

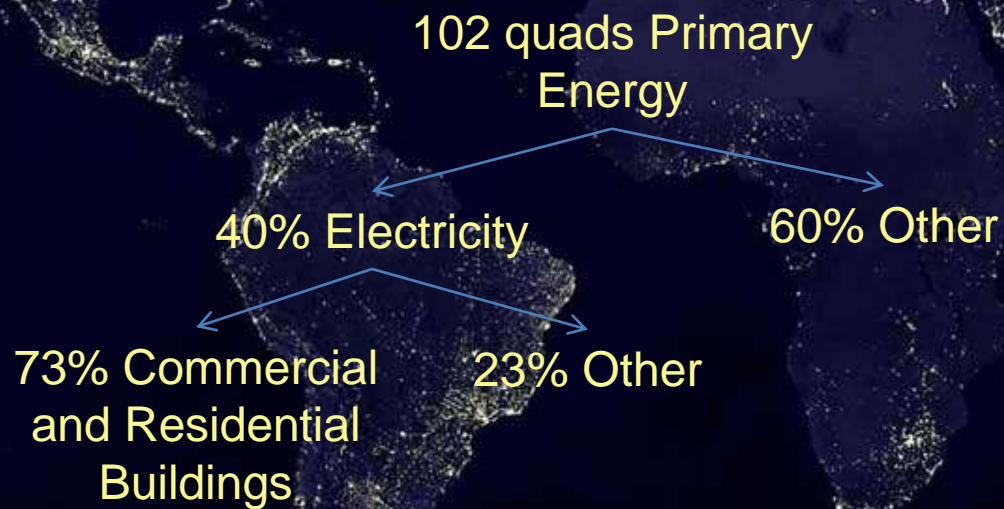
# Non-Intrusive Load Monitoring and other technology-enabled demand-side management strategies

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03/10/2010 – CMU Electricity Industry Conference




Earth at Night

More information available at:

<http://antwrp.gsfc.nasa.gov/apod/ap020810.html>

# {Introduction}





**B** Account Number: 0000-000-000-000  
 Rate: 00-Residential Service  
 Date Prepared: 03/21/08

**Information:**  
 Jan Bill: \$51.10  
 amount as of 01/07/08  
 Dec Bill: \$4.15  
 amount as of 12/07/07  
 1 Debt From Your Last Bill: \$0.00

**Electric Usage:**  
 Difference: 07  
 Your Meter Multiplier: 1  
 Total kWh Used: 894

**Comparing Your Usage:**

	Jan 07	Jan 08
Avg. kWh Per Day	21	22
Avg. Temperature (F)	37	40
YTD Usage (kWh)	720	894

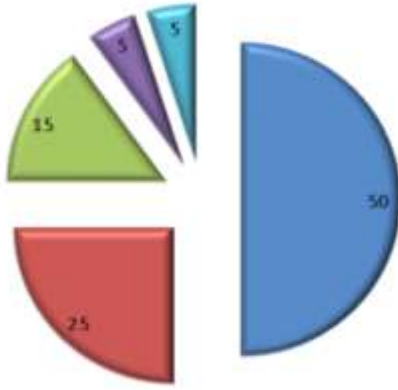
**Electric Usage:**  
 kWh: 894  
 1,000

**DLG Basic Service Charges:** \$0.00

**TOTAL ACCOUNT BALANCE PAYABLE TO DLG:** \$94.96  
**TOTAL BUDGET PAYMENT PLAN AMOUNT:** \$94.96

**F ACTUAL METER READING BILL**  
 See following pages for more detailed information.  
 Please contact us at 1-888-713-7100 with any billing questions before the due date on your bill.

