

# **CASE STUDIES FROM THE UNIVERSITY OF PENNSYLVANIA: CAMPUS-WIDE LIGHTING UPGRADES TO REDUCE ENERGY CONSUMPTION**

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# AGENDA

- Introduction / History of Campus Energy Master Plan
- Evolution of Approach for Lighting Projects / Design and Project Delivery Strategies
- Case Studies: Lighting Projects
- Results
- Future for Penn Lighting Projects

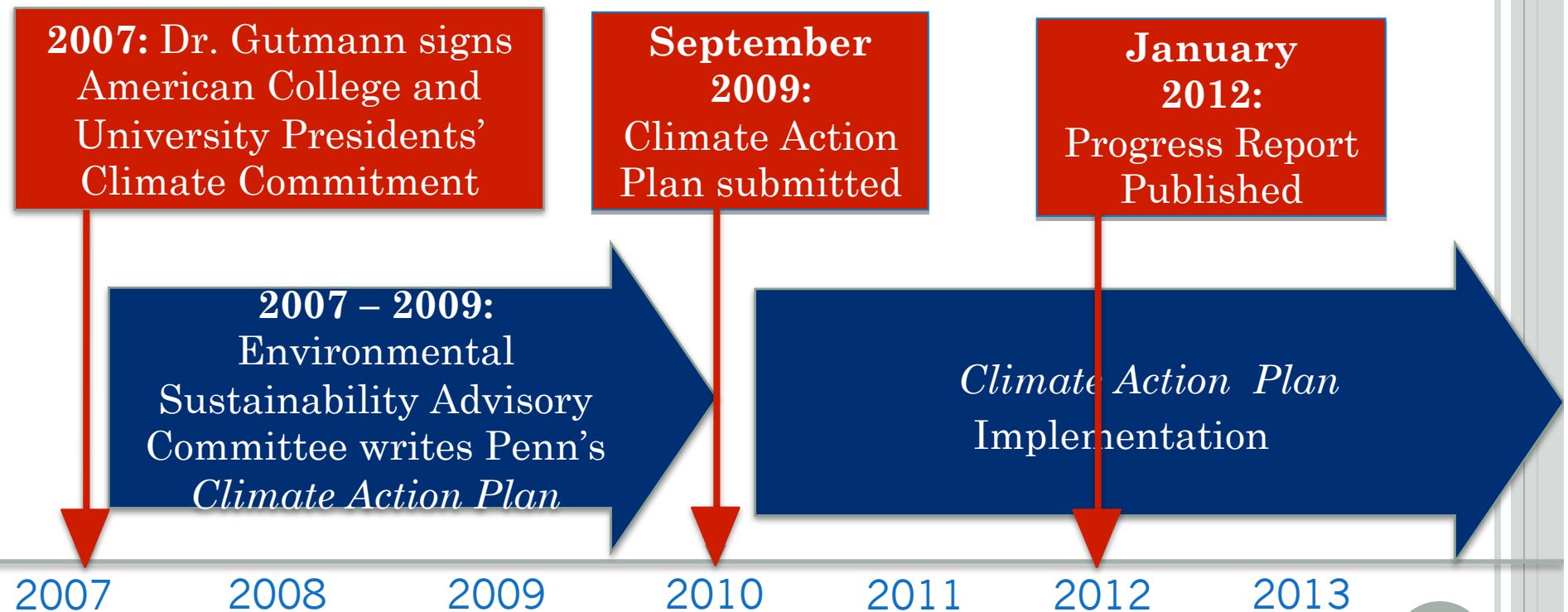


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# INTRODUCTION TO AND HISTORY OF PENN'S ENERGY MASTER PLAN

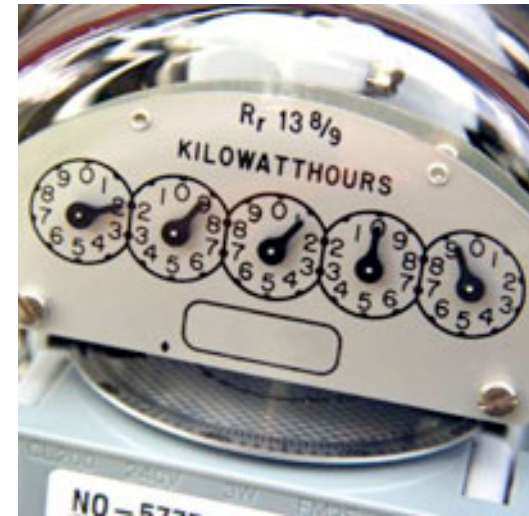
# SUSTAINABILITY COMMITMENT & CLIMATE ACTION PLAN

Goal: 17% reduction in steam and electrical energy consumption by 2014, as compared to 2007 baseline. Achieved goal.



# BENCHMARKING & METERING

- Campus-wide Meter Project installed 400 energy meters at all utility services (steam, chilled water and electric) to 180 buildings.
- 203 Electric Meters were installed and report to the University's SCADA system
- Real-time graphic displays and reports available to building administrators to track energy usage.
- Allows for rapid response to spikes in energy for greater energy conservation
- Allows for benchmarking for lighting projects: comparison of total energy usage before and after lighting upgrades. (Lighting panels are not metered)
- M&V program: 3<sup>rd</sup> party firm looking at connected load at a sampling of fixtures, verifying calculated data is correct.



# FUNDING STRATEGIES

## Energy Reduction Funds (ERF) Program

- Used surplus from School/Center contributions for utility bills to fund projects that would save additional energy.
- ERF projects included lighting renovations and HVAC modifications like AHU conversions, VFD installations, and equipment upgrades.
- 11 Buildings were identified as ERF Lighting Projects.
  - 9 of these were eventually funded from a different source.



