Trivia (no googling!)

1. When was germicidal UV-C first used to inactivate infectious diseases in classrooms and lecture halls?
   a. 1890s
   b. 1930s
   c. 1970s
   d. 2010s
Clearing the Air: Healthier, Safer, More Efficient Buildings with Germicidal UV Systems

Lighting Systems Technology Research Team
September 15, 2022
Trivia (no googling!)

1. When was germicidal UV-C first used to inactivate infectious diseases in classrooms and lecture halls?
   a. 1890s
   b. 1930s
   c. 1970s
   d. 2010s

   In 1937, William Wells use upper-room UVGI to prevent the epidemic spread of measles in suburban Philadelphia day schools where infection outside the school is unlikely.


Agenda

- Today’s Speakers
- Recent Work and Events
- 2022 ILC Recognitions
- Lighting Resources
- Clearing the Air: Germicidal UV Systems
- Adjourn
Today’s Speakers

Axel Pearson, LC  
PNNL

Ruth Taylor  
PNNL

Gabe Arnold, PE, LC  
PNNL
Recent Work and Events

• **GUV field evaluations / case studies**
  • Looking for new and existing host sites to evaluate GUV system performance

• **L-prize Prototype Phase (Phase 2) has launched!**
  • Two tracks; many ways to win!
  • Anyone can participate, not just winners from the first phase
    • View the August 3 webinar for an overview of the L-Prize Prototype Phase requirements and timeline
    • View the August 17 webinar on diversity, equity, and inclusion requirements and opportunities
    • View the August 17 webinar on product life cycle and sustainability requirements and opportunities
  • Visit the [L-Prize website](#) to learn more and view the complete rules document

• **Events**
  • [ASHRAE Building Performance Analysis Conference and SimBuild](#), Chicago, IL. Sep. 14-16
  • [IUVA Americas Conference](#), Cincinnati, OH. Sep. 26-28
  • [2022 IES Street and Area Lighting Conference](#), Dallas, TX. Oct. 10-13
  • [69th NALMCO Annual Convention & Trade Show](#), Glendale, AZ. Oct. 16-19
Integrated Lighting Campaign (ILC)

Get your Integrated Lighting Project Recognized!

- Recognized participants announced at IES Annual Conference
- Case Studies developed
- Promoted by DOE
- Technical Assistance and Resources available
2022 ILC Recognitions

- 18 Recognized organizations
  - 15 Participants
  - 3 Supporters

<table>
<thead>
<tr>
<th>Recognition Category</th>
<th># of Recognitions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Advanced Use of Sensors and Controls</td>
<td>11</td>
</tr>
<tr>
<td>Integrated Controls for Plug Loads</td>
<td>0</td>
</tr>
<tr>
<td>Integrated Controls for HVAC</td>
<td>2</td>
</tr>
<tr>
<td>Other Integrated Systems</td>
<td>2</td>
</tr>
<tr>
<td>Integrated Lighting and Horticultural Controls</td>
<td>2</td>
</tr>
<tr>
<td>Innovative Maintenance, Operation, and Financing Service Models</td>
<td>1</td>
</tr>
<tr>
<td>Exemplary Supporter</td>
<td>2</td>
</tr>
<tr>
<td>Diversity, Equity, and Inclusion Champion</td>
<td>1</td>
</tr>
</tbody>
</table>
The Lighting Systems Technology Research Team (LS TRT) aims to reduce lighting energy use by sharing insights and experiences related to emerging lighting and control systems and documenting the application of solutions.
Advanced Lighting Resources

Ruth Taylor
Advanced Lighting Project Manager
For each of the resources you selected, for whom are they most useful?

<table>
<thead>
<tr>
<th>Resource</th>
<th>Building Owners / Managers</th>
<th>Installers / Contractors</th>
<th>Lighting Designers</th>
<th>Utility / Consultants</th>
<th>Manufacturers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating and Maintaining a CLS</td>
<td>17</td>
<td>13</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Cybersecurity in CLS</td>
<td>14</td>
<td>7</td>
<td>7</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>Energy Reporting in CLS</td>
<td>8</td>
<td>1</td>
<td>3</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>Installation and Configuration Methods</td>
<td>8</td>
<td>12</td>
<td>4</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Futureproofing and Upgradeability</td>
<td>12</td>
<td>1</td>
<td>6</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Integrating Lighting &amp; Plug Load</td>
<td>4</td>
<td>6</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Integrating Lighting &amp; HVAC</td>
<td>10</td>
<td>9</td>
<td>8</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Understanding Proprietary and Open Protocols</td>
<td>8</td>
<td>7</td>
<td>8</td>
<td>5</td>
<td>6</td>
</tr>
<tr>
<td>Capitalizing on the Benefits of CLS</td>
<td>19</td>
<td>9</td>
<td>9</td>
<td>13</td>
<td>2</td>
</tr>
<tr>
<td>System Selection</td>
<td>16</td>
<td>13</td>
<td>19</td>
<td>10</td>
<td>4</td>
</tr>
</tbody>
</table>
Which topics do you see the greatest need to address with educational resources on connected lighting systems?

