Computing & Sustainable Energy

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Proposed Coverage

- How can CS research support drive for sustainable energy?

Topics

- Generation
  - Wind, solar, …
- Transmission & Storage
  - Making the grid more effective
- Consumption
  - Homes & businesses
  - Transportation

Not Included

- More general issues of environment & sustainability
- Making computers & data centers more energy efficient

US Energy Basics: Generation

- Data from 2007, extracted from report NSB-09-55

US Energy Basics: Consumption

- **Data from 2007, extracted from report NSB-09-55**

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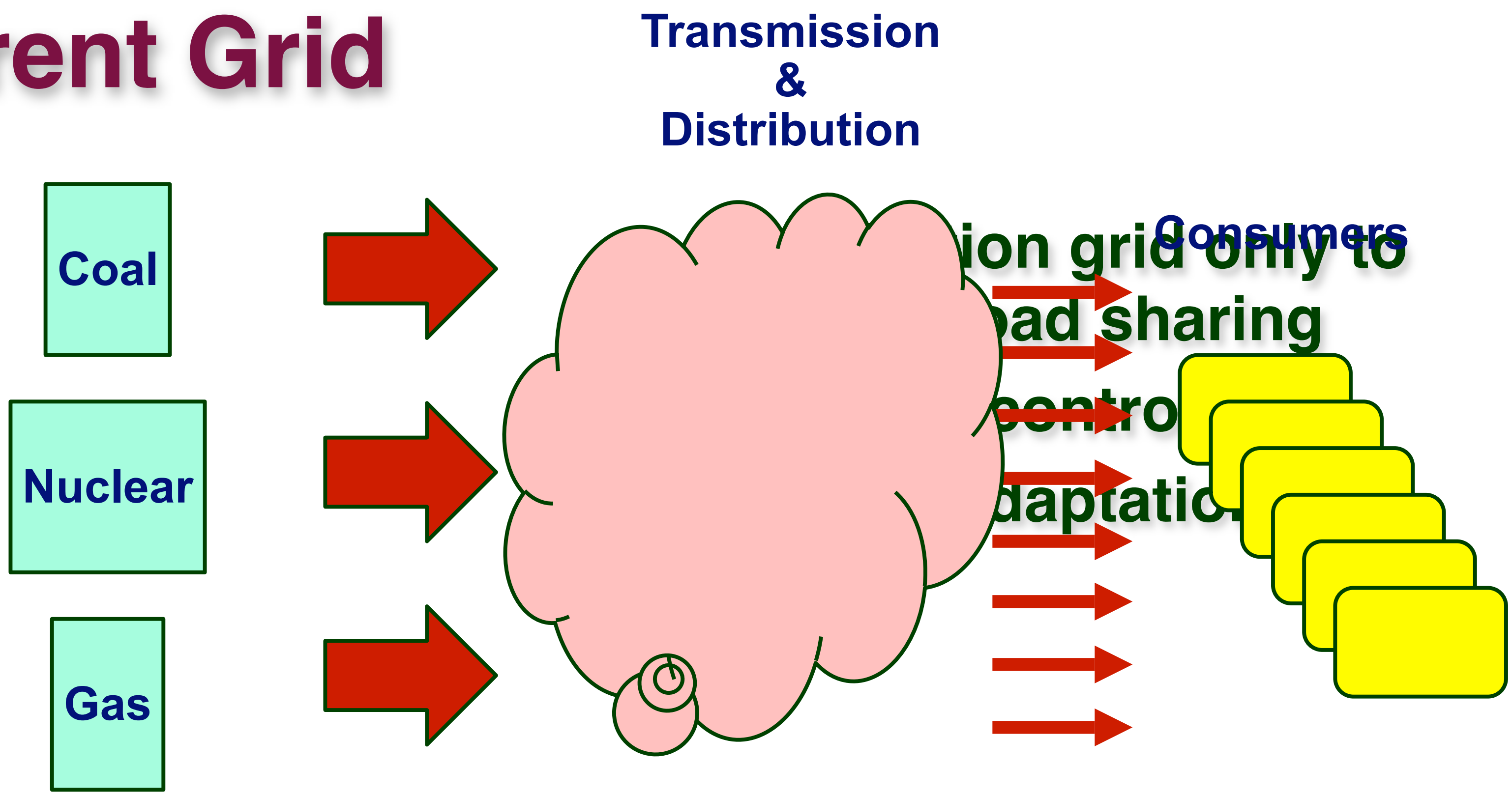
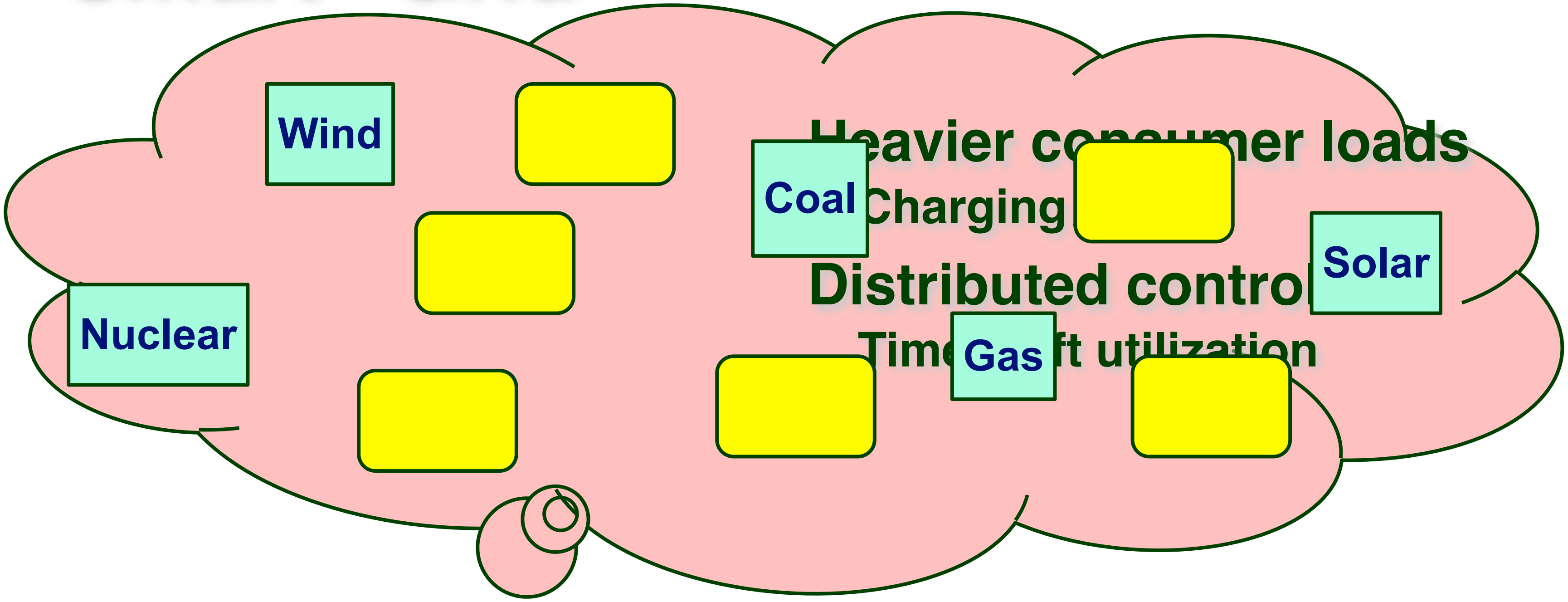
Current Grid



