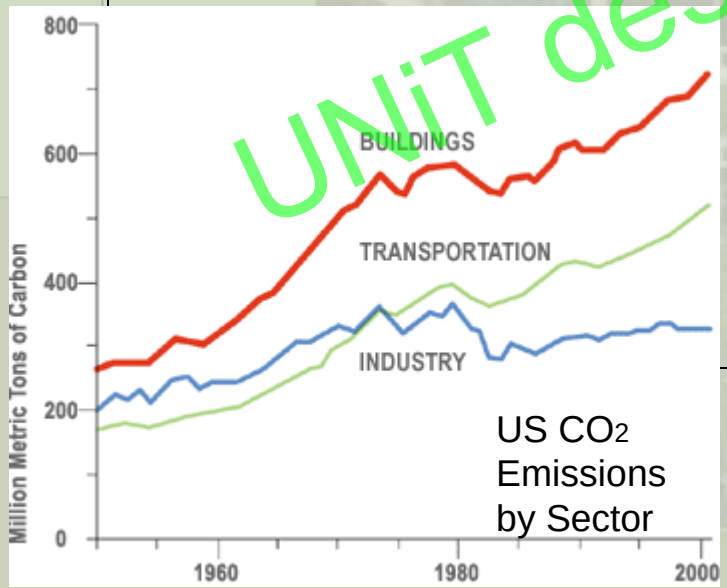
The Future of Architecture & Being Green
The University of Colorado at Denver

Presented by: Fred Andreas, AIA - LEED AP

Why Green Design?

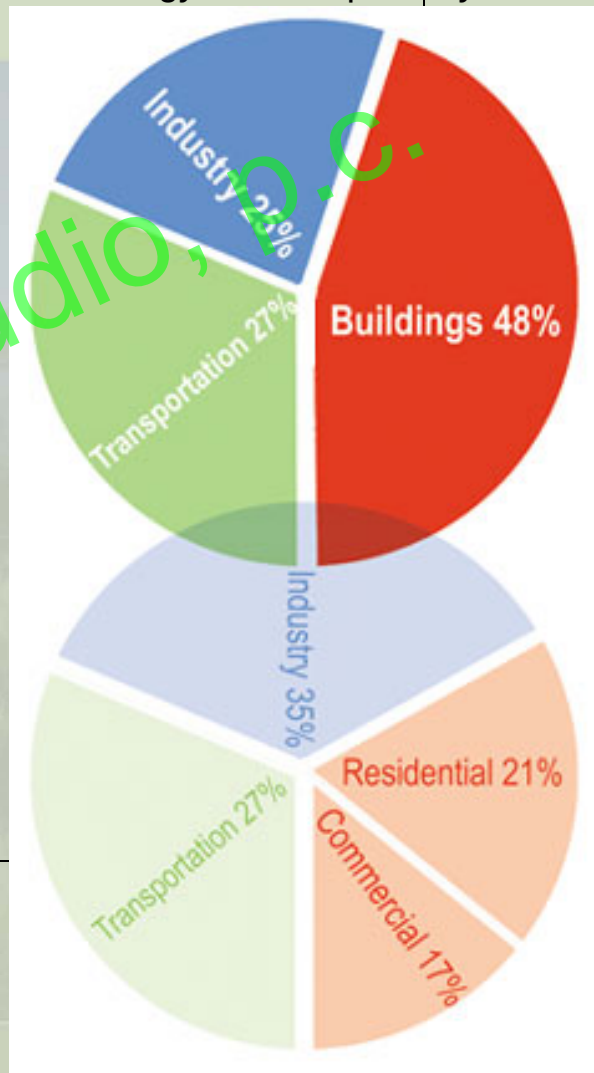
- **Global Warming Crisis**
- **Carbon Loading Crisis**
- **Energy and Water Crisis**
- **Buildings = 48% of Total US Energy**
- **Buildings = 78% of Electrical Energy**
- **Sustainability is Achievable**
- **LEED Ratings**