**E**



- HVAC
- Refrigerator
- Lights
- Microwave
- Other

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# {Motivation}



N/A



\$20k -  
\$60k



\$2k -  
\$10k



Monthly: Free

Daily: Free\*

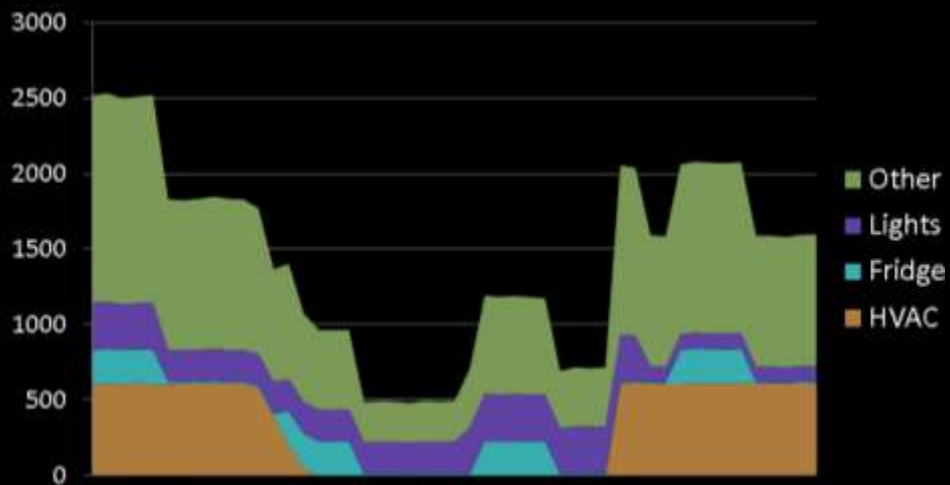
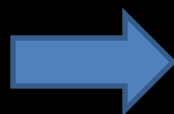
Real-Time:  
\$200 - \$3k

Moore's law doesn't apply to labor!

# {Vision}

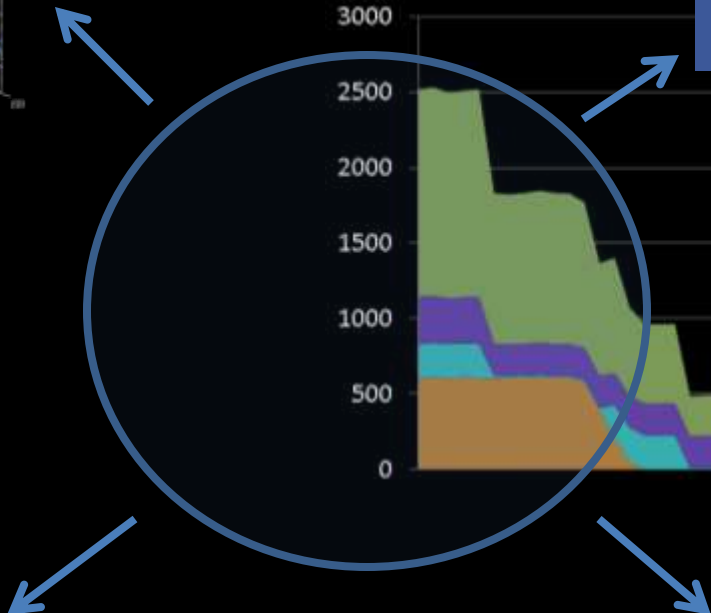
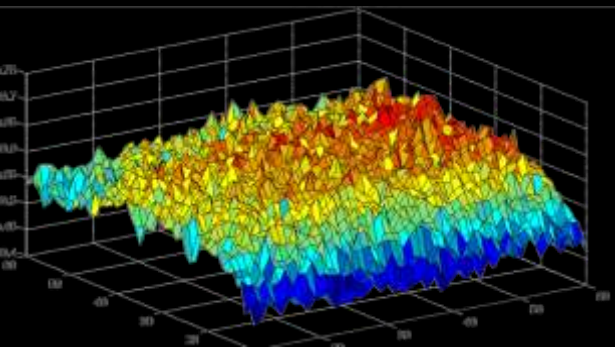


