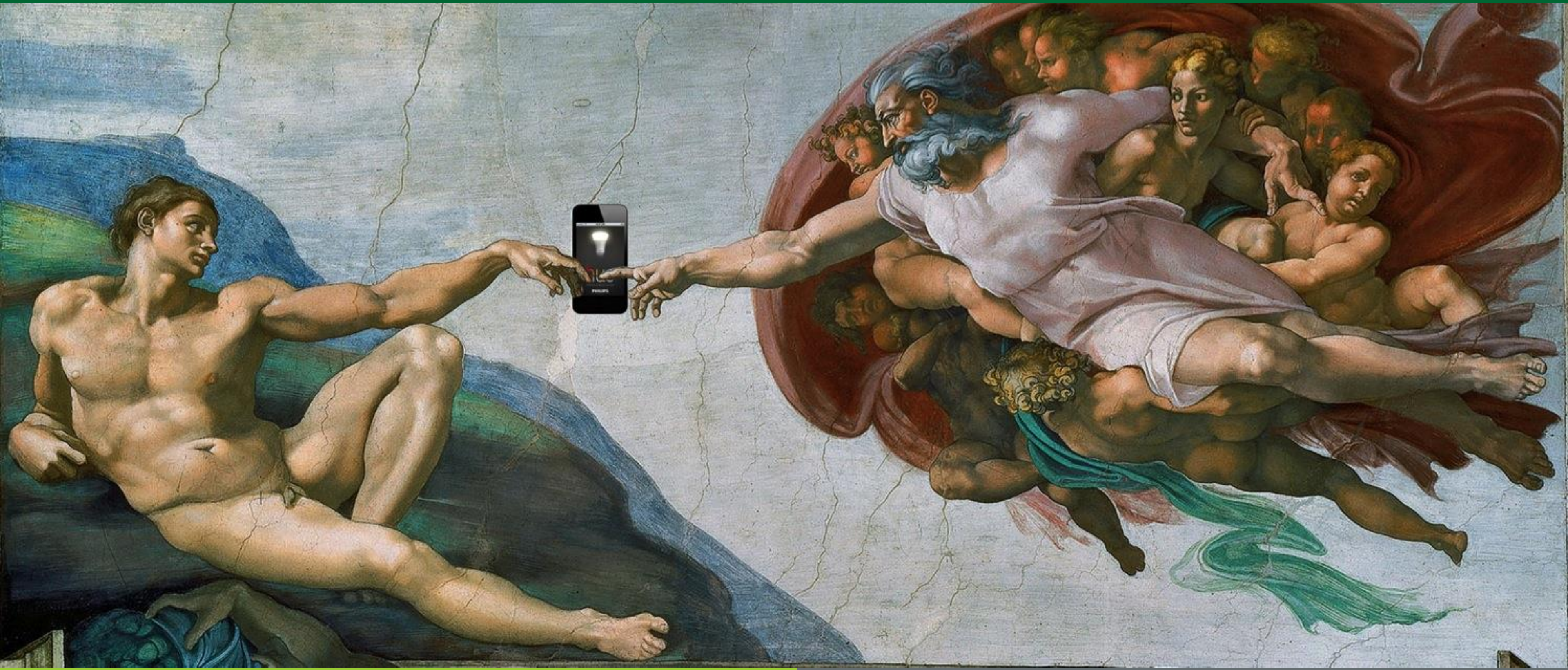
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Intelligent and Adaptive Lighting Systems of the Future



