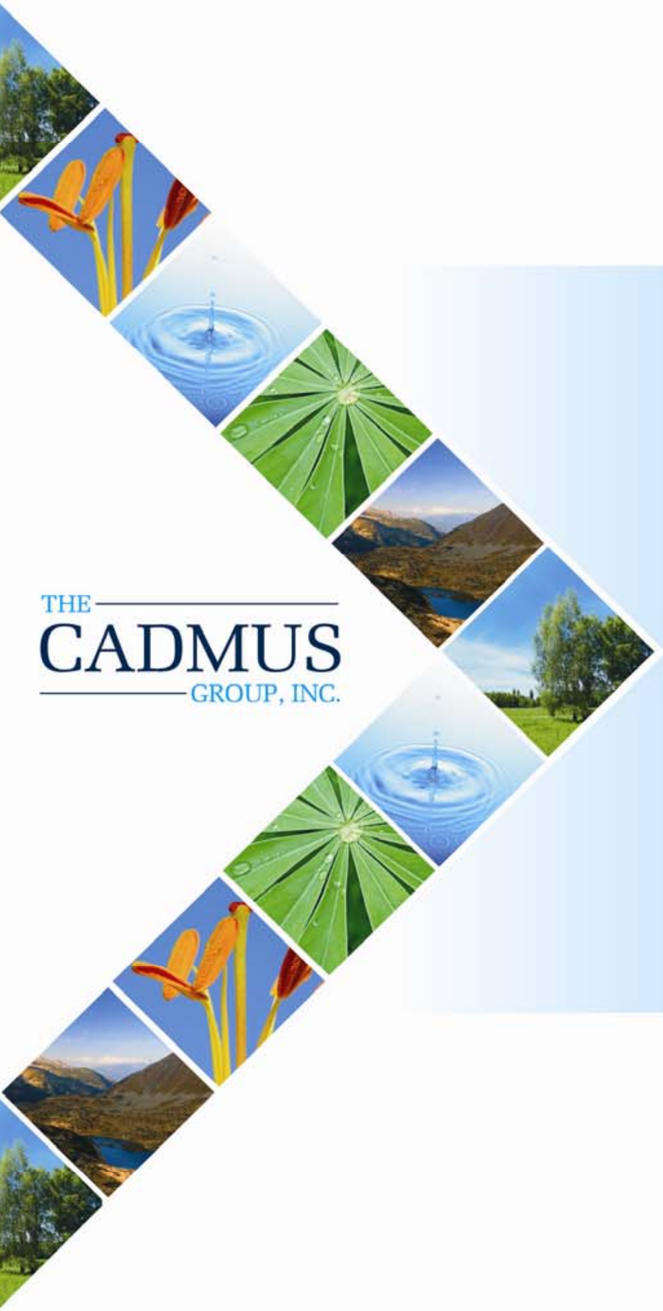

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Principles of Demand-Side Management

Michigan Public Service Commission

January 2010

INSTRUCTOR:

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Agenda (Times Are Flexible)

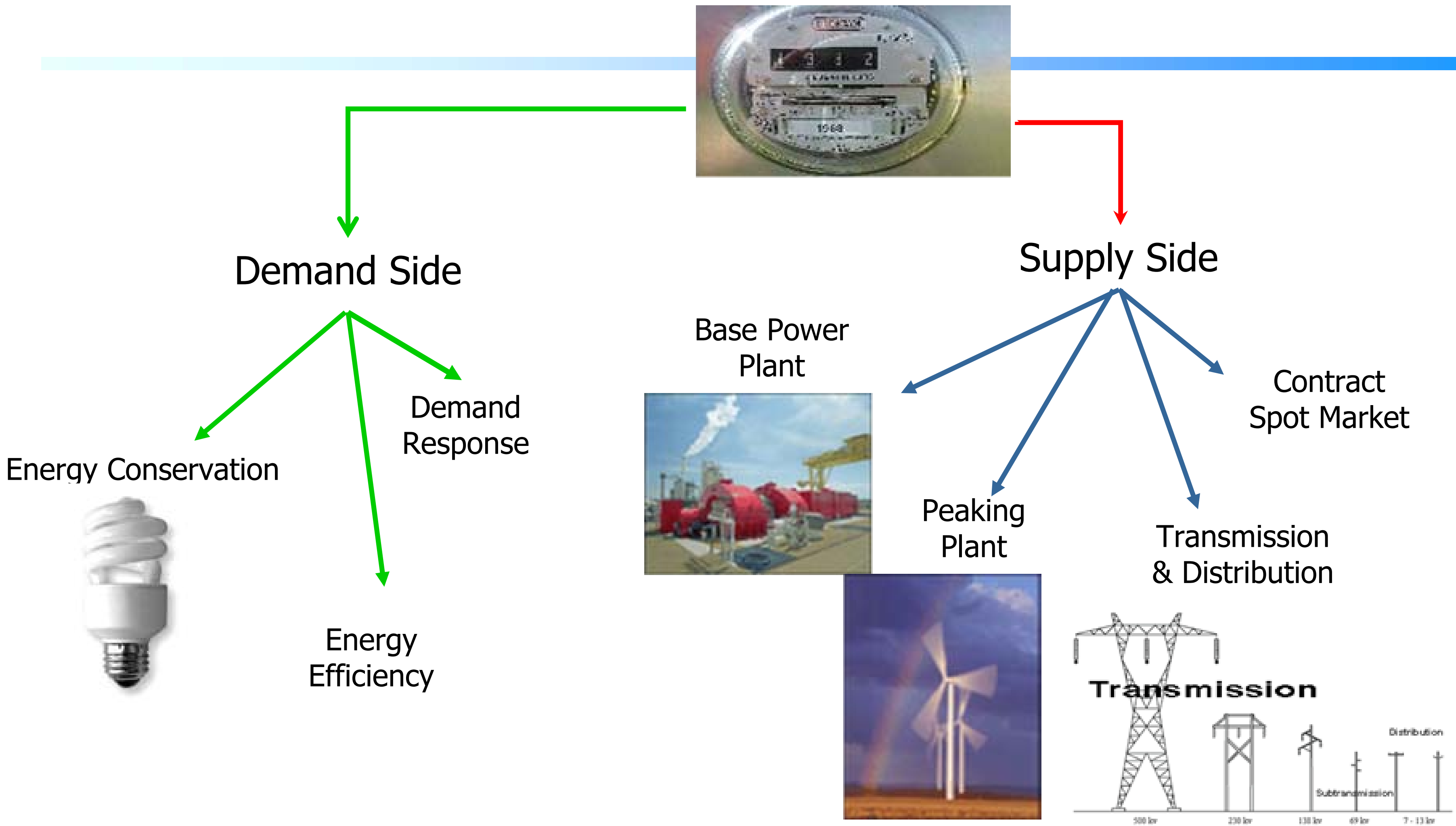
- Introductions & Overview
- DSM Economics
- Impact Evaluation

Introduction andOverview

- What is DSM?
- Types of programs
- Definitions
- Key drivers for DSM

Overview of DSM

What Is DSM?


Demand Side
Supply Side
Energy Conservation
Demand Response
Energy Efficiency
Base Power Plant
Peaking Plant
Transmission & Distribution
Contract Spot Market
Transmission

What Is DSM? (continued)