Low-Cost



High-Value

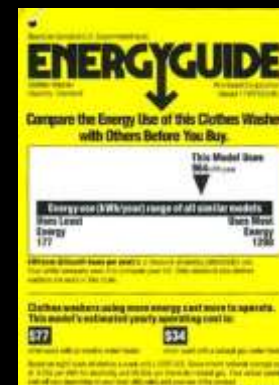
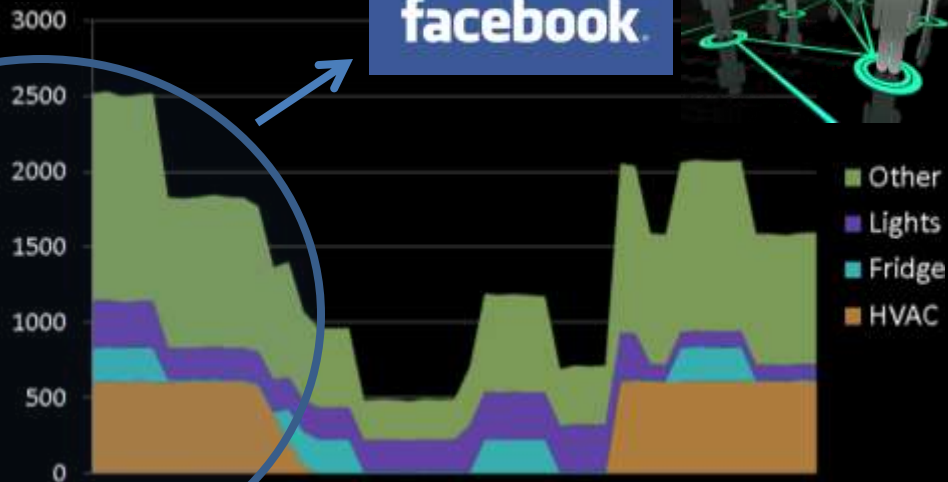
# {Vision}

