The Power of Energy Management

The Potential of Information Technology to
Monitor and Manage Small Energy Systems

Defining the Problem

Introduction:

- Architect with a minor study in building sciences
- Not a electrical engineer
- Began career as Residential Energy Consultant
- Segued to traditional architectural practice
- Clients expressed interest in PV solar
- PV solar costs about $50/watt average use
- First client average usage 3,000 kWhrs/month
- 4,100 watts X $50 = $200,000
- Pushed conservation, but unable to quantify
- How are we using our energy?

Defining the Problem

Accounting for usage:

Lights	420 watts
Television and cable box	250 watts
Laptop	30 watts
Desktop	100 watts
Refrigerator	60 watts
Total	860 watts

Typical weekday: 6 hours x 800 watts + 24 hours x 60 watts x 22 days/mo.
Typical weekend day: 12 hours x 800 watts + 24 hours x 60 watts x 9 days/mo.

236.6 kWhrs

Our usage averaged 660 kWhrs per month
The average U.S. household consumes 936 kWhrs per month

Defining the Problem

Accounting for usage:
The average U.S. household consumes 936 kWhrs per month

1 load of laundry every day adds	7.9 kWhrs
1 load of dishes every day adds	9.3 kWhrs
New Total	253.9 kWhrs

1 load of laundry every occupied hour	61.5 kWhrs
1 load of dishes every occupied hour	72.0 kWhrs
New Total	370.1 kWhrs

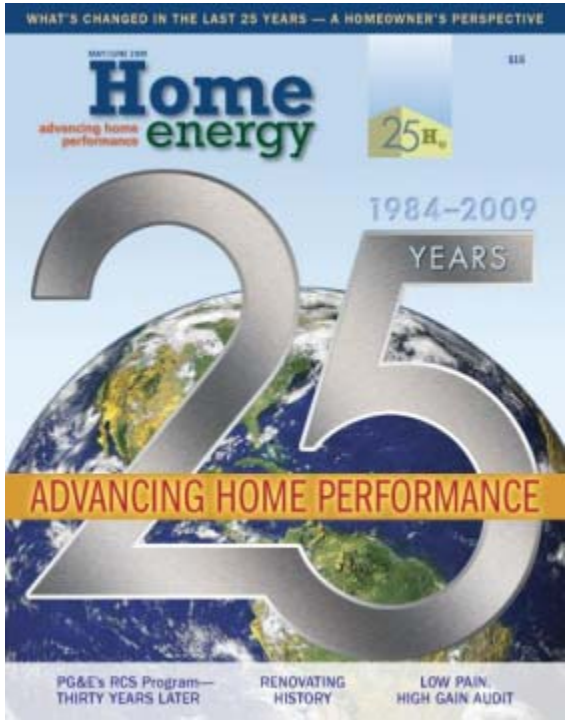
1 load of laundry every hour 24/7	190.5 kWhrs
1 load of dishes every hour 24/7	223.2 kWhrs
New Total	650.3 kWhrs

Where is all this electricity going?
Develop Audit & Analysis Methodology

Defining the Problem

Part I: Define electricity flows:

1. Examine historical utility records
2. Map Electrical system by circuit
3. Put home in “sleep state”
4. Measure “snapshot” current flows by circuit
5. Allocate usage beyond “sleep state” by estimation



Defining the Problem

Part I: Define electricity flows:

1. Examine historical utility records ⟵ Take what we know
2. Map Electrical system by circuit ⟵
3. Put home in “sleep state”
4. Measure “snapshot” current flows by circuit
5. Allocate usage beyond “sleep state” by estimation

Defining the Problem

Part I: Define electricity flows:

1. Examine historical utility records
2. Map Electrical system by circuit
3. Put home in “sleep state”
4. Measure “snapshot” current flows by circuit ← Do some simple measuring
5. Allocate usage beyond “sleep state” by estimation