Meet Demand

Demand Side

Energy Conservation

Demand Response

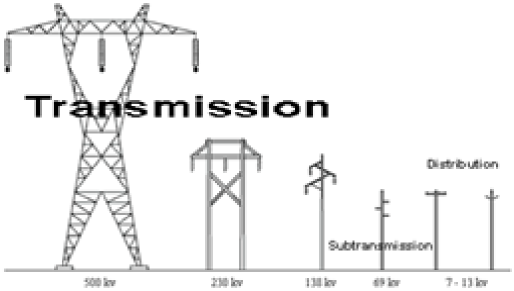
Energy Efficiency

Base Power Plant

Peaking Plant

Contract Spot Market

Transmission & Distribution



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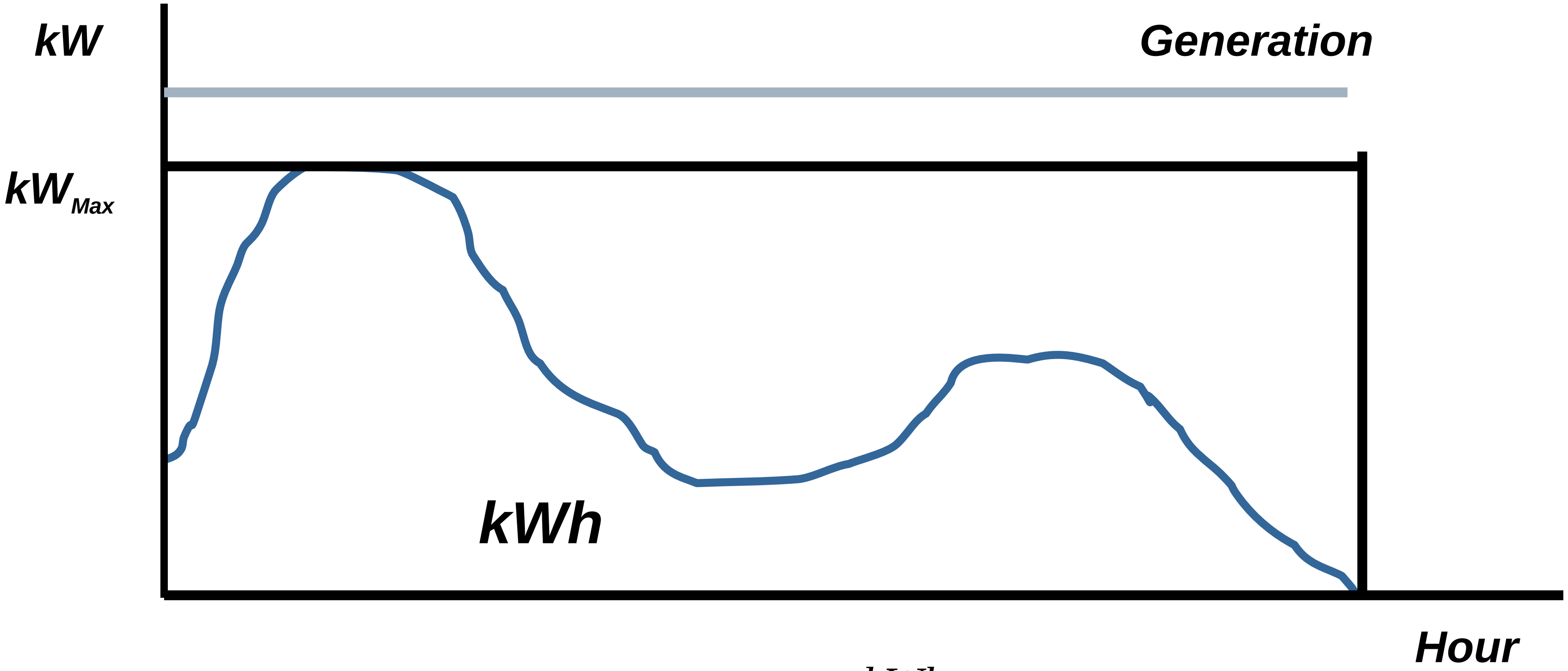
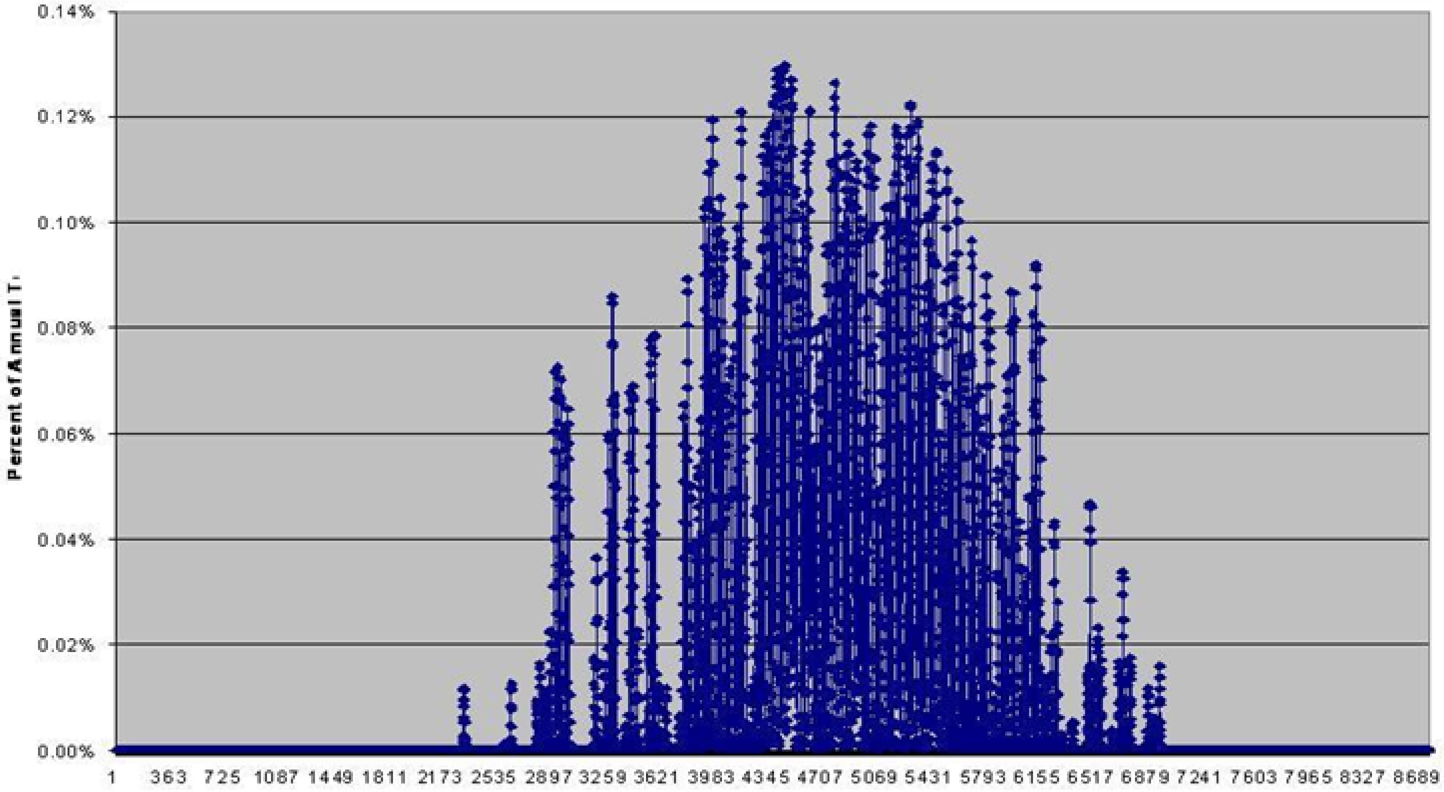
Daily Load Profile

