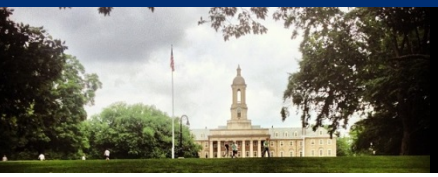

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Lean and Green

RESEARCH INITIATIVE

A Relative Energy Prediction Methodology To Support Decision Making In Deep Retrofits

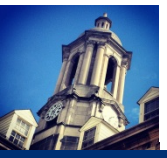
Pelin Gultekin, Chimay J. Anumba & Robert M. Leicht

Department of Architectural Engineering

The Pennsylvania State University

pelin@psu.edu

5th International/11th Construction Specialty Conference



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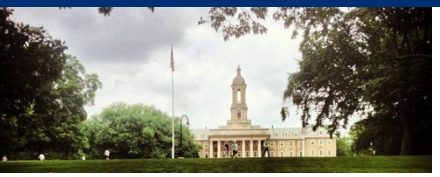
COMPUTER INTEGRATED CONSTRUCTION

CSCE CCGC



Outline

MOTIVATION

PROJECT AIM

RESEARCH TIERS

CASE STUDIES

DSS DEVELOPMENT: Decision Point Window Generation

ENERGY EFFICIENCY PREDICTIONS: Case Studies & Calculations

CONTRIBUTIONS

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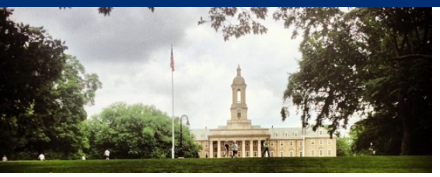
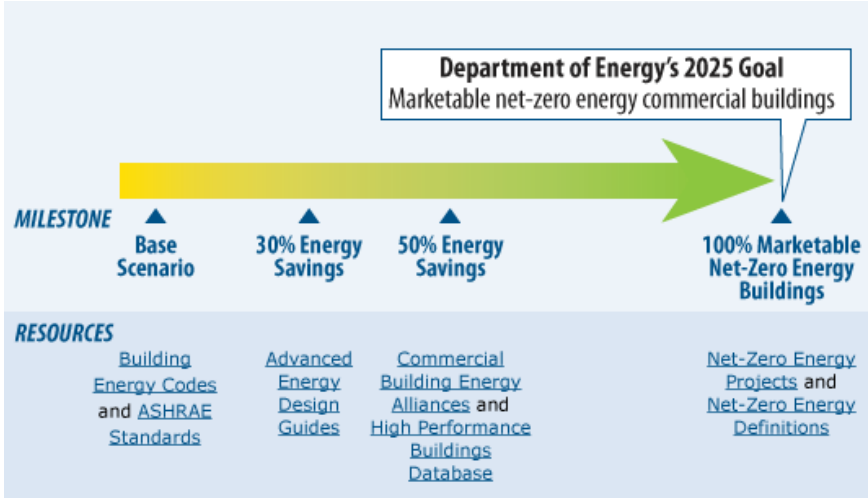
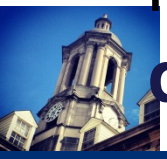
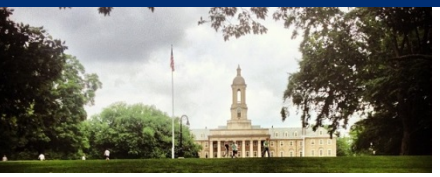


Motivation

- Building energy services require significant energy use, about **40 quadrillion Btu (quads)** per year.
- Existing building constituting **more than 98% of the building stock**, the greatest impact on reducing building energy consumption in the US will result from retrofitting of existing buildings.
- Retrofit projects require **more integration due to the need for resolution of the inherent characteristics** of existing building and designing "best fit" for these specific characteristics.
- Hence, the complexity of the process can be improved with **transparency of the critical decisions** early in the process.