- **Green Building = High Design**



US CO_2 Emissions by Sector

US Energy Consumption by Sector



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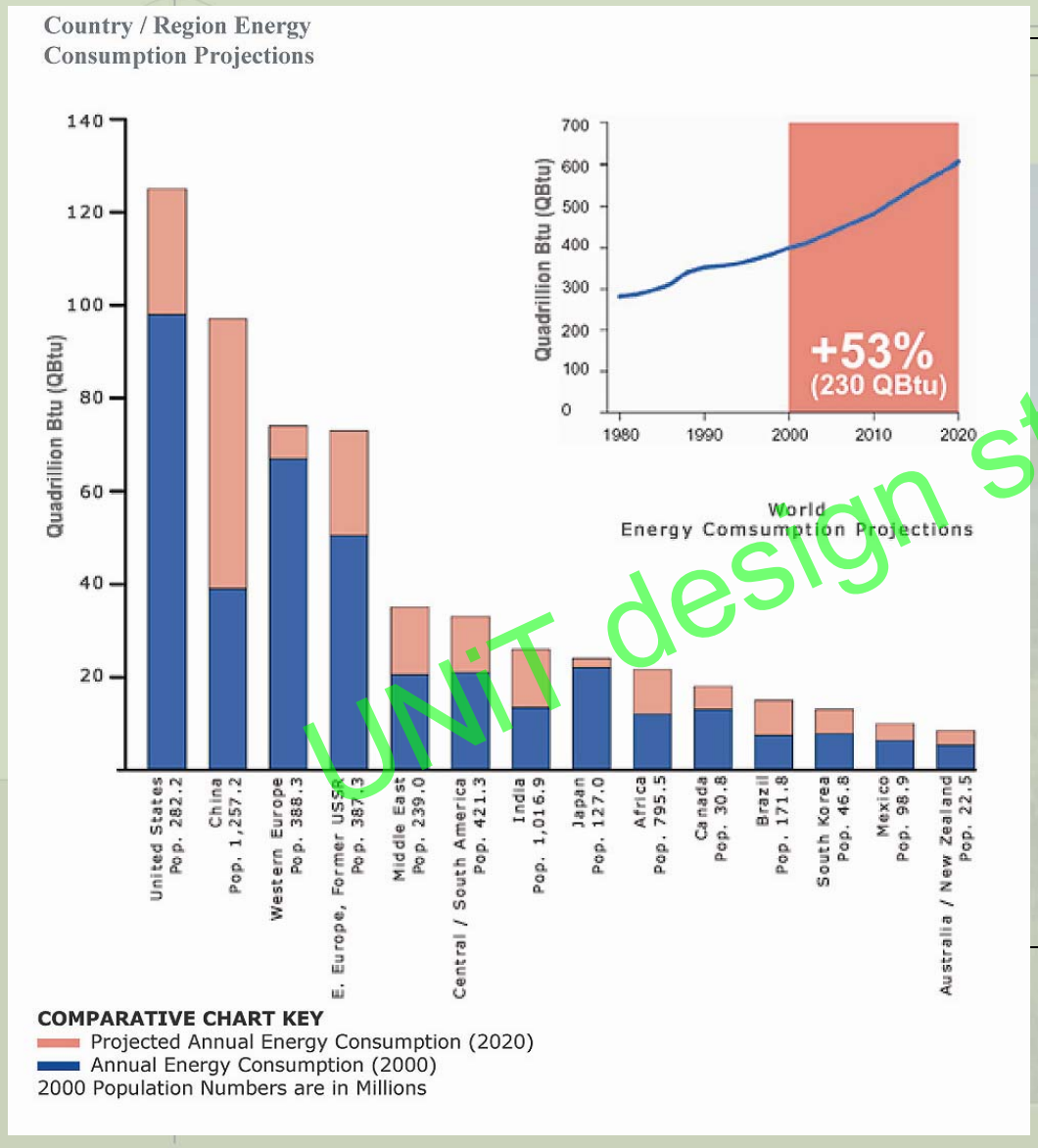
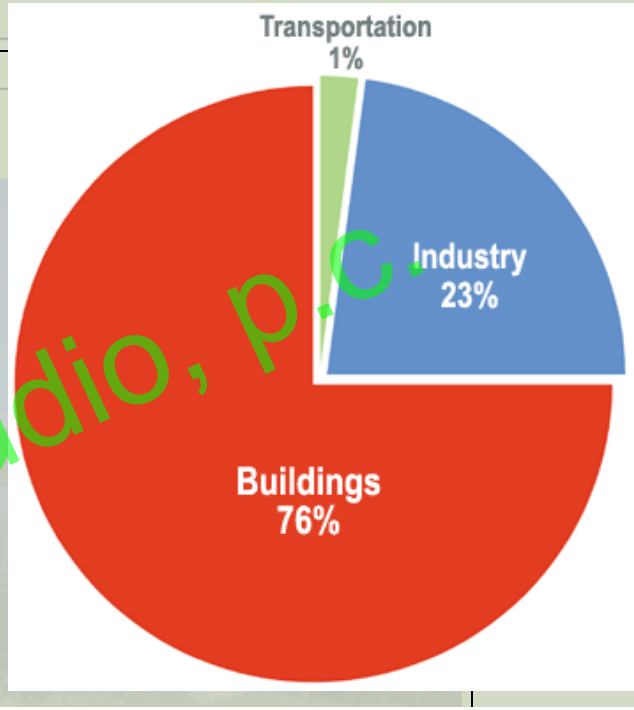
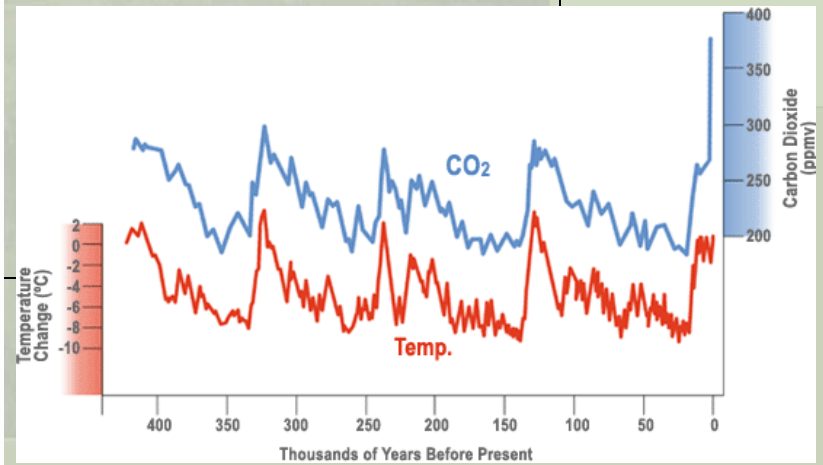
Why Green Design?







