Distributed Computing and Systems
Chalmers university of technology

An information-centric energy infrastructure: The Berkeley view

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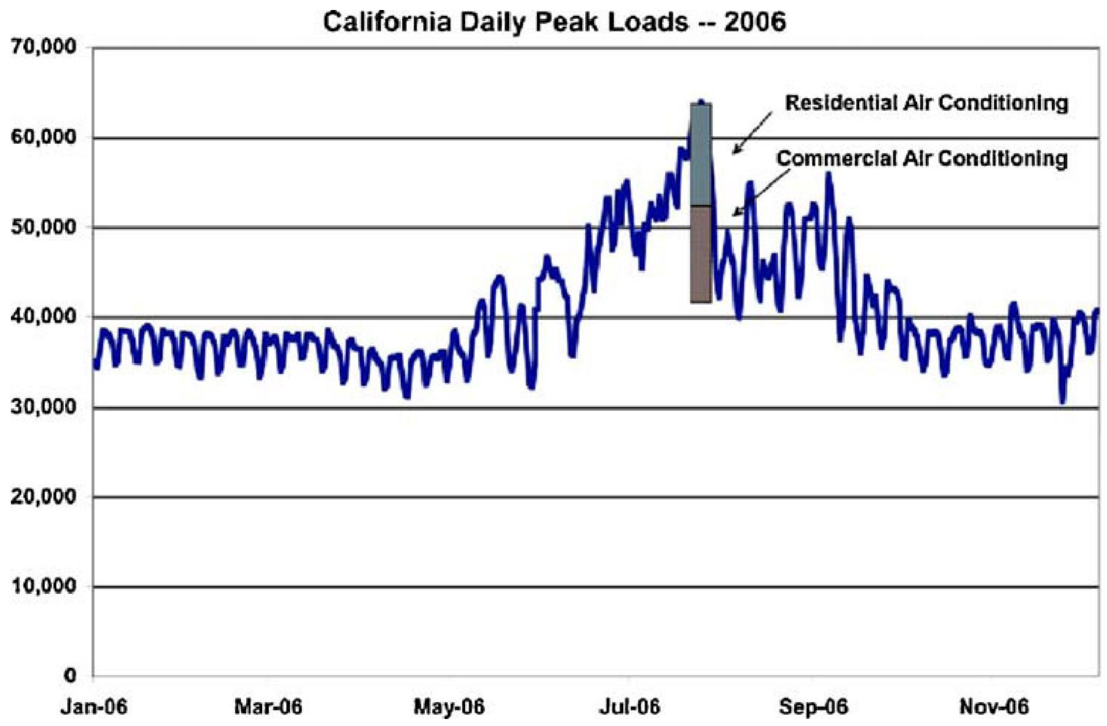
Overview

- Introduction to Smart Grids
  - State of the world
  - State of the art
  - State of the future: a manifesto (of sorts)
- (Information-centered) Energy networks
  - The concepts
  - The tools
- Architecture for Energy Networks
  - Building management (operating) system
  - Building-scale web services architecture

Introduction to Smart Grids

State of the world

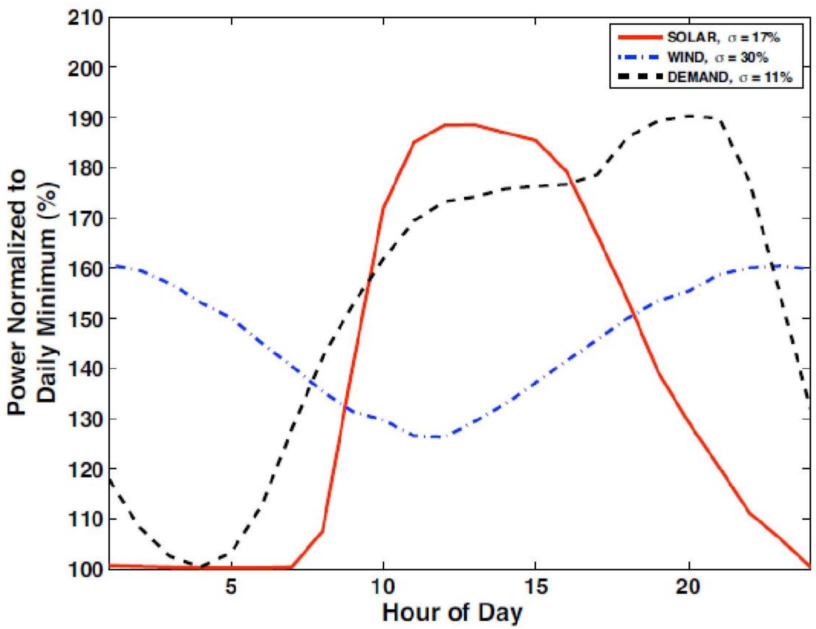
- Load-following supply
- Challenge #1: Demand variability yearly/daily