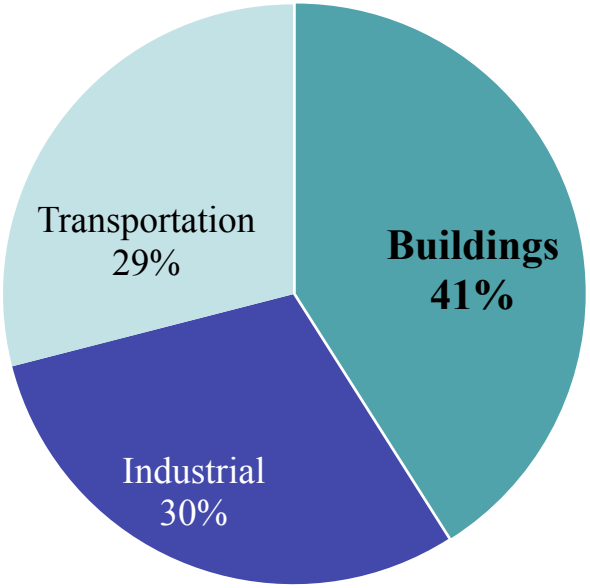






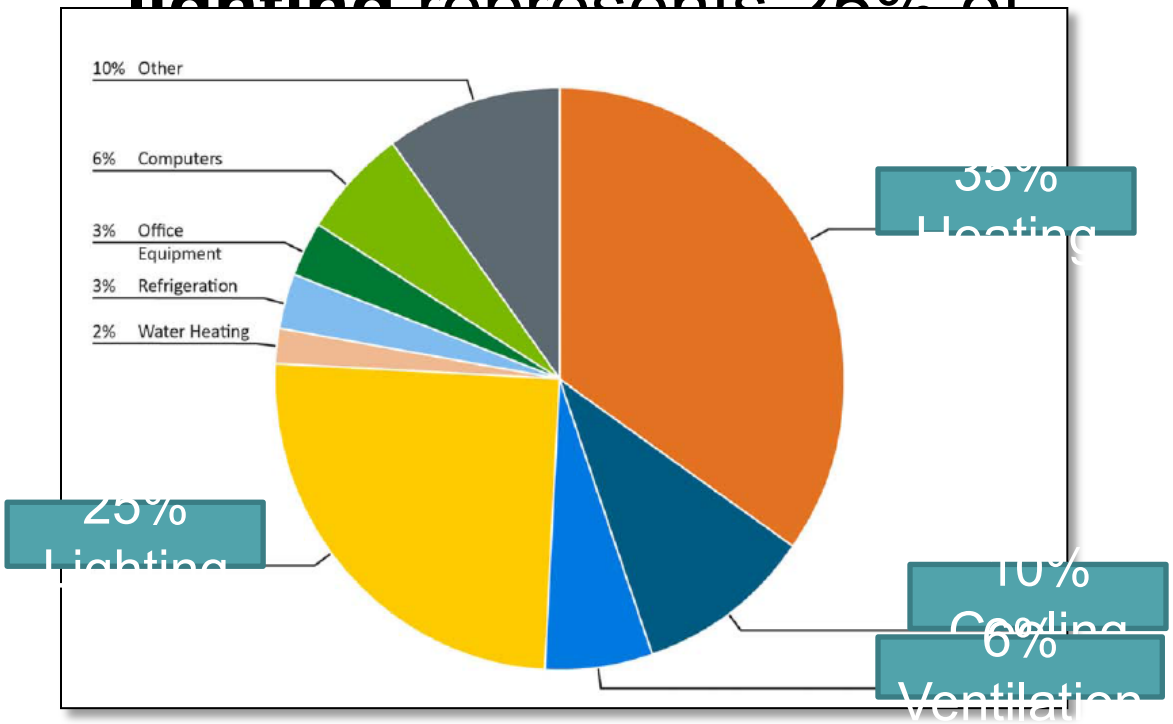
Energy Consumption by Sectors

nsumed Energy by Sectors



(US Energy Information Administration 2009)

HVAC system makes up 51% of total energy use, and **lighting** represents 25% of



(US Energy Information Administration 2006)

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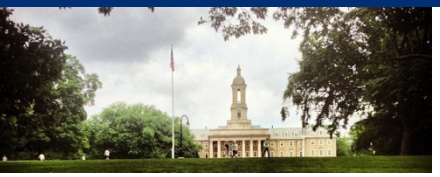
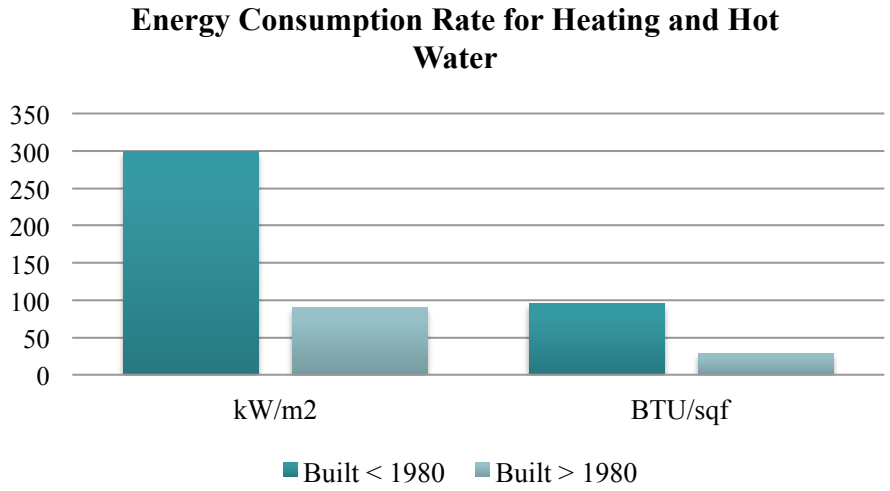


Retrofit Measures



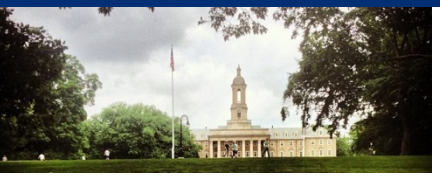
Energy consumption of buildings built before 1980 can be as high as 300 kW/m2 which is greater than the triple consumption of the modern structure built with the least energy-efficient guidelines

Bldg.	Area (m^2)	Built Year	EU	EU Standard		Window	Wall	Roof
				good practice	typical			
Kane	13699	1971	615	348	568	Single	No insulation	No insulation
Boole	19662	1971	620	348	568	Double	No insulation	No insulation
O'R	11812	1997	340	348	568	Double	Insulation	Insulation
CEE	1741	1910	424	112	205	Single	No insulation	No insulation
EE	2791	1954	445	112	205	Double	No insulation	No insulation
ERI	2781	2004	182	112	205	Double	Insulation	Insulation

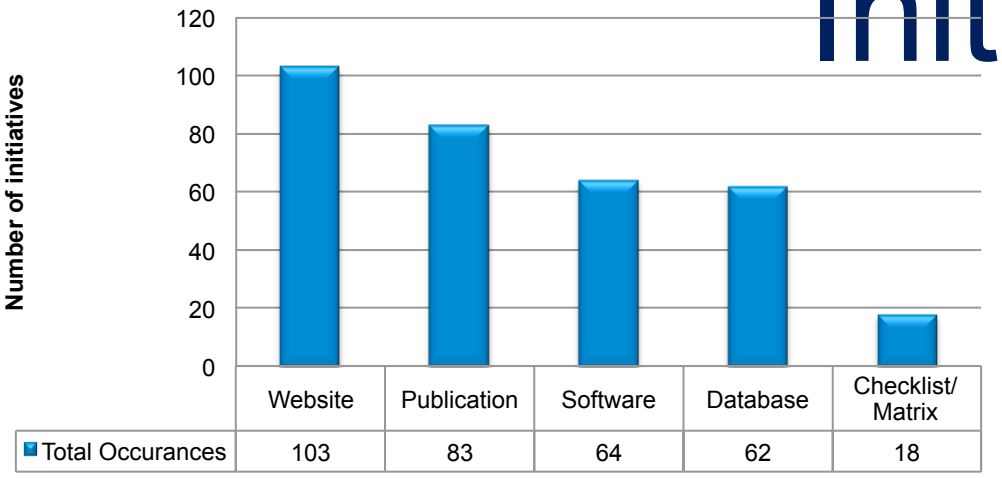
EU – Energy Usage (kWh/m2/yr); EU Standard – reference: energy consumption guide 19.

