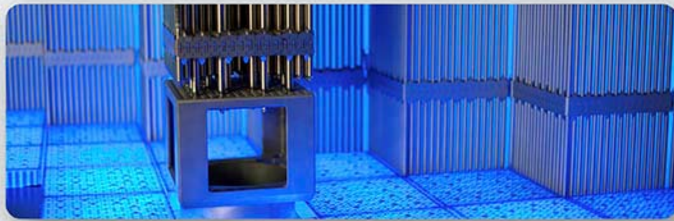



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The Value of Home Area Networks for Demand Response

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Smart Grid Informational Webcast

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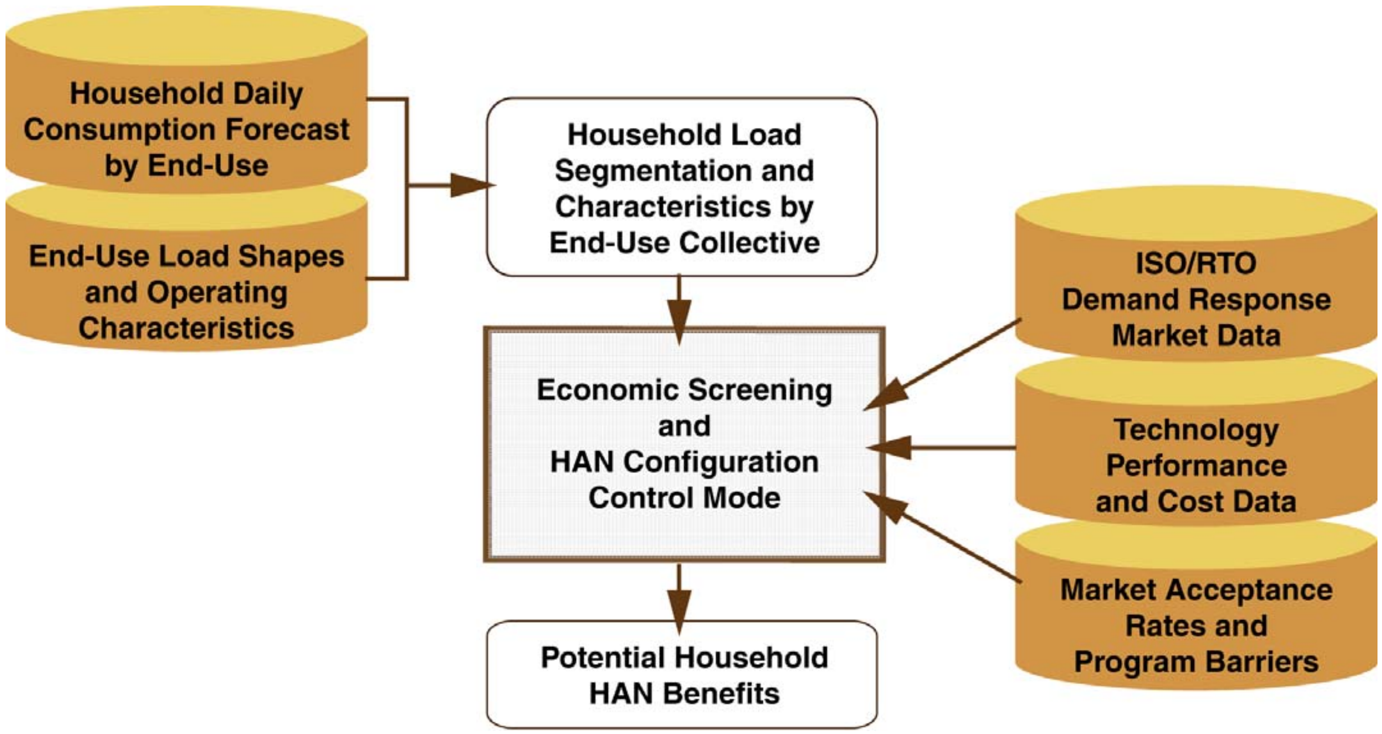
Objective and Methodology

Quantify the marginal value of HAN/EMS technologies in fostering demand response:

– Add loads not now participating

– Better control of all loads



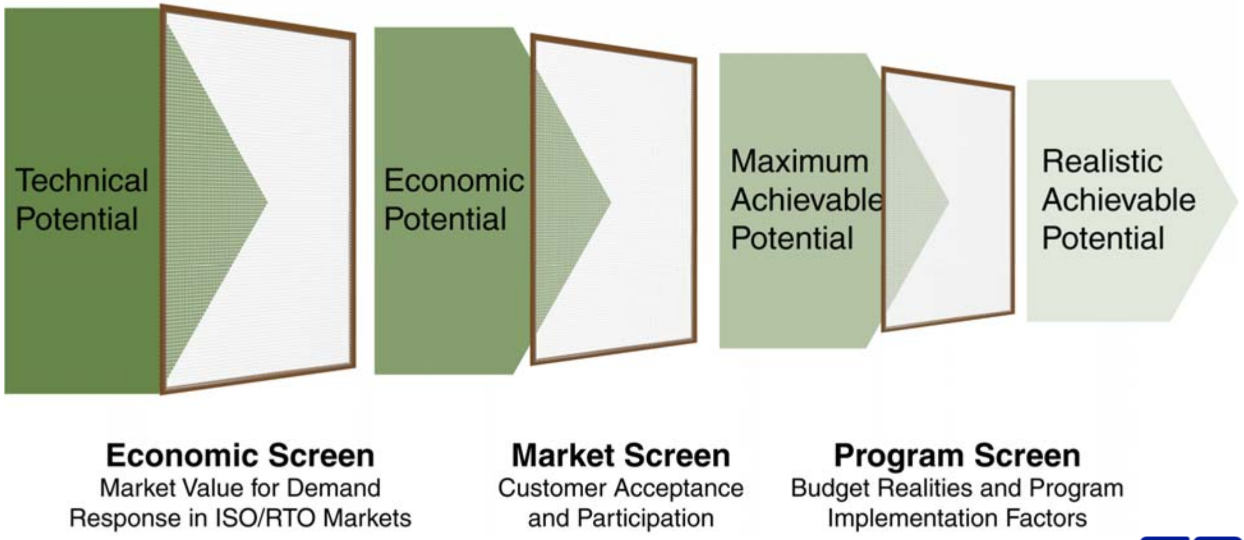
Varying Levels of Potential

Technical Potential

- Upper bound for load reduction within a house (kWh and kW)
- Assume large numbers of households and end-uses are able to be controlled
- Implementation factors are not considered
- Costs for communications networks, HAN systems, and implementing the necessary utility programs are not considered

