CAE 465/526 Building Energy Conservation Technologies

Fall 2022

October 19, 2022

Building Retrofit and Energy Efficiency Measures (EEMs) – Part 1

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Dr. Mohammad Heidarinejad, Ph.D., P.E.
Civil, Architectural and Environmental Engineering
Illinois Institute of Technology
muh182@iit.edu

ANNOUNCEMENTS

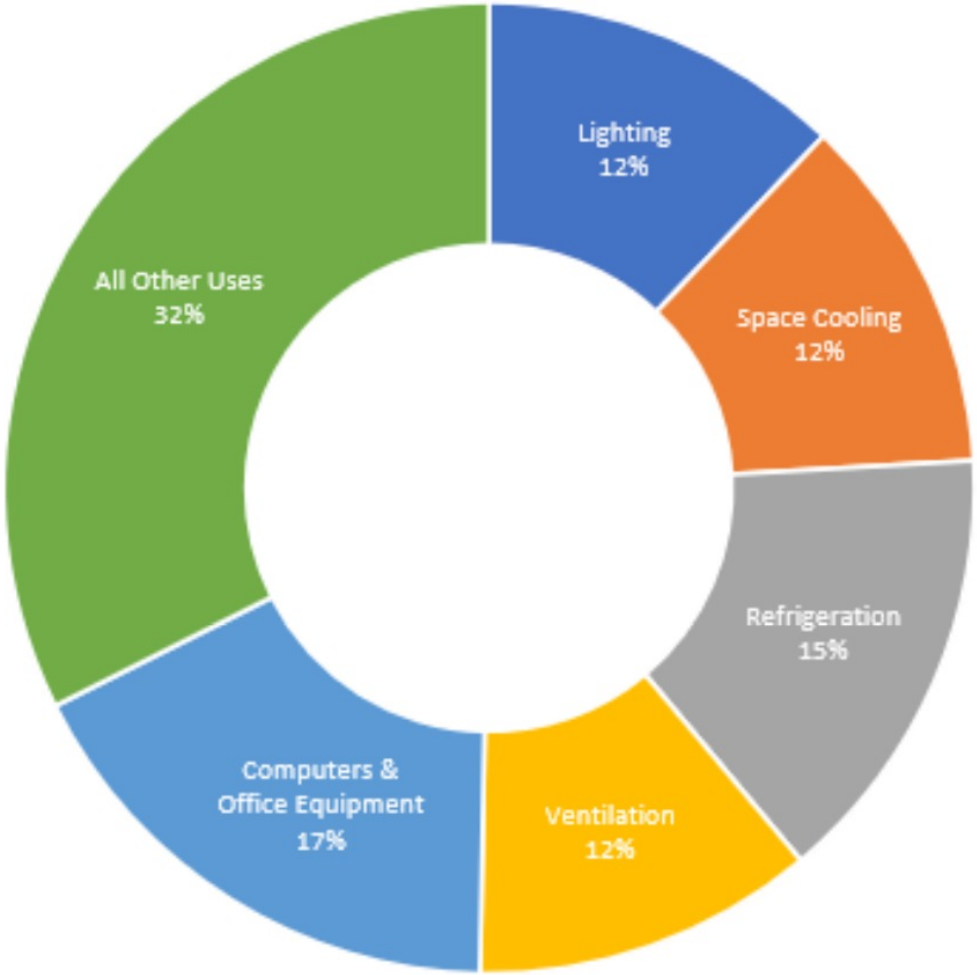
Announcements

- How was the career fair?
- How is your Project Part (1) submission is going on?
- Past exams are posted

LIGHTING RETROFIT

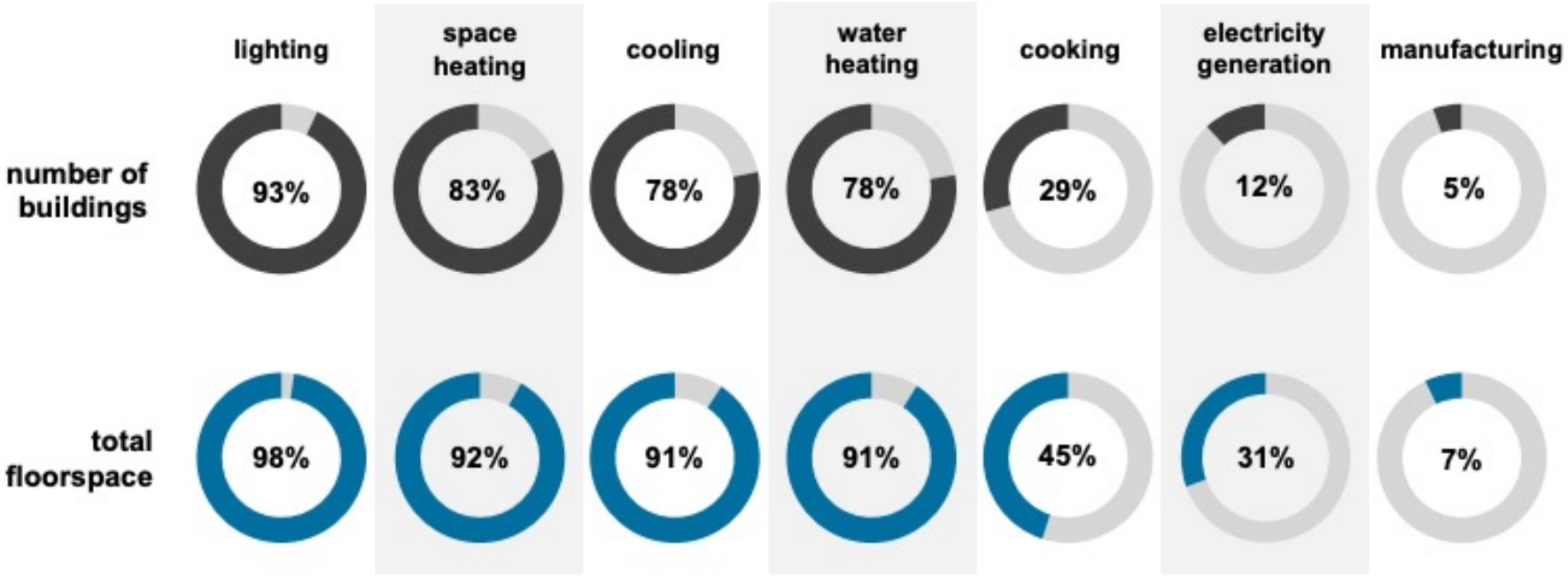
Lighting Retrofit

- How is the percentage of lighting in commercial buildings?



Lighting Retrofit

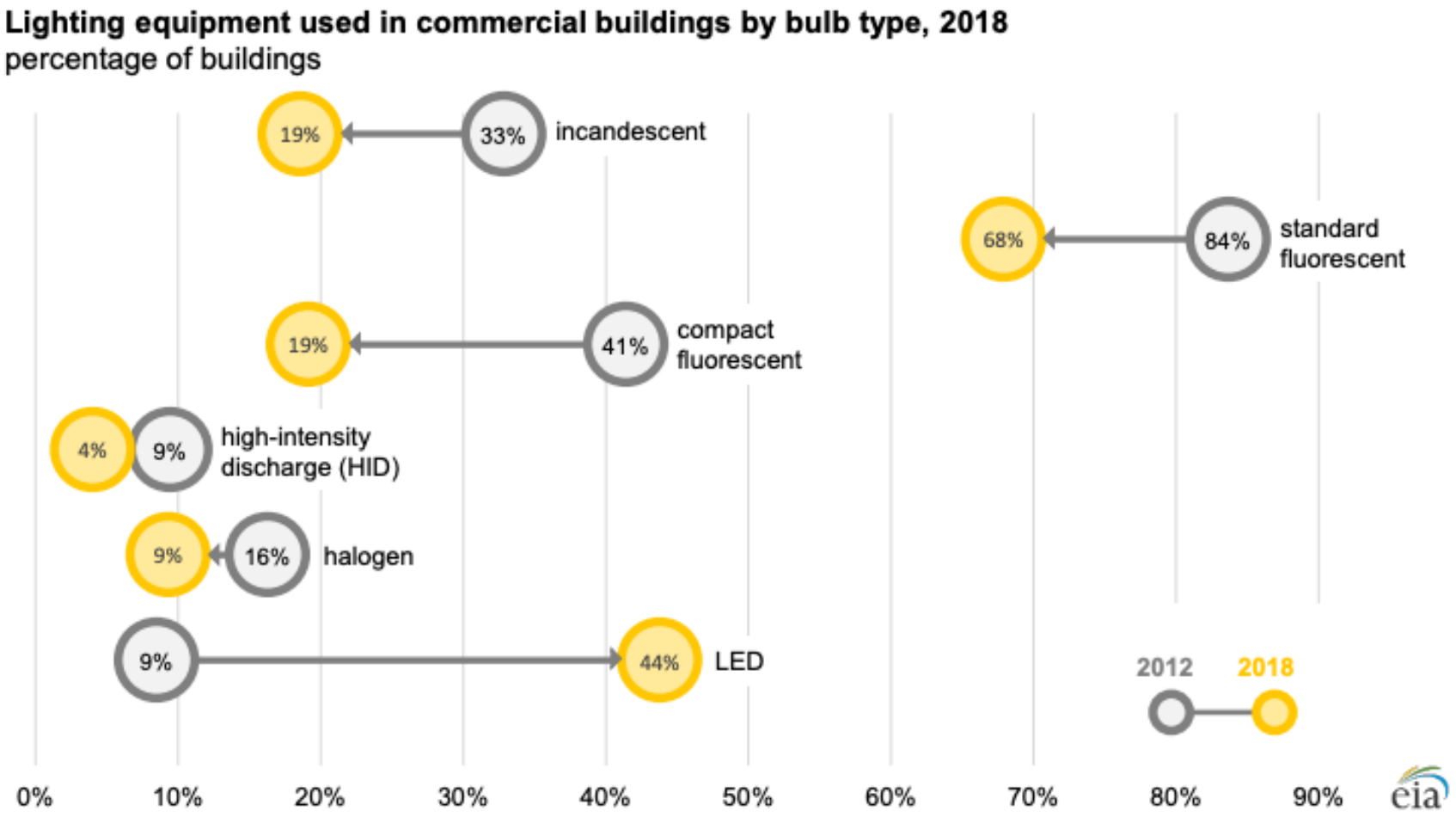
- From CBECS 2018:



Source: U.S. Energy Information Administration, *Commercial Buildings Energy Consumption Survey*

Lighting Retrofit

- From CBECS 2018:



Lighting Retrofit

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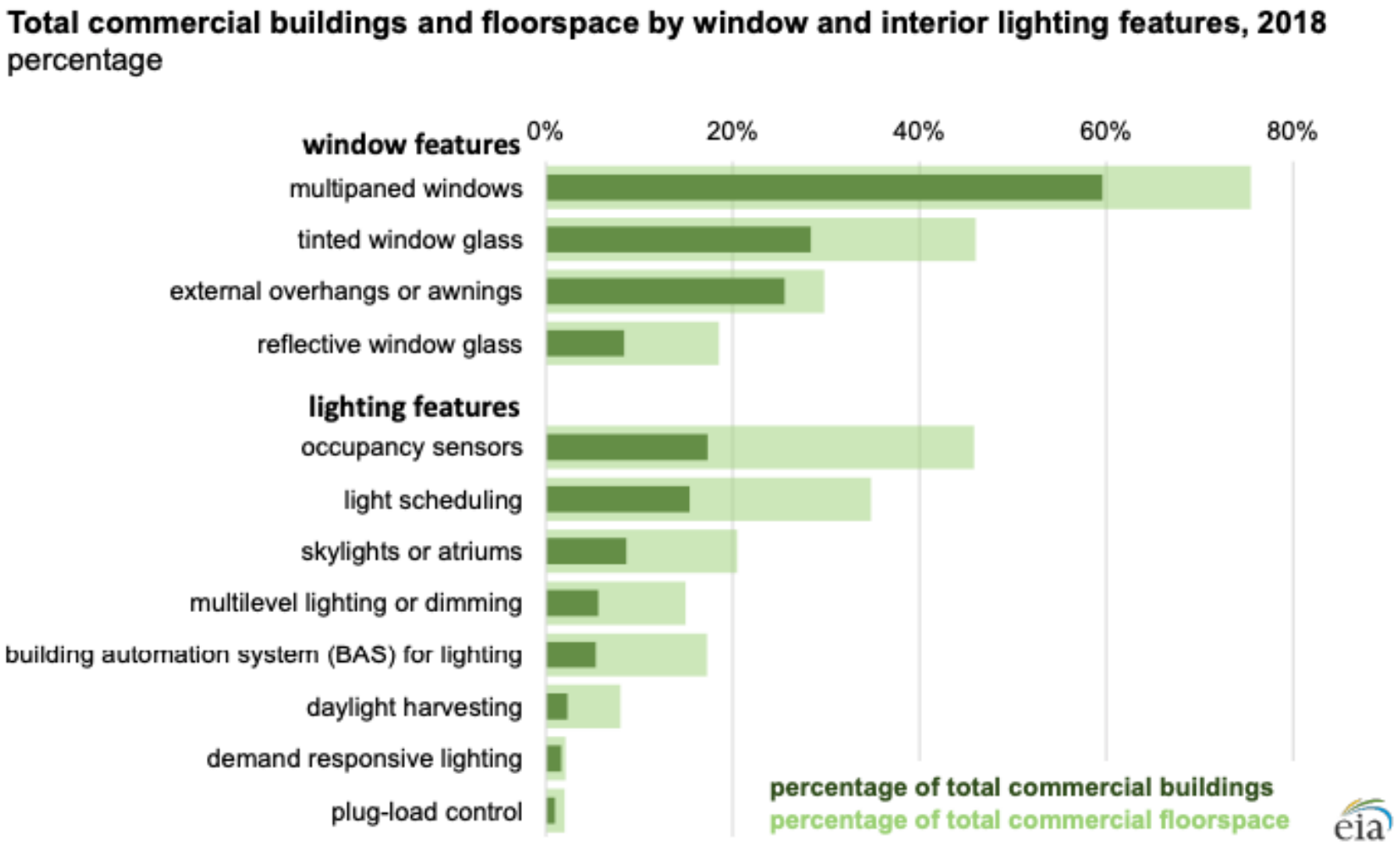


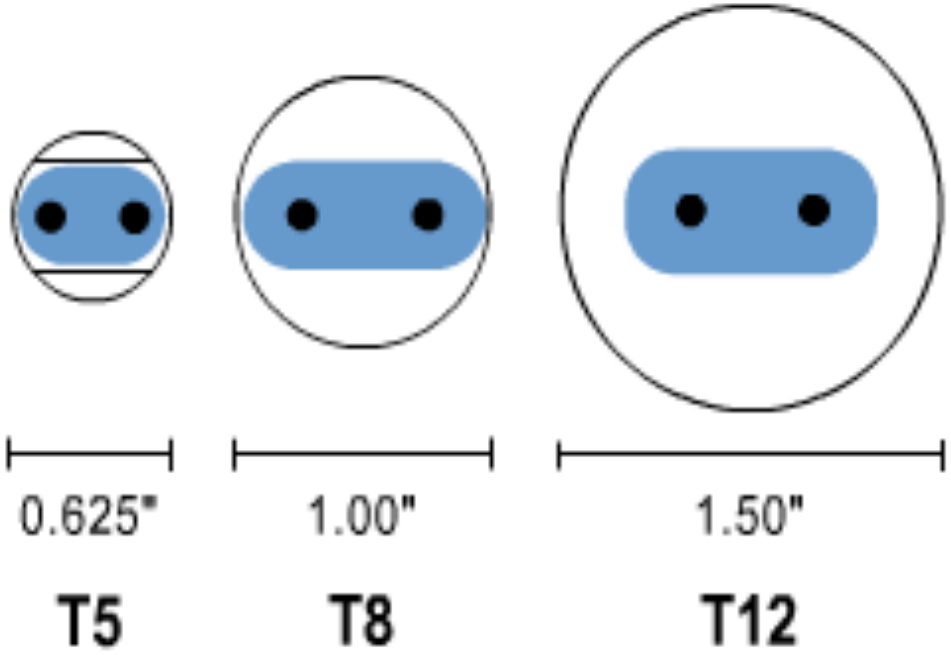
Lighting Retrofit

- Lighting bulb types:

https://www.viribright.com/lumen-output-comparing-led-vs-cfl-vs-incandescent-wattage/

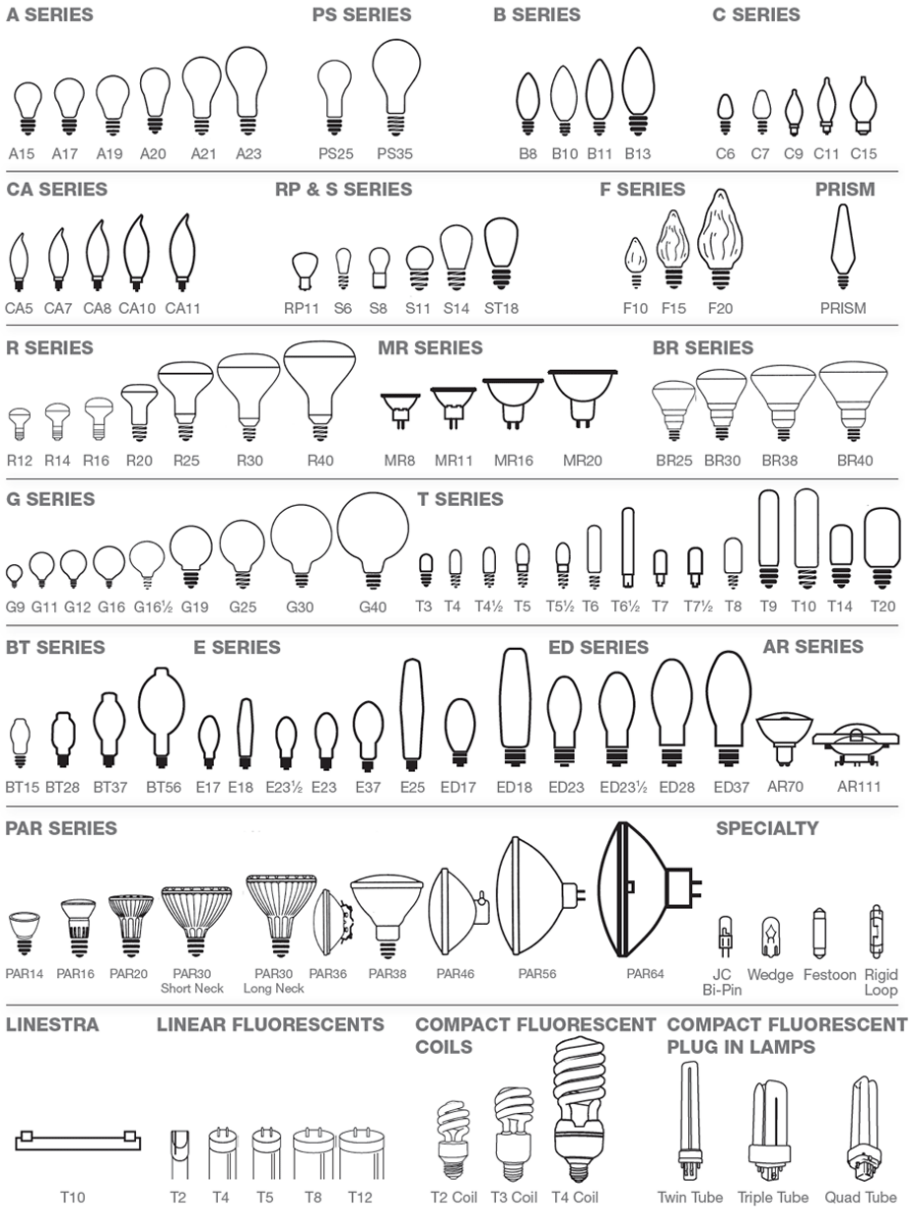
Lighting Retrofit

- Light tubes:



Lighting Retrofit

- Light bulb shape and size chart:



https://www.bulbs.com/learning/shapesandsizes.aspx

Lighting Retrofit

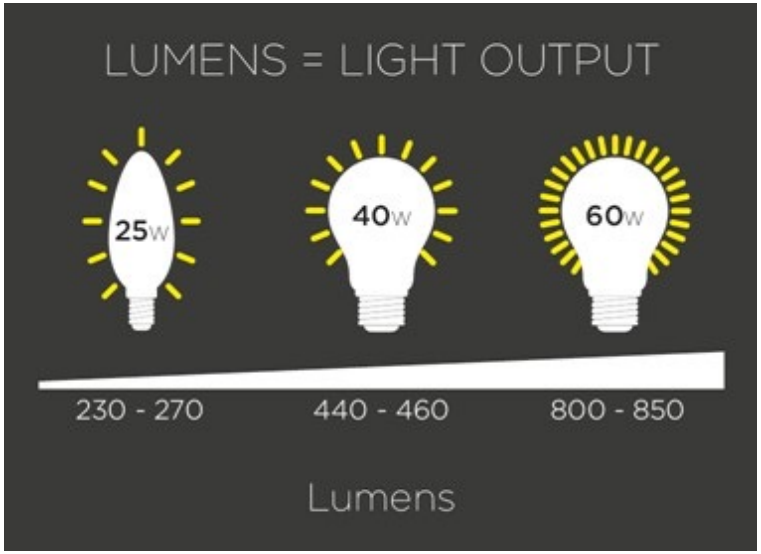
- Current LED installation and the projection:

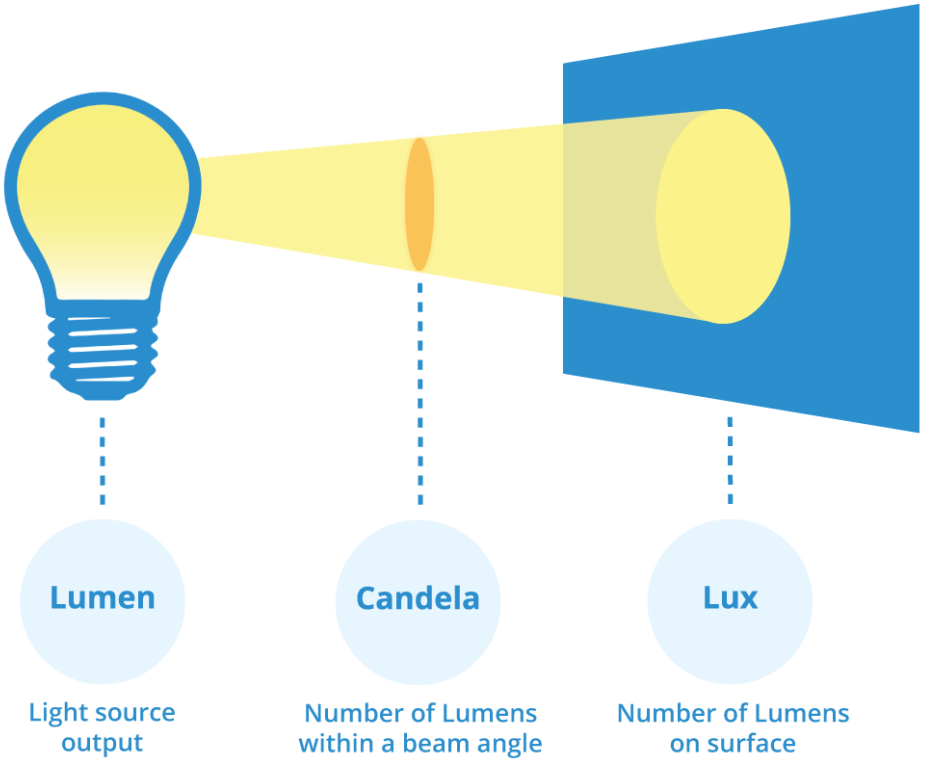
		2020	2025	2030	2035
Current SSL Path	**LED Installed Stock (million units)**	**2,790**	**5,040**	**6,780**	**7,910**
	Commercial	558	964	1,230	1,370
	Residential	2,060	3,800	5,230	6,210
	Industrial	25	56	76	84
	Outdoor	146	218	242	256
	LED Installed Stock Penetration (%)	**35%**	**60%**	**76%**	**84%**
	Commercial	44%	72%	88%	93%
	Residential	33%	56%	73%	82%
	Industrial	29%	63%	83%	90%
	Outdoor	66%	93%	98%	99%

