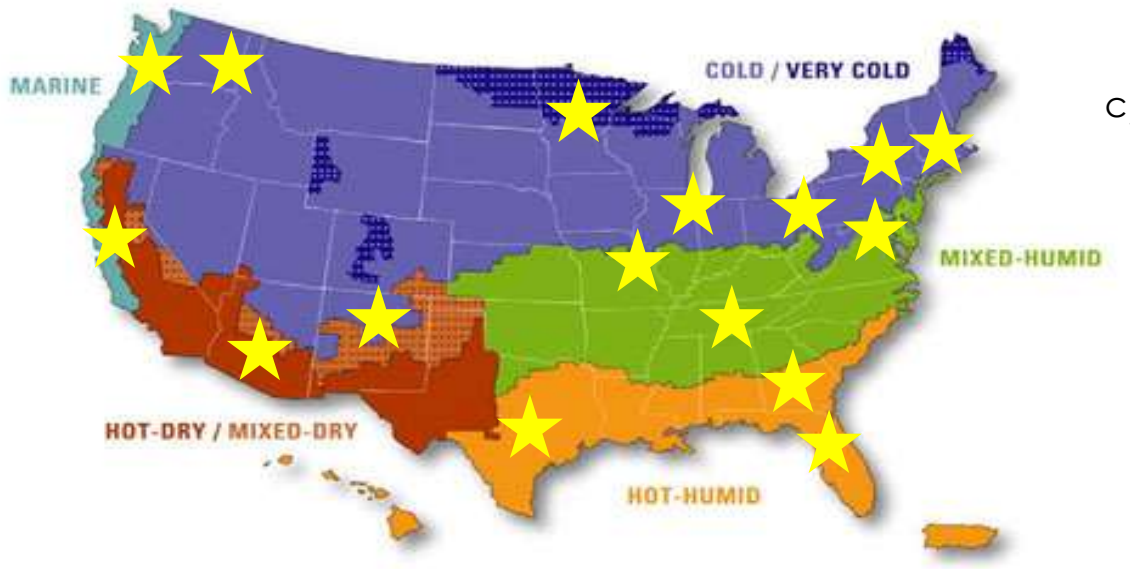
Sample Commercial Load Shape Measurement (Segmentation)

