U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

SSL EVALUATION

Evaluating Tunable LED Lighting in Three Texas Classrooms

A trial installation of tunable-white LED lighting systems in three classrooms in the Carrollton-Farmers Branch Independent School District provided insights into the use of this technology in a real-world setting.

New tunable lighting in a classroom. The four SPD settings are shown in clockwise order, beginning with the upper left photo: 3000 K (Reading), 3500 K (Testing), 4200 K (General), and 5000 K (Energy). The Scene 1 setting was used during the photographs, so all luminaires were on at full light output. *Photos courtesy of Acuity Brands Lighting*

While reducing the energy used for lighting remains a priority for most school districts, an increasing number of them are also interested in the possible non-energy benefits of lighting. That's why the Carrollton-Farmers Branch Independent School District (CFB) in Carrollton, Texas, invited the U.S. Department of Energy (DOE) to conduct a GATEWAY evaluation of a trial installation of tunable-white LED lighting systems in a fifth-grade math and science classroom at Dale B. Davis Elementary School (DES), a fourth-grade reading and language arts classroom at Sheffield Elementary School (SES), and an eighth-grade science laboratory at Charles M. Blalack Middle School (BMS).

Control station installed in each of the classrooms, with two nLight® nPODM controllers. The controller shown on the left provides SPD control, and the controller shown on the right provides light-output control. *Image courtesy of Acuity Brands Lighting*

Pacific Northwest National Laboratory conducted the investigation on behalf of DOE. The lighting system was designed by the consulting engineering firm Estes, McClure & Associates, working in collaboration with the manufacturer (Acuity Brands Lighting). The school district's objectives for the trial installation included considerations beyond energy savings—specifically, assessing the potential for tunable lighting to enhance teacher engagement with students and improve student performance.

Back to School

The LED lighting systems were installed in August 2016, just before the start of the 2016–2017 school year. Each incumbent recessed fluorescent luminaire was replaced with a 2' x 4' Lithonia Lighting® BLT Series Tunable White LED luminaire from Acuity. The LED luminaires offer tunable white lighting with a CCT range of 3000–5000 K. The 4800-lumen light-output option was specified for the classrooms, resulting in a rated light output of 4600–5000 lumens and input power of 34–45W at full output. The luminaires were specified with a curved diffuser with linear prisms and with an nLight® nTune™ control interface.

The lighting control system provided the ability to vary the spectral power distribution (SPD) across four preset conditions, associated with nominal CCTs of 3000 K, 3500 K, 4200 K, and 5000 K. There were also preset scene controls to vary the on/off status and dimming level of different luminaire zones within the room, to better support classroom functions such as audiovisual presentations and student speeches.

The reduction in input power for the tunable-white LED lighting system was estimated to be 58% relative to

Color-Quality Metrics for the Tunable Lighting Systems

LIGHTING SYSTEM	CCT (K)	D_{uv}	R_f	R_g	R_a (CRI)	R_9
Fluorescent – BMS	3691	0.0048	78	99	81	7
Fluorescent – DES	3813	0.0065	79	98	81	5
Fluorescent – SES	3890	0.0093	62	82	57	-111
LED 3000 K	3074	-0.0011	82	98	82	13
LED 3500 K	3487	-0.0023	82	97	84	19
LED 4200 K	4272	-0.0015	82	96	85	21
LED 5000 K	5145	0.0012	82	95	84	13

Color-quality metrics for the lighting systems in the CFB schools. The data for the fluorescent systems are the average values of two luminaires measured at each school. The LED system data are the average values of the six luminaires at one of the schools (DES), measured at full light output for each of the four CCT control settings.

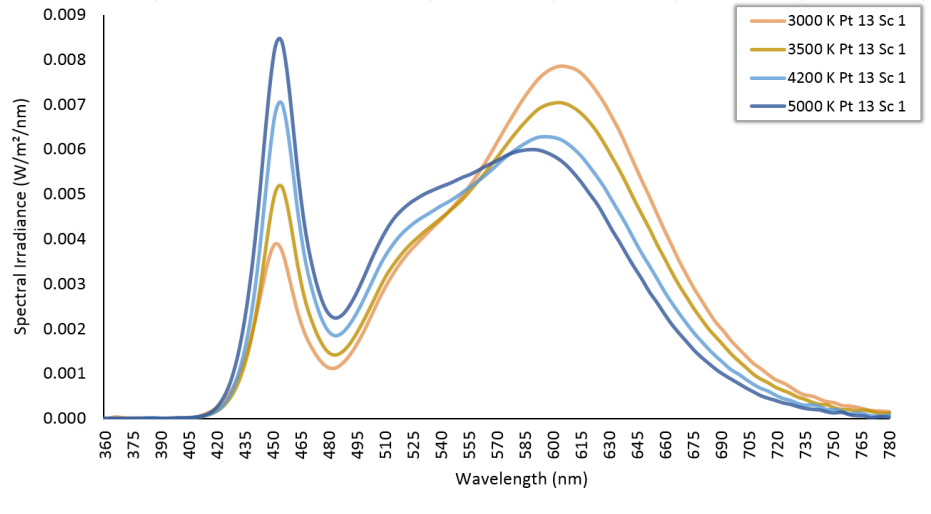
the incumbent fluorescent system. This reduction is attributable to the higher efficacy of the LED luminaires and a reduction in illuminances, which previously exceeded IES-recommended levels. Dimming—which was incorporated into the scene controls and also enabled by separate dimming controls—furthered the energy savings in each classroom. While the individual teacher's usage of the controls varied widely as recorded by the monitoring system, in each case the lighting consistently operated with all or some of the luminaires turned off or dimmed for portions of the school day.