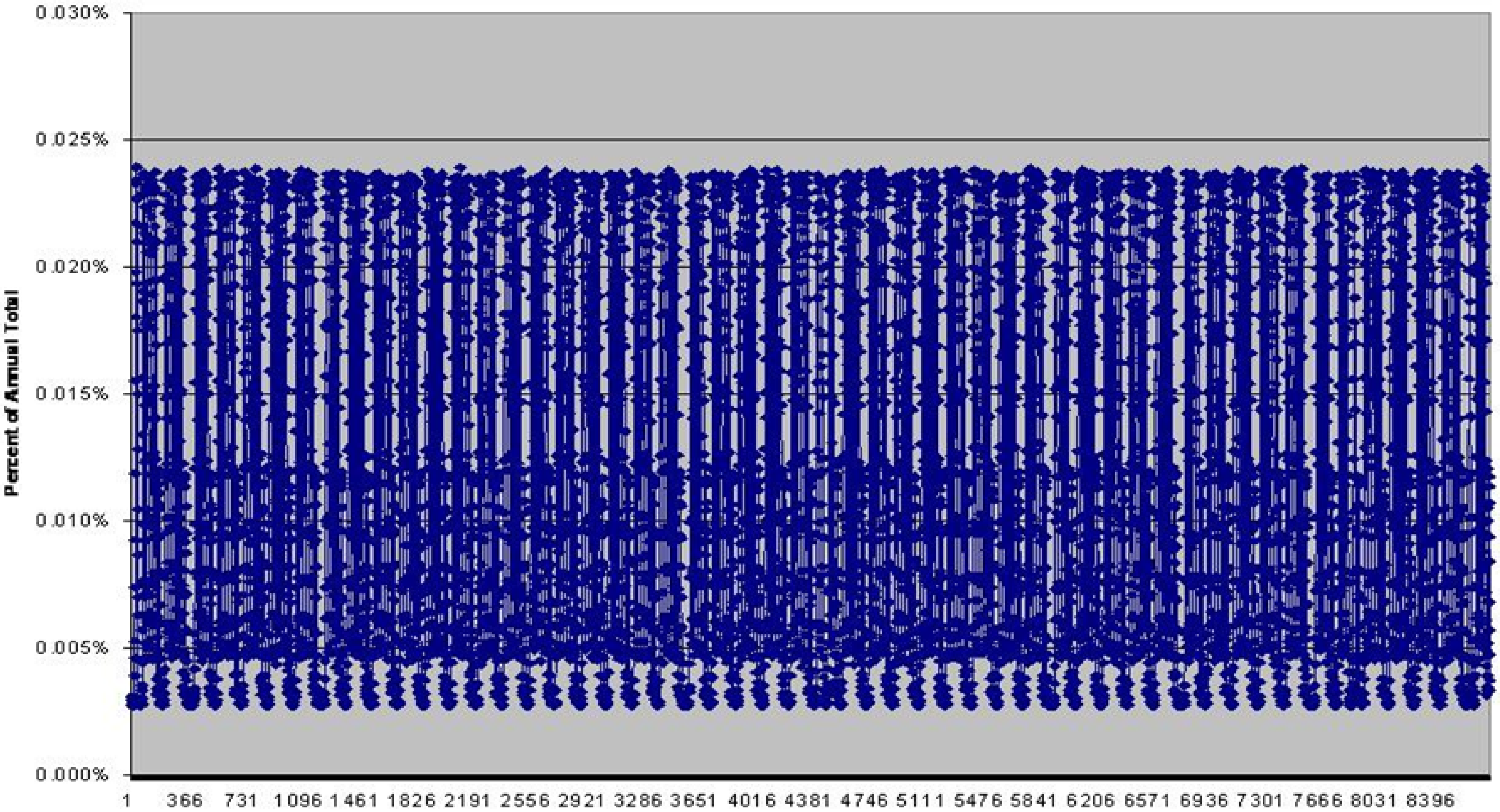


$$Load\ Factor = \frac{kWh}{kW_{max} * Hours}$$

Residential Cooling



Commercial Lighting



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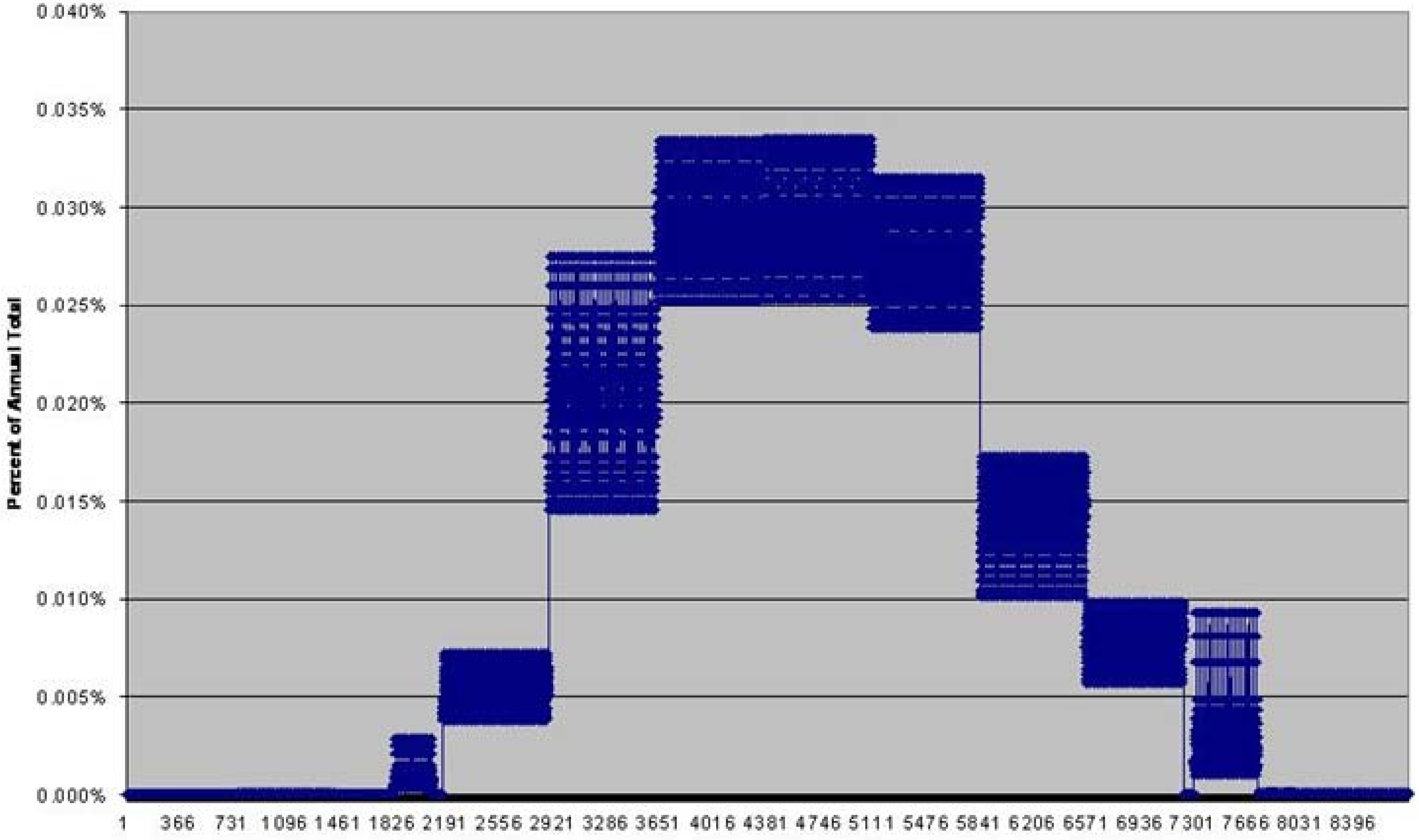
Irrigation



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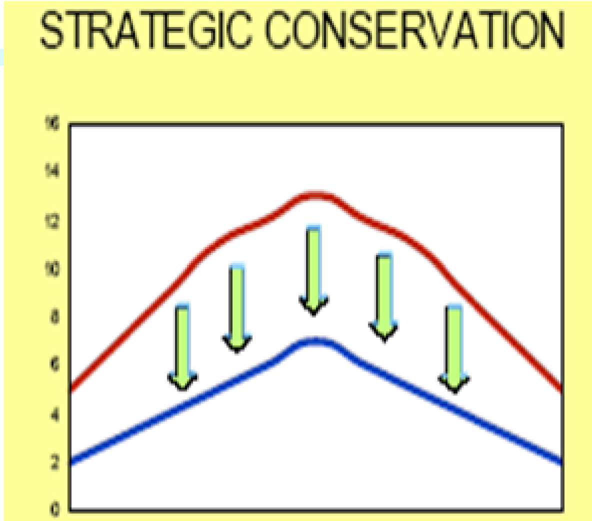
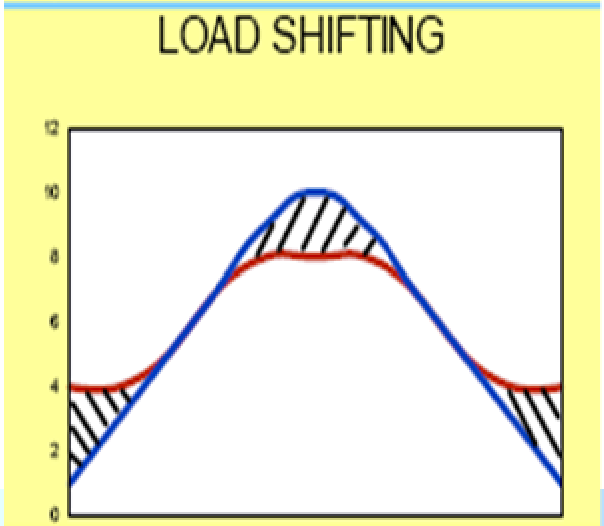
Types of Programs

Meeting Utility Objectives Through DSM

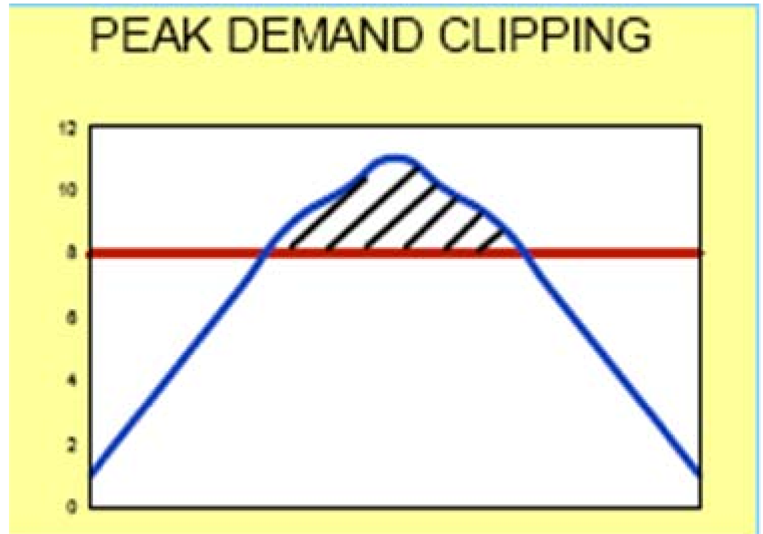
Lighting, Water Heating



Thermal Storage

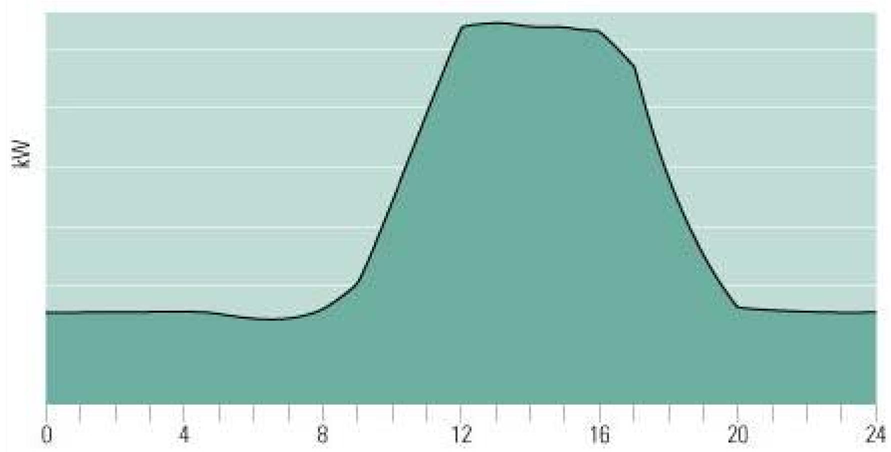


DR, Interruptible



About DSM

- DSM = Manipulations of Load Shape
  - Lower
  - Change shape
- Methods
  - Change technologies
  - Change behavior
  - Pricing
  - Codes and standards



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Energy Efficiency

- Involves technology measures that use less energy while producing the same or better levels of energy services (such as light, space conditioning, and motor drive power).
- Technologies tend to be long-lasting and save energy across all times when the end-use equipment is in operation.
- Depending on the time of use, energy-efficiency measures can produce significant reductions in peak demand.