## FUNDING STRATEGIES

- \$300M Century Bond was issued in Spring 2012  
\$200M to be used for deferred maintenance and energy-saving projects. \$100M set aside for strategic University priorities
- Feasibility Study conducted
  - Lighting: all buildings with T12s will be converted; 32 Buildings surveyed. Estimated \$20M for lighting projects.
  - Infrastructure / HVAC: 17 Buildings studied and prioritized; 8 Buildings moved into design. Estimated \$180M for HVAC projects.



# LIGHTING MASTER PLAN – TIMELINE

- 2010: 43 Buildings on Campus still contained T12 and incandescent lamps
  - 2010-11: Energy Reduction Funds, from savings surplus, were used for 3 large buildings – comprehensive lighting upgrades
  - 2012: Century Bond was issued for use on energy upgrades and deferred maintenance needs.
    - 8 Buildings moved through design, were bid and built.
    - Feasibility Study commissioned for remainder (32 buildings): presently completing lighting upgrades in these buildings.
- 17 buildings complete,  
→ 17 building in construction  
→ 9 buildings awarded and ready to begin construction





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# EVOLUTION OF APPROACH TO DESIGN & CONSTRUCTION OF LIGHTING PROJECTS

## EVOLUTION OF APPROACH

- First 3 Buildings – through ERF – multiple options were studied in early design.
- Solutions for each building were unique and full design was completed. T8 most cost-effective.
  - Stemmler Hall: mostly lamps & ballasts, wireless controls
  - Chemistry 1973: new fixtures throughout, modular, bi-level controls
  - Stellar Chance: lamps & addressable ballasts, building-wide control system
- Exploration of different procurement and delivery strategies:
  - Penn purchased material directly for Stemmler
  - Pilot program on Chem 73 w/in-house electricians
  - Opened bid to GCs as well as Electrical Contractors