- Large, monolithic sources
- Increase / decrease output at will

“Smart” Grid



- **Small to large sources**
  - Including from “consumer”
- **Non-steady sources**
  - wind, sunlight

Changing Conditions

Generation / Transmission

- Range of sources
- Generation not always when needed
  - Calm weather, night time
- Generation not always where needed
  - High plains, offshore, deserts

Consumption

Higher loads

Charging electric car = 1 – 2 X household load

Willingness to time shift load

Willingness to make cost / consumption tradeoffs

Impediments

Fragmentation

- Different industries for generation, distribution, equipment, appliances, …
- Many rules, regulations, laws; controlled by many entities

Costs

- Large scale, complex system
- Long-term payoffs
- Lack of incentive for regulated monopolies
  - Payed based on output generation
  - Guaranteed profit

Reimagining the Grid

Berkeley LoCal Project

(1) pervasive information about energy availability and use,

(2) interactive load/supply negotiation protocols,

(3) controllable loads and sources, and

(4) logically packetized energy, buffered and forwarded over a physical energy network.

Lots of focus on data center power management

Technical Challenges

Energy Storage

- Batteries, compressed air, raised water tanks
- ~50% loss to store & retrieve
- Current grid tries to continually match supply to load

An Internet-Style Grid?

- Much harder to transmit or store joules than watts
- No Moore's Law

Tracking Energy Consumption

Lester Lavé (CMU public policy) Analogy

- **Go to supermarket. There are no prices on any products. You take what you think you need & can afford. You get sent a bill one month later.**

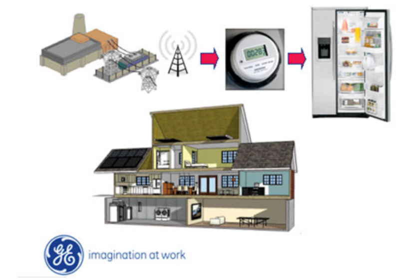
Measuring Consumption

- **Appliances that report their energy consumption**
  - Via wireless connection or over power lines
- **Machine learning to recognize power signatures**
  - Individual appliances; entire rooms
- **Issues**
  - Cost
  - Privacy
  - Ease of deployment

Household Consumption Control

PG&E "Smart" Meter

- Monthly, hourly, daily usage
- Notify you of up to 15 "smart days" per year
  - Rates set higher than normal from 2pm to 7pm
  - Up to you to decide whether / how to conserve



GE "Smart Appliances"

- Receive signal from power company when peak pricing in effect
- Appliance can be programmed to reduce load then

Problems

- People don't want to yield control
- People worry about their privacy
- It's not flexible/scalable

Enlightened Household Consumption

Your Home Knows You

- Who is there; what you are doing
- Your preferences and habits

Power Company & House Negotiate

- Electricity price changes based on load conditions
- Company provides futures market
  - When should it charge the car or wash the dishes
- House makes cost / convenience / comfort trade-offs
- Also detects and diagnoses anomalies

What About Privacy?

- House serves as consumption firewall
- Could add obfuscation, but at a price

Electric Vehicles

Current

- **Try to duplicate performance of gasoline car**
  - 200+ mile range
- **Requires lots of expensive batteries**
  - Frequent replacement

Alternative

- **Illah Nourbakhsh, CMU, Charge Car Project**
- **71% of commutes are < 24 km.**
  - Build lower cost commuter cars with less range
- **Batteries wear out with charge/discharge cycle**
  - Add supercapacitor as energy cache
- **Learn driving patterns**
  - Where are hills, stoplights, slow vs. fast travel

Tapping into the ARPA-E?

2009: Open Solicitation $151M

- 3700 concept papers
- 334 full proposals
- 37 funded projects

Funded Projects

- Solar, wind, & biomass-based energy generation
- Batteries, capacitors
- Energy conversion, waste heat capture
- Gas-powered engines, fuel cells
- Carbon capture
- Low-cost LED lighting
- Energy efficient desalination
- *Sensor-rich buildings (Stanford, $5M)*

Tapping into the ARPA-E?

Recent Solicitatiions

2009 ($100M)

- Generating fuel from CO_2 with microorganisms
- Carbon capture
- Batteries

2010 ($100M)

- Cost-effective, grid-scale energy storage
- Materials for magnetics, switches, charge storage
  - Apply to power conversion
- Efficient cooling (air conditioning, refrigeration)

Promising CS Research Areas

Cyberphysical systems

- Sensors
- Self-monitoring, self-diagnosing systems

Machine Learning / Operations Research

- Optimizing placement / design of infrastructure
- Learning preferences & patterns
- Market-based pricing and allocation

Human-Computer Interaction

- Capturing user preferences
- Balancing information availability & privacy