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High Performance Standards
Greenbuilding Design

- LEED Certified, Silver, Gold and Platinum & alternates
- 2030 Challenge, ZNE and ZNC within 23 years
- 2010 Imperative, High Performance Standards in Schools
- 2025 Denver, Greenprint Denver
- Colorado's SB 051, High Performance Standards
- ZNE and ZNC achieved through "Passive Systems"
- ASHRAE 189, the new baseline, IGCC 2011, IECC 2009
- Land-use planning and transportation
- Water conservation standards

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LEED-NC Gold Certification

Negligible cost
Low cost/ Less than 5 years payback
Medium cost/ 6-9 years payback
Higher Cost/ 10+ years payback

Yes	?	No	Sustainable Sites	Points		Consultants		Calc	Xmp
10	2	2		14					
Y			Prereq 1 **Construction Activity Pollution Prevention**	Required		CIV			
x			Credit 1 **Site Selection**	1		CIV	AR	N	N
x			Credit 2 **Development Density & Community Connectivity**	1		ARCH		Y	N
		x	Credit 3 **Brownfield Redevelopment**	1		ENV	CIV	N	N
x			Credit 4.1 **Alternative Transportation**, Public Transportation Access	1		ARCH		Y	Y
x			Credit 4.2 **Alternative Transportation**, Bicycle Storage & Changing Rooms	1		ARCH		Y	Y
	x		Credit 4.3 **Alternative Transportation**, Low-Emitting and Fuel-Efficient Vehicles	1		ARCH		Y	Y
x			Credit 4.4 **Alternative Transportation**, Parking Capacity	1		ARCH		Y	Y
	x		Credit 5.1 **Site Development**, Protect or Restore Habitat	1		ARCH	LAND	N	Y
x			Credit 5.2 **Site Development**, Maximize Open Space	1		ARCH	LAND	Y	Y
x			Credit 6.1 **Stormwater Design**, Quantity Control	1		CIV		Y	N
		x	Credit 6.2 **Stormwater Design**, Quality Control	1		CIV		Y	N
x			Credit 7.1 **Heat Island Effect**, Non-Roof	1		ARCH	LAND	Y	Y
x			Credit 7.2 **Heat Island Effect**, Roof	1		ARCH		Y	Y
x			Credit 8 **Light Pollution Reduction**	1		ELEC	ARCH	Y	N

Yes	?	No	Water Efficiency	5		Consultants		Calc	Xmp
3	1	1							
x			Credit 1.1 **Water Efficient Landscaping**, Reduce by 50%	1		LAND	ARCH	Y	N
	x		Credit 1.2 **Water Efficient Landscaping**, No Potable Water Use or No Irrigation	1		LAND	ARCH	Y	N
		x	Credit 2 **Innovative Wastewater Technologies**	1		MEP			Y
x			Credit 3.1 **Water Use Reduction**, 20% Reduction	1		MEP			Y
x	←		Credit 3.2 **Water Use Reduction**, 30% Reduction	1		MEP		Y	Y

Yes	?	No	Energy & Atmosphere	17		Consultants		Calc	Xmp
11	4	2							
Y			Prereq 1 **Fundamental Commissioning of the Building Energy Systems**	Required		C/A	MEP		
Y			Prereq 2 **Minimum Energy Performance**	Required		MEP			
Y			Prereq 3 **Fundamental Refrigerant Management**	Required		MEP			
x			Credit 1.1 **Optimize Energy Performance, 10.5% New / 3.5% Existing**	1		MEP	ENRG	Y	N
x			Credit 1.2 **Optimize Energy Performance, 14% New / 7% Existing**	1		MEP	ENRG	Y	N
x			Credit 1.3 **Optimize Energy Performance, 17.5% New / 10.5% Existing**	1		MEP	ENRG	Y	N
x			Credit 1.4 **Optimize Energy Performance, 21% New / 14% Existing**	1		MEP	ENRG	Y	N
x			Credit 1.5 **Optimize Energy Performance, 24.5% New / 17.5% Existing**	1		MEP	ENRG	Y	N
x			Credit 1.6 **Optimize Energy Performance, 28% New / 21% Existing**	1		MEP	ENRG	Y	N
x	←		Credit 1.7 **Optimize Energy Performance, 31.5% New / 24.5% Existing**	1		MEP	ENRG	Y	N
	x		Credit 1.8 **Optimize Energy Performance, 35% New / 28% Existing**	1		MEP	ENRG	Y	N
		x	Credit 1.9 **Optimize Energy Performance, 38.5% New / 31.5% Existing**	1		MEP	ENRG	Y	N
		x	Credit 1.10 **Optimize Energy Performance, 42% New / 35% Existing**	1		MEP	ENRG	Y	N
x	←		Credit 2.1 **On-Site Renewable Energy - 2.5%**	1		ENRG	MEP	Y	N
	x		Credit 2.2 **On-Site Renewable Energy - 7.5%**	1		ENRG	MEP	Y	N
	x		Credit 2.3 **On-Site Renewable Energy - 12.5%**	1		ENRG	MEP	Y	N
x			Credit 3 **Enhanced Commissioning**	1		C/A	MEP	N	N
	x		Credit 4 **Enhanced Refrigerant Management**	1		MEP		Y	N
x	←		Credit 5 **Measurement & Verification**	1		MEP	OWN	Y	N
x			Credit 6 **Green Power**	1		MEP	OWN	Y	N