## EVOLUTION OF APPROACH

- Next 8 Buildings were funded through Century Bond program
  - 3 Different Consultants: used on-call A/E agreements to move through design “quickly”
  - Traditional **design → bid → build** approach
  - Planned to bid through CM, who provided estimates throughout the design phases
  - Very high estimates based on project delivery method, as well as what we were learning from the Feasibility Study underway, caused us to scale back the project scope to achieve good paybacks

- |                              |                        |
|------------------------------|------------------------|
| • Franklin Building          | • 3401 Walnut Street   |
| • Chemistry 1958             | • Sweeten Alumni House |
| • Tanenbaum Building         | • McNeil Building      |
| • Clinical Research Building | • Caster Building      |

## EVOLUTION OF APPROACH

- 32 Remaining Buildings across campus
- Initially, during the Feasibility Study, full lighting replacements and comprehensive renovations were studied and priced.
- Requirements to remove/reconfigure ceilings, patch, paint, and run new wire for fixtures and controls drove pricing up and paybacks were unacceptable (50 years in some cases!)
  - Trade-specific activities and union atmosphere drive costs up
  - Originally believed a Construction Management firm would be necessary



## EVOLUTION OF APPROACH

- Shifted mindset about half-way through study and had consultant look at bare minimum scope (lamps and ballasts replacement) to achieve best payback.
- Deliverables included lighting audits, in itemized spreadsheets
- Project procurement strategy changed, back to original method of bidding to Electrical Contractors, in lieu of using CM

... Then we had to figure out *HOW to Bid* ...



## EVOLUTION OF APPROACH

- Buildings were divided into 6 logical groups according to School and/or proximity on campus.
- Hired a consultant to assist with manipulating spreadsheets and producing something that was “biddable.”
- Result was a 2-Round Bidding Process using two main components: the bid template spreadsheets and the lighting standards developed over the course of the previous six months.



# LIGHTING STANDARDIZATION PROCESS






Teamed with consultant to create standards in two phases:

1. Lamps, ballasts, fixtures
2. Controls

Included input from Design & Construction, O&M, and Office of University Architect

Created a “Roadmap” document for Facilities, Operations & Maintenance, and personnel throughout the schools and centers to use.

Standards now included in Instruction to Design Professionals for use in renovation and new construction projects.

Retrofitting Standards - Mapping from Existing Fixtures													
Existing Fixture Types	Building Description	Lighting Performance	Technology	Proposed Retrofit Kit Type	Proposed Kit Description	Efficiency	Lamping	Ballast	Starting Method Factor	Sample Lighting Specification	Specification Address	Dimming	Controls
Retrofit Kits													
	Self-perforated fluorescent fixture	Maintain or Improve Average FC Level and Uniformity	Fluorescent		Self-Retrofit Kit with Volumetric Lens	80%	(2) T8 Lamps	(2) Electronic Ballast	Maintained to Lighting Level Requirements	ULCULS 2X10R 2.0 2X20W SHUP (30-watt)	Ballast Factor Step Dimming Full Range Dimming	Preferred if R-32 Load/Feed	Preferred if R-32 Load/Feed
			LED		Self-Retrofit Kit with 100% Delivered Lumens	9,000 - 9,000 Delivered Lumens Package	(2) Recessed Dimming Driver	N/A		ULCULS 2X10R 40.0 2X20W SHUP 90 (30-watt)	Light Dependent Management	Standard	
	Self-perforated fluorescent fixture	Maintain or Improve Average FC Level and Uniformity	Fluorescent		Self-Retrofit Kit with Volumetric Lens	80%	(2) T8 Lamps	(2) Electronic Ballast	Maintained to Lighting Level Requirements	ULCULS 2X10R 2.0 2X20W SHUP (30-watt)	Ballast Factor Step Dimming Full Range Dimming	Preferred if R-32 Load/Feed	Preferred if R-32 Load/Feed
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	Self-perforated fluorescent fixture	Maintain or Improve Average FC Level and Uniformity	Fluorescent		Self-Retrofit Kit with Volumetric Lens	80%	(1) or (2) T8 Lamps	(2) Electronic Ballast	Maintained to Lighting Level Requirements	ULCULS V10R 2.0 2X20W SHUP (30-watt)	Ballast Factor Step Dimming Full Range Dimming	Preferred if R-32 Load/Feed	Preferred if R-32 Load/Feed
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			LED		Self-Retrofit Kit with 100% Delivered Lumens	9,000 - 9,000 Delivered Lumens Package	(2) Recessed Dimming Driver	N/A		ULCULS 2X10R 40.0 2X20W SHUP 90 (30-watt)	Light Dependent Management	Standard	
	T8 linear indirect lighting fixture	Maintain or Improve Average FC Level and Uniformity	Fluorescent		Self-Retrofit Conversion Kit	N/A	(2) 1' or 18" T8 Lamps	(2) Electronic Ballast	Maintained to Lighting Level Requirements	ULCULS A000R 2.0 2X20W SHUP (30-watt)	Ballast Factor	Preferred if R-32 Load/Feed	Preferred if R-32 Load/Feed