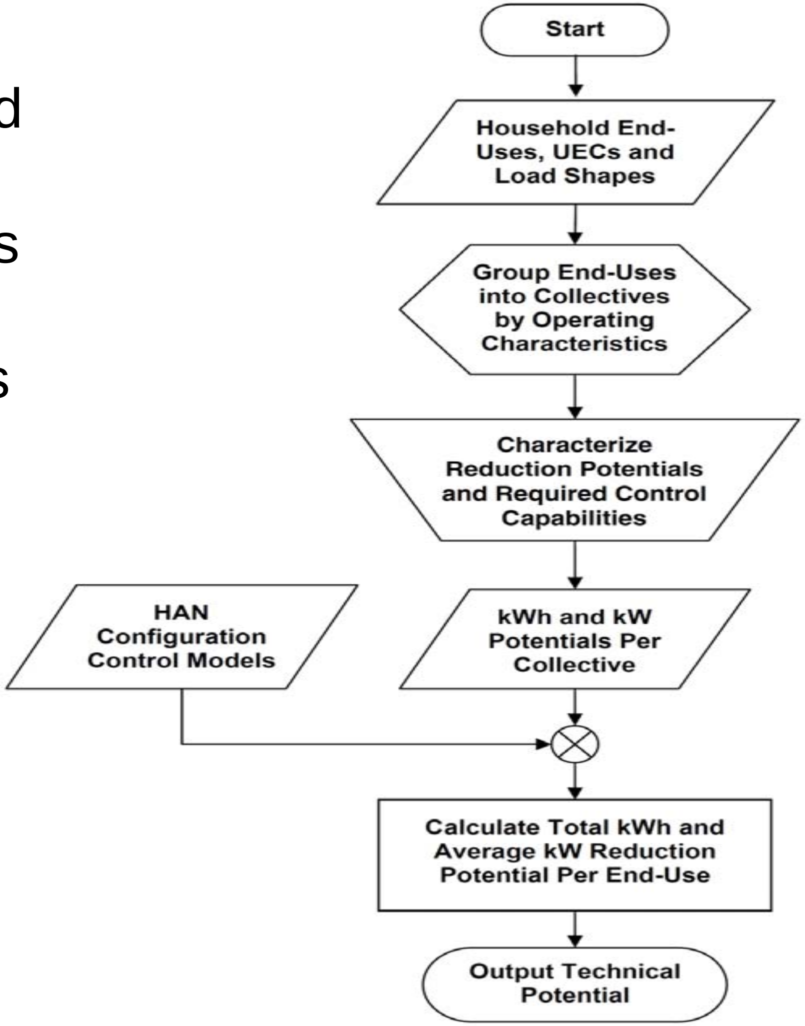
Economic Potential

- Define value streams associated with the potential kW and kWh reductions
- Net economic benefit to homeowner based on the cost of the HAN



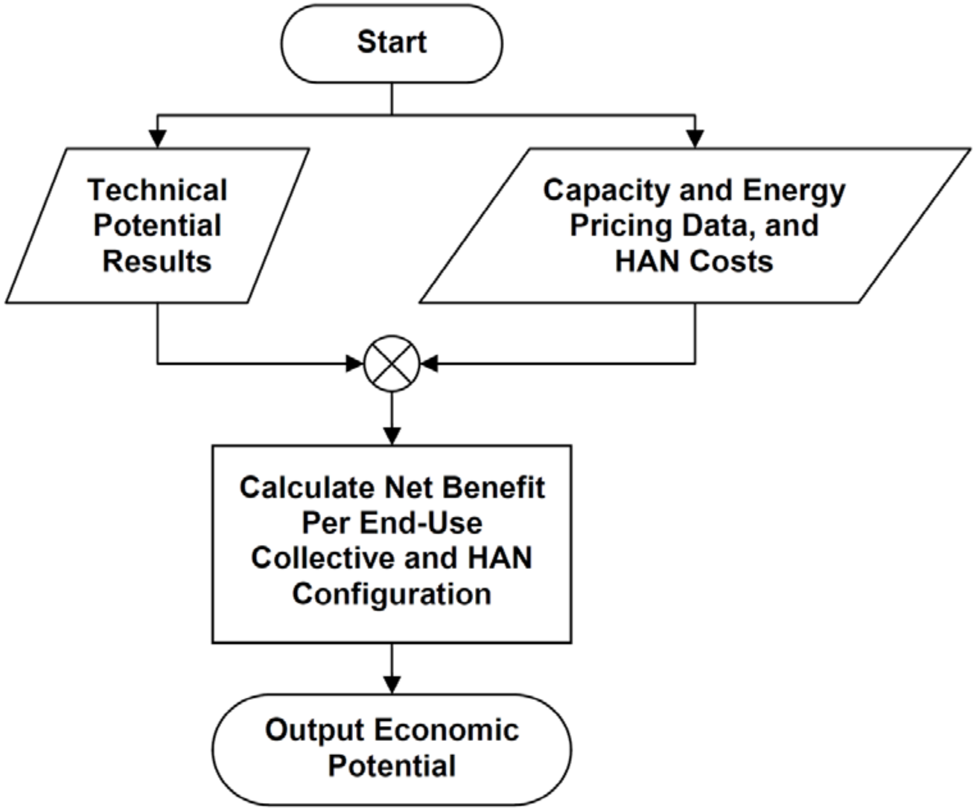
Technical Potential Framework

- Load shape is based on the temporal operating characteristics of household loads
- Each piece of end-use equipment has unique operating characteristics
- End uses are grouped into collectives according to similarities in their load profiles and control opportunities
- Reduction potential is based on operating modes and control limitations
- HAN configuration control modes define increasing household monitoring and load control capabilities



Economic Potential Framework

- Refine technical potential results
- Value available from DR in a home depends on the market value for the services they provide
- Market prices for capacity and energy supply are used to calculate the financial benefits for load control
- The result is a set of value streams for each end-use collective and level of end-use control class

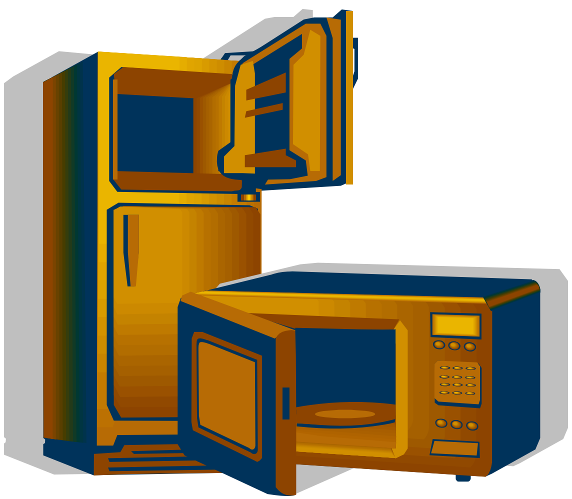


The Devil is in the Details (and Assumptions)

