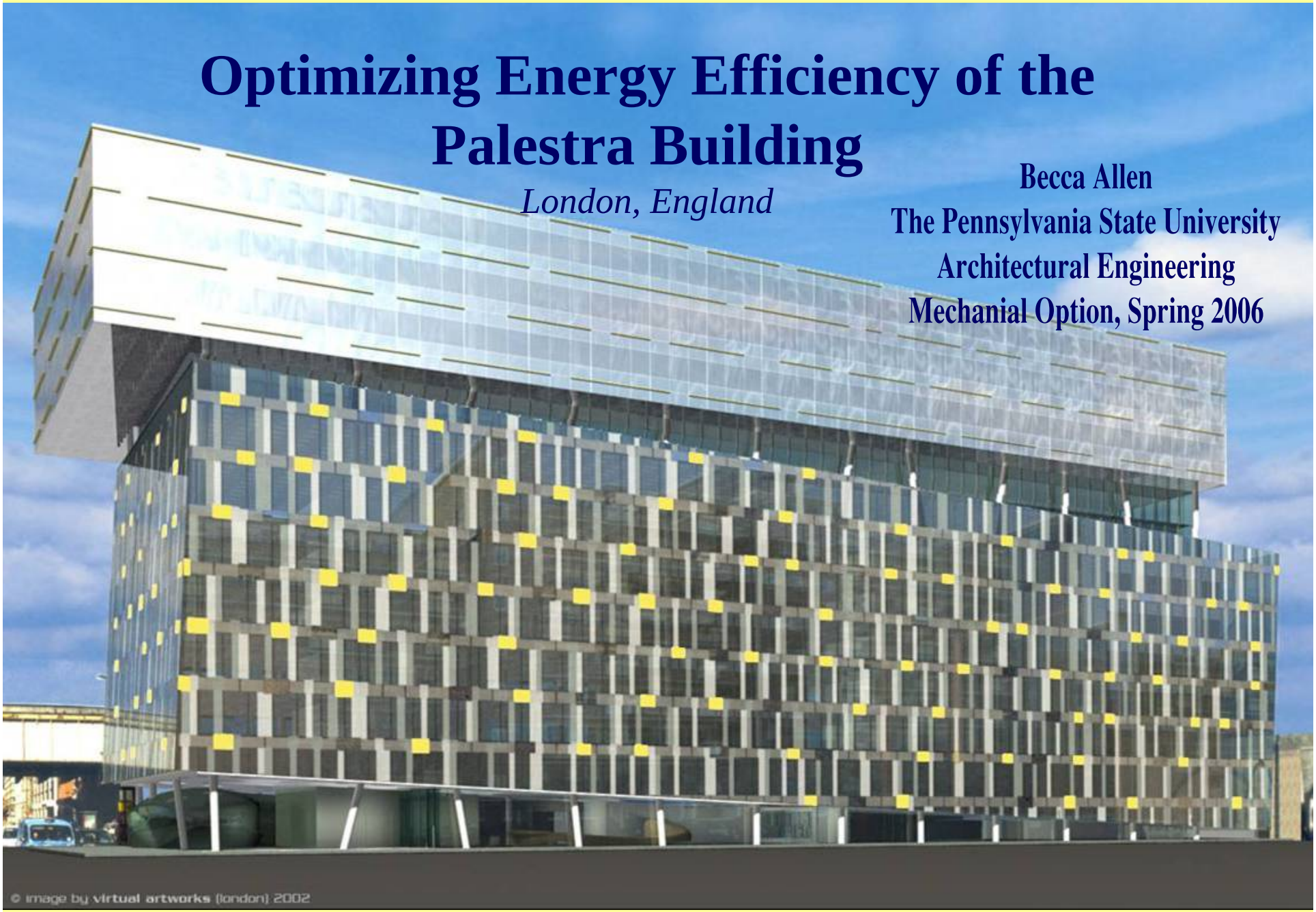
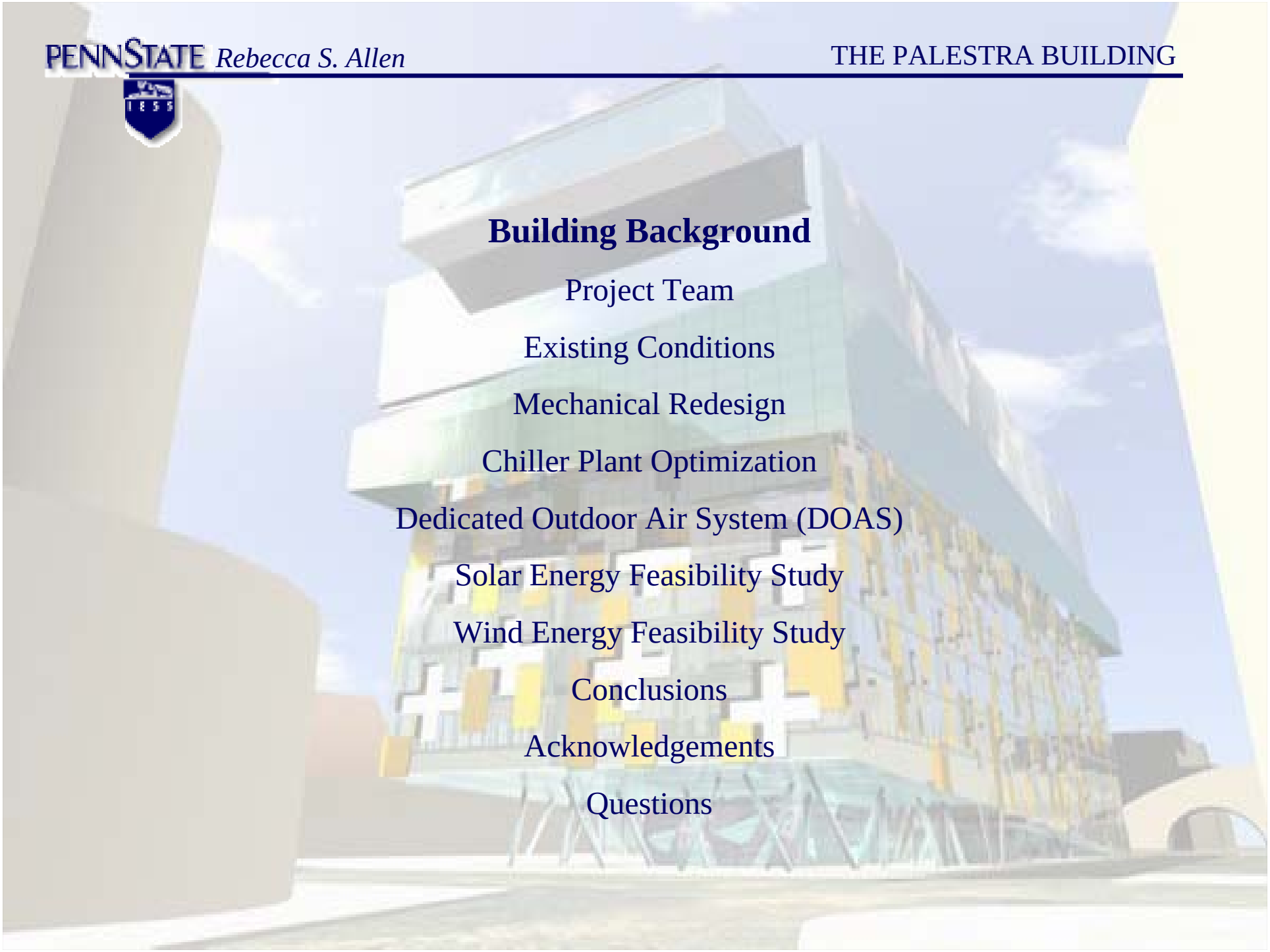
Optimizing Energy Efficiency of the Palestra Building