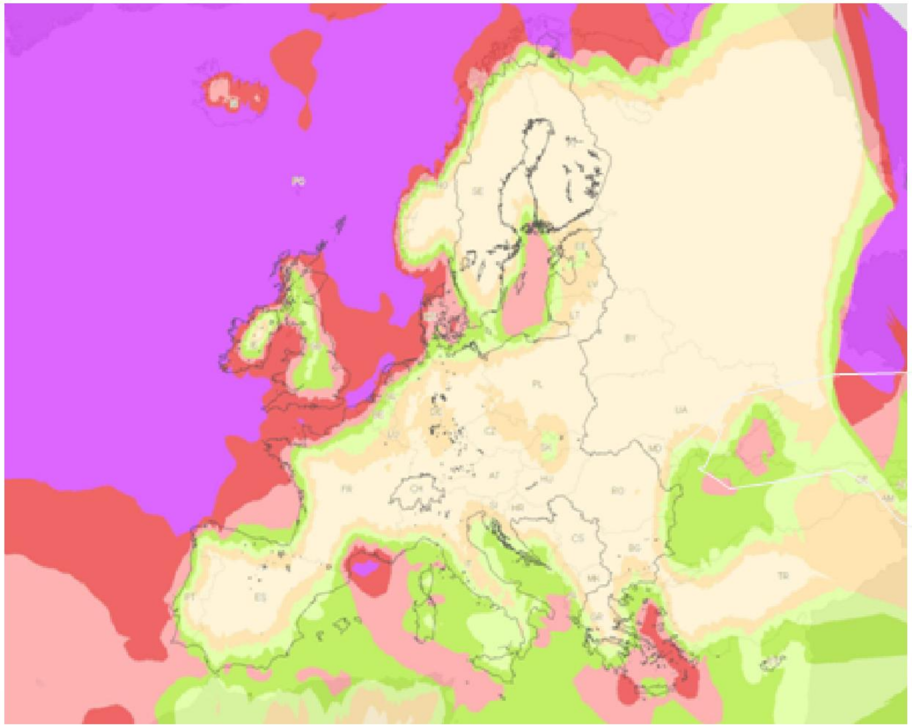
Introduction to Smart Grids

State of the world

- Challenge #2: increasing (the) penetration of renewable sources



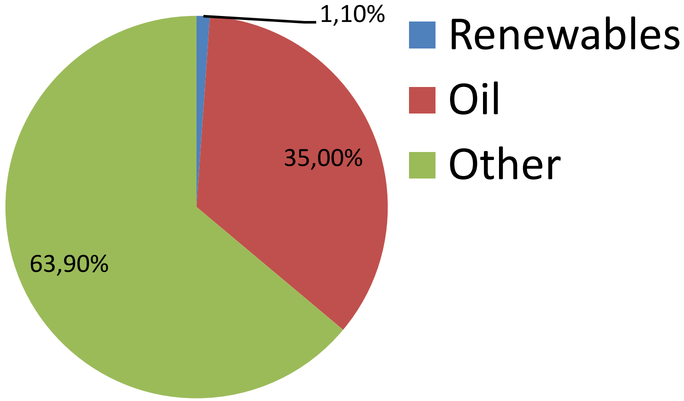
Wind



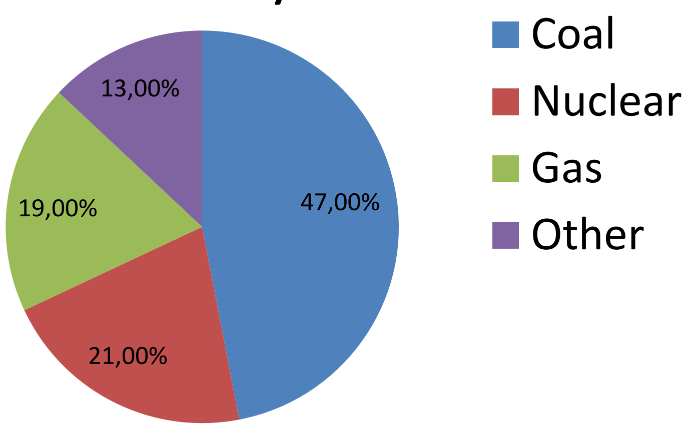
Introduction to Smart Grids

State of the US

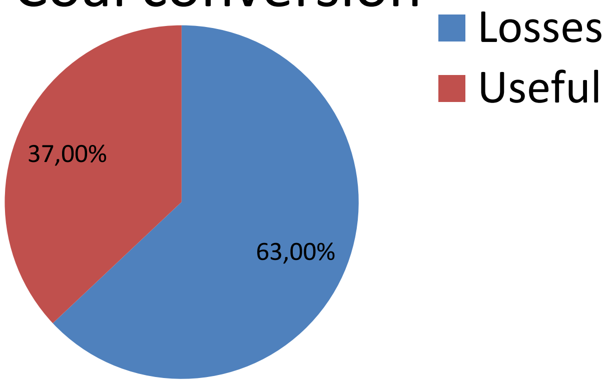
Energy mix



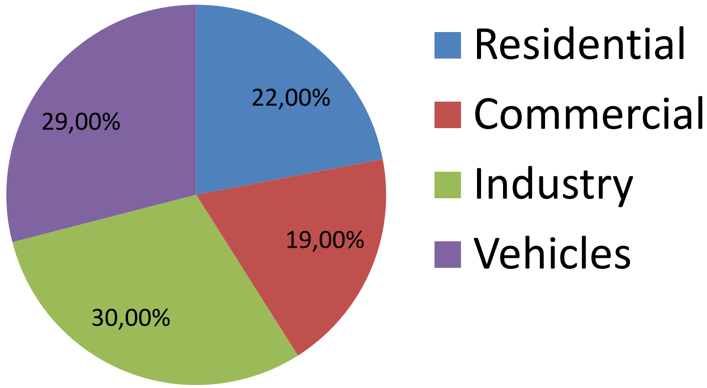
Electricity mix



Coal conversion



Energy usage

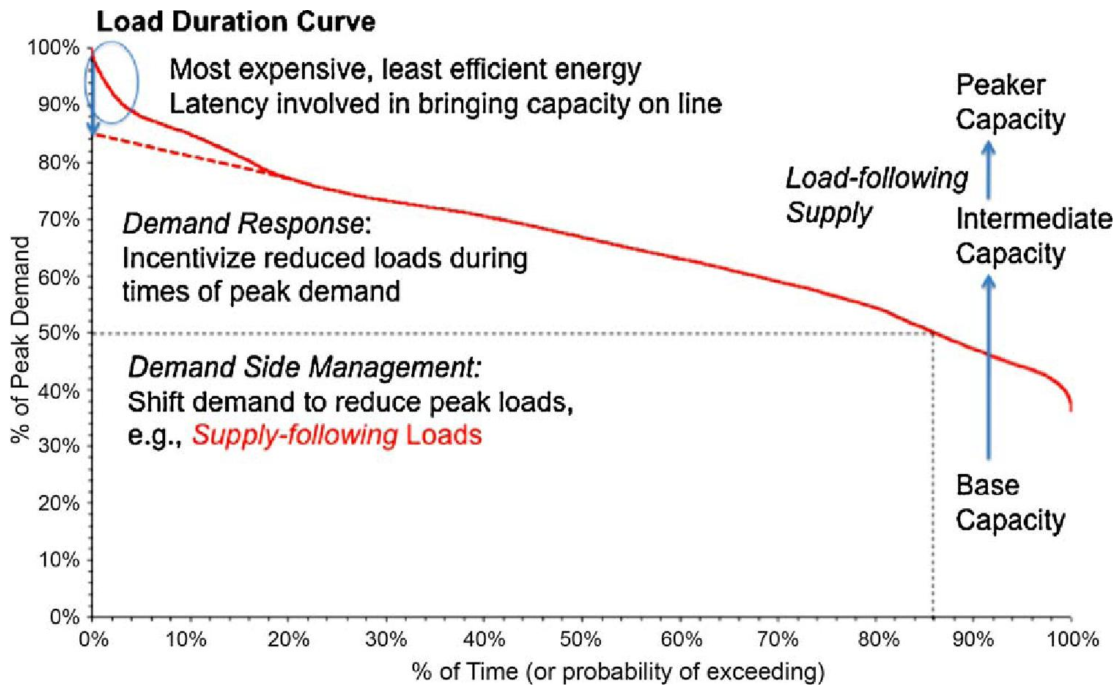


Introduction to Smart Grids

State of the art: mitigate consumption

Why?

- Cost of new infrastructure
- Reducing carbon content of fuel mix



How?

- *Demand response*
- *Demand-side management*

The problem: How to exploit renewable generation?

Introduction to Smart Grids

State of the future

- Radical approaches will not work
  - Wide deployment
  - High capital costs
  - Well –understood technologies
- Supply-following loads
- Storage
- An architecture
- Remember the modems!

Introduction to Smart Grids

A manifesto (of sorts)

- Combining intelligent communication protocols with energy transmission
- Continuous demand response to pricing signals (or more)
- From worst (peak) case to average case +headroom
- Use headroom to control generation, storage, loads
- Push intelligence to the edges!

Plug into

- Regional grid
- Neighborhood peer-to-peer grid
- Facility grid

Do

- Use local storage
- Smooth load
- Adapt demand
- Engage in exchange

Introduction to Smart Grids
A computing systems analogy

- Hierarchy, aggregation, layering, APIs, protocols
- Storage works as a network buffer, breaks synchronization
- Critical services
  - Resource allocation
  - Load balancing
  - Load shifting

