INSIDE THE NGLS LIVING LABS

The Impact of Wall Control Performance on Connected Lighting Systems

Pacific Northwest NATIONAL LABORATORY

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Wall controls form the only touchpoint for individual room users and that room's lighting control system. As such, these interfaces strongly influence user understanding and utilization of the system, as well as overall acceptance.

The Next Generation Lighting Systems (NGLS) program began an evaluation of the wall controls in 14 connected lighting systems installed in various rooms of the NGLS Living Lab at Parsons School of Design in New York City. These systems demonstrate the wide range of approaches to wall control design and functionality taken by manufacturers. Characterizing the 14 wall controls across six attributes, only four, or 29%, were identical.

Requirements for wall control design were not specified *explicitly* by NGLS. Rather, wall controls were required to meet three criteria: vacancy control (manual on/auto off) of two zones; manual continuous dimming of the same two zones; and an AV presentation mode in one of the two zones.

This report examines the classification of wall controls, the assessment method used to evaluate the system response to wall control use from installation through day-to-day use, and the system performance observed to date for each.

NEXT GENERATION LIGHTING SYSTEMS

NGLS is organized by the Department of Energy in partnership with the Illuminating Engineering Society and the International Association of Lighting Designers, and managed by Pacific Northwest National Laboratory. NGLS uses "Living Labs" to conduct observational research in real-world settings—indoors at Parsons School of Design in New York City and outdoors at the Corporate Research Center adjacent to the Virginia Tech Transportation Institute in Blacksburg, Virginia. NGLS teams consist of a broad range of industry experts, including lighting designers, engineers, and utility professionals.

NGLS evaluators use detailed protocols to observe, document, and measure how systems are installed and configured, how well they perform, and how users operate them. NGLS seeks to learn from manufacturers' varied approaches—identifying those that work, revealing needed improvements, articulating effective principles and practices, and publishing findings for the benefit of the lighting community.

CLASSIFICATION OF ENTRIES

The 14 wall controls currently installed in the NGLS Living Lab at Parsons School of Design can be broadly classified across six attributes: user interface type, configuration, quantity used, power source, communication to luminaires/ sensors, and labels for functionality.

The systems evaluated demonstrate considerable diversity among the designs used by different control system manufacturers. Scrutiny of the rows in the table below show that no single overall design is preferred by manufacturers.

User Interface Type

Rocker (paddle-style) devices are the most common user interface in this evaluation.

Configuration

Pre-configured wall controls were generally easier to set up but did not permit users to modify device functionality. Field-configurable types offered more flexibility for modifications but required more time to set up. Note that all wall devices need to be incorporated into the system network. Procedures for discovering or linking the wall control to the system are discussed under Installation and Configuration on page 5.

Classification of Entries

		UI		Configuration		Quantity Used			Power Source			Communication to Luminaires/Sensors						Labels	
Entrant	Control Systems	Rocker	Button	Pre-Configured	Field-Configured	1 Device	2 Device	3 Device	Wired	Kinetic	Battery	Zigbee or IEEE802.15.4	Bluetooth	Other	Mesh Network	Point-to-Point	Unidentified	Labels	No Labels
Lutron	Vive		●	●			●				●			●		●		●	
Acuity	nLight AIR		●	●		●					●		●				●	●	
Cree	SmartCast	●		●			●		●			●					●		●
Lumenwerx	Magnum	●		●			●			●				●	●				●
Signify/Selux	EasySense	●		●			●			●		●			●				●
Signify	SpaceWise	●		●			●			●		●			●				●
Signify	SpaceWise	●		●			●			●		●			●				●
Silvair	Silvair	●			●		●			●			●		●				●
Avi-on/MaxLite	Avi-on Pro	●			●		●				●		●		●			●	
Cooper Lighting	WaveLinx		●		●	●			●			●					●	●	
Crestron	Zūm		●		●		●				●			●	●			●	
Nextek	SKY-controls	●		●				●			●			●		●		●	
RAB Lighting	Lightcloud	●			●			●	●			●					●		●
LG	Sensor Connect		●	●		●					●	●					●	●	
	14 Entries	9	5	9	5	3	9	2	3	5	6	7	3	4	7	2	5	7	7
	12 Technologies	7	5	7	5	3	7	2	3	3	6	5	3	4	5	2	5	6	6
	14 Entries	**64%**	36%	**64%**	36%	21%	**64%**	14%	21%	36%	**43%**	**50%**	21%	29%	**50%**	14%	36%	43%	**50%**