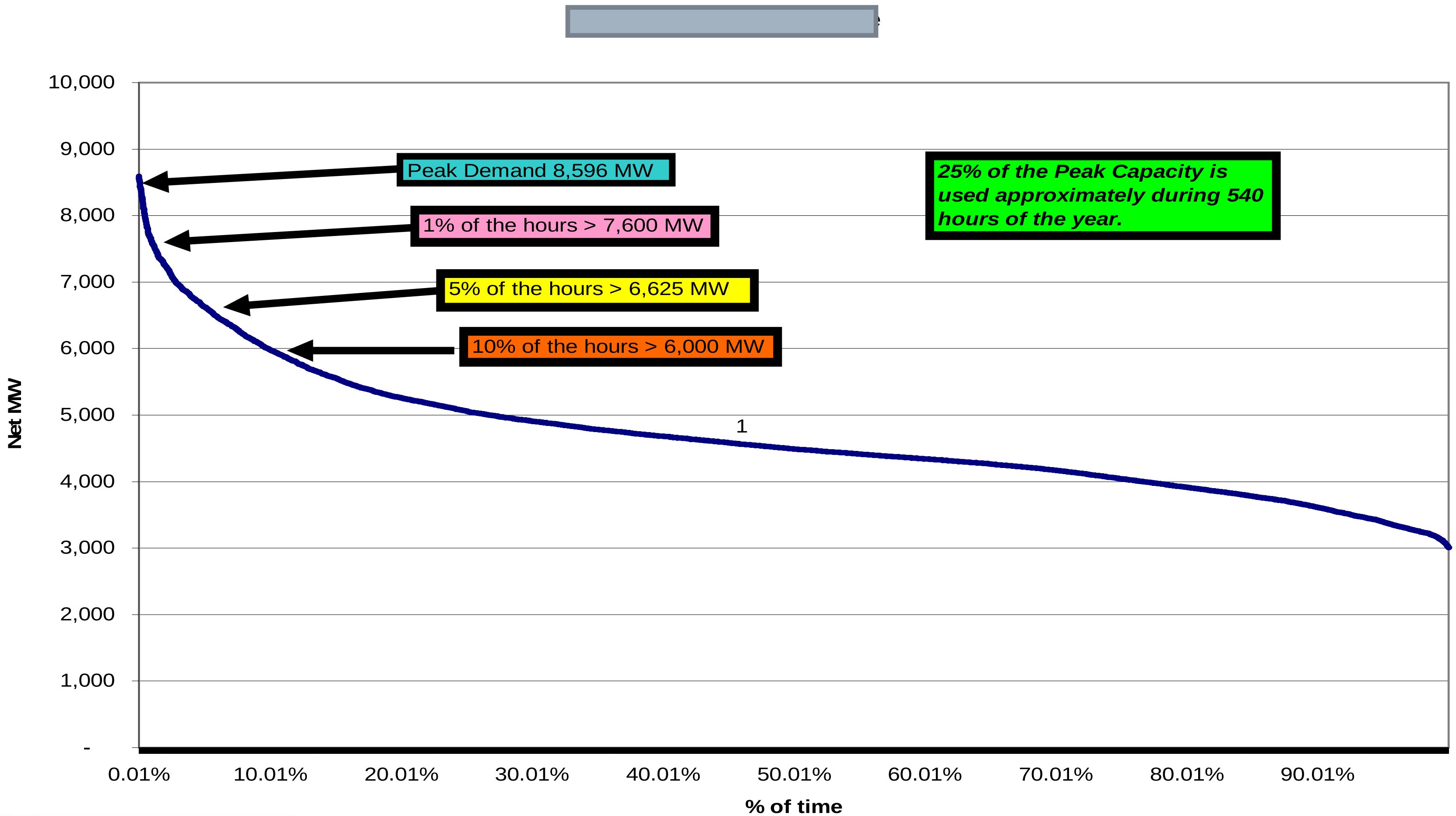
Conservation

- Involves saving energy and/or reducing demand by reducing the level of energy services, such as
  - setting thermostats lower in winter & higher in summer,
  - turning off lights, and
  - taking shorter showers
- Often involves behavioral changes more than technological improvements
- Often is not as lasting or reliable as implementing energy-efficiency measures.

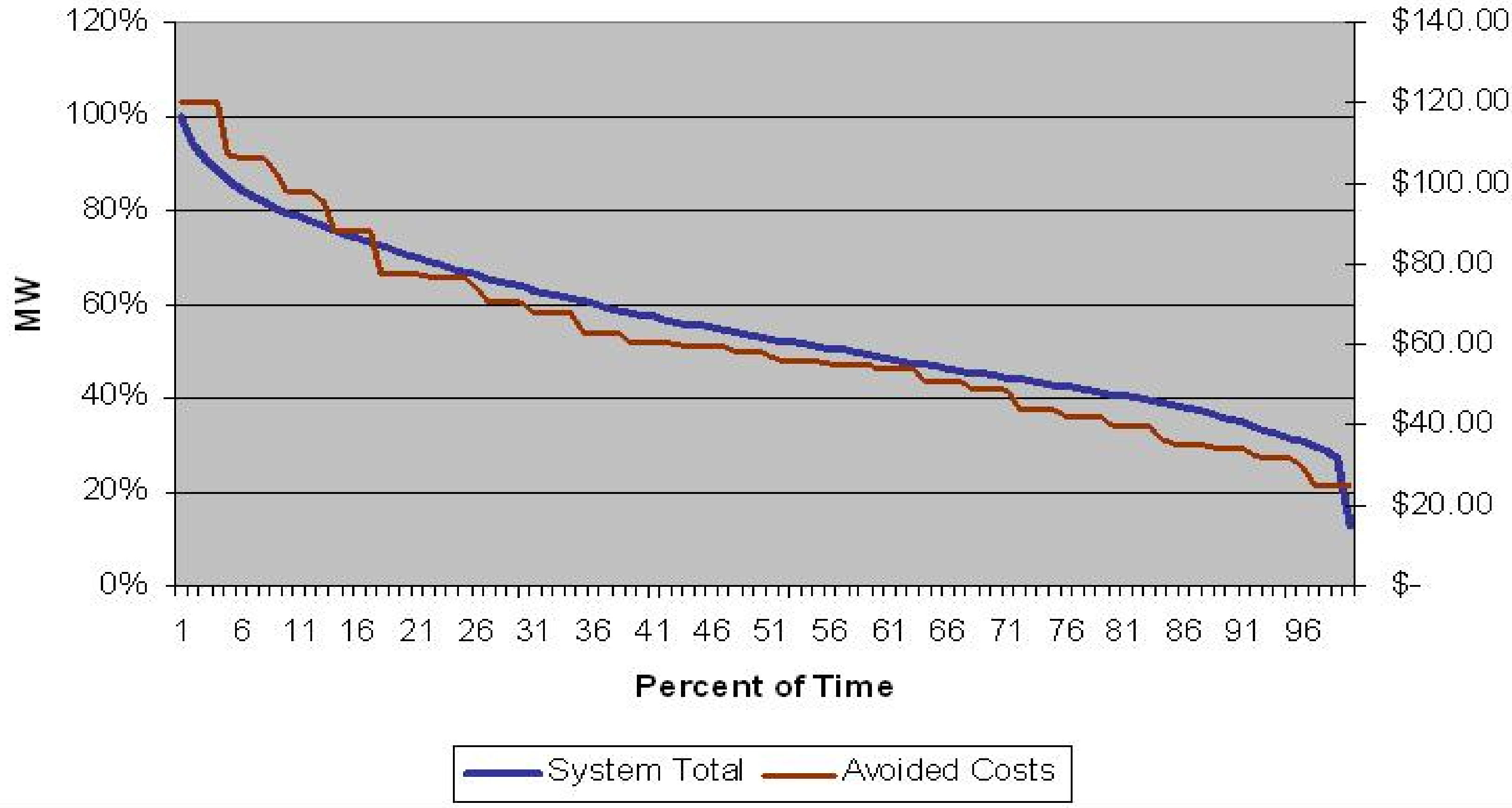
Codes and Standards

- Change the efficiency level of products and building practices
- Varies quite a bit from state to state
- Can be set at federal or local government

Load Duration Curve



Demand Response



Program Planning & Design

Program Planning & Design: Agenda

- How much is out there?
- Developing a portfolio of programs
- Identifying the savings opportunities
- Determining baseline for high efficiency
- Identifying market barriers
- Integrating programs
- Determining program goals and budgets
- Designing incentives

DSM Planning: Calculating Potential Savings

Technical Potential

What is the technical energy efficiency potential given baseline consumption patterns and available technologies?

→

Economic Potential

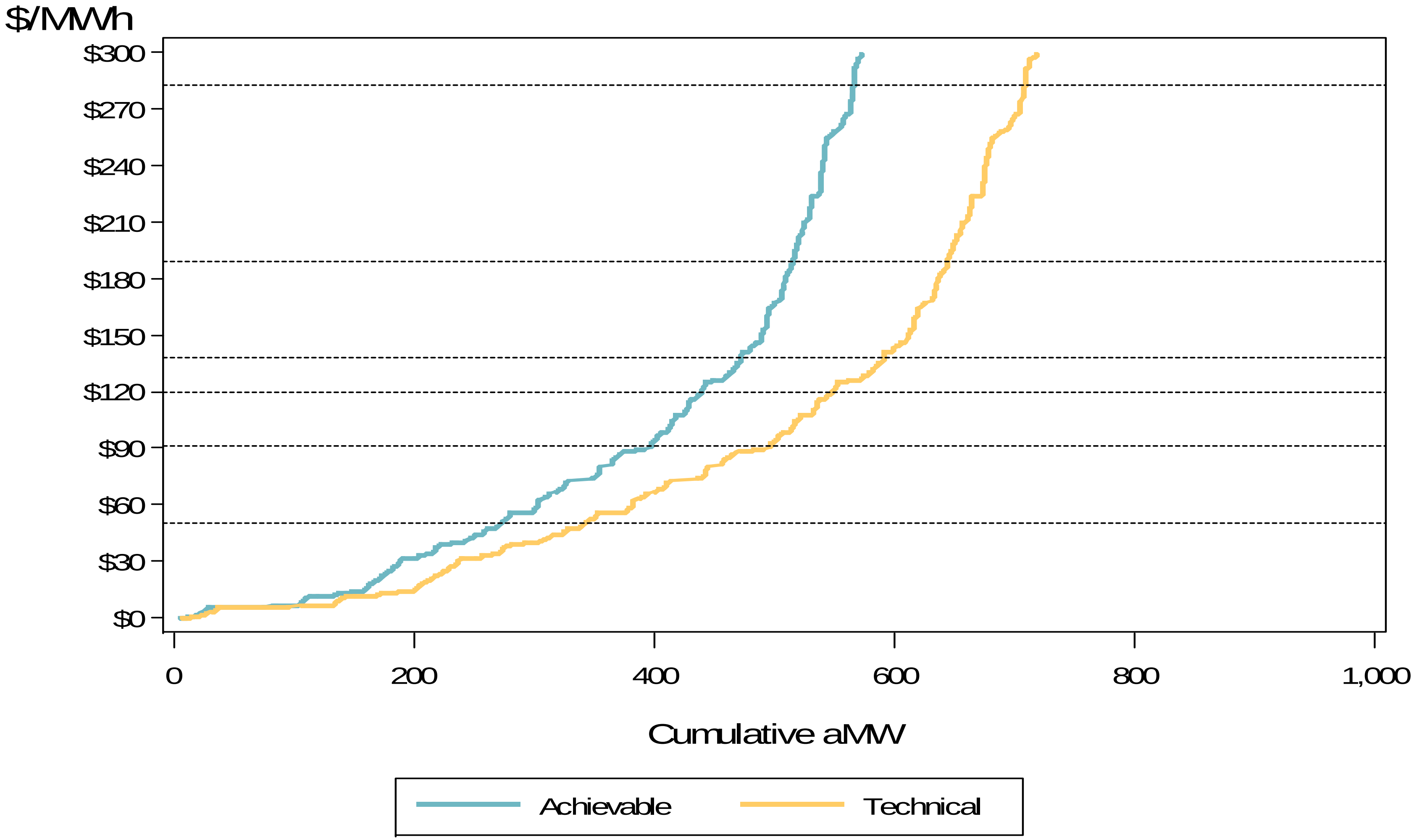
What energy efficiency potential from application of cost-effective measures?