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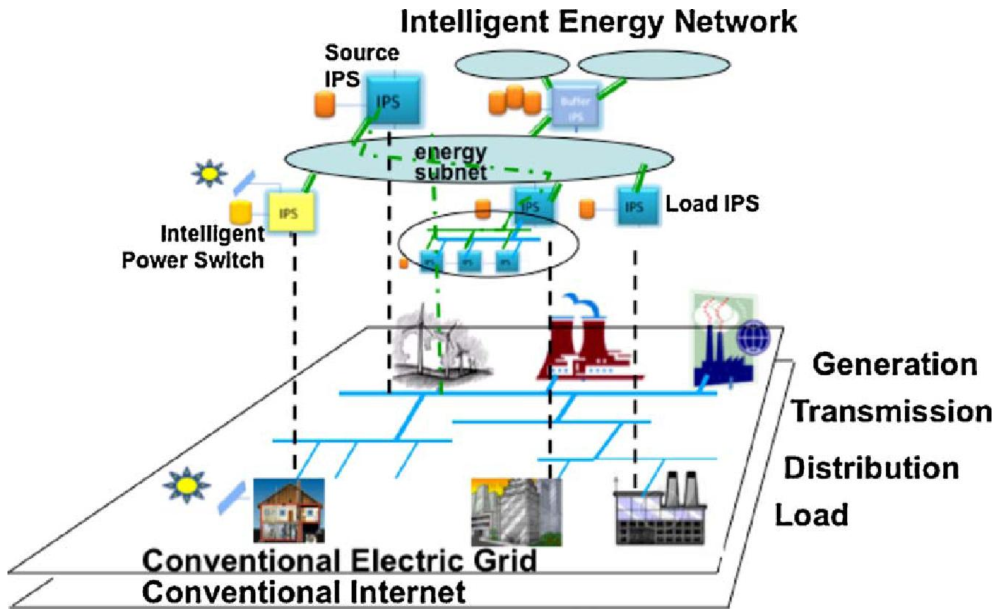
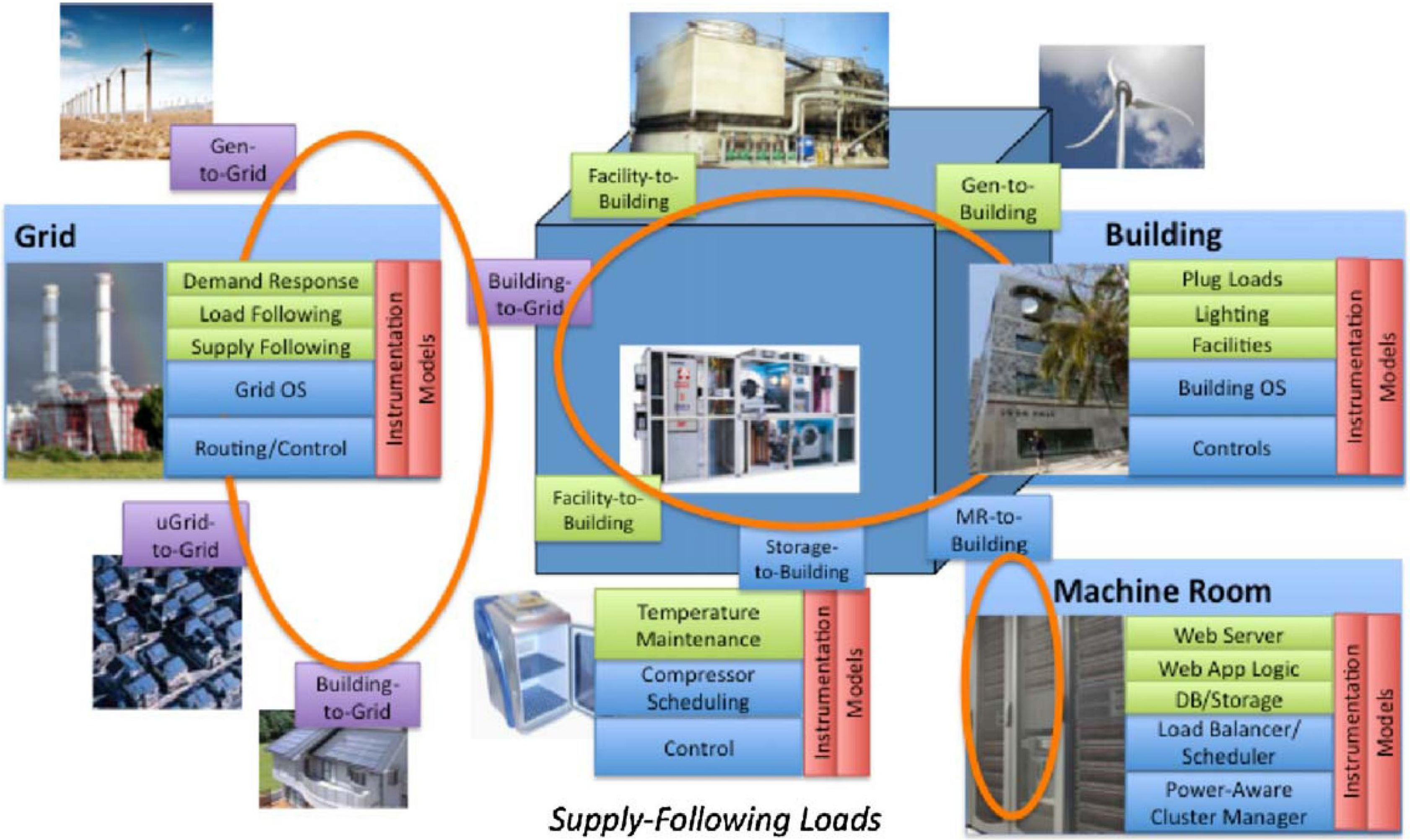
- **(Information-centered) Energy networks**
  - **The concepts**
  - **The tools**
- Architecture for Energy Networks
  - Building management (operating) system
  - Building-scale web services architecture

Energy networks

- Integrate information exchange everywhere that power is transferred
- Match instantaneous demand to available supply on finer scales, be they geographical, logical aggregations, time grain, as well as all of these at once.