- Representative South Atlantic residence
  - Average regional square footage
  - Single family home
- All electric end uses modeled in detail
- ISO/RTO perspective on demand response value and deployment

Household Modeling

- Example: hot summer day
- Modeled an eight hour period, noon - 8 p.m.
- To model control used one minute demand data
- Load shapes for all appliances and devices in the home
- What is in a typical home?



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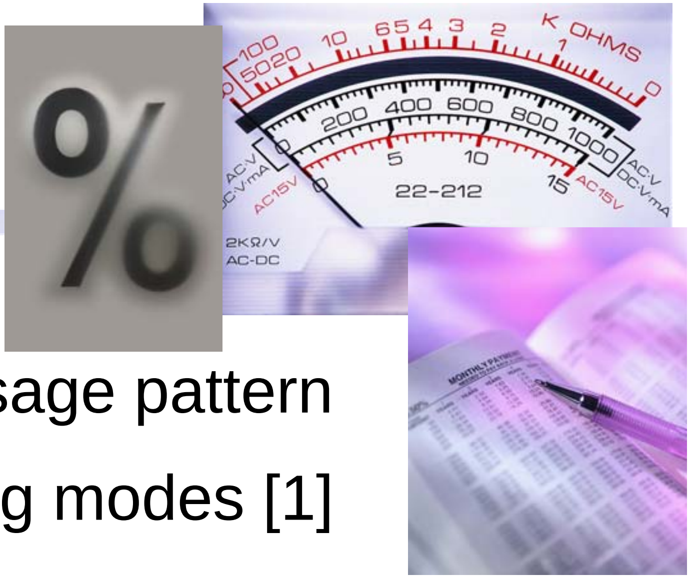
Load Shape Development



- Duty cycle data with assumed daily usage pattern
  - Time and watts in different operating modes [1]
- Statistical profiles based on average cycles per day and probability of operation each hour [2]
- Measured load data available from previous EPRI projects
- Correlation of daily kWh consumption with typical values from U.S. DOE EIA data [3,4]