→

Achievable Potential

What energy efficiency improvements can be achieved with available incentives and given customer preferences?

Supply Curves



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From Measures to Programs to Portfolios

- Process above produces a list of measures across end uses and sectors
- Supply curves
- Measures need to be bundled into programs
  - By sector?
  - By technology?

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DSM Economics

DSM Economics: Overview

- What is “cost-effectiveness” and why check?
- Basics of Economics
  - Avoided costs
  - Valuing efficiency resources
  - Benefits and costs
- Time value of money
- Metrics
- Cost-effectiveness tests policy issues

What Is Cost-Effectiveness?

- Measures the relative performance or economic attractiveness of an energy-efficiency investment compared to not making the investment (baseline).

- Compares present value of costs and benefits of efficient equipment with those of baseline (non-efficient) equipment.

Avoided Cost of Energy

- Represents estimates of current and future costs for energy on the margin
  - If considering DSM as an alternative, may consider the new supply cost in lieu of avoided costs

- Avoided cost components typically include:
  - Generation/Fuel
  - Peak capacity
  - Transmission and Delivery capacity

Time Value of Money

Interest: The cost of using capital; the price of money or the compensation to be paid to its owner for its use over time

Time Preference: Assigning different values to essentially the same item according to when it takes place (take possession of the item)

1 $ Today ≠ $ Tomorrow

(Even in an inflation-free world)

Time Value of Money

- Compounding: Present → Future
- Discounting: Present ← Future

$100 today @ 10%= $110 next year

$100 next year @ 10%= $90.91 today

Period	Value @ Beginning of Period	Increase in Value During the Period	Value @ End of Period
1	$1,000.00	$50.00	$1,050.00
2	$1,050.00	$52.50	$1,102.50
3	$1,102.50	$55.13	$1,157.63

Time Value of Money

In 1626, Manhattan Island was purchased for
60 Dutch Guilders ≈ $24

Periods / Years	Value @ Beginning of Period	Increase in Value During the Period	Value @ End of Period
383	$24.00	$3,131,214,231.24	$3,131,214,255.24

Future Value of $24 in 383 years
at a 5% interest rate
= $3,131,214,255.24

Payback Analysis Example:
Ranking by payback, ***shorter is better***.

- Initial project cost: $5,000
- Annual savings in energy cost: $2,500

Payback period is __________.

- Payback Period = Initial Cost / Net Annual Return

Project	Initial Cost	YR1	YR2	YR3	Payback
A	$3,000	$3,000	$2,000	$2,000	
B	$10,000	$4,000	$4,000	$4,000	
C	$15,000	$10,000	$10,000	$4,000	

Project	Initial Cost	YR 1	YR 2	YR 3	YR 4	YR 5	Payback
I	$10k	$10K					
II	$10k	$5K	$5K	$5K	$5K	$5K	

The Calculations

Net Present Value

$$NPV = \sum_{t=1}^{n} \frac{(B_t - C_t)}{(1+i)^n}$$

Benefit/Cost Ratio

$$B/C = \frac{\sum \frac{B_t}{(1+i)^n}}{\sum \frac{C_t}{(1+i)^n}}$$

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Levelized Cost Per kWh:

$$\frac{\text{First-Year Program Cost * Capital Recovery Factor}}{\text{Annual kWh Savings}}$$

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1}$$

What is the LC per kWh of a DSM program if:

(1) total initial cost is $10,000,

(2) has resulted in installation of measures with expected economic life of 10 years and 50,000 kWh in savings,

(3) the cost of capital is 10%?

Cost of Capital

- Usually derived as a weighted average from the composition of capital pool.
- The weighted cost of capital sets the lower boundary for the minimum acceptable rate of return.
- The actual rate of return expected from new investments is normally greater than cost of capital.
  - Rate of return depends on the risk involved.
  - Riskier projects are subject to higher discount rates to compensate for the chance that they will not meet net return expectations.

Debt and Equity

- The financial structure of firms is composed of debt and equity
- Each carries an obligation for monetary return
- Cost of capital is a weighted average of debt and equity capital cost

$$K_w = K_e * W_e + K_d * W_d$$

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Discounting Inputs

- Measure life
- Incremental installed cost
  - Cost above baseline equipment
- Incentive (rebate)
- Annual energy savings (at meter)

What C-E Tests Measure

Elements	TRC	RIM	UCT	PCT	SCT
Benefits					
Avoided Power Supply Costs	✓	✓	✓		✓
Avoided T&D Costs	✓	✓	✓		✓
Bill Reductions				✓	
Environmental Adder					✓
Costs					
Direct Utility DSM Costs	✓	✓	✓		✓
Direct Customer DSM Costs	✓			✓	✓
Utility Program Administration	✓	✓	✓		✓
Lost Revenues		✓			

How It's Done

- Benefits determined by spreading saved energy over the load profile and multiplying by corresponding avoided cost hour-by-hour over the life of the measure, discounted to the present
- Avoided Costs
  - Hourly energy costs
  - Annual Energy plus demand costs
- Energy Load Profile
  - 8760 hour load profiles by end use by building type
  - Load profiles developed by direct metering

Externalities

- **Definition:** by-products of activities that affect the well-being of people or the environment, where those impacts are not reflected in market prices.
- States **try to include these societal factors** in cost-effectiveness: health, income and employment generation, improved payment behavior, reduced bad debt and reduced carbon footprint.

Externalities (continued)

- Some states **create a conservation "advantage"**: increasing all avoided cost annually by a fixed percentage (10% usually).
- Some states try to **place a value on carbon reductions** for inclusion in cost benefit tests.

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The Most Important Externality?

At what value is cap-and-trade?

- Carbon is currently traded at $1 to $2 per ton
- Cost of DSM per MWh at approx. $115/MWh
- The $2/ton is (at best) 4% reduction in cost
- Carbon needs to be in the $30 to $50 range to make a significant difference

Key Issues With Cost-Effectiveness

- Discount rate to use for the various tests
- Avoided costs
- Value of externalities (most importantly, the value of carbon emissions)
- Freeriders / spillover / net-to-gross (NTG)

About Discounting

- All inputs and outputs in one year's dollars
- Real Discount Rate
  - Discount future costs/benefits to one year
  - Reflects time value of money (not inflation)
- Nominal Discount Rate
  - Includes inflation

Example

Program Inputs

- 40 kWh savings per CFL
- $4 incremental measure cost
- $2 incentive paid by utility
- 9 year measure life
- 10,000 bulbs installed
- $5,000 in administrative costs
- $50 avoided cost per MWh
- $0.085 retail rate
- 7.7% discount rate
- 7.2% line loss
- 10% societal adder

Annual Results

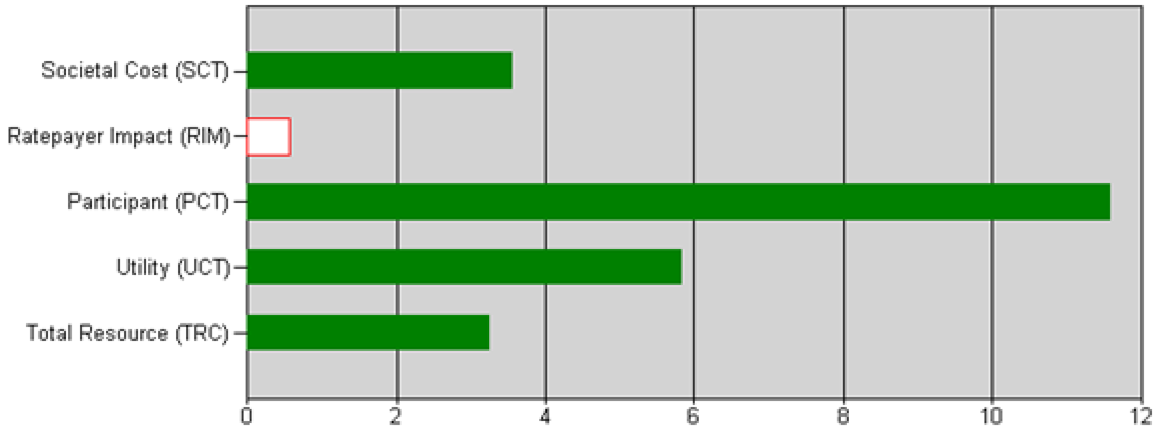
	TRC		Utility		Participant		RIM		Societal	
	Benefits	*Costs*	*Benefits*	*Costs*	*Benefits*	*Costs*	*Benefits*	*Costs*	*Benefits*	*Costs*
2009	$21,440	$45,000	$21,440	$25,000	$34,000	$20,000	$21,440	$59,000.000	$23,584.0	$45,000
2010	$21,440	$0	$21,440	$0	$34,000	$0	$21,440	$34,000.000	$23,584.0	$0
2011	$21,440	$0	$21,440	$0	$34,000	$0	$21,440	$34,000.000	$23,584.0	$0
2012	$21,440	$0	$21,440	$0	$34,000	$0	$21,440	$34,000.000	$23,584.0	$0
2013	$21,440	$0	$21,440	$0	$34,000	$0	$21,440	$34,000.000	$23,584.0	$0
2014	$21,440	$0	$21,440	$0	$34,000	$0	$21,440	$34,000.000	$23,584.0	$0
2015	$21,440	$0	$21,440	$0	$34,000	$0	$21,440	$34,000.000	$23,584.0	$0
2016	$21,440	$0	$21,440	$0	$34,000	$0	$21,440	$34,000.000	$23,584.0	$0
2017	$21,440	$0	$21,440	$0	$34,000	$0	$21,440	$34,000.000	$23,584.0	$0
2018	$0	$0	$0	$0	$0	$0	$0	$0.000	$0.0	$0
NPV	***$146,063***	***$45,000***	***$146,063***	***$25,000***	***$231,630***	***$20,000***	***$146,063***	***$256,630***	***$160,669***	***$45,000***
B/C Ratio	***3.25***		***5.84***		***11.58***		***0.57***		***3.57***	

Results Summary

Name	Type	Start Year	End Year	Average Measure
RES - CFL	program	2009	2009	9.00

Cost Effectiveness Summary

	Benefits (NPV)	Costs (NPV)	Net Benefits	B/C Ratio	Cost of Conserved
Total Resource (TRC)	$146,063	$45,000	$101,063	3.25	$0.015
Utility (UCT)	$146,063	$25,000	$121,063	5.84	$0.009
Participant (PCT)	$231,630	$20,000	$211,630	11.58	$0.007
Ratepayer Impact (RIM)	$146,063	$256,630	-$110,567	0.57	$0.088
Societal Cost (SCT)	$160,669	$45,000	$115,669	3.57	$0.015



Evaluation

What Is Evaluation?