London, England

Becca Allen
The Pennsylvania State University
Architectural Engineering
Mechanial Option, Spring 2006





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Mechanical Redesign

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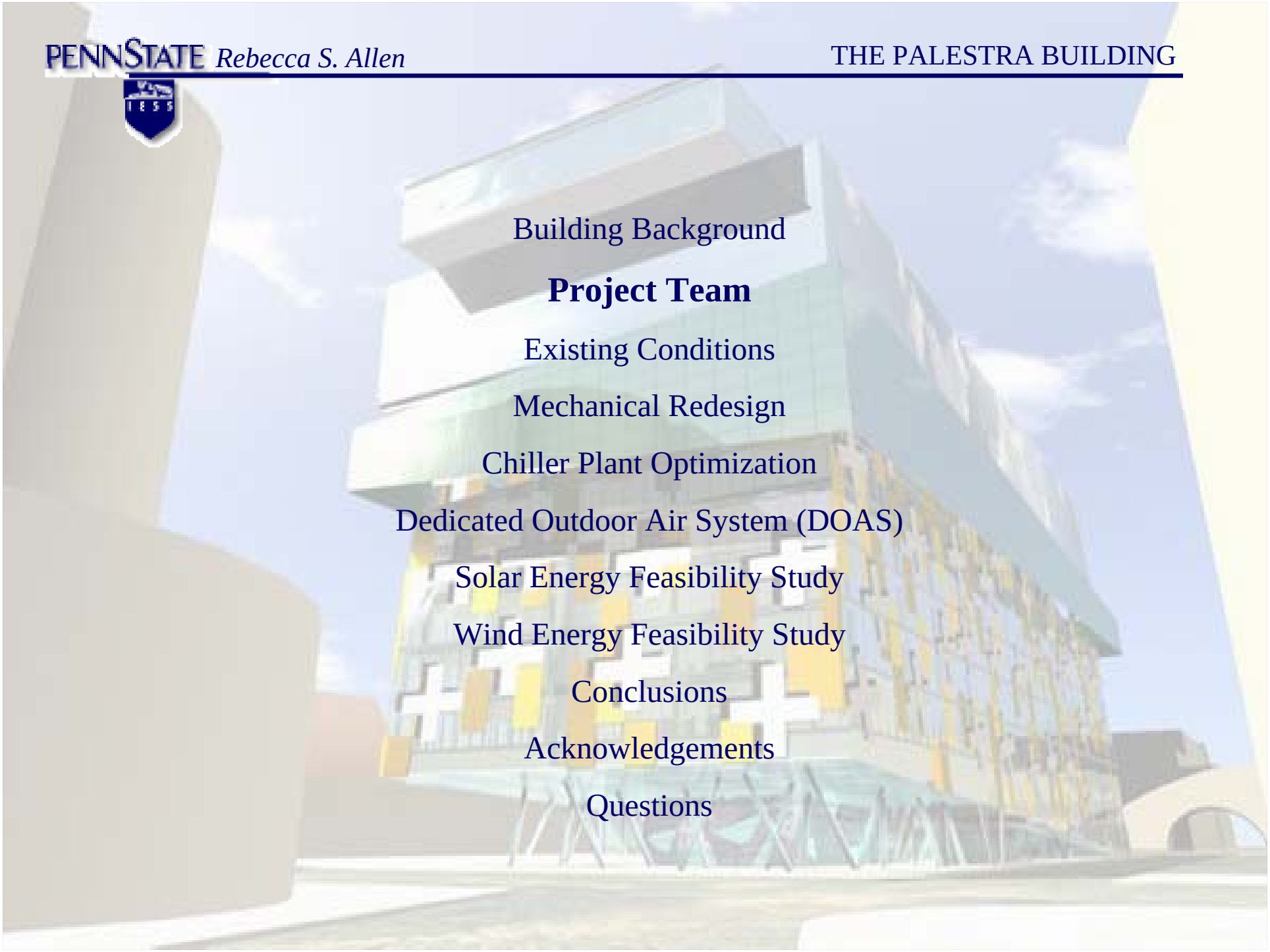
Building Background

- **Occupancy:** Multi-Tenant Office Space
- **Location:** London, England
- **Size:** 37,098 m^2 (399,319 ft^2)
- **Cost:** £68 million
- **Procurement Type:** Design & Build
- **Projected Completion:** July 2006

