# Communication Methods for Energy Management

- Communication Protocols

- Load Side Problem

  Problem Constraints that shaped it

  Clean Slate Smart Load

- Solution Concepts

  Architecture

  Components and Topology

  Communication Method

  Information Model

- What's Needed Next

# Energy Grid

**Generation / Transmission / Distribution**

SCADA Protocoal

DNP3

IEC 60870-5

IEEE 61850

GOOSE / GSSE

**Load (Residential, Commercial, Industrial)  - RS-485 / IP**

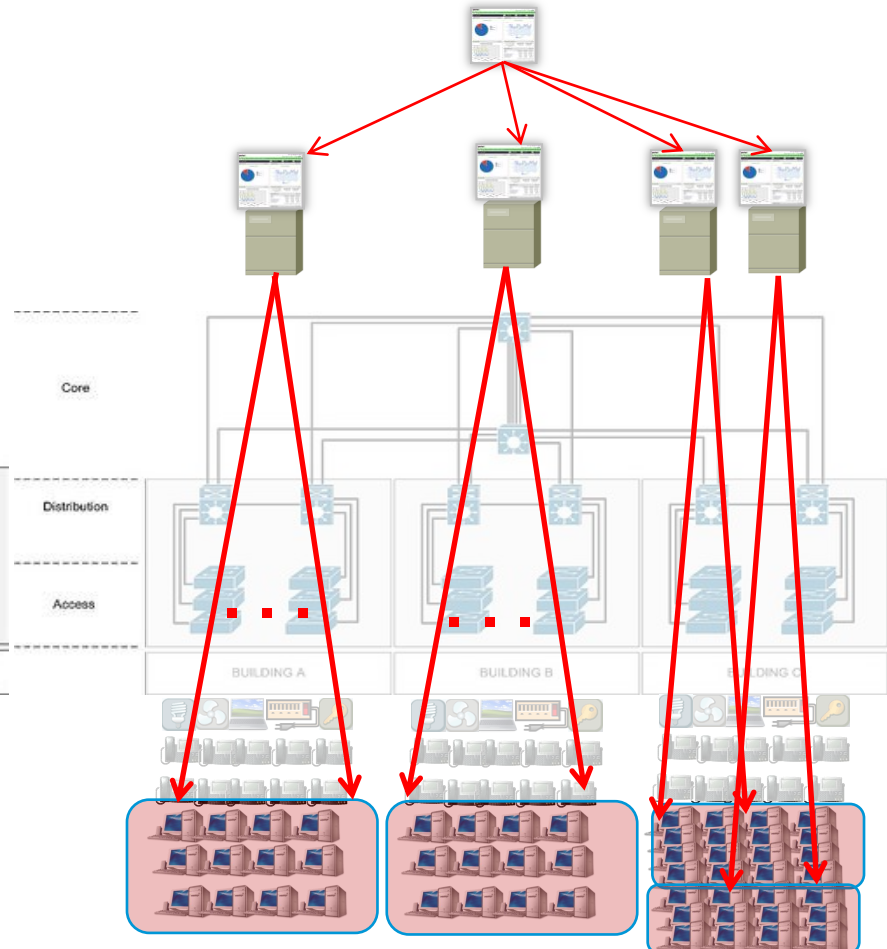| | |
|---|---|
| SNMP | Barber-Colman |
| Zigbee | ALC WebCTRL SOAP Interface |
| DeviceNet (CIP) | Lennox SysBus |
| BACnet | Trane Com3-4 |
| Dallas | TCS Basys |
| Modbus | SNRA |
| C-Bus | ETC-USAP |
| Johnson N2 | OmniMeter |
| ….and FAX!! | |

# Load Management Overlays
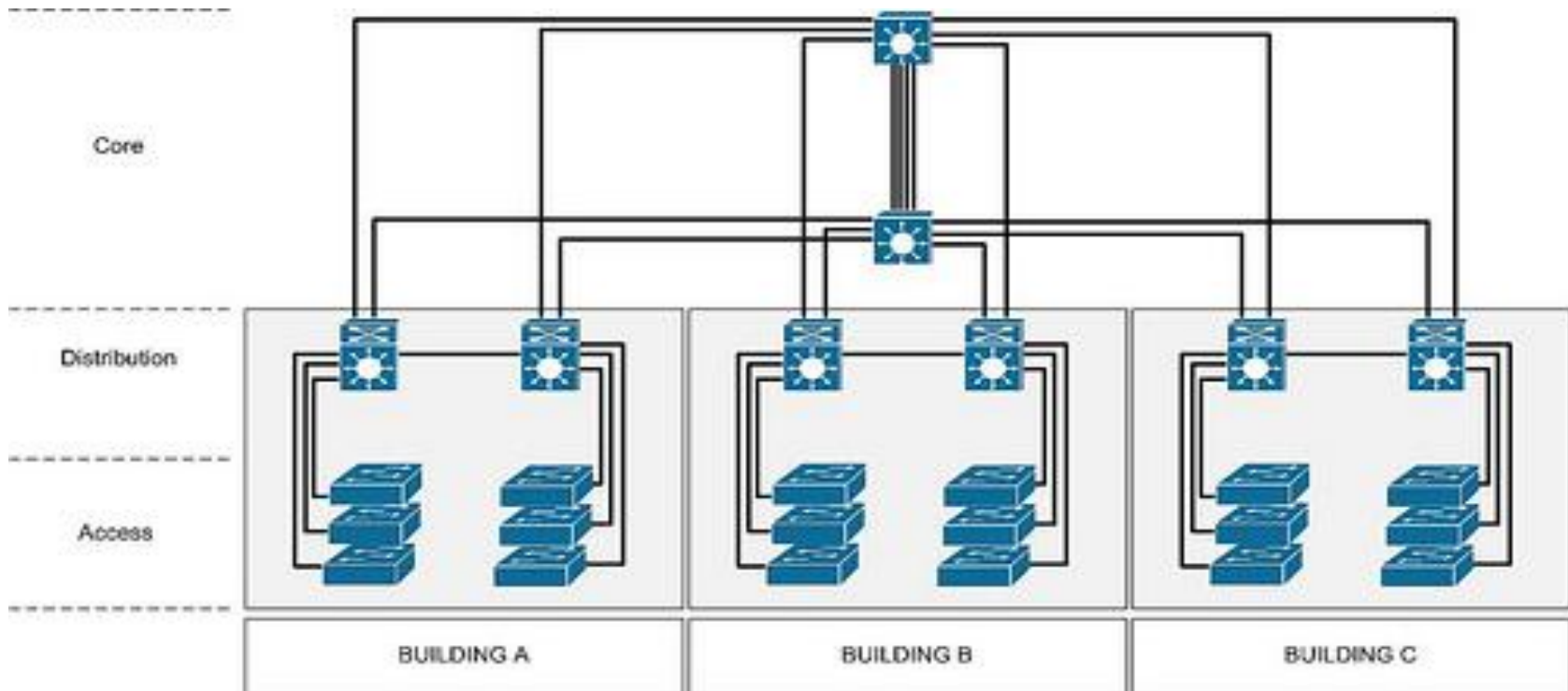
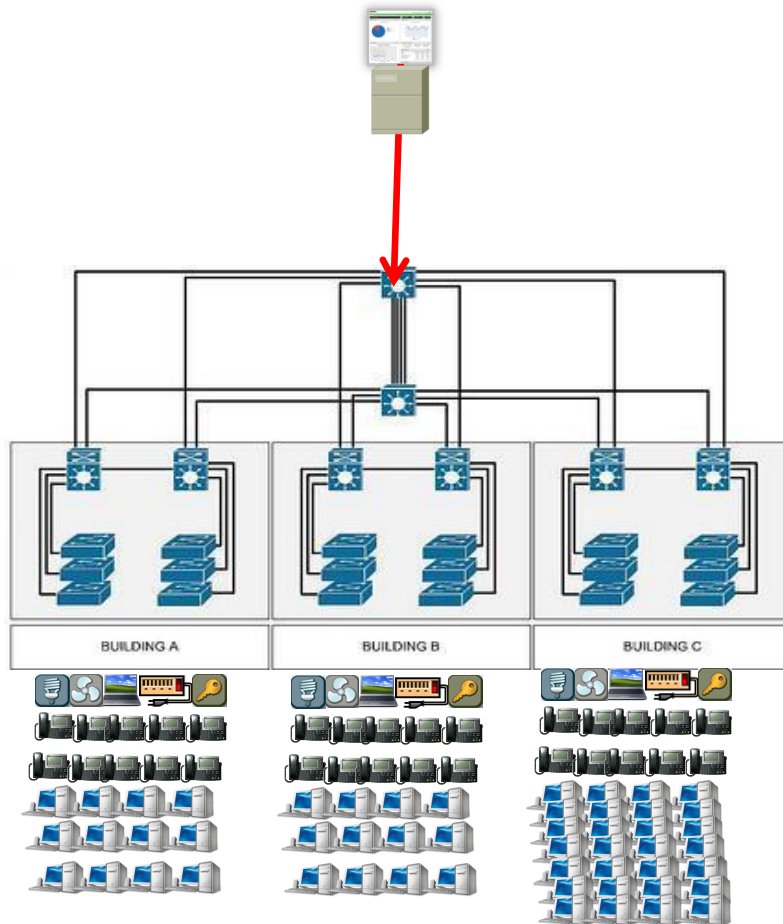## Single Overlay
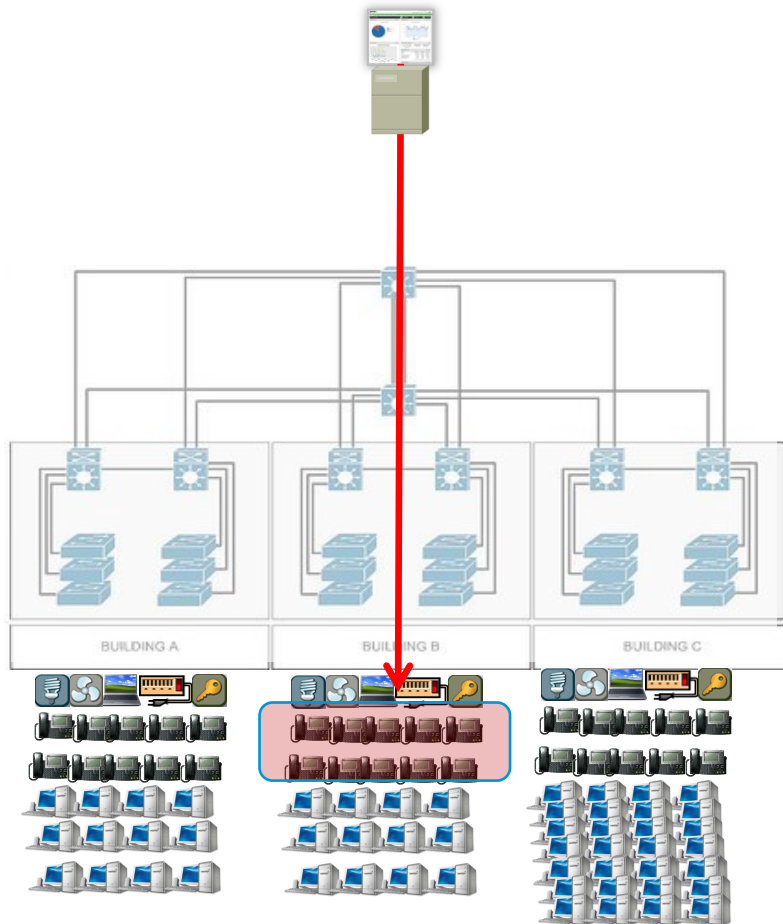
## MoM Overlay