## EVOLUTION OF APPROACH

- Round 1 Bidding: Prescriptive
  - Base Bid – most basic scope as identified in the FS, T12 lamps and ballasts, incandescent lamp replacement
  - Alt 1A – Re-lamp existing T8s w/ more efficient, longer life T8 lamps
  - Alt 1B – Retrofit existing T8s w/ lamps and ballasts
  - Alt 2 – LED re-lamping in place of CFLs
- Bid to ~5 electrical contractors and lighting specialty companies
- Evaluated bid pricing with respect to energy savings and paybacks
- Short-listed to 2 – 3 firms for Round 2





# EVOLUTION OF APPROACH

- Round 2 Bidding: Subjective / Voluntary Pricing
  - Short-listed bidders invited to walk through the buildings to provide pricing for suggested voluntary alternates:
    - Controls / Occupancy Sensors
    - New Fixtures
    - Volumetric Retrofit Kits
    - Exit Signs
    - Complete Re-design
    - Other Voluntary Alternates



## EVOLUTION OF APPROACH

- Even with this approach, there were still many differences in the bid results, since the “Design-Build”-type mentality is unique to each bidder.
- For some of the more complicated buildings, an in-depth review of the bids was required by our lighting consultant to see whose alternates were viable, logical and worthwhile.
  - Looked at how sensors were placed, which types were being used
  - Questioned justification for use of kits and/or new fixtures: condition, lens type, consistency.
- Overall goal was to achieve paybacks < 10 years



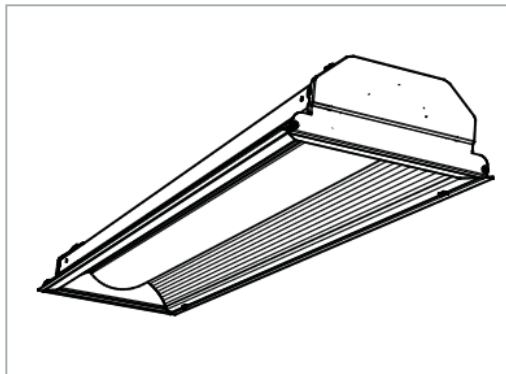


# PROJECT DESIGNS AND RESULTS

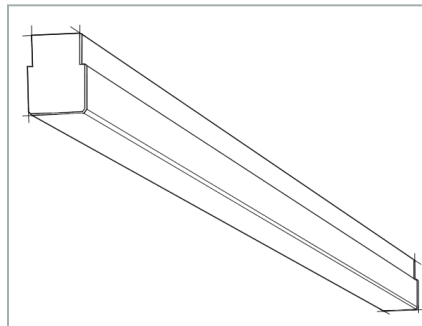
# STEMMLER HALL

250,000 SF Lab Building

- Project Cost = \$1.0M
- Lighting Energy Savings = 1,400,000 kWh/year (66% reduction)
- Payback ~ 7.2 years
- Scope of Work:
  - T12 → T8 & some LED; controls
  - 30% volumetric kits, 20% new fixtures, 50% lamps/ballasts