DOE, 2022 Solid-State Lighting R&D Opportunities

Lighting Retrofit

- Comparison between different light bulbs





https://integral-led.com/en/content/what-are-lumens & https://www.any-lamp.com/blog/lumen-and-lux

Lighting Retrofit

- Comparison between different light bulbs

Lumens	LED (Watts)	CFL (Watts)	Incandescent (Watts)
400 to 500	6 to 7	8 to 12	40
650 to 850	7 to 10	13 to 18	60
1000 to 1400	12 to 13	18 to 22	75
1450 to 1700+	14 to 20	23 to 30	100
2700+	25 to 28	30 to 55	150

https://www.viribright.com/lumen-output-comparing-led-vs-cfl-vs-incandescent-wattage/

Lighting Retrofit

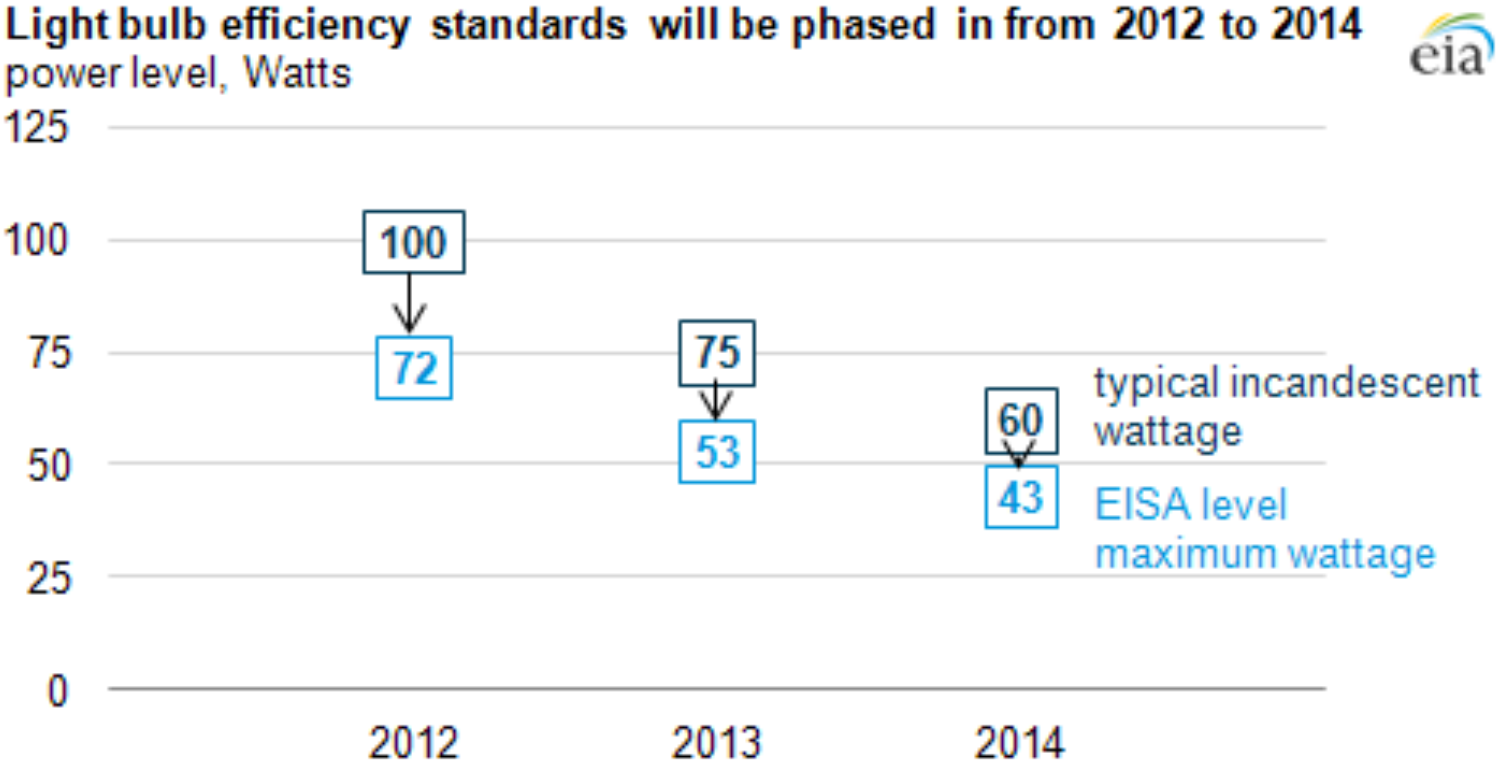
- Comparison between lifespan

	Incandescent	CFL	LED
Average life span	1,200 Hours	8,000 Hours	25,000 Hours

https://www.viribright.com/lumen-output-comparing-led-vs-cfl-vs-incandescent-wattage/

Lighting Retrofit

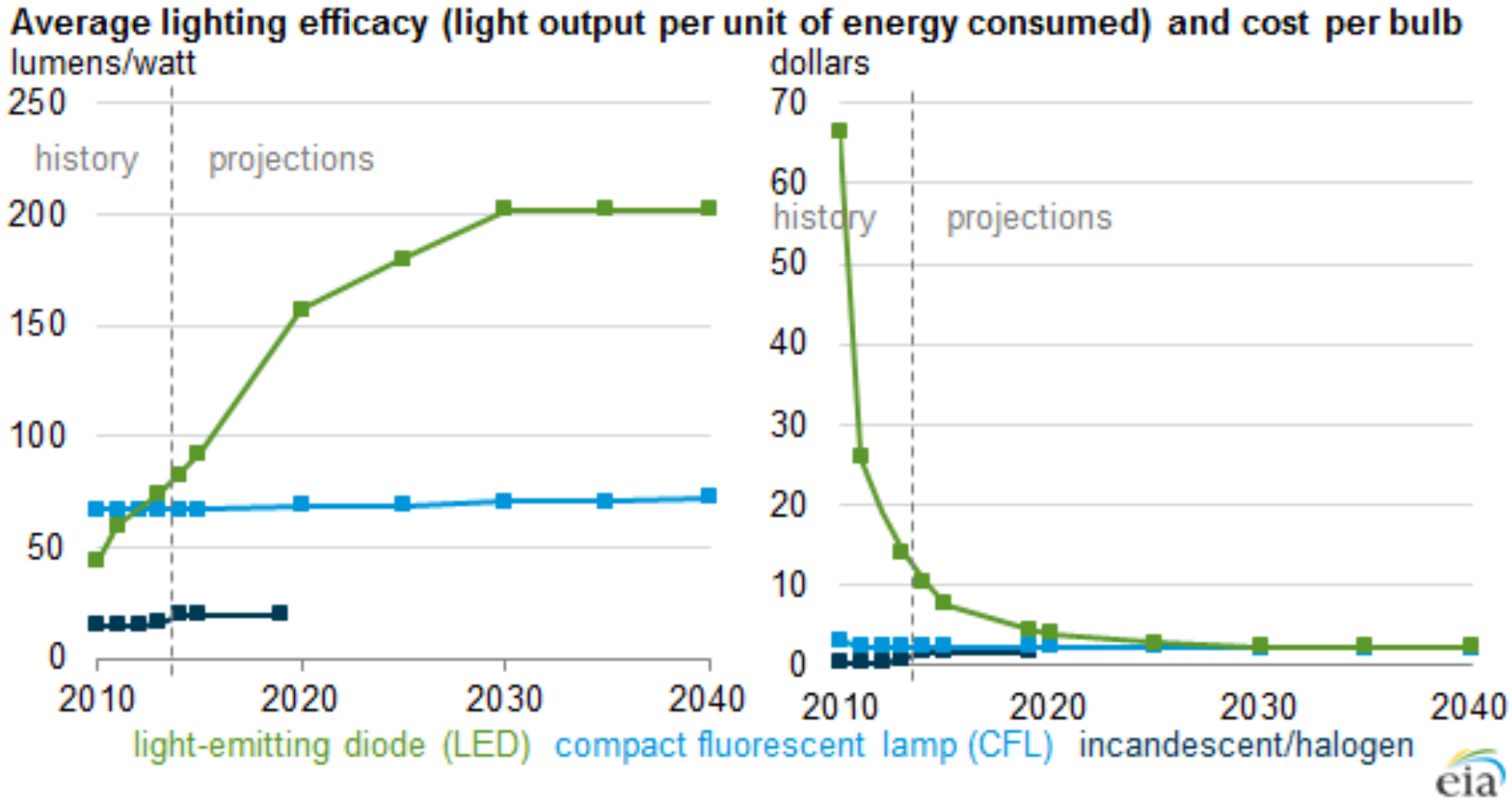
- Lighting bulb standard took into effect in 2012 to provide:
  - ❑ brighter, higher-wattage general service bulbs
  - ❑ Light output of about 1,600 lumens for a typical 100-Watt incandescent bulb fell into the first stage



https://www.eia.gov/todayinenergy/detail.php?id=4150

Lighting Retrofit

- LED bulbs efficiency have improved significantly while their costs have decreased drastically



https://www.eia.gov/todayinenergy/detail.php?id=15471

Lighting Retrofit

- LED bulbs efficiency have improved significantly while their costs have decreased drastically

Efficiency Channel	2014	2015	2020	Goal
Package Efficacy Projection[2] (lm/W)	146	162	220	250
Thermal Efficiency Droop (increased T_{op})	87%	88%	93%	95%
Driver Efficiency	86%	87%	93%	96%
Fixture/Optical Efficiency	87%	89%	94%	96%
Current Efficiency Droop Correction Factor (reduced I_{op})	1.14	1.13	1.09	1.05
Overall Luminaire Efficiency	74%	77%	89%	92%
Luminaire Efficacy[3] (lm/W)	108	125	196	230