**Note:** Overlay and multiple connections is repeated for each type and vendor of devices or management solution - shown is just for PC..
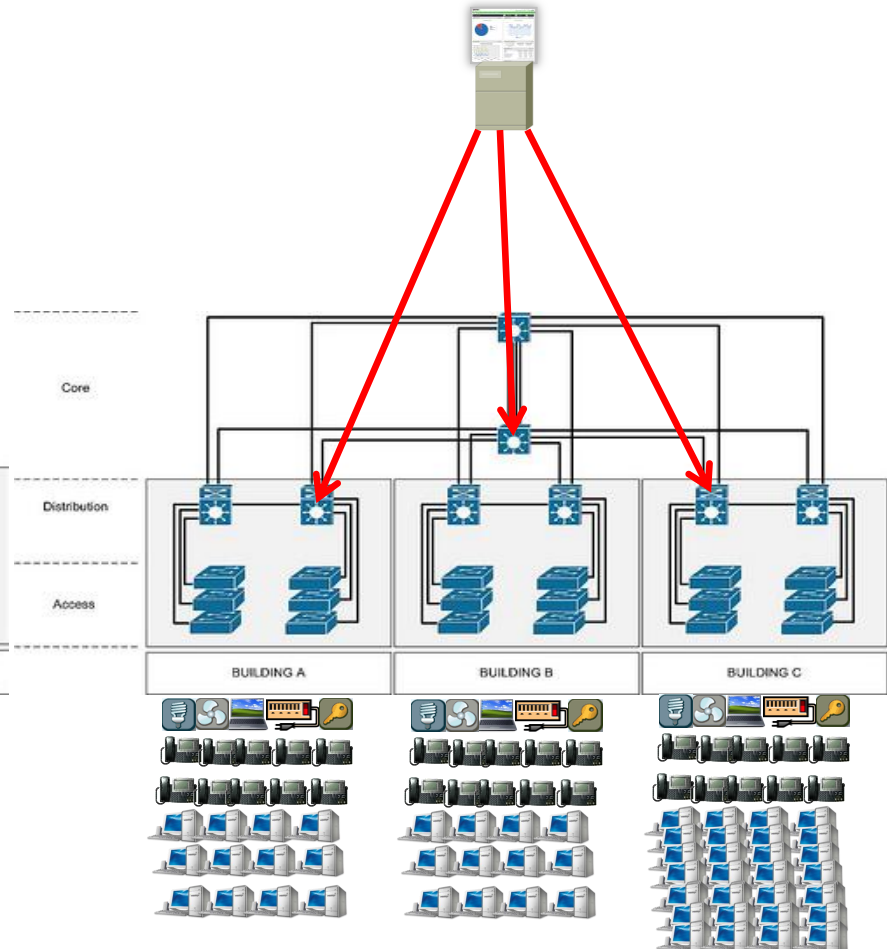
# Revealing a Network Topology

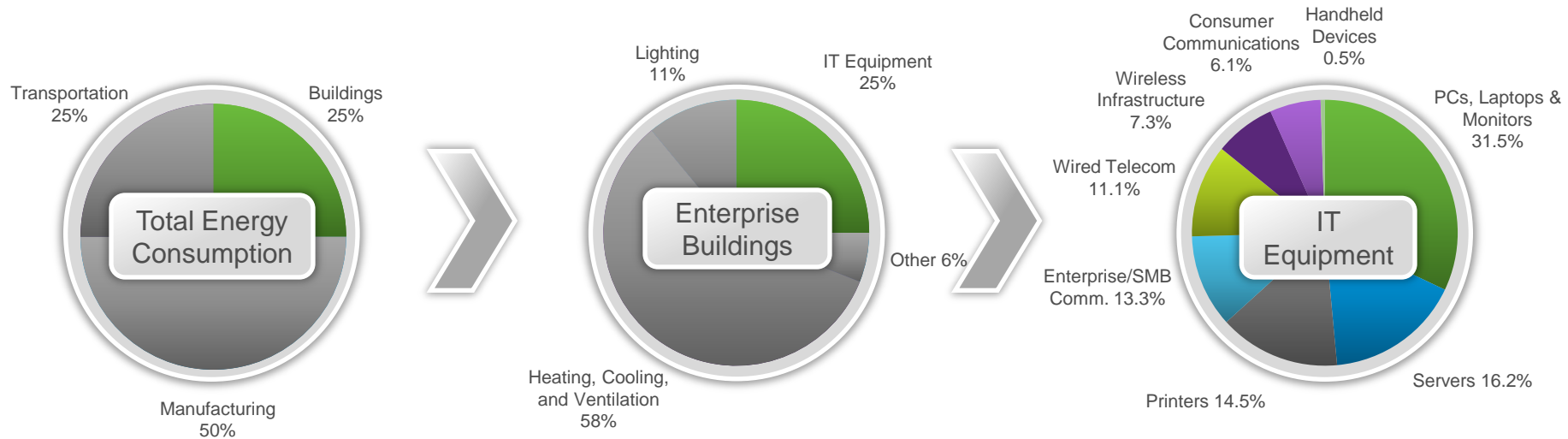# Network as the Overlay



Single Overlay

MoM Overlay

Core

Distribution

Access

BUILDING A     BUILDING B     BUILDING C

BUILDING A     BUILDING B     BUILDING C

# Load Side Problem

# Energy Consumtion

**Total Energy Consumption**

- Transportation 25%
- Buildings 25%
- Manufacturing 50%

**Enterprise Buildings**

- Lighting 11%
- IT Equipment 25%
- Other 6%
- Heating, Cooling, and Ventilation 58%

**IT Equipment**

- Consumer Communications 6.1%
- Handheld Devices 0.5%
- Wireless Infrastructure 7.3%
- PCs, Laptops & Monitors 31.5%
- Wired Telecom 11.1%
- Enterprise/SMB Comm. 13.3%
- Printers 14.5%
- Servers 16.2%

## Cost Savings

- Rising energy costs
- IT device proliferation
- Change Behavior

## Sustainability Mandates

- Regulatory compliance
- Government mandates
- Company requirements

Source: BOMA 2006, EIA 2006, AIA 2006
Source: UK Energy Efficiency Best Practice Program; Energy Consumption Guide 19: Energy Use in Offices
*Source: Gartner Dataquest, Forecast of IT Hardware Energy Consumption, Worldwide, 2005-2012.