The LED lighting systems were installed and commissioned with very few difficulties, and any issues with initial performance were quickly resolved. The three teachers used the scene controls regularly during the school day, but used the SPD controls infrequently. As was the case with the incumbent fluorescent systems, illuminance levels in the classrooms at maximum output met or exceeded IES recommendations for the typical visual tasks with the new LED systems. Color consistency for the tunable-white LED luminaires was very good, even over the dimming range, with only minor variations in CCT and D_{uv}.

The Teachers' Perspective

The two teachers interviewed by DOE appreciated the ability to tailor the lighting to different classroom needs, and felt that the lighting and controls allowed the students to be engaged in choosing the settings for various classroom activities. Both teachers stated that the lighting system improved the overall learning environment.

Although most teachers are unfamiliar with CCT and other lighting metrics related to color quality, labeling lighting control settings with familiar terms may provide barriers to full usage of the controls. In this project, labels such as "Reading," "Testing," and "Energy" tended to be interpreted too narrowly by the teachers, who didn't seem to use those control settings for classroom



SPDs for the four control settings, measured at point 13 for Scene 1 (100% output).

functions that didn't match the labels. The "General" control setting served as the default.

Use of lighting controls may be enhanced when the control locations are convenient for the teacher. The control locations for this project were constrained by the existing wiring, and where the control locations were more easily accessed by the teacher, the settings (specifically, the dimming level) were varied more regularly than when the controls were less accessible for the teacher.

Beyond Energy Savings

Energy savings from tunable classroom systems results from the switching and dimming functionality of the scene control settings and the manual dimming controls; the ability to vary the color quality doesn't necessarily provide additional energy savings. Because color-tunable systems are at present more costly than fixed-color LED systems (which can still provide full scene and dimming control), an economic argument for color-tunable systems can't be based on energy alone. As with other classroom upgrades, the justification for color-tunable lighting systems needs to include non-energy benefits related to a better learning and working environment, possibly linked to student learning outcomes, teacher satisfaction and retention, and human-health impacts. The difficulty in documenting and assigning economic value to these potential non-energy benefits poses a major challenge for color-tunable lighting systems in classrooms and other applications.

Light-Output Control Buttons

LABEL	DESCRIPTION
SCENE 1	FULL – All luminaires on at 100% setting
SCENE 2	AV MODE – Luminaire row A turned off; other rows dimmed to 40% setting
SCENE 3	PRESENTATION MODE – Luminaire Row A on at 100% setting; other rows dimmed to 50% setting
SCENE 4	DIM – All luminaires on at 10% setting
ON	All luminaires powered on at their previous setting
OFF	All luminaires powered off
UP ARROW	Light output of all luminaires increased by 5%
DOWN ARROW	Light output of all luminaires decreased by 5%
LABEL	**SPD CONTROL BUTTONS**
GENERAL	All luminaires set to 4200 K setting
READING	All luminaires set to 3000 K setting
TESTING	All luminaires set to 3500 K setting
ENERGY	All luminaires set to 5000 K setting

Descriptions for the control buttons installed in each classroom.

The combination of spectral tuning and dimming in the classrooms provides greater opportunity to vary lighting parameters that may affect circadian and behavioral responses for students, teachers, and other users, relative to the fluorescent systems. While documenting these circadian and behavioral effects was beyond the scope of this project, the tunable LED systems may be adaptable to reinforce the desired outcomes, should scientific consensus emerge that supports specific SPD and intensity settings for related effects. ■

GATEWAY Evaluations

GATEWAY evaluations showcase high-performance LED products for general illumination in commercial, municipal, and residential applications. Evaluations yield real-world experience and data on the performance and cost effectiveness of lighting solutions. For more information, see energy.gov/eere/ssl/gateway-demonstrations.

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