- Doing unto others what you **don't want** done unto you
- A rigorous **scientific process** of:
  - examining programs as designed and as delivered,
  - examining impacts as the difference between **what happened** and **what could have happened**,
  - assessing some **ROI**, and
  - providing **feedback** for program **improvement**

The Evaluation Challenge

Evaluation attempts to measure **what did not happen.**

- Actual measure is energy use
- **Savings:** The difference between energy use after the program and what the energy use would have been without the program

- Not an easy question to answer; we need a baseline…

- **Nutshell:** Impact = Actual post – Actual pre ± Adjustment

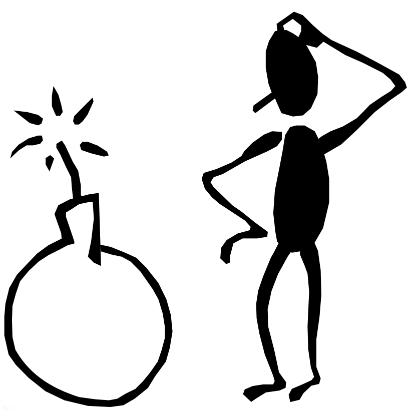
Guiding Principles

- Transparency
  - Guidelines? Protocols?
  - Enough to be understood?
  - Evaluation utilization: Cost recovery, improving design, planning, emission calculations
  - Discussion of limitations of methods and results

The Secrets of Data

If you torture the data long enough, they will confess.

"Things that are measured tend to improve." John Kenneth Galbraith



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Impact Evaluations

Impact Evaluation Basics

Assess the changes in energy use that can be attributed to a particular intervention, such as:

- the installation of energy efficient equipment,
- participation in a demand response program,

or

- increase in awareness

Energy Savings

- The reduction in energy use after treatment or installation of an energy-efficient device
- A baseline attempts to define what energy use would have been had the treatment not been applied

- Not easy to answer; we need a baseline…

- In a nutshell:

Impact = Actual Post – Actual Pre ± Adjustment

Adjustment Examples

- Weather corrections (if the program involves heating or air-conditioning systems in buildings)
- Occupancy levels and hours (if the program involves lighting retrofits in hotels or office buildings)
- Production levels (if the program involves energy-efficiency improvements in factories)

Demand Savings

Reductions in the rate of use of electric power measured in kilowatts or thousands of watts, abbreviated kW.

Example:

Changing a 100-watt incandescent light bulb with a 23-watt CFL reduces energy use by 77-watts when the light bulb is in use.

Impact Evaluation Methods

Typically, analysts can use secondary or primary data

- **Secondary data:** Using results from a similar program, with minor adjustments for local conditions and installation rates
- **Primary data:** Data collected directly from program participants and nonparticipants

Secondary Data

- Much knowledge has been developed over three decades of DSM program evaluations.
- Always explore use of secondary data, as it can have a great impact on evaluation costs.
- Some programs may not require direct evaluation.
- In all cases, adjustments are needed.
- Evaluators can use secondary data from one program **and** collect primary data on critical or uncertain inputs.

Methods of Energy Estimation

- Statistical
  - Simple Pre/Post (difference of means)
  - Simple Regression (accounting for weather)
  - Simple with Comparison Group (quasi-experimental design)
  - Detailed Regression
- Engineering
  - Simple Engineering
  - Simulation Models

Methods of Estimation (continued)

Demand

- Existing Load Factors
- Secondary Load Shapes
- End-Use Metering
- Simulations

When to use billing analysis?

- Pre/Post data available
- Savings large enough to be found in billing
  - Rule of thumb: >=10% of consumption
  - Possibly smaller savings if have large sample size
  - Possibly smaller savings if limited to shoulder months
- Larger scale programs
  - Many participants
  - Homogenous participants

Billing Analysis

- Simple Pre/Post
- Normalized Annual Consumption (NAC)
- Conditional Savings Model
- Analysis of Covariance/Fixed Effects
- Statistically Adjusted Engineering (SAE)

Example

- Average annual actual pre = 13,128 kWh
- Average annual actual post = 10,279 kWh
- Simple difference: Program savings = 2,850 kWh

	PRE	Post
Month	kWh	kWh
January	1,837	1,424
February	1,946	1,318
March	1,084	866
April	525	629
May	850	775
June	743	616
July	762	588
August	810	479
September	936	574
October	668	636
November	1,247	855
December	1,720	1,519
Total	13,128	10,279
Pre/Post Difference		2,850

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Energy Impact

Simple Regression: Weather Normalization

- Normal Pre – Normal Post = Normal Savings (vs. Actual)
- How? Most common PRISM
- Energy = a + b HDD + c CDD (or just one)
- Run regression model
- Replace actual HDD and CDD with long-run average values

Example of One Home

	PRE			Post		
Month	kWh	HDD	CDD	kWh	HDD	CDD
January	1,837	500	0	1,424	480	0
February	1,946	550	0	1,318	500	0
March	1,084	200	0	866	180	0
April	525	50	0	629	45	0
May	850	0	300	775	0	275
June	743	0	240	616	0	225
July	762	0	200	588	0	195
August	810	0	180	479	0	175
September	936	50	150	574	40	150
October	668	100	0	636	98	0
November	1,247	300	0	855	275	0
December	1,720	500	0	1,519	490	0
Total	13,128	2,250	1,070	10,279	2,108	1,020
Pre/Post Difference				2,850		

Example

1. Run regression on **both** pre and post data
   - Pre kWh = (462 * 12) + 2.67 HDD + 1.47 CDD
   - Post kWh = (449 * 12) + 1.95 HDD + 0.76 CDD
2. Annualized
   - Pre kWh = 5,549 + 2.67 HDD + 1.47 CDD
   - Post kWh = 5,394 + 1.95 HDD + 0.76 CDD
3. Average 10-year weather pattern
   - Average HDD = 2,000
   - Average CDD = 1,000
4. NACs
   - Pre NAC = 5,549 + 2.67 (2,000) + 1.47 (1,000) = 12,358 kWh
   - Post NAC = 5,394 + 1.95 (2,000) + 0.76 (1,000) = 10,053 kWh
5. Normalized savings = 2,305 kWh (Not 2,850)

Comparison Group

- How much would have occurred absent the program?
- Need a comparison group
- Use difference of difference model

Savings =

$$(Use_{pre} - Use_{post})_{Participants} - (Use_{pre} - Use_{post})_{Comparison}$$

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Comparison Group

- Assume similar group of homes had a change in average NAC of 500 kWh
- Program gross impact is 1,525 kWh
- Program net impact is 1,025 kWh

Client Group	Preprogram Normalized Energy Consumption (kWh)	Postprogram Normalized Energy Consumption (kWh)	Change in Consumption (kWh)
Nonparticipants	12,953	13,415	462
Participants	12,414	11,328	(1,086)
Net program Impact			(1,548)
Net impact in percentage terms			12.5%
Precision of Estimates (95% confidence)			±50%

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Detailed Regression Models

Additional explanatory variables include:

- occupancy
- square footage
- production levels
- details of installed measures

Example: If the explanatory variables indicate presence or absence of individual measures, the estimated regression coefficients would provide information on the impact of these measures.

Methods of Estimating Energy: Engineering Models

Engineering Models

- Approaches range from simple definitional calculations to complex building simulations
- Methods vary over a wide range from simple algorithms (e.g., CFL savings equation) to complex simulation tools such as DOE2
- Simple engineering calculations work best when energy savings can be computed using predictable inputs (change in wattage and hours of use for lighting measures, etc.)

Energy Impact: Simple Engineering

- SEM may use deemed or estimated values
- Example: ΔkWh=(Pre Watt-Post Watt)*hrs
- You may stipulate all or some

Simulation Models

When the energy relationships are more complex or the required level of detail is more rigorous, the preferred analysis method is Calibrated Simulation (IPMVP Option D).

Energy Simulation Models	
Commercial	**Residential**
eQUEST EnergyPro	Energy-10 REMRATE
EnergyPlus TRACE	EnergyGauge USA ESPRE
BLAST	
EZSIM	

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Simulation Models (continued)

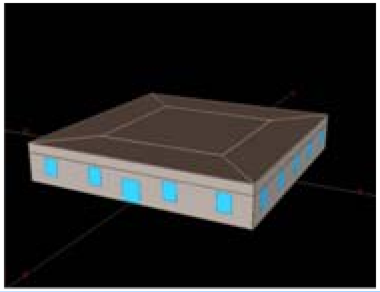
After creating a theoretical model, perform a preliminary simulation for billing history comparison.

- If the predicted energy consumption is within ±10 percent of the billing data, the model is considered valid for impact evaluation.
- If not, a calibration process is necessary: adjust assumed input values until the model is within a reasonable level (e.g., within ±10 percent).