# Problem: The Electric Load Curve and Peak Billing
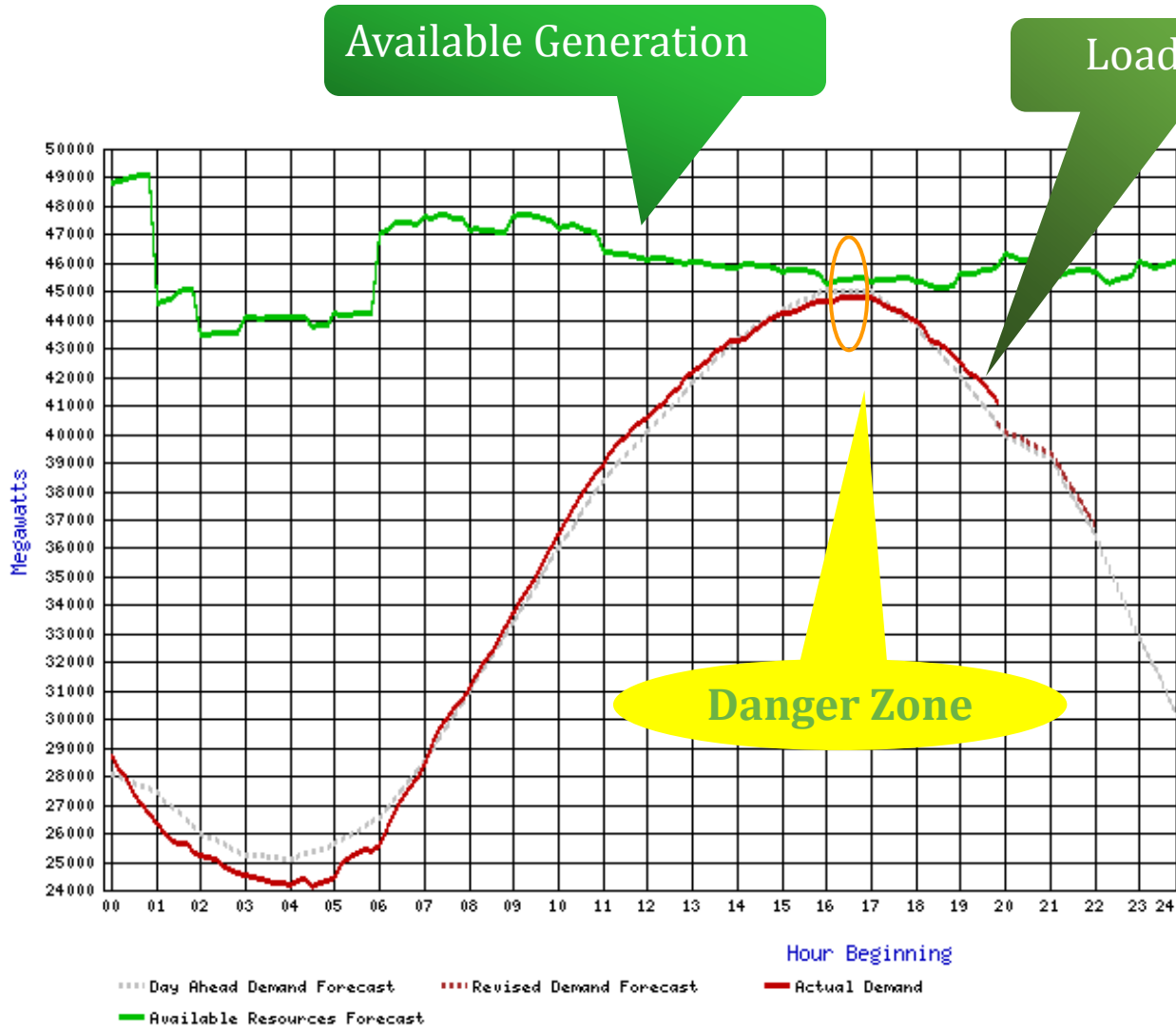
Available Generation

Load Demand

- Passive strategies reduce the curve

- Active strategies shape the curve

- Networked systems will drive efficiency

Danger Zone



Megawatts: 50000, 49000, 48000, 47000, 46000, 45000, 44000, 43000, 42000, 41000, 40000, 39000, 38000, 37000, 36000, 35000, 34000, 33000, 32000, 31000, 30000, 29000, 28000, 27000, 26000, 25000, 24000

Hour Beginning: 00 01 02 03 04 05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24

Day Ahead Demand Forecast    Revised Demand Forecast    Actual Demand
Available Resources Forecast

**California Heat Wave 7/6/07**

# New Energy Regulatory Mandates

**Canada** Energy Efficiency Act – external power supplies, battery chargers, TV set top boxes, and digital TV adapters

**EU** EuP Directive – energy using products, including set top boxes; Data Center Code of Coduct

**Japan** –networking equipment

**US** Energy Policy Act of 2005 – battery chargers and external power supplies; EnergyStar for Servers, Storage, UPS, and Data Centers

**China** –TV receivers, set top boxes, and DVD players

**Mexico** evaluating efficiency standards for electronic products

**Australia** – DVD players and recorders, hard disk recorders, AV receivers, other audio / video equipment

**US** HR 3221 – external power supplies, promote energy efficient data centers.
HR 6 – energy efficiency labeling for set top boxes and DVR products.

**Enacted / Proposed**

# Original Mission: Reduce Energy Usage for Network Devices

BUT… Looking at a Device….

Power per port of attached devices in a Cisco Test Building

**How much of the power for a switch is used to actually do switching?**

Between 40-150W to do switching - based on model, load and/or rate (GE v 10GE)

**What percentage of a switch's power is used to power attached devices?**

70% of Power supply on average used to power PoE

**What's the average aggregate power consumption of devices connected to a switch ?**

48 port switch has on average 3392W connected to it

**What's the average per port power usage?**

~70W per port - TODAY!

# Redefined the Problem

- **Smart Load**

  Add E to FCAPS for Network Management  (FCAPS+E)

  Network plus attached devices can be a smart load

- **Monitor**

  Awareness of energy (usage, context, demand, quality)

  Fast Protocol for collection and aggregation

- **Control**

  Normalized information over common interface

  Fast Protocol for control especially peak demand

- **Interact**

  Interface to Smart Grid / Control / Procurement (ADR)

# Clean Slate view of a Smart Load

- Needs Communication and Semantics

- Communication

  Create a scalable grid computer from a selection of devices to be managed

  Self organize into a domain via discovery

  Nodes in the domain should implement distributed hash maps

  Nodes will aggregate data for subtended or associated endpoints

  Use a broadcast protocol for message propagation

  Layer 3 ISIS type flooding (why not multicast you ask)

  Responses to broadcast can be aggregated and reduced

  Adds aggregation, map / reduce, search

  Fast response for requests to collect or control

  No single point of failure, registry, or aggregation

- Semantics

  Information Model for Energy with Context

  Control Interface

# Solution Architecture Goals

- Use the network to measure, monitor and manage energy.

- Allow the network nodes to be the command and control plane for power management

- Network Node is an arbiter or timer for energy management

- Use the nodes to aggregate power usage reporting

- Allow the network to provide secure, reliable energy management

- Develop an eco-system to manage anything connecting to the network.

- No Technology Religion – Everything that draws power controlled using lowest common denominator

80-100W

3-12W

18W    13W

30-50W

Close to 3000 W attached to a 48 port switch consuming about 100 W
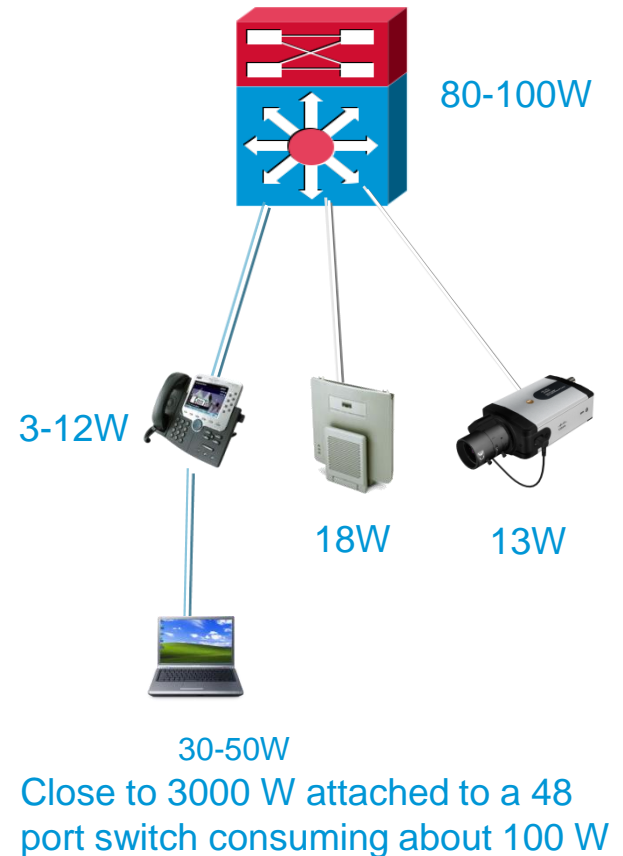
# Solution Concepts

# Cisco EnergyWise Architecture

## MANAGEMENT / SMART LOAD APPLICATIONS

| Energy Management Applications | Network Management Applications | Building Management Systems |
|---|---|---|

**EnergyWise Management API**

Cisco Catalyst Switching Network

**Management API**

Gateways

**SDK**

**EnergyWise SDK – PARTNER DEVICES**

**POE / POE+ / UPOE**

**Building Protocols/Devices**

IT DEVICES

BUILDING DEVICES

# Use the network to create a Smart Load

- Logical grouping of devices that are managed as one power consuming unit

- Self organize to form a grid for communication

- Members can propagate messages within the domain

- Domain members create neighbor relationships with each other and parent child relationships with endpoints