For the impacts of system measures, a research compared six buildings with different renovation solutions and their energy usage performances.

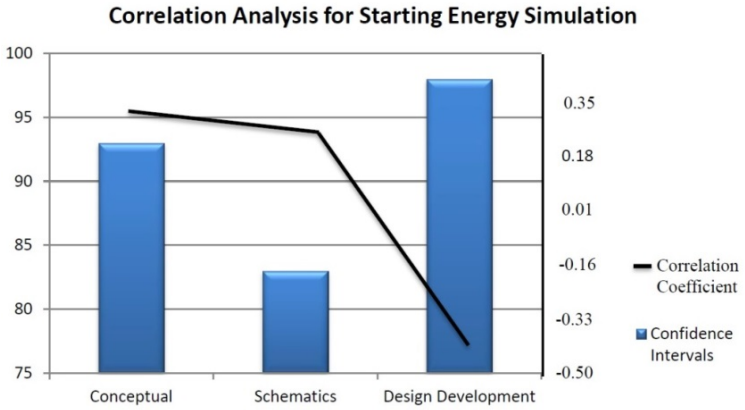
(Yin & Menzel 2011)



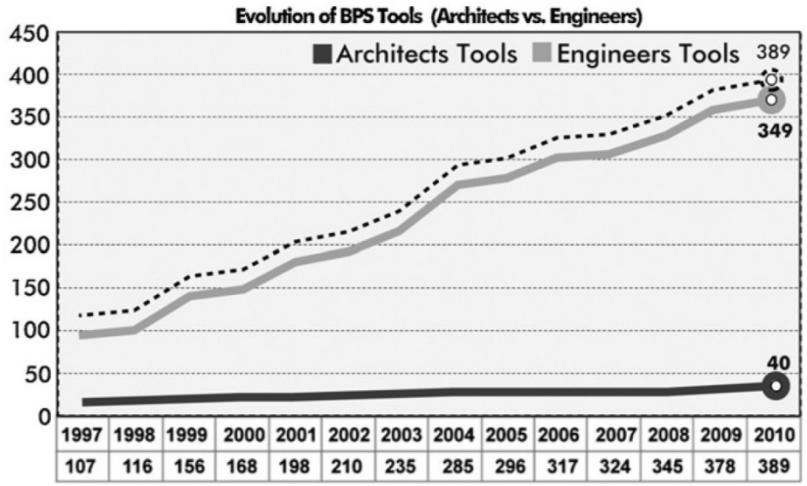
Energy Efficiency Initiatives

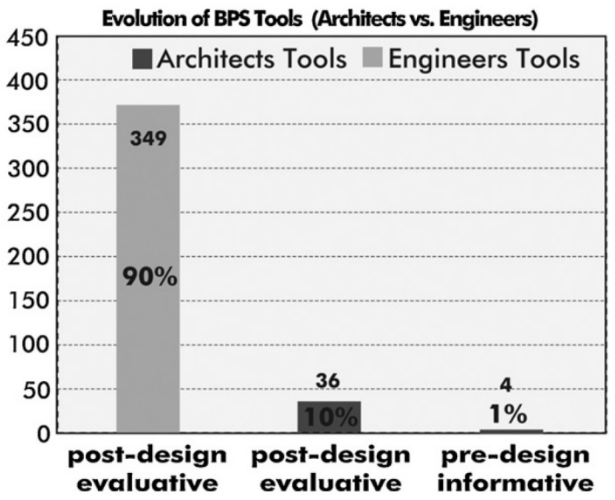


(Adapted: Kaysare WBDG 2007)



(Source: Gultekin et al. 2011)





(Source: Attia et al. 2012)