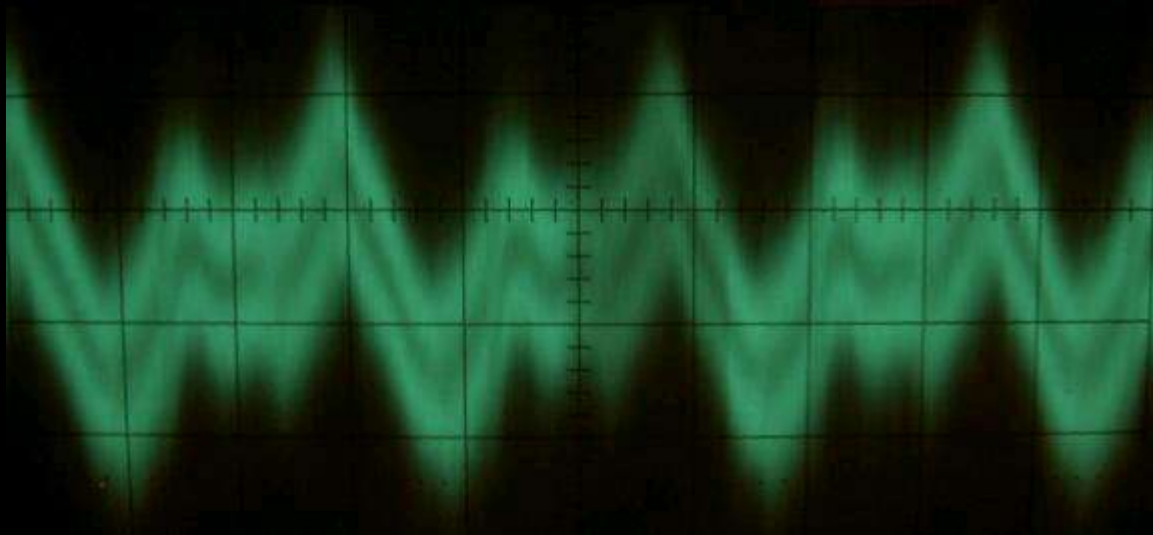


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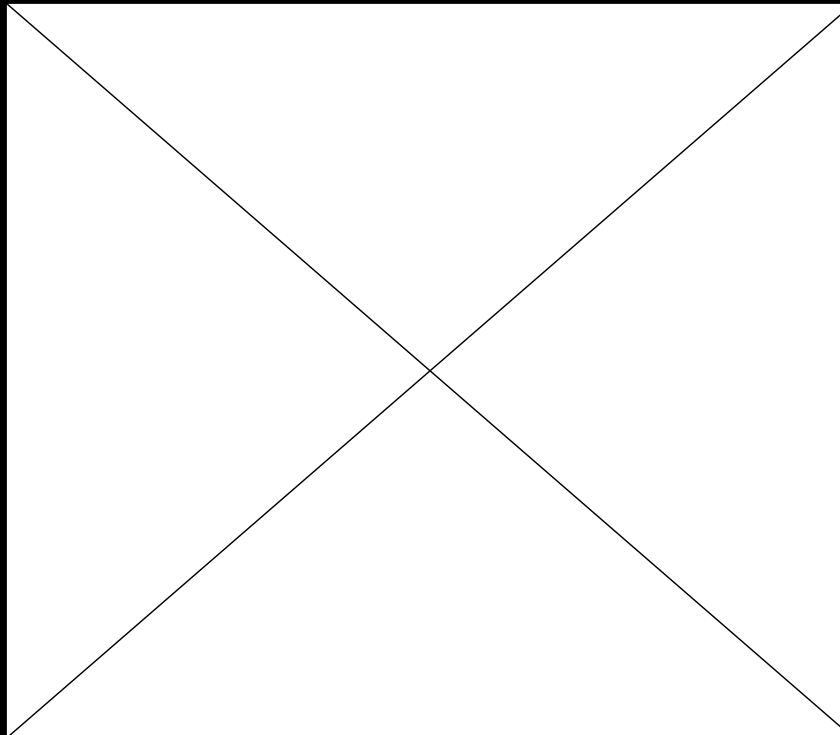


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# {Non-Intrusive Load Monitoring}