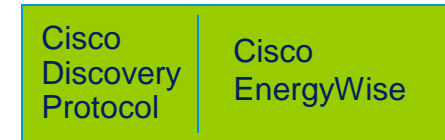- The domain is a single unit of energy management

Cisco EnergyWise Domain
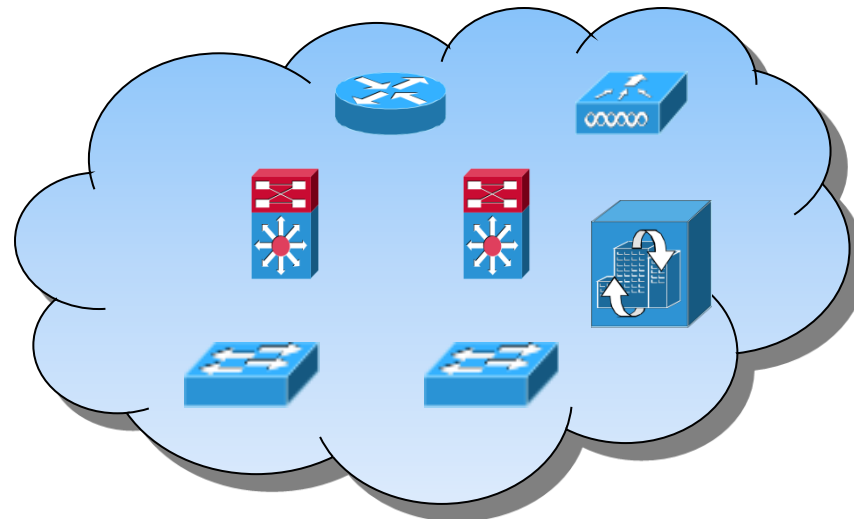
# Network Devices can Self Organize
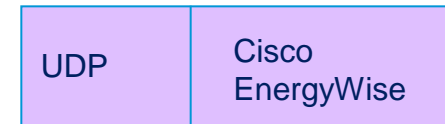
- Neighbor relationships are discovered through Cisco® Discovery Protocol , LLDP, or User Datagram Protocol (UDP) handshakes

Distribution A    Distribution B
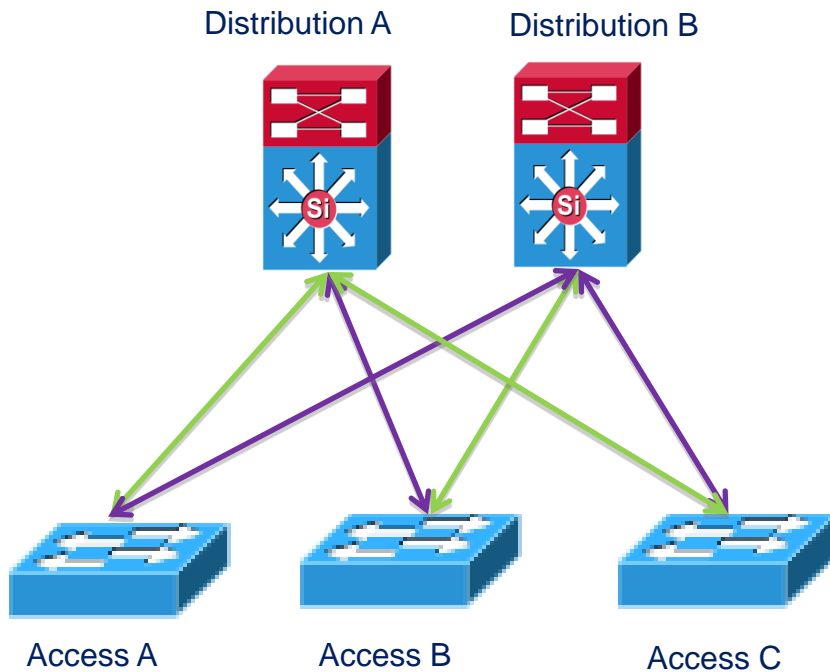
Cisco Discovery
Protocol Handshake

| Cisco Discovery Protocol | Cisco EnergyWise |
|---|---|

UDP Handshake

| UDP | Cisco EnergyWise |
|---|---|

Access A    Access B    Access C

- Alternatively, can establish static neighbors

# Endpoints

- Endpoints connect to a parent for aggregation, control (query or time of day)

- Pattern exists for PoE, PDU, Lighting, Utility-Building, etc.

- Endpoints respond to command and control queries but do not forward them.

- Endpoints could speak many different protocols
  - BACNET, MOD-BUS, Zigby, SNMP, LonBus, CIP

Traditional IP  Devices

Converging Non-IP Devices
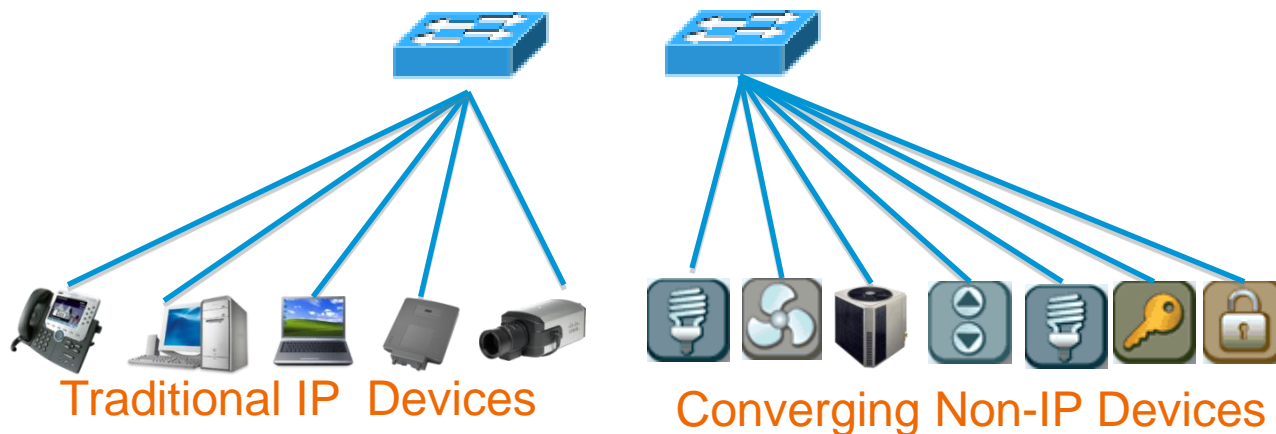
# Communication

# Scaling

- Need a protocol that is fast and can scale as a domain grows

- Adding more management stations to process does not scale

- Use the natural order and scale of internetworking

- Group network communities to form a smart load with attached devices

Point to Point from Central Management



SNMP
SNMP
SNMP

Broadcasting within a Domain



API
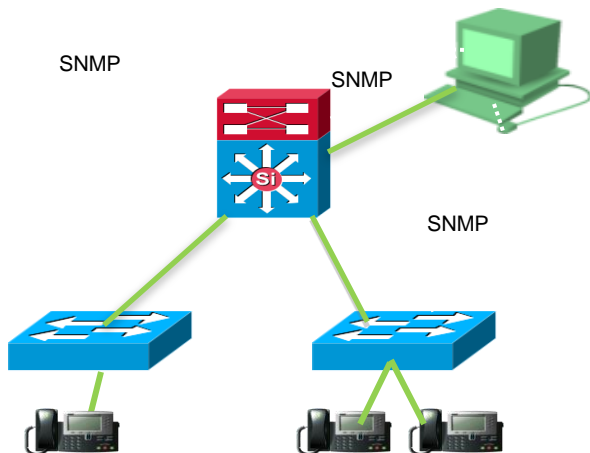
Query
Query

Processing done by single management station. Requires more messages sent and not parallel
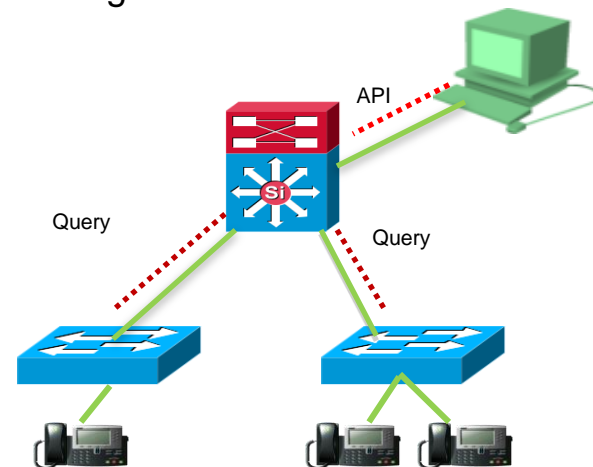
Internetworking adds processing as grid increases in size. Less messages sent and parallel

# Query and Messaging

A domain becomes a virtual distributed power information database

Provides the ability to query this database for information similar to SQL

Question : What is the power consumed by building X?