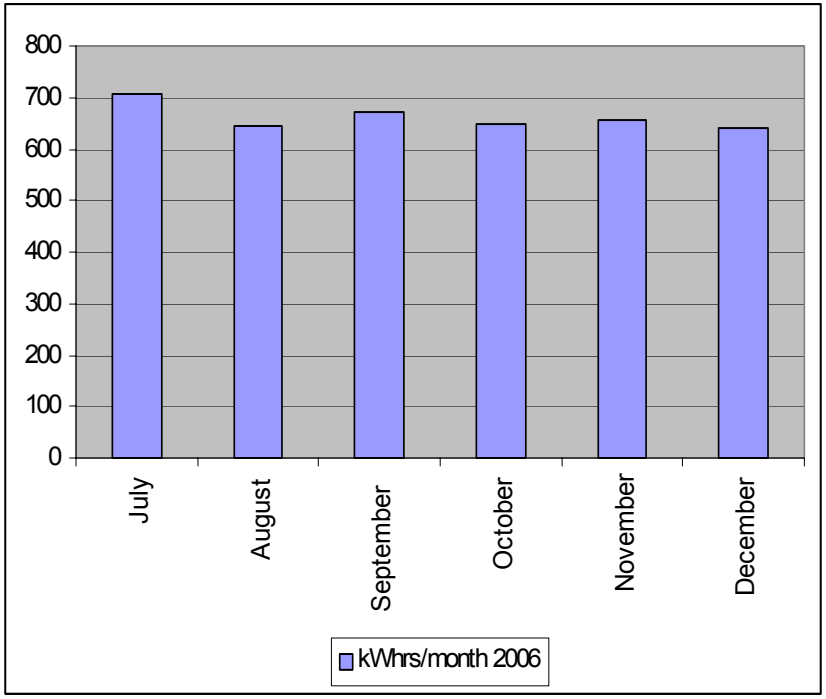
Defining the Problem

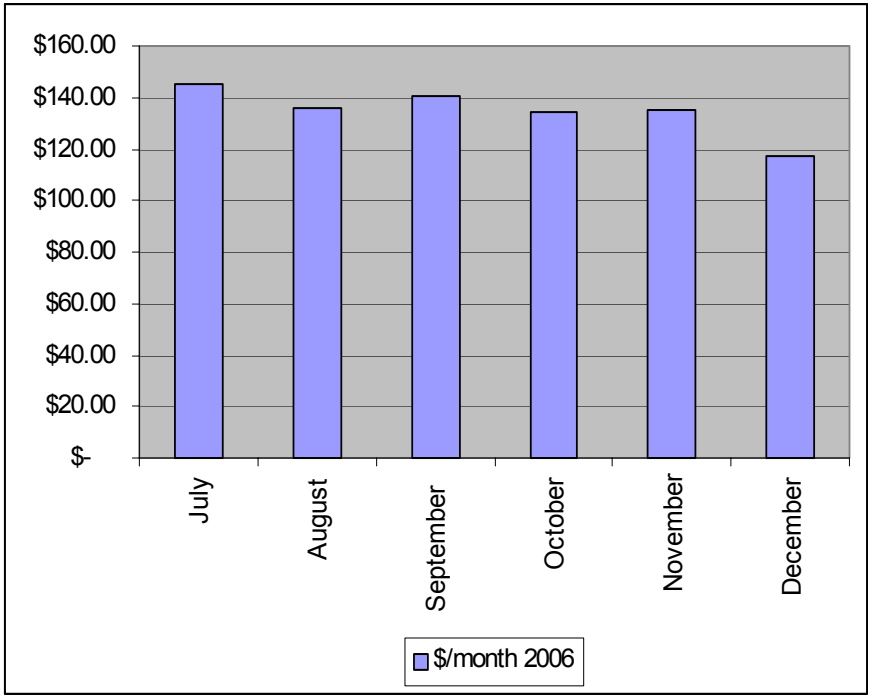
Part I: Define electricity flows:

1. Examine historical utility records
2. Map Electrical system by circuit
3. Put home in “sleep state”
4. Measure “snapshot” current flows by circuit
5. Allocate usage beyond “sleep state” by estimation

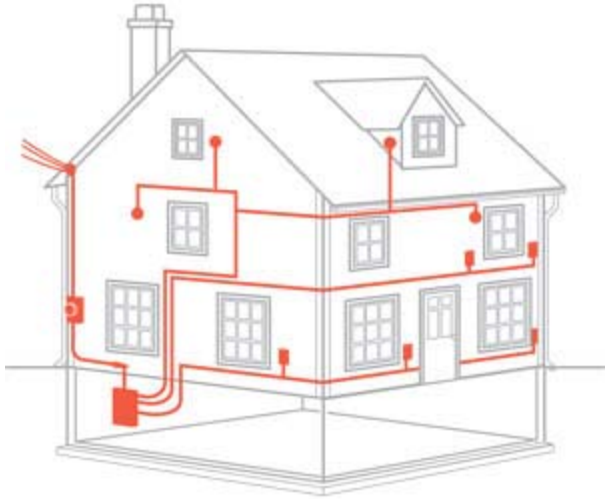
Guess at the rest

Analyzing the Problem





Analyzing the Problem



Map Electrical system by circuit
Put home in “sleep state”