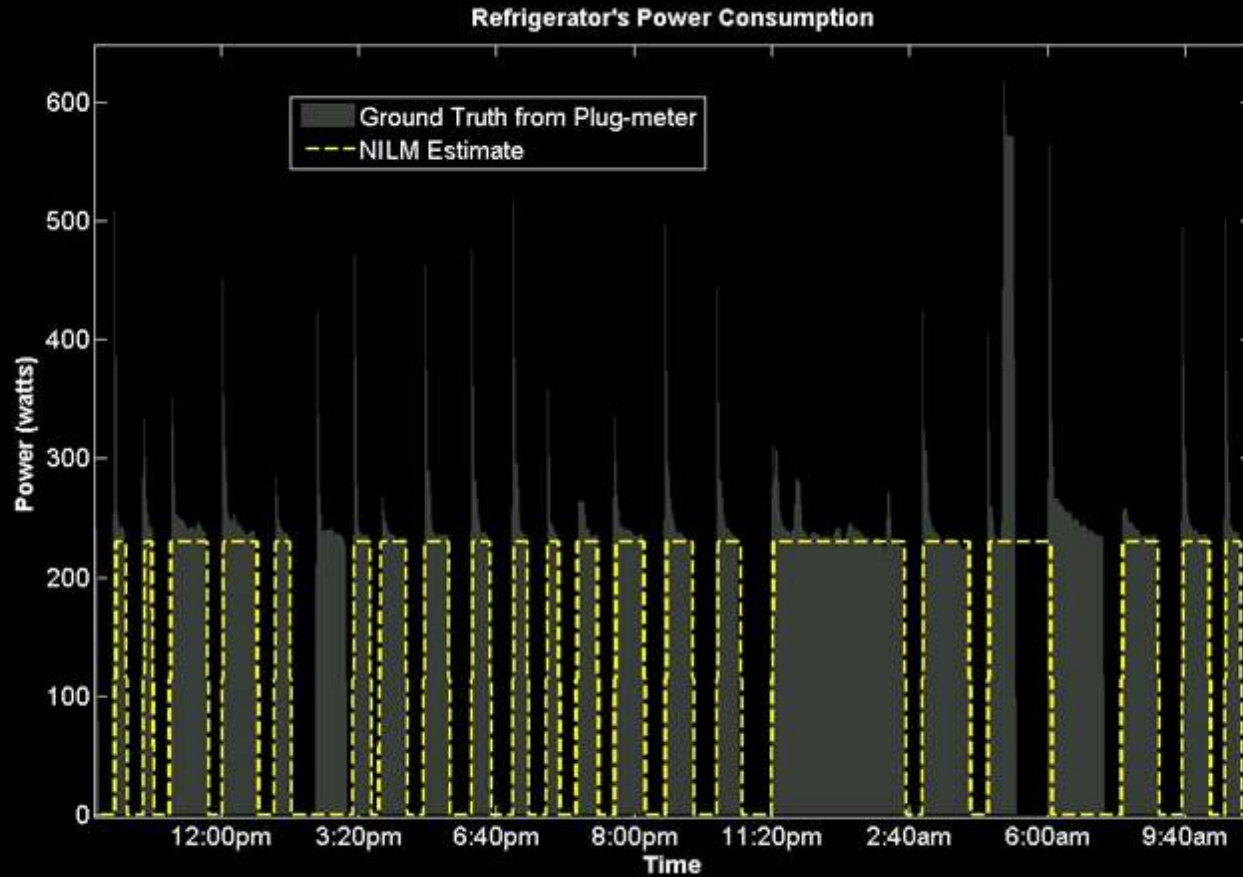




# {Preliminary Results}

Appliance	State Transition	Approx Power (Watts)	Training F-1	Validation F-1
Fan	Medium — high	3	100%	100%
Fan	High — medium	-3	100%	100%
Fan	Low — medium	5	100%	100%
Fan	Medium — low	-5	100%	100%
Overhead Light A	On — off	10	67%	100%
Overhead Light A	Off — on	10	100%	67%
Desk Light	Off — on	15	50%	67%
Desk Light	On — off	15	0%	0%
Air Purifier	Medium — low	-25	100%	100%
Air Purifier	Low — medium	25	100%	100%
Overhead Light D	Off — on	30	100%	100%
Overhead Light D	On — off	-30	0%	0%
Fan	Off — high	40	100%	100%
Fan	High — off	-40	0%	0%
Electric Kettle	Off — on	500	0%	0%
Electric Kettle	On — off	-500	100%	100%
Stove (Small Burner)	Off — Medium	570	100%	100%
Stove (Small Burner)	Medium — Off	-570	100%	100%
Stove (Large Burner)	Medium — Off	-870	67%	67%
Stove (Large Burner)	Off — Medium	870	0%	0%
Toaster	Off — on	1500	100%	67%
Toaster	On — off	-1500	100%	100%
Heating System	Fan — off	-2000	100%	100%
Heating System	Off — Fan	2000	100%	100%
Heating System	Heating — off	-14000	100%	100%
Heating System	Off — Heating	14000	100%	100%