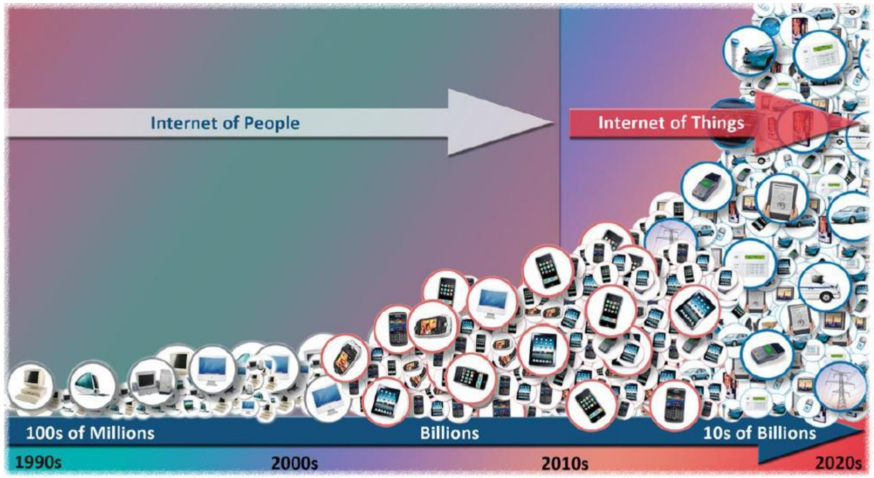
LIGHTFAIR International

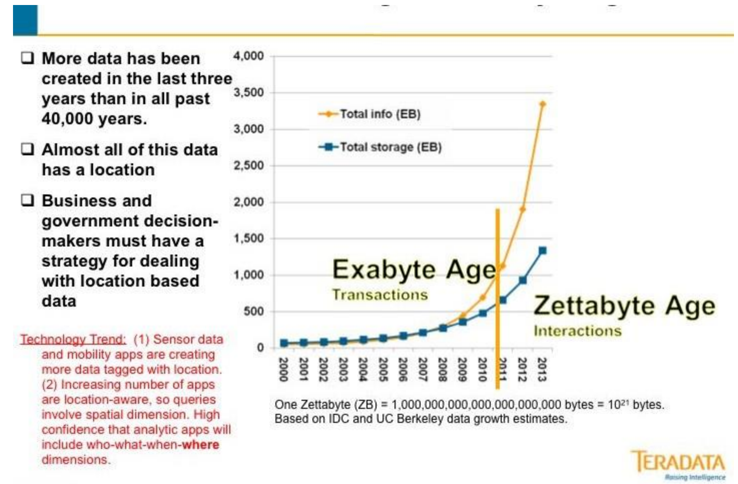
May 5-7, 2015

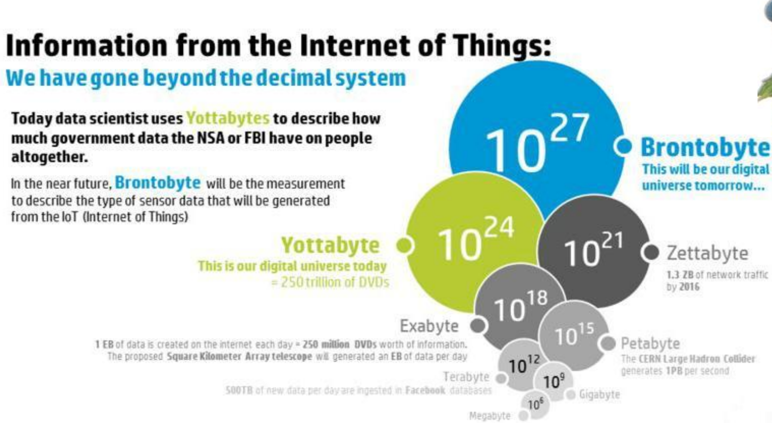
Tess Perrin – Lighting Scientist
Michael Poplawski – Senior Engineer

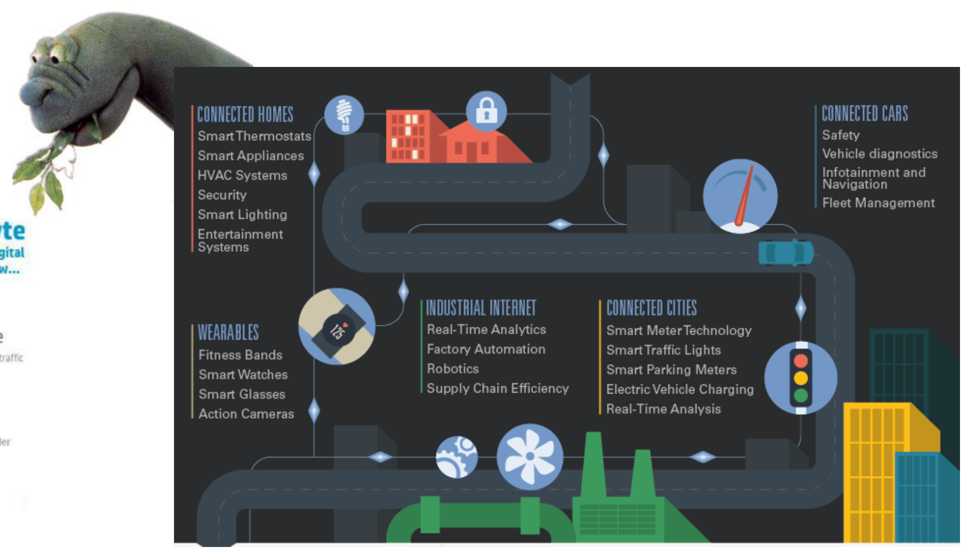
Pacific Northwest National Laboratory

What is the Internet-of-Things, and who cares?





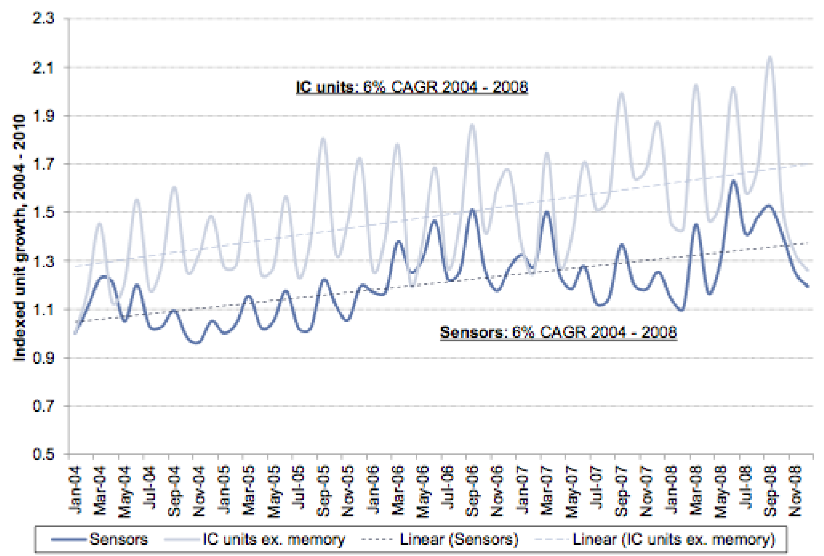




What technologies are enabling the IoT?