Building Background



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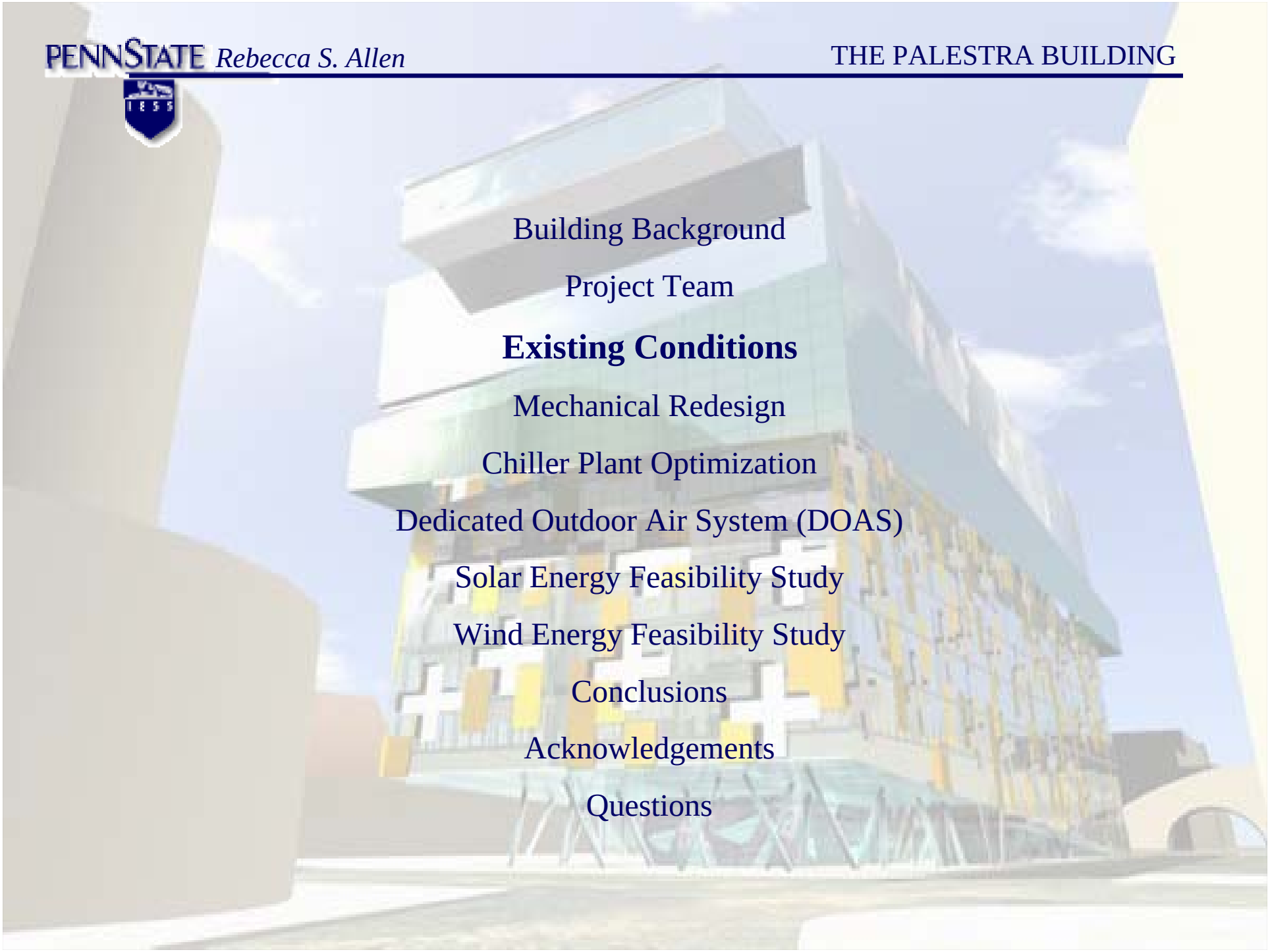
- **Owner:** Blackfriars Investments and Royal London Asset Management
- **Architect:** Will Alsop, Alsop Architects
- **MEP Engineers:** Buro Happold Ltd.
- **General Contractor:** Skanska UK
- **Structural Engineers:** Buro Happold Ltd.

Andrew Lacey, Structural Engineer

***Former Leeds Exchange Student**



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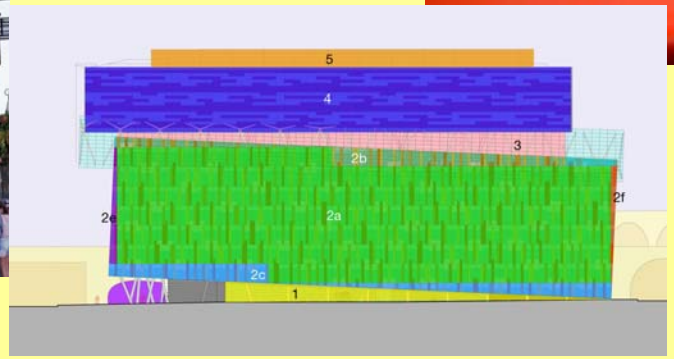
Architectural Concept

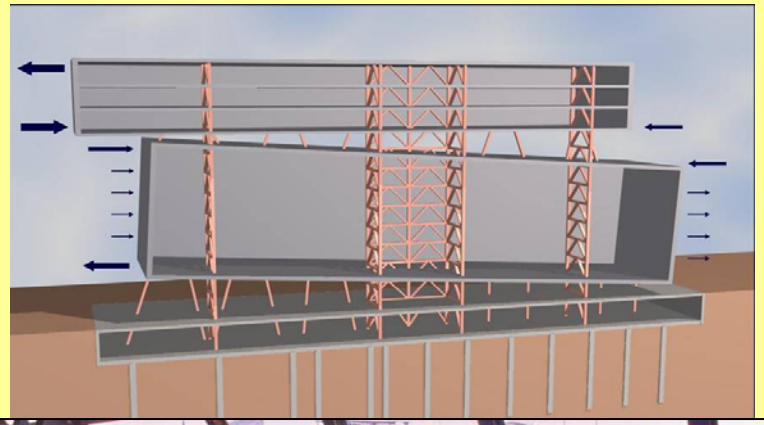
- Floating Boxes
- ‘Dancing’ Columns
- Tilted Facade



Existing Conditions

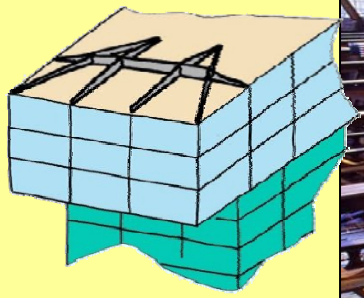
Lighting/Electrical

- 4MVA substation in basement
- Lighting Density: 15 W/m^2
- 4 – 800 amp, 500kVA busbars service tenant area
- Recessed modular flourescent fixtures, fitted with controls for brightness management



Structural

- Steel construction
- Dancing columns
- 9 m cantilever
- 10m x 7.5m structural bays



Existing Conditions

Mechanical

- (7) 537 kW Air-cooled Screw Chillers
  - Chilled Water Supply 7ºC
- (4) 800 kW Natural Gas-fired Boilers
- (7) Constant Air Volume Units coupled with terminal Fan Coil Units

Existing Conditions

Space Design Conditions

Outdoor Air Temperature:

WINTER, 4ºC

SUMMER, 29ºC DBT 20ºC WBT

Internal Air Temperature:

22ºC ± 2ºC, Office Space

18ºC min, Toilets and Stairs

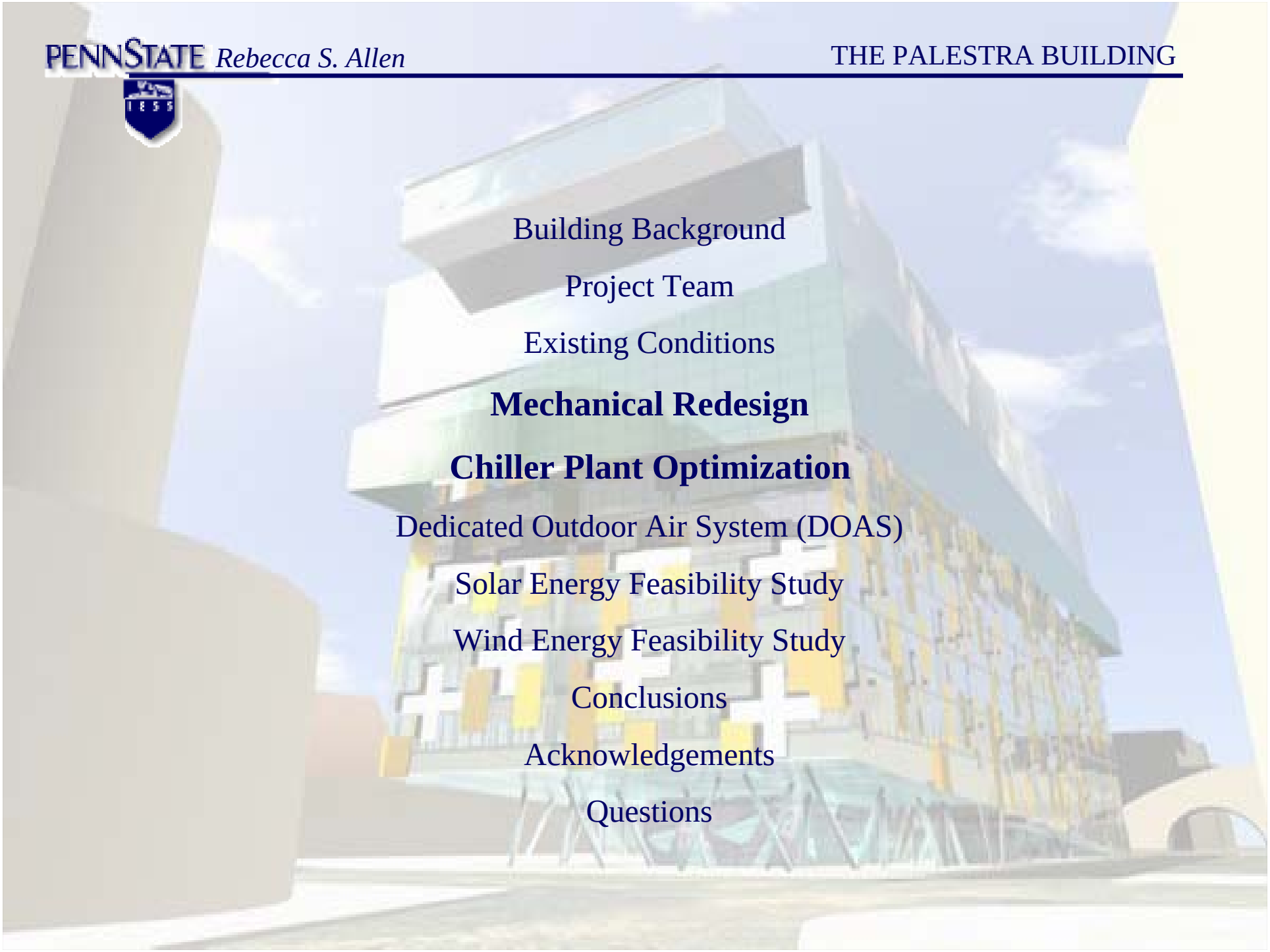
Air Movement:

WINTER, 0.15 m/s (30 fpm)

SUMMER, 0.25 m/s (50 fpm)

Relative Humidity:

35-65%, output from FCUs



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Chiller Plant Optimization

Proposal

Replace existing Electric Chiller Plant with Gas Engine Driven Chiller Plant

Justification for Proposal

- Natural Gas prices
- Opportunities for lower building emissions/heat recovery
- No base-loaded turbine

Utility Rates - London, England

Electric	
Day	4.592 p/kWh
Night	2.658 p/kWh
Supply Point Charge	55.88 £/month
Availability Charge	106 p/kVA
Gas	
per unit	1.515 p/kWh
Water	
per unit	88.85 p/m^3
Fixed cost for connection	860 £/year

3 pence difference per kWh at peak

Chiller Plant Optimization

IC Engine Selection

- (5) 200 ton Tecogen Water-Cooled Gas Engine Driven Chillers

Electric versus IC Engine Chiller Costs

Type	Electric Air-Cooled Screw	Water-Cooled Engine Driven
Cost Per Unit	£51,320.00	£103,625.00
No. Units	7	5
Total Cost	**£359,240.00**	**£518,125.00**