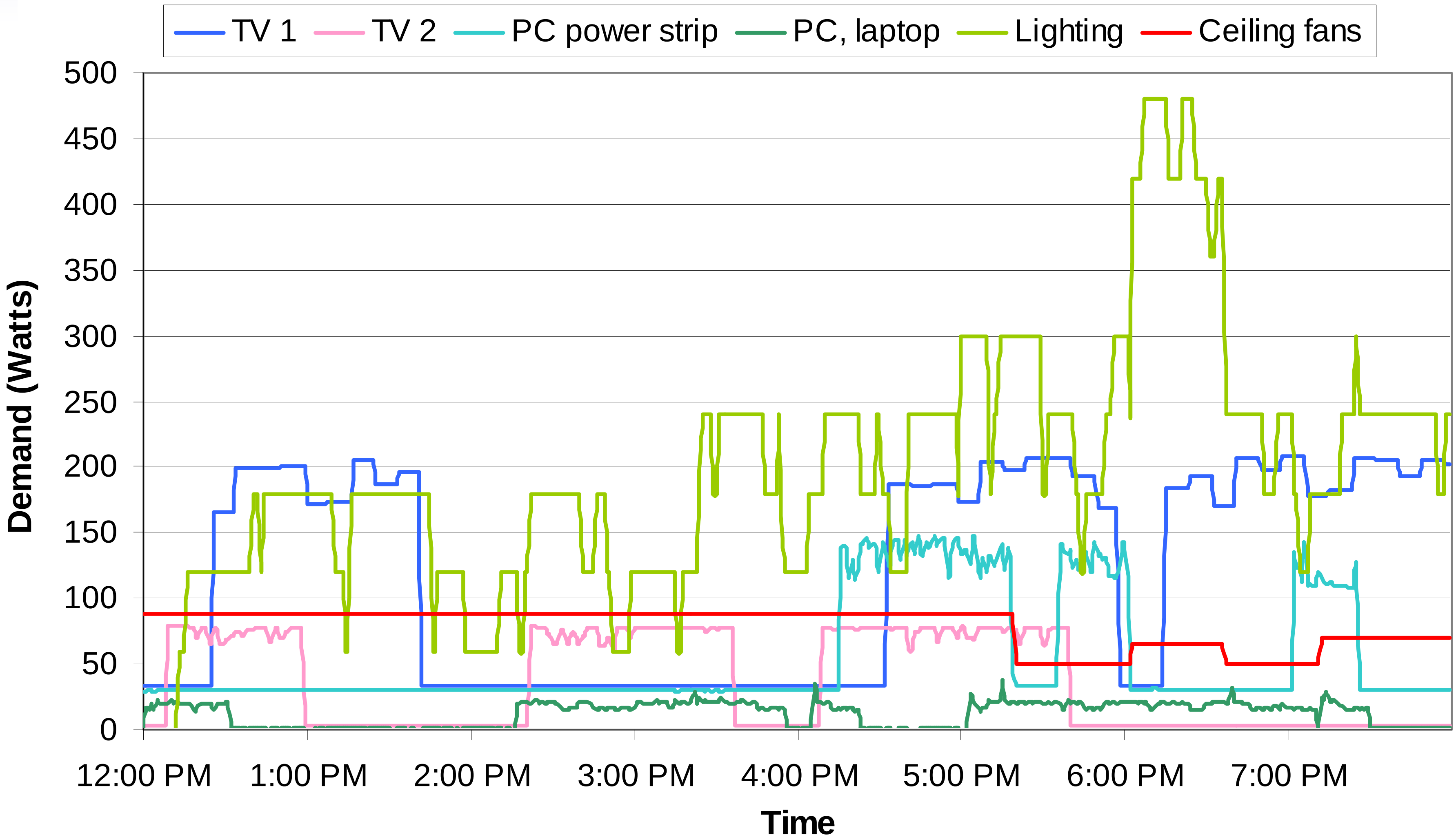
[1] Ecos Consulting. "Final Field Research Report." Prepared for the California Energy Commission.

[2] Paatero J.V. and Lund P. D. "A Model for Generating Household Electricity Load Profiles." Wiley InterScience, DOI: 10.1002/er.1136.

[3] Energy Information Administration. "2005 Residential Energy Consumption Survey." Released 2008.

[4] Energy Information Administration. "Annual Energy Outlook 2009 with Projections to 2030." Released March 2009.