Custom 1' x 4' volumetric kits



Surface-mounted fixtures  
w/integral occ sensors



Flat panel LED “skylights”

# CHEMISTRY 1973 WING

150,000 SF Lab Building

- Project Cost = \$1.1M
- Lighting Energy Savings = 1,120,000 kWh/year (79% reduction)
- Payback ~ 9.8 years
- Scope of Work:
  - New fixtures throughout to replace original T12s with linear T8s – labs, library
  - Reduced quantity of corridor fixtures by 70%
  - Modular controls



Lab pendant fixtures



Corridors – before and after

# STELLAR CHANCE LABORATORIES

215,000 SF Lab Building

- Project Cost = \$1.65M
- Lighting Energy Savings = 1,690,000 kWh/year (70% reduction)
- Payback ~ 9.4 years
- Scope of Work:
  - New lamps and addressable ballasts
  - Building-wide control system





# CLINICAL RESEARCH BUILDING

205,000 SF Lab Building

- Project Cost = \$1.24M
- Energy Savings = 988,000 kWh/year (85% reduction)
- Payback ~ 15 years
- Scope of Work:
  - Pendant fixture replacement in labs and corridors
  - Volumetric kits in offices
  - Modular controls



CRB Labs – pendant fixtures before and after

# TANENBAUM HALL - LAW LIBRARY

112,000 SF Office and  
Law Library Building

- Project Cost = \$230K
- Energy Savings:  
388,000 kWh/year  
(69% reduction)
- Payback ~7.0 years
- Scope of Work:
  - Lamps & Ballasts
  - Local controls





# FRANKLIN BUILDING SWEETEN ALUMNI HOUSE

Franklin Building: 100,000 SF Office (3 floors in this project)

- Project Cost = \$52K
- Energy Savings = 109,000 kWh/year (57% reduction)
- Payback ~5.7 years
- Scope of Work: Retrofit kits on one floor, new fixtures in mechanical spaces, local controls



Sweeten Alumni: 12,500 SF  
Office Building

- Project Cost = \$46K
- Energy Savings = 63,000 kWh/year (77% reduction)
- Payback ~8.8 years
- Scope of Work: Mainly new lamps and ballasts, controls

## CHEMISTRY 1958 WING

Chem '58: 43,000 SF  
Teaching Labs (2 floors in  
this project)

- Project Cost = \$70K
- Energy Savings =  
109,000 kWh/year (58%  
reduction)
- Payback ~7.6 years
- Scope of Work: Retrofit  
kits on one floor, new  
fixtures on second floor,  
local controls



## 3401 WALNUT STREET

150,000 SF Office / Data Center

- Project Cost = \$360K
- Energy Savings = 345,000 kWh/year (54% reduction)
- Payback ~12.4 years
- Scope of Work:
  - Volumetric retrofit kits to reduce lamp quantity at every fixture





# McNEIL BUILDING

120,000 SF Office and Classroom Building

- Project Cost = \$600K
- Energy Savings = 400,000 kWh/year (43% reduction)
- Payback ~14.1 years
- Project Scope:
  - Mostly lamps and ballast replacement
  - Volumetric kits in acoustical ceilings and at shallow fixtures (custom solution)
  - Low voltage switches and relays removed; local controls installed



Shallow surface-mounted 2'x4's – before and after custom kit

# CASTER BUILDING

25,000 SF Office and Classroom

- Project Cost = \$94K
- Energy Savings = 130,000 kWh/year (48% reduction)
- Payback ~8.6 years
- Project Scope
  - Primarily lamps and ballasts with local controls
  - Some volumetric kits in select areas, for consistency w/ surroundings