Energy networks



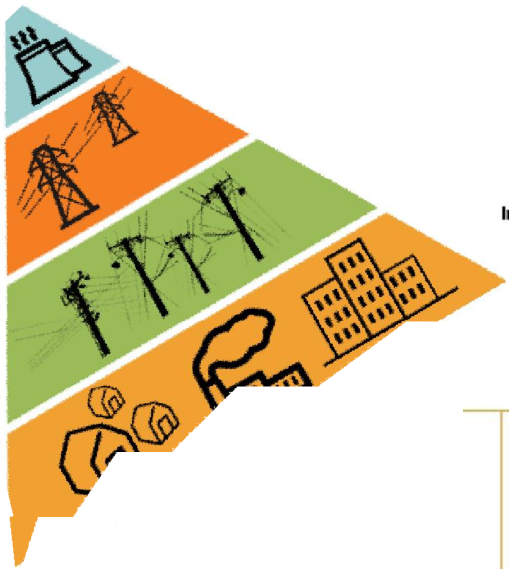
Energy networks
The concepts

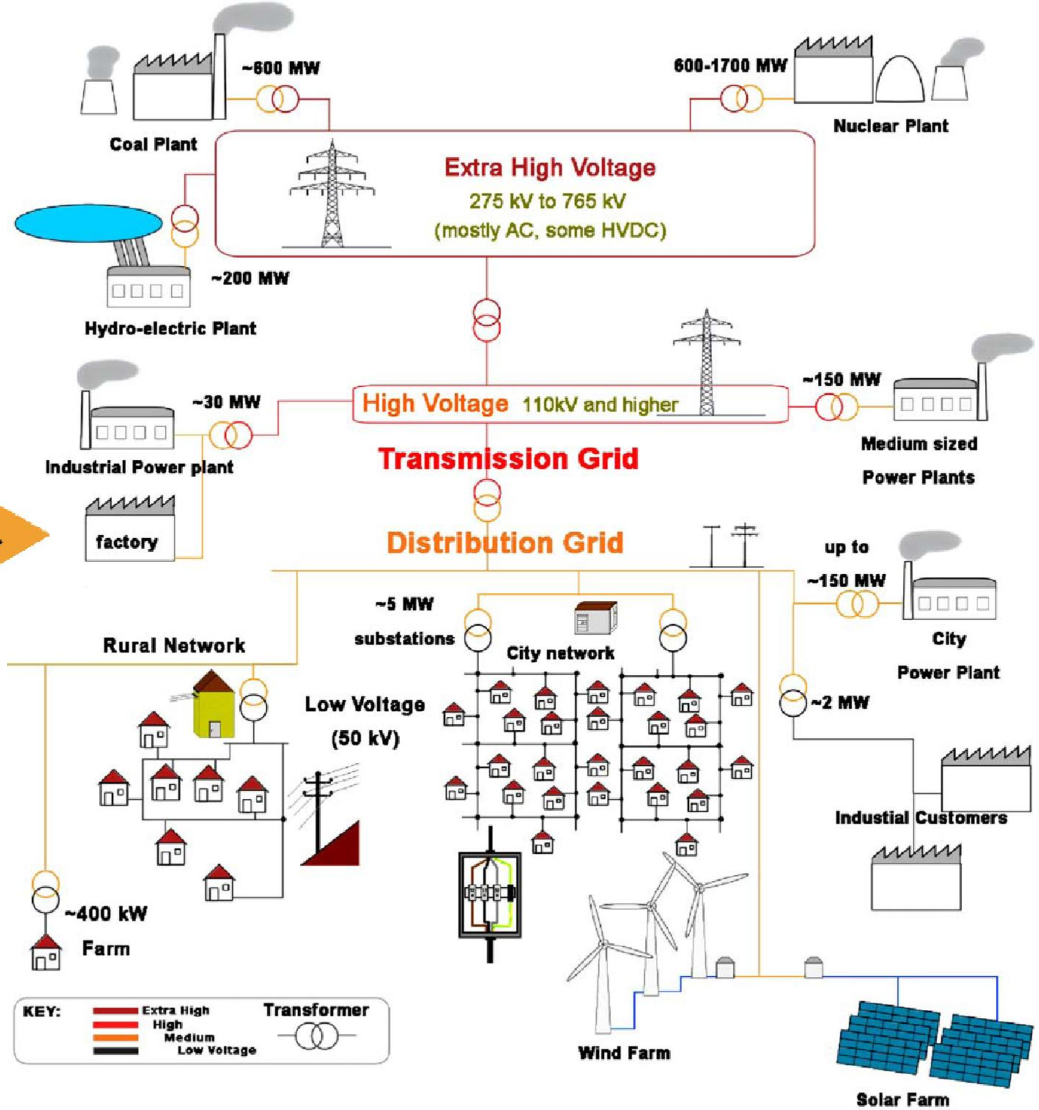
Generation

Transmission

Distribution

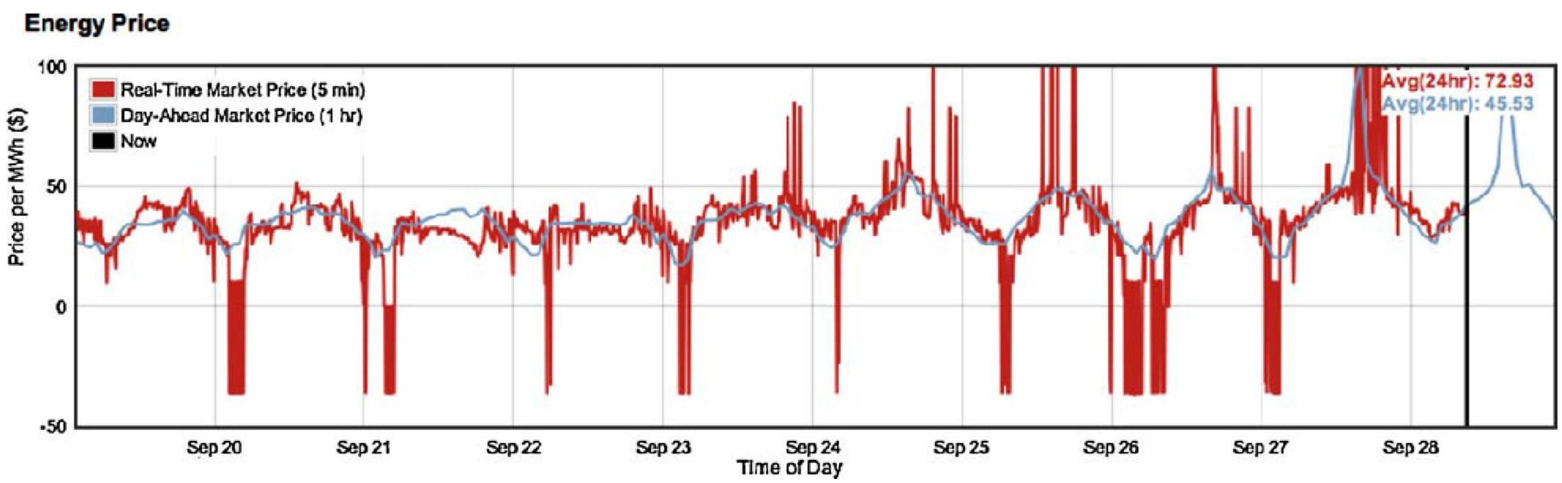
Consumption





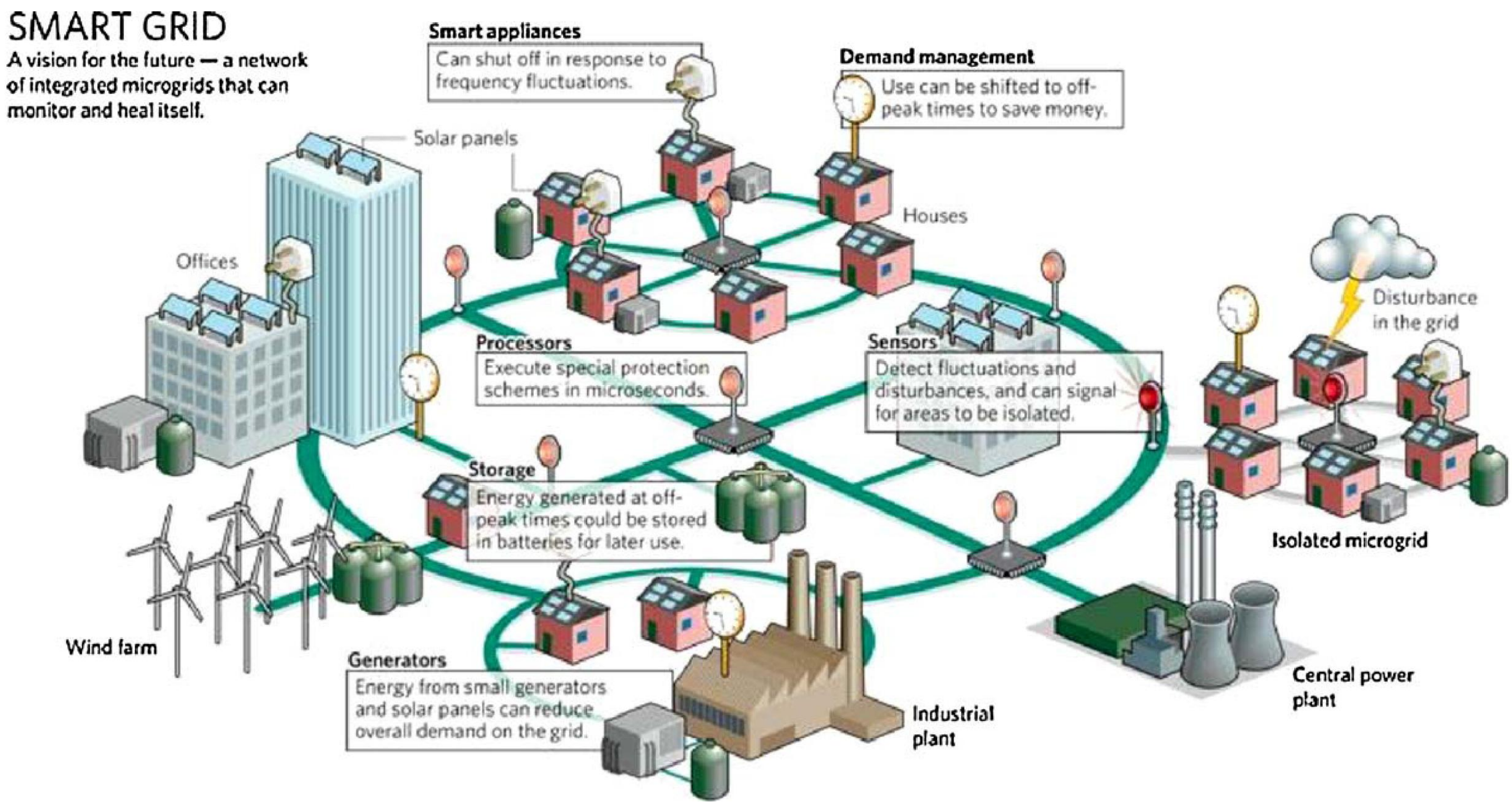
Energy networks
The concepts

- Distributed generation
- Energy storage
  - Chemical, mechanical, thermal
- Energy markets



Energy networks

The Smart Grid



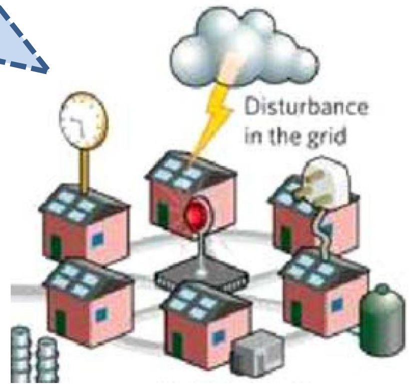
Energy networks

The tools: where are the smart meters?

- Pervasive motoring and information communication
- Smart meters
  - Communicate real-time prices to consumers
  - Respond to price increase/reduction
- Demand response
  - Automatic reduction of load demand
  - Turnoff non-critical loads or shift them
- Slack

  > "*the amount of time an energy-consuming operation can be advanced or delayed while still performing its intended function.*"

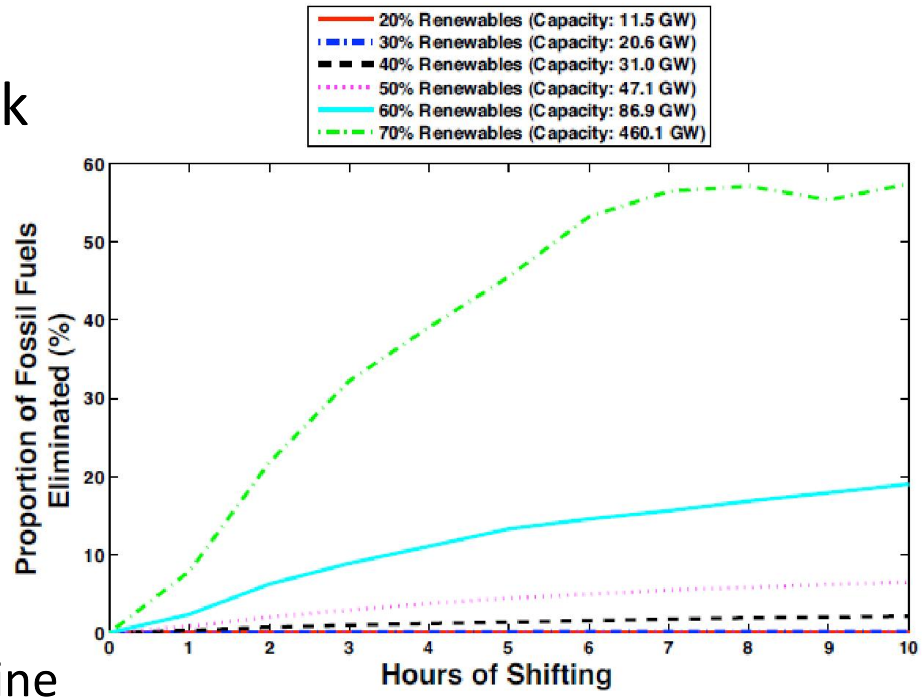
- Slide



Energy networks

The tools: Slack & slide example - refrigerator

- Its consumption schedule involves choices on when to consume energy
- Capacity to store energy: slack
  - Precooling cycle
- Ability to schedule energy consumption: slide