Example of Individual Load Curves



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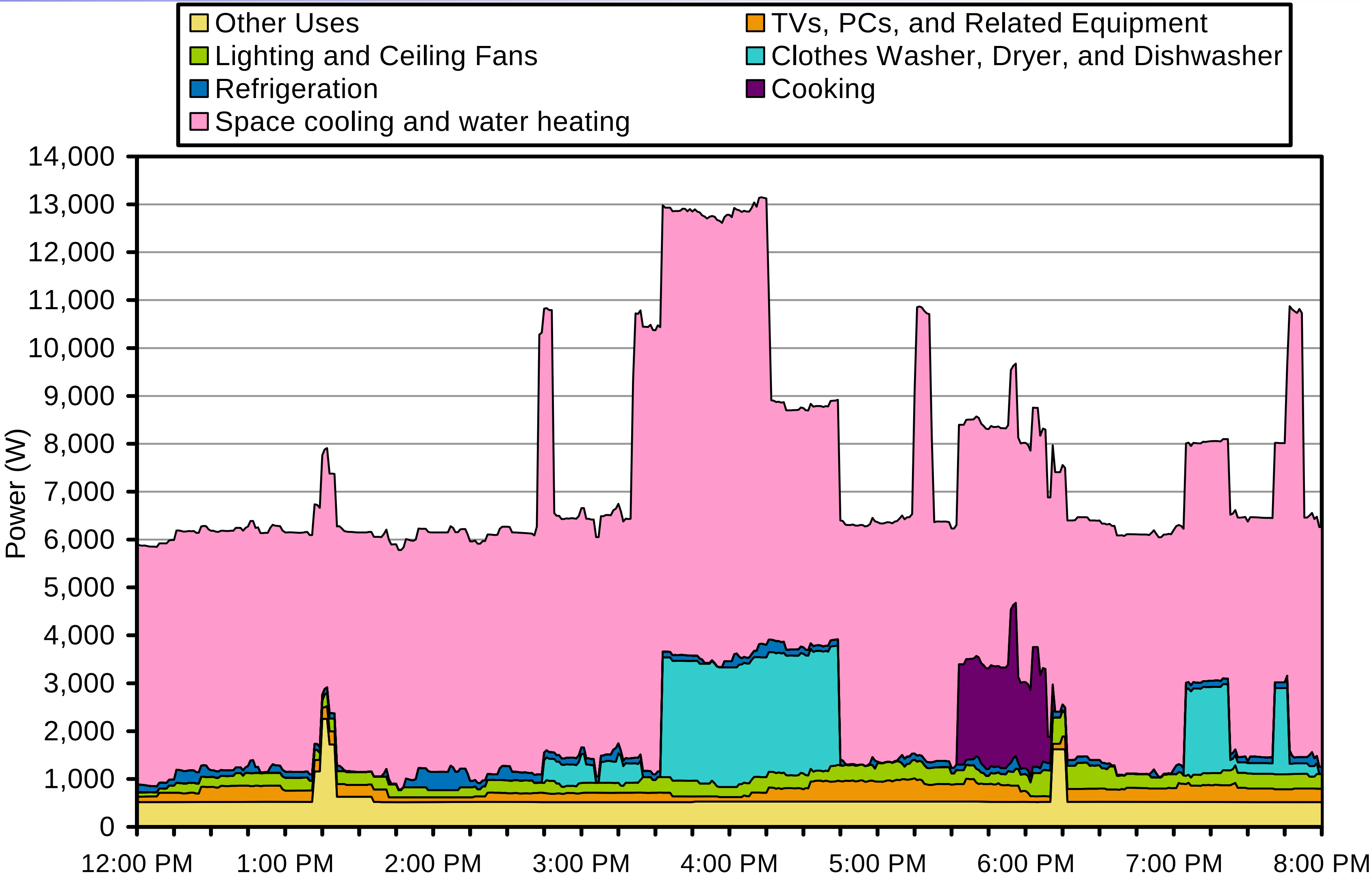
Household Load Shapes – Functionally Aggregated



Control Collectives

Control Category	Description	Benefits
Demand Response: Traditional direct load control (DLC)	Direct load control allowing cycling or delay of major appliance operation Cycle air conditioning units Disable water heater or pool pump operation	Reduce system demand during peak periods or emergencies. Abate load when prices are high
HAN Level 1: Enhanced DLC	DR controls, plus multi-level switching of select end uses System notification of turn-on of major appliances is available with no real-time consumption information Reduction of AC compressor speed for a preset duration when turn-on of other major appliances is sensed Switching of additional end uses with multiple discrete levels of operation, e.g., ceiling fans	Use local operating information to perform additional load control. Reduction of system demand during peak or emergencies. Reduce some coincident demand with multiple large appliances operating.
HAN Level 2: Coordinated end-use switching	Reduction/increase demand on shorter notice for real-time consumption information, perform load leveling, optimize operation of equipment Demand response controls, control capabilities of HAN Level 1, plus variable/multi-level end-use control and removal of standby loads Instead of discrete reduction of AC compressor for a fixed duration, control of continuously variable compressor to level demand in the home with operation of larger loads, e.g., dishwasher, clothes dryer, coffee maker.	Using appliance level consumption information, implement advanced control strategies, e.g. pre-cooling to increase comfort levels with AC cycling. Highest level of control over and management of the degree of impact on inhabitant comfort levels.

Demand Response: Traditional Direct Load Control

End Use	Control Opportunities
Central air conditioning	Reduce compressor operation to 50% duty cycle and keep fan running to circulate air while compressor is off
Water heater	Disable operation
Pool pump	Disable operation

HAN Level 1: Enhanced Direct End-Use Switching

End Use	Control Opportunities
All utility-controlled demand response control strategies	
Central AC	Reduce compressor speed to decrease power draw by 1,000 Watts for a preset amount of time with turn-on of the dishwasher, clothes washer, and clothes dryer. The minimum draw will be 400 Watts for fan operation to keep air circulating.
Lighting	Turn off individual light bulbs to reduce load 50%. This does not include the ceiling fan light fixture.
Ceiling fans	Reduce speed by one level without turning any off. This will minimize discomfort with coincident curtailment of AC.