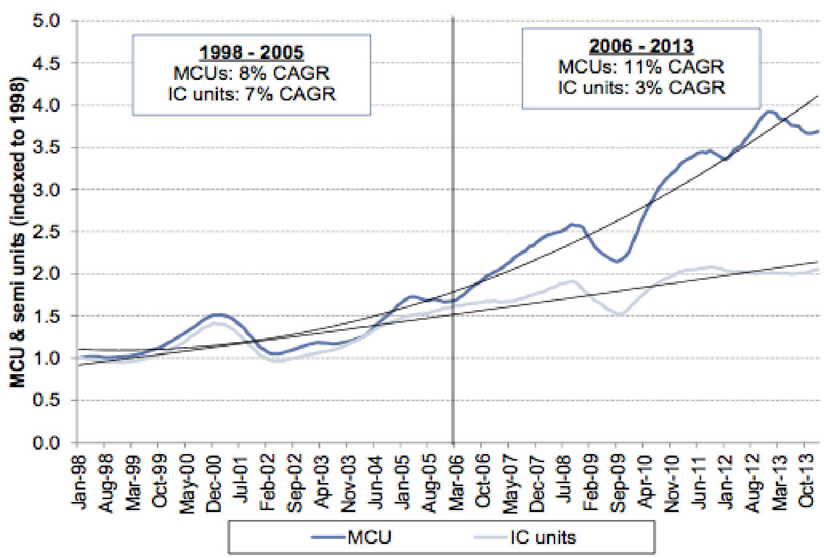
- Cheap sensors
- Cheap intelligence
- Cheap data transport
- Cloud Computing?
- Smart Phones?
- Lighting?

Exhibit 3: Sensor growth outstripped the overall semiconductor market from 2011-2013 (5% CAGR vs. semis at 0%)
Indexed IC units and sensor units to January 2011



Source: SIA, Goldman Sachs Global Investment Research.

Exhibit 4: Microcontroller growth has significantly outpaced the semiconductor market
Market size and unit CAGR



Source: SIA, Goldman Sachs Global Investment Research.

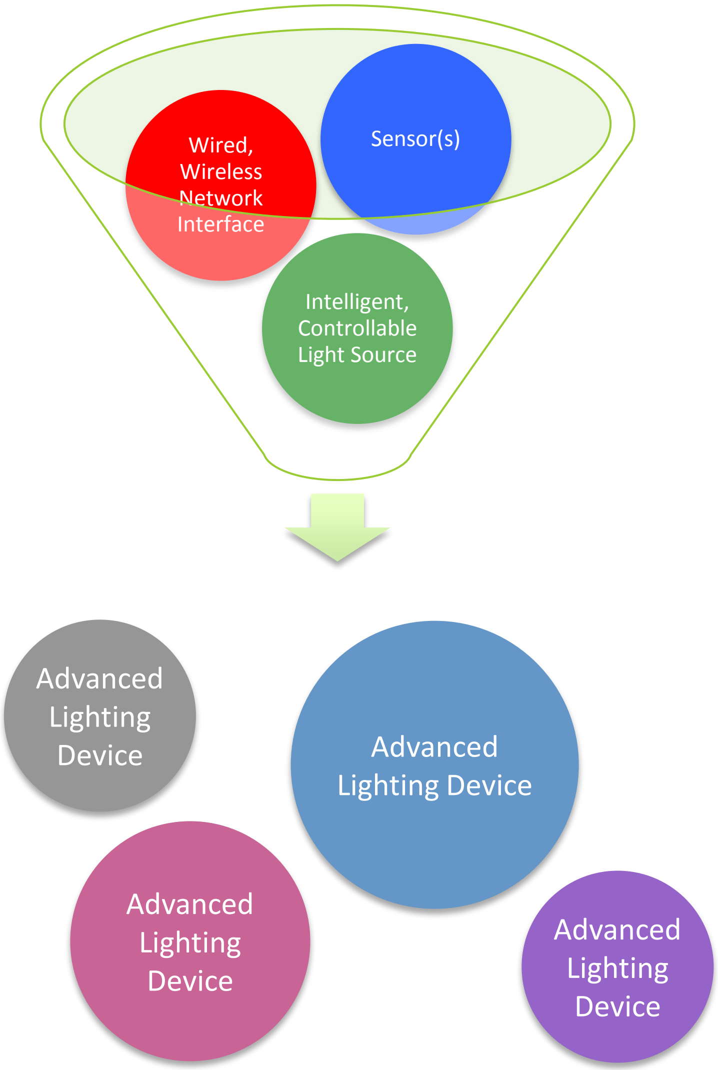
Why lighting? SSL is the catalyst…

- Solid-State Lighting (SSL) is the most energy efficient, flexible, controllable lighting technology in history
  - Spectral power distribution (color characteristics, e.g. CCT, CRI, Duv), light output (e.g. luminous flux, intensity, distribution)
  - System architecture, partitioning, and power conversion
- SSL is blurring the traditional lines between lighting system devices (e.g. lamps and ballasts/drivers, luminaires, and lighting controls)
- SSL is poised to catalyze the deployment of intelligent, networked lighting devices that collect and exchange data
  - Embedded intelligence (e.g. for managing power conversion) can be leveraged for other purposes (e.g. output control, network interface)
  - Microelectronic platform facilitates the cost-effective integration of additional functionality (e.g. network interfaces, sensors)

How can the IoT benefit lighting and buildings?