  - Allow temperature to rise in order to reduce consumption at a given time
  - Better example: washing machine



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- **Architecture for Energy Networks**
  - Building management (operating) system
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Architecture for Energy Networks

- Disclaimer: too early to tell (fully)
- However:
  - Energy storage and buffering
  - Forecast energy availability, use to negotiate between suppliers-consumers
  - Pervasive monitoring
- Information flow
  - Centrally?
  - Alternative view
    - Intelligent supplies: communicate forwardlooking profiles
    - Intelligent loads: shape workload to availability signals from suppliers

Architecture for Energy Networks

Building management (operating) system

- Provides context and runtime for other software
- Now: monolithic, proprietary
- Want: flexible, open, service-based
- Building-scale applications
  - batch and real-time analytics, supervisory control loops, and individualized energy feedback.
- Service abstractions
  - sensor and actuator access
  - access management
  - metadata
  - archiving
  - discovery

Architecture for Energy Networks

Building management system

- Sensor and actuator access
  - uniform data model, devices expose multiple sense points and channels
  - simple set of objects and properties required for interpreting nearly any sensor (**Simple Measurement and Actuation profile - sMAP**)
- Archiving
  - a custom file-based engine with a simple query language on top
  - SQL-based stores
  - NoSQL document stores
  - acceptable (3000 points at 20 second resolution)
  - degrade historical data

Architecture for Energy Networks
Building management system

- Access management
  - A need for
    - Authentication
    - Integrity checking
      - e.g. certain data is public but consumers need to check that it has not been altered since production in transit
    - Confidentiality
      - e.g. a malicious user discovers when a person is in their office
  - Key concepts
    - Principals: identities that receive capabilities
    - Roles: capabilities granted to a principal are determined by the role they play
  - How
    - Kerberos, PKI
    - well-known cryptographic primitives
    - ...defining a new HTTP authentication mechanism... “kerberized” web service protocols...