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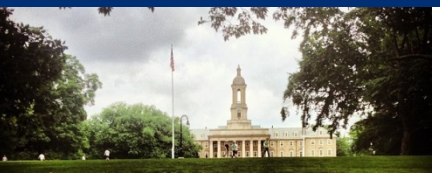
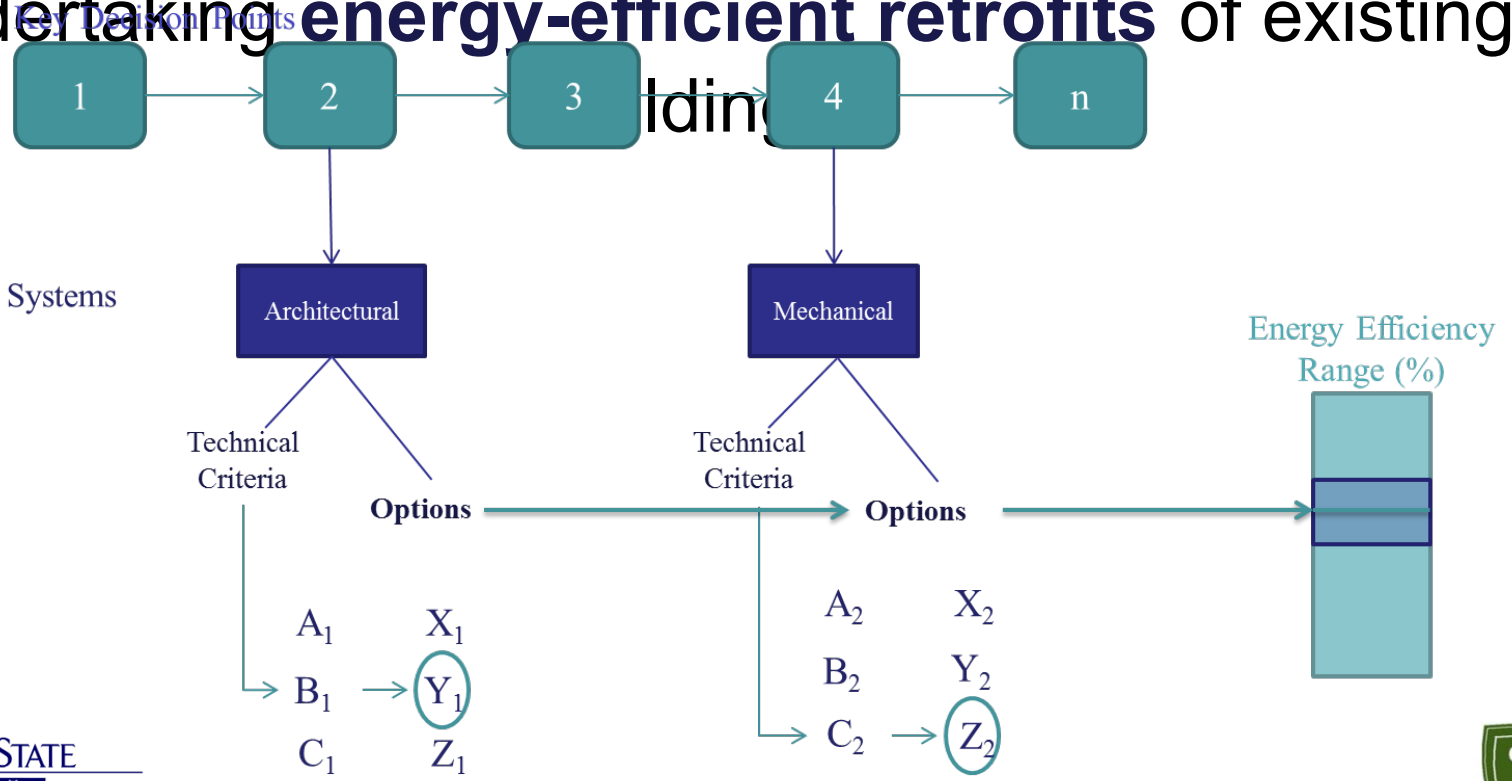


Project Aim

To develop an **integrated process model and decision support system** that can provide proactive guidance to project managers and integrated teams in undertaking **energy-efficient retrofits** of existing



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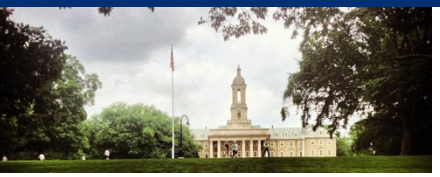
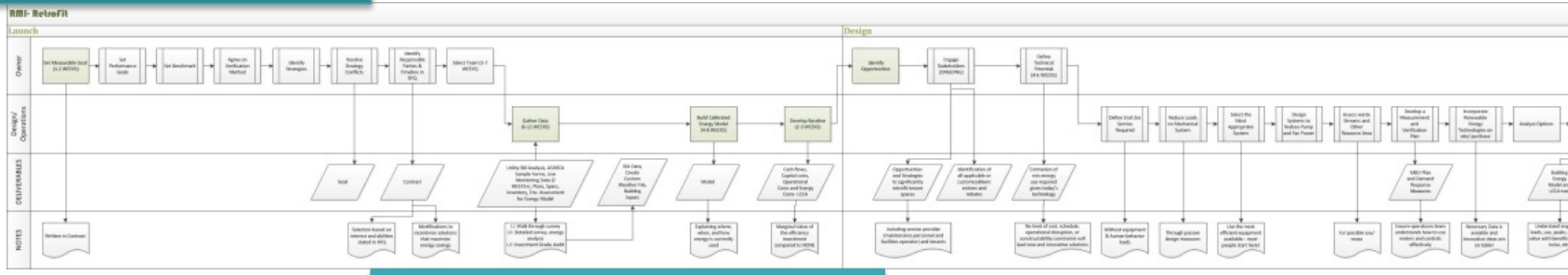


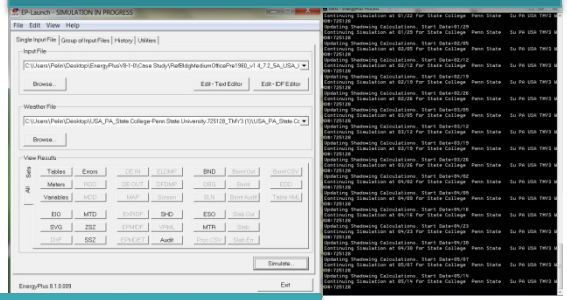
Research Tiers

To-Be Process Model

TIER 1: *Early Design → Evaluate Decision Alternatives*



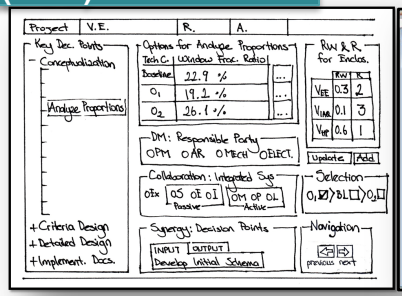
TIER 2 **Energy Performance Prediction**

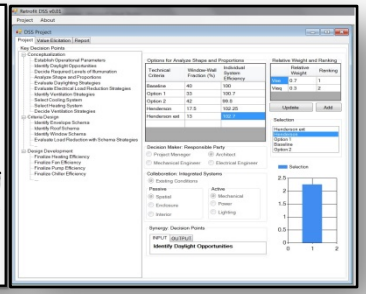


Simplified → Measures for Collaborative Teams

TIER 3 **Decision Support System (DSS)**

Retrofit → Flexible Measures





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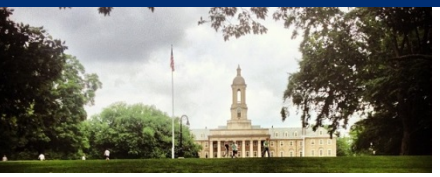