Note: "Device" in this discussion refers to an individual wall control component (rocker, keypad, or similar). For the entrants listed where systems included products from two different manufacturers, the primary contact during installation and configuration is listed first.

Quantity Used

The number of wall controls needed to operate the system per the NGLS specification was determined by the entrant. Most systems employed two user interface devices, one for each zone. Only three systems used a single, multi-button device and two others used three devices. Based on user experience, a separate device for each zone proved more intuitive and easier to operate than additional (or fewer) devices.

Power Source

All approaches to powering the wall controls appear to have issues. Installation of the three AC-powered devices was sometimes confusing to contractors and generally required more time than installation of kinetic- or battery-powered devices. Devices using kinetic power, generated by pressing the rocker panel, challenged some users because more pressure is required than with other rocker devices. Finally, battery life and maintenance were identified as concerns for battery-powered devices.

Some systems offered a choice in power source, providing options for the user (see the Classification of Entries table on page 3 for the installed condition). A benefit of self-powered devices using a battery or kinetic energy is that they can be located without the cost and limitations of new or existing electrical wiring.

Communication to Luminaires/Sensors

Information about the wireless communication used by each wall control was not observable. We relied on review of the manufacturer documentation and conversations with manufacturers to characterize the methods of communication.

In terms of radio protocol, most systems use Zigbee or one complying with IEEE 802.15.4. The most recently installed systems use Bluetooth®. Of the four systems with communication listed as "Other," two are confirmed as fully proprietary at this time.

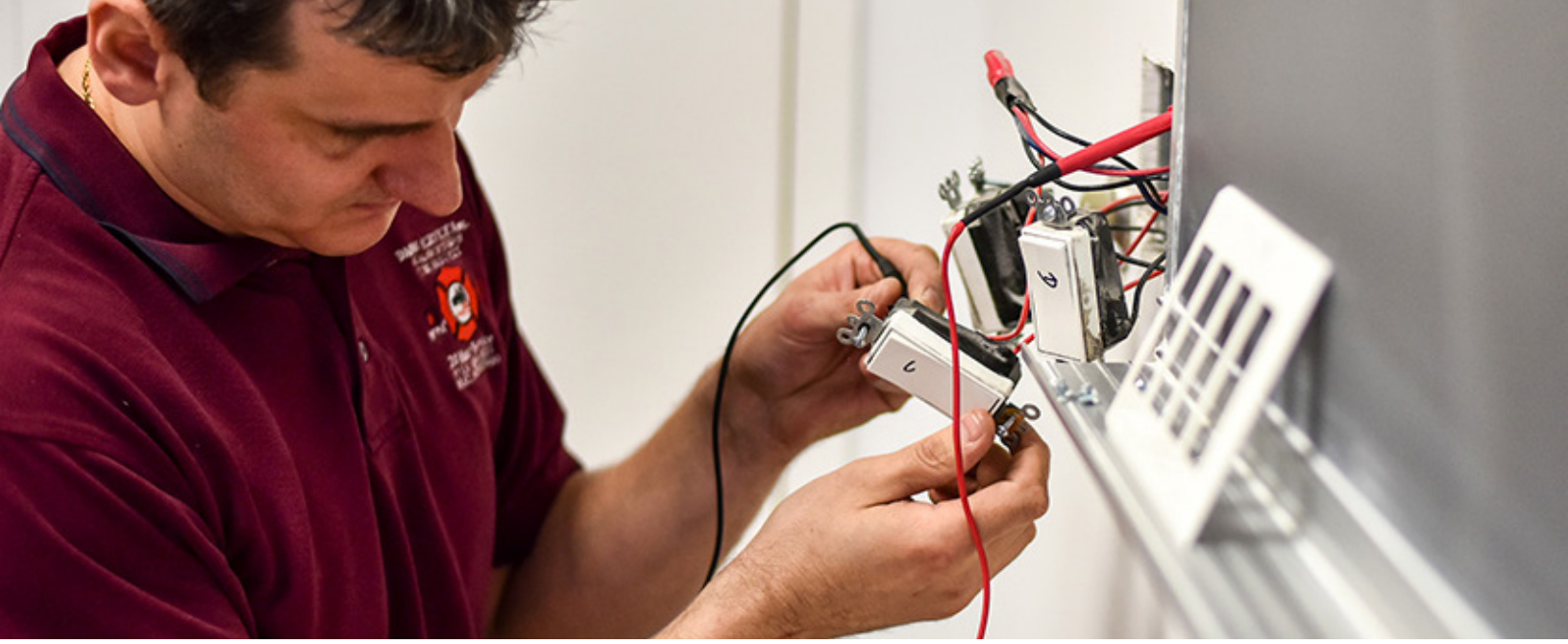
Similarly, half of the systems feature a mesh network; two rely on point-to-point communication; and five did not specify.