Notes:

https://www.energy.gov/sites/prod/files/2015/06/f22/ssl_rd-plan_may2015_0.pdf

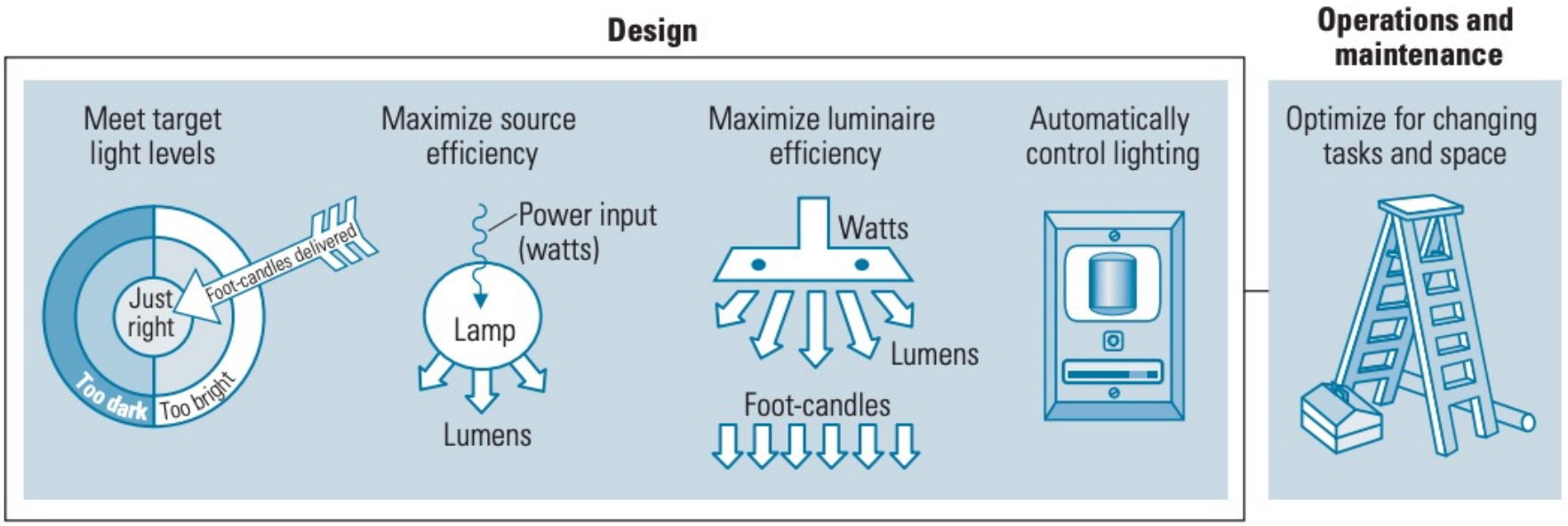
Lighting Retrofit

- Current Lighting Standards:
  - ❑ Efficiency (or efficacy) of incandescent lamps has increased only moderately
  - ❑ A typical 60-Watt incandescent lamps produce only 16 lumens/Watt and has a lifetime of 1,000 hours on average while comparable:
    - Halogen incandescent lamp produce close to 20 lumens/Watt
    - Compact fluorescent lamp (CFL) provides 67 lumens/ Watt and has 10 times lifetime
    - Solid-state light-emitting diode (LED) lamps currently produce 83 lumens/ Watt and are rated to last more than 30 times

https://www.eia.gov/todayinenergy/detail.php?id=15471

Lighting Retrofit

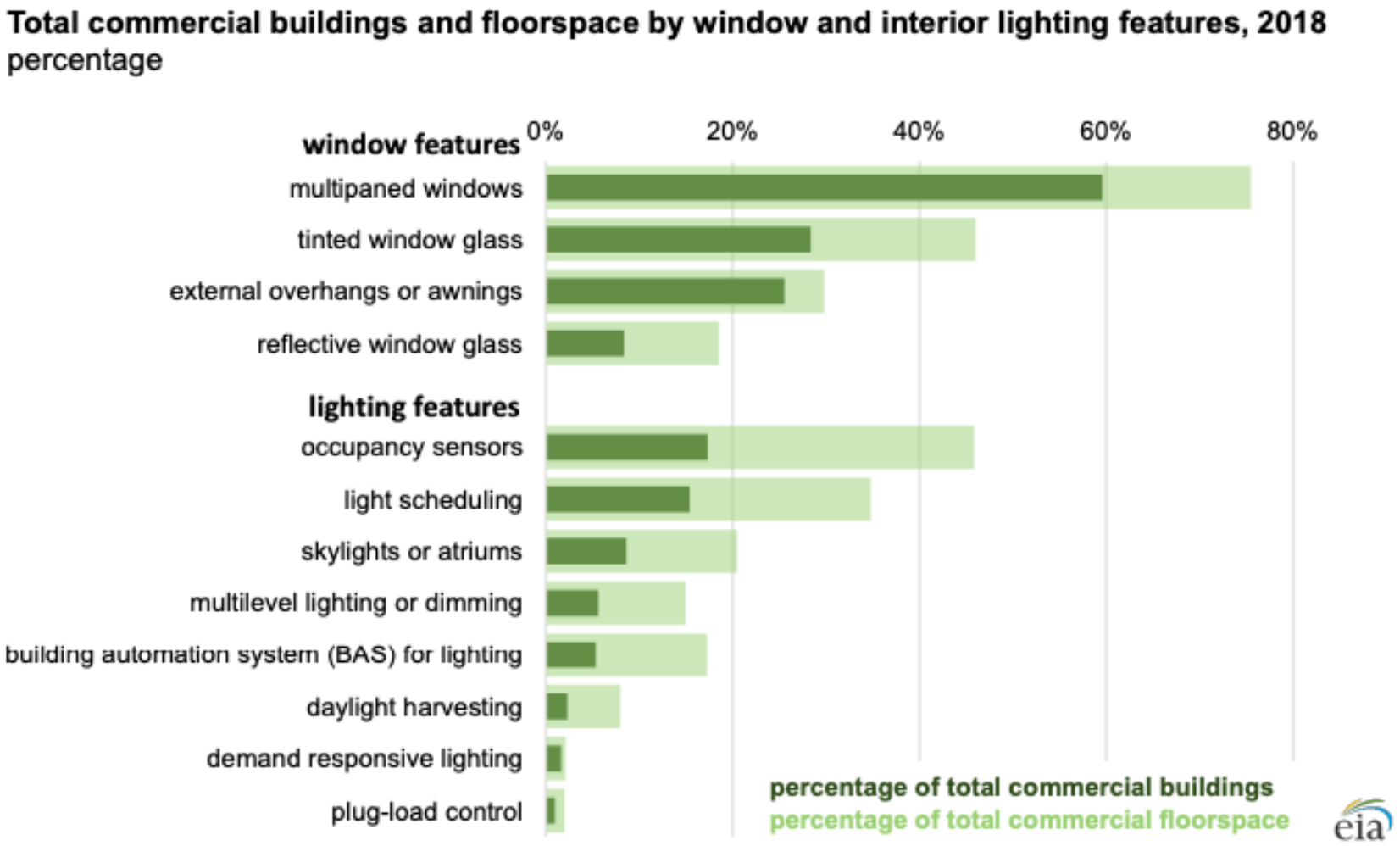
- Efficient lighting retrofit considers:



Source: EPA

Lighting Retrofit

- Efficient lighting retrofit considers (From CBECS 2018):



Lighting Retrofit

	Lamp property					
Lamp type	Mean efficacy, including ballast (mean lm/W)	Lumen maintenance (%)	Rated life (hours)	Color rendering index	Correlated color temperature (K)	Typical applications
Full-size fluorescent (T5, high-performance T8)	80 to 97	92 to 93	20,000 to 30,000	80 to 85	2,700 to 6,500	General area lighting of all kinds, including open and closed offices, classrooms, and high-bay areas
Compact fluorescent	43 to 71[a]	86	6,000 to 12,000	80 to 85	2,700 to 6,500	Incandescent replacements in table and floor lamps, cans, wall washers, and sconces
Quartz pulse-start metal halide	60 to 80[a]	65 to 75	20,000	65 to 70	2,900 to 4,200	Outdoor lighting, high-bay lighting, and remote-source lighting
Ceramic pulse-start metal halide	60 to 80[a]	80	20,000	85 to 94	2,900 to 4,200	Where color is critical, including high-bay and retail applications
High-pressure sodium	60 to 110[a]	85 to 90	24,000	22	1,900 to 2,200	Outdoor lighting and in high-bay applications where color is not critical
Induction	50 to 60[a]	70 at 60,000 hours; 55 at 100,000 hours	100,000	80	2,700 to 4,100	Where maintenance costs are high, including roadways and tunnels, parking garages, escalator wells, warehouses, and malls
LED	15 to 30	70	50,000[b]	80 to 90	2,700 to 10,000	In color-based applications such as exit signs, niche applications such as outdoor signage, task lamps, and accent lighting

Notes: K = kelvin; LED = light-emitting diode; lm/W = lumen per watt.
a. Higher efficacies for higher-wattage lamps.
b. Time at which output has degraded to 70 percent of initial output.

Courtesy: E SOURCE

Lighting Retrofit

- For most general lighting upgrades, the best choices are:
  - T8 (eight-eighths of an inch in diameter) or T5 (five-eighths of an inch in diameter) lamps
  - The most efficient T8s are the high-performance type
  - High-performance T8 lamps can be installed to replace T12 lamps
  - T5 lamps are not a good retrofit option, unless fixtures are being replaced as well as lamps and ballasts
  - The efficacy of T5s is similar to that of T8 lamps, but because they are smaller, they provide better optical control
  - The most common length for T8 lamps is four feet, which makes it the cheapest and easiest length to buy and stock
  - Eight-foot lamps are slightly more efficient, but they break more easily and can be difficult to transport

Lighting Retrofit

- Compact Fluorescent Lamp (CFL)

Sort E

Compare

Best Seller **EcoSmart** 60-Watt Equivalent Spiral Non-Dimmable CFL Light Bulb Soft White (4-Pack)

Model# ESBM8144

★★★★☆ (370)

$6.97 /package ($1.74 /bulb)

Compare

More Options Available

Philips 100-Watt Equivalent T2 Twister CFL Light Bulb Daylight Deluxe (4-Pack)

Model# 433557

★★★★½ (574)

$11.97 /set ($2.99 /bulb)

Compare

More Options Available

Feit Electric 60W Equivalent Daylight (5000K) Spiral GU24 CFL Light Bulb

Model# BPESL13T/GU24/D

View the Collection

★★★★☆ (390)

$5.37

Limit 35 per order

Lighting Retrofit

SHAPE CODE

T2

BASE CODE

E26
MEDIUM

BULB COLOR

SOFT WHITE

WATT EQUIVALENCE & LUMENS

60
WATTS

900
Lumens

BULB COUNT

4 ×

ENERGY SAVING

LOCATION

INDOOR

INDOOR OR OUTDOOR

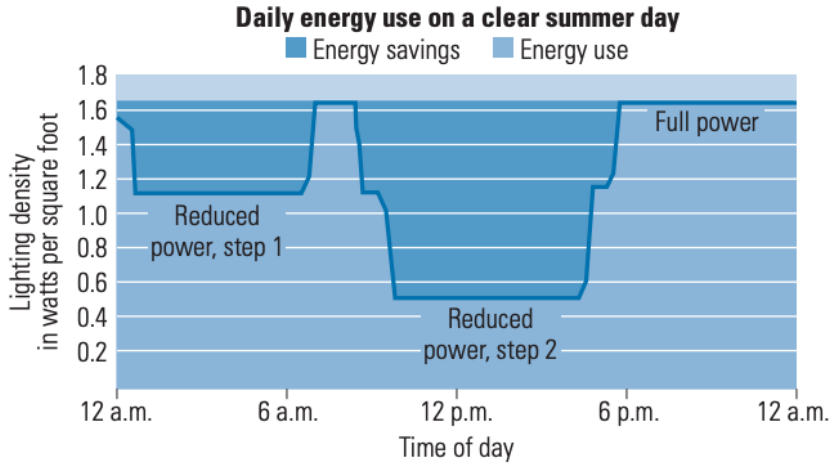
OUTDOOR

COMPATIBLE FIXTURES

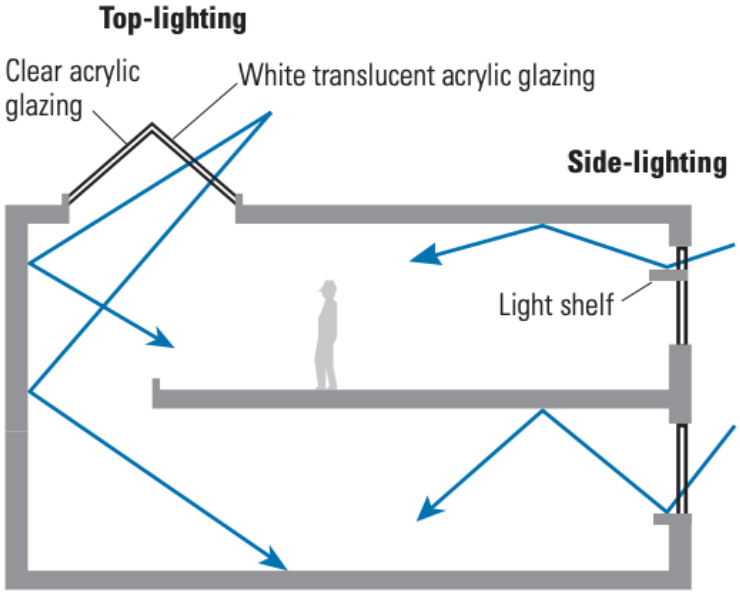
Table Lamp, Sconce

Lighting Retrofit

- Maximize daylighting:



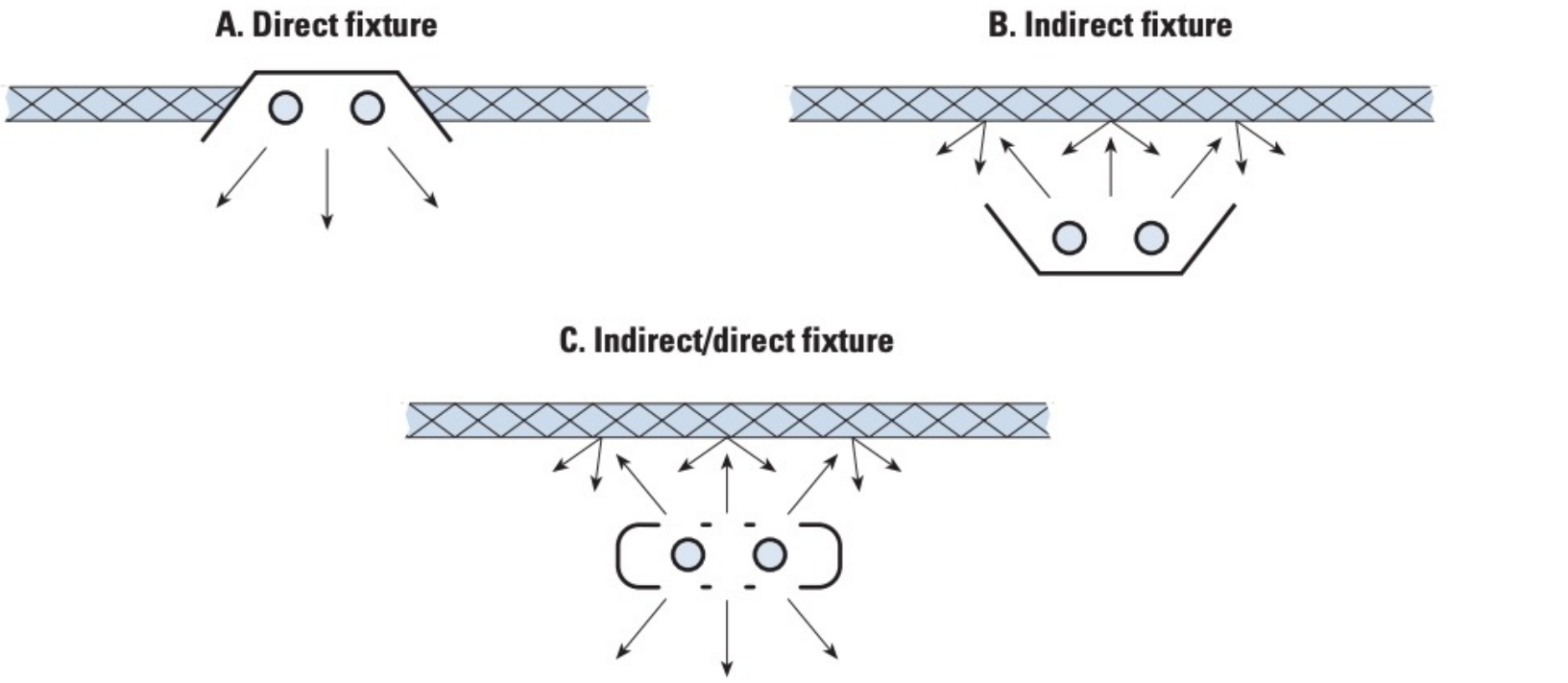
Source: California Energy Commission, PIER program



Courtesy: *E SOURCE Lighting Technology Atlas* (2005)

Lighting Retrofit

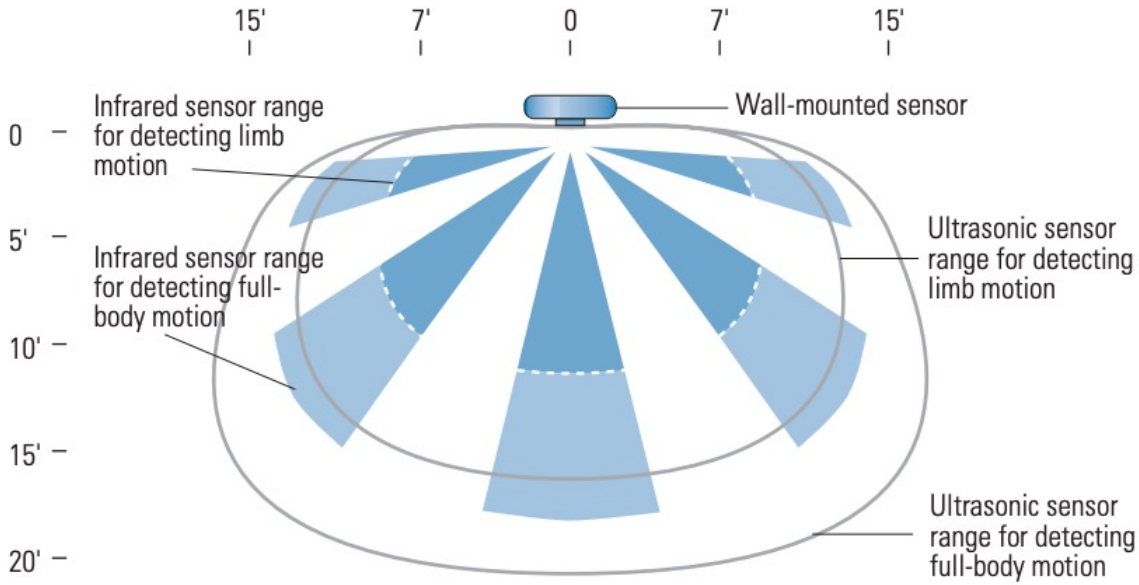
- Fixture installation options are:



Courtesy: *E SOURCE Lighting Technology Atlas* (2005)

Lighting Retrofit

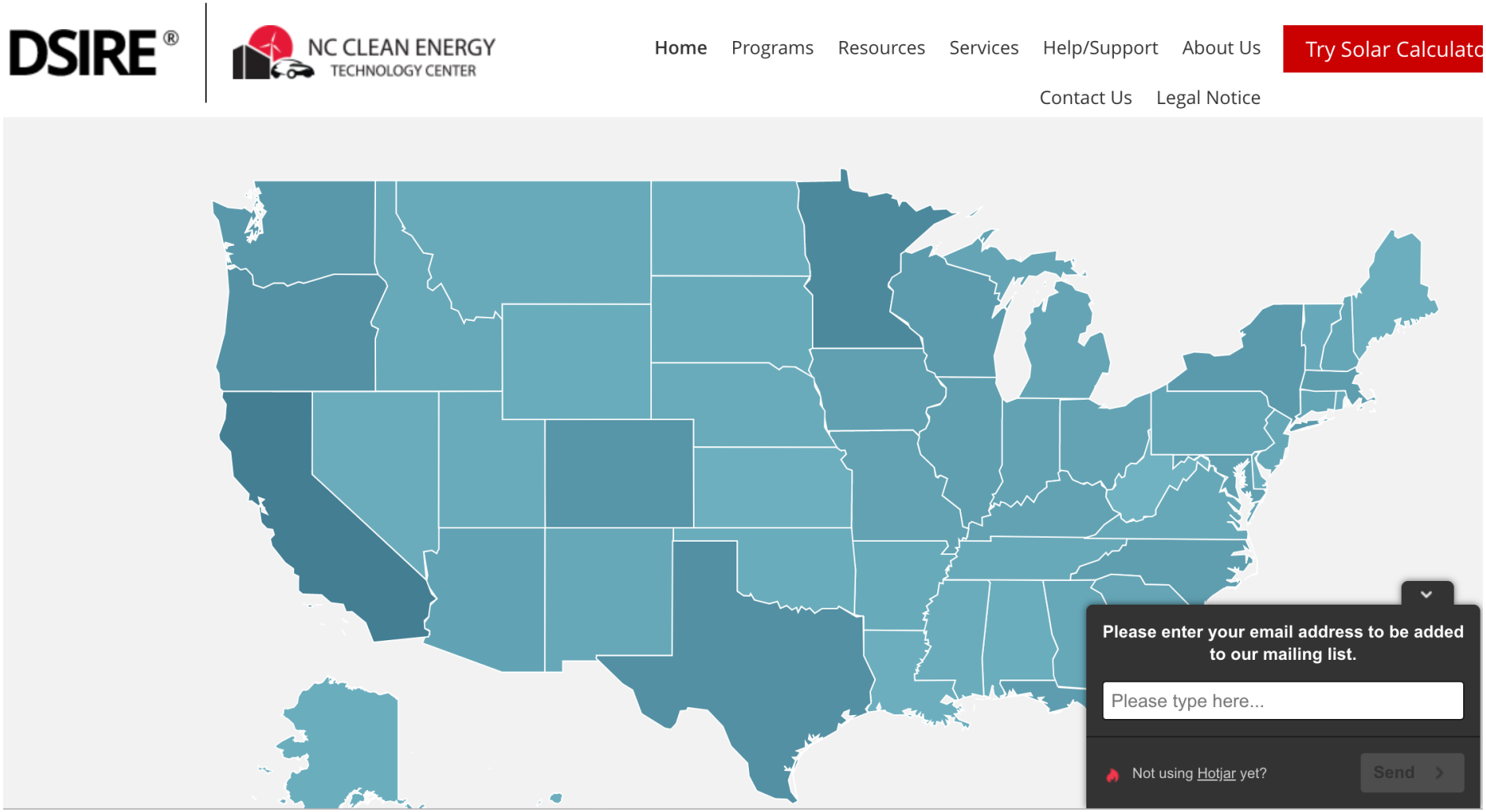
- Occupancy sensor technologies are relatively inexpensive and cost effective:



Courtesy: *E SOURCE Lighting Technology Atlas* (2005)