- Operating and Maintaining a CLS: 52%
- Cybersecurity in CLS: 42%
- Energy Reporting in CLS: 30%
- Installation and Configuration Methods: 36%
- Futureproofing and Upgradeability: 39%
- Integrating Lighting & Plug Load: 21%
- Integrating Lighting & HVAC: 42%
- Understanding Proprietary and Open Protocols: 33%
- Capitalizing on the Benefits of CLS: 61%
- System Selection: 67%

In the works, feedback needed

New resource, in review
Guidance for Successful Advanced Lighting Control Systems

Contents
Introduction .........................................................................................................................
Focused System Selection .................................................................................................
System Objectives ..............................................................................................................
Controls Intent Narrative ....................................................................................................
System Capabilities ............................................................................................................
System Scale ....................................................................................................................... System Architecture ..............................................................................................................
Network Options ................................................................................................................
Wireless Networks ............................................................................................................... Wired Networks ..................................................................................................................... Components of a Lighting Controls System ...................................................................
System Resiliency and Flexibility ....................................................................................... Specifying the System and Its Operation ..............................................................................
Focused System Selection at a Glance .................................................................................
Glossary ............................................................................................................................... Additional Resources ..............................................................................................................
Appendix A – Focused System Selection Example .............................................................

Understanding the Potential of Connected Lighting Systems

The potential of connected lighting systems can have significant benefits for many organizations, including potential energy and cost savings. These systems can be integrated into existing infrastructure and can be controlled remotely. This can lead to more efficient lighting and cost savings for organizations.

Strategies for Success with Connected Lighting Systems

Common Use Cases
- Occupancy
- Daylighting
- Energy Management
- Lighting Control

Strategic Benefits
- Energy Efficiency
- Occupancy
- Daylighting
- Automation
- Flexibility
- Security

Common Mistakes
- Lack of proper planning
- Inadequate system design
- Insufficient maintenance
- Inefficient operation

Under review


NGLS Resources

- An Observational Understanding of Connected Lighting Systems (14 pages)
- The Impact of Wall Control Performance on Connected Lighting Systems (11 pages)
- The Influence of Communication on the Complexity of Connected Lighting Systems (17 pages)
- Overview video – Inside the NGLS Living Labs (6 minutes)
- Presence Detection in Connected Lighting Systems (17 pages)
- Characterizing Connected Lighting Systems (13 pages)

Future
- Assessing Daylight Harvesting Performance in Connected Lighting Systems
- The Role of Configuration Tools in Effective Connected Lighting Systems
## NGLS/ILC Educational Resources – (People & Process)

<table>
<thead>
<tr>
<th>Decision Document</th>
<th>Audience</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complete</td>
<td>Owners</td>
<td>Understand the benefits of CLS</td>
</tr>
<tr>
<td>Complete</td>
<td>Owners</td>
<td>Recommended best practices for design and implementation of CLS</td>
</tr>
<tr>
<td>Ongoing</td>
<td>Specifiers</td>
<td>Guidance for selecting an appropriate lighting control system to meet functional goals</td>
</tr>
<tr>
<td>Future</td>
<td>Specifiers</td>
<td>Targeted controls language templates for CIN and SOO</td>
</tr>
<tr>
<td>Future</td>
<td>Specifiers &amp; Programmers</td>
<td>Programming report template based on CIN and SOO</td>
</tr>
<tr>
<td>Future</td>
<td>Facility Staff</td>
<td>Protocols for maintenance and upgradability</td>
</tr>
</tbody>
</table>
## Educational Resources