Case Study

Test+Range

TraneTrace
eQuest
HAP

Test

1. Individual ECM calculated

Case Study

Critical Decisions

Process Model

DSS

Energy Prediction

Literature Review

Technical Criteria

2. Synergies informed

RMI Retrofit Guide

3 Retrofit Processes

To-Be Deep Retrofit Process

ECM

Simplified Tools: *E10 & DA*

Technical Reports: NL, AIA-DOE ASHRAE (baseline)

Calculation

Comprehensive Forward Simulation: *EnergyPlus*

Commercial Reference Building (PNNL & NREL)

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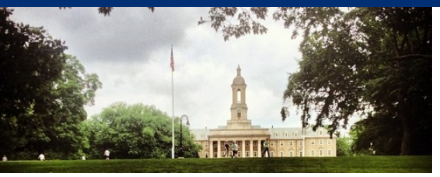
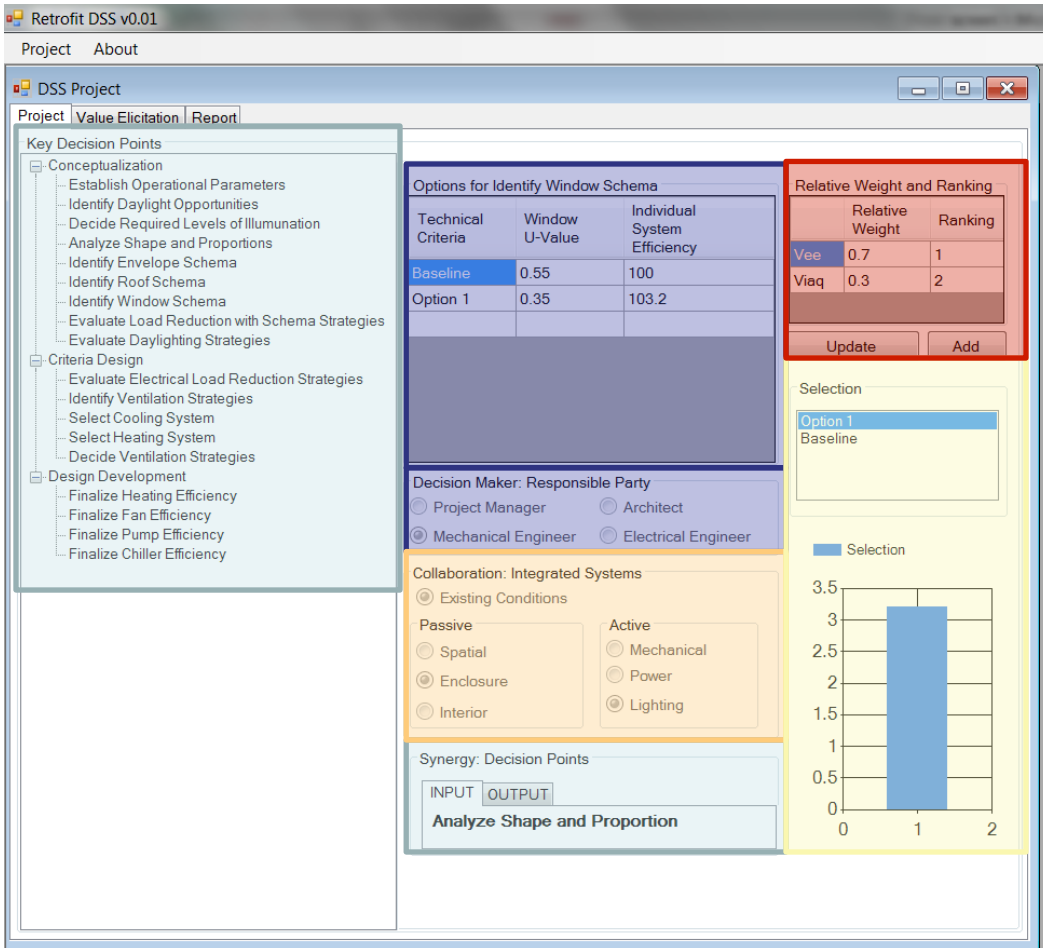