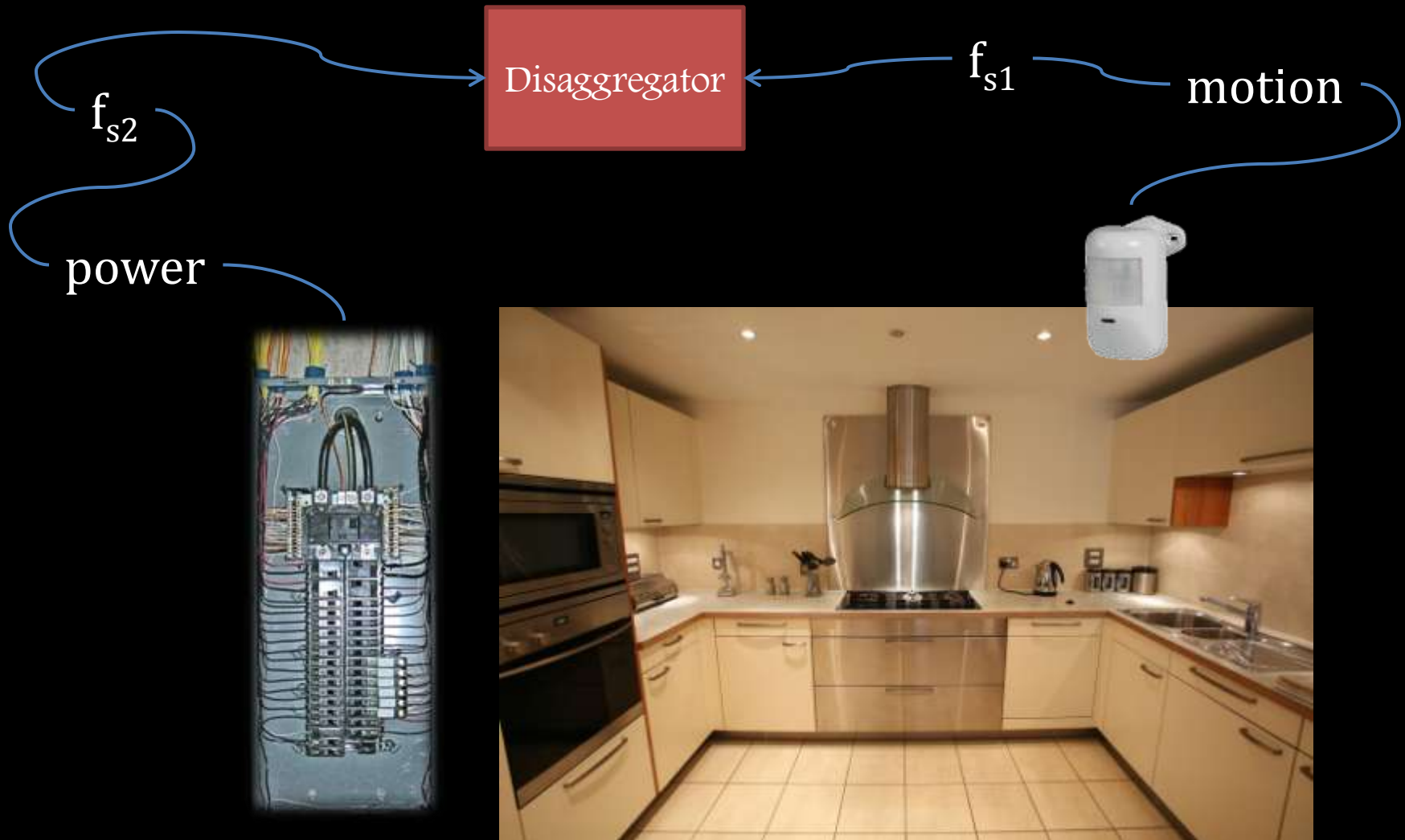
# {Preliminary Results}



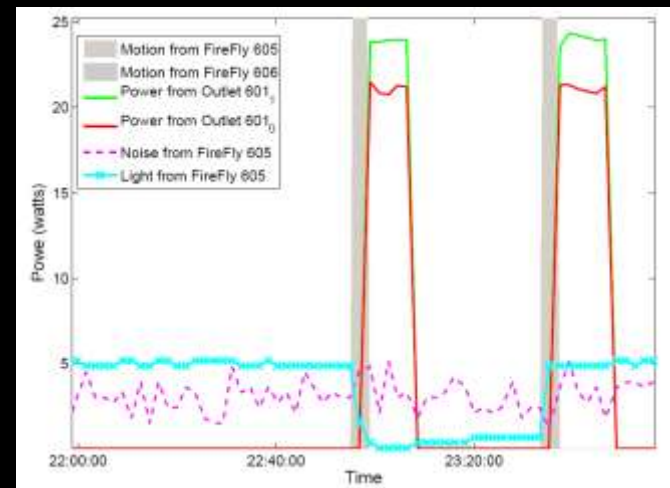
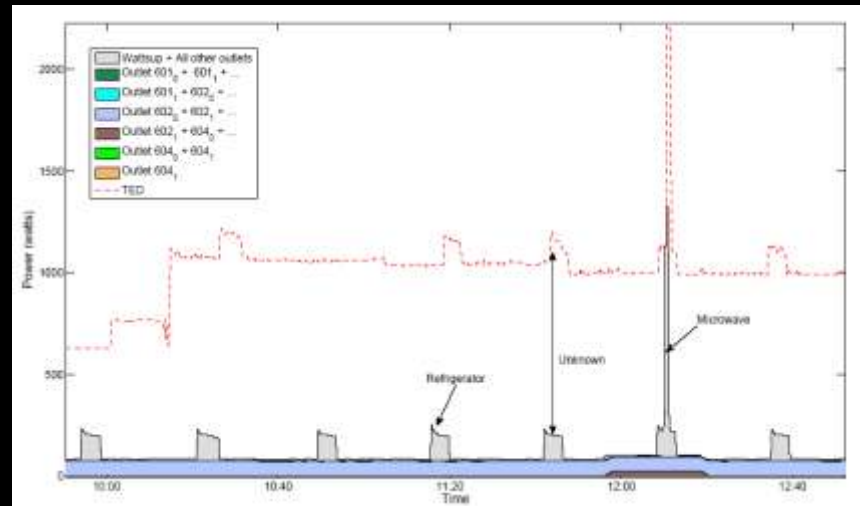