<table>
<thead>
<tr>
<th>Decision Document</th>
<th>Audience</th>
<th>Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Specifiers</td>
<td>Guidance for selecting an appropriate lighting controls system to meet functional goals</td>
</tr>
<tr>
<td>4</td>
<td>Specifiers</td>
<td>Targeted controls language templates for CIN and SoO</td>
</tr>
<tr>
<td>5</td>
<td>Specifiers &amp; Programmers</td>
<td>Programming report template based on CIN and SoO</td>
</tr>
<tr>
<td>6</td>
<td>Facility Staff</td>
<td>Protocols for maintenance and upgradability</td>
</tr>
</tbody>
</table>

### Collaborative Web Tools
- In coordination with IES and ongoing committee activities
- NGLS committee
- Controls Working Group
These documents equip decision makers with an organized approach to lighting controls when establishing defined objectives. A best practice approach to design and implementation is also provided.

**DECISION DOCUMENTS 1 & 2:**

**Educational Resources for Decision Makers**

**Building and Code Compliance**
This use case represents the minimum requirement for most projects and is generally the least costly.

**SYSTEM CAPABILITIES INCLUDE:**
- Switches & dimmers
- Programmable clock
- Presence detection
- Daylight detection

**Enhanced Lighting Performance**
This use case aims at improving workforce productivity, wellness, and facility appeal.

**SYSTEM CAPABILITIES INCLUDE:**
- Programmable scene control
- AV controls
- Shade control
- Tunable color

**Enhanced Energy Savings**
This use case supports both aggressive cost reduction as well as zero carbon goals.

**SYSTEM CAPABILITIES INCLUDE:**
- Energy reporting
- System status feedback
- Environmental sensors
- Grid interaction

**Enhanced Facility Productivity**
This use case includes increased spatial and asset efficiency, retail performance, safety and security, and engagement.

**SYSTEM CAPABILITIES INCLUDE:**
- Data sharing and analysis
- Indoor positioning
- Asset identification
- Occupant counting

**DECISION DOCUMENT 3:**

**Educational Resources for Specifiers**

The same organizational framework is applied to advise specifiers through a focused system selection and specification process.
Clearing the Air: Healthier, Safer, More Efficient Buildings with Germicidal UV Systems

September 15, 2022

Gabe Arnold, P.E.
Disclaimer

This presentation was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor Battelle Memorial Institute, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof, or Battelle Memorial Institute. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.
The Electromagnetic Spectrum

Optimal UV Disinfection Range

Wavelength (nm)
Wells, Wells, and Wilder. 1941. The environmental control of epidemic contagion. Swarthmore public schools
GUV Room Disinfection Methods

Upper Room

Direct Irradiation when Unoccupied

GUV User Station Example
Key required to turn system on, can only be operated by authorized personnel.

Source: CDC
Source: Aeromed
Source: Signify
Source: Xtralight
Source: Cooper Lighting
Source: Cooper Lighting
Source: Larson Electronics
GUV Room Disinfection Methods

Direct Irradiation
Below Exposure Limits (DIBEL)

Continuous UVC helps inactivate airborne viruses while operating below exposure guidelines set by BCP 62471 and IEC60601 TUV.

Continuous operation 24 hours/day for high-traffic occupied spaces.

Room Air Cleaner

Portable Air Cleaner
Source: EPA

Source: GE Current
Source: Acuity Brands
Source: Olympia Lighting
Source: Lowes.com
GUV Room Disinfection Methods

In-duct UV
Upper room GUV (UR-GUV) is most tried, tested, and proven.
For many commercial buildings, HVAC energy use and carbon emissions are up from the pandemic.

Measures to Reduce Virus Transmission in Buildings

- Increase air change rate
- Increase fraction of outdoor air
- Improve in-duct filtration to at least MERV-13
- Disable demand control ventilation
- Pre- and post-occupancy flushing
- Use upper room GUV
- Standalone air cleaners
### Initial 2020 Pandemic Recommendations

1. Increase minimum outdoor air to 100%
2. Upgrade to MERV 13 filters
3. Disable demand-controlled ventilation

### Current “Core” Recommendations

1. Provide at least required outdoor air as specified by codes and standards
2. Use MERV 13 filters or equivalent measures supported by system
3. Maintain equivalent clean air supply design occupancy whenever space is occupied

Implications at National Scale – Commercial Building Stock

Implications at National Scale – Schools

Increase in energy required to reduce infection risk below 1%

Ventilation increase

- MERV13
- MERV14
- MERV15
- MERV16

Annual energy cost increase (dollar/m²)

Cai et al. 2022. Nationwide assessment of energy costs and policies to limit airborne infection risks in U.S. schools
How does germicidal ultraviolet disinfection compare to recommended ventilation measures in terms of effectiveness and energy use?
Increasing the fraction of outdoor air
Increasing air change rate
Improved filtration

Utilizing Upper Room GUV

Air Handling Unit
Supply

New DOE-funded PNNL paper evaluates GUV and three HVAC strategies for effectiveness and energy use against SARS-CoV-2.