Interviews with
Project Team

Process Model



Case Studies
Decision-Making
Environment

Energy Plus Calculation
eQuest Reports

OMNI Class
OPP Design Division

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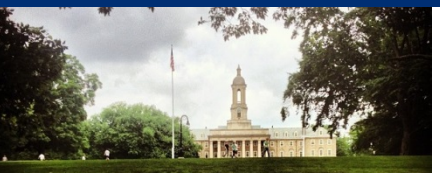
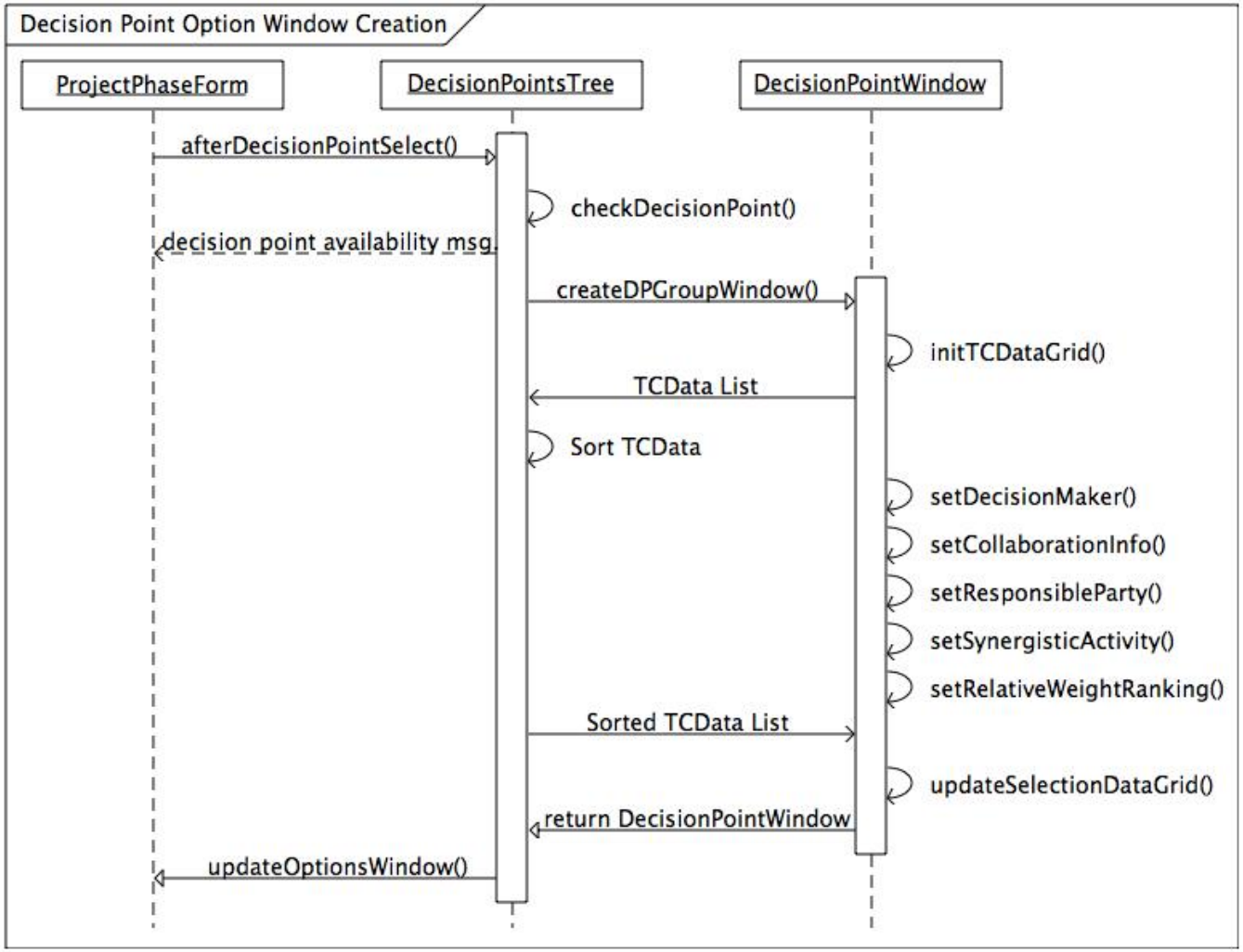


Decision Point Window Generation Sequence Diagram



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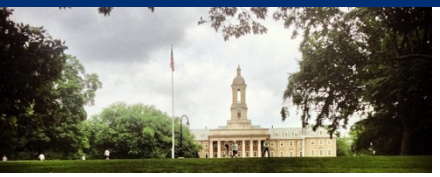
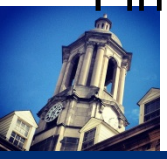


Critical Energy Efficiency Decision Points

- Identify Daylight Opportunities
- Decide Required Levels of Ill
- Analyze Shape and Proportio
- Identify Envelope Schema
- Identify Roof Schema
- Identify Window Schema
- Evaluate Daylighting Strategi
- Evaluate Electrical Load Red
- Identify Ventilation Strategies
- Select Cooling System
- Select Heating System
- Finalize Heating Efficiency
- Finalize Fan Efficiency
- Finalize Pump Efficiency

	ECM	Unit	Baseline	Option	Individual System Efficiency (%)
ECM1	Natural Lighting Hours	% daylight hours	100	10	0.9
ECM2	Interior Lighting Power Density	W/sqf	1.1	1	0.8
ECM3	Window-Wall Fraction	% (<50)	33	20	0.9
ECM4	Wall R-Value (assembly)	ft2fh/BTU	5	20	3.4
ECM5	Roof R-Value	ft2fh/BTU	20	30	1.3
ECM6	Window U-Value	BTU/ft2fh	0.62	0.4	3.2
ECM7	Shading	Y/N	0	1	0.4
ECM8	Daylighting controls	Y/N	0	1	4.3
ECM9	Ventilation Rate	cfm/sqf	0.7	0.5	4.7
ECM10	Chiller Efficiency	COP	2.638	3.517	3.8
ECM11	Boiler/Furnace Efficiency	%	78	88	6.1
ECM12	Heat Recovery	Y/N	0	1	2.7
ECM13	AHU Fan Type	kw/cfm	0.000702	0.0005	3.7
ECM14	Pump Type	%	85	95	3.9



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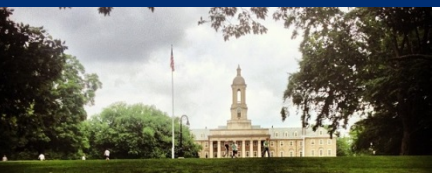
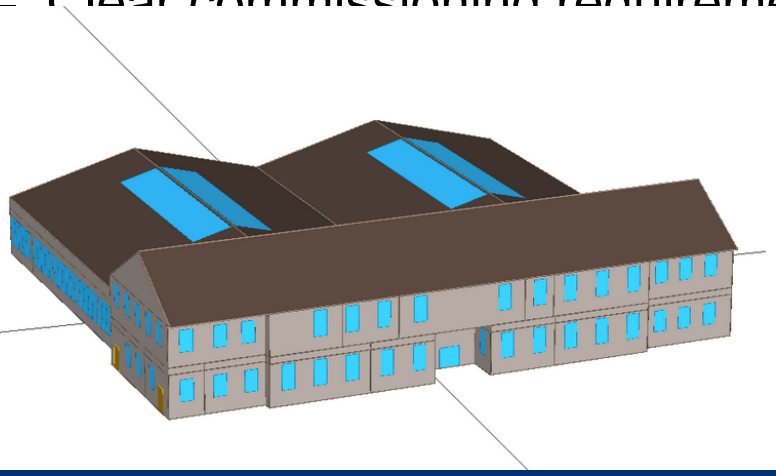
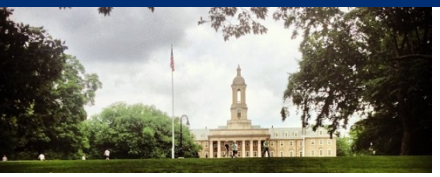