Simulation Models (continued)

- Once calibrated, user can “install” the specific measure data into the model.
- Compare post-installation consumption to the baseline data to determine net energy savings for the energy-efficient measure.
- To determine the interactive effect, simulate a multiple measure evaluation (1) as individual measures in a specific order to determine unique measure savings, or (2) as a combination of measures in order.

eQUEST Outputs



- Develop prototypical model
- Input building characteristics and weather location
- Input measure efficiency levels to run from either existing to high efficiency or code to high efficiency
  - DX Cooling of EER 9.3 to EER 11.5
  - lighting power density reduction of 15%

Inputs: Office	Electric for All Heating End
	Existing
Exterior Wall Construction	2x4 -16" o.c. wood with brick exterior finish medium abs.
Roof Construction	standard wood frame built up roof
# of Floors	1
Floor Area [sqft]	4,800
Roof Area [sqft]	4,800
Envelope	
Window U-factor	U=0.60
Window to Wall Area	18%
Wall Insulation (R Value)	R-3
Roof Insulation (R Value)	R-11
Floor Insulation (R Value)	R-11
Lighting Density [W/sqft]	1.6
Occupancy Schedule WkDay	8am-5pm
Occupancy Schedule WkEnd	11am-4pm - Sat
HVAC	
Percent of Building Cooled/Heated	100
Heap Pump Heating Efficiency	2.7 COP
DX Cooling Efficiency	9.3 EER
Heat Pump Cooling Efficiency	9.2 EER
Heating Daytime Set point [°F]	69
Heat. Setback/Setup Set point [°F]	61
Cooling Daytime Set point [°F]	72
Cool. Setback/Setup Set point [°F]	75

eQUEST Outputs (continued)

Measure runs for various efficiency levels

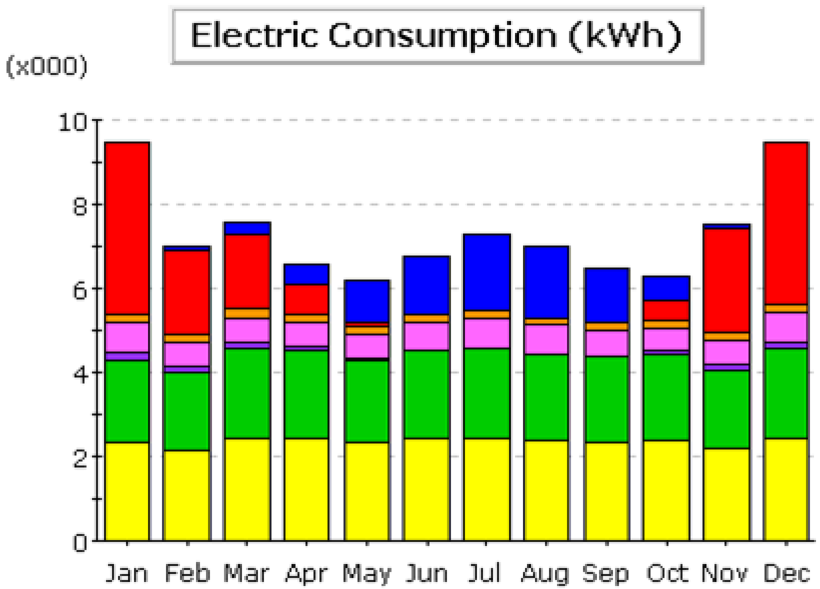
– 21.6% DX cooling savings

– 15% LPD savings, but note the interactive HVAC effects

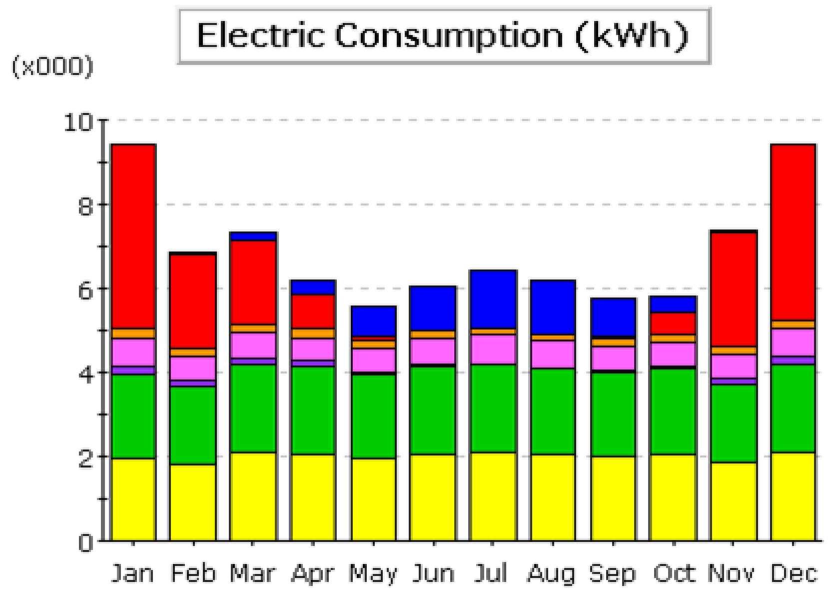
Annual Energy Consumption (kWh x000)				
Office: Seattle	Baseline	DX High	LPD 15%	DX & LPD
Space Cool	8.75	6.86	8.17	6.41
Heat Reject.	0	0	0	0
Refrigeration	0	0	0	0
Space Heat	15.49	15.49	16.98	16.98
HP Supp.	0	0	0	0
Hot Water	2.26	2.26	2.26	2.26
Vent. Fans	7.5	7.5	7.42	7.42
Pumps & Aux.	1.04	1.04	1.05	1.05
Ext. Usage	0	0	0	0
Misc. Equip.	24.27	24.27	24.27	24.27
Task Lights	0	0	0	0
Area Lights	28.31	28.31	24.07	24.07
Total	87.62	85.74	84.22	82.46

DX = direct-expansion unitary system (rooftop cooling unit)
LPD = lighting power density

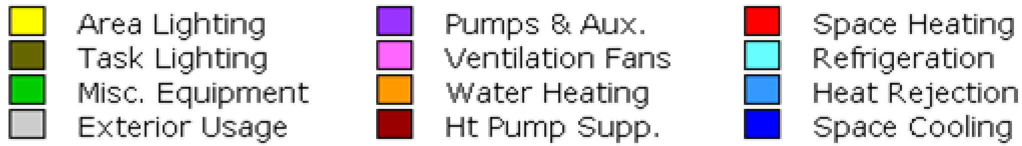
eQUEST Outputs (continued)



Small Office: Baseline



Small Office: EE (DX & LPD)



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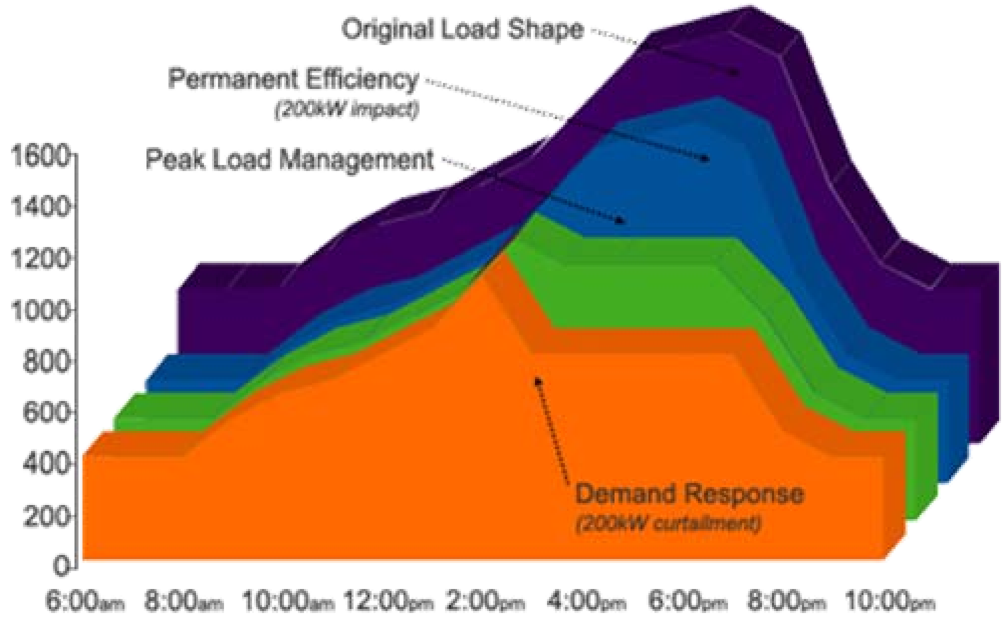
Methods of Estimating Demand