Measure “snapshot” current flows by circuit

Analyzing the Problem

Spreadsheet A	Circuit #	Lighting	Entertain.	Outlets	Building Svc	Appliances	Misc	Circuit Designation	Contributing Devices
Panel A	1							Spare	
Unadjusted	3							Spare	
Amperes	5		0.29					Dedicated Family Room #1	Electronics stack (Family Room, music accessories)
	7a		0.51					Dedicated Family Room #2	Electronics stack (Family Room TV stack)
	7b				0.09			Basement Furnace	
	9a				0.04			Basement Lights	Includes tankless water heater
	9b				0.26			Dedicated Hall Closet	Telephone panel, wireless router etc.
	11					0.05		Microwave	
	13a				0.02			Vaccum system	
	13b	0.06						Entry lights	
	15a		0.31					Dedicated Family Room #3	Electronics stack (Family room computer, phone)
	15b							Garage lights	
	17							Powder room	
	19			0.17				Garage receptacles	Includes garage door operators
	2							Dishwasher/Disposer	
	4							Spare	
	6	0.06						Family Room Lights	
	8							Family Room receptacles	
	10					0.12		Small appliances	Countertop appliances/misc.
	12	0.07						Living Room lights	
	14					0.72		Refrigerator	
	16							Living Room receptacles	
	18			0.09				Dining Room receptacles	Includes hood and range
	20					0.39		Small appliances	Countertop appliances/chargers
Panel B	1a			0.01				Master bath receptacles	
Unadjusted	1b							Master bath lights & fans	
Amperes	3						0.01	Guest bath	Lights, fans and receptacles
	5						0.01	Common bath	Lights, fans and receptacles
	7a	0.07						E. bedrooms & closets lights	
	7b	0.03						W.bedrooms & closet lights	
	9a			0.08				Guest suite receptacles	Includes electronics stack, TV
	11			0.42				Study receptacles	
	13a			0.22				Master bedroom receptacles	Includes electronics stack, TV
	13b				0.14			Smoke detectors	
	15			0.01				Small bedroom receptacles	Includes air deionizer
	17							Washer	
	19a							Laundry receptacles	
	19b							Dryer	
	2							Air conditioning	
	4							Air conditioning	
	6							Air conditioning	
	8							Air conditioning	
	10							Jaccuzzi	
	12							Spare	
	14							Spare	
	16							Spare	
	18				0.05			Attic furnace	
	20							Attic lights	

	Lighting	Entertain.	Outlets	Building Svc	Appliances	Misc
Passive Amps	0.28	1.11	1.00	0.59	1.28	0.01
Passive Watts	33.96	132.84	119.40	71.04	154.08	1.44
Active Adjustment	NA	1.50	1.50	1.50	1.50	1.50
Active Watts	145.42	66.42	59.70	35.52	77.04	0.72
Proj. Monthly kW hours	130.94	145.46	130.74	77.79	168.72	1.58
Total projected KWhrs/month						655.23