# CENTURY BOND GROUP 1

- 7 Buildings:
  - DRIA - Hollenback & Annex, Palestra, Weightman
  - Design - Fisher Fine Arts, Duhring Wing, Morgan
- Project Cost = \$215K
- Energy Savings = 607,000 kWh/year (72% reduction)
- Payback ~ 4.0 years
- Scope of Work: T12 to T8 lamps & ballasts, local controls



Palestra court lighting is shown:  
handled as a separate project



## CENTURY BOND GROUP 2

- 3 Buildings:
  - Franklin Annex (office, server rooms)
  - Silverman (Law – classrooms, offices, and stacks)
  - Stouffer Triangle (Office areas only)
- Project Cost = \$475K
- Energy Savings = 870,000 kWh/year (62% Reduction)
- Payback ~6.1 years
- Scope of Work: T12 retrofits, T8 relamping, LED re-lamping and local controls



## CENTURY BOND GROUP 3

- 5 Buildings:
  - Perelman School of Medicine:
    - Anatomy Chemistry (lab & office)
    - Johnson Pavilion (lab, library, office)
    - John Morgan Building (lab & office)
  - School of Veterinary Medicine
    - Rosenthal Building (lab & office)
    - Old Vet Quadrangle (lab & office)
- Project Cost = \$1.3M
- Energy Savings = 1,289,000 kWh/year (42% reduction)
- Payback ~7.8 years
- Scope of Work: T12 retrofits, T8 relamping, LED re-lamping, local controls, new volumetric fixtures in JP Library and other strategic locations.





# CENTURY BOND GROUP 3



Rosenthal Hall Teaching Laboratory



Johnson Pavilion Biomedical Library



## CENTURY BOND GROUP 4

- Buildings: David Rittenhouse Labs, Cret Wing, Fels Center, Center for Judaic Studies, Stiteler Hall, Williams Hall
- Project Cost = \$443K
- Energy Savings = 505,600 kWh/year (57% reduction)
- Payback ~9.8 years
- Scope of Work: T12 retrofits, T8 relamping, LED re-lamping and local controls



## CENTURY BOND GROUP 5

- Buildings: Moore School, Towne Building, Hayden Hall, Evans Dental, Levy Dental, Annenberg Center
- Project Cost = \$458K
- Energy Savings = 595,500 kWh/year (41% reduction)
- Payback ~8.6 years
- Scope of Work: T12 retrofits, T8 relamping, LED re-lamping and local controls



## CENTURY BOND GROUP 6

- 5 Buildings: Van Pelt Library, University Museum, Lauder-Fischer Hall, Colonial Penn Center, Institute for Contemporary Art
- Project Cost = \$750K
- Energy Savings = 1,220,000 kWh/year (57% reduction)
- Payback ~7.4 years
- Scope of Work: T12 retrofits, T8 re-lamping, LED re-lamping, select new fixtures, some retrofit kits, and local controls



## UTILITY REBATES

- Have participated in Phases 1 and 2 of PECO's Act 129 Rebate Program
- Currently receiving approximately \$0.30 per Watt reduced
- Will offset project costs by approximately 6 – 12%
- Rule changes:
  - Pre-approval required before any materials can be ordered
  - Pre-inspection by PECO required before any work can begin
  - Any application projecting over 500,000 kWh savings will require 2 – 4 weeks pre-metering on lighting
  - Larger areas require data logger installation to verify hours of occupancy, at PECO's discretion





# NEXT STEPS FOR PENN

## FUTURE FOR LIGHTING PROJECTS

- Century Bond funding can continue to be used for future projects
- There is no intention of stopping once all of the T12s have been eliminated.
- Will continue to identify projects that can achieve energy savings and increase efficiency.
- Potential future projects:
  - LED Retrofits when pricing allows
  - Unique situations – e.g., Scherr Pool metal halides
  - ??





QUESTIONS?

Thank you!