**SQL Query :**
```
Select sum(usage) from MyDomain where importance <= 100 and
name like "BldgX%";
```

**Cisco EnergyWise Query:**
```
Switch# energywise query importance 100 name BldgX* sum usage
```
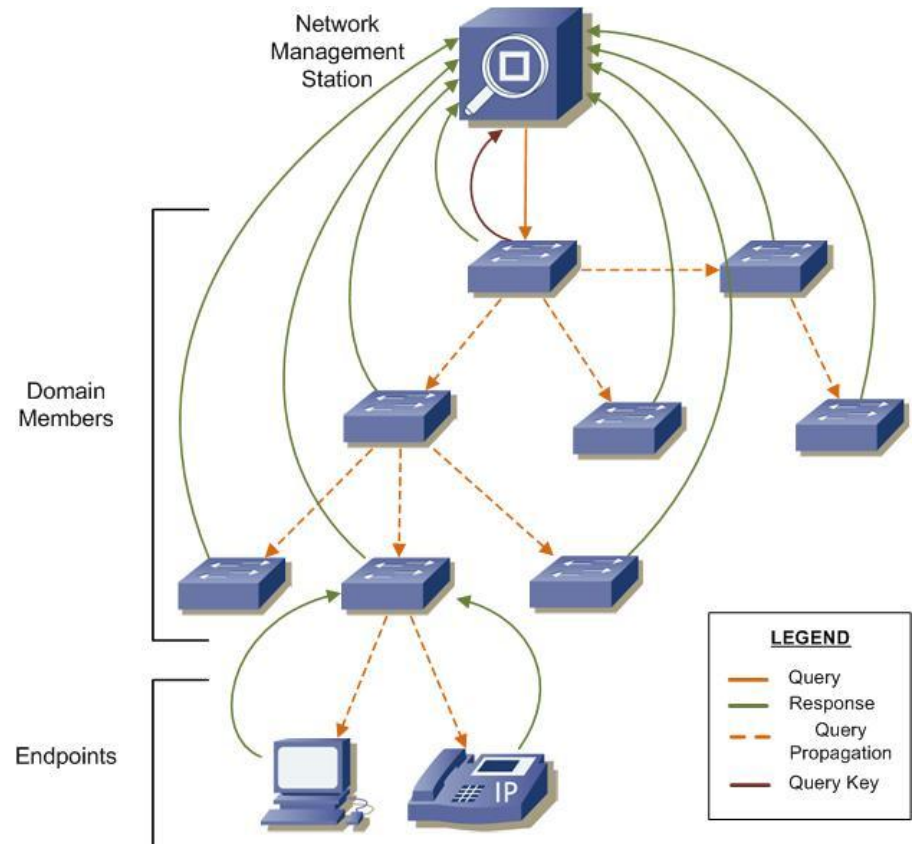
# Message Propagation

Requests are flooded at Layer 3
  (Similar to ISIS)

Only local trimming needed
  ( No routing tables)

Leverage the usage pattern
  (Not a chatty protocol)

Efficient for Broadcast
  (not Point-to-Point)



Network Management Station

Domain Members

Endpoints

LEGEND
— Query
— Response
---- Query Propagation
— Query Key

# Queries

Data is TLV based and provides distributed hash map

Allows for aggregation and map/reduce type processing

- Set : Change power levels of devices using Cisco® EnergyWise query
- Sum : Get the aggregated power consumption of all the devices searched
- Collect : Get a list of individual power consumptions of all the devices searched

Query : What is the power consumed by the domain bldg 19 ?

Response: 596 Watts

300 W

100 W

100 W

100 W

Bldg 19
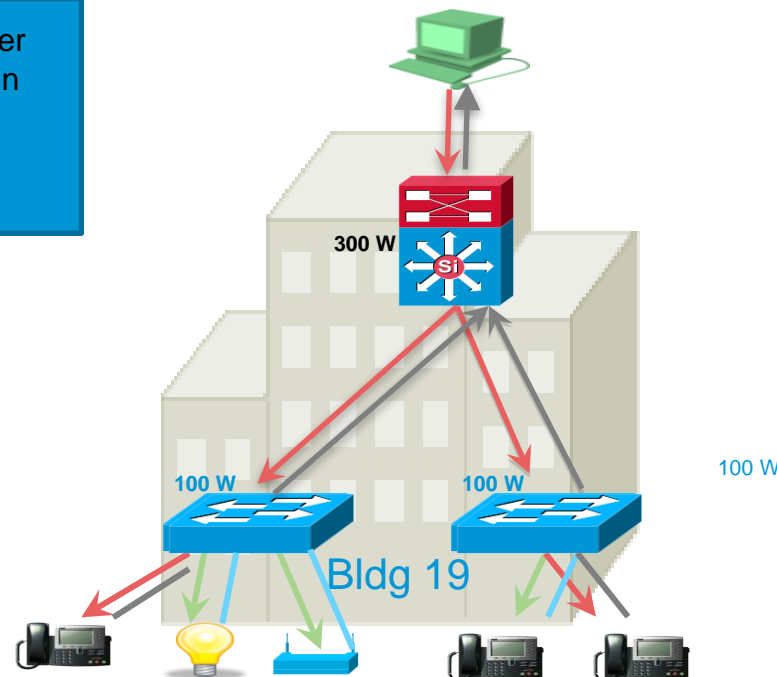
# Minimal and Expandable Information Model

- ## Identification

  Class : Make/Model (species)

  Instance : Unique identifier within domain (UUID)

- ## Security

  Authentication : message Digest

  Authorization : with Access

  Encryption : Not addressed. Deferred to network.

- ## Energy

  Power : instantaneous reading

  Energy : Odometer

  Demand / Quality : optional based on existing standards

  Levels :  monitor and control interface

  Caliber : characteristics of a measurement

- ## Context

  Domain : management community

  Role : use in the deployment

  Keyword :  tagging for arbitrary organization

  Importance : local setting rolled up to relative rating
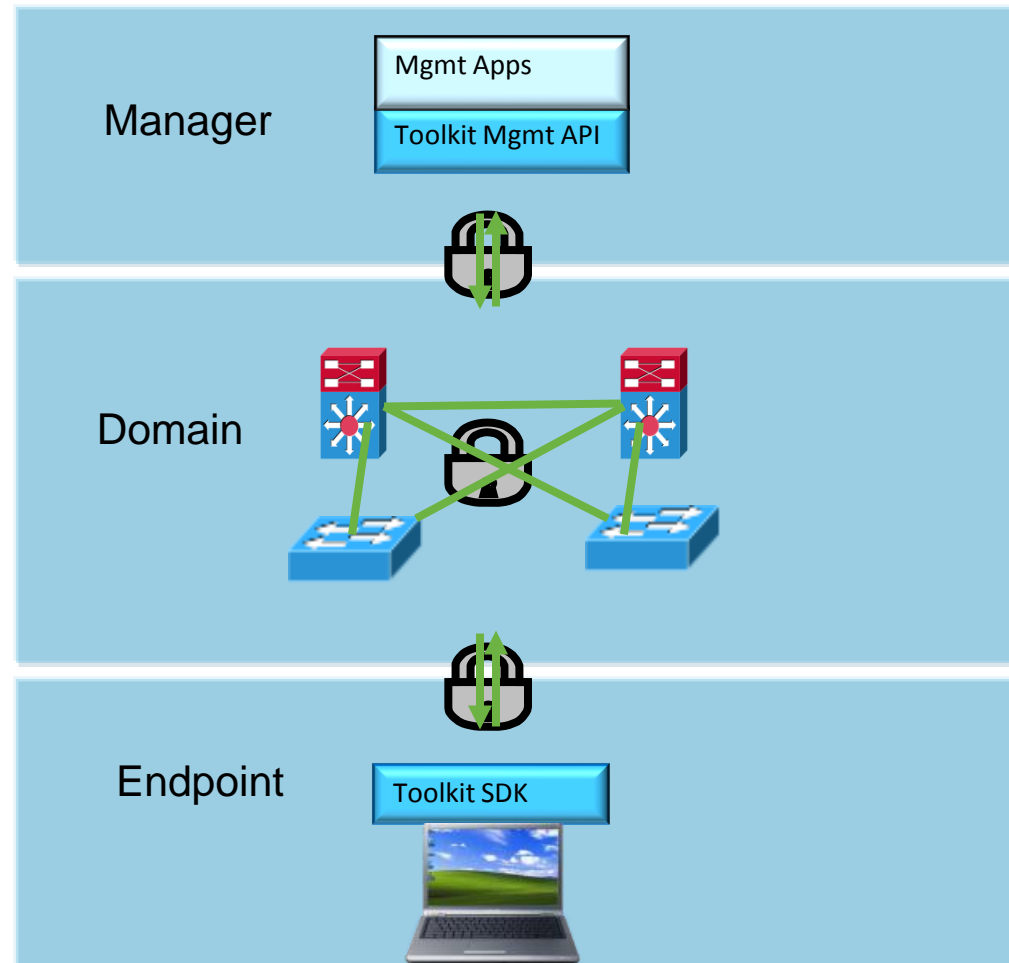
# Security