Analyzing the Problem

Spreadsheet A	Circuit #	Lighting	Entertain.	Outlets	Building Svc	Appliances	Misc	Circuit Designation	Contributing Devices
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Unadjusted	3							Spare	
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	7b				0.09			Basement Furnace	
	9a				0.04			Basement Lights	Includes tankless water heater
	9b				0.26			Dedicated Hall Closet	Telephone panel, wireless router etc.
	11					0.05		Microwave	
	13a				0.02			Vaccum system	
	13b	0.06						Entry lights	
	15a		0.31					Dedicated Family Room #3	Electronics stack (Family room computer, phone)
	15b							Garage lights	
	17							Powder room	
	19			0.17				Garage receptacles	Includes garage door operators
	2							Dishwasher/Disposer	
	4							Spare	
	6	0.06						Family Room Lights	
	8							Family Room receptacles	
	10					0.12		Small appliances	Countertop appliances/misc.
	12	0.07						Living Room lights	
	14					0.72		Refrigerator	
	16							Living Room receptacles	
	18			0.09				Dining Room receptacles	Includes hood and range
	20					0.39		Small appliances	Countertop appliances/chargers
Panel B	1a			0.01				Master bath receptacles	
Unadjusted	1b							Master bath lights & fans	
Ampheres	3						0.01	Guest bath	Lights, fans and receptacles
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	7a	0.07						E. bedrooms & closets lights	
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	19a							Laundry receptacles	
	19b							Dryer	
	2							Air conditioning	
	4							Air conditioning	
	6							Air conditioning	
	8							Air conditioning	
	10							Jaccuzzi	
	12							Spare	
	14							Spare	
	16							Spare	
	18				0.05			Attic furnace	
	20							Attic lights	
		Lighting	Entertain.	Outlets	Building Svc	Appliances	Misc		
Passive Amps		0.28	1.11	1.00	0.59	1.28	0.01		
Passive Watts		33.96	132.84	119.40	71.04	154.08	1.44	512.76	Passive average watts
Active Adjustment		NA	0.50	0.50	0.50	0.50	0.50		
Active Watts		145.42	66.42	59.70	35.52	77.04	0.72	384.82	Active average watts
Proj. Monthly kW hours		130.94	145.46	130.74	77.79	168.72	1.58		
Total projected KWhrs/month							655.23		

Analyzing the Problem

Spreadsheet A
Panel A
Unadjusted
Ampheres

Circuit #	Lighting	Entertain.	Outlets	Building Svc	Appliances	Misc	Circuit Designation	Contributing Devices
1							Spare	
3							Spare	
5		0.29					Dedicated Family Room #1	Electronics stack (Family Room, music accessories)
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17							Powder room	
19			0.17				Garage receptacles	Includes garage door operators
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Analyzing the Problem

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Passive Watts	33.96	132.84	119.40	71.04	154.08	1.44
Active Adjustment	NA	0.50	0.50	0.50	0.50	0.50
Active Watts	145.42	66.42	59.70	35.52	77.04	0.72
Proj. Monthly kW hours	130.94	145.46	130.74	77.79	168.72	1.58
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Addressing the Problem

PART II: Analysis

1. Evaluate usage for conservation potential
2. Implement conservation strategies
3. Verify with new utility records

Spreadsheet B

Action	Wattage savings per unit	Total units	Daily Hours of Operation	KWHrs Monthly Potential savings	Cost per unit*	Total cost	Monthly Utility Savings	ROI
Switch Electronics stack (Family Room TV stack)	61.1	1	22	40.9	$ 10.00	$ 10.00	$ 9.28	1113.2%
Switch furnace #1	10.3	1	12	3.8	$ 1.00	$ 1.00	$ 0.85	1025.9%
Switch Electronics stack (Study computer stack)	50.6	1	24	36.9	$ 10.00	$ 10.00	$ 8.39	1006.8%
Switch Electronics stack (Family Room, music accessories)	34.9	1	24	25.5	$ 10.00	$ 10.00	$ 5.79	694.3%
Switch furnace #2	5.9	1	12	2.1	$ 1.00	$ 1.00	$ 0.49	584.5%
Switch Electronics stack (Family room computer)	30.8	1	22	20.6	$ 10.00	$ 10.00	$ 4.68	562.0%
Switch Electronics stack 4 (master bedroom TV stack)	26.0	1	24	19.0	$ 10.00	$ 10.00	$ 4.31	517.7%
Replace 60W incandescent with 10W CFL (Primary lighting fixtures)	50.0	9	6	82.1	$ 5.00	$ 45.00	$ 18.64	497.0%
Switch Electronics stack 5 (Guest bedroom TV stack)	17.9	1	24	13.0	$ 10.00	$ 10.00	$ 2.96	355.5%
Switch microwave	6.4	1	24	4.6	$ 10.00	$ 10.00	$ 1.05	126.4%
Replace 100W incandescent with 18W CFL (occasionally used fixtures)	82.0	10	0.25	6.2	$ 5.00	$ 50.00	$ 1.42	34.0%
Remove X10 Switch	3.0	12	24	26.3	$ 25.00	$ 300.00	$ 5.96	23.9%
Remove X10 Receptacle	2.2	7	24	11.0	$ 25.00	$ 175.00	$ 2.51	17.2%
Switch Garage door openers	6.5	2	12	4.7	$ 50.00	$ 100.00	$ 1.08	12.9%
Install 3.3 KW solar PV system (with rebate and tax credit)		1		400.0	$ 16,200.00	$ 16,200.00	$ 90.83	6.7%
Install 3.3 KW solar PV system (without rebate)		1		400.0	$ 26,000.00	$ 26,000.00	$ 90.83	4.2%