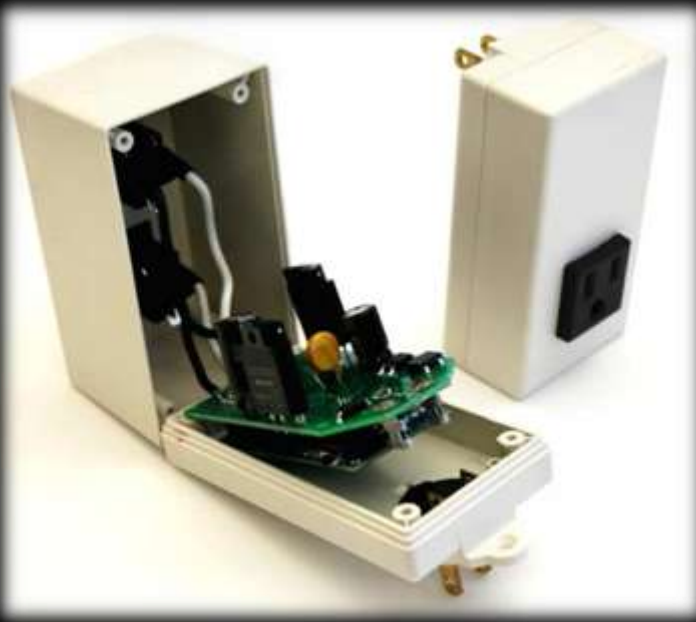
# {Challenges}

- Training
- Multi-state appliances
- Obtaining ground truth
- Dynamic environment
- Accumulating errors
- Installation