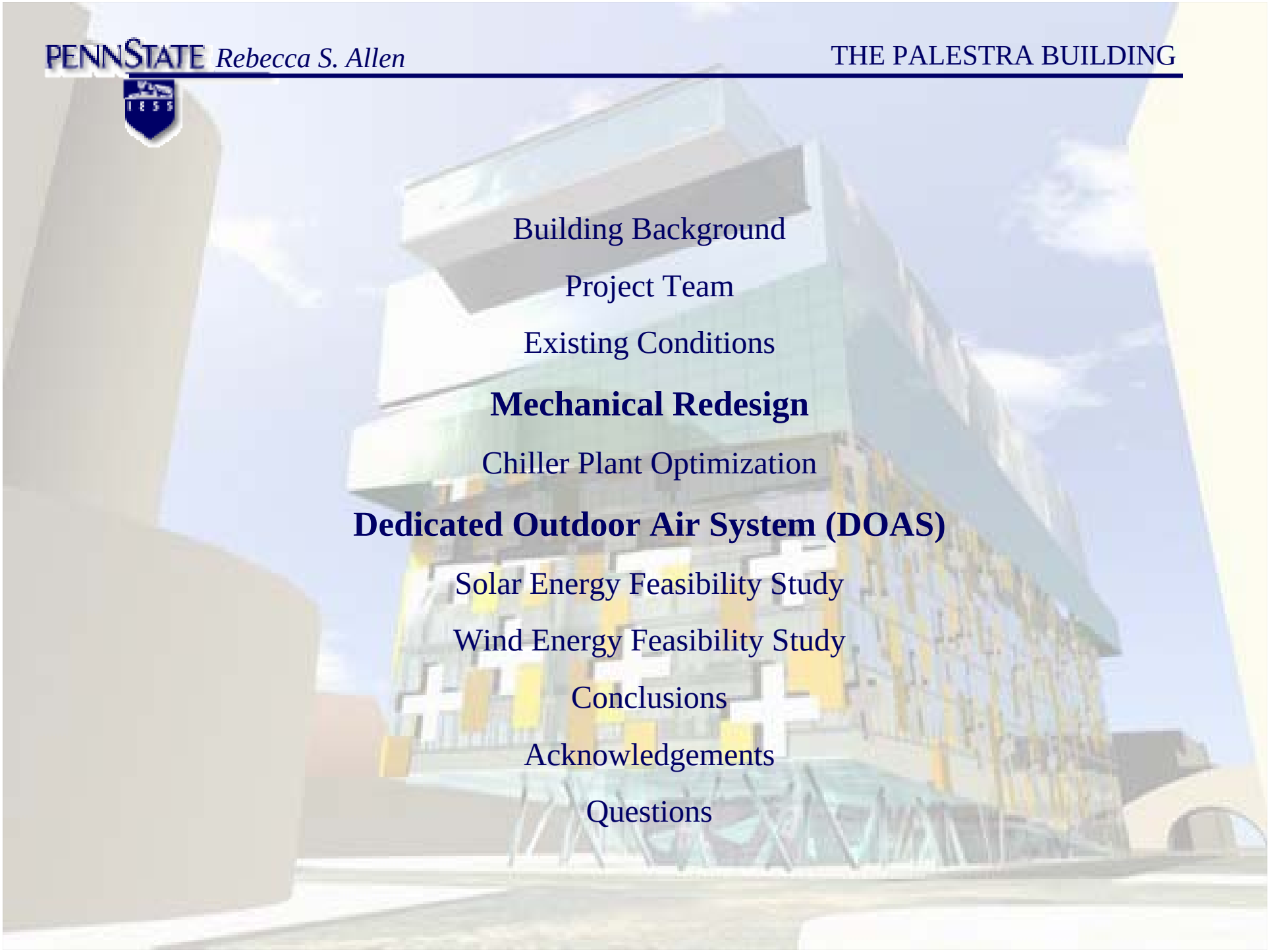
44% INCREASE IN FIRST COSTS

Chiller Plant Optimization

Trace™ Energy Consumption Data

	Original Electric Scheme		Proposed Engine Scheme	
Monthly Energy Consumption	Energy, kWh	Cost, £	Energy, kWh	Cost, £
Electric	20,394,152 kWh	£937,840.56	12,803,427 kWh	£589,274.44
Gas	8,288,669 kWh	£14,622.22	8,182,627 kWh	£14,435.56
Water	--	--	4,285 kL	£11,325.56
Total Monthly Utility Cost		£952,462.78		£615,035.56
First Costs		£359,240.00		£518,125.00
Total Yearly Consumption	69,913,486 kWh		47,027,416 kWh	
Life Cycle Cost		**£17,704,689.24**		**£16,163,972.20**

8.7% LCC savings; £337,427 Monthly Savings



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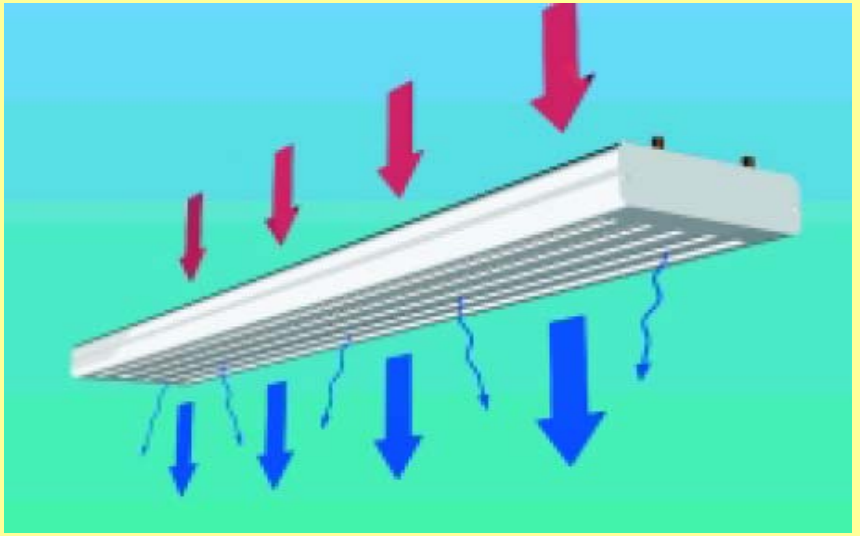
Ventilation Optimization

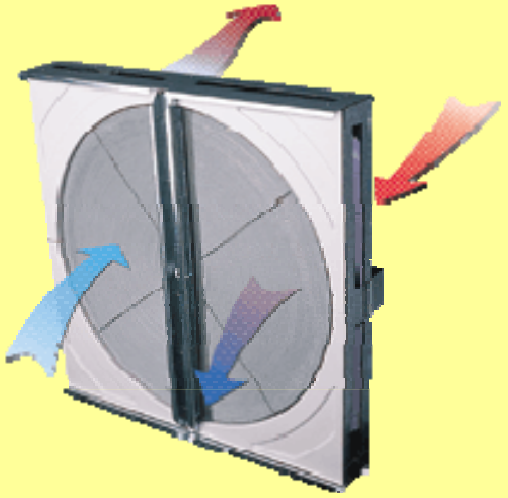
Proposal

Replace existing CAV system with FCUs with Dedicated Outdoor Air System (DOAS) with Suspended Chilled Beams



Justification for Proposal

- Better humidity control
- Lowered first costs
- Smaller Duct sizes, reduced costs



DOAS Design

- Run as a “neutral” system where air is supplied at same temperature as typical VAV system
- Total and Sensible Heat Recovery
- Additional Sensible Load met by Chill Beams

Ventilation Optimization

Chilled Beam Selection

Building's Total Sensible Load:

Q_{total} = 1,422,700 W

Sensible Load Met by DOAS:

Q_{DOAS} = 549,619 W

No. Beams per Floor = 72

Total Beams Needed: 718

Halton CLL2/780/4100 Passive Beam

AHU Resizing

	Original Scheme	Proposed DOAS Scheme	% Difference
AHU -1	18346 L/s	7600.12 L/s	-59.78%
AHU -2	2332.7 L/s	237.6 L/s	-89.81%
AHU -3	3204 L/s	280.8 L/s	-91.24%
AHU -4	1026 L/s	923.5 L/s	-9.99%
AHU -7			

First Cost Savings

	Existing	Proposed	Savings
AHUs	£214,262.00	£114,570.00	46.53%
Chilled Beams	--	£495,500.00	
FCUs	£612,643.00	--	19.12%

Ventilation Optimization

Table 5.8 Trace™ Energy Consumption Data

	Original Ventilation Scheme		Proposed DOAS Scheme	
Monthly Energy Consumption	Energy, kWh	Cost, £	Energy, kWh	Cost, £
Electric	20,394,152 kWh	£937,840.56	13,608,401 kWh	£626,238.89
Gas	8,288,669 kWh	£14,622.22	1,242,134 kWh	£2,191.11
Water	--	--	--	--
Total Monthly Utility Cost		£952,462.78		£628,430.00
Total Yearly Consumption	69,913,486 kWh		42,136,788 kWh	
Life Cycle Cost		**£17,704,689.24**		**£15,878,842.97**

10.3% LCC savings; £324,032 Monthly Savings

Building Optimization

Trace™ Energy Consumption Data

	Original Scheme		Proposed DOAS+Engine Chiller Scheme	
Monthly Energy Consumption	Energy, kWh	Cost, £	Energy, kWh	Cost, £
Electric	20,394,152 kWh	£937,840.56	12,669,017 kWh	£583,102.22
Gas	8,288,669 kWh	£14,622.22	2,770,855 kWh	£4,888.33
Water	--	--	19,061 kL	£14,794.44
Total Monthly Utility Cost		£952,462.78		£602,785.00
Total Yearly Consumption	69,913,486 kWh		40,927,536 kWh	
Life Cycle Cost		**£17,704,689.24**		**£15,899.365.13**

10.2% LCC savings; £349,677 Monthly Savings

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Solar Energy

Solar PV Cell Selection

BP Solar 5160 S

Max Output: 160 W

Weight: 15 kg

Area Allotted: 100m^2

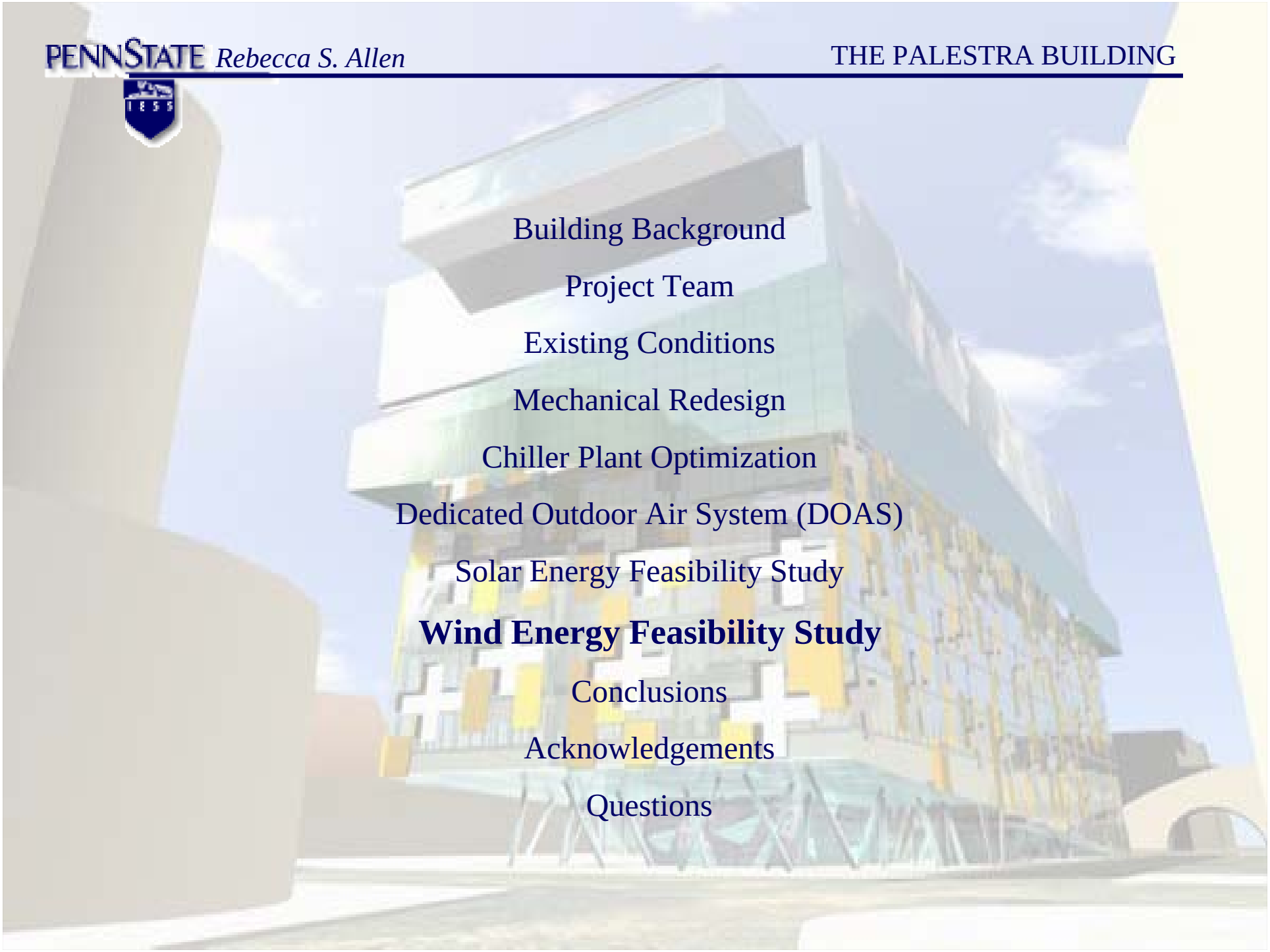
Estimated Annual Energy Produced

Specific Yield	102.4 kWh/m^2
Overall PV System Efficiency	10.20%
Renewable Energy Delivered	19,995 kWh

Solar Energy

RETScreen Cost Summary

Total Initial Cost	**£205,303.00**
Total Annual Cost	**£ 880.00**
Total Annual Savings	**£31,152.00**
Simple Payback	**9.1 years**
Years to Positive Cash Flow	**6 years**
Net Present Value (NPV)	**£125,778.00**
Annual Life Cycle Cost Savings	**£12,805.00**



