DOE Building Technologies Office (BTO):

Some History, Buildings and the Grid

Florida Energy Systems Consortium (FESC) Conference, Orlando, Florida, May 20 – 21, 2015

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Jim Payne (jim.payne@ee.doe.gov)

May 21, 2015

Some History

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President Jimmy Carter speech: April 18, 1977

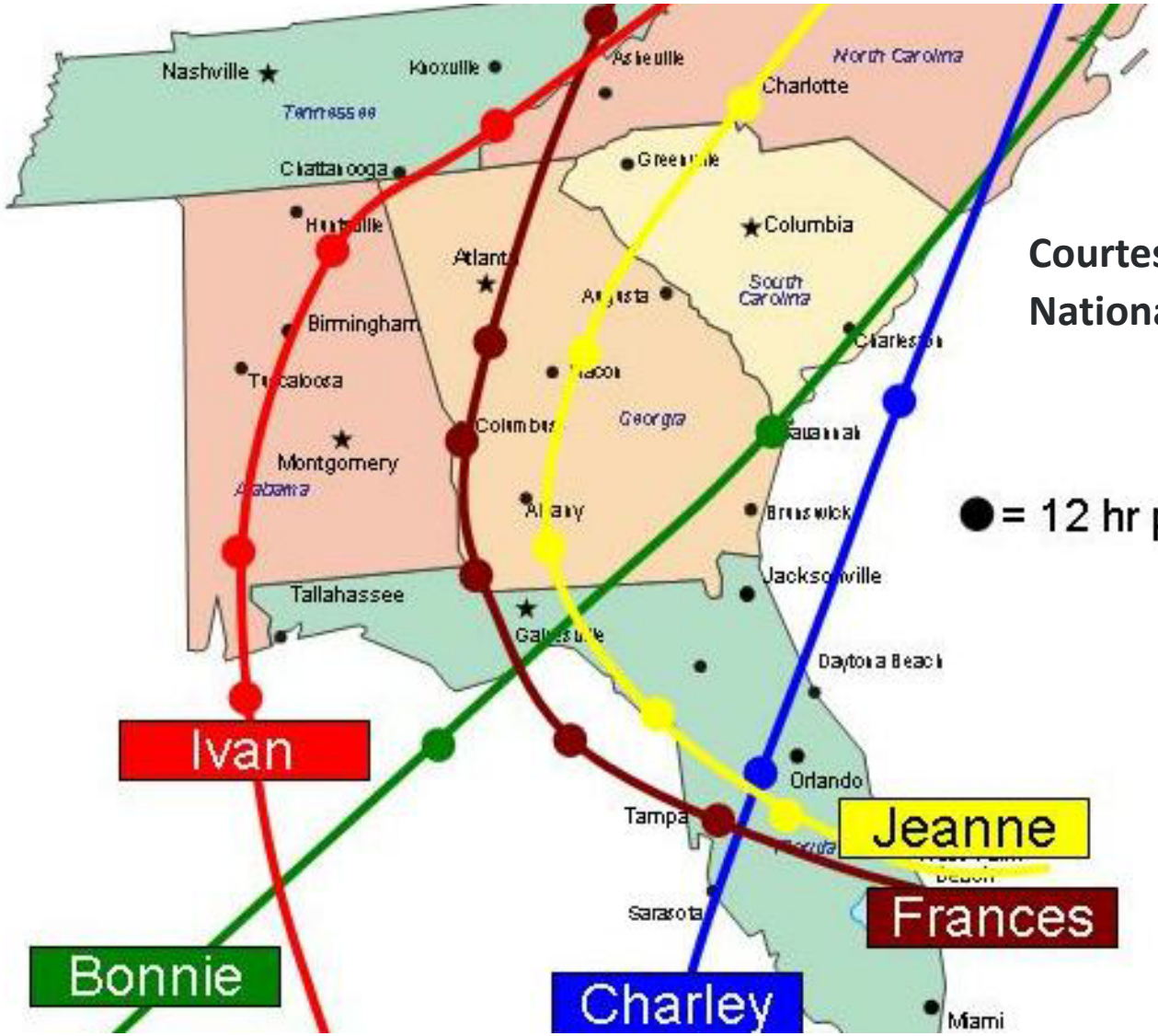
DOE created on August 4, 1977

A Vision – Creating the Department of Energy

1. **Have an effective and comprehensive energy policy**
2. **Healthy economic growth must continue. Only by saving energy can we maintain our standard of living and keep our people at work.**
3. **Protect the environment.**
4. **Reduce our vulnerability to potentially devastating embargoes (aka Energy Security)**
5. **The cornerstone of our policy is to reduce the demand through conservation.**
6. **Government policies must be predictable and certain**
7. **Develop the new, unconventional sources of energy we will rely on in the next century.**

Jimmy Carter, "The President's Proposed Energy Policy." 18 April 1977.
Vital Speeches of the Day, Vol. XXXXIII, No. 14, May 1, 1977, pp. 418-420.

2004 Hurricane Season



Courtesy:
National Weather Service

● = 12 hr position

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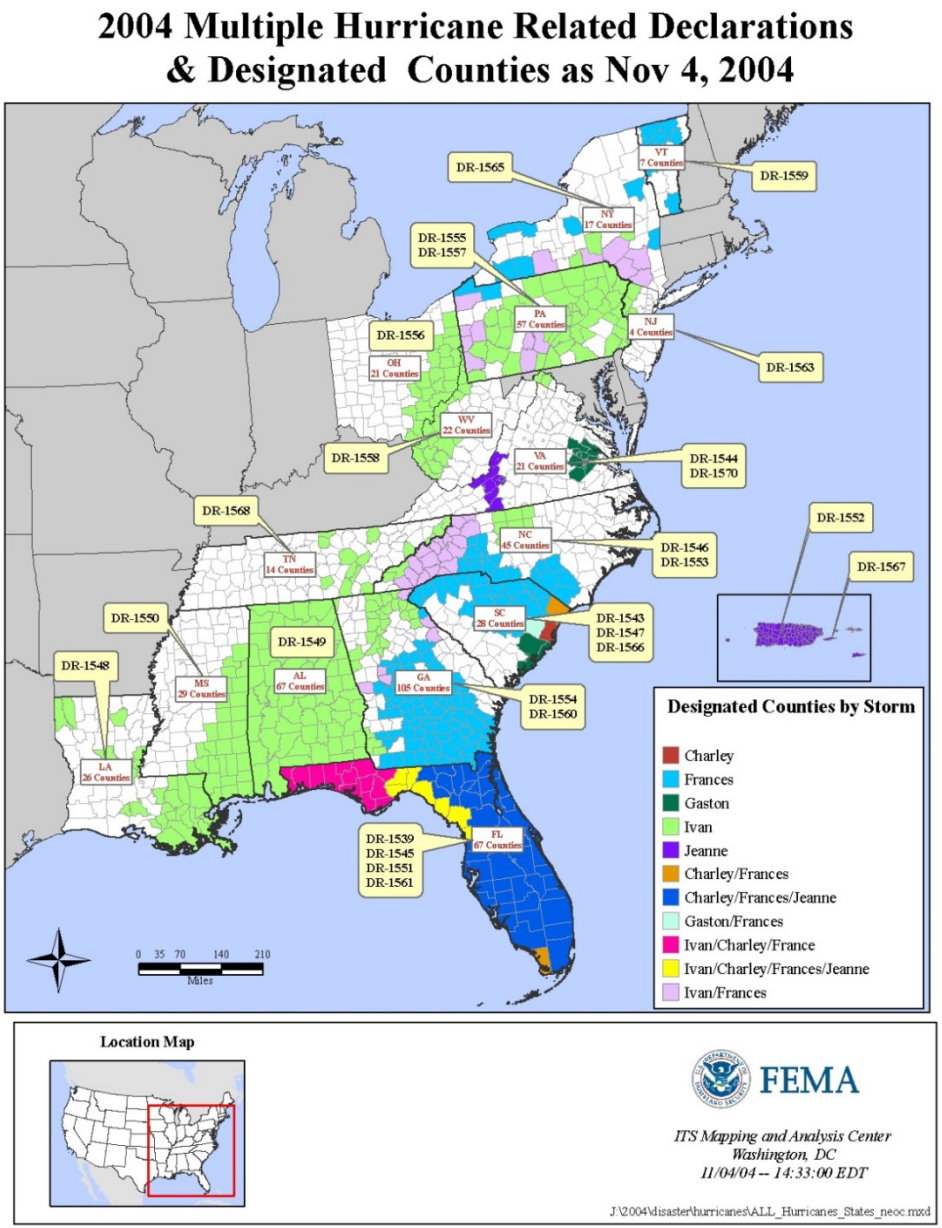
Counties Affected by the 2004 Hurricanes



Florida Hurricanes

Name	Category	Landfall	From	To
Charlie	4	8/13	8/9	8/14
Frances	4	9/2	8/24	9/8
Ivan	5	9/16	9/2	9/24
Jeanne	3	9/26	9/13	9/28
Bonnie	0		8/3	8/13

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PG&E Utility Substation Attack

Pacific Gas and Electric suffered an attack on its Metcalf Transmission Substation near San Hose, CA in April of 2013. There is a $250K reward offered to assist Law Enforcement with the investigation.

Gunfire caused significant damage, with more than a hundred rounds expended. The weapon(s) used may have been an AK-47.

Security Video:

https://www.youtube.com/watch?v=RQzAbKdLfW8

PG&E Announcement

http://www.pge.com/about/newsroom/newsreleases/20140410/pge_announces_reward_for_information_on_metcalf_substation_attack.shtml

The Grid

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What Was And Is And Is To Come

In Amory Lovins 2011 book 'Reinventing Fire' he discusses electrical power systems (the grid) in four Scenarios (page 168):

1. **Maintain – Business as usual with some PV, and a few plug in electric cars. Centralized power is king.**
2. **Migrate – A carbon reducing environment, more environmentally focused. Centralized power remains king.**
3. **Renew – Significant renewable energy generation. Centralized power remains king.**
4. **Transform – Significant renewable energy generation, coupled with significant distributed generation and local and centralized energy storage. The birth of the micro-grid on a national scale. Major Change.**

The fourth scenario Transform holds the promise for the greatest gains and most significant challenges.

Smart Grid Efforts within DOE

Goals include higher energy efficiency, improved asset utilization, integrating distributed energy sources with utilities, and improved redundancy, robustness and security

DOE Offices working on Grid Integration:

Office of Electricity Delivery & Energy Reliability

Energy Efficiency and Renewable Energy Offices:

Wind and Water

Hydrogen and Fuel Cells

Solar

Buildings

Vehicles

DOE Expects to Promote and Enable This Vision

The future energy economy will include an open, interoperable transaction system that facilitates physical transactions of energy, energy related services, and the financial settlements associated with these transactions. The characteristics of this system will include the development of common data taxonomy, robust open communication interfaces, and monetization scenarios for products and services for this fully integrated grid environment.

Joe Hagerman – Senior Policy Advisor for DOE/Buildings

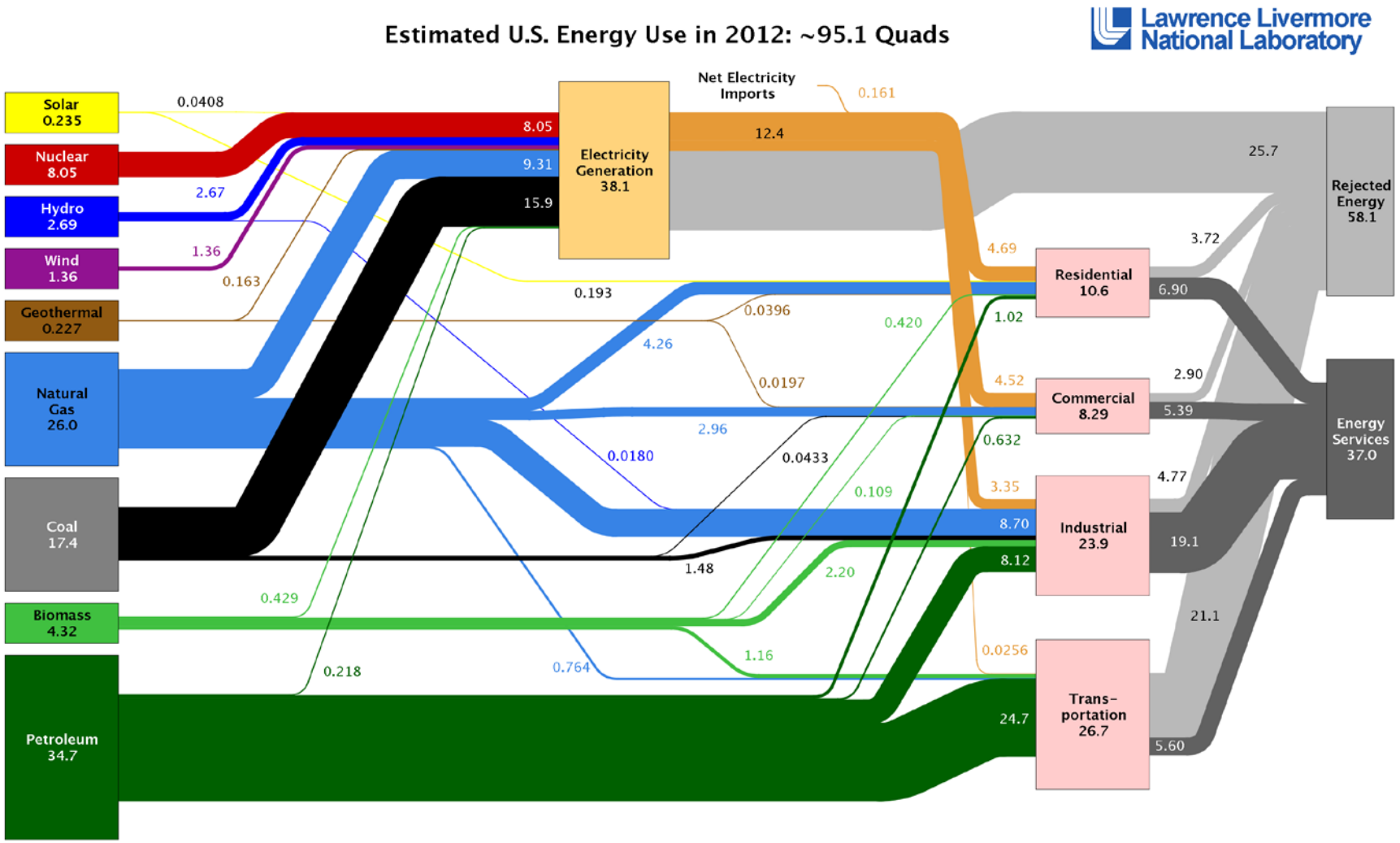
Buildings to Grid Integration Technical Meeting:

National Renewable Energy Laboratory, Energy Systems Integration Facility

Golden, CO

December 2012

Power – Source to Load/Loss (The Opportunity)



https://www.llnl.gov/sites/default/files/field/image/28228_flowcharthighres.png

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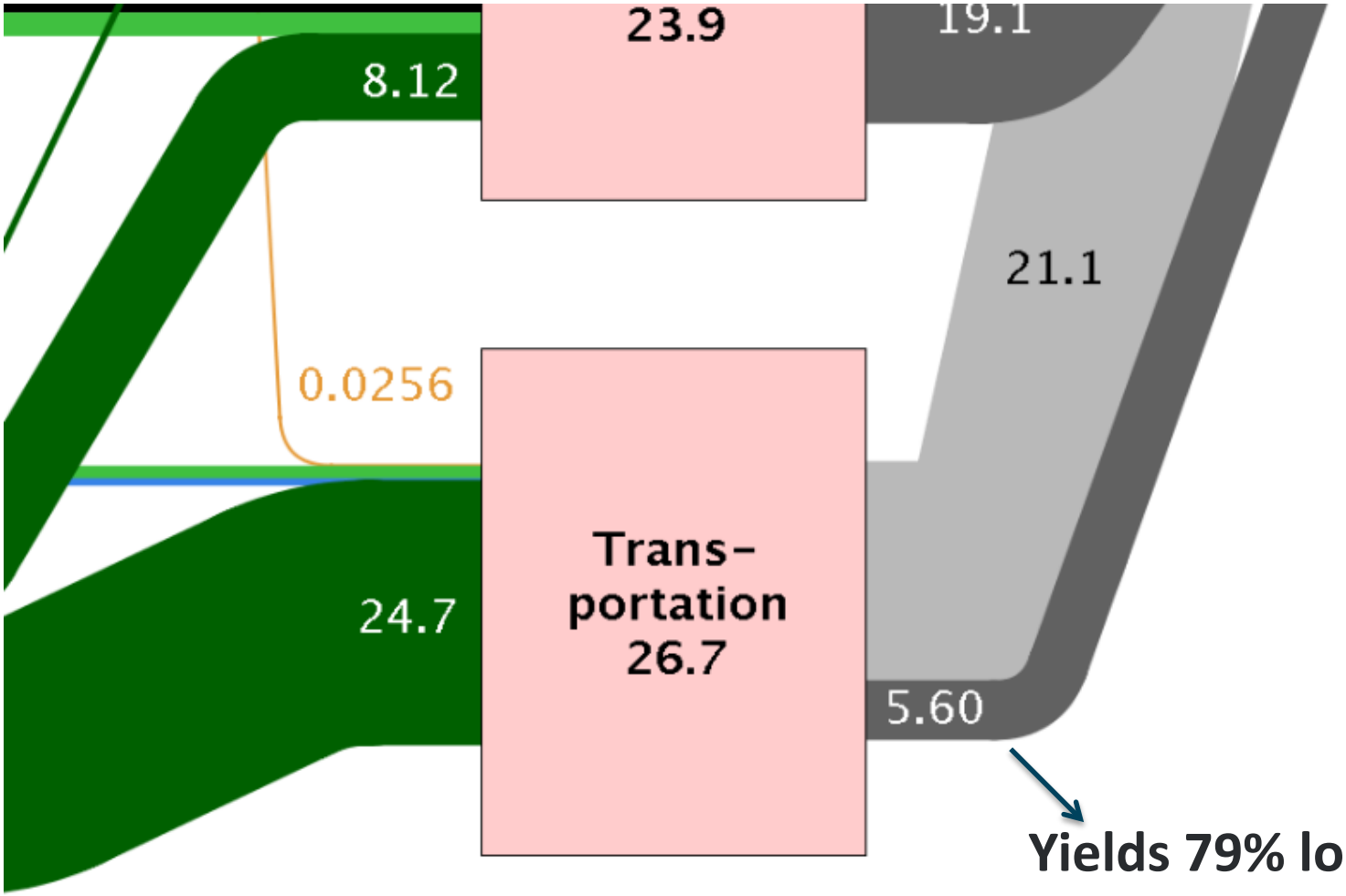
Transportation Sector (Energy in Quads)



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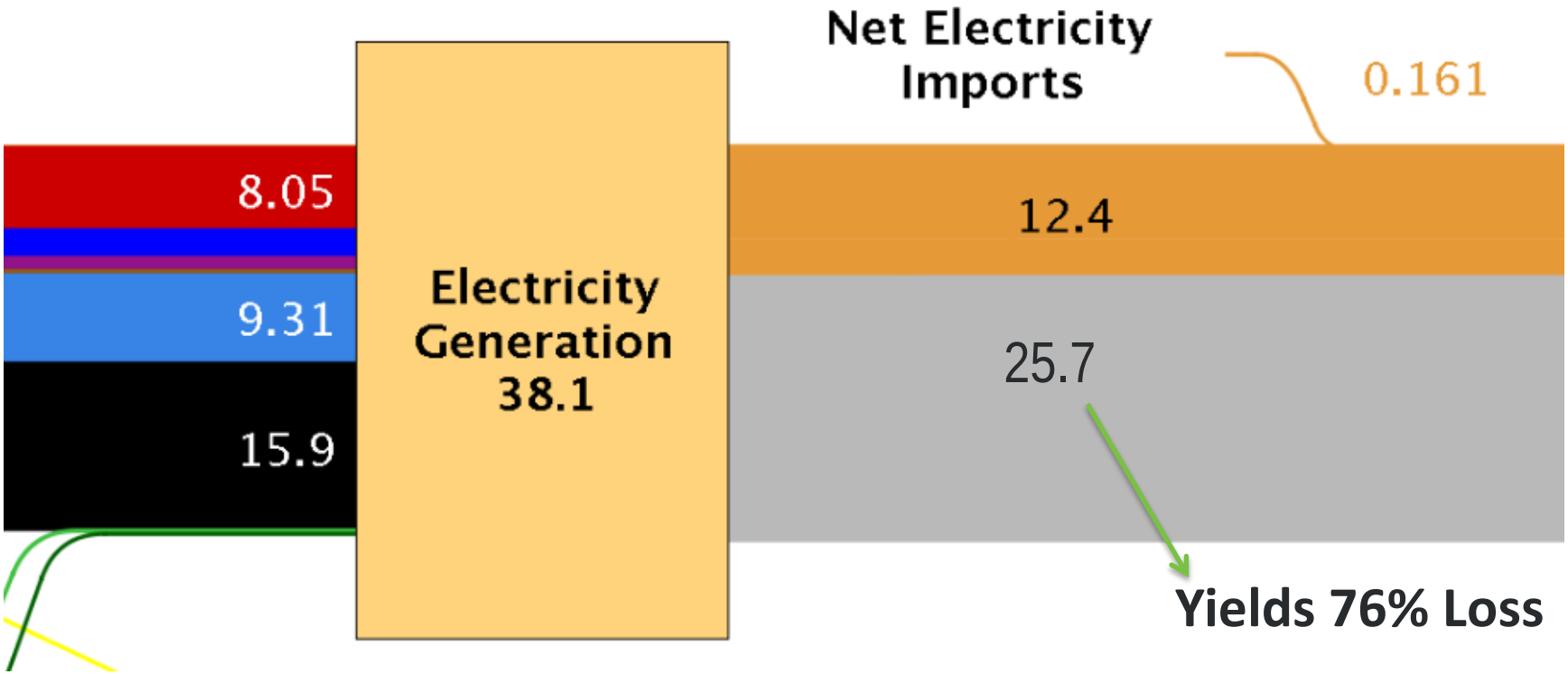
Power Generation and Distribution (Energy in Quads)



Transmission and distribution accounts for 6% of this loss

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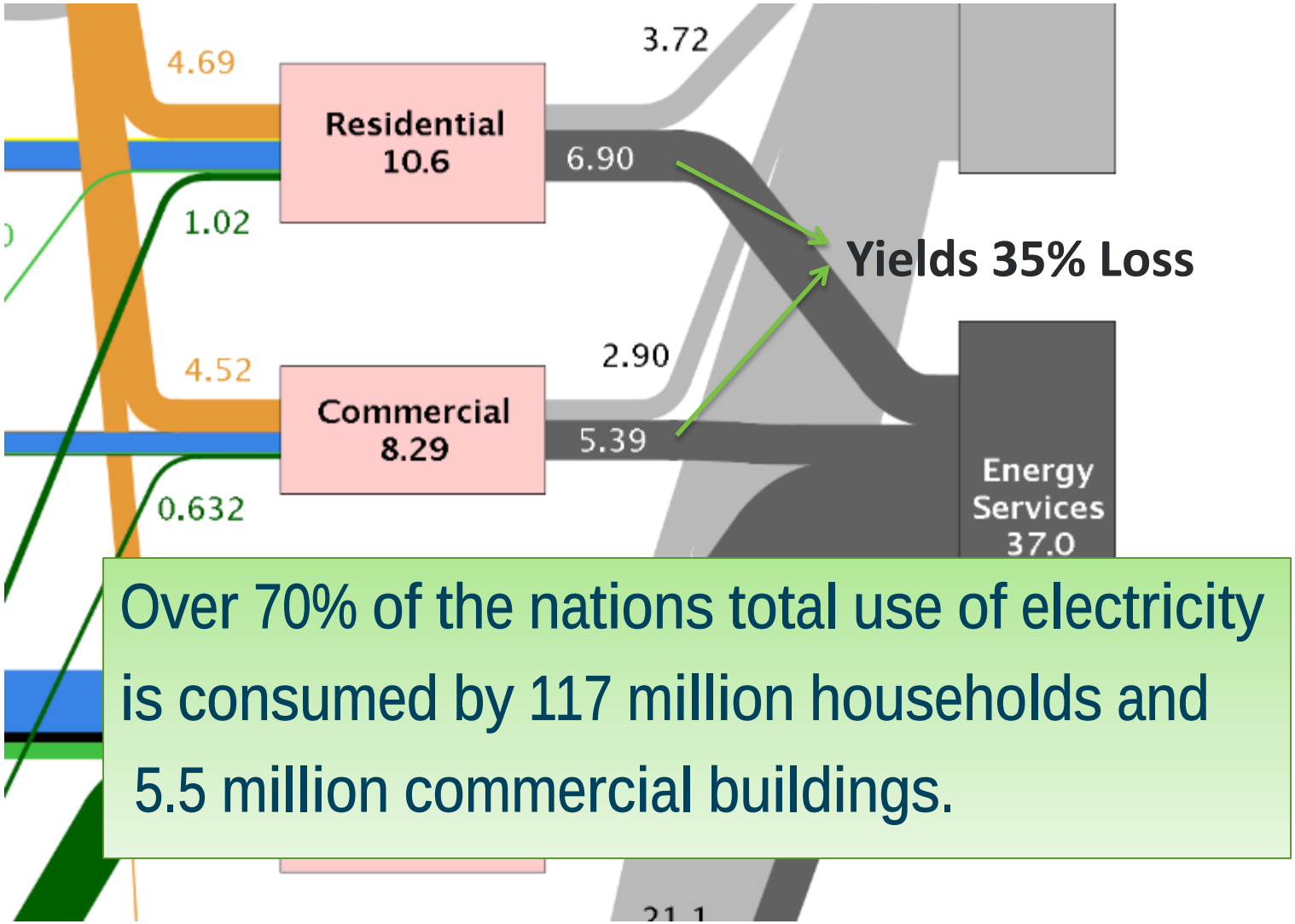
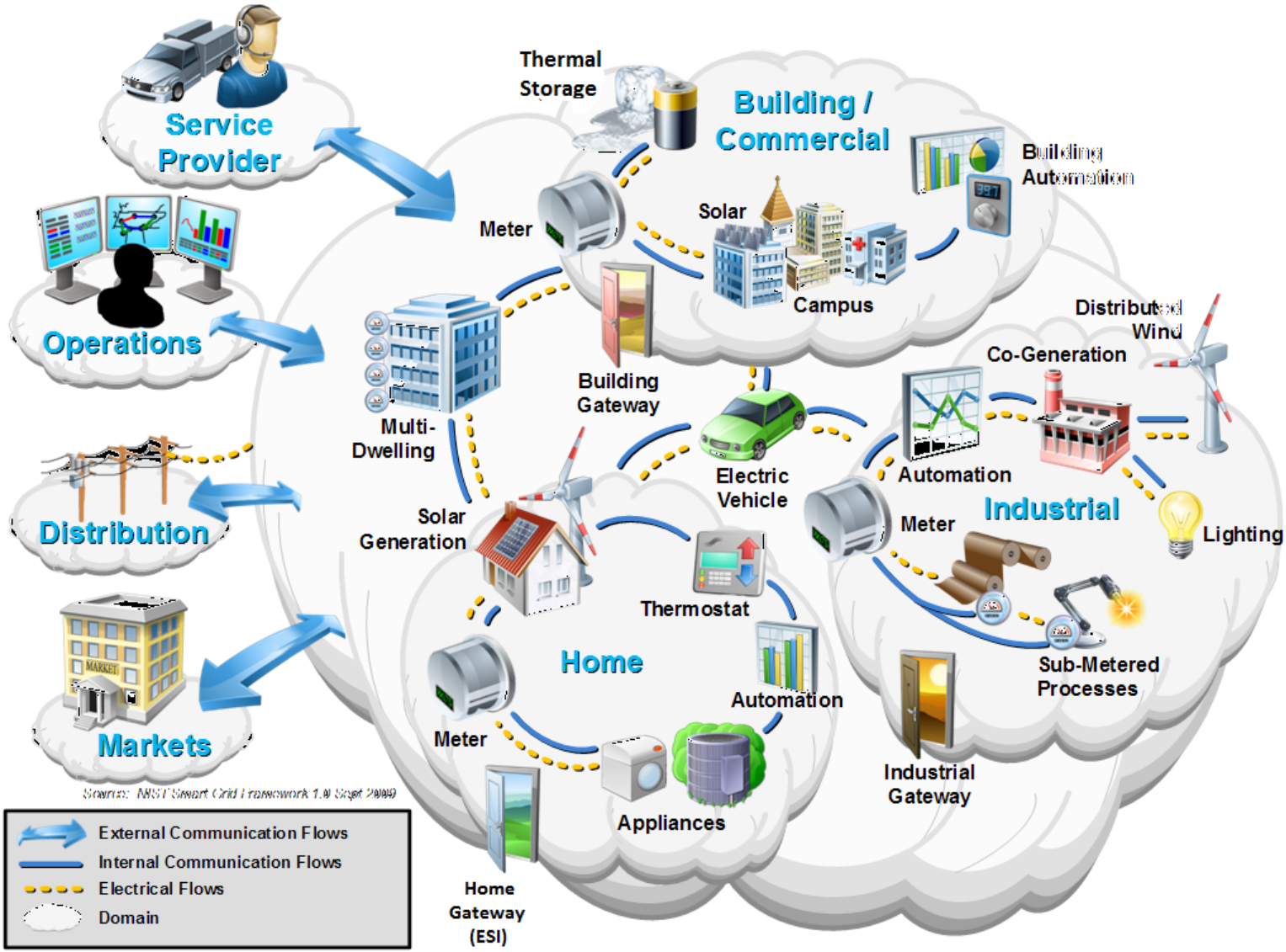
Residential and Commercial Sector (Energy in Quads)



Over 70% of the nations total use of electricity is consumed by 117 million households and 5.5 million commercial buildings.

http://www.eia.gov/energyexplained/index.cfm?page=electricity_use

Transform The Grid – Using Energy Transactions



Buildings

What are we doing now? A Sampling…..

Three Projects:

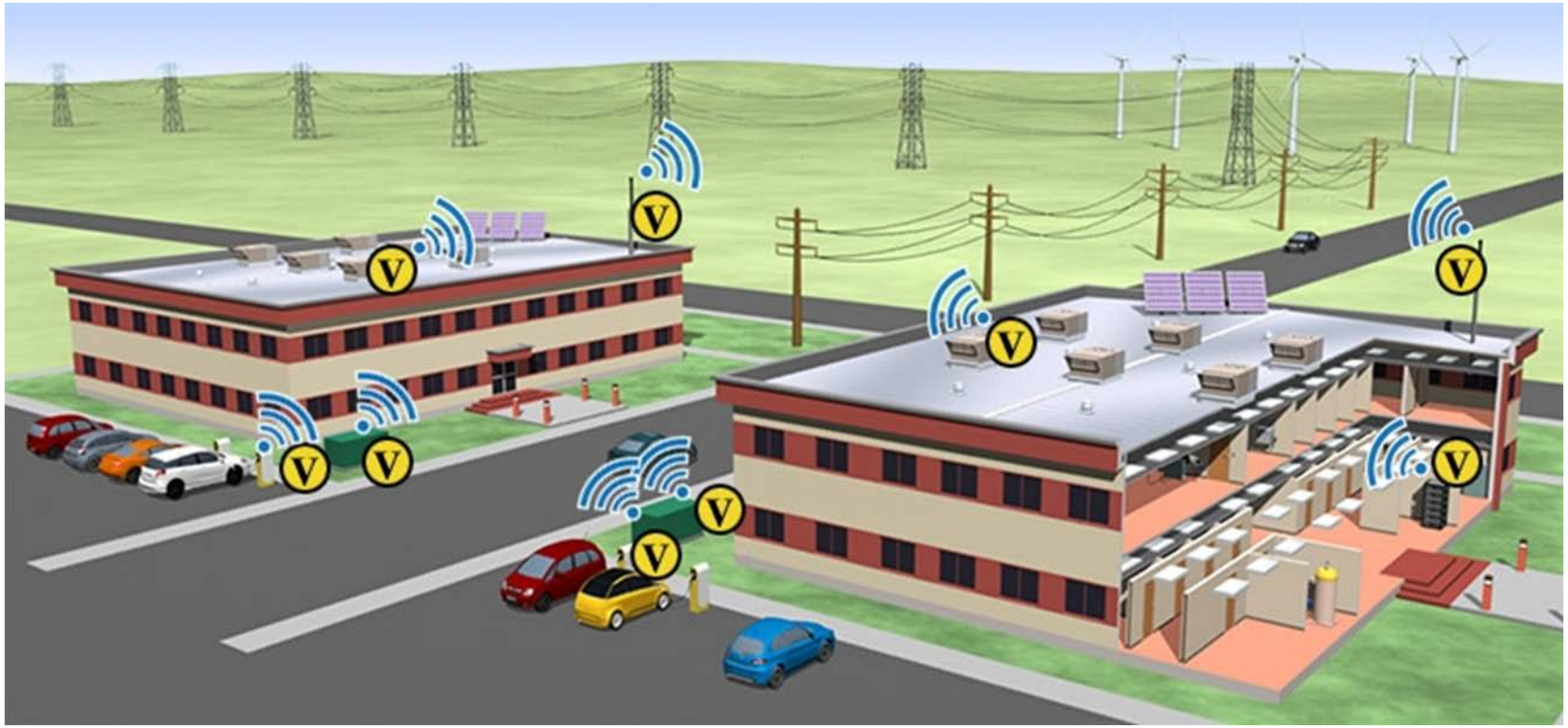
1. **PNNL - VOLTTRON**
2. **Virginia Tech - BEMOSS**
3. **PNNL, LBNL and ORNL – Retro Commissioning**

PNNL – Pacific Northwest National Laboratory (WA)

LBNL – Lawrence Berkeley National Laboratory (CA)

ORNL – Oak Ridge National Laboratory (TN)

VOLTTRON™ developed at PNNL



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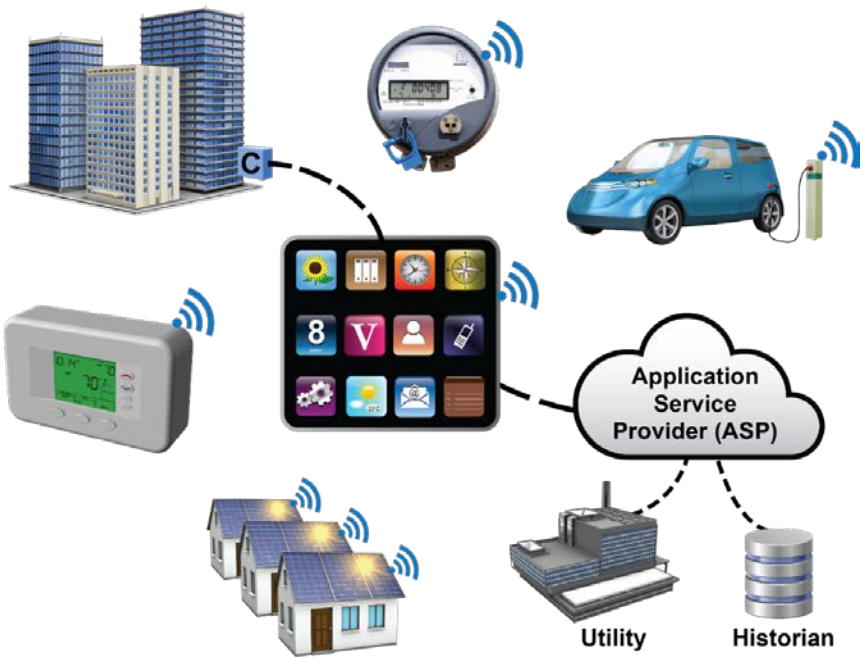
What is VOLTTRON?

- VOLLTRON is an application platform (e.g., Android, iOS) for distributed sensing, monitoring and controls applications
- VOLTTRON is open source, flexible and scalable
- It includes a suite of applications already implemented to perform transactions for improving energy efficiency and providing grid services



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What VOLTTRON is NOT

- A fully realized commercial grade product with a suite of applications already implemented to perform transactions
  - It enables application development, but in and of itself, it is not an energy efficiency solution
- A protocol
  - Protocols, such as SEP 2.0. (Smart Energy Profile) or OpenADR, are implemented as applications
- An application, such as demand response
  - DR can be implemented as an application

VOLTTRON Attributes

Open, flexible and modular software platform

- **Easy application development**
- **Enables interoperability across vendors and applications**
- **Simplifies power and control system complexities for developers**
- **Object oriented, modern software development environment**
- **Language agnostic. Does not tie the applications to a specific language**

$50 Beagle Bone Black CPU Board

Ruby C C#
C++ Python
Java Perl

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VOLTTRON Attributes (continued)

- Broad device and control systems protocols support built-in
  - ModBUS, BACNet, and others
  - Multiple types of controllers and sensors
  - Low CPU, memory and storage footprint requirements
  - Supports non-Intel CPUs
- Secure
  - Security libraries and cryptography built-in
  - Manage applications to prevent resource exhaustion (CPU, memory, storage)
  - Robust against denial-of-service (e.g. does not crash when scanned via NMAP)
  - Supports modern application development environments

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VOLTTRON Is Secure

- VOLTTRON Open Source
  - Encrypted multi-node communication
  - SSL to external resources supported
- VOLTTRON PNNL IP
  - Agent validation – Signed agent code validated before execution
  - Agent packaging – Agent code and files signed at each stage of development/deployment
  - Resource management – Agents present resource contract. Platform determines if it can support agent and manages resource utilization during agent execution
- VOLTTRON 3.0+ Proposed Security Enhancement
  - Hardening and penetration testing
  - Sandboxing applications

Load Management Using VOLTTRON

Transformer assigns energy consumption goals via VOLTTRON messaging

EVs share information with each other to coordinate Their charging via VOLTTRON application

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Frequency and voltage support using VOLTTRON

- Management and integration of distributed storage
  - For voltage & frequency support
  - For integration of renewables
    - Wind-following or wind-compensating
    - Generation time-shift for solar
  - Utility-aware control of vehicle-to-grid

- Enable true two-way power flow for rooftop PV
  - Allow utility to have better awareness of PV generation
  - Use PV inverters for support of voltage or frequency

Gaining Research Acceptance & Increasing Commercial Interest

A National User Community

Oak Ridge National Laboratory

NREL

Berkeley Lab
Lawrence Berkeley National Laboratory

Virginia Tech VT

Drexel University

Case Western Reserve University
Est. 1826

UTSA
University of Texas at San Antonio

Montana State

Fresno State
California State University, Fresno

University of Victoria

State University of New York at Binghamton
Unity Identity Excellence
1946

Commercial Users

transformativewave

Siemens

Energy Analytics

Energy Analytics & Consulting

Emerson Climate Technologies

Johnson Controls

MelRok

BOSCH

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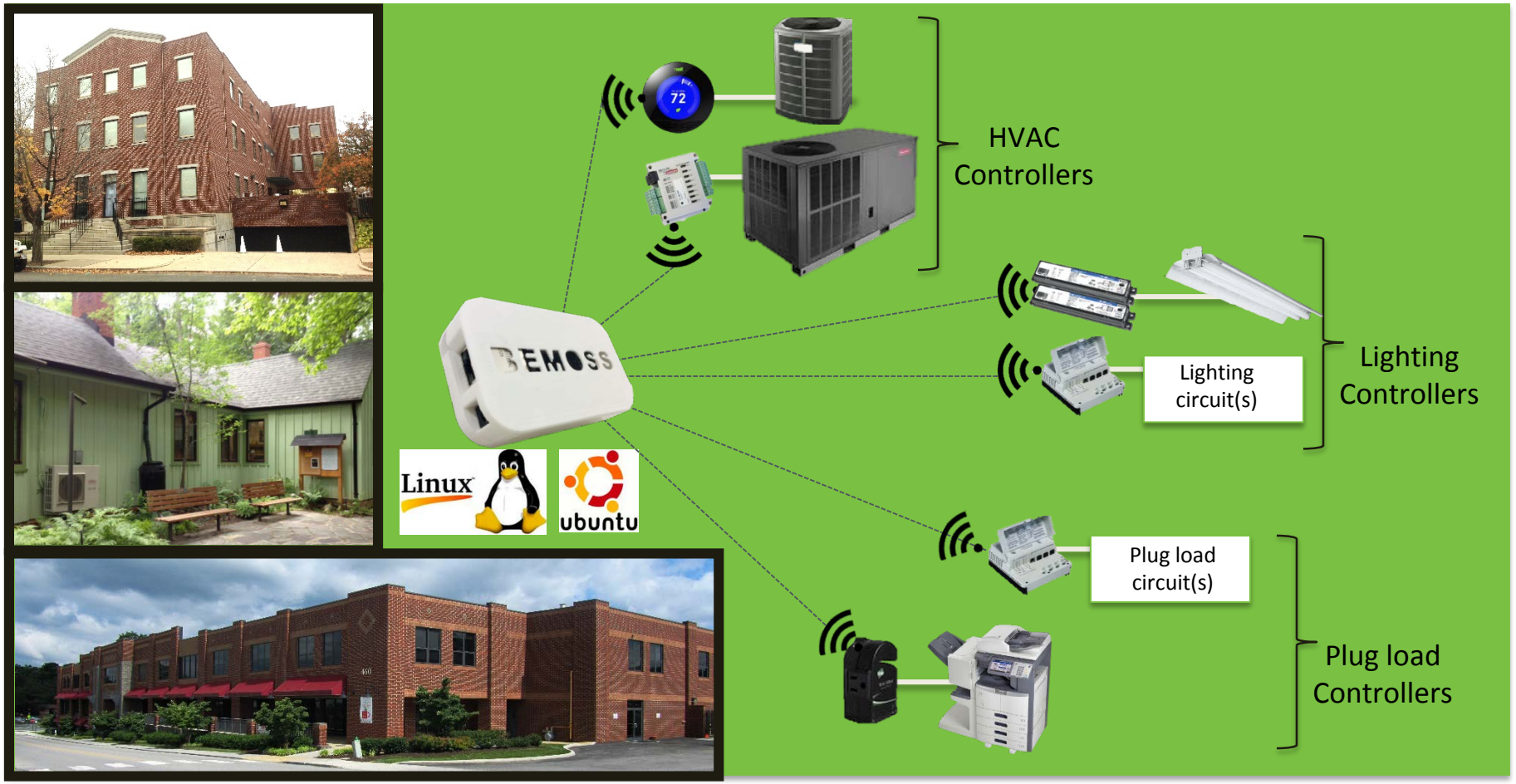
Building Energy Management Open Source Software

BEMOSS is an operating system that is engineered to improve sensing and control of equipment in small and medium sized commercial buildings



Virginia Tech - Advanced Research Institute
900 N Glebe Rd., Arlington, VA 22203

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BEMOSS is Built upon Open-Source Software

VOLTTRON™ was used as a platform to host our BEMOSS solution. It is open-source and not hardware specific.

Linux

ubuntu

Other software used:

python

C++

jQuery
write less, do more.

JavaScript

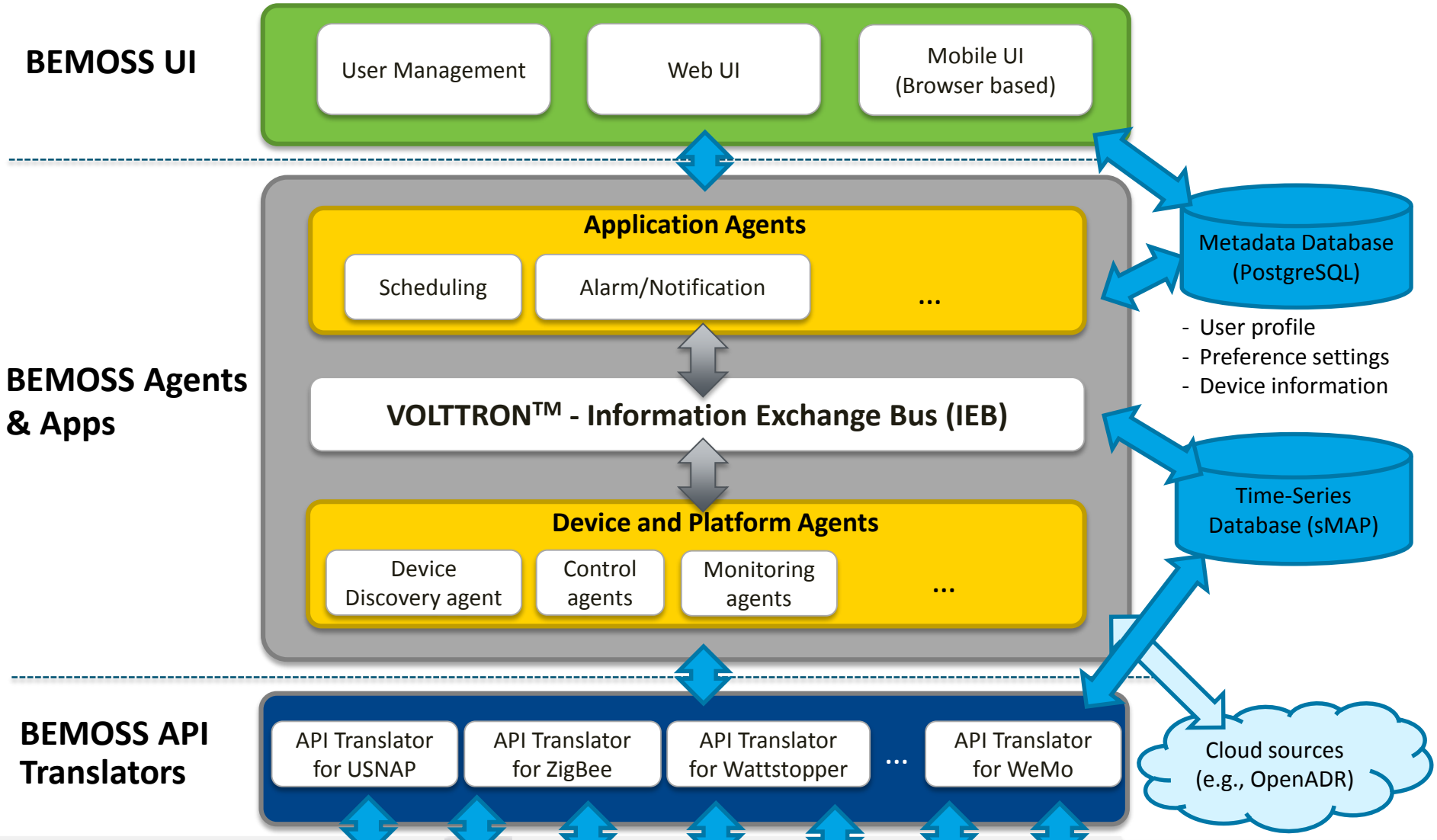
PostgreSQL

django

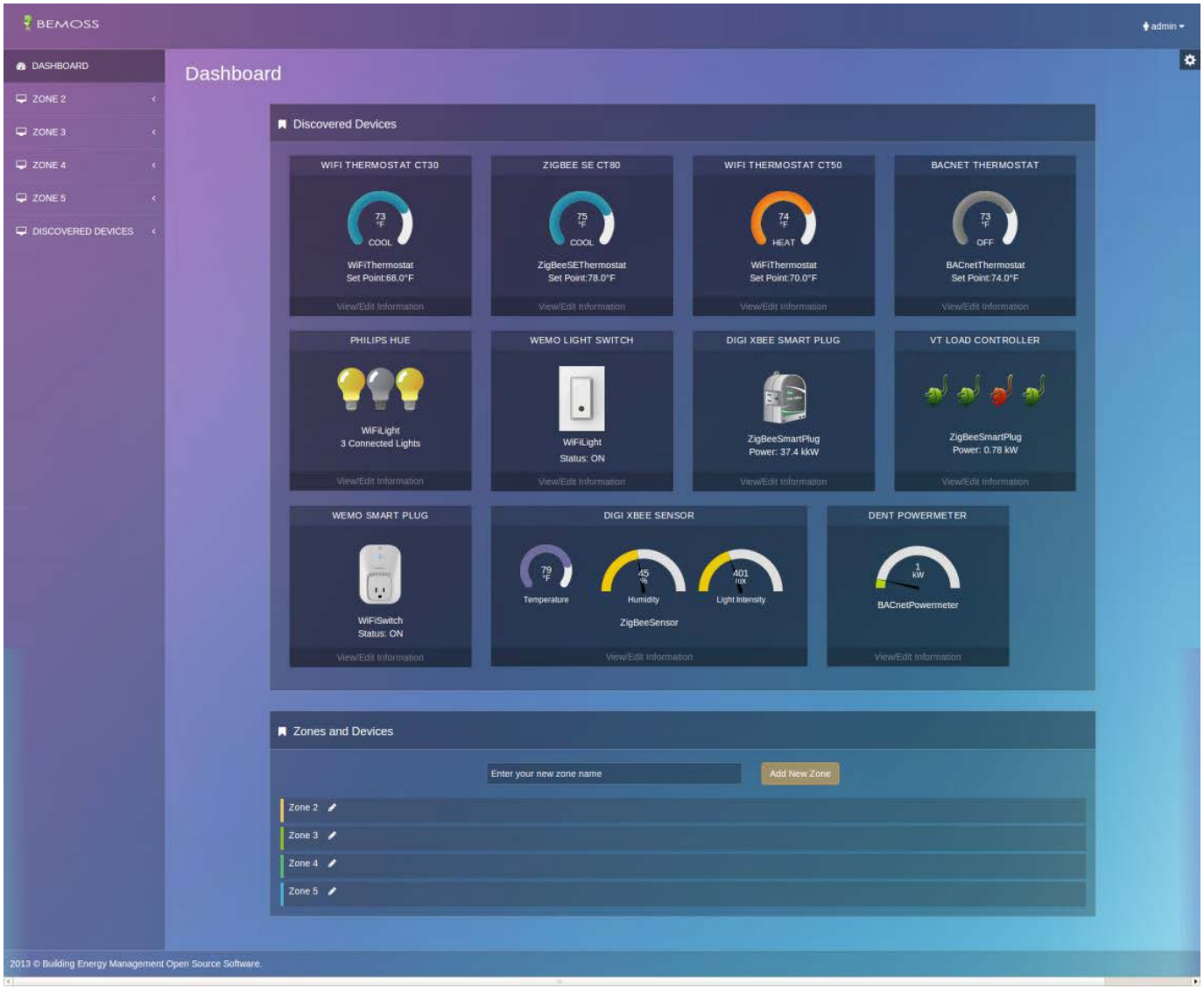
ZeroMQ

sMAP

BEMOSS Software Architecture



BEMOSS User Interface (PC, Tablet, Smart Phone)



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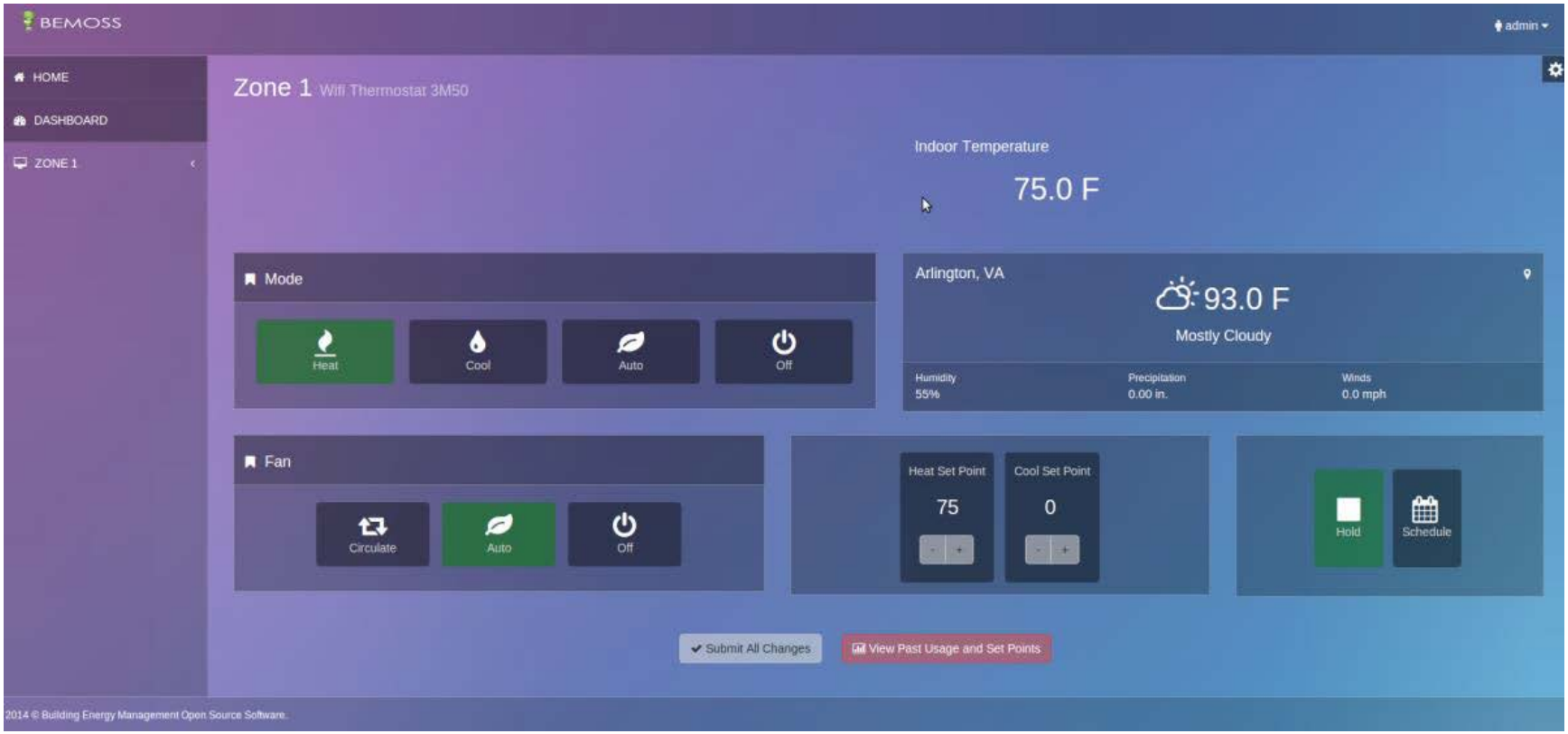
BEMOSS Thermostat Page



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BEMOSS Advisory Committee

BEMOSS is developed in consultation with industry

BEMOSS advisory committee has representatives from 21 organizations:

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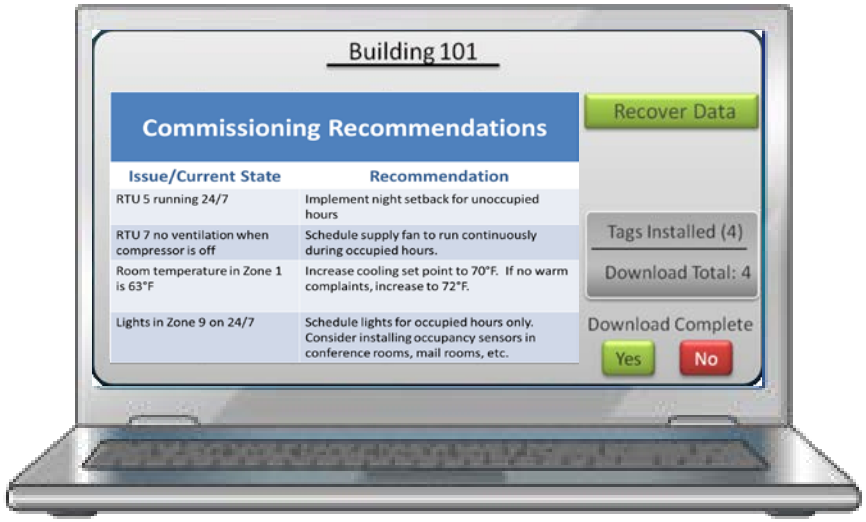
Retro-Commissioning Sensor Suitcase – PNNL

with LBNL and ORNL

Sensors:
Temperature
Lighting
HVAC State



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Test Project #2 - SensorSuitcase

Sensor Suitcase Project Building Help

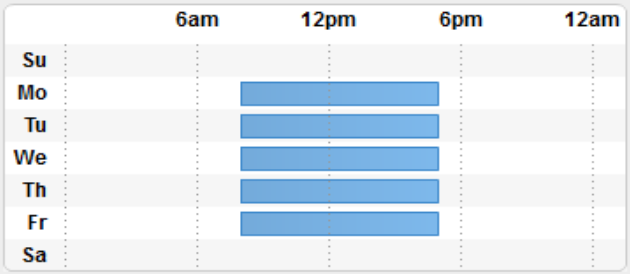
Start Project Building Recommendations

BLDG90

Utility Expenses

Gas:	3,230	$/year
Electricity:	4,042	$/year
Total:	7,272	$/year

Occupancy Schedule



Building Details

Owner:	Lawrence Berkeley Labs
Location:	East Campus
Address:	12 Main St.
Size:	10,000 sq.ft.
Timezone:	PST5PDT

Recommendations

Problem	Recommendation	Location	Savings ($/year)
Excessive lighting during occupied/daytime hours	Install occupancy sensors in locations with intermittent occupancy, or engage occupants to turn the lights off when they leave the area	151	70
Excessive lighting during unoccupied/nighttime hours	Install occupancy sensors in locations where it is not necessary or intended for the lights to be on all night, or encourage occupants to turn the lights off upon exit	151	50
RTU cycling on and off too frequently, potentially leading to equipment failure	Ask HVAC service providers to check refrigerant levels, thermostat location, and control sequences	151	70
Under use of free cooling, i.e., under-economizing	Ask … TU does not have…	151	330
Overly narrow separation between heating and cooling setpoints	Adjust the heating and cooling setpoints so that they differ by more than four degrees	151	40
Nighttime thermostat setbacks are not enabled	Program your thermostats to decrease the heating setpoint, or increase the cooling setpoint during unoccuppied times. Additionally, you may have a contractor configure the RTU to reduce ventilation.	151	420
Over-conditioning, thermostat heating setpoint is high	Program your thermostats to decrease the heating setpoint during occupied hours	151	30
Over-conditioning, thermostat cooling setpoint is low	Program your thermostats to increase the cooling setpoint during occupied hours	151	3

Estimated 10% Energy Savings

Total recommendations: 8

Total Annual Cost Savings **$ 1,013 / year**

Print to PDF Close Building

BTO Technologies – An Incomplete Summary

- Solid State Lighting – including organic LED's
- Appliance Standards (Energy Star Program) and Building Codes
- HVAC
  - Air Sourced
  - Ground Sourced
  - Low Global Warming Potential Refrigerants
  - Vapor and Non-Vapor Compression cycles
- Refrigeration
- Building Automation Systems (Sensors and Controls)
- Building Energy Models and Calculators (EnergyPlus)
- Building Envelopes
  - Insulation (air blown, structural, vacuum insulated glazing)
  - Windows and Walls

How To Get Involved with DOE and BTO

- **Get on our email list (http://www1.eere.energy.gov/buildings/newsletter.html, and click on "Sign up to receive news and events from BTO")**
- **Volunteer to be a reviewer**
- **Participate in workshops, RFIs (Requests for Information), and the annual program peer review. RFI responses are used to help improve our programs.**
- **EERE Post-Doctoral Science & Technology Policy Fellowships - http://energy.gov/eere/energy-efficiency-and-renewable-energy-science-and-technology-policy-fellowships**
- **Apply to a FOA (multiple FOAs to be released each year)**

Funding Opportunity Announcements

DOE FOA's

- https://eere-exchange.energy.gov/
- https://arpa-e-foa.energy.gov/
- http://science.energy.gov/funding-opportunities
- https://bpa-exchange.energy.gov/
- http://www.netl.doe.gov/business/solicitations

Major Repository

- http://www.grants.gov

Catalog of Domestic Financial Assistance:

81.086 – Conservation R&D

81.087 – Renewable Energy R&D

Questions?

Jim Payne

Technical Project Officer

Building Technologies Office

Office of Energy Efficiency and Renewable Energy

U.S. Department of Energy

Golden Field Office @ RSF

15013 Denver West Parkway

Mailstop RSF/C246-3

Golden, CO 80401-3111

jim.payne@ee.doe.gov **720-356-1744 (Office)**

Additional Material

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Introductory Material

Ariane 5 – first launch, June 4, 1996 - event at 53 seconds

https://www.youtube.com/watch?v=gp_D8r-2hwk

The failure of Ariane 501 was due to a software error. The navigation computers were almost clones of the Ariane 4 units, which had proved quite reliable. However, the horizontal velocity of the Ariane 5 was five times higher than that of its predecessor, triggering a data conversion error early in the flight that was not trapped. The last communication the navigation computer had with the engine steering system was an error code, not a command. The code was effectively interpreted as 'turn around', leading to loss of mission (about $1B).

Lesson learned – the landscape changed much faster than expected, and systems were not prepared, leading to loss.

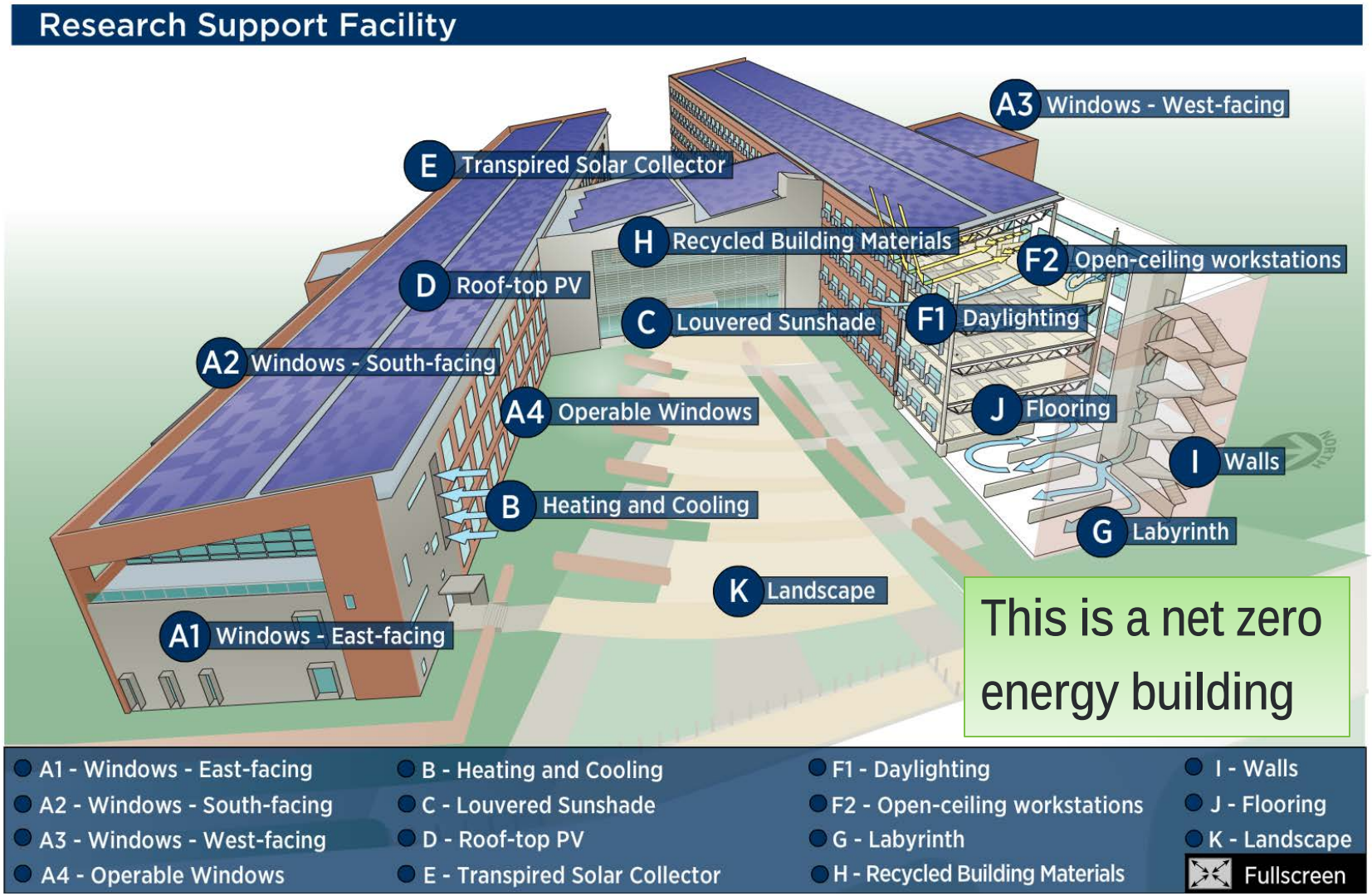
SuperTruck Making Leaps in Fuel Efficiency

This SuperTruck is a demonstration vehicle that is part of the Energy Department's SuperTruck initiative. This program's goal is to develop tractor-trailers that are 50% more efficient than baseline models by 2015.

The truck on display, developed by heavy-duty manufacturers Cummins and Peterbilt, has exceeded this goal. Since 2010, the truck has demonstrated a 20% increase in engine efficiency and a 70% increase in freight efficiency, reaching over 10 miles per gallon under real world driving conditions on a Class 8 tractor-trailer (GVWR > 33,000lbs). In comparison, an average Class 8 truck typically gets 5.8 miles to the gallon.

http://energy.gov/eere/articles/supertruck-making-leaps-fuel-efficiency

National Renewable Energy Laboratory - RSF Bldg.



http://www.nrel.gov/sustainable_nrel/rsf.html