Demand Impacts

- Existing Load Factors
- Secondary Load Shapes
- End-Use Metering
- Simulations



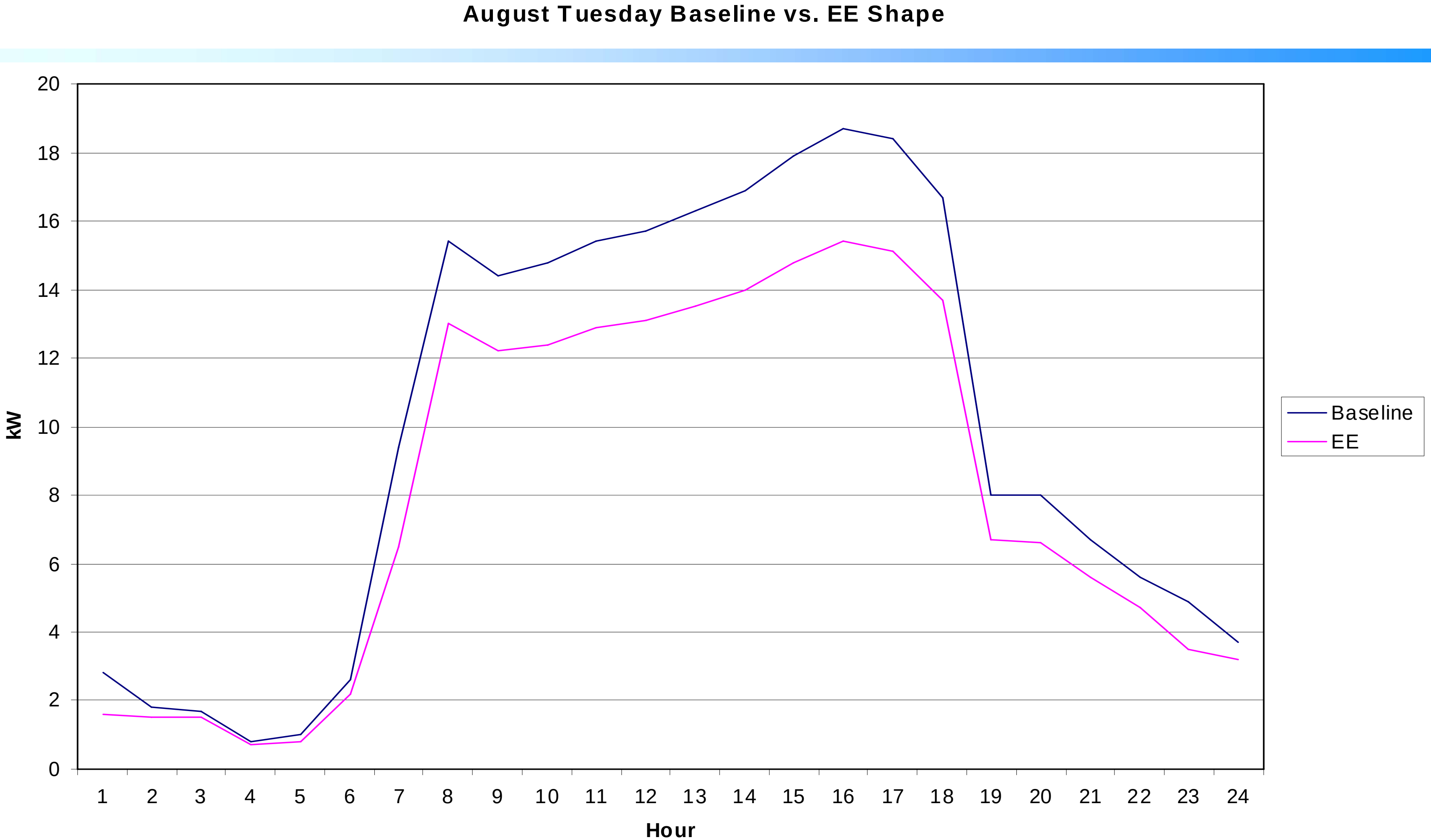
•www.cpowered.com/images/chart_dailyload.gif

End-Use Metering

- Can be most expensive approach **and** most accurate
- Primary step: Develop a detailed plan identifying
  - end-use equipment to be metered
  - parameters and data involved
  - length of time required for data collection
  - metering equipment
- A description of

  (1) baseline (pre-retrofit)
  (2) the anticipated post-retrofit equipment
  (3) operating conditions
  (4) assumptions made for unknown conditions

Simulation-eQUEST



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Components of Net-to-Gross

Adjusted Gross Savings

- Installation rates
- Failure rates
- Baseline assumptions
- Leakage

Components of Net-to-Gross

Net Savings

- Free riders
- Spillover
- Rebound or take-back effects (to a lesser extent)

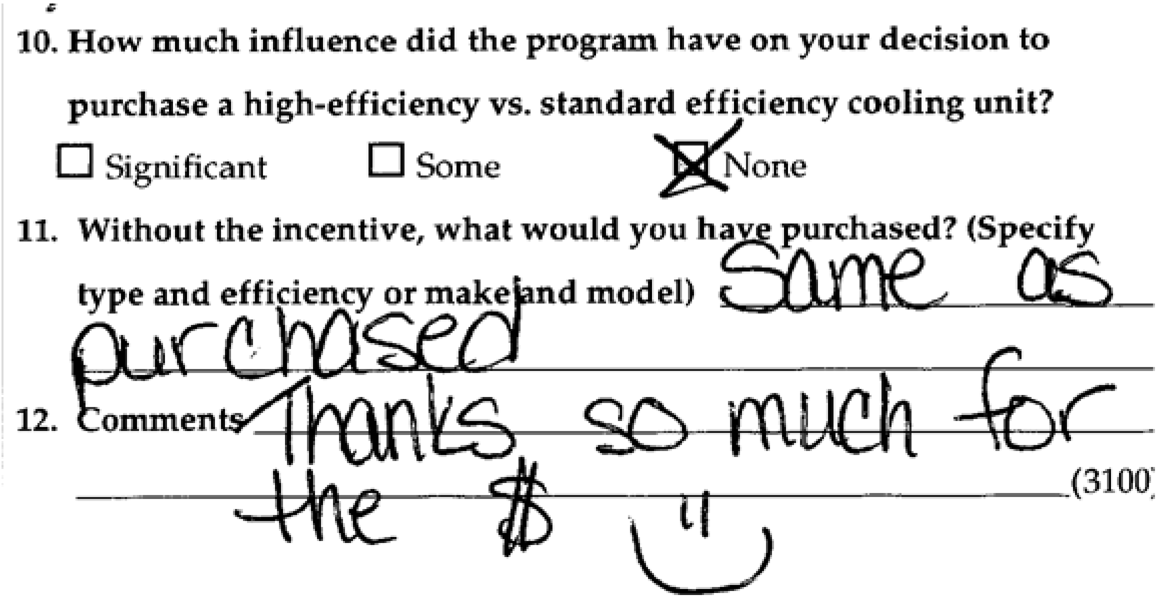
www.baylor.edu/content/imglib/1613.jpg

Approaches to Measurement of Free Riders, Spillover & Take-Back

- Quasi-Experimental Design
- Self-Reporting
- Enhanced Self-Reporting Surveys
- Qualitative Choice
- Stipulated Net-to-Gross Ratios

Estimating NTG

Not always as easy as for this respondent (particularly for upstream programs)



10. How much influence did the program have on your decision to purchase a high-efficiency vs. standard efficiency cooling unit?

☐ Significant ☐ Some ☒ None

11. Without the incentive, what would you have purchased? (Specify type and efficiency or make and model) Same as purchased

12. Comments Thanks so much for the $:) (3100)

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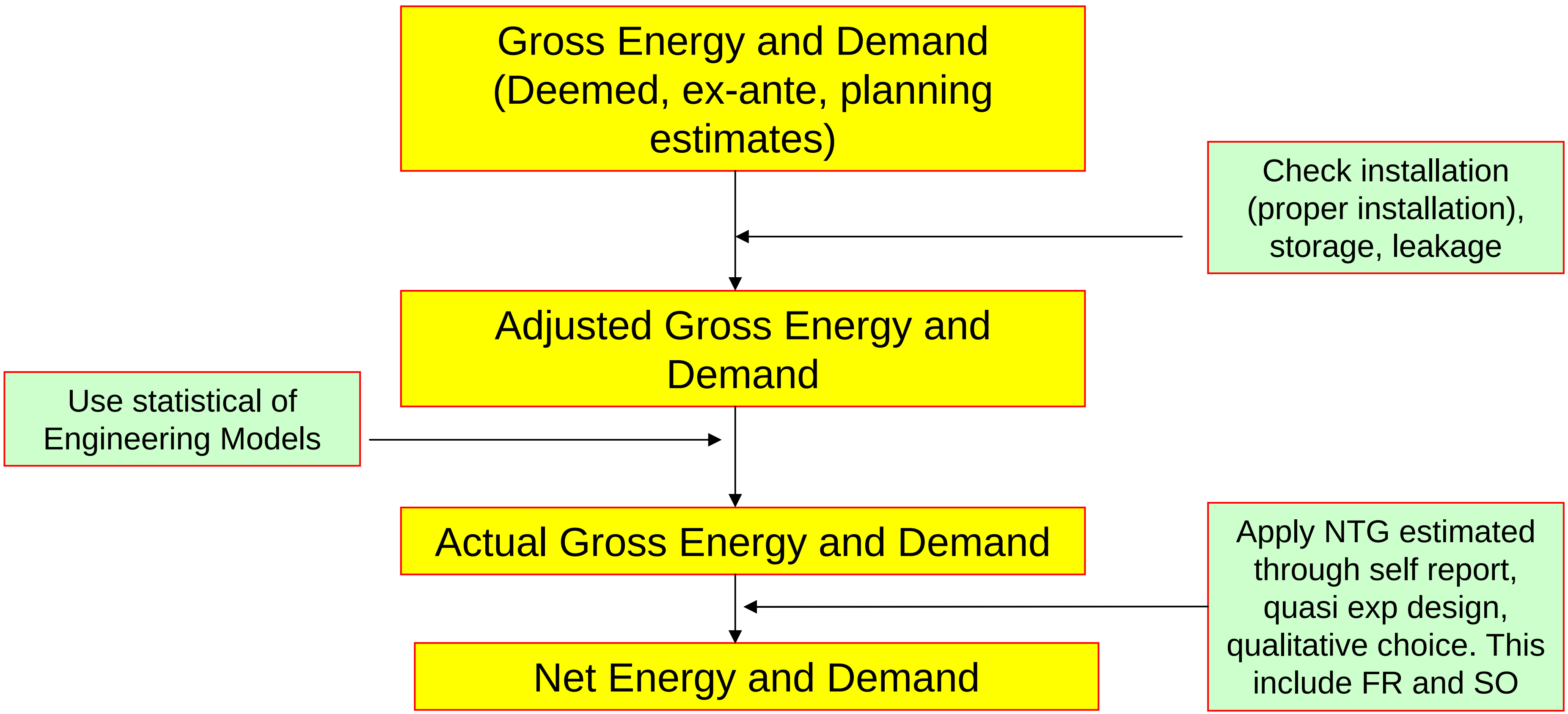
Overall Summary of Impact Evaluation



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