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

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

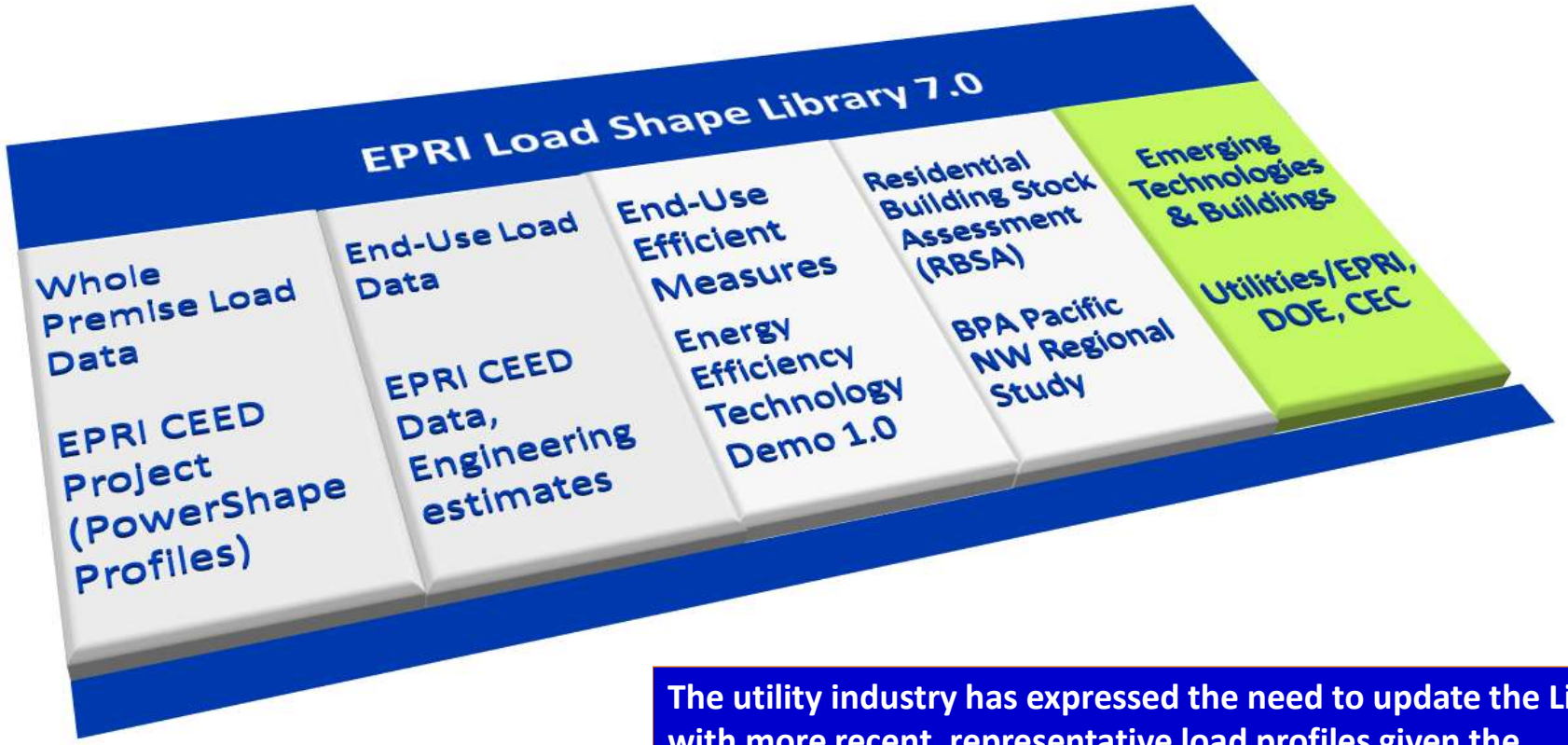


a) CDA for Utilities with both interval data and metadata

b) CDA for Utilities with interval data but no metadata, and…

c) Low cost direct metering for Utilities with neither

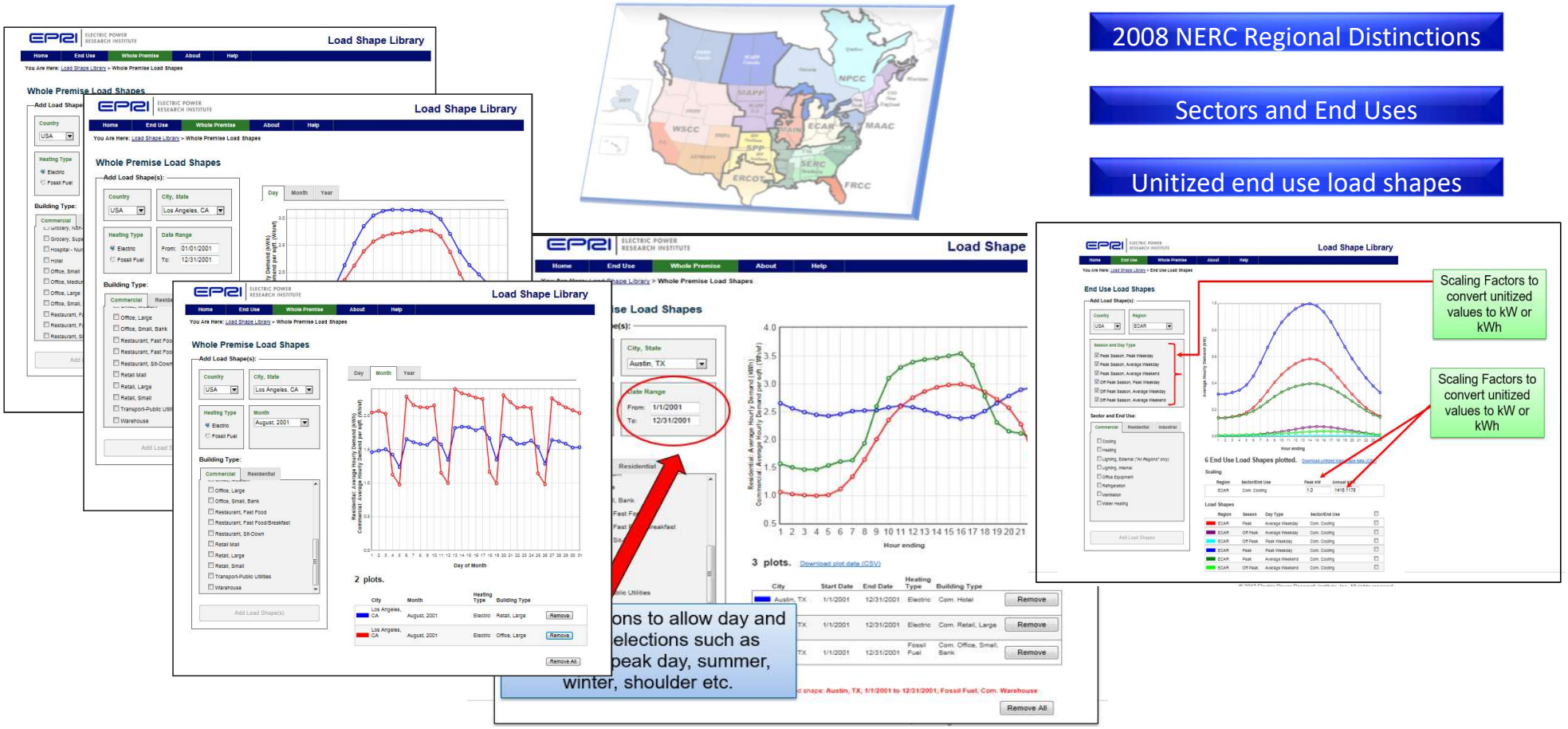
EPRI Public Product: Load Shape Library