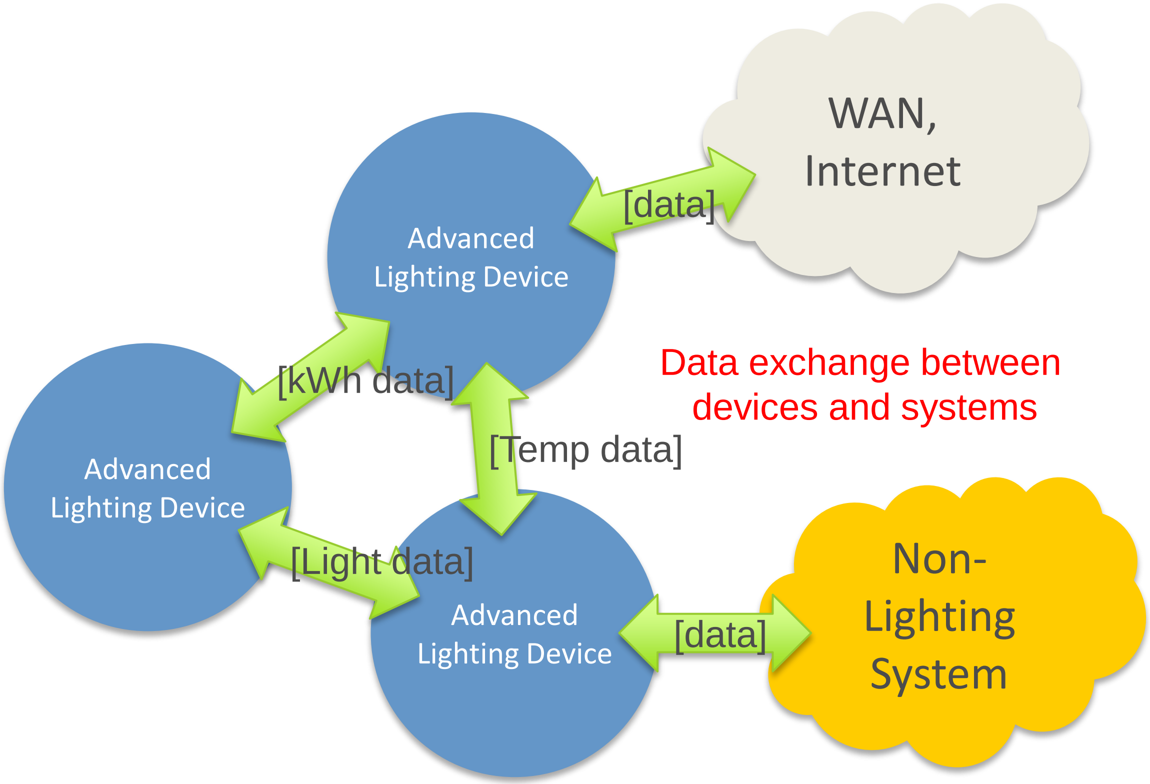
- Enabling intelligent lighting systems with data can result in reduced energy consumption and improved lighting performance
- The data collected (via sensors) by advanced lighting devices and exchanged (via network interfaces and interoperability protocols) with other lighting and non-lighting devices can facilitate reduced energy consumption and improved performance of those devices, as well as a growing number of non-lighting and non-energy related benefits
  - Lighting is pervasive (in all buildings and spaces), well-distributed, and AC powered
  - Leverage SSL transition driven by energy and maintenance savings

Lighting is poised to dramatically change in the future



- Many integration possibilities
  - Single-function (e.g. sensor-only) devices
  - Multi-function devices (e.g. controllable light source and sensor(s) and network interface)
- Not clear that any particular device integration or system architecture will dominate
  - Many will be likely be able to succeed in the market
  - Solutions for retrofits and new install