Energy Efficient Buildings Hub

- Research Laboratory and Education Facility
- 30,000 sqf- Design-Bid-Build
- Target: LEED Gold & **38% reduction** in energy consumption of the building
  - Energy Efficient System Selection, Sensory-rich, stimulating and scale appropriate environment
  - Daylighting, Natural Ventilation and Lighting, with User-interaction
  - Clear commissioning requirements





Energy Efficient Buildings Hub Calculations

ECM		Unit	Baseline	Proposed	Individual System Parameter Efficiency (%)
ECM1	Natural Lighting Hours	% daylight hours	100	10	0.9
ECM2	Interior Lighting Power Density	W/sqf	1.1	2.48	-11.04
ECM3	Window-Wall Fraction	% (<50)	13	17.5	-0.31153846
ECM4	Wall R-Value (assembly)	ft2fh/BTU	4	24	4.533333333
ECM5	Roof R-Value	ft2fh/BTU	0	30	3.9
ECM6	Window U-Value	BTU/ft2fh	0.67	0.32	5.090909091
ECM7	Shading	Y/N	0	0.4	0.16
ECM8	Daylighting controls	Y/N	0	1	4.3
ECM9	Ventilation Rate	cfm/sqf	0.6	0.3	7.05
ECM10	Chiller Efficiency	COP	2.726	3.517	3.419567691
ECM11	Boiler/Furnace Efficiency	%	80	96	9.76
ECM12	Heat Recovery	Y/N	0	1	2.7
ECM13	AHU Fan Type	kw/cfm	0.000702	0.000661	0.750990099
ECM14	Pump Type	%	85	90	1.95

Overall: 33%

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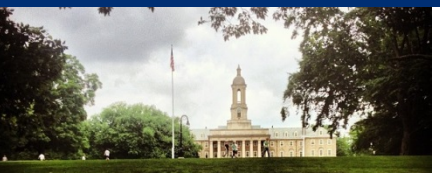
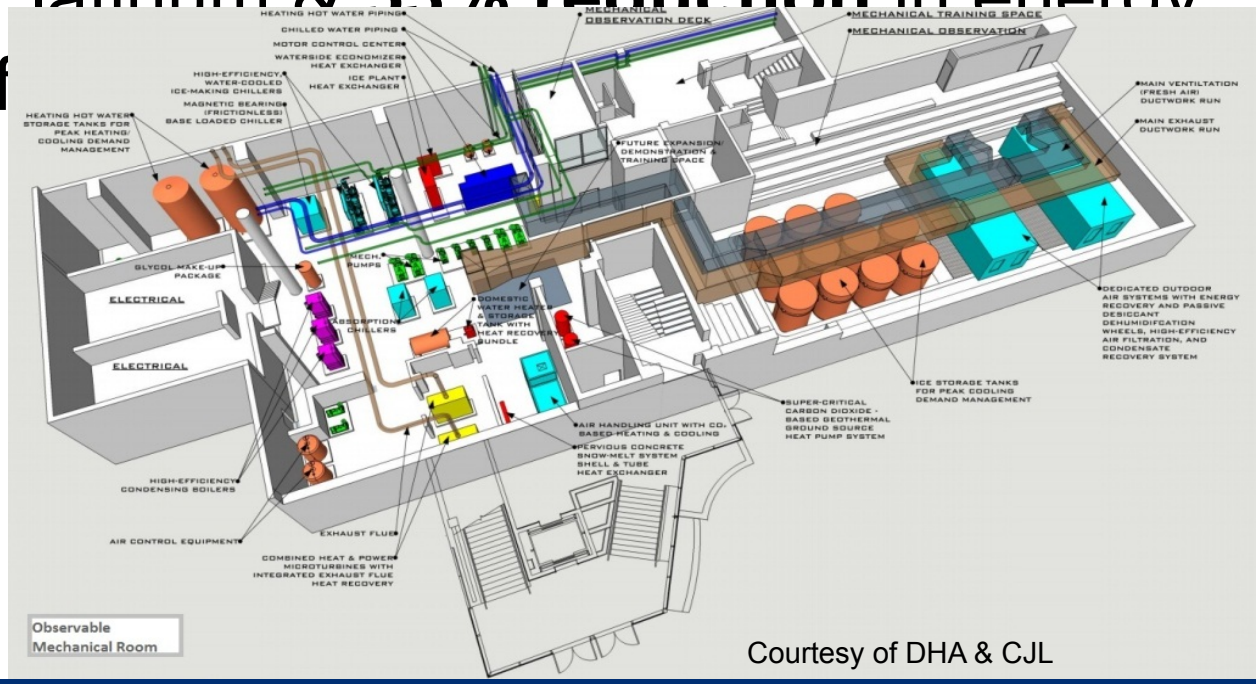


Energy Innovation Center

- **Business Incubator**: Green Technology Demonstration Showcase under the ownership of Pittsburgh Green Innovators Inc.
- 300,000sqf (27,870sqm)- Design Build Delivery
- Target: LEED Platinum & **53% reduction** in energy consumption of



Courtesy of DHA & CJL

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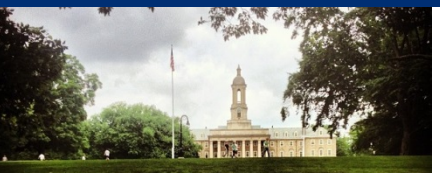
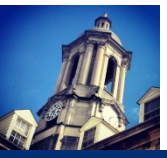