*CFL conversion costs do not include replacement of some halogen fixtures to receive CFLs

*Solar system cost estimated

Addressing the Problem

PART II: Using What we now know

1. Evaluate usage for conservation potential
2. Implement conservation strategies
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Addressing the Problem

PART II: Using What we now know

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Switch Electronics stack 4 (master bedroom TV stack)	26.0	1	24	19.0	$ 10.00	$ 10.00	$ 4.31	517.7%
Replace 60W incandescent with 10W CFL (Primary lighting fixtures)	50.0	9	6	82.1	$ 5.00	$ 45.00	$ 18.64	497.0%
Switch Electronics stack 5 (Guest bedroom TV stack)	17.9	1	24	13.0	$ 10.00	$ 10.00	$ 2.96	355.5%
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Replace 100W incandescent with 18W CFL (occasionally used fixtures)	82.0	10	0.25	6.2	$ 5.00	$ 50.00	$ 1.42	34.0%
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Addressing the Problem

PART II: Using What we now know

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Switch Electronics stack (Family room computer)	30.8	1	22	20.6	$ 10.00	$ 10.00	$ 4.68	562.0%
Switch Electronics stack 4 (master bedroom TV stack)	26.0	1	24	19.0	$ 10.00	$ 10.00	$ 4.31	517.7%
Replace 60W incandescent with 10W CFL (Primary lighting fixtures)	50.0	9	6	82.1	$ 5.00	$ 45.00	$ 18.64	497.0%
Switch Electronics stack 5 (Guest bedroom TV stack)	17.9	1	24	13.0	$ 10.00	$ 10.00	$ 2.96	355.5%
Switch microwave	6.4	1	24	4.6	$ 10.00	$ 10.00	$ 1.05	126.4%
Replace 100W incandescent with 18W CFL (occasionally used fixtures)	82.0	10	0.25	6.2	$ 5.00	$ 50.00	$ 1.42	34.0%
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Install 3.3 KW solar PV system (with rebate and tax credit)		1		400.0	$ 16,200.00	$ 16,200.00	$ 90.83	6.7%
Install 3.3 KW solar PV system (without rebate)		1		400.0	$ 26,000.00	$ 26,000.00	$ 90.83	4.2%