Yes	?	No	Materials & Resources	13		Consultants		Calc	Xmp
6	2	5							
Y			Prereq 1 **Storage & Collection of Recyclables**	Required		ARCH		Y	N
		x	Credit 1.1 **Building Reuse**, Maintain 75% of Existing Walls, Floors & Roof	1		ARCH		Y	N
		x	Credit 1.2 **Building Reuse**, Maintain 95% of Existing Walls, Floors & Roof	1		ARCH		Y	N
		x	Credit 1.3 **Building Reuse**, Maintain 50% of Interior Non-Structural Elements	1		ARCH		Y	N
		x	Credit 2.1 **Construction Waste Management**, Divert 50% from Disposal	1		GC		Y	Y
		x	Credit 2.2 **Construction Waste Management**, Divert 75% from Disposal	1		GC		Y	Y
	x		Credit 3.1 **Materials Reuse**, 5%	1		OWN	ARCH	Y	Y
	x		Credit 3.2 **Materials Reuse**, 10%	1		OWN	ARCH	Y	Y
x			Credit 4.1 **Recycled Content**, 10% (post-consumer + ½ pre-consumer)	1		GC	ARCH	Y	Y
x			Credit 4.2 **Recycled Content**, 20% (post-consumer + ½ pre-consumer)	1		GC	ARCH	Y	Y
x			Credit 5.1 **Regional Materials**, 10% Extracted, Processed & Manufactured Regionally	1		GC	ARCH	Y	Y
x			Credit 5.2 **Regional Materials**, 20% Extracted, Processed & Manufactured Regionally	1		GC	ARCH	Y	Y
x	←		Credit 6 **Rapidly Renewable Materials**	1		GC	ARCH	Y	Y
x	←		Credit 7 **Certified Wood**	1		GC	ARCH	Y	Y

Yes	?	No	Indoor Environmental Quality	15		Consultants		Calc	Xmp
12	3	0							
Y			Prereq 1 **Minimum IAQ Performance**	Required		MEP			
Y			Prereq 2 **Environmental Tobacco Smoke** (ETS) **Control**	Required		OWN			
x	←		Credit 1 **Outdoor Air Delivery Monitoring**	1		MEP		N	N
	x		Credit 2 **Increased Ventilation**	1		MEP	ARCH	Y	N
x			Credit 3.1 **Construction IAQ Management Plan**, During Construction	1		MEP	GC	N	N
x			Credit 3.2 **Construction IAQ Management Plan**, Before Occupancy	1		MEP	OWN	N	N
x			Credit 4.1 **Low-Emitting Materials**, Adhesives & Sealants	1		ARCH	SPEC	N	N
x			Credit 4.2 **Low-Emitting Materials**, Paints & Coatings	1		ARCH	SPEC	N	N
x			Credit 4.3 **Low-Emitting Materials**, Carpet Systems	1		ARCH	SPEC	N	N
x			Credit 4.4 **Low-Emitting Materials**, Composite Wood & Agrifiber Products	1		ARCH	SPEC	N	N
x			Credit 5 **Indoor Chemical & Pollutant Source Control**	1		ARCH	MEP	N	N
x			Credit 6.1 **Controllability of Systems**, Lighting	1		MEP	ARCH	Y	N
x	←		Credit 6.2 **Controllability of Systems**, Thermal Comfort	1		MEP		Y	N
	x		Credit 7.1 **Thermal Comfort**, Design	1		MEP		Y	N
	x		Credit 7.2 **Thermal Comfort**, Verification	1		MEP		N	N
x			Credit 8.1 **Daylight & Views**, Daylight 75% of Spaces	1		ARCH		Y	Y
x			Credit 8.2 **Daylight & Views**, Views for 90% of Spaces	1		ARCH		Y	Y

Yes	?	No	Innovation & Design Process	5		Consultants		Calc	Xmp
4	1	0							
x			Credit 1.1 **Innovation in Design**: Exemplary in Recycled Materials	1		GC	ARCH	Y	
x			Credit 1.2 **Innovation in Design**: Exemplary in Regional Materials	1		GC	ARCH	Y	
x			Credit 1.3 **Innovation in Design**: Comprehensive Transportation Management Plan	1		OWN		N	
x	←		Credit 1.4 **Innovation in Design**: Heat Island, Non-roof	1		ARCH	LAND	Y	
	x		Credit 2 **LEED® Accredited Professional**	1		ARCH	OWN	N	

Yes	?	No	Project Totals (pre-certification estimates)	69
46	13	10		
Gold			**Anticipated Certification Level**	

Certified 26-32 points **Silver** 33-38 points **Gold** 39-51 points **Platinum** 52-69 points

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High Performance Strategies

Greenbuilding Design

- **LEED is the floor, not the ceiling!**
- **ZNE and ZNC achieved through…**
- **Zero Net Energy, Zero Net Carbon through ECM**
- **Currently achieving 75% efficiencies of DSM**
- **High Performance Building Skins**
- **High Performance HVAC Strategies**
- **Passive Heating, Cooling and Lighting**
- **Renewable Energy, BIPV and BAWT**

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Passive Principles
SMART

High Tech

- **Passive Solar Heating, Gain and Controls**
- **Passive Solar Cooling, the hotter the better**
- **Thermal Storage & Inertia, store & distribute**
- **Daylighting, open space high and wide light**
- **Integration of Systems, active and passive**

integrating a combination of building features to reduce or even eliminate the need for mechanical heating, cooling and daytime artificial lighting

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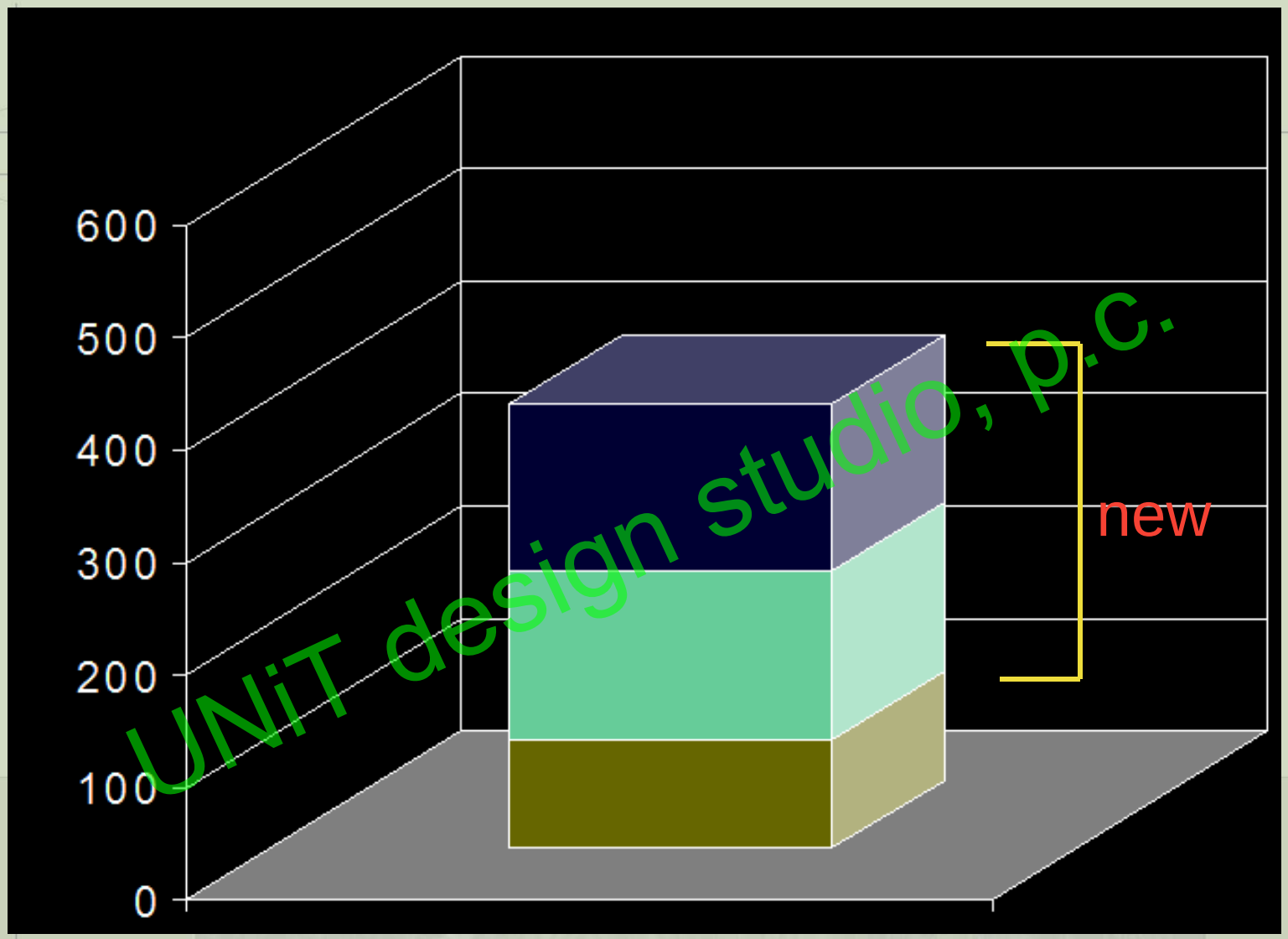

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source: architecture 2030

The 2030 Challenge…
ZNE and ZNC by the year 2030!

AIA's carbon emission reduction targets

By 2010…New & Renovated Buildings

A Minimum of 50% Reduction

2012 – 60%

2015 – 70%

2020 – 80%

2025 – 90%

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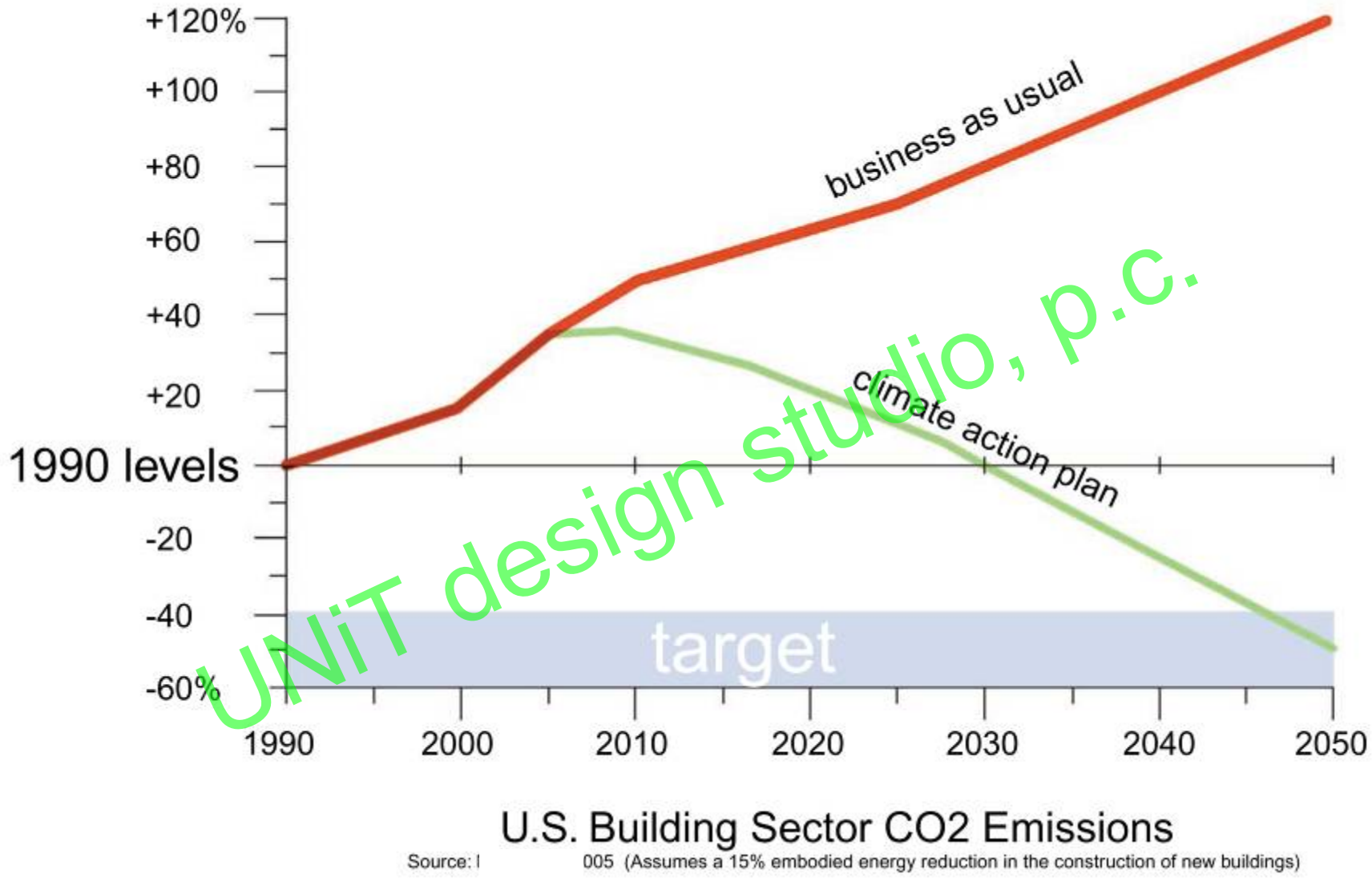

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Source: Ed Mazria, Architecture2030

Greenbuilding Studio 2005

P3 Competition, Washington, D.C.

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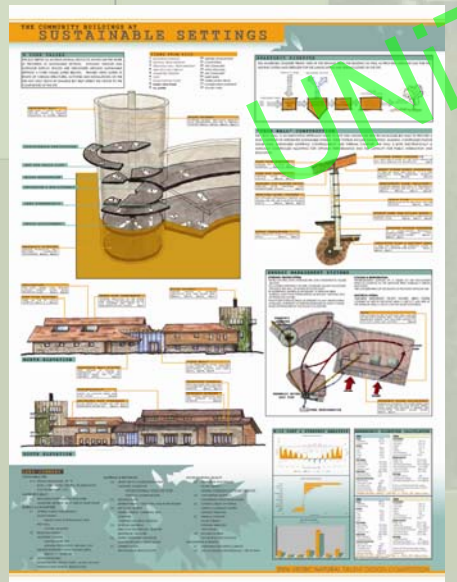
Greenbuilding Studio 2006

THIS WEEK in the College of Architecture and Planning

July 10-14, 2006

CAP STUDENTS SWEEP LOCAL USGBC NATURAL TALENT DESIGN COMPETITION WIN NATIONAL HONORABLE MENTION



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Competitions

- **USGBC Natural Talent Design Competition**
  - **Applied learning in the principles of integrated design, sustainability, innovation, and social consciousness**

  Objectives:
  - **Empower students within green building movement**
  - **Raise awareness of Green-building design**
  - **Utilize LEED as a guideline**

  Evaluation Criteria:
  - **Conceptual Design & Program Fulfillment**
  - **Integration of green design strategies**
  - **Creativity in process, design & innovation**
  - **Engagement of environmental, economic and social aspects of program and site**

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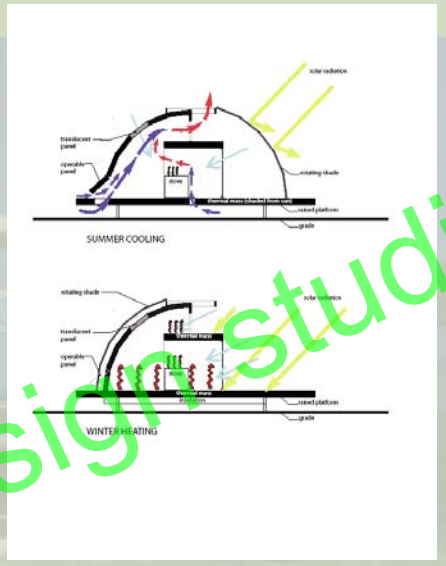
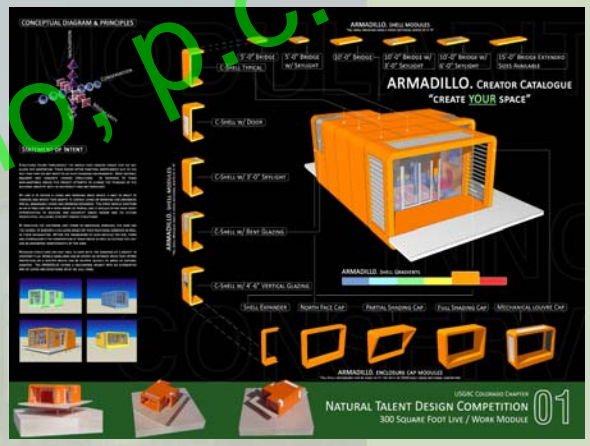
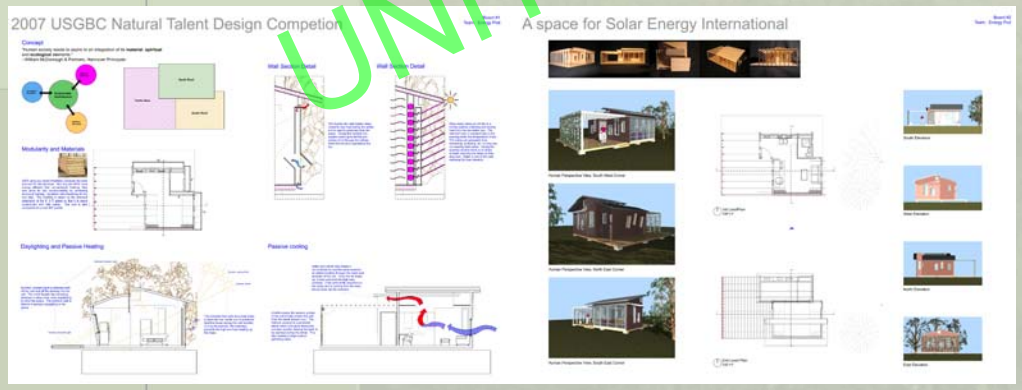
Greenbuilding Studio 2007

CAP STUDENTS PLACE IN TOP 4 OF 5 CATAGORIES
USGBC NATURAL TALENT DESIGN COMPETITION







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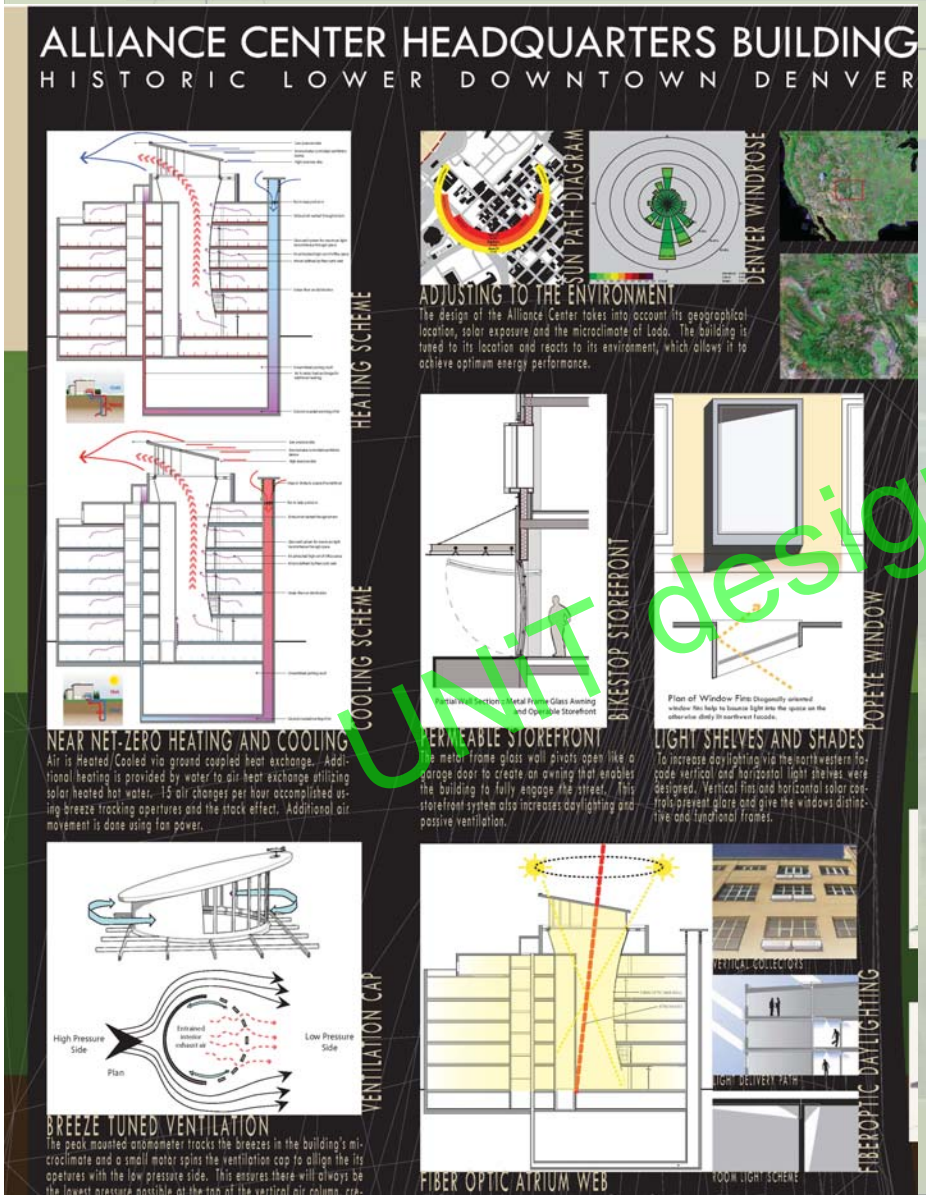
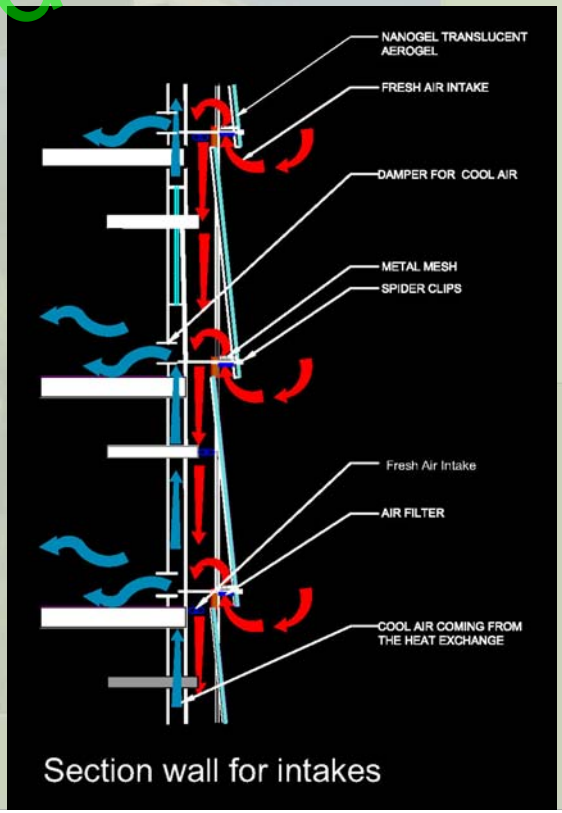
Greenbuilding Studio 2008





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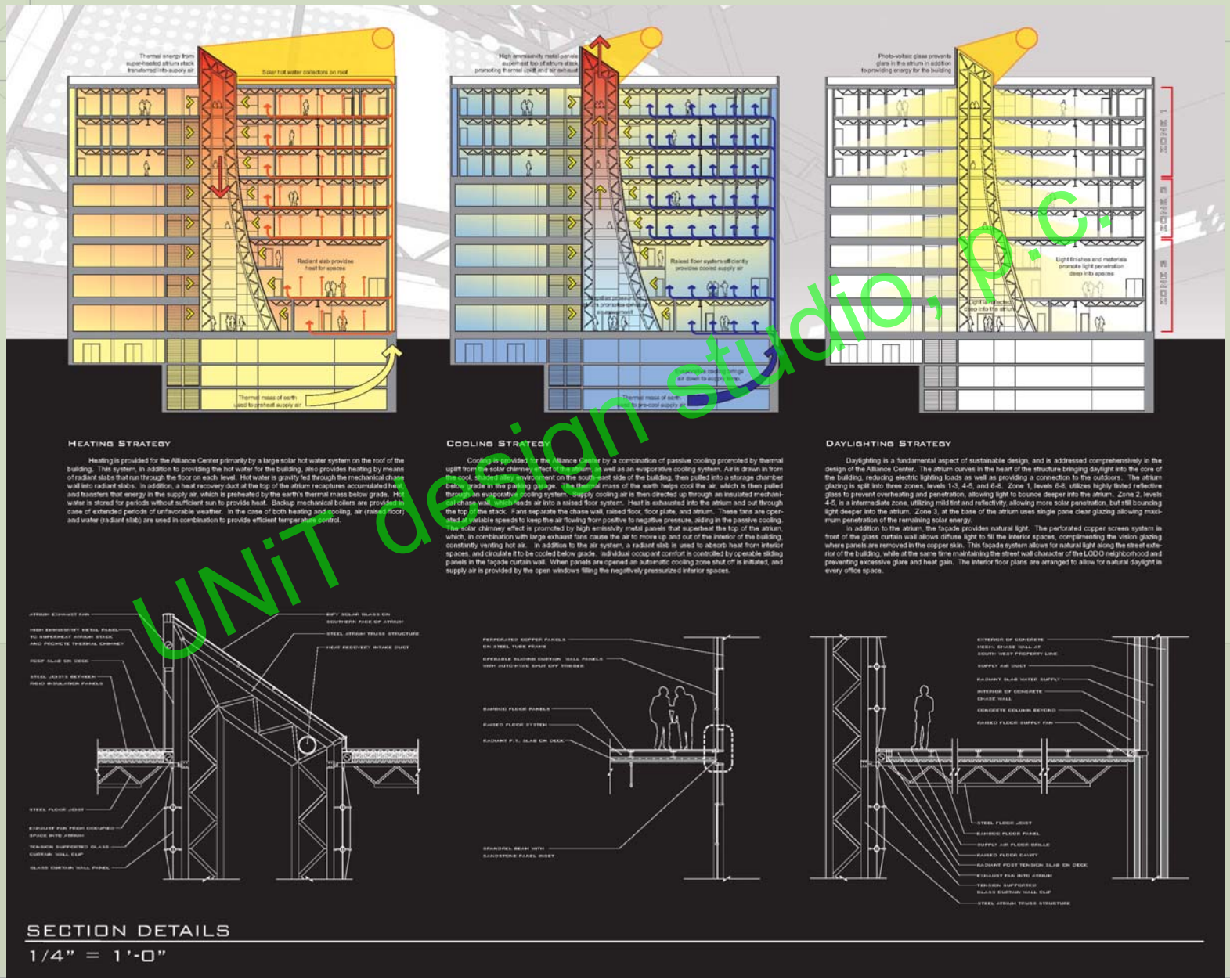
Greenbuilding Studio 2008



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Greenbuilding Studio 2008

WINTER HEATING SYSTEM
A. DAYTIME CIRCULATION: DAMPERS ON THE ROOF ARE OPENED TO LET IN FRESH AIR. THE STACK CHIMNEY EFFECT IS CREATED IN THE ATRIUM WITH TIGHTLY WOVEN RECYCLED ALUMINUM. THE ALUMINUM IS HEATED BY THE SUN.

B. FANS DISTRIBUTE THE AIR THROUGH THE ATRIUM AND INTO CHAMBERS, WHERE THEY WILL BE CIRCULATED THROUGH RAISED FLOORING. WHILE PASSING THROUGH THE CHAMBERS THEY WILL ALSO PASS THROUGH A HEAT PUMP TO INCREASE THE AIR TEMPERATURE.

C. ONCE THE AIR IS CIRCULATED THROUGH THE RAISED FLOORING THE AIR IS RE-CIRCULATED BACK THROUGH THE BUILDING. SEE SECTIONS.

D. NIGHT TIME CIRCULATION: WHEN THE BUILDING IS AT ITS LOWEST OCCUPANCY, THE BUILDING DAMPERS, VENTS, AND FANS WILL ALL BE OPENED AND TURNED ON FOR A DAILY BUILDING FLUSH OUT. ONCE THE PROCESS ENDS, THE DAMPERS ARE SHUT AND THE BUILDING GOES INