OAK RIDGE National Laboratory

Building Monitoring Needs for PWS Technologies

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Passive Wireless Sensor Technology (PWST) Workshop

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ORNL is managed by UT-Battelle, LLC for the US Department of Energy

U.S. DEPARTMENT OF ENERGY

Opportunity Space

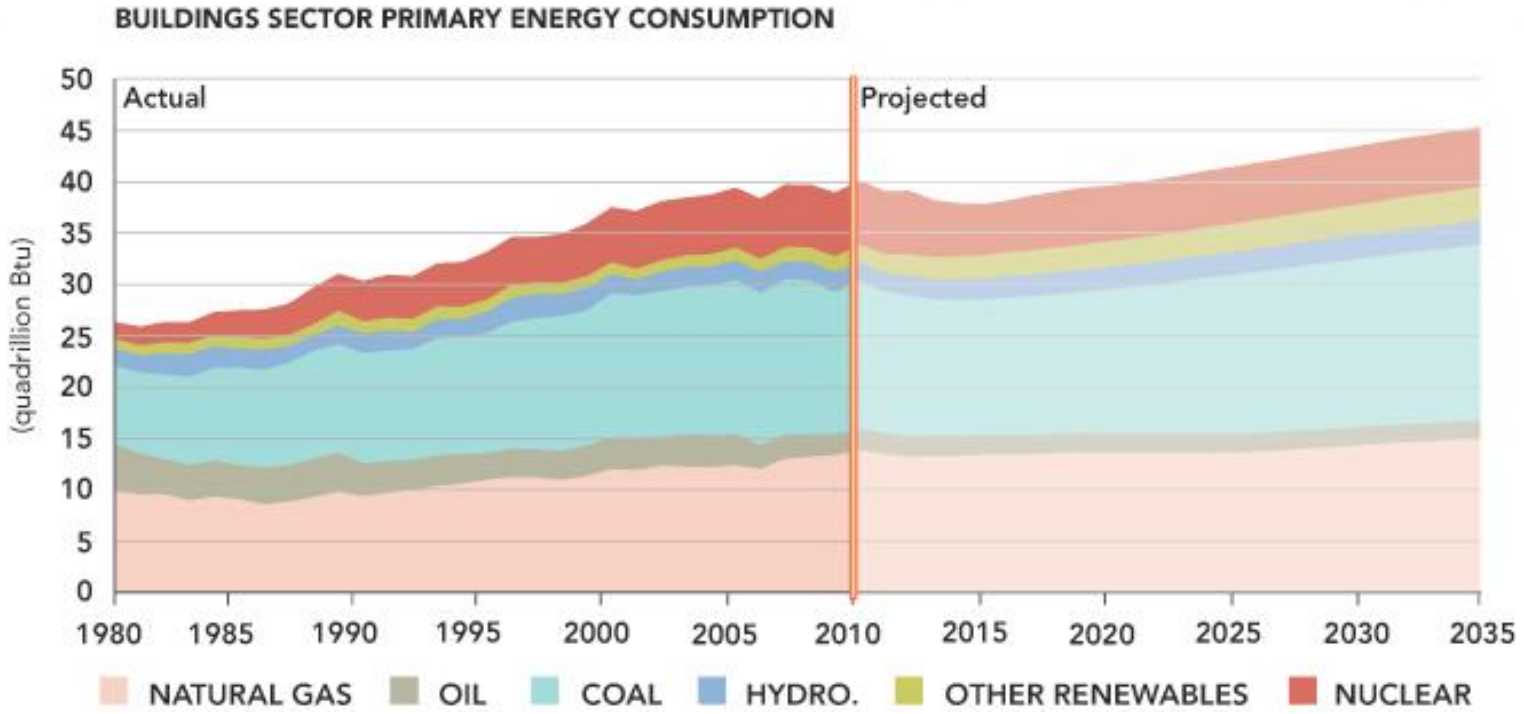
Buildings consume 74% electricity produced in the US

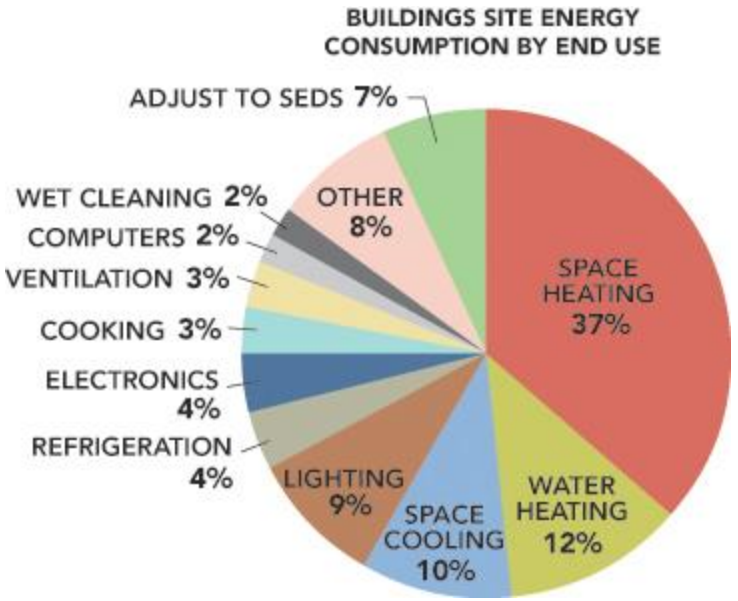
Buildings have the potential to reduce their consumption by 20%-30% (18 quads or 2,500 million tons of oil) through advanced sensors and controls

Potential nationwide value of demand dispatch could be several billion dollars yearly in reduced energy costs with 10% participation
(NETL, Demand Dispatch – Intelligent Demand for a More Efficient Grid, August 2011)

One-fourth of the 713 GW of US electricity demand in 2010 could be dispatchable

90% of the commercial buildings are < 50,000 ft^2 and need aggregation

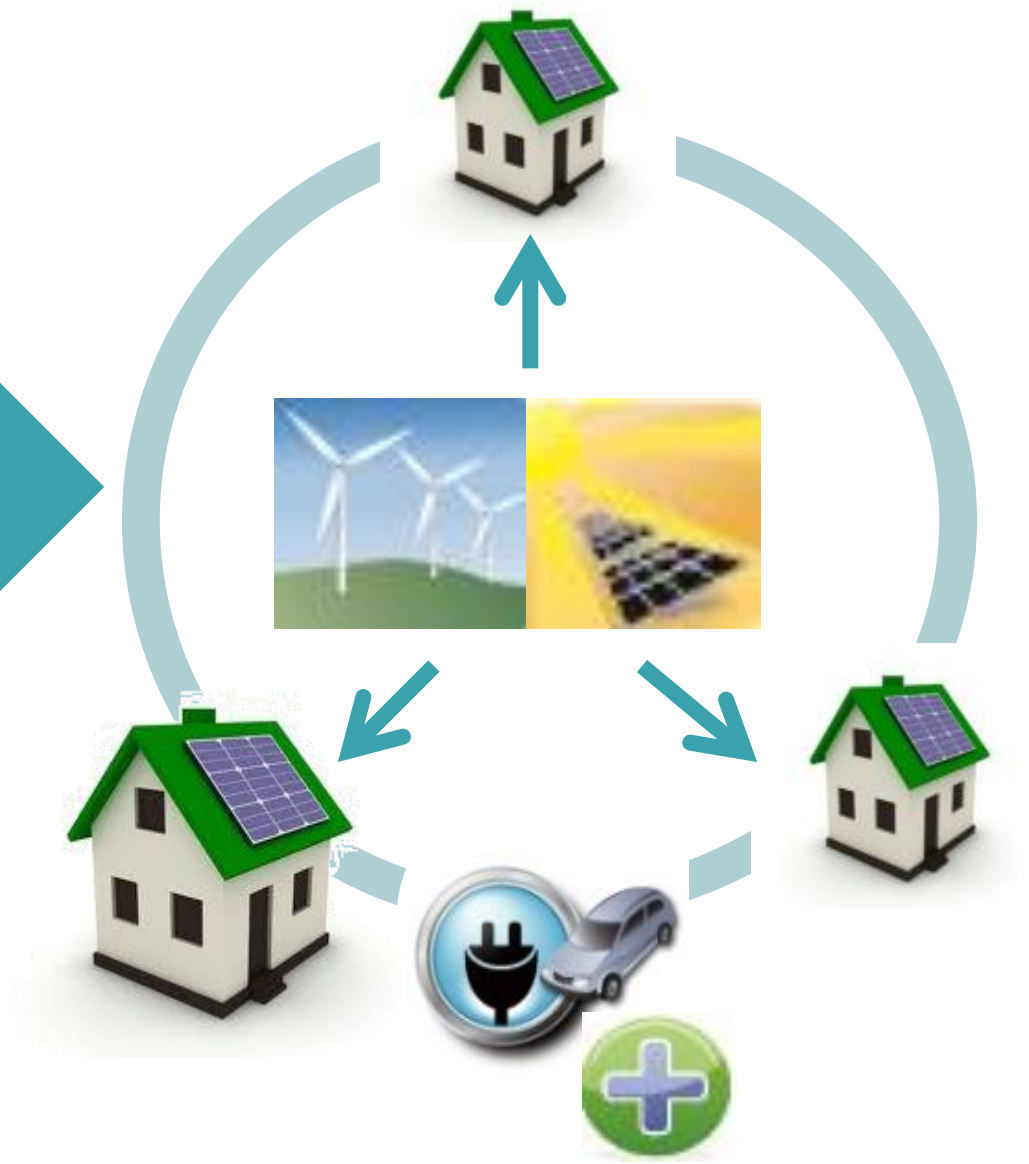




5.5 million commercial, 117 million residential, projected to be 80% of load growth through 2040