**Management Secret**
Authenticates communication from a management station

**Domain Secret**
Authenticates communication between members

**Endpoint Secret**
Authenticates communication between domain endpoints.



Manager

- Mgmt Apps
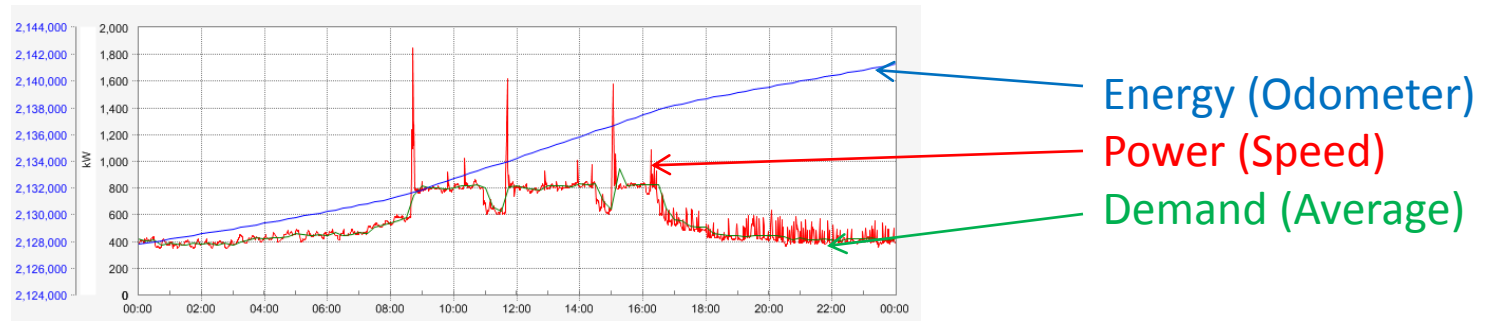- Toolkit Mgmt API

Domain

Endpoint

- Toolkit SDK

# Semantics & Control Interface

# Energy Awareness…

Energy (W) is a resource that enables work to be done
Power (P) is the rate of converting energy to work per unit of time
Demand (kW) is the average rate of energy consumed per interval of time



Energy (Odometer)
Power (Speed)
Demand (Average)

- US Utilities charge for the highest interval demand in a month

  Demand is figured at each main incoming meter

  Demand acknowledges equipment capability to absorb short-time overloads

  Demand charges add penalty and uncertainty to cost forecast

# Context: Keywords, Roles, Importance

ExampleLight:

    Type – Light

    Role – Decorative

    Keyword – Lobby, Public

    Importance –  20

ExampleWorkStation:

    Type – Workstation

    Role – Equities Trading

    Keyword – Trading, Restricted

    Importance –  90

Importance…
  90 to 100 Emergency response
  80 to 90 Executive or business critical
  70 to 79 General or Average
  60 to  69 Staff or support
  40 to  59 Public or guest
  1  to 39 Decorative or hospitality
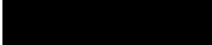
# Control Interface
## Representation of device power states

| Category | Color | Code | Color | Level | Label |
|---|---|---|---|---|---|
| **Operational** (1) | | FF0000 | Red | 10 | High |
| | | | | 9 | HighMinus |
| | | FFFF00 | Yellow | 8 | Medium |
| | | | | 7 | MediumMinus |
| | | 00FF00 | Green | 6 | Low |
| | | | | 5 | LowMinus |
| **Standby (0)** | | 0000FF | Blue | 4 | Ready |
| | | | | 3 | Standby |
| | | A52A2A | Brown | 2 | Sleep |
| | | | | 1 | Hibernate |
| **Nonoperational (-1)** | | 000000 | Black | 0 | Off/SoftOff |

# Standards based levels

| State | DMTF Power State | ACPI State | MIB Power EW/IETF State Name |
|---|---|---|---|
| **Non-operational states:** | | | |
| 0 | Off-Hard | G3, S5 | Shut/Mech Off |
| 0 | Off-Soft | G2, S5 | Shut/Soft Off |
| 1 | Hibernate | G1, S4 | Hibernate/Hibernate |
| 2 | Sleep-Deep | G1, S3 | Sleep/Sleep |
| 3 | Sleep-Light | G1, S2 | Standby/Standby |
| 4 | Sleep-Light | G1, S1 | Ready/Ready |
| **Operational states:** | | | |
| 5 | On | G0, S0, P5 | Low/LowMinus |
| 6 | On | G0, S0, P4 | Frugal/Low |
| 7 | On | G0, S0, P3 | Medium/MediumMinus |
| 8 | On | G0, S0, P2 | Reduced/Medium |
| 9 | On | G0, S0, P1 | High/HighMinus |
| 10 | On | G0, S0, P0 | Full/High |

# Queries:  Sums and Deltas

**Summing can give the total possible power change in the domain based on present configuration options.**

```
Switch# energywise query importance 50 keyword 'Decorative` sum delta

EnergyWise query, timeout is 3 seconds:

Level     Label          Delta Power (W)
-----     -----          -----------
0         Shut           -723.8
1         Hibernate      -610.3
2         Sleep          -520.3
3         Standby        -520.3
4         Ready             0.0
5         Low Minus         0.0
6         Low               0.0
7         Medium Minus      0.0
8         Medium            0.0
9         High Minus     +223.8
10        High           +223.8

Queried:  48    Responded:  48      Time:  0.15 seconds
```
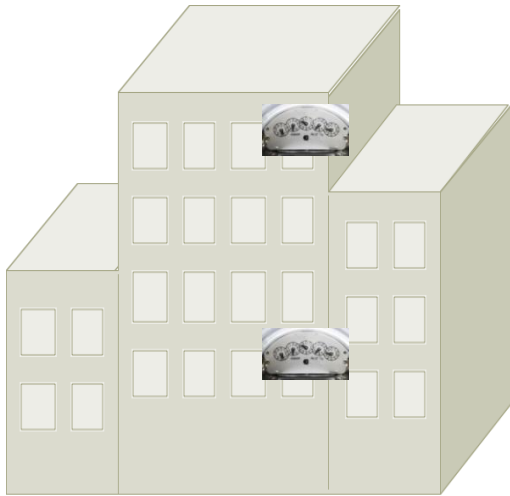
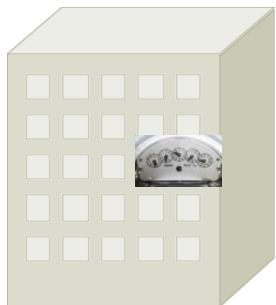# Deployments