Energy Innovation Center Calculations

ECM		Unit	Baseline	Proposed	Individual System Parameter Efficiency (%)
ECM1	Natural Lighting Hours	% daylight hours	100*	10	0.9
ECM2	Interior Lighting Power Density	W/sqf	1.1	2.1	-8
ECM3	Window-Wall Fraction	% (<50)	33	23	0.692308
ECM4	Wall R-Value (assembly)	ft2fh/BTU	0	20	4.533333
ECM5	Roof R-Value	ft2fh/BTU	20*	30	1.3
ECM6	Window U-Value	BTU/ft2fh	1.2	0.43	11.2
ECM7	Shading	Y/N	0*	0.8	0.32
ECM8	Daylighting controls	Y/N	0*	1	4.3
ECM9	Ventilation Rate	cfm/sqf	0.6	0.2	9.4
ECM10	Chiller Efficiency	COP	2.93	4.4	6.354949
ECM11	Boiler/Furnace Efficiency	%	80*	98	10.98
ECM12	Heat Recovery	Y/N	0*	1	2.7
ECM13	AHU Fan Type	kw/cfm	0.000702*	0.001	-5.45842
ECM14	Pump Type	%	85*	97	4.68

Overall: 44%



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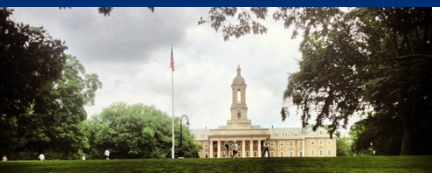
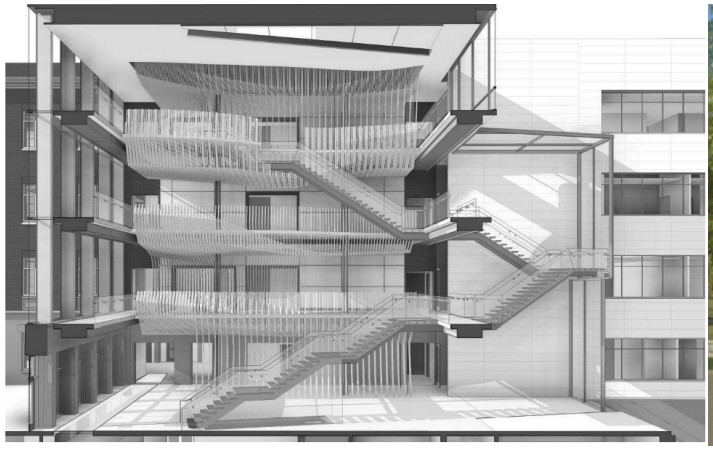


Health and Human Development Building

- Research Laboratory and Education Facility
- 39,147 sf- Design-Bid-Build (Standard Retrofit Process)
- Target: LEED Silver & **23% reduction** in energy consumption of the building
  - Include the use of recycled materials, regional materials, and low-emission materials



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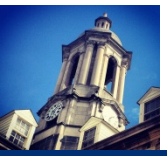
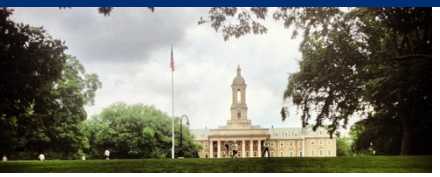


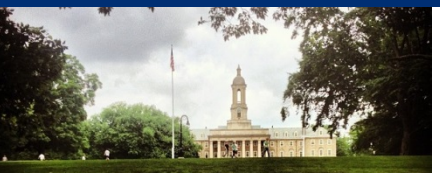


Health and Human Development Building Calculations

ECM		Unit	Baseline	Proposed	Individual System Parameter Efficiency (%)
ECM1	Natural Lighting Hours	% daylight hours	100*	60	0.4
ECM2	Interior Lighting Power Density	W/sqf	1.03	0.93	0.8
ECM3	Window-Wall Fraction	% (<50)	22.9	23.1	-0.01385
ECM4	Wall R-Value (assembly)	ft2fh/BTU	15.38	15.62	0.0544
ECM5	Roof R-Value	ft2fh/BTU	20.82	21.28	0.0598
ECM6	Window U-Value	BTU/ft2fh	0.45	0.4	0.727273
ECM7	Shading	Y/N	0*	0.4	0.16
ECM8	Daylighting controls	Y/N	0*	0	0
ECM9	Ventilation Rate	cfm/sqf	N/A	N/A	N/A
ECM10	Chiller Efficiency	COP	2.93	4.11	5.101251
ECM11	Boiler/Furnace Efficiency	%	80*	100	12.2
ECM12	Heat Recovery	Y/N	0*	0	0
ECM13	AHU Fan Type	kw/cfm	N/A	N/A	N/A
ECM14	Pump Type	%	N/A	N/A	N/A

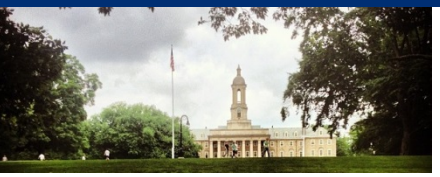
Overall: 19%

PENNSTATE



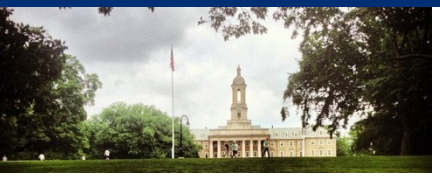
Contributions

- This study contributes to an integrated design process by **providing critical decision stages with regard to energy performance**, and describing the resolution of system decision making conflicts by adding criteria impact.
- This **relative system performance evaluation is also useful in defining the scope of system retrofit** by presenting a comparison of options relative to a standard baseline.
- It **assists project managers and collaborative design teams to evaluate the individual impact of sub-system decisions earlier** by identifying



Thank you

PENNSTATE



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