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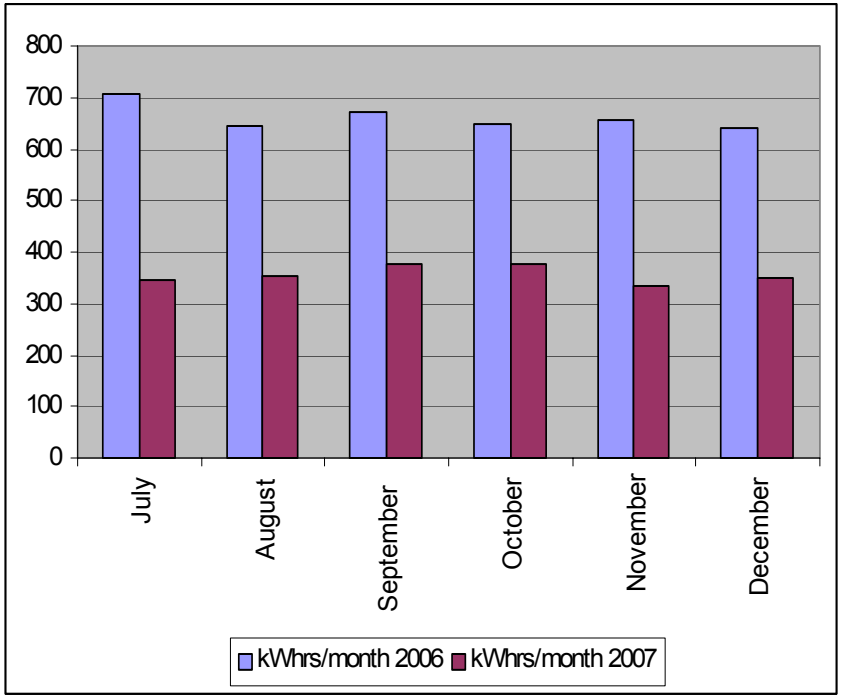
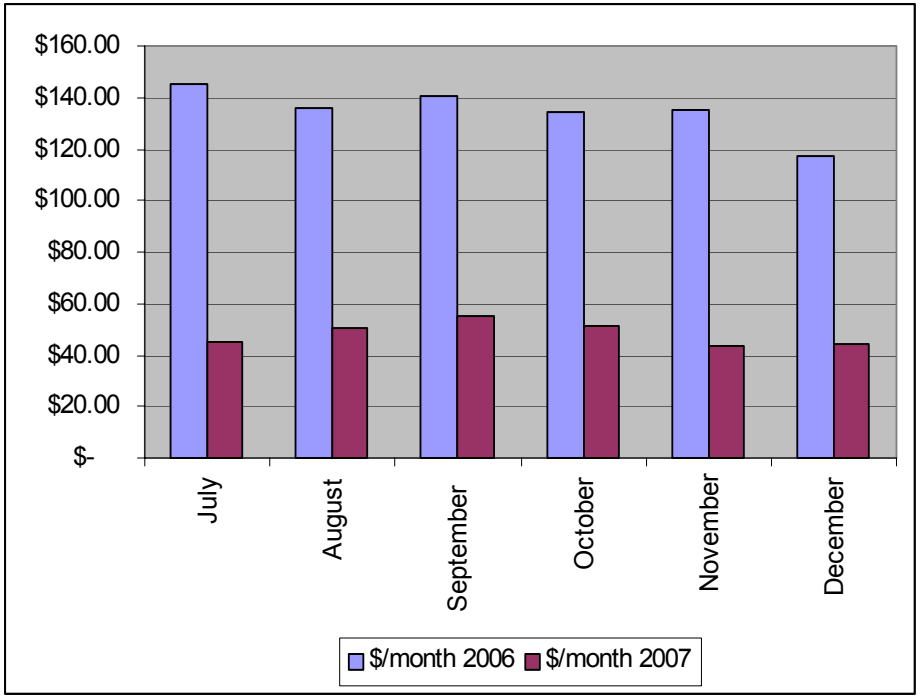
*Solar system cost estimated

Total 296.8

Addressing the Problem





Addressing the Problem

Spreadsheet C

	Kilowatt hours		Total Electricity Charges	
	2006	2007	2006	2007
July	705	347	$ 145.48	$ 44.76
August	644	354	$ 136.13	$ 50.22
September	673	378	$ 140.26	$ 54.83
October	648	375	$ 134.35	$ 51.59
November	657	333	$ 135.36	$ 43.61
December	639	351	$ 117.09	$ 44.33
Average	661	356	$ 134.78	$ 48.22
Savings		46.1%		64.2%

Depth of the Problem

Why is this so high?

	Lighting	Entertain.	Outlets	Building Svc	Appliances	Misc	
Passive Amps	0.28	1.11	1.00	0.59	1.28	0.01	
Passive Watts	33.96	132.84	119.40	71.04	154.08	1.44	512.76 Average Passive Watts
Active Adjustment	NA	0.50	0.50	0.50	0.50	0.50	
Active Watts	145.42	66.42	59.70	35.52	77.04	0.72	384.82 Average Active Watts
Proj. Monthly kW hours	130.94	145.46	130.74	77.79	168.72	1.58	
Total projected KWhrs/month						655.23	

Depth of the Problem

Embedded 24/7 leaks: The high cost of Convenience

- Furnaces
- Water heaters
- Phone systems
- Intercoms
- Sprinkler systems
- Lighting controls
- Gate operators
- Computers
- Printers
- Scanners
- Copiers
- Fax machines
- Televisions
- Appliances
- Garage door operators
- Air fresheners
- Vacuum systems
- Electric tooth brushes
- Coffee makers
- Automated receptacles
- Ground fault receptacles
- Smoke detectors
- Security systems
- Conveying systems
- Internet access
- Cable boxes
- Stereo systems
- Clock radios
- Ionizers
- Doorbells
- Battery chargers
- Timers
- Microwave ovens
- Toasters

