Achieving Sustainable Energy:

New Approaches Based on the Tools of Computer Science

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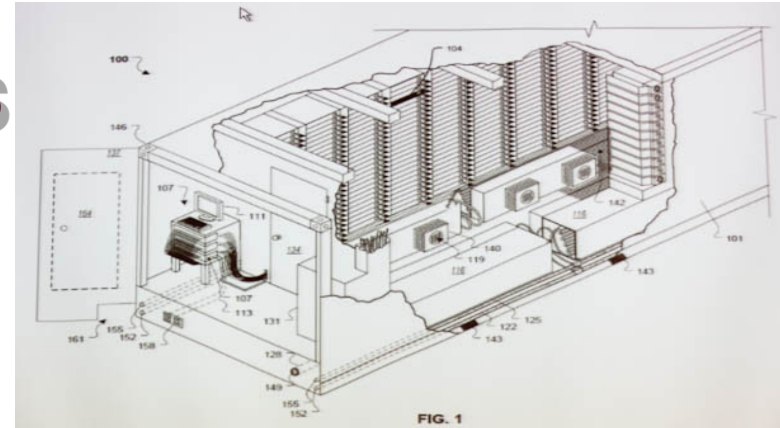
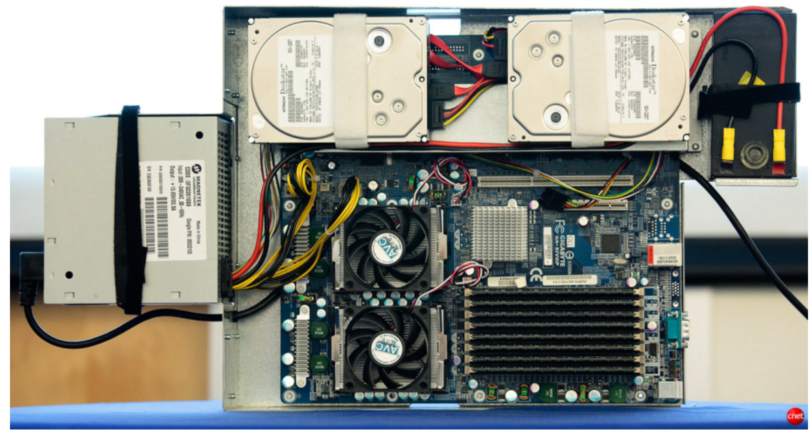
Google Data Centers



Dalles, Oregon

- **Hydroelectric power @ 2¢ / KW Hr**
- **50 Megawatts**
  - Enough to power 6,000 homes



- **Engineered for maximum modularity & power efficiency**
- **Container: 1160 servers, 250KW**
- **Server: 2 disks, 2 processors**

IT and Energy

Data Center Power

- The topic of choice for many computer scientists
- Interesting problems, lots of progress
- ~2% of US power consumption

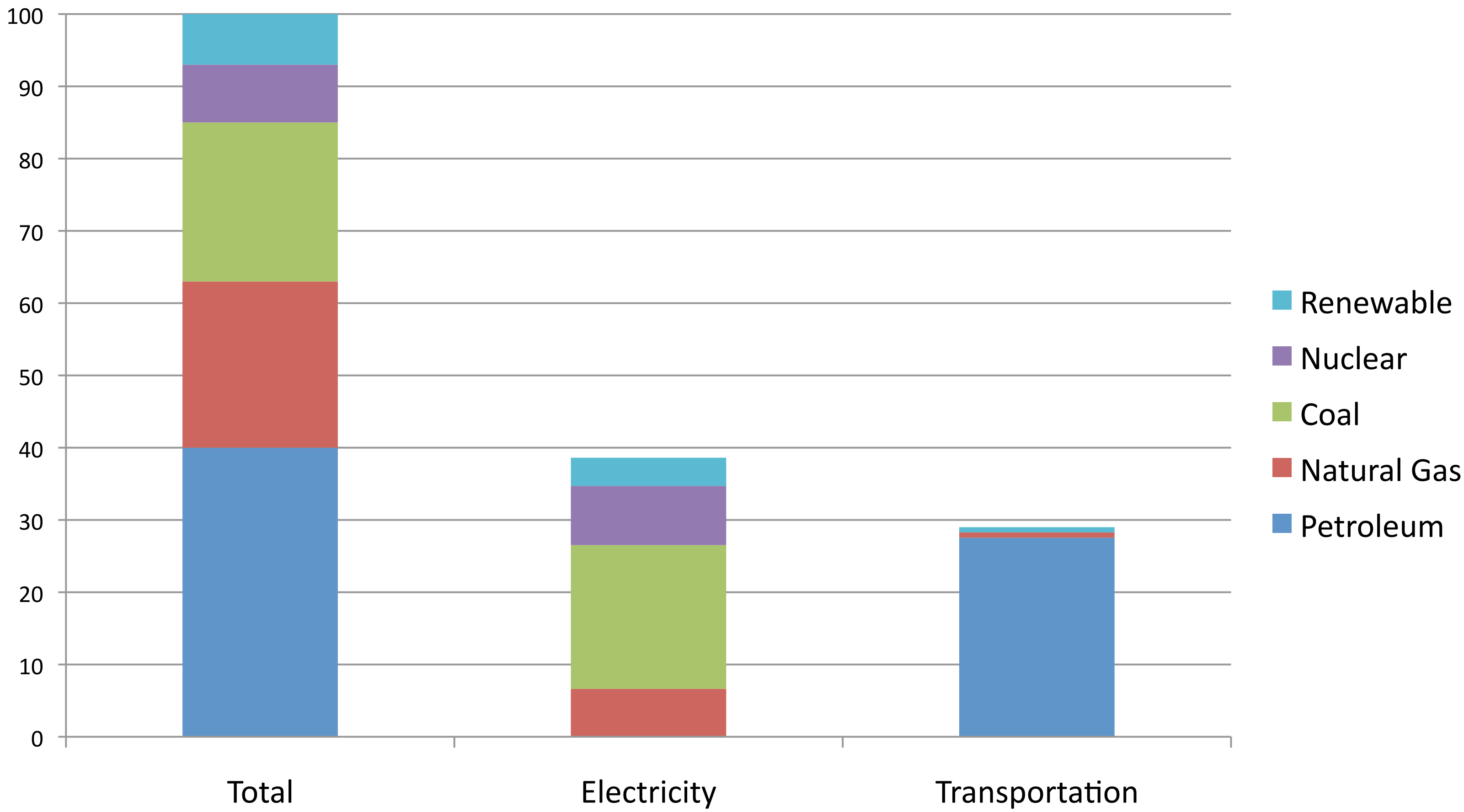
Beyond Data Centers

- How can IT fundamentally improve the processes of electricity generation, transmission, and consumption?
- How can computer scientists contribute?
  - With ideas & approaches that our counterparts in electrical engineering, mechanical engineering, & civil engineering would not think of