Lighting Retrofit

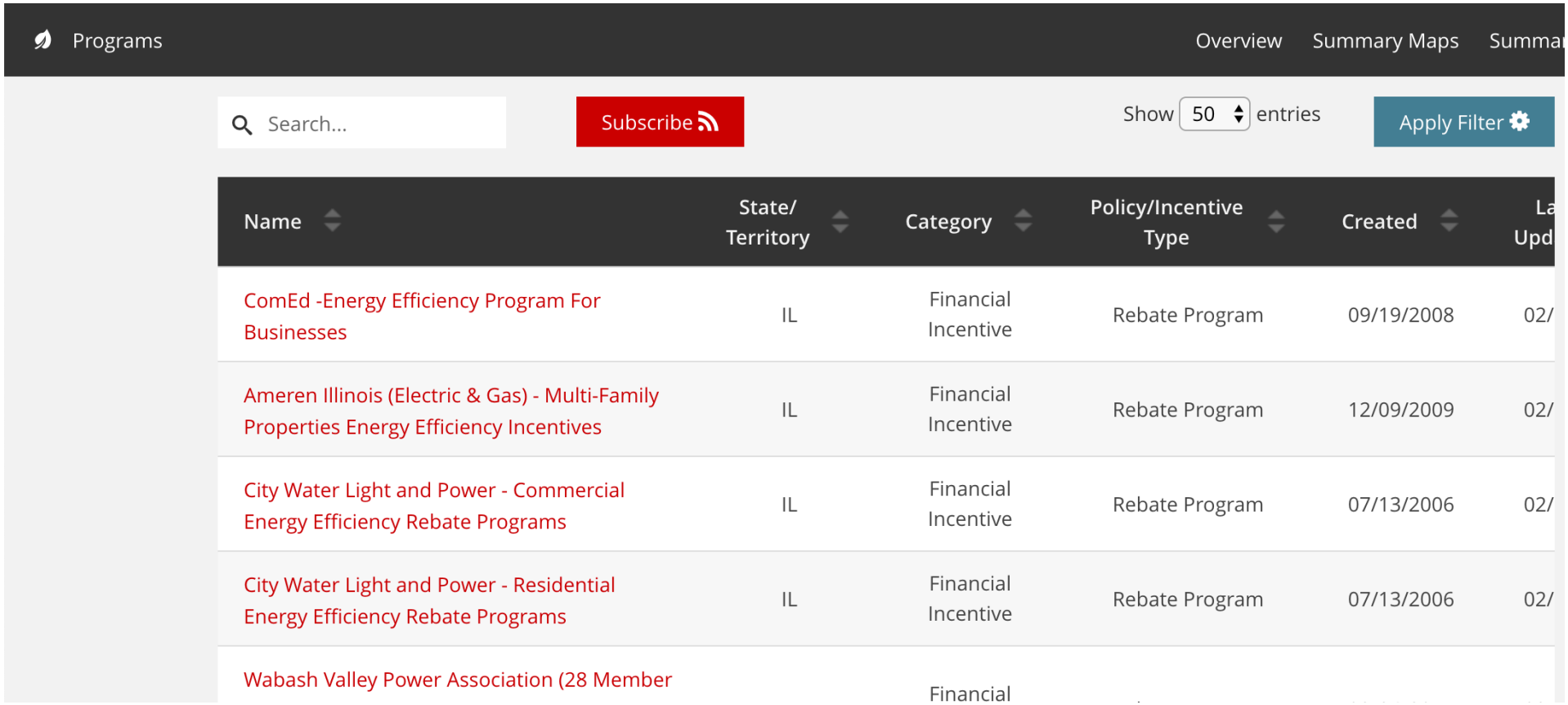
- Resources to find local policies and incentives:



http://www.dsireusa.org/

Lighting Retrofit

- For example, for IL, we can find the following resources:



Name	State/ Territory	Category	Policy/Incentive Type	Created	La Upd
ComEd -Energy Efficiency Program For Businesses	IL	Financial Incentive	Rebate Program	09/19/2008	02/
Ameren Illinois (Electric & Gas) - Multi-Family Properties Energy Efficiency Incentives	IL	Financial Incentive	Rebate Program	12/09/2009	02/
City Water Light and Power - Commercial Energy Efficiency Rebate Programs	IL	Financial Incentive	Rebate Program	07/13/2006	02/
City Water Light and Power - Residential Energy Efficiency Rebate Programs	IL	Financial Incentive	Rebate Program	07/13/2006	02/
Wabash Valley Power Association (28 Member		Financial			

http://www.dsireusa.org/

Lighting Retrofit

- For example, we can consider ComEd lighting retrofit incentives:

Programs | Overview | Summary Maps

Incentive Amount:	**Lighting** Building Energy Management System: $0.15 - $0.35/sq. ft. LED Fixtures/Retrofits: $0.50 - $0.60/watt reduced LED Open Sign: $40/sign LED Channel Sign: $12 - $30/letter Occupancy Sensors: $0.10/watt controlled Vacancy Sensors: $0.10/watt controlled Daylighting Controls: $0.12/watt controlled Time Clocks for Lighting: $0.03/watt controlled Plug-Load Occupancy Sensors: $10/sensor Occupancy Sensors + Daylighting Controls: $0.18/watt controlled Lighting Control System: $0.25/watt controlled Measurement & Verification: $0.10 - $0.15/kWh saved above target LED Traffic Signals: $40 - $100/lamp Photocells: $0.08/watt controlled Photocells + Time Clock: $0.09/watt controlled

http://www.dsireusa.org/

Lighting Retrofit

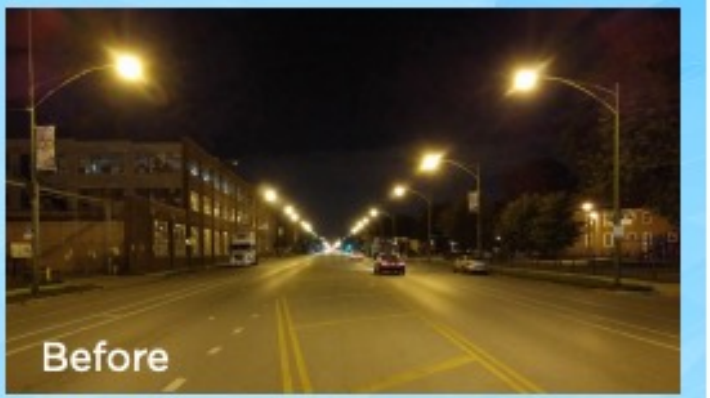
- Replacing city lights

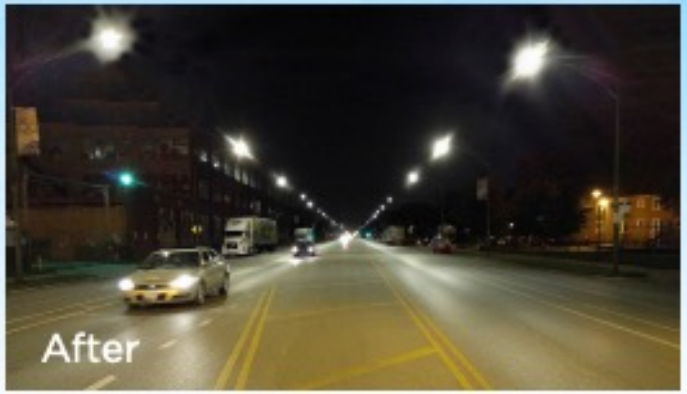
CHICAGO SMART LIGHTING PROGRAM

See Chicago in a Whole New Light

The City of Chicago is installing better quality, more reliable LED light fixtures on streets, alleys and viaducts to increase safety, reduce energy costs and improve the environment.

The city-wide lighting initiative will replace over 270,000 existing outdated High Pressure Sodium (HPS) light fixtures with new energy-efficient LED lights and create a modern lighting management system to streamline maintenance and repairs. This program will also include a limited amount of pole replacement and wiring repairs to stabilize the lighting.





http://chicagosmartlighting-chicago.opendata.arcgis.com/pages/program-background-and-benefits#sixteen

CLASS ACTIVITY

Class Activity

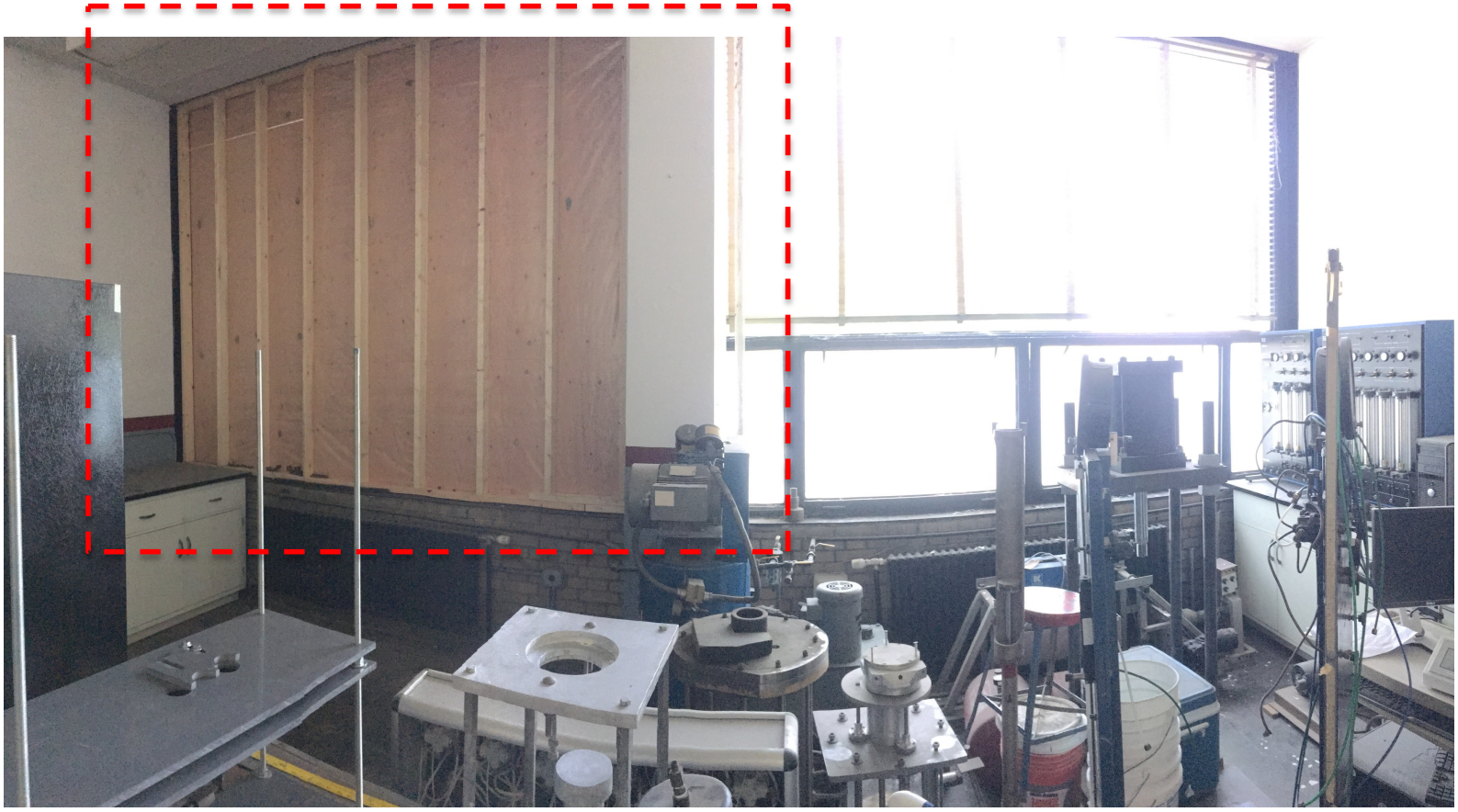
- Spend 20 to 30 minutes to compare different lighting options:
  - ❑ CFL, Fluorescent, LED
  - ❑ Lumen
  - ❑ Foot-Candle
  - ❑ Wattage
  - ❑ Sizes
  - ❑ Length

- Complete this table:
  - ❑ https://docs.google.com/spreadsheets/d/14sF09IPNmiycBBCkLjfJTHg9MfXONQ8RqfUBOE0EaSE/edit#gid=1517786264

BUILDING WINDOW RETROFIT

Building Window Retrofit

- Window replacement in AM Hall:
  - Remove the old windows
  - Build a temp wall within the spaces approximately 10-12 inch off the window/brick wall



Window Replacement

Building Window Retrofit

- Window replacement in AM Hall:

Class Activity

- Take a look at the documents for the window replacement of Alumni Memorial Hall building uploaded on Blackboard and summarize your findings

- Complete this table:
  - https://docs.google.com/spreadsheets/d/14sF09IPNmiycBBCkLjfJTHq9MfXONQ8RqfUBOE0EaSE/edit#gid=1882682778

THERMOSTAT RETROFIT

Thermostat Retrofit

nergy Systems

s premier smart-home
utomation specialist.
ians will install and
ew technology and put
ancements in energy
nt to work for you.