# {Other data-sources}

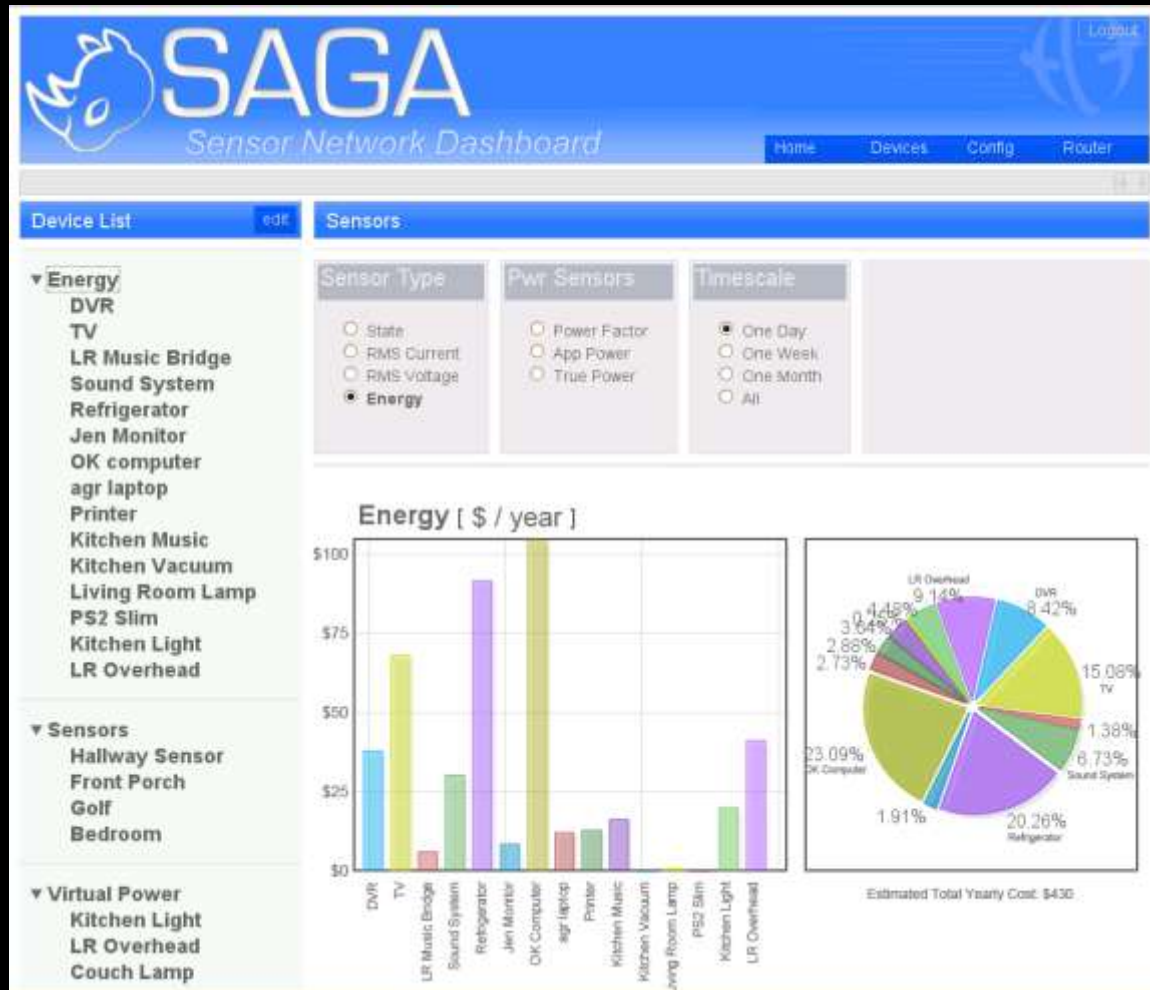


# Energy Monitoring



# {Preliminary Results}

Correlations	Best correlated with	Correlation Coefficient	P-value
bathroom light	bathroom motion	0.59	0
bathroom motion	bathroom light	0.59	0
bed lamp 1	bedroom motion	0.09	7.33E-19
bed lamp 2	bedroom motion	0.09	3.97E-17
bedroom light	media laptop	0.28	2.21E-176
bedroom motion	bathroom motion	0.24	5.29E-132
refrigerator	kitchen motion	0.09	2.64E-19
kitchen motion	living room motion	0.34	2.69E-269
laptop	lcd monitor	0.77	0
lcd monitor	laptop 1	0.77	0
living room audio	tv	0.36	4.51E-300
living room motion	kitchen motion	0.34	2.69E-269
media laptop	bedroom light	0.28	2.21E-176
tall lamp	laptop 1	0.15	3.06E-50
toaster	kitchen motion	0.13	2.48E-35
tv	living room audio	0.36	4.51E-300



## Testbed demonstration

<http://undisclosed.location.com>

Questions?

**THE END**