➢ Computational thinking for energy

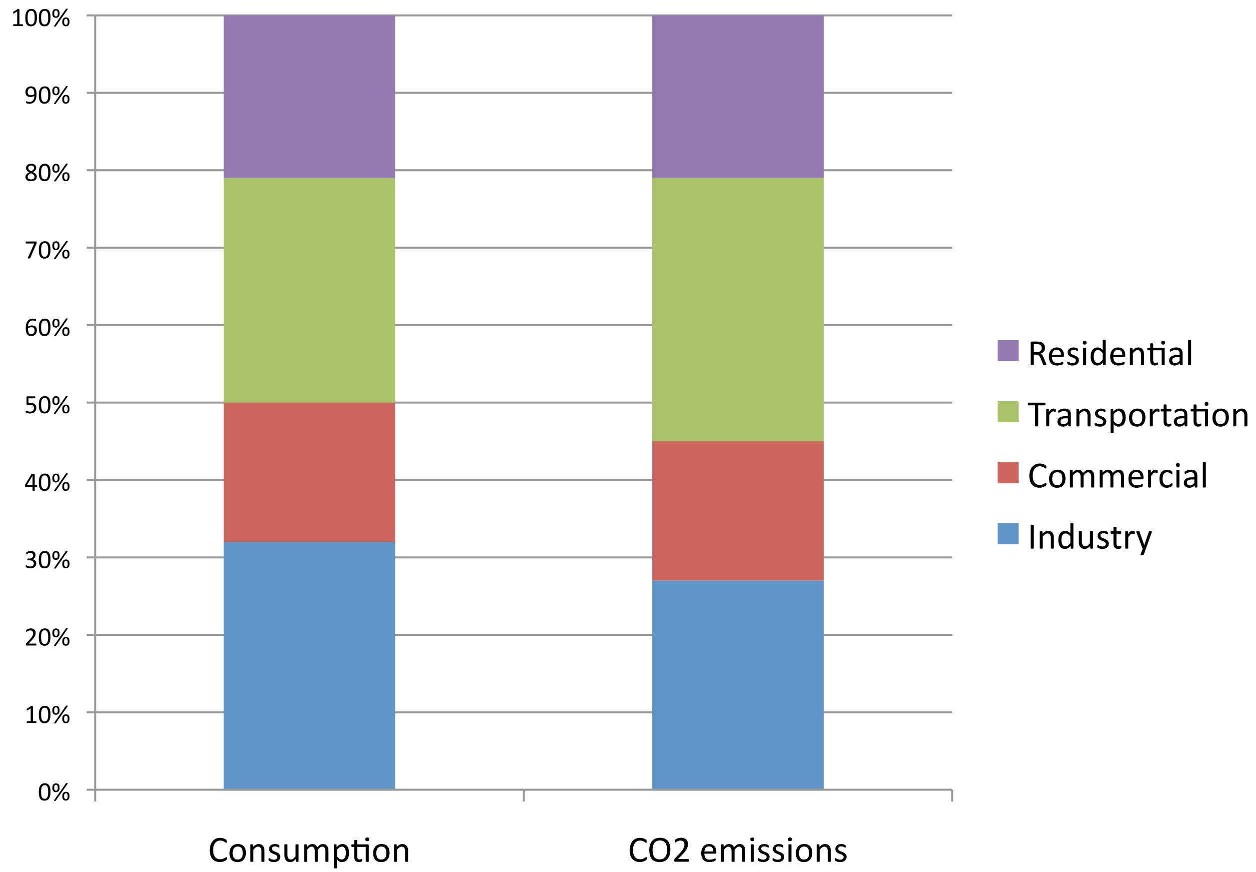
US Energy Basics: Generation

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

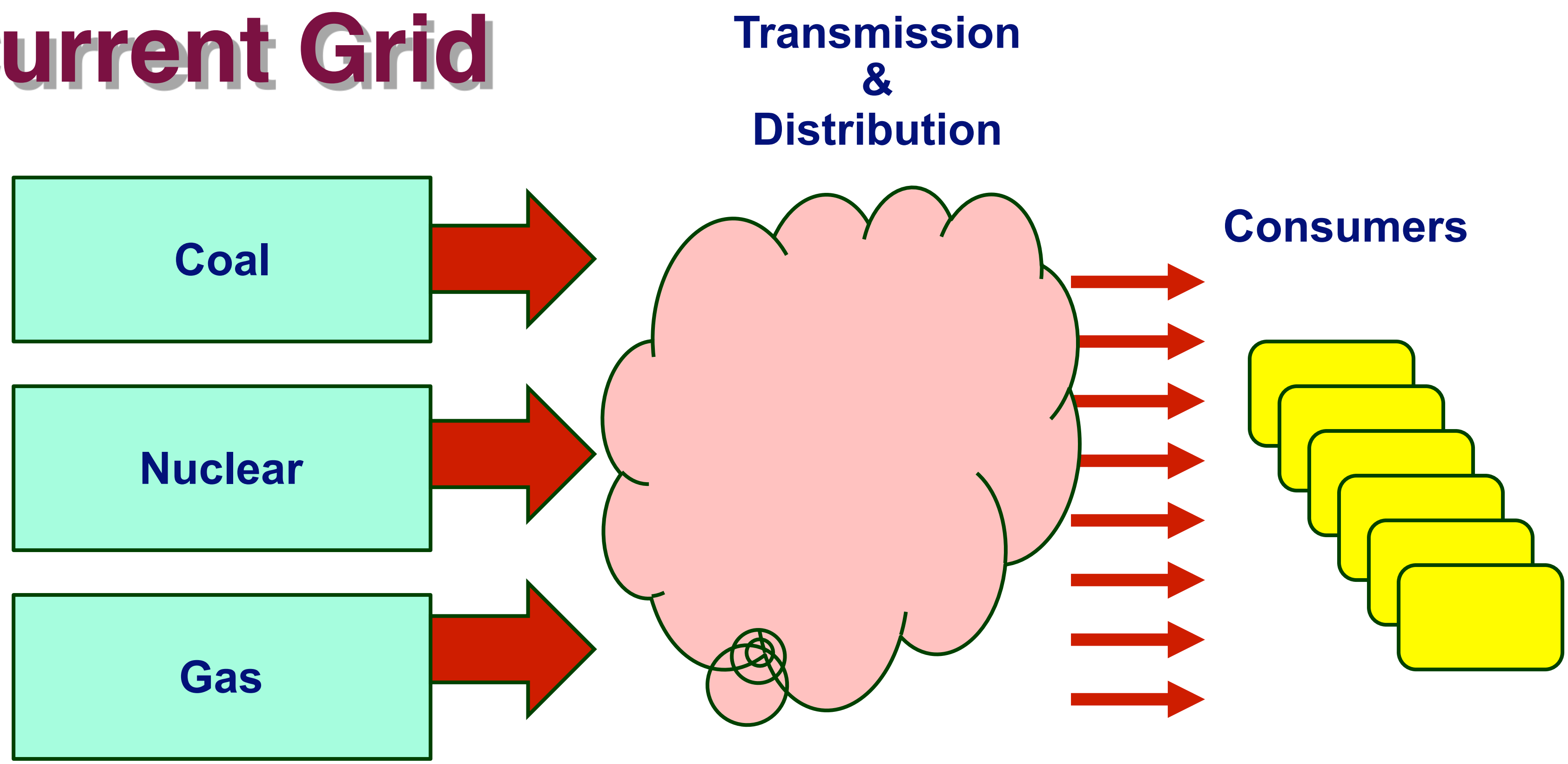


US Energy Basics: Consumption

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

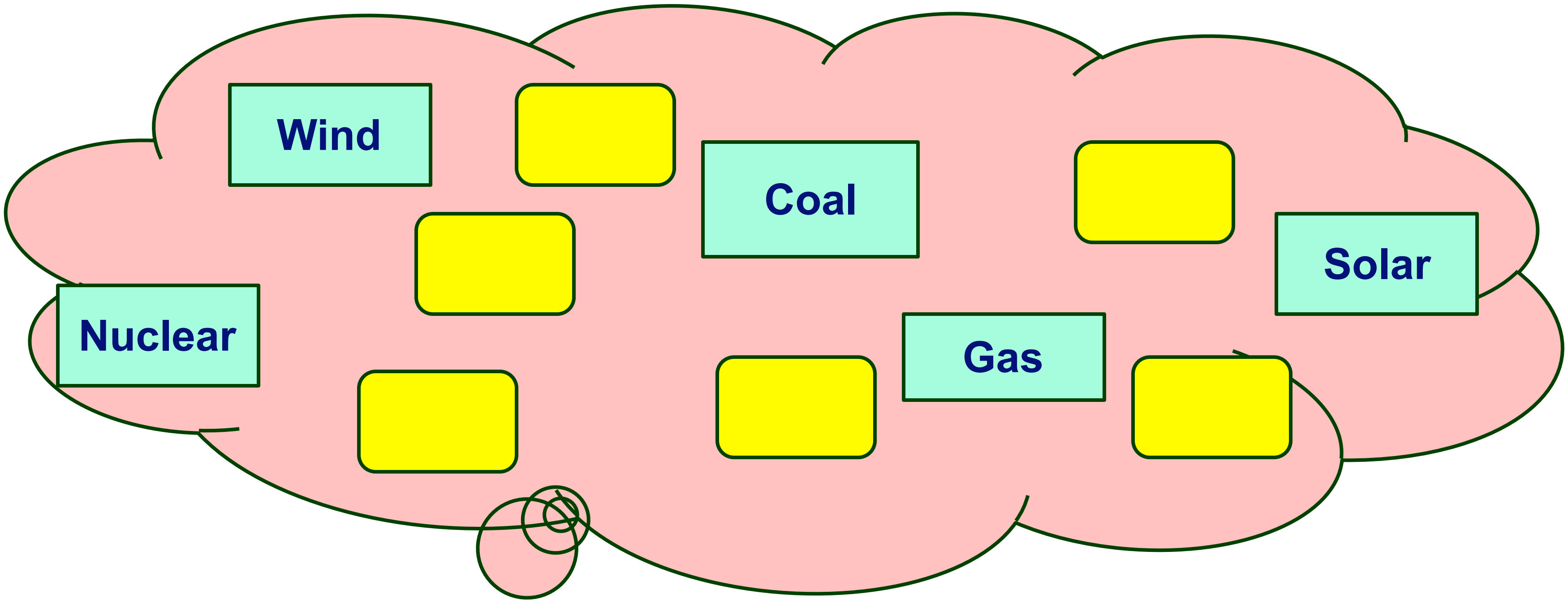


Current Grid



- Large, monolithic sources
- Increase / decrease output at will
- Distribution grid only to allow load sharing
- Centrally controlled
- Minimal adaptation

"Smart" Grid



- **Small to large sources**
  - Including from "consumer"
- **Non-steady sources**
  - wind, sunlight
- **Heavier consumer loads**
  - Charging cars
- **Distributed control**
  - Time shift utilization

Changing Conditions for Grid

Generation / Transmission

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