Future advanced lighting systems

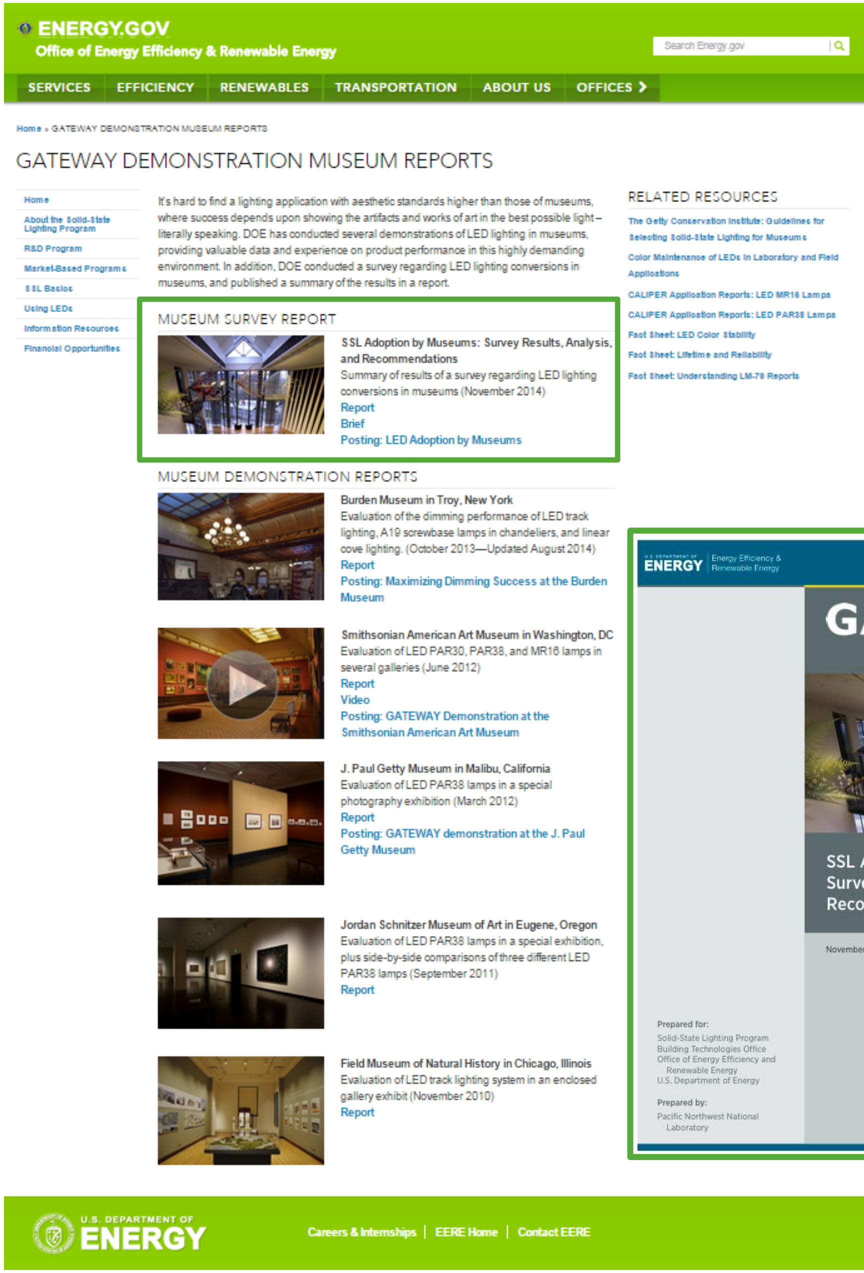


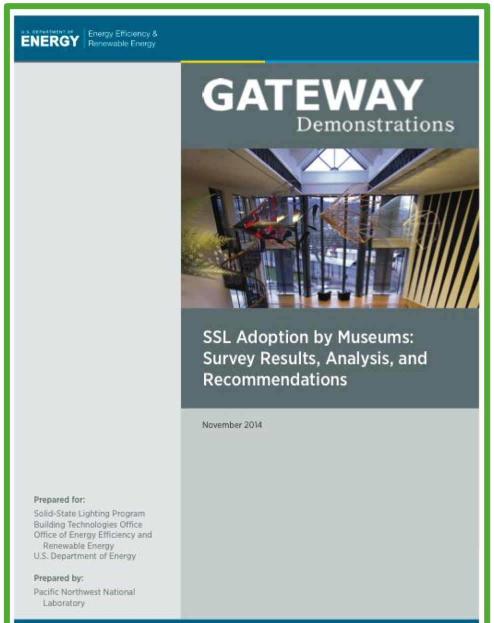
Data exchange between devices and systems

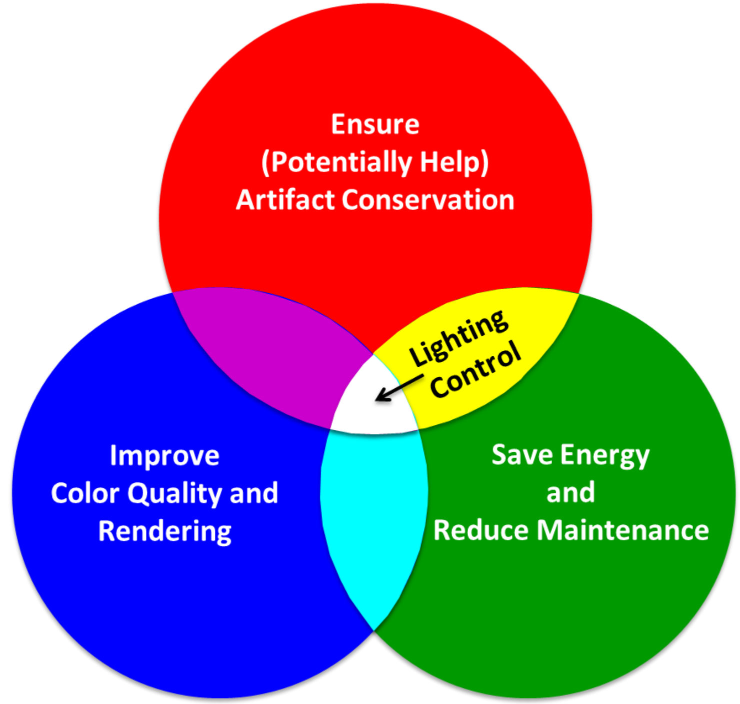
Aren't there already technologies for controlling lighting?

- Lighting control is a function that requires the integration of devices; while a controlled lighting system can far out-perform a static system, performance depends on much more than device capabilities
- Lighting control strategies have been overly focused on devices that are tightly coupled to installed luminaires, with not enough consideration given to system issues and intangibles such as owner organizational maturity
- Lighting control energy savings have been widely varying and unpredictable, and limited by the number of installations, failure to adopt performance monitoring and continuous optimization, and lack of interaction with non-lighting systems
- Complex configuration requirements, high total cost of deployment, poor user satisfaction, and difficult to predict performance have been and remain significant barriers to adoption (estimated as < 1%) and energy savings

DOE Museum Resources







Survey responders:

39% incandescent dimming

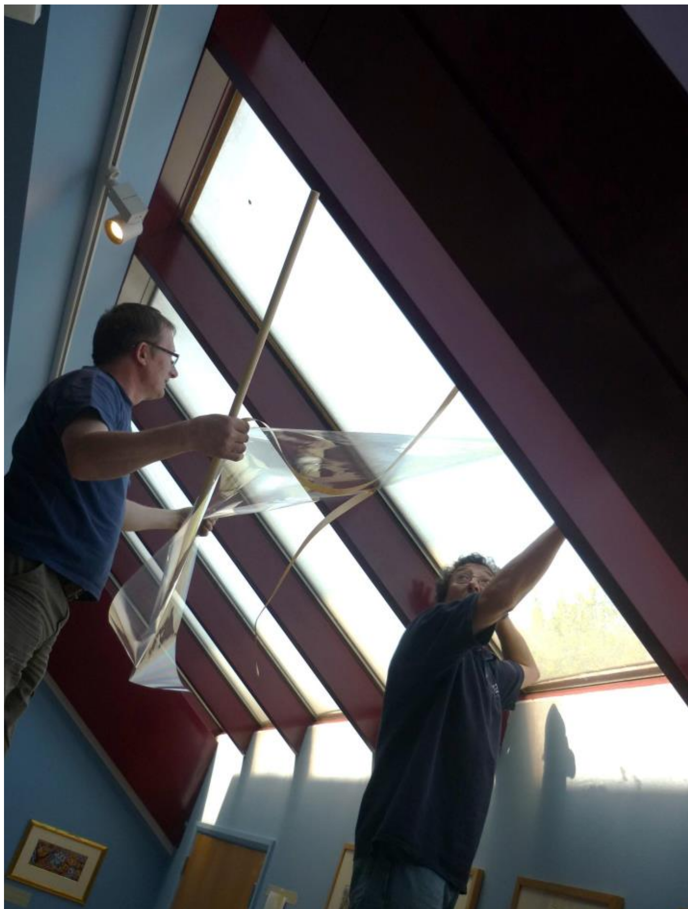
42% 0-10V/DALI/DMX

12% combination

33% no controls

Control of Lighting in Museums

MECHANICAL METHODS
are the dominant approach for limiting exposure



INTEREST IN AUTOMATIC CONTROL

65% would use lighting controls if they worked with existing infrastructure and afford lamp-by-lamp control

"It is hard to imagine having the money for replacing existing equipment with these options when ***what we have [filters, screens] works fine with manual installation****."*

Flicker?

Additional wiring?

Dim down to 50 lux?

Why does DOE work with museums?

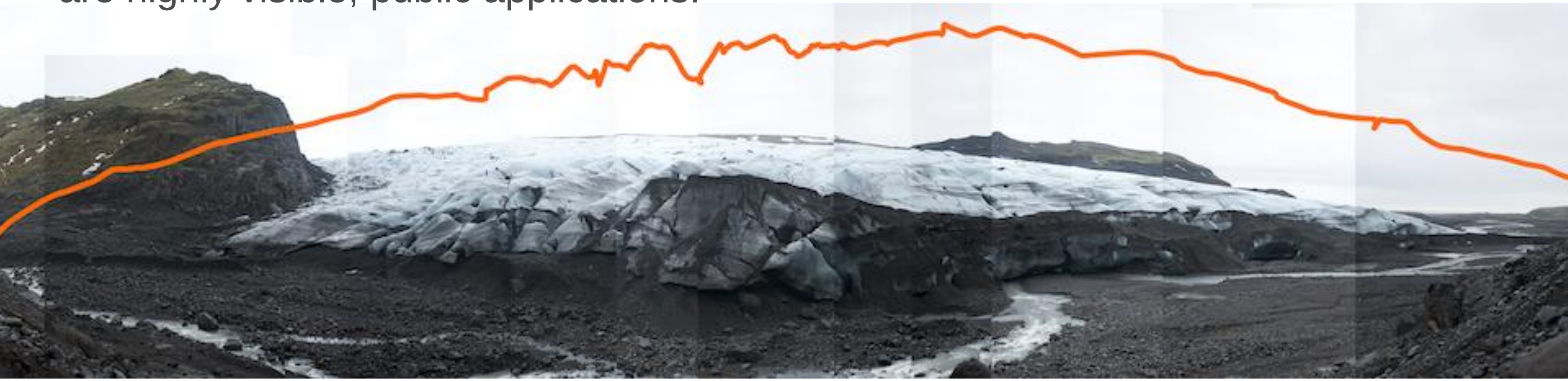
LEDs have the potential to save **80% or more** in energy, with further savings from controls.

Museums use approximately **twice** the electricity compared to other commercial buildings due to the increased HVAC used to regulate the relative humidity.

Museums require optimal lighting conditions, need to control exposure, and are highly visible, public applications.

Common goals:
sustainability and energy savings

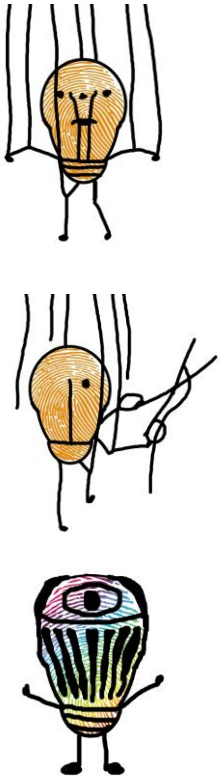
National Museum, Stockholm
Intelligent combination of daylight with SSL