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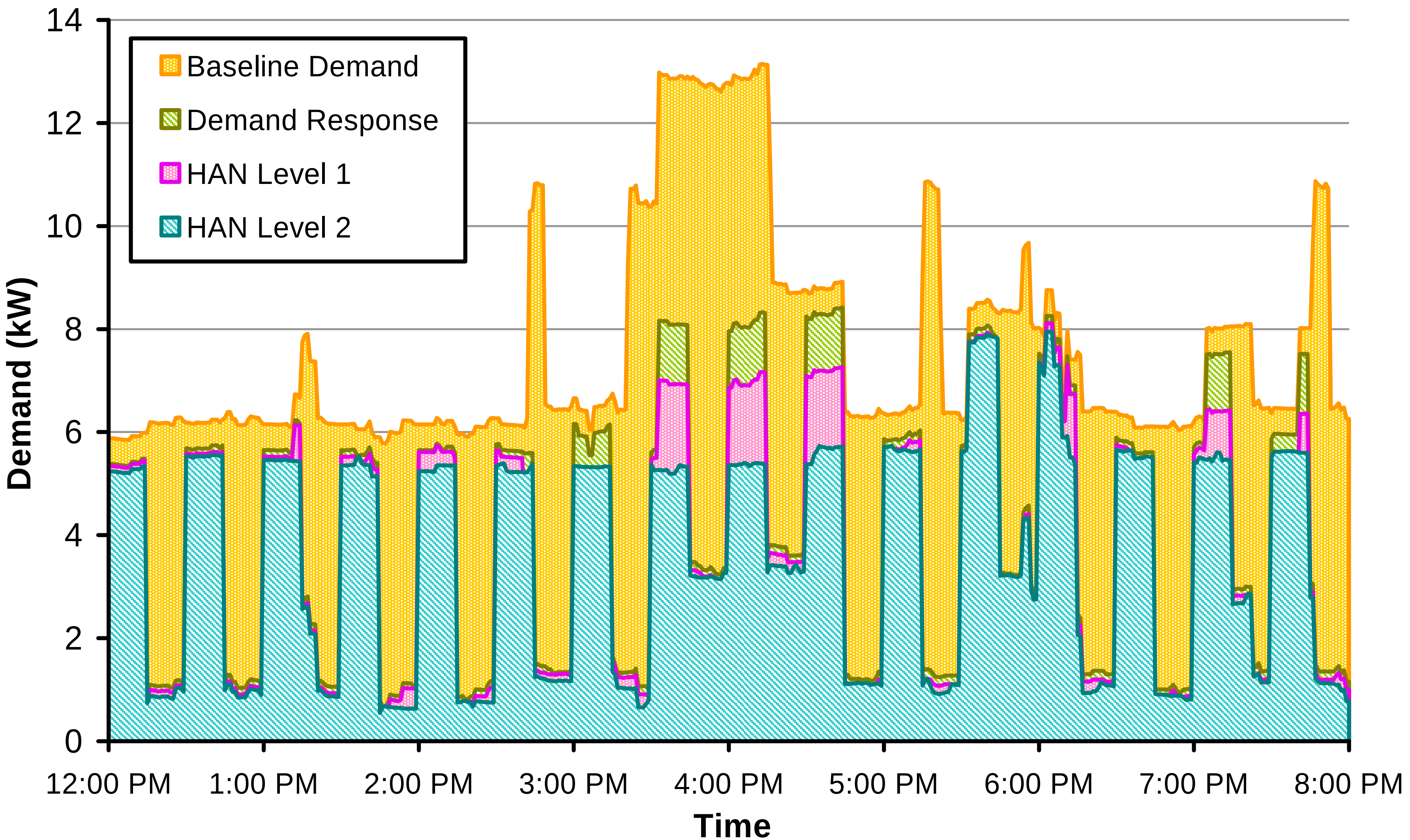
HAN Level 2: Intelligent Coordinated Control of End-Use Devices

End Use	Control Opportunities
All utility-controlled demand response and Level 1 strategies	
Central AC	Reduce continuously variable compressor speed to offset the instantaneous draw of the dishwasher, clothes washer, clothes dryer, coffee maker, and microwave operation. The minimum draw in any case will be 400 watts for fan operation to keep air circulating.
TVs, set-top boxes, PCs and peripherals, audio equipment, rechargeable devices, and equipment with digital displays	Disable devices with standby draw, based on knowledge of typical operations, i.e. to cut power to the cable box only when the TV associated with it is not operating.
Refrigeration	Disable auto-defrost cycle
Lighting	Dim lighting that is still on after Level 2 reductions by 80%, including ceiling fan fixture.