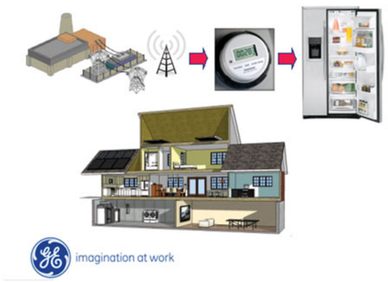
Consumption

- **Higher loads**
  - Charging electric car = 1 – 2 X household load
- **Willingness to time shift load**
- **Willingness to make cost / consumption tradeoffs**

Today's "Smart" Grid

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

Key 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 bytes
- No Moore's Law
- But, some principles can be adapted

Techno-Political 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**
  - Paid based on output generation
  - Guaranteed profit

Panelists

- Point way to fundamental capabilities enabled by IT

David Culler, UC Berkeley

- Applying network technology to supply & consumption sides of grid

Shwetak Patel, U Washington

- Low cost energy consumption monitoring

Illah Nourbakhsh, Carnegie Mellon

- New thinking about electric vehicle design, manufacturing, and use

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

Funding Opportunities

NSF SEES Program

- **Energy, climate, environment**
- **FY 2011 request: $766M total, $26M for CISE**
  - This is a high priority topic!
- **CISE needs participation & leadership**
  - Looking for program director

Funding Opportunities (cont.)

Department of Energy?

- **Current prospects not good**
  - Most of the funding for core technology (batteries, solar cells, …
  - They see IT mostly as a way to simulate and model energy systems
- **Future prospects**
  - There are some people within DoE who understand potential role of IT
  - CCC is trying to expand understanding

What’s Needed?

- **Projects that demonstrate new possibilities**
- **Leadership from within CS community**