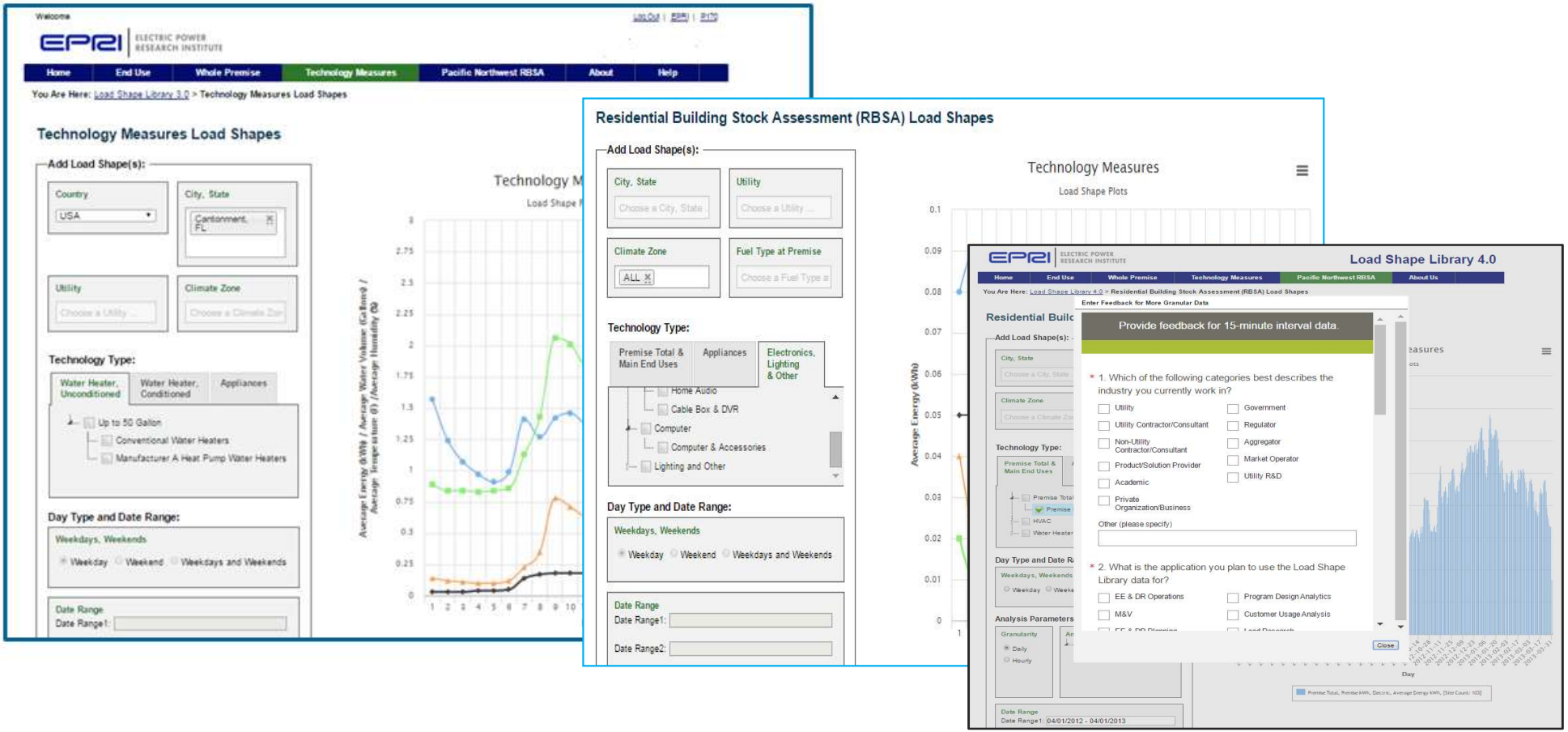
The utility industry has expressed the need to update the Library with more recent, representative load profiles given the availability of AMI data

End-Use & Whole Premise Databases

(EPRI CEED PowerShape™, Model +Limited Field Validated)



Technology Measures & RBSA Databases



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