Sequential Dispatch of Household Loads



Case 1. Marginal Load Curtailments by Control Category

Control Category	Total Energy (kWh)	Average Demand (kW)	Peak Demand (kW)
Base DR	27.7	3.5	4.7
HAN Level 1	2.4	0.3	0.3
HAN Level 2	1.8	0.2	0.2
Cumulative	**31.9**	**4.0**	**5.2**

HAN System Cost

	HAN Level 1	HAN Level 2
Required Equipment	•AC controller •10 lighting switches[a] •3 ceiling fan controllers •Sensors for clothes washer, dryer, and dishwasher	•Controllers for microwave and coffee maker •Dimmable controller for ceiling fan lights •10 dimmable controllers for other lighting •Controllers for refrigerators •Six controllers for standby loads[b]
Central Control Unit	$500	N/A
Sensors	$51	$33
Switch – on/off	$70	$56
Controllers – dimmable or multi-level	$40	$130
Total HAN Cost	**$661**	**$219**
Equipment Lifetime	10 years	10 years
Annual HAN Cost	**$66.10**	**$21.90**

[a] Assumed ten total bulbs to be controlled and a maximum of five bulbs operating at once from noon to 8 p.m.

[b] Assumed six power strips or switches that could be opened to accommodate all non-kitchen loads consuming standby.

Payments for Delivered Demand Response

Control Category	Average Demand Reduction (kW)	Capacity Payment		
		$25 per kW	$50 per kW	$75 per kW
Base DR	3.5	$86.70	$173.40	$260.10
HAN Level 1	0.3	$7.58	$15.16	$22.74
HAN Level 2	0.2	$5.58	$11.17	$16.75
Cumulative	**4.0**	**$99.86**	**$199.73**	**$299.59**

Control Category	Total Energy Reduction (kWh)	Energy Payment		
		0.75 $/kWh for 5 days	0.75 $/kWh for 5 days 0.50 $/kWh for 5 days (total 10 event days)	0.75 $/kWh for 5 days 0.50 $/kWh for 5 days 0.25 $/kWh for 10 days (total 20 event days)
Base DR	28	$104.04	$173.40	$242.76
HAN Level 1	2	$9.10	$15.16	$21.23
HAN Level 2	2	$6.70	$11.17	$15.63
Cumulative	**32**	**$119.84**	**$199.73**	**$279.62**

Net Benefits by HAN Control Category

Base Case

Control Category	Total Payment	Annualized HAN Cost	Marginal Net Benefit
Demand Response	$190.74 – $502.86	$0	$190.74 – $502.86
HAN Level 1	$16.68 – $43.97	$66.10	(-$49.42) – (-$22.13)
HAN Level 2	$12.28 – $32.38	$21.90	(-$9.62) – $10.48

HAN as an Energy Bidding Enabler

Control Category	Average Demand Reduction (kW)	Capacity Payment		
		$25 per kW	$50 per kW	$75 per kW
Base DR	3.5	$86.70	$173.40	$260.10
HAN Level 1	0.3	$7.58	$15.16	$22.74
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Cumulative	**4.0**	**$99.86**	**$199.73**	**$299.59**

Control Category	Total Energy Reduction (kWh)	Energy Payment		
		0.75 $/kWh for 5 days	0.75 $/kWh for 5 days 0.50 $/kWh for 5 days (total 10 event days)	0.75 $/kWh for 5 days 0.50 $/kWh for 5 days 0.25 $/kWh for 10 days (total 20 event days)
Base DR	28	$0	$0	$0
HAN Level 1	2	$9.10	$15.16	$21.23
HAN Level 2	2	$110.74	$184.57	$258.39
Cumulative	**32**	**$119.84**	**$199.73**	**$279.62**

Net Benefits by HAN Control Category

HAN-enabled Energy Bidding

Control Category	Energy Payment	Annualized HAN Cost	Net Benefit
Demand Response	$86.70 – $260.10	$0	$88.70 – $260.10
HAN Level 2	$116.32 – $275.14	$88	$94.42 – $253.24

Some Observations

- Most demand response potential resides in a few appliances
- Many utilities have already exploited these resources cost-effectively using individual device controls
- HAN may be most beneficial for accessing price response

- HAN may expand participation in demand response programs
- Electrification may add new DR options (EVs) that utilize HAN
- More complete analysis would be useful

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