Labels for Functionality

All of the multi-button devices used labels to communicate functionality—usually engraved words or icons. Only one of the rocker-type systems was labeled by the manufacturer, and this labeling was added after installation.

Since rockers are a familiar style of wall control, it is likely that manufacturers assume rocker operation is sufficiently familiar and no identification is needed. Unfortunately, this did not prove to be the case during the NGLS evaluations. Users found the kinetic rockers unfamiliar to operate because of the hard press required. The use of three rockers for two zones was also found to be confusing.

Labels that were clear and easy to read while users stood at the wall control definitely improved ease-of-use, absent other factors. However, lack of consistent and intuitive descriptions for zones, scenes, and actions presented a major challenge. In one case, simple and straightforward icons, including engraved up/down arrows, were not enough to explain operation, as one longtime room occupant was unaware that the system could dim.



INSTALLATION AND CONFIGURATION

Wall control installation challenges due to faulty equipment, outdated firmware, or on-site breakage were observed in half the systems. Ironically, three of the four systems with no installation issues encountered serious issues in other aspects of the system.

General installation and configuration issues observed by NGLS evaluators included the following:

1) Installers spent time removing existing wall controls and identifying the AC connection to luminaires in order to wire in the controls. Some did not recognize that the AC wires were providing only power, and not being used to control on/off operation of the luminaires.

2) Resolving differences between the number of new and old devices placed in the wall took time, as did securing additional components to cover openings in the outlet box.

3) Kinetic- and battery-powered devices installed more easily than AC-powered devices and offered the opportunity for easy relocation instead of mounting in the existing outlet box.

4) Pairing wall controls with luminaires and programming was often not intuitive. Manufacturer tech support was often required to resolve issues.

5) In several cases, the NGLS specification was misinterpreted or misunderstood by the manufacturer and wall controls were provided that could not deliver the required operational performance.

Specific installation and configuration issues with each system faced by installers, observed by NGLS evaluators, or captured in installation debriefs are included in the appendix.

Wall Control Issues

System	Incorrect Switch Provided	Initial Pairing Difficulty	On-Site Breakage	Operational Failure (User Complaint)
1				
2	●	●	●	
3	●			
4	●			
5	●			●
6			●	
7	●			●
8	●	●		
9				
10		●		
11				
12				●
13		●		
14	●			●

PERFORMANCE

To satisfy the NGLS specification, all systems needed to provide the same basic wall control operation: manual on and manual dimming in each of two zones. The specification required vacancy control, so manual off was not explicitly required.

General performance issues observed by NGLS evaluators included the following:

1) Dimming response: For all systems, there was a delay between a button press and a change in luminaire light output. This slow response led to confusion for all users.

2) On/off: For most controls, a light touch was sufficient to activate on or off. Kinetic switches, however, required a firmer press, which users found unfamiliar and counterintuitive.