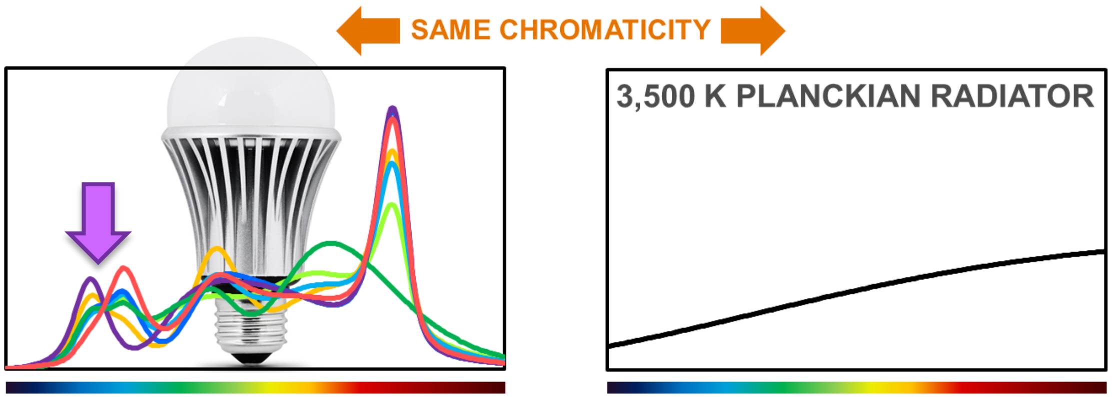
Museum Interest in Advanced Lighting Systems

Control of more than just light intensity

- Specification of lighting exposure (illuminance, spectrum, time) in order to
  - Minimize damage
  - Optimize viewing conditions
  - Maintain color performance
- Integration with sensors that monitor
  - Ambient light (e.g. daylight)
  - Physical environment (RH, T)
  - Use of space
- Adaptive exposure control
- Network interfaces to enable
  - Reporting of logged data
  - Central management

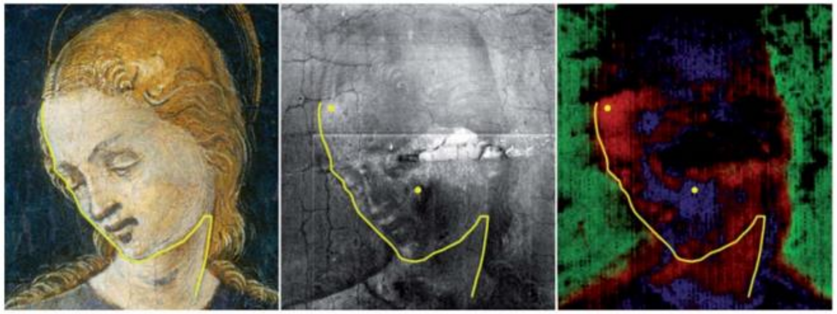


How adaptive exposure control helps conservators



Enable more accurate evaluation of potential damage for the selected spectrum, intensity, and material

Reduce the burden of frequent hand-held monitoring



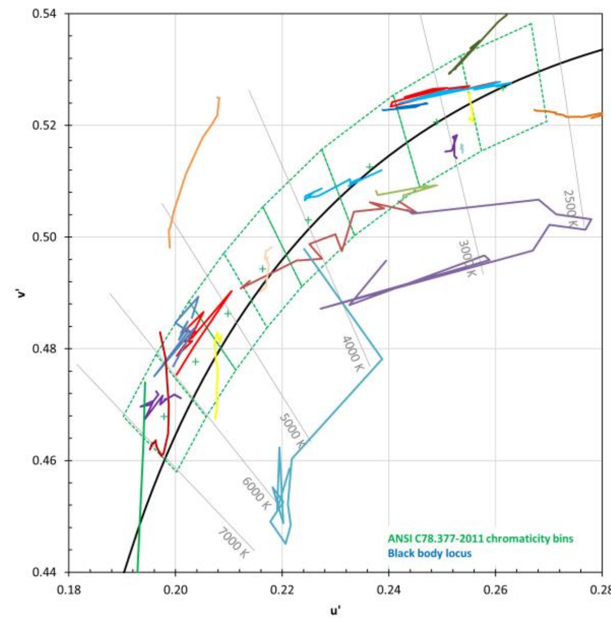
Complement more nuanced tracking of condition over time


Minimize the labor involved in precision measurements

Eliminate the subjectivity of using the ISO Blue Wools

How adaptive exposure control helps industry

Log measurements



User-driven database on performance

<u>Benefit Manufacturers</u>
Improved products and innovation

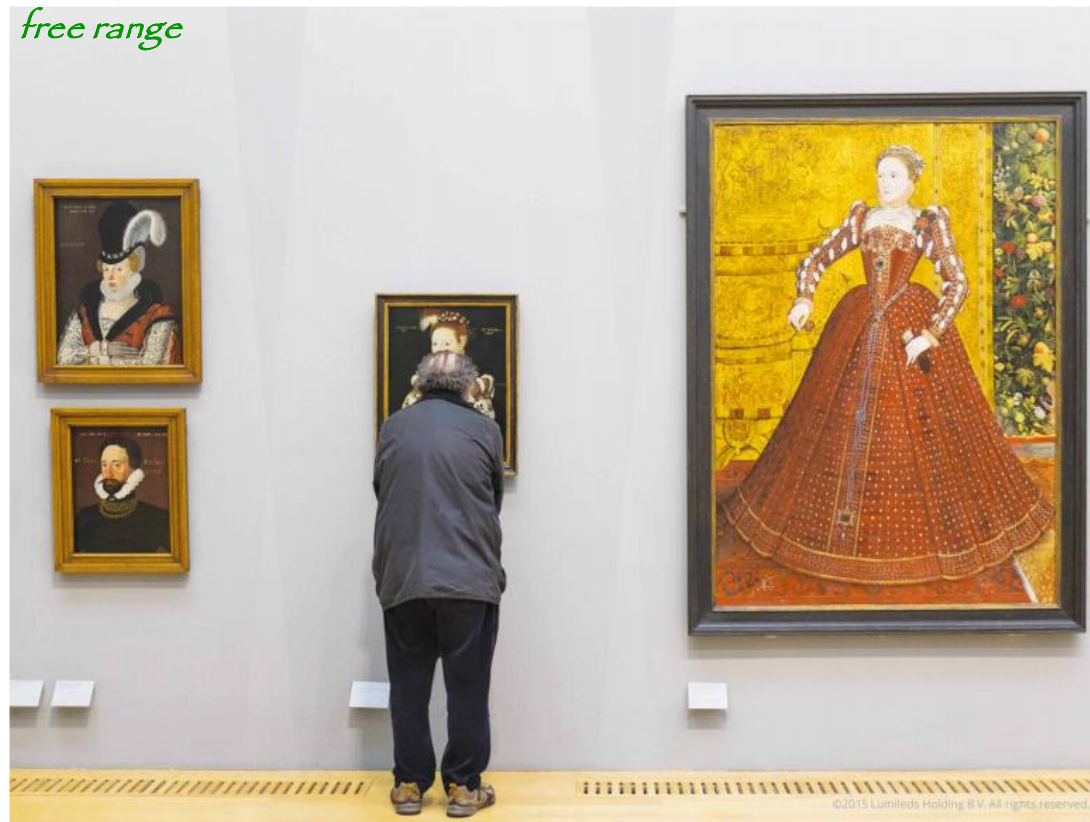
<u>Benefit Primary Institution</u>
Long-term performance supports warranty claims