	Nest Pro	Ecobee Pro	Honeywell Pro
			
Display	3.3 inch Digital Ring	3.5 Inch Touch Screen	3.5 Inch Touch Screen
Fan Speed	High/Med/Low *(auto + override)*	Up to 3 Speeds** *(auto + override)*	Single Speed
Occupancy Sensor	✓	✓	Temperature Only
Room Sensor	✓	✓	✓
Power Method	Hardwired	Hardwired	Hardwired
5-Year Pro Warranty	✓	✓	✓
Integrations	Google Assistant Amazon Alexa	Amazon Alexa (built in) Apple HomeKit IFTTT	Google Assistant Amazon Alexa Apple HomeKit

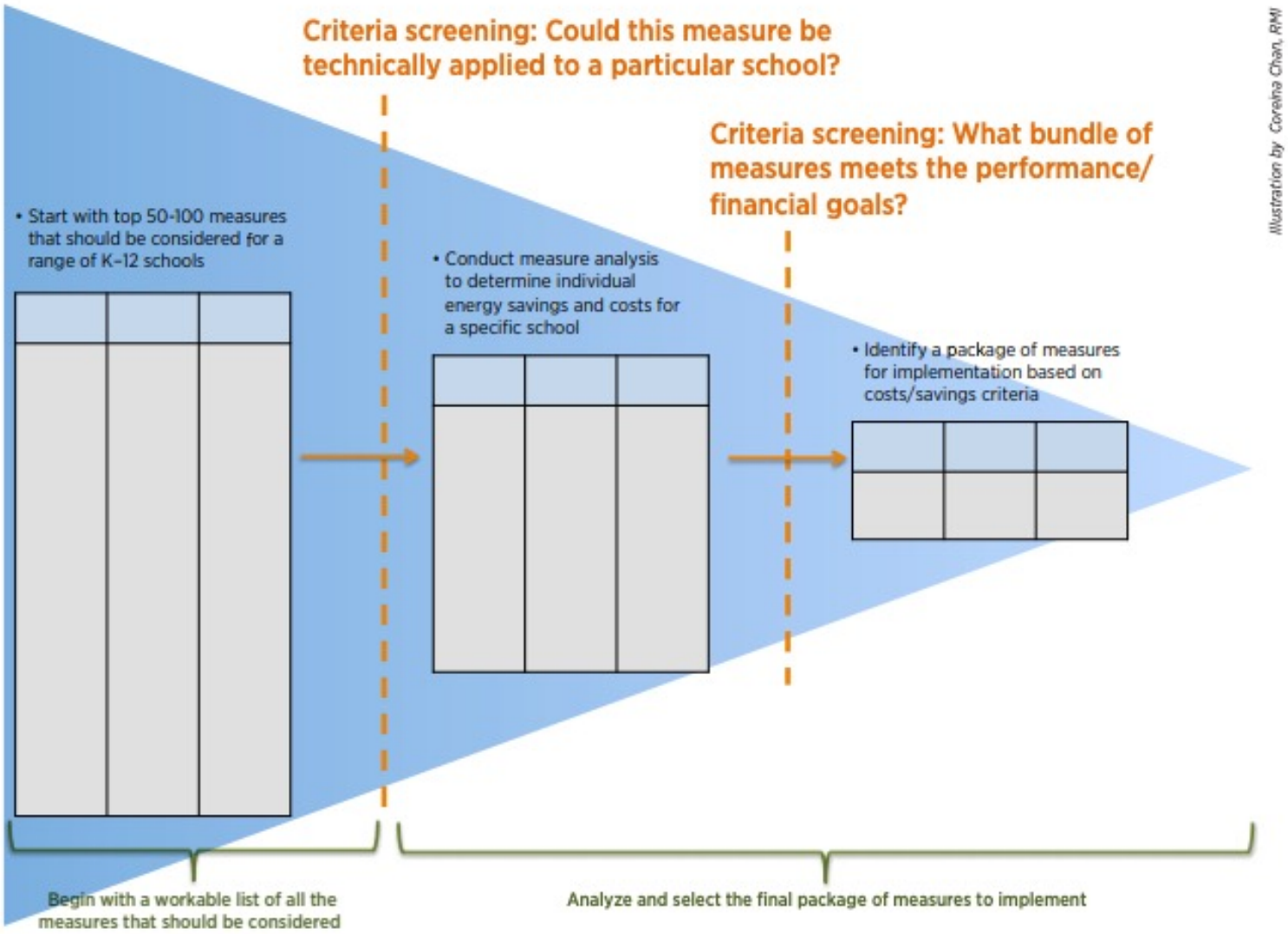
AERG EXAMPLE (K-12)

AERG Example

	Energy Manager	Custodial Staff	School Board or Financial Manager	Teachers and Students	Community and Parents	Utilities and Auditors
1 Introduction	●	●	●	●	●	●
2 Overview: Plan, Execute, Follow Up	●		●			
3 Existing Building Commissioning	●	●		●		●
4 Building Retrofits	●		●			●
5 Measurement and Verification	●	●				
6 Operations and Maintenance	●	●				
7 Conclusion	●	●	●	●	●	●

https://buildingdata.energy.gov/cbrd/resource/17

AERG Example



https://buildingdata.energy.gov/cbrd/resource/17

AERG Example

Case Study 1: Vigo County School Corporation

Quick Facts

- Facility Name: Vigo County School Corporation
- Facility Type: K-12 Schools
- Location: Terre Haute, Indiana
- Number of Buildings: 29

Photo from NAESCO

Project Description

The Vigo County School Corporation (VCSC) in Terre Haute, Indiana, and under the leadership of Superintendent Daniel Tanoos, partnered with Energy Systems Group to develop and implement comprehensive energy savings performance contracts. VCSC is made up of 3 high schools, 2 alternative schools, 6 middle schools, and 18 elementary schools.

In 1999, VCSC decided to take control over rising operating costs with an assessment of its utility costs, which at the time averaged $\$0.845/ft^2$. This was compared to other Indiana school facilities that had installed energy retrofits resulting in energy costs as low as $\$0.65/ft^2$. Of the 19 VCSC schools surveyed, 9 were operating at more than $\$0.90/ft^2$.

In 2000, VCSC and Energy Systems Group entered into an initial agreement to provide energy-related upgrades at 20 of its facilities. This initial project resulted in a guaranteed cost reduction of more than $1 million per year over the term of the agreement. To date, Energy Systems Group has met its savings guarantee.

VCSC has implemented more than $29 million in comprehensive energy improvements and renovation projects in six phases which are estimated to save close to $35 million over the terms of the contracts.

Environmental Benefits

1. *Removes emissions equivalent to more than 5,200 passenger vehicles per year.*
2. *Creates enough electricity to provide power for more than 3,800 homes per year.*
3. *Planting more than 6,500 acres of forests annually.*

https://buildingdata.energy.gov/cbrd/resource/17

AERG Example

Key EEMs:	
• Comprehensive HVAC improvements and replacements • Lighting systems redesigns and retrofits • First school in Indiana to be 100% retrofitted with light-emitting diodes (LEDs) • Electrical system upgrades • District-wide EMS	• Window replacements • Hot water pump replacements • 1.5-kW wind turbine with curriculum for science students • High school pool improvements.

Installation Costs	M&V Costs	Total Cost Without Incentives	Financial Incentives	Actual Project Costs
$29,922,466	$75,477	$29,977,943	$60,000	$29,862,466

Energy $ Savings	O&M $ Savings	Capital Cost Avoidance	Total Annual $ Savings
$592,321/year	$1,395,838/year	$1,206,457/year	$3,194,616

Energy Cost Intensity Pre-Retrofit	Energy Cost Intensity Post-Retrofit	Energy Cost Intensity ASHRAE 90.1-2004	Simple Payback (years) (Excluding Incentives)
$0.84/ft^2	$0.70/ft^2	$1.40/ft^2	9.3 (9.4)

https://buildingdata.energy.gov/cbrd/resource/17

AERG Example

System	EEM Description	Applicable to:				
		Hot-Humid	Hot Dry	Marine	Cold	Very Cold
Lighting	Replace incandescent lamps in exit signs with LEDs	✓	✓	✓	✓	✓
	Replace T12 fluorescent lamps and magnetic ballasts with high- efficiency T8 lamps and instant-start electronic ballasts	✓	✓	✓	✓	✓
	Replace incandescent lamps with compact fluorescent lamps (CFLs)	✓	✓	✓	✓	✓
	Install wireless motion sensors for lighting in rooms that are used intermittently	✓	✓	✓	✓	✓
	Install photosensors and dimming ballasts to dim lights when daylighting is sufficient	✓	✓	✓	✓	✓
	Replace high intensity discharge (HID) lights with T5 high- output (HO) fluorescents in gymnasiums	✓	✓	✓	✓	✓
	Install more efficient exterior lighting for façades and parking lot	✓	✓	✓	✓	✓
Plug and process loads	Replace cafeteria appliances with ENERGY STAR models	✓	✓	✓	✓	✓
	Install VSD demand control for kitchen hood exhaust fans	✓	✓	✓	✓	✓

https://buildingdata.energy.gov/cbrd/resource/17

AERG Example

System	EEM Description	Applicable to:				
		Hot-Humid	Hot Dry	Marine	Cold	Very Cold
Envelope	Add reflective roof covering	✓	✓		✓	
Service water heating	Install low-flow showerheads in locker rooms	✓	✓	✓	✓	✓
HVAC Heating and cooling	Add evaporative precooling of condenser supply air		✓			
	Add a small condensing boiler to handle the base load and summer load, with current inefficient boiler operating when heating loads are highest	✓	✓	✓	✓	✓
	Install VSDs on chilled-water and hot water pumps	✓	✓	✓	✓	✓
	Replace standard furnace with a high-efficiency condensing furnace	✓	✓	✓	✓	✓
	Install an EMS and replace pneumatic controls with direct digital controls (DDCs)	✓	✓	✓	✓	✓
	Replace oversized, inefficient fans and motors with rightsized National Electric Manufacturers Association (NEMA) premium efficiency models	✓	✓	✓	✓	✓
	Convert CV or dual-duct air handling system to variable air volume (VAV) (add dampers, VSD fan motors)	✓	✓	✓	✓	✓
	Install VSDs on cooling tower fans	✓	✓	✓	✓	✓
HVAC Ventilation	Install a dry-bulb airside economizer	✓	✓	✓	✓	✓
	Upgrade to DCV to reduce OA flow during partial occupancy	✓	✓	✓	✓	✓
	Add heat/energy recovery to the ventilation system	✓	✓	✓	✓	✓

https://buildingdata.energy.gov/cbrd/resource/17

AERG Example

Table E-2 Recommended Temperature Setbacks and Setups for U.S. Climate Zones

Climate Zone	Massive Building		Metal Building	
	Heating Setback (°F)	Cooling Setup (°F)	Heating Setback (°F)	Cooling Setup (°F)
1A	4.3	10.4	4.1	7.7
2A	9.4	13.9	10.1	11.2
3A	9.4	13.1	13.3	12.9
4A	19.4	16.4	20.7	15.3
5A	18	10.8	22.1	13.5
6A	20.5	10.4	23.9	12.7
2B	9.7	20.5	8.6	15.5
3B	7.9	14.2	12.1	13.5
4B	20.7	16.5	21.9	15.8
5B	19.4	10.6	22.1	12.1
6B	19.4	10.3	22.3	12.1
7	20.7	8.8	6.3	11.5
8	22.3	5	23	7.9

https://buildingdata.energy.gov/cbrd/resource/17

PAYBACK PERIOD EXAMPLES

Payback Period Examples

- An example of short payback period in Dayton Ohio:

	AR No.	Description	Payback (yrs)
Lighting	1	Replace Metal Halide Lamps with T-8 Flourescent Fixtures	2.3
	2	Install Photosensor Controls to Utilize Daylight	0.6
Space Conditioning	3	Install Programable Thermostat in the Office	0.2
	4	Adjust the Year Round Thermostat Set Points in the Office	0.2
Compressed Air	5	Reduce Overall Pressure in Compressed Air System	0.2
	6	Reduce Leaks in Compressed Air System	1.1
	7	Eliminate use of Air Motors on Pipe Turners	1.0

	AR No.	Description	Cost-Benefit Analysis Results	Simple Payback (yrs)
Lighting	1	Replace 8' T-12 Bulbs with 8' T-8 Bulbs	1.085	3.6
	2	Install Photo Sensor Controls	0.525	2.0
Comp Air	3	Lower Air Compressor Discharge Pressure	0.093	0.3
Space Conditioning	4	Install Programmable Thermostats	0.128	0.4
	5	Increase Air Conditioning Thermostat Set Points	0.012	0.0
Other Rec.		Replace 4' T-12 Lamps with 4' T-8 Lamps	1.881	4.9

Economic analysis of energy retrofit of buildings, 2011

Payback Period Examples

- Building: Liberty Tower (Dayton, Ohio)
  - ❑ 85-year-old
  - ❑ 114,000 ft^2
- Three energy efficiency measures are:
  - ❑ Steam boiler replaced with vertical fire tube boilers
  - ❑ Replace interior and exterior with LEDs
  - ❑ Building control upgrade

https://www.forbes.com/sites/pikeresearch/2016/04/13/energy-efficient-building/#6fd887e748f8

Payback Period Examples

- Building: Liberty Tower (Dayton, Ohio)
  - ❑ LEDs consume 60% less energy
  - ❑ Add controls to dim or turn off the lights
  - ❑ LED lights fail in a different way, so control may be an important factor in the light selection

https://www.forbes.com/sites/pikeresearch/2016/04/13/energy-efficient-building/#6fd887e748f8

Payback Period Examples

- Building: Liberty Tower (Dayton, Ohio)
  - ❑ Total cost: $870,000
  - ❑ Annual utility cost savings $99,000
  - ❑ Payback period:

$$Payback = \frac{870{,}000}{99{,}000} = 8.8\ years$$

  - ❑ The project has received $70,000 in utility rebates, making the economic case more practical

$$Payback = \frac{(870{,}000 - 70{,}000)}{99{,}000} = 7.8\ years$$

https://www.forbes.com/sites/pikeresearch/2016/04/13/energy-efficient-building/#6fd887e748f8

Payback Period Examples

- Long payback period for building envelopes:
  - ❑ It is hard to do a building envelope retrofit since owners only 60% of the commercial floorspaces
  - ❑ They do not have a good payback period
  - ❑ Usually there are different motivations to conduct a building envelope retrofit

https://www.forbes.com/sites/pikeresearch/2016/04/13/energy-efficient-building/#6fd887e748f8

Payback Period Examples

EEM	Cost / Unit	Cost	Source
Occupancy Sensors	$1.06/ft^2	$ 44,991	RSMeans, "5 fixtures per 1000 S.F., including occupancy and time switching"
Condensing Boiler	$20,706 + $13.82/MBH	$ 31,401	RSMeans, commercial gas boilers
Light Power Density Reduction	$4.78/ft^2	$ 202,886	RSMeans, "Fluorescent high-bay 4 lamp fixture, 1W/sf,59FC, 4 fixtures per 1000 S.F."
Condensing Unit Replacement	$7,909 + $766/ton	$ 132,687	RSMeans, packaged air-cooled refrigerant compressor and condensor
Window Film	$18.93/ft^2 glazing	$ 182,311	RSMeans, "Solar Films on Glass" average of min/max value
Wall Insulation	$4.78/ft^2 wall area	$ 927,930	RSMeans, "4 in. EPS insulation, Commercial renovation Exterior Insulation and Finish System",

Payback Period Examples

Energy Efficiency Measures	Simple Payback
Condensing Boiler	9.4
Occupancy Sensors	10.4
Light Power Density Reduction	32.4
Condensing Unit Replacement	41.2
Window Film	70.7
Wall Insulation	247.0

OPENSTUDIO MEASURES

OpenStudio Measures

- Creating a Project
- Loading a Baseline Model
- Organize and Edit Measures for Project
- Select Measures and Create Design Alternatives
- Run Simulations
- Create and View Reports
- Running on the Cloud
- Viewing Results
- Publications

Back to OpenStudio®

Parametric Analysis Tool (PAT) Interface Guide

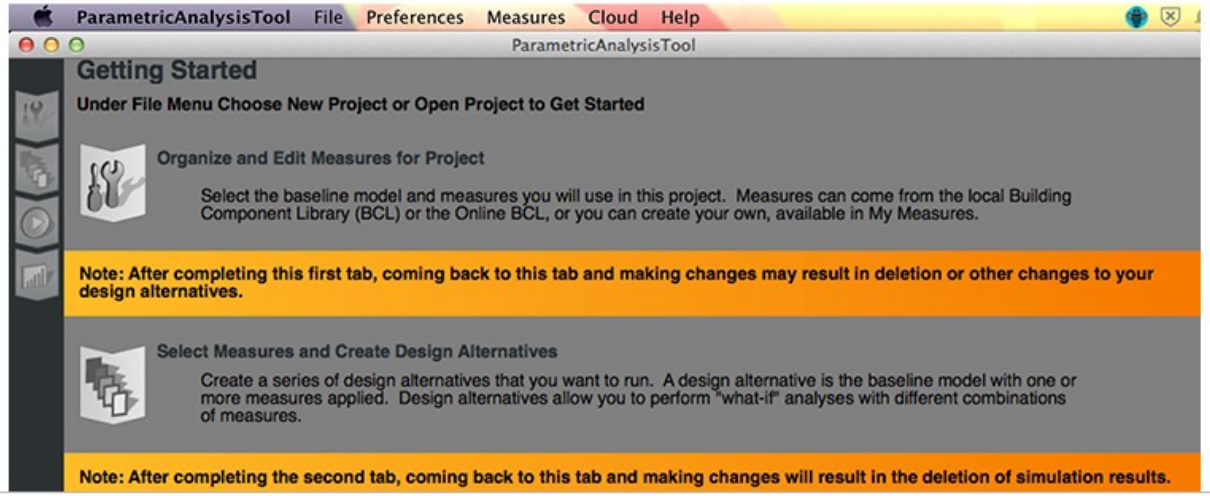
PAT removes the need to hand edit each model to try out different architectures, energy efficiency measures, and mechanical systems. PAT applies scripts to your baseline model and lets you quickly compare many alternatives. OpenStudio has developed a workflow that allows energy modelers to create and run a customized parametric analysis using commercially available cloud computing services. This workflow will enable anyone to perform powerful parametric studies in a reasonable time for a relatively low cost.

Creating a Project

The Parametric Analysis Tool Quick Start Guide (PDF) provides an introduction to the interface and workflow for creating multiple design alternatives from a seed model.

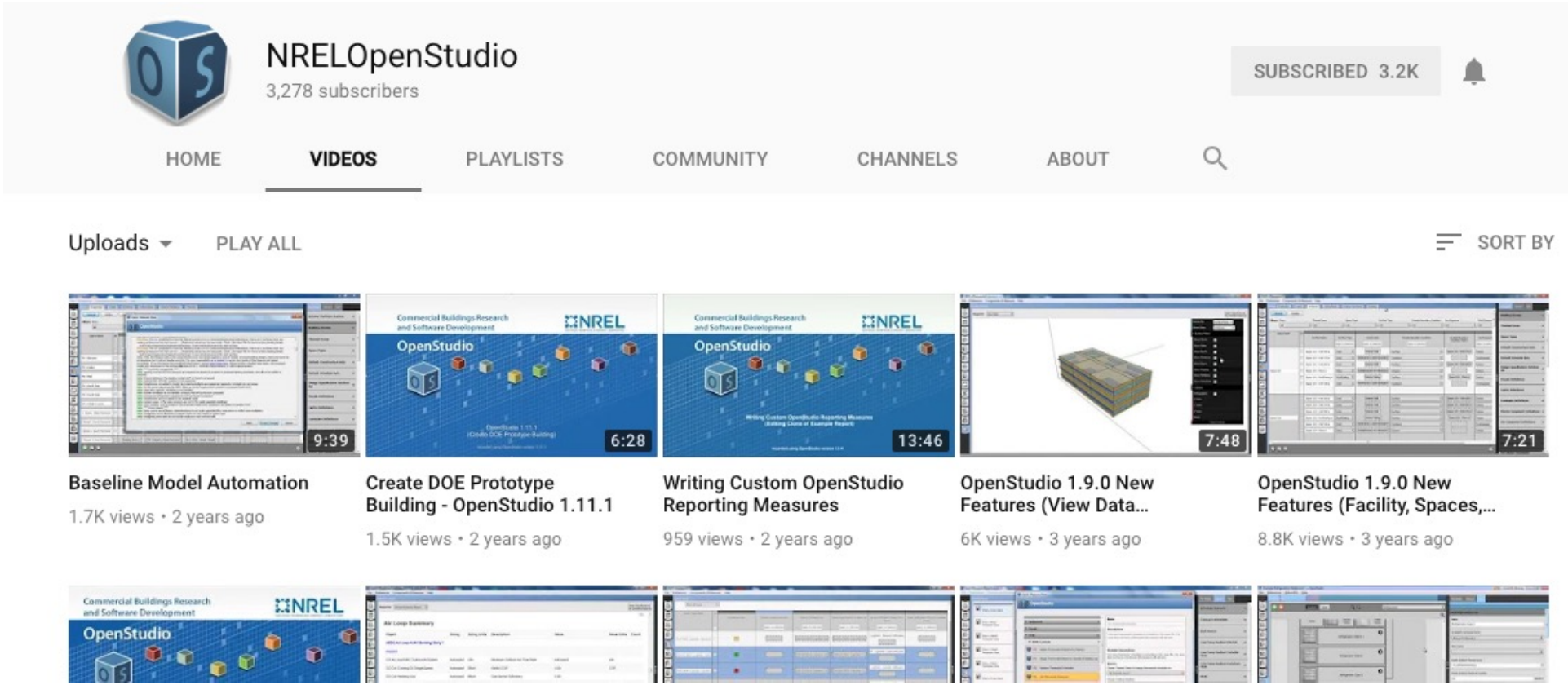
When you first open PAT you will see the screen below. It shows the workflow:

1. Organize and edit measures for project
2. Select measures and create design alternatives
3. Run simulations
4. Create and view reports



http://nrel.github.io/OpenStudio-user-documentation/reference/parametric_studies/

OpenStudio Measures



How many of you have watched any videos related to OpenStudio?

https://www.youtube.com/user/NRELOpenStudio/videos

OpenStudio Measures

- Useful links:
  - https://www.youtube.com/watch?v=3rmElK_OB28
  - https://www.youtube.com/watch?v=4g5nJzDoh58
  - https://www.youtube.com/watch?v=9WgUhiJ785I
  - https://www.youtube.com/watch?v=0llNfGNe5x0

http://nrel.github.io/OpenStudio-user-documentation/reference/parametric_studies/

OpenStudio Measures