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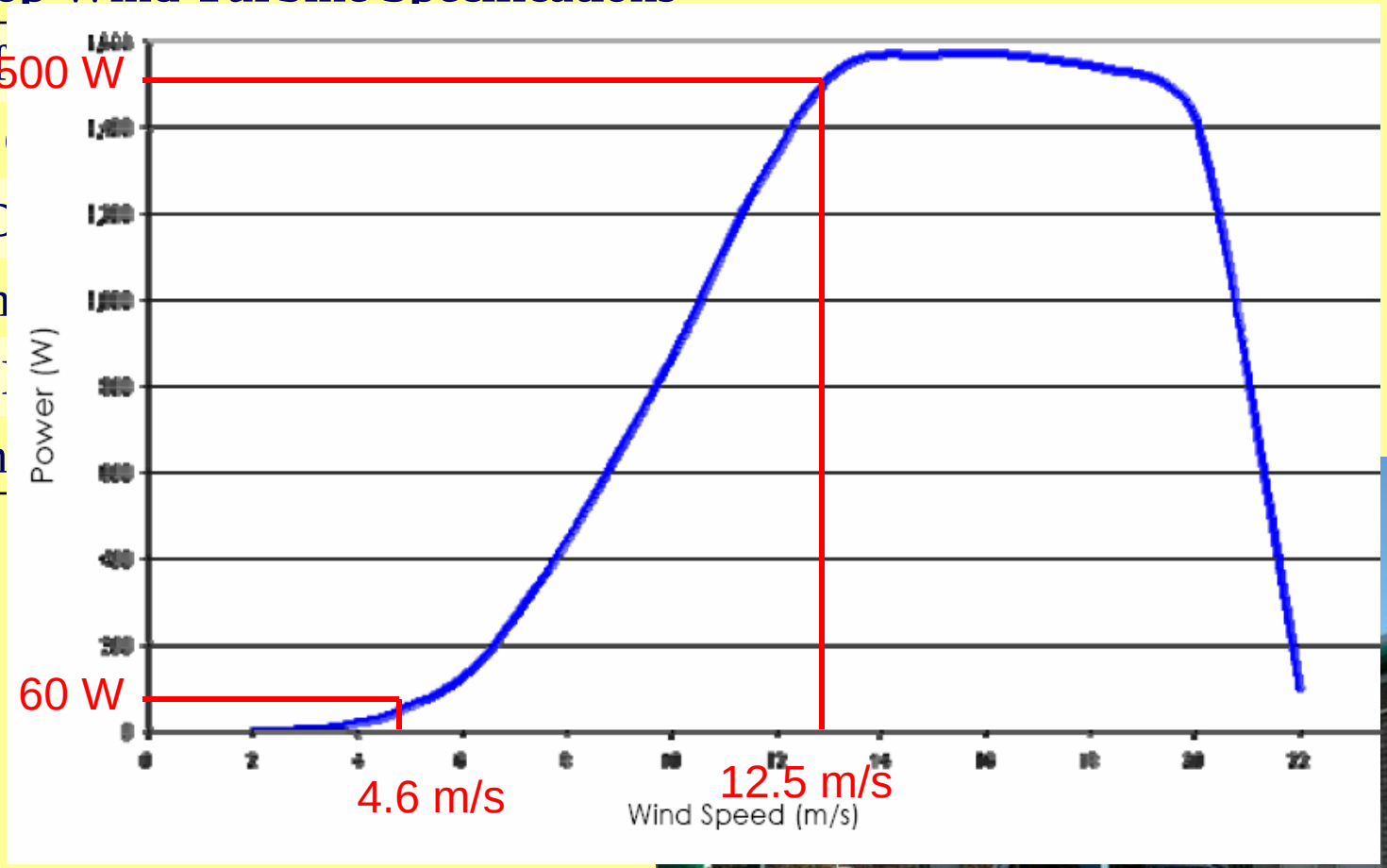
Wind Energy

Rooftop Wind Turbine Specifications

Manuf	
Rated	
CO2 D	
Turbin	
Rotor	
Weigh	



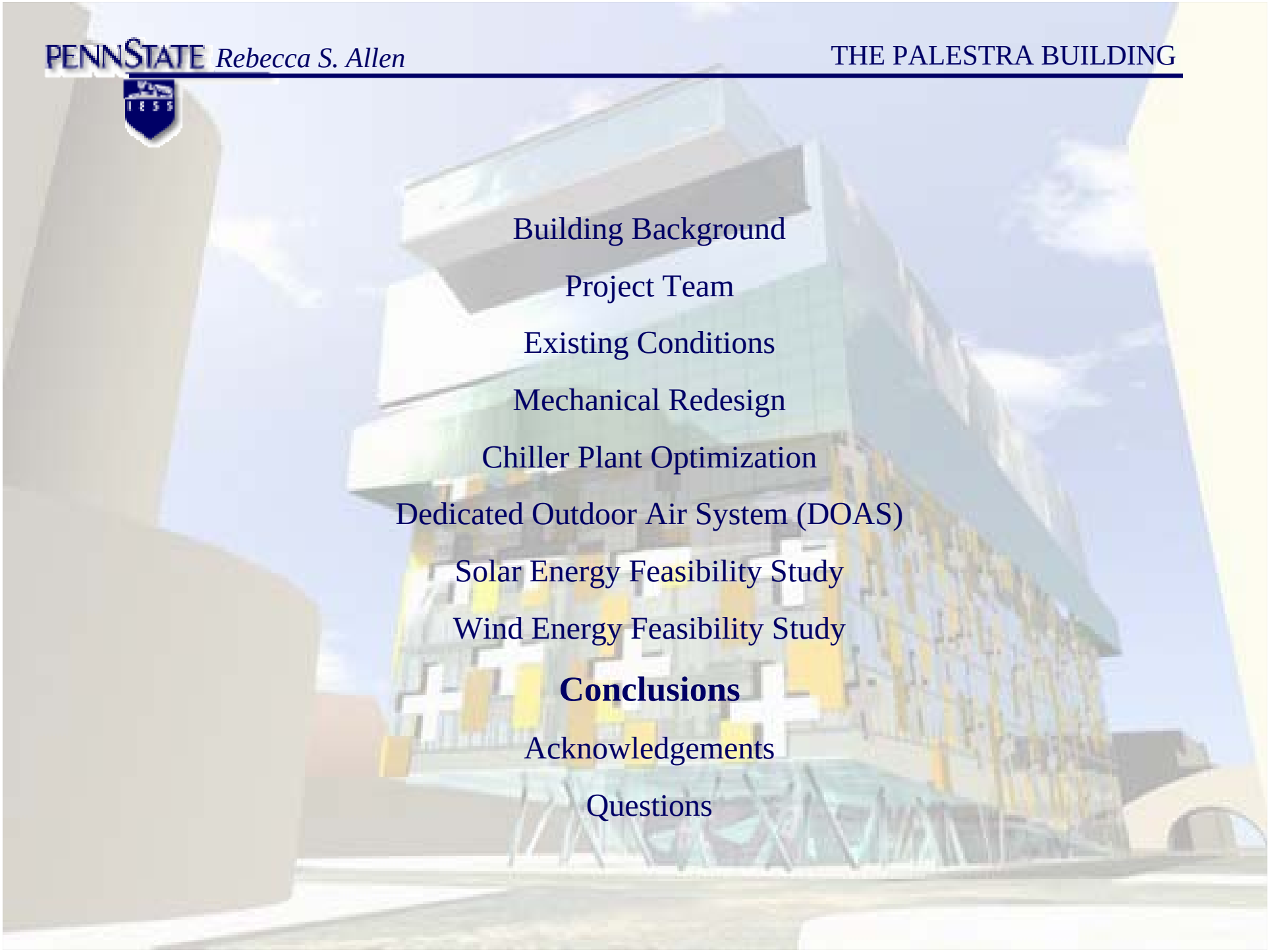
Wind Energy

Wind Turbine Costs

No. Units	10
Clearance Per Unit	2.12 m
Area Required	50 m^2
Total Weight	950 kg
Initial Investment	£15,000
Total Power Output	600 W
Annual Savings	120 kWh

$$Payback\ Period\ (in\ years) = \frac{Initial\ Investment}{Annual\ Savings\ (Cash\ Flow)}$$

$$Payback\ Period = \frac{£15{,}000}{£5.51} = \textbf{2722 years}$$



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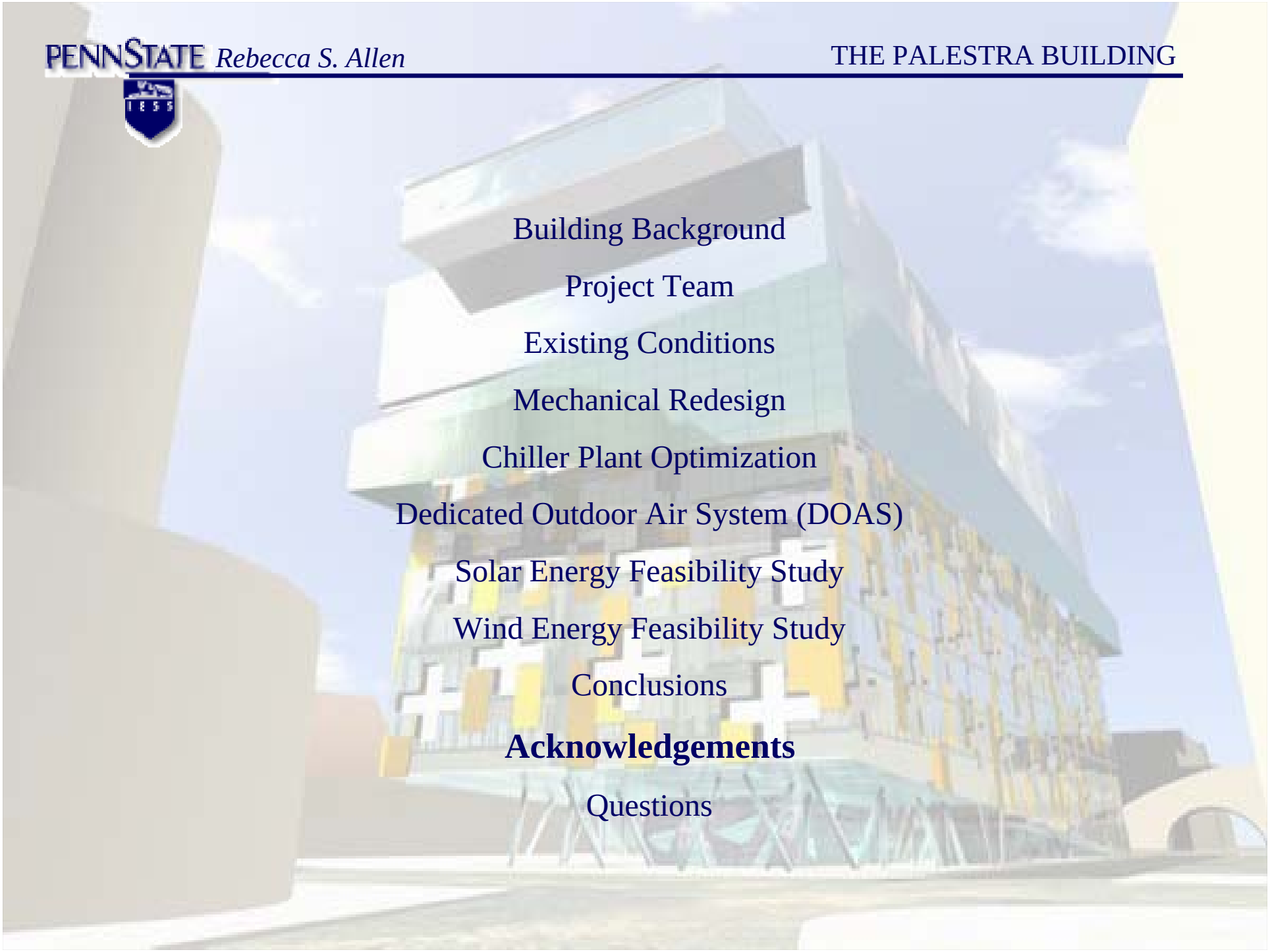
RECOMMENDATIONS

- **Chiller Optimization:** Natural Gas Engine Driven Chiller Plant ✓
- **Ventilation Optimization:** Dedicated Outdoor Air System ✓
- **Building Optimization:** Integration of both proposed schemes ✓
- **Solar Energy:** Payback Period 9.1 years ✗
- **Wind Energy:** Payback Period 2722 years ✗



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- **Buro Happold Ltd.:** Pirooz Kani
- **Skanska UK**: Adrian Head, Stephen Fox
- **Blackfriars Investments**
- **Penn State Schreyer Honors College**
- **AE Faculty**, especially Prof Ling
- **AE Class 2006**
- **Friends and Family**

Buro Happold

PENNSTATE Schreyer Honors College
Achieving academic excellence with integrity

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