<u>Benefit Other Institutions</u>
Long-term performance helps decision making

How adaptive exposure control helps visual performance

Norman Brommelle, Color and conservation, Studies in Conservation, **1955**

free range



Canadian Conservation Institute

Benchmark value

50 lux

For dark surfaces

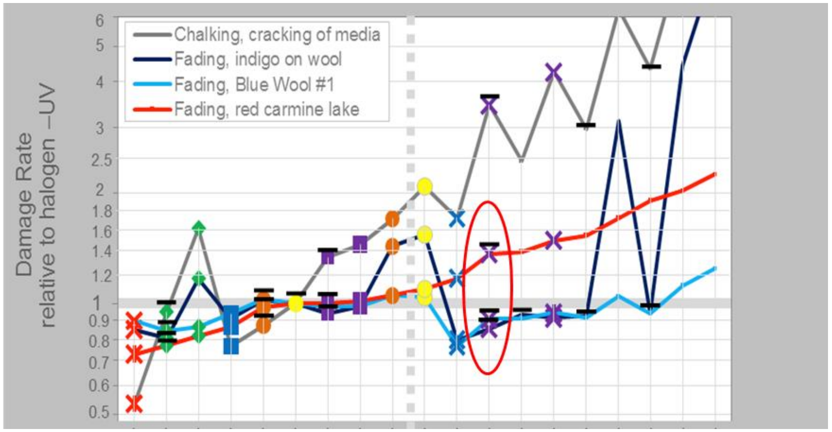
For low contrast detail

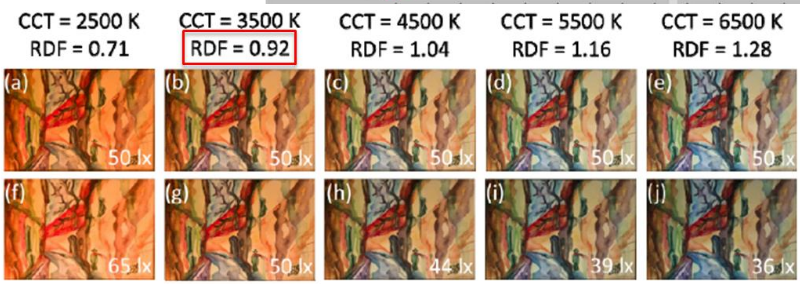
For fine detail or complex tasks

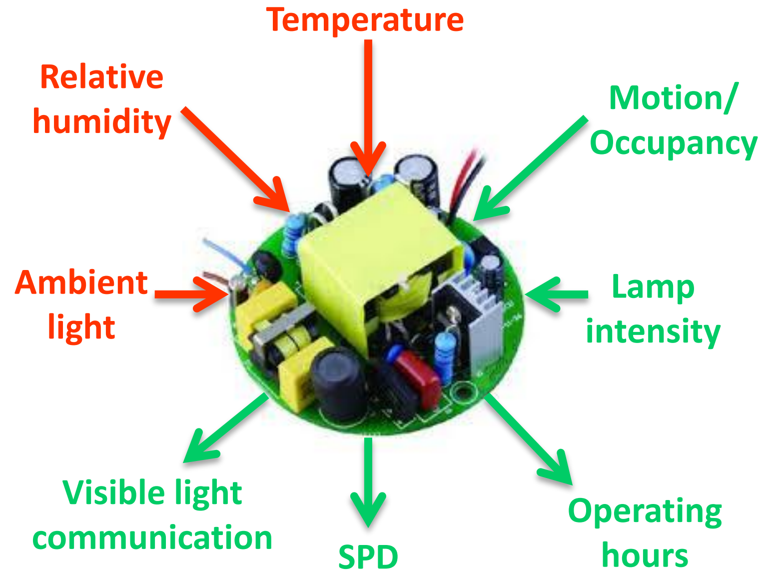
For older viewers

up to 150 lux

Potential application of adaptive exposure control







Integrate with other environmental monitoring strategies → combining three major agents of deterioration (light, RH, T) to:

Analyze
(controller, logic)

Measure
(sensor)

Cause action
(controlled device)

QUESTIONS?

Photograph by Sisse Brimberg

NATIONAL GEOGRAPHIC