3) Manual dimming (raise/lower): For most controls, press and hold was required to raise or lower light levels. Due to the slow dimming response described above, this function was not obvious to many users.

4) Zone control: Some systems dedicated separate controls for each zone; other systems provided buttons on a single control.

    a) Separate zone controls usually worked well, especially if wall placement intuitively related to zone layout.

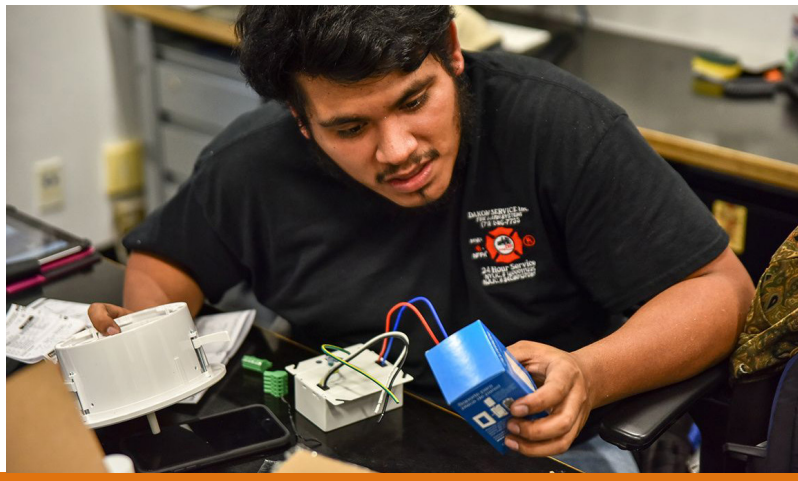
    b) In cases where zone control was provided by buttons on a single device, ease of operation depended on effective identification. Some labels and button positions worked better than others.

5) Compound functionality: Some systems featured buttons that initiated different system responses based on system condition. This functionality proved very difficult to understand and use.

6) Some systems featured “scenes”—lighting presets for specific purposes. Unless such scenes were clearly identified, users found them confusing.

7) A comparison of two sets of users, evaluators from NGLS and students from Parsons, revealed that NGLS evaluators found it easier to operate the controls, possibly due to professional familiarity with lighting systems, resulting in more patience with non-intuitive functionality.

Specific performance issues with the wall controls for each system are included in the appendix.



Wall Controls Ease-of-Use Exercise Evaluators (knowledgeable users) and students (naïve users) operated wall controls to complete a specific control sequence (on/off, dimming, AV zone).						
	Knowledgeable Users			Naïve Users		
System	On/Off	Dimming 2 Zones	AV Zone	On/Off	Dimming 2 Zones	AV Zone
1	Yes	Yes	Yes	Yes	Yes	Yes
2	Yes	Yes, but delay to dim caused confusion	Yes	Yes	No, delay to dim led to failure	Yes
3	No	Yes	No	No	No	No
4	Yes	Yes, but delay to dim caused confusion	Yes	Yes	No, delay to dim led to failure	Yes
5	Yes	Yes	Yes	Yes	No	Yes
6	Yes	Yes	Yes	Yes	Yes	Yes
7	Yes	No	Yes	Yes	No	Yes
8	Yes	Yes, but delay to dim caused confusion	Yes, but label not intuitive	Yes	Yes, but delay to dim caused confusion	Yes, but label not intuitive
9	Yes	No	Yes	No	No	Yes
10	Yes	Yes, but delay to dim caused confusion	Yes	Yes	No, delay to dim led to failure	Yes
11	Yes	Yes	Yes	Yes	No	Yes
12	Yes	Yes	Yes	Yes	Yes	Yes

Note: Due to COVID-19 restrictions, the wall controls ease of use exercise has not been completed for the two newest systems.

Supplemental Room Placards

Recognizing the difficulties users encountered in understanding how to operate wall controls, the NGLS team decided to create explanatory "operating the lighting controls" placards for each room in the Parsons Living Lab (sample below).

COVID-19 and the consequent lack of access to school buildings have limited this effort to just the five rooms using kinetic energy devices. Installation of placards for the remaining rooms awaits approval from Parsons facilities team and building access.

THE NEW SCHOO

Operating the lighting controls:

- One switch controls the front (screen) of the room; the other controls the back of the room.
- For lights ON, push the top of the switch until it clicks.
- For lights OFF, push the bottom of the switch until it clicks.
- To dim UP, press and hold the top of the switch; release to stop dimming.
- To dim DOWN, press and hold the bottom of the switch; release to stop dimming.
- Lights will automatically turn off after the room is no longer occupied.
- Lights will automatically dim when sufficient daylight is present.

Problems?
Call or email Facilities at xxx-xxxx or xxxxxx@newschool.edu.

Comments?
Please send any thoughts you have - good or bad - regarding the lighting and controls to livinglab@pnnl.gov. And please be sure to identify the room.

GENERAL CONCLUSIONS

NGLS observations in the Parsons Living Lab—from installation and configuration to operation and use—combined with measurement of system effectiveness and feedback from installers and users, have resulted in the following general conclusions:

1) Clarity in the design of wall controls is essential to the successful user operation of the entire system.

2) "Extra" devices, such as supplemental scene controls beyond those required, should be avoided.

3) Physical location of the devices on the wall (left to right or upper and lower) help identify zones.

4) Clear labels help with correct operation. Simple icons (e.g., arrows for raise/lower) also work well.

5) Controls should prompt visual (or tactile) feedback to assure users of response.

6) A light touch and press works better than requiring a strong "click" and press.

7) User preference varies between well-designed single (multi-button) and multi-devices, although one device per zone appears a useful default approach.

8) Although the NGLS system requirements were simple and routine, unfamiliar users could overlook the dimming functionality or two-zone configuration (for example) if not motivated to search them out.

9) Some controls were clearly better than others; some were largely unsuccessful. Pre-configured kinetic types fared well due to their simplicity, but the hard press to operate was a disadvantage. User evaluation of wall control performance was also affected by overall system problems.

10) There is considerable diversity among wall control designs, with no single design approach predominating. This fact may impede the ability of installers to adapt to new systems, as each has to be learned individually (at least to some degree).

APPENDIX

System 1 included a double, pre-configured, kinetic, rocker wall control.

Installation and configuration notes: No issues with installation of wall controls were observed.

Performance notes: Slow dim response and the hard-press required with the device resulted in difficulty understanding whether the system was actually responding. The two zones could not be dimmed at the same time; sequential dimming was required.

System 2 included a double, pre-configured, kinetic, rocker wall control.

Installation and configuration notes: An incorrect switch was provided initially. A faulty replacement switch required factory diagnosis before replacement. Mechanical pairing (disassembly of device and simultaneous pressing of two components) was an unfamiliar action to installers and needed several tries.

Performance notes: The press-for-dim vs. click-for-on/off design proved confusing for users in their first attempts.

System 3 included a double, field-configured, battery-powered, multi-button wall control.

Installation and configuration notes: No issues were observed with physical installation of wall control. However, wiring errors in the fixtures prevented the system from operating separate front (AV) and back zones, so the wall controls could not be configured to the NGLS specification. Wiring issues required extensive tech support.

Performance notes: The keypads offered scene rather than simple two-zone control. Combined with the inability of the installed system to provide the specified AV zone control, the keypad configuration made control from the wall both inadequate and confusing.

System 4 included a double, pre-configured, kinetic, rocker wall control.

Installation and configuration notes: A faulty replacement switch required factory diagnosis before replacement. Also, the same mechanical pairing situation as System 2 occurred with System 4.

Performance notes: The press-for-dim vs. click-for-on/off design proved confusing for users in their first attempts.

System 5 included a triple, field-configurable, wired, rocker wall control.

Installation and configuration notes: No issues were observed with installation of the wall control. However, serious issues in other respects required extensive tech support.

Performance notes: Indicator lights corresponding to dim level proved useful. Three switches were provided, which was confusing. The third switch offered a preset for all lights, 75/25%, which was not part of the NGLS specification.

System 6 included a double, pre-configured, dual rocker wall control.