# Metering and Sub-metering

**Midsize Branch Office**



1 or More Meters
or Submeters

**Large Campus Building**



Many Meters or
Submeters

**Small Branch Office**



1 Submeter
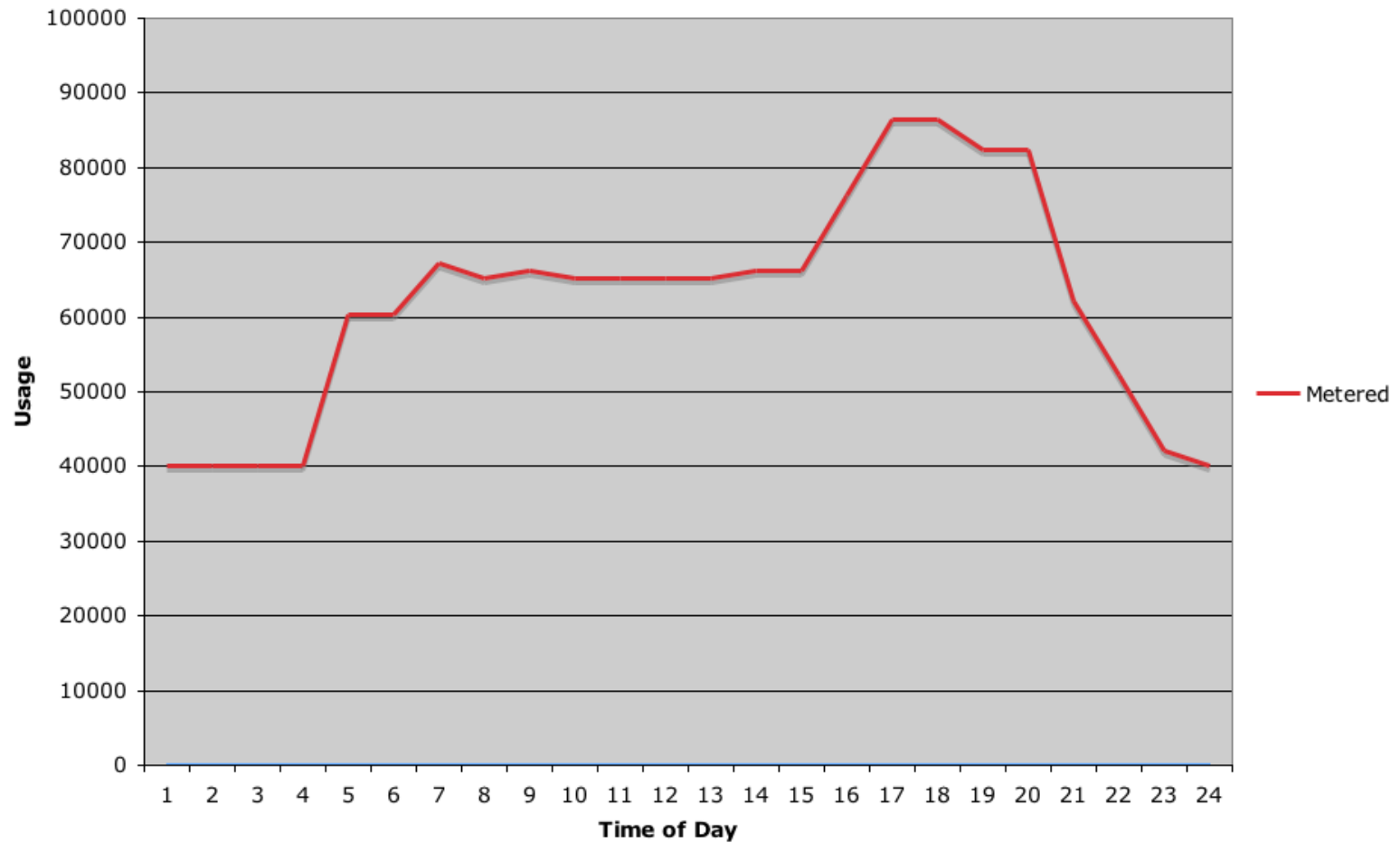
# Typical Metering



Energy Domain Metered

# Match Energy Domains to Electrical Distribution



com.example.building

com.example.building.elevator8

com.example.building.chillerb

com.example.building.panel-8-1ldp3

com.example.building.panel-8-1ldp4

com.example.building.panel-8-3hdp1

com.example.building.panel-8-1ldp1

through

com.example.building.panel-8-1ldp6
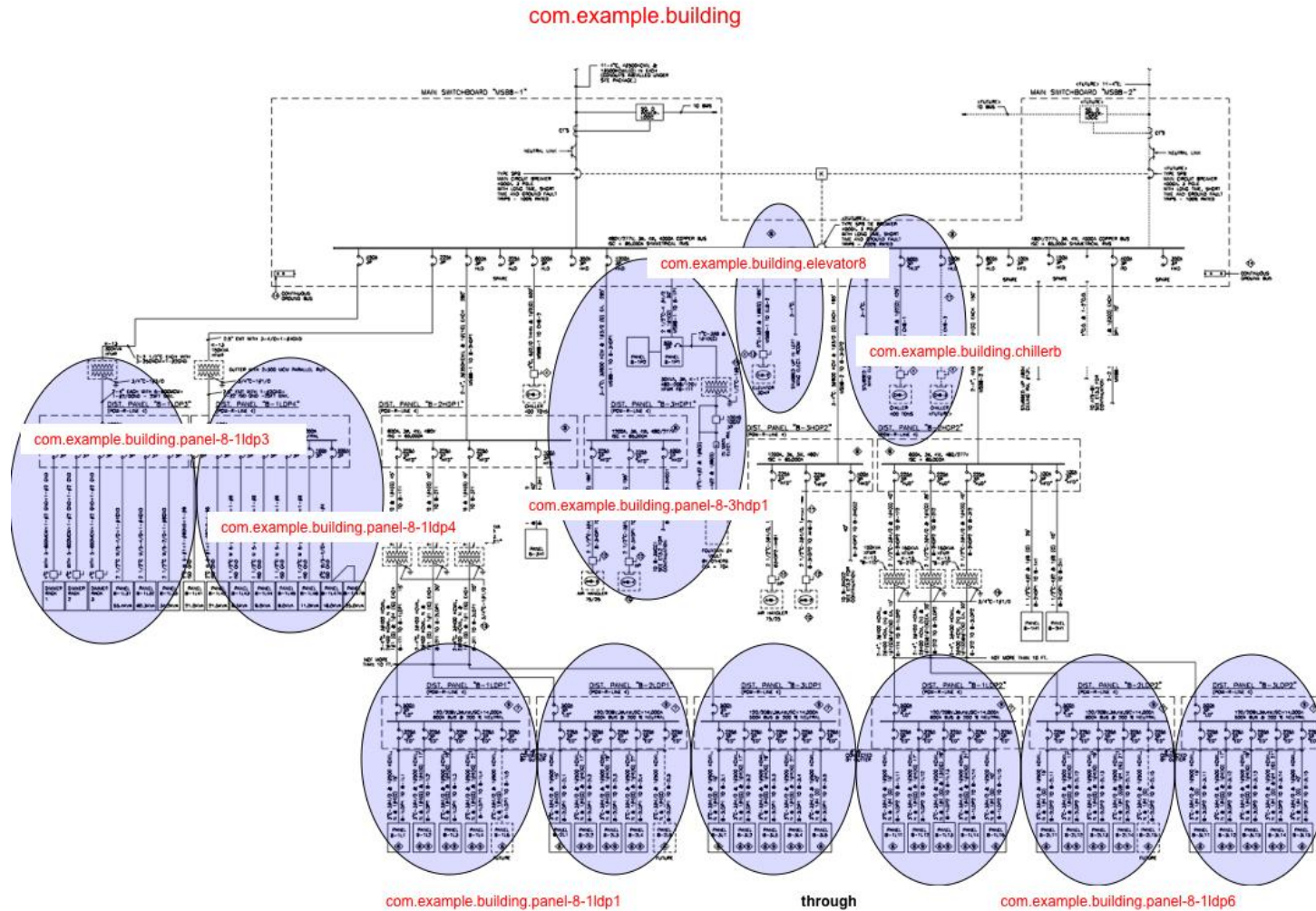
# Add Business Context
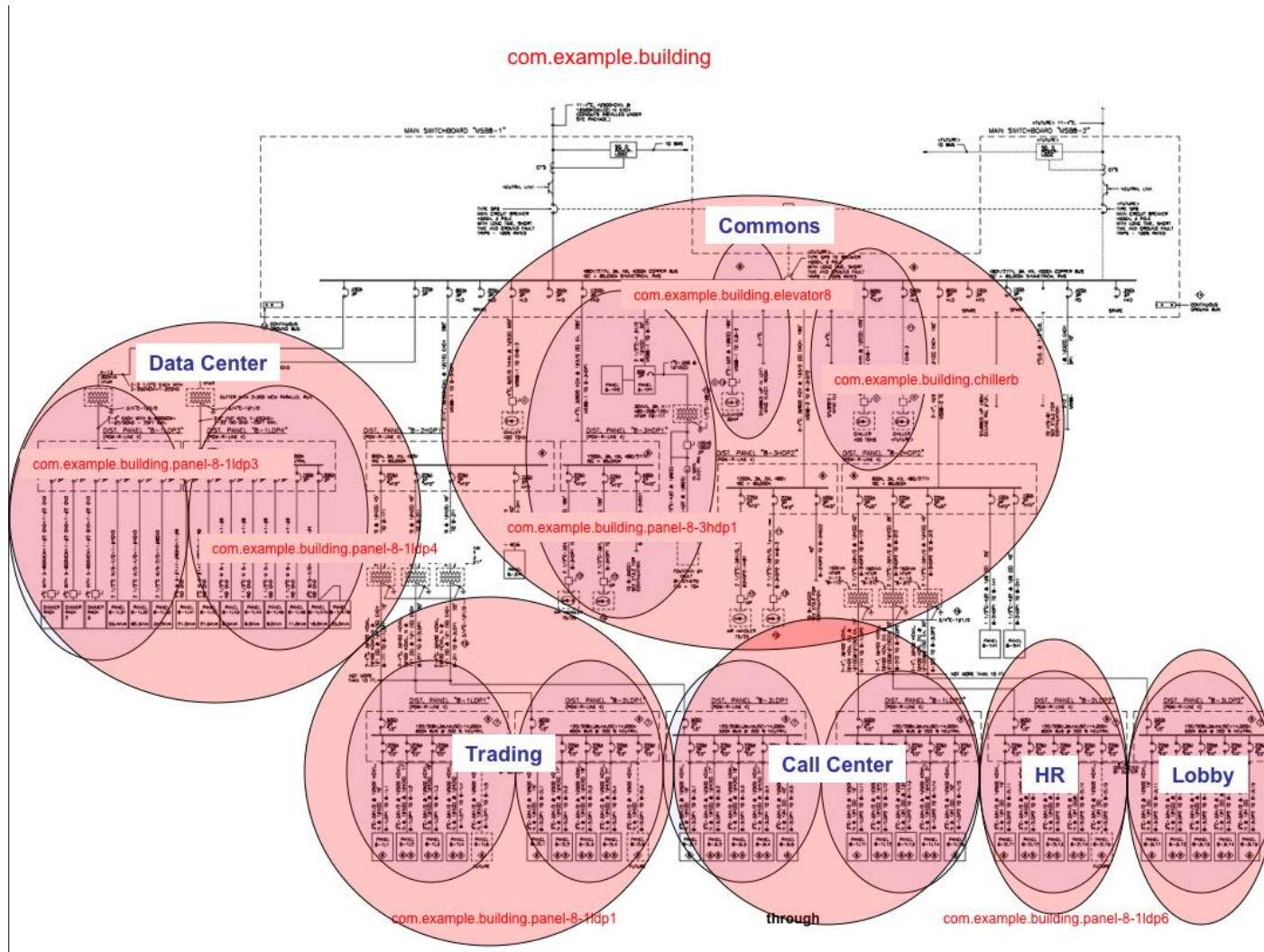
# Details From Domain Estimating True Metering