Architecture for Energy Networks

Building management system

- Metadata
  - Examples: building models, locations and types of ...nsors and actuators, logical entity relationships bet... ...vices
  - Two prototypes
    - simple application buil... ...a (Electrical Engineering at ...
    - Stre... ...r exposing the bu...
- Discovery
  - Minimu... ...e able to enumerate the access management server, en... ...g other services may itself require a particular role.
  - DNS based approaches

Will the architecture scale (to multiple buildings etc)?

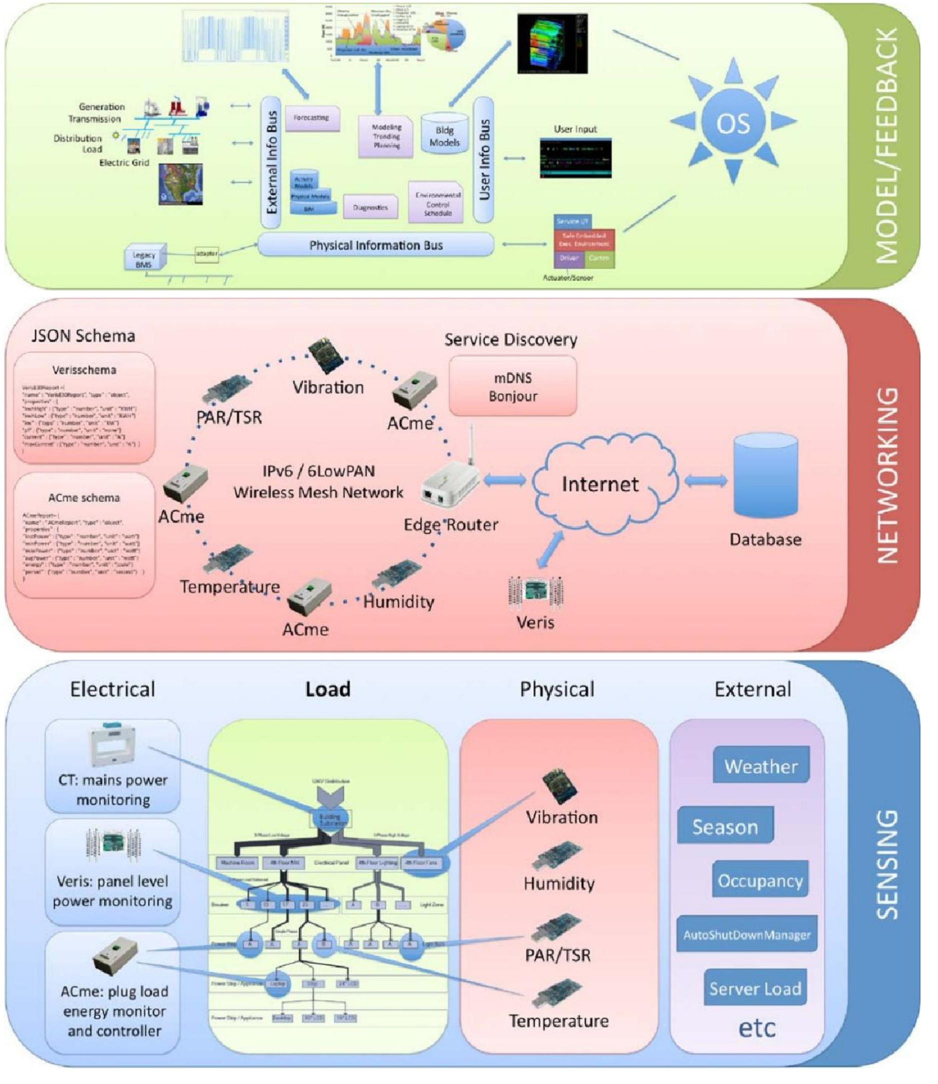
Architecture for Energy Networks

Building-scale web services architecture

> “While it is easy to wrap readings in XML and transport them over HTTP, it is challenging to get widespread agreement on a simple, easily understood solution.”

- Tiny embedded information servers
- Simple representation of measurement information and actuation events (RESTful web services)
- Design space
  - Metrology (the study of measurement)
  - Syndication
  - Scalability
- Prototypical interaction

Architecture for Energy Networks



Summary

- Renewable energy sources a challenge
- Just mitigating consumption is not enough
- Storage + a computing systems analogy
- Slack & slide
- Building management (operating) system
- Building-scale web services architecture

Thank you!

Questions/comments?