Cycling Components

- Refrigerators
- Freezers
- Terrariums
- Aquariums
- Spas

Depth of the Problem

Alan Meier, Lawrence Berkeley National Labs

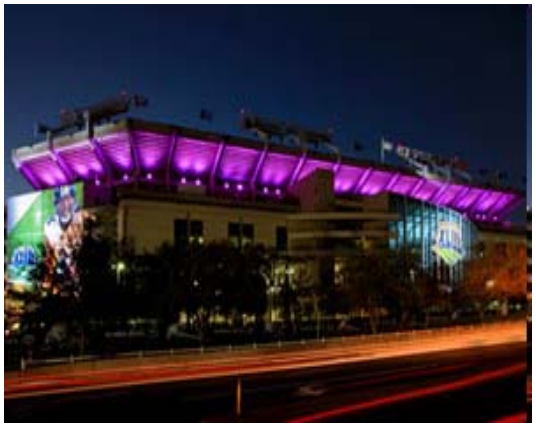
Item/Condition	Ave	Min	Max	Units
Heating, furnace central				
Off	4.21	0.00	9.80	16
Hub, USB				
Off	1.44	0.95	1.81	5
On	2.06	1.06	3.55	7
Modem, DSL				
Off	1.37	0.33	2.02	16
On	5.37	3.38	8.22	20
Modem, cable				
Off	3.84	1.57	6.62	8
On	6.25	3.64	8.62	16
Standby	3.85	3.59	4.11	2
Set-top Box, digital cable with DVR				
Not recording, TV off	44.63	44.38	44.87	2
Not recording, TV on	44.40	44.20	44.60	2
Off by remote	43.46	43.30	43.61	2
Set-top Box, digital cable				
On, TV off	24.65	14.20	74.74	18
On, TV on	29.64	14.10	102.23	18
Off by remote	17.83	13.24	30.60	14
Off by switch	17.50	13.70	26.30	16

Depth of the Problem

The 24/7 Effect

32 Bays x 580 watts/bay x 3 hours=

55,680 watt hours



Depth of the Problem

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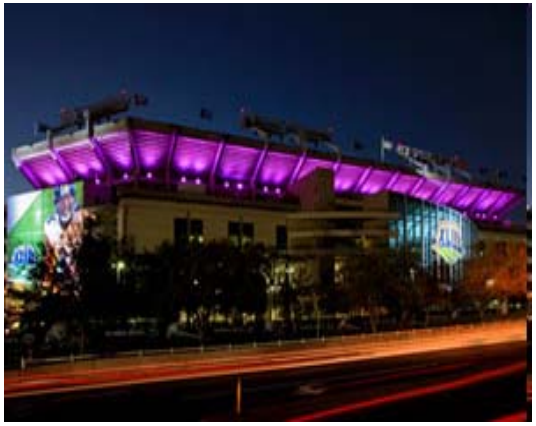

6 watts x 24 hours x 365 days=

52,560 watt hours

Depth of the Problem

24 hours x  =1 hour x

Depth of the Problem

24 hours x  288 watt unused stack=

Depth of the Problem

Plus this many

Depth of the Problem

Plus this many again

Depth of the Problem

Plus this many yet again

Depth of the Problem

Plus this many
For 1 hour

Addressing the Problem with Information Technology

Significant Savings through Monitoring and Managing an Energy System

Parts to the Problem

- Power sensing
- Data collection
- Data analysis
- System Control

Issues to Address

- Price sensitivity
- Energy cost
- Sensing technology
- Sensing resolution
- Sensing frequency
- User profiles
- Convenience

Addressing the Problem with Information Technology

Macro Scale IT Solution: Smart Electrical Grid

Allows Utilities to Better Manage Power Generation and Distribution

Smart Meter

Interior Display

Addressing the Problem with Information Technology

Smart Micro Scale Solutions:

- Greater awareness of consumption
- Ability to quantify results from specific actions
- Quantification of convenience costs
- IT driven matching of demand and consumption
- Ability to analyze tiered and time-of-use rate structures
- Increased demand for smarter/greener products
- Potential for 20-40% reduction in sector electricity usage
- Ability to monitor active loads

The Wider Context

A Very Small Step (unless cold fusion saves us):

- Large Range of Solutions Required
- National Security/Energy Independence
- Coherent National Energy Policy
- Population Issues
- Overall Energy and Social Sustainability
- Pay-as-you-go Solutions
- National Lifestyle Issues
- Developing World Lifestyle Issues
- Developing Priorities