Installation and configuration notes: Physical damage to the device after installation impaired operation until replaced. The replacement needed to be programmed, which was not obvious or easy.

Performance notes: A dual-rocker control for each zone proved relatively easy to understand and operate.

System 7 included a triple, pre-configured, battery-powered, rocker wall control.

Installation and configuration notes: No issues were observed with installation of the wall controls, but serious issues in other respects were present, requiring extensive tech support. Parsons requested removal of the system after user complaints.

Performance notes: A master switch for on/off of the entire room proved useful when labeled. The system dims to off, making it difficult to set lowest light level. Daylight and AV zone control were found to be very confusing.

System 8 included a single, field-configured, wired, multi-button wall control.

Installation and configuration notes: Incorrect switches needed repeated replacement. The system design coupled with conflicting information from factory support resulted in serious configuration issues and the need for extensive tech support.

Performance notes: On/off and raise/lower buttons were labeled and easy to find; scene buttons were not clear ("half lights" meant "zone," not level, for example). Multiple buttons were confusing to some. The wall controls originally provided were ultimately replaced by a simpler, two-button control.

System 9 included a single, pre-configured, battery-powered, multi-button wall control.

Installation and configuration notes: Old firmware required physical replacement before the control was operational. Serious operational issues were present. Tech support was required, but the product was withdrawn from the market (and mothballed in the Living Lab) before it was available to users.

Performance notes: This wall control was found to be generally confusing and unintuitive in most functions. The requirement to press a button to enable the dimming function was particularly confusing. The unit lacked a simple all-on button. One evaluator needed two hands to operate the controls.

System 10 included a double, pre-configured, kinetic, rocker wall control.

Installation and configuration notes: A faulty replacement switch required factory diagnosis before replacement. Also, the same mechanical pairing situation as Systems 2 and 4 occurred with System 10.

Performance notes: The press-for-dim vs. click-for-on/off design proved confusing for users in their first attempts.

System 11 included a double, pre-configured, battery-powered, multi-button wall control.

Installation and configuration notes: No issues with installation or configuration of wall controls were observed.

Performance notes: This was found to be a generally successful control with intuitive buttons, although one longtime room occupant did not recognize the dimming functionality. “Oh, it dims!” was the happy response when shown.

System 12 included a single, pre-configured, battery-powered, multi-button wall control.

Installation and configuration notes: A new keypad and old firmware both required updates before the control was operational, which made considerable tech support necessary.

Performance notes: Control functions proved easy to identify and press for the desired result. However, the system did not perform until replacement equipment and firmware were installed.

System 13 included a double, field-configured, battery-powered, multi-button wall control.

Installation and configuration notes: No issues were observed with the physical installation of the wall controls. However, system configuration was complicated due to a previous pairing at the factory, which prevented identification by a new user account. In addition, the phone app was not intuitive. These issues required extensive tech support.

Performance notes: A user’s Apple Watch interfered with this system’s Bluetooth connection, which added to the difficulty of (a) identifying the problem and (b) achieving successful system operation. Factory support resolved the interference, but vacancy mode (manual on, auto off) did not work (probably a sensor issue), forcing the use of occupancy mode (auto on/auto off). The system thus lacks the manual-on wall control functionality required by the NGLS specification. Manual dimming is achieved through the use of preset buttons with printed light levels, which is less intuitive to occasional users than labeled raise/lower rockers.

System 14 included a double, field-configurable, kinetic, rocker wall control.

Installation and configuration notes: The dual-rocker control that was provided initially could not be programmed to achieve the two-zone specification, and extensive tech support was required. A pair of dual-rocker devices was installed as an interim measure, with one of the rockers intentionally disabled. Ultimately, two single-rocker devices were secured, paired, and programmed.

Performance notes: Operation of this unit proved similar to Systems 4 and 10. Pressing the two devices simultaneously caused interference; rapid “one-two” presses worked fine. This issue was confirmed in the other kinetic devices (Systems 1, 2, 4, and 10).

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www.energy.gov/eere/ssl/next-generation-lighting-systems

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