**Energy Domain Business Context**



**Energy Domain Details**

# What's Needed Next…

# Eco-System

## Management – Energy, Network, Others

joulex ENTERPRISE GREEN IT
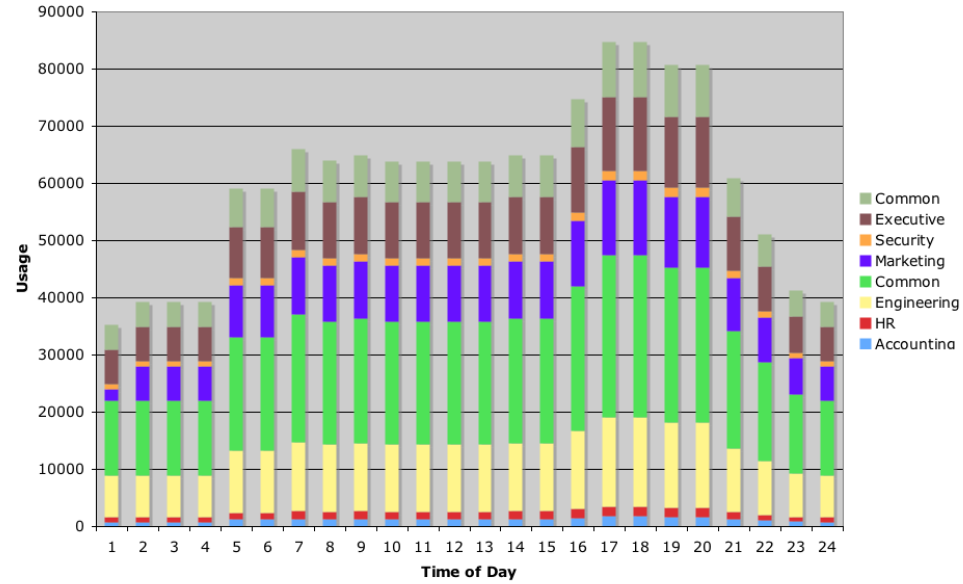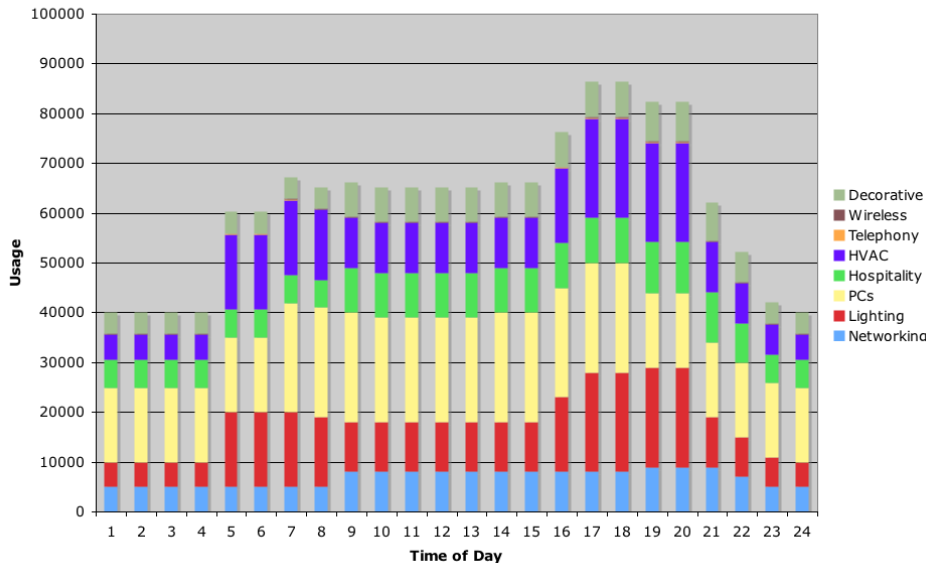
Verdiem.

ca technologies

COMMSCOPE®

entuity

1E

IBM

avob

NETFORMX

Cloud Systems

Enterprise Infrastructure Partners

CSRware Powering Efficiency

halcyonsoftware
The Experts in Multi-Platform Systems Management

PAESSLER
the network monitoring company

ExtraHop

## End Devices

lenovo FOR THOSE WHO DO.

EATON Powering Business Worldwide

Raritan. Know more. Manage smarter.™

FOXCONN

legrand®

xerox

CYBER SWITCHING®

WTi

WATTECO

Delta CONTROLS ™

CISCO

Server Technology
Solutions for the Data Center Equipment Cabinet

Jacarta

## BMS, Gateways

Schneider Electric

Johnson Controls

Robinson SOLUTIONS

FieldServer Technologies

## Services, Regional, Other Value-add

UBITEQ UBIQUITOUS TECHNOLOGY

MITSUI

ayehu

SUMITOMO DENSETSU

地球産業のエコロジーになりたい手
SANKI

UMPI ELETTRONICA

WAFER SYSTEMS

# Standards Work

- Established IETF EMAN working Group

    Leading effort for Energy over IP

    Standardizing Information Model first

    Specifying Architecture

    Working with Existing bodies such as DMTF, IEC, IEEE, ASHRAE etc


- ODVA work with CIP for Industrial Automation

- Integration via 802.3az (EEE)

# Areas for Research

- Power distribution like VOIP (power setup, power route, QoS)

- Negotiating Power, Energy, and Demand over Electrical lines
  - Identification of devices based on power characteristics

- Sleeping a device and proxy presence

- Broadcast communication
  - Storm prevention within a palatable multicast
  - How to add Point-to-Point easily (registry?)

- Estimating and Characterizing Measurements (virtual devices)

- Protocol translations and routing (mediation)

- Accounting / Negotiating overlapping measurements

- Track energy cost of packet / routing based on cost

- Predicting MTTR and/or Maintenance based on energy usage

http://books.google.com/books?isbn=9780470607251
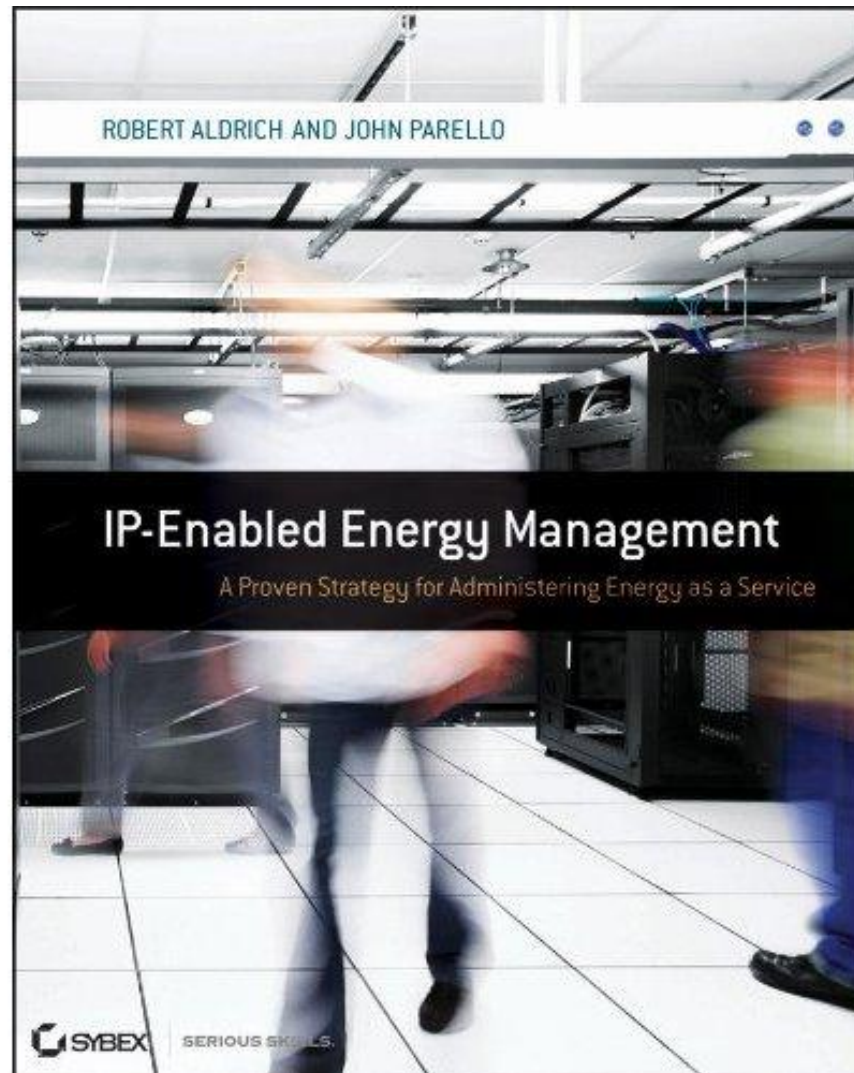
# References

John Parello - jparrello@cisco.com
Tirth Ghose  - tirghose@cisco.com

Reduced / Free for Academic Research:
EnergyWise CDN Portal:  http://developer.cisco.com/web/esdk/home

- Cisco EnergyWise Validated Design Guide

    - http://www.cisco.com/en/US/docs/solutions/Enterprise/Borderless_Networks/Energy_Management/energywisedg.html

- Cisco EnergyWise fundamentals Video Tutorial

    - http://www.youtube.com/watch?v=hGf6DADO468

- Cisco EnergyWise concepts and summary paper

    - http://www.cisco.com/en/US/prod/collateral/switches/ps5718/ps10195/white_paper_c11-568212.html

Thank you.