Download:
https://www.energy.gov/eere/ssl/germicidal-ultraviolet-disinfection
GUV is compared to HVAC ventilation strategies using eACH metric

- 1 ACH of ventilation removes 63% of airborne pathogens
- 1 eACH = the number of equivalent air changes needed to achieve the same inactivation rate of airborne pathogens as UR-GUV
- Equivalent only in terms of disinfection
- All studies show multiple ACH needed to match disinfection of GUV
Energy cost per EACH of various strategies

- Current studies show GUV has much lower energy cost than 100% outside air for equivalent disinfection
- Energy cost savings and decarbonization benefits vary by location
Energy Efficiency, Decarbonization, Electrification Opportunities of GUV

**Energy Efficiency**
- Use GUV as more efficient alternative to increasing ventilation above code or disabling demand-controlled ventilation
- Use more efficient GUV fixtures or design approaches

**Decarbonization**
- Decrease fossil fuel heating needed for ventilation by using electric GUV for disinfection

**Electrification**
- Use GUV to reduce ventilation load in HVAC system design, thereby reducing size, cost, infrastructure requirements of fuel switch from fossil fuel heat to electric heat pump
PNNL Activities and Next Steps

**CALiPER Product Evaluations**
- How do products perform and compare to manufacturer claims? What efficiency opportunities exist?
- Round 1 test report coming soon

**GATEWAY Field Evaluations**
- Case studies of real-world applications
- Seeking existing installations and new installation host sites to work with – contact us with ideas

**Technical Reports**
- Energy implications of upper room GUV vs. HVAC (published)
- Report on current test methods, standards, testing infrastructure

**Simulation Model**
- Characterize and quantify effectiveness, energy efficiency, decarbonization, electrification benefits across building types and climate zones
Poll Question 1:

Has GUV been installed on one of your projects or in your building? If yes, what type?
[Select as many as apply]

a. Yes – Upper room GUV system
b. Yes – GUV direct irradiation system
c. Yes – In-duct GUV system
d. Yes – In-room portable air cleaner
e. Yes – GUV robot/tower for healthcare applications
f. No
Poll Question 2:

What do you see as greatest value of this technology?
[Select your top 2]

a. Reduce work/school sickness and absenteeism
b. Safer buildings
c. Reduce energy costs, decarbonization
d. Improve indoor air quality
e. Prepare for future pandemics
f. Other: write into chat
Poll Question 3:

What are your biggest concerns with deploying this technology with your clients, on your projects, or in your buildings? [Select your top 2]

a. Safety concerns – causing temporary injury to eye or skin
b. Effectiveness – uncertainty of how well it works
c. Resources – trained workforce to install, operate, and maintain it
d. Cost – high cost of GUV fixtures
e. Other: write into chat
Poll Question 4:

What are examples of key data or information you would need to make a decision to deploy this technology with clients, projects, buildings?

[Select your top 2]

a. Case studies/data demonstrating energy savings and costs
b. Case studies/data demonstrating germicidal effectiveness
c. Case studies/data demonstrating it is safe
d. Design and installation guidelines
e. Training/education resources for how to operate and maintain
f. Other: write into chat
Thank you

Gabe Arnold, PE

gabriel.arnold@pnnl.gov

902 Battelle Boulevard
P.O. Box 999
Richland, WA 99352

www.pnnl.gov
Lighting Systems Technology Research Team

• **We want to continue to develop resources for the lighting industry**
  • Advisory committees and working groups will take specific topics and will develop targeted guidance based on industry feedback

• **Are you interested in getting involved?**
  • You can provide input to the advisory committee and/or contribute to resources

• **Please send a chat now or email axel.pearson@pnnl.gov for more info!**
Any more questions or discussion, please email axel.pearson@pnnl.gov

Slides will be posted to the Technology Research Team webpage soon!