Sensors will lead to significant energy savings for the market

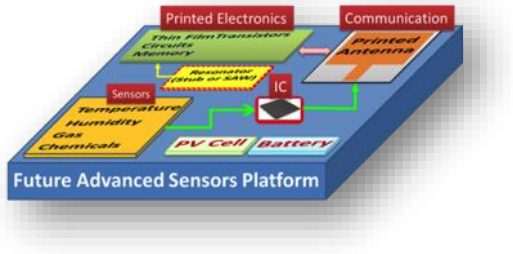
Buildings will be self-configuring, self-commissioning and self-learning such that they optimize operation, maximize energy savings cost effectively and can participate in transactions within the building, between buildings and with the grid



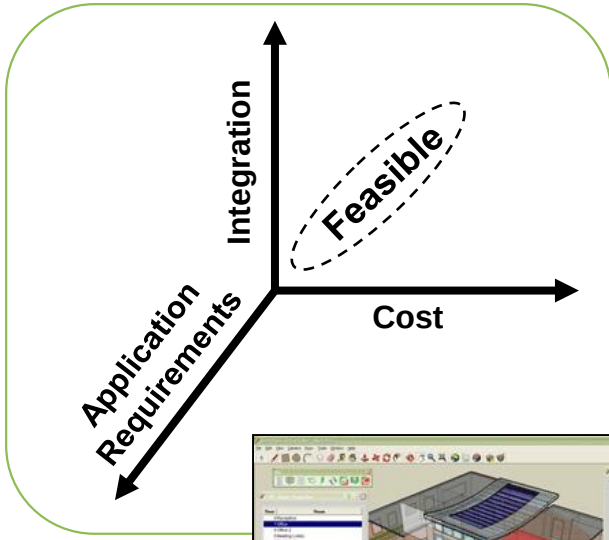
Requirements for Building Monitoring

Impact on Buildings Technology
Advanced Sensor, Control Technology Brings Big Growth to Building Energy Management Market:

- **Market Growth**: 17% compound annual rate to become a $2.14 billion industry by 2020(Lux Research)

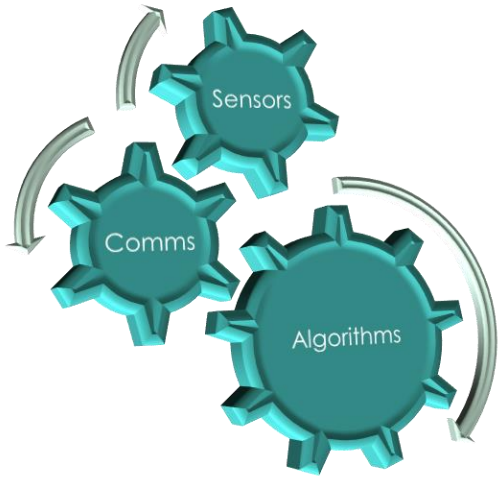


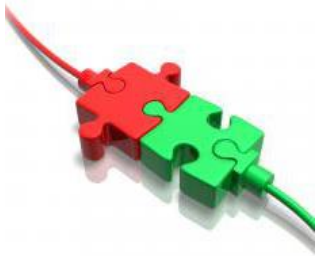
- Non-Orthogonal Multi-dimensional requirements for low-cost wireless sensors
  - Application Requirements (data rate, sensor accuracy, sampling rate, battery, RF communications)
  - Integration Requirement (printable materials, functionality, device/sensor integration, regulations)
  - Cost: Low-cost, Manufacturing infrastructure (COTS wireless sensors are still at a high cost per node)
- ASHRAE Standards 90.1, 90.2, 55, 62.1, and 189.1
- IECC, IBC, and NFPA 5000 code.

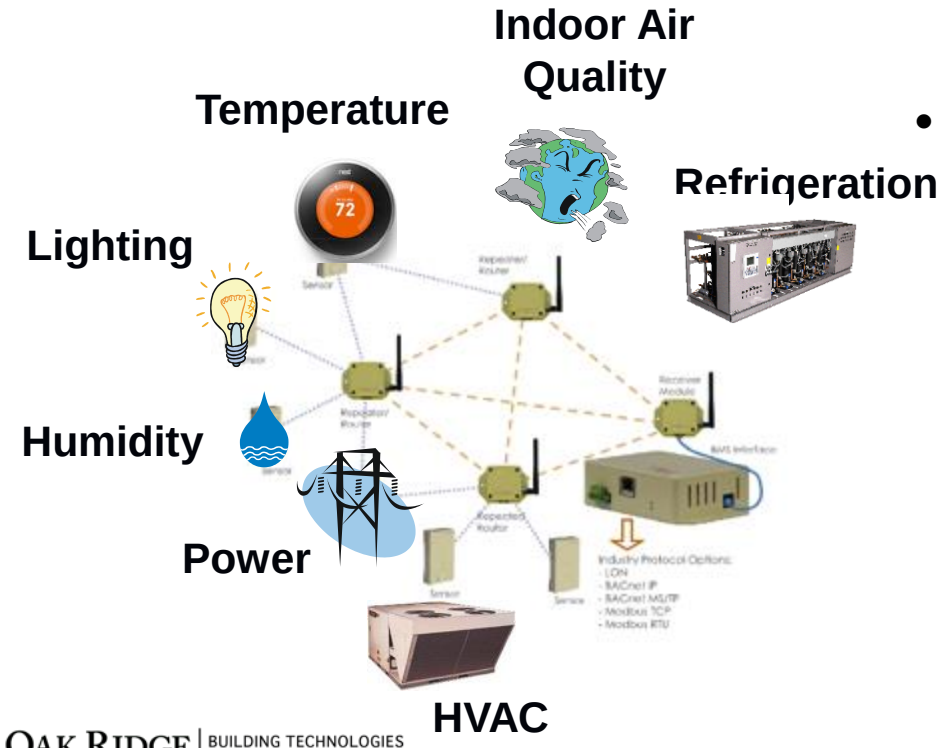


Self-powered, Wireless Technology will Enable Multifunctional Sensor Platform at feasible cost and reliability

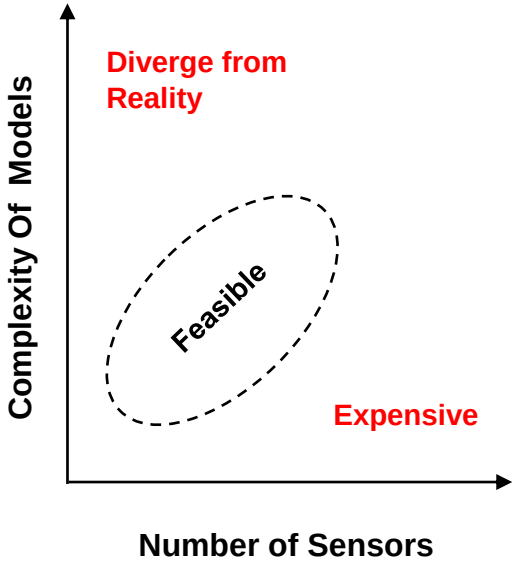
Connectivity – Observe & Control

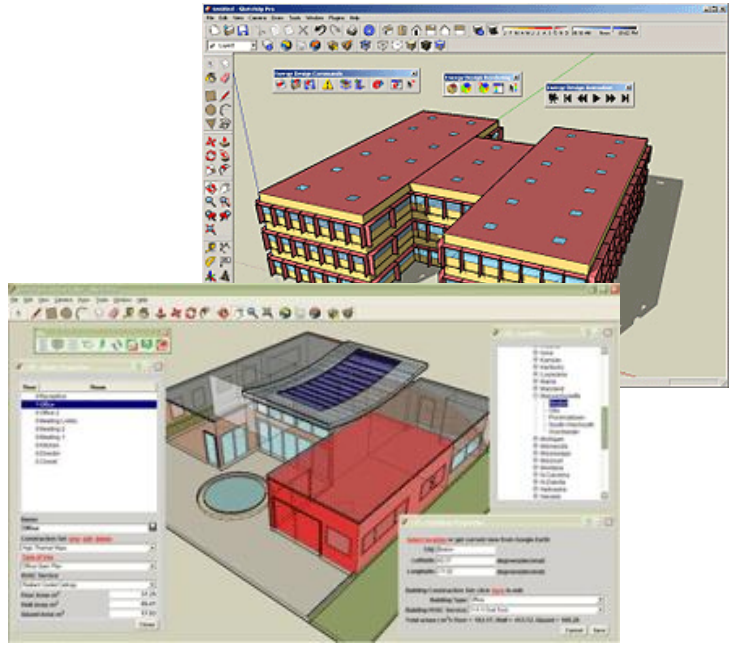




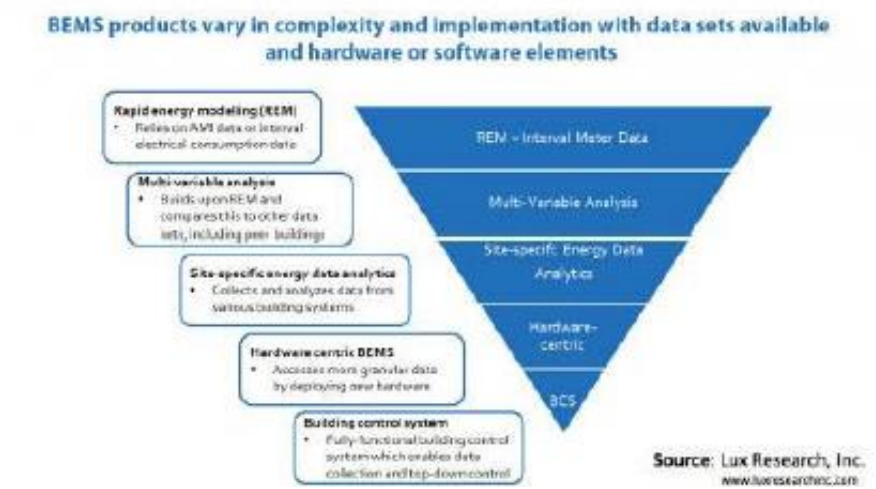


- Today's stock of buildings are noticeably "un-connected"
  - Limited by existing control and coordination
  - Advanced automation only in large buildings
  - Value streams are often hidden and untapped
- Large-scale deployment of clean energy technologies - building equipment integration and electric grid coordination
- Improved integration approaches for deploying technology can enable new services
- Retrofit deployment with ROI in 1-2 years





Market is Growing

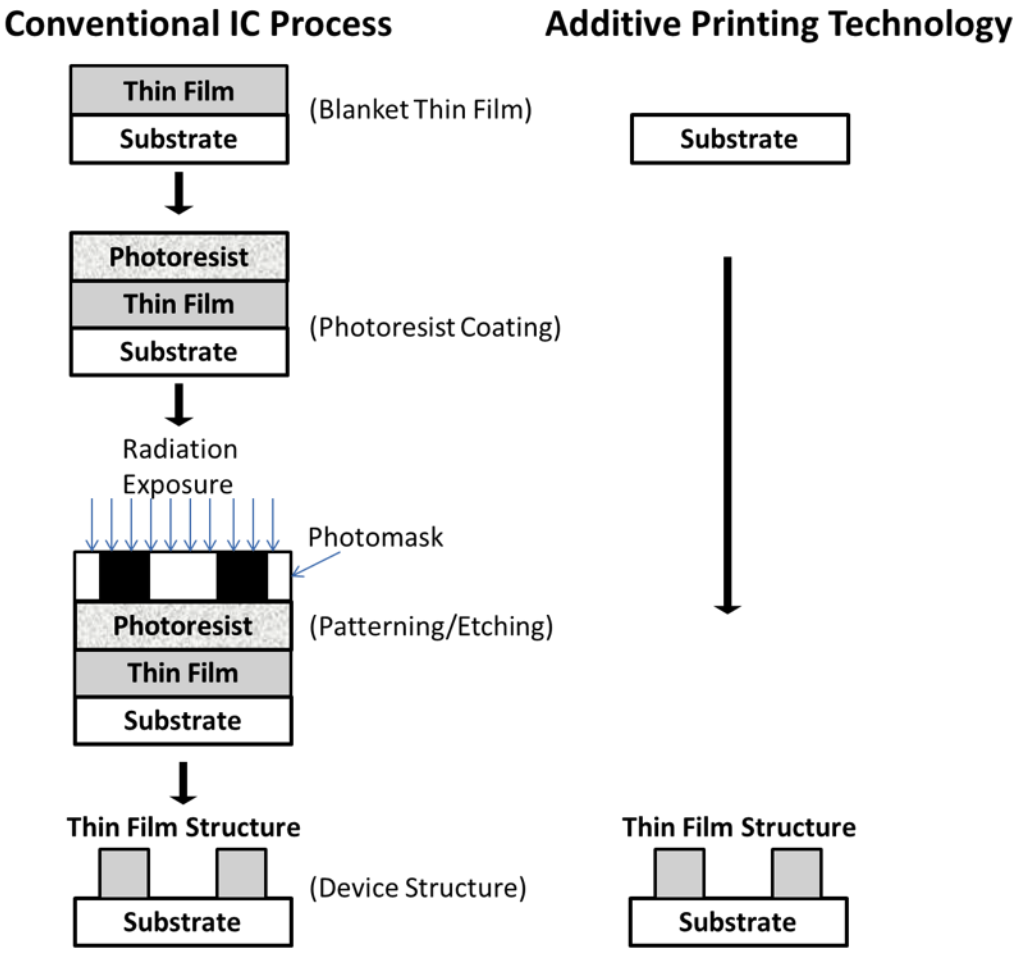


- Building Energy Management Systems (BEMs) attracted $1.4 B in VC Funding from 2000-2014 (26% of all investment in building energy technology): 30%software, 27% energy services, 25%sensors and controls; 13%semiconductors
- Market transitioning from BAS-dominant to BEMS. In 2020, about 77% of the $2.14 billion U.S. market will comprise BEMS applications, and 40% will come from buildings below 50,000 square feet.
- U.S. market for sensors and controls for BEMs will rise at a 17% compound annual growth rate to $2.14 billion in 2020.

Source: 2016 Peer Review Presentation on S&C Overview

Additive Integration Approaches

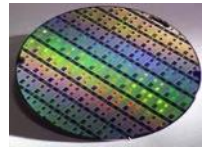
CMOS Processing



Demands on Material Performance do not change significantly

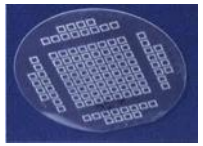
Substrate Integration

Si: CMOS



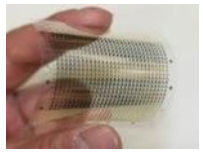
T<1000°C

Glass: Transparent Electronics



T<600°C

Plastic: Low-cost Electronics



T<200°C

3D Structures: Free-form

Resolution: 0.02µm

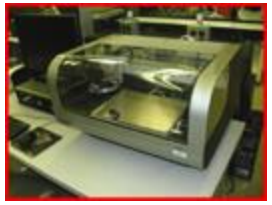
Resolution: 10µm

Resolution: 50µm

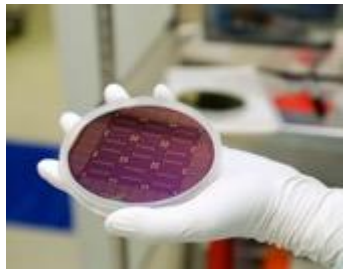
Integration Opportunity: Mask-less Design

Sensors – Peel-and-Stick Wireless Sensors

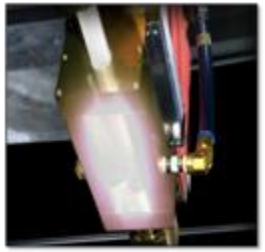
Thin Film Deposition



- Inkjet Printing
- Ultrasonic Spray
- Sputtering
- E-beam Evaporation

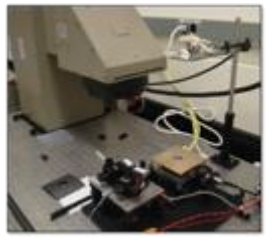


Low Temperature Photonic Curing



- PulseForge 3300
- Vortek-300
- Vortek-500

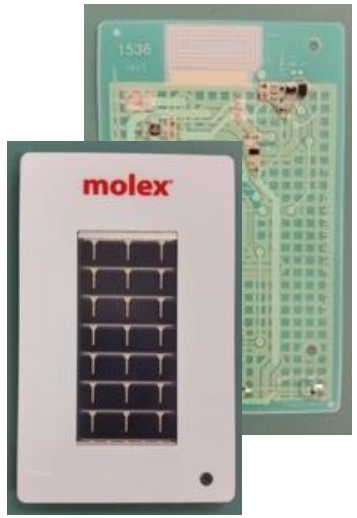
Materials and Device Characterization

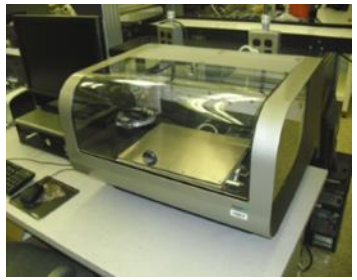


- CNMS
- CATS Lab
- NSTL
- EMC2
- RF-Clean Room
- RF Test Setups

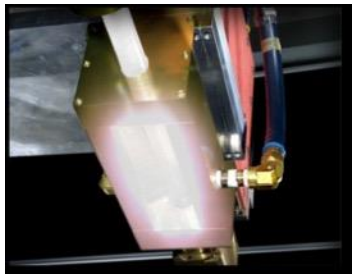
Target Technologies

- **Sensors** (Chem-Bio, Temperature, Environment, Mechanical)
- **Optoelectronics** (Phosphor, OLED, Display)
- **Batteries** (CNT, Nanoparticles, C-fiber)
- **RF Electronics** (Energy Harvesting, RF Tags)
- **Photovoltaics** (a-Si, CIGS, CZTS, Polymer)
- **Organic Electronics** (PV, Sensor, TFTs, RF)

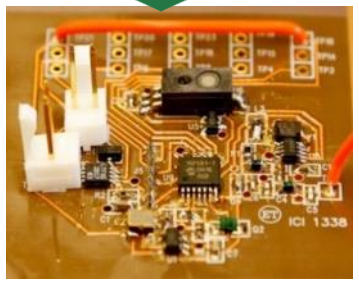




Print components on flexible substrates



Low temperature photonic curing

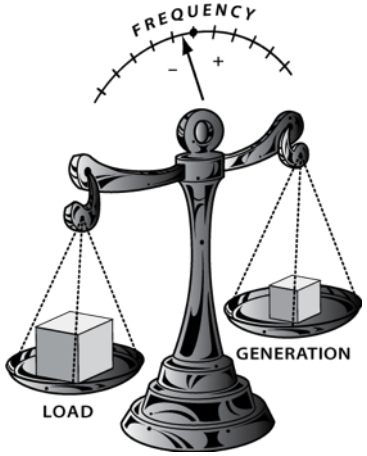


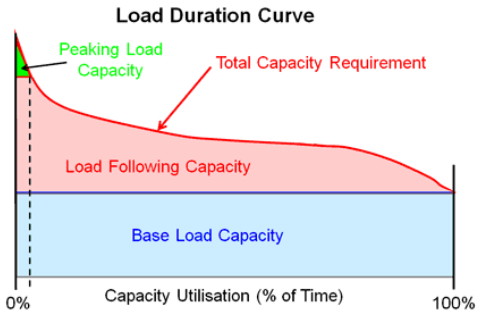
Add what is unprintable, demonstrate platform

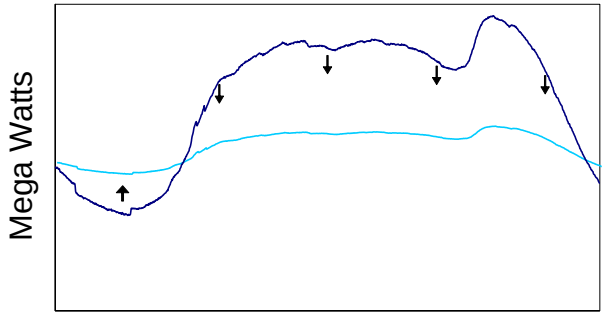
Engage industry partner to manufacture prototypes for OEMs

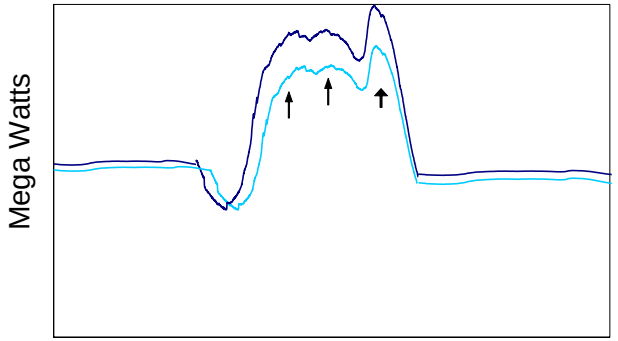
Transactive Control - It is a delicate balancing act

Load > Generation – under frequency → Load < Generation – over frequency → When you see frequency change – it is too late.





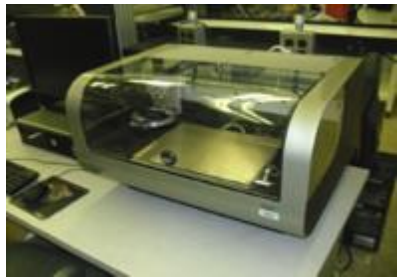


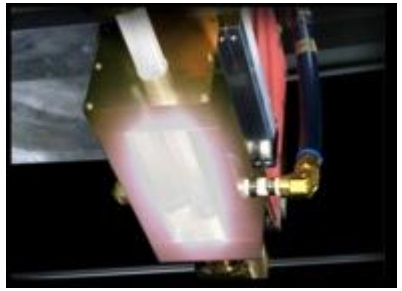


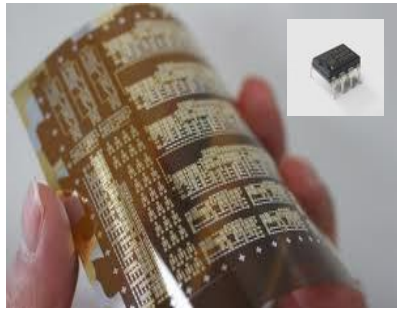
Reduce Energy Intensity and Increase Energy Efficiency

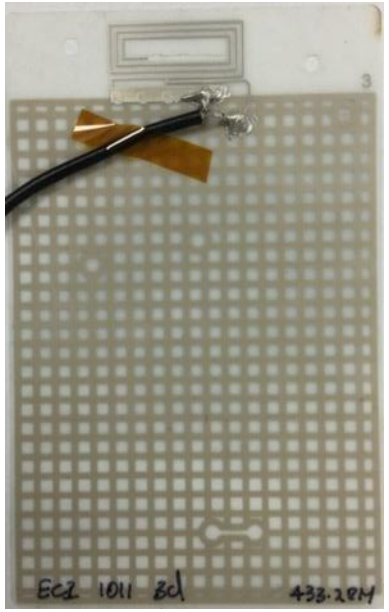
Increase Load Flexibility and Improve Grid Resiliency

Next Generation Sensors – Passive Sensing

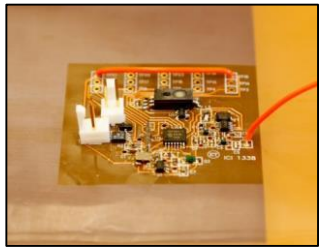




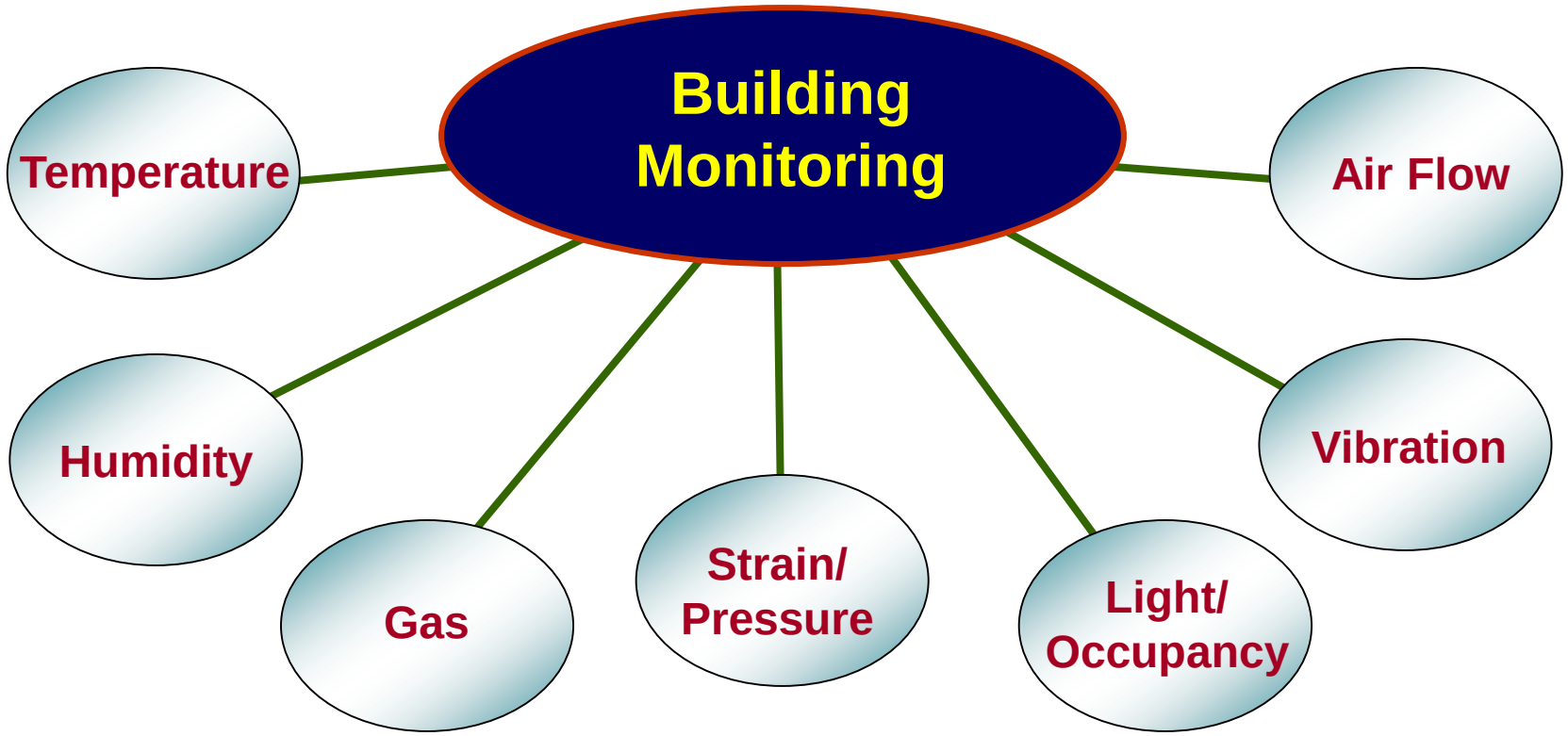




- Passive communication scheme
- Sensor miniaturization
- Reduced infrastructure cost of networking through increased range
- Multi-modal sensors in a single platform
- Additive, roll-to-roll manufacturing compatible



Sensor Needs: Materials, Process, and Devices



- In-situ sensing for equipment conditioning monitoring - often times limited power availability
- A clear understanding of process-structure-property correlation is critical to evaluate the technology potential

Summary

- Significant energy efficiency gains possible with ubiquitous sensing
- Reliability the grid can be significantly improved by responsive loads
- Enable intelligence in low-touch retrofits
- Seamless deployment requires:
  - Advanced Monitoring
    - Innovative “real” and “virtual” sensors
  - Automated Response
    - Distributed control strategies
  - Scalable Testing Platforms
    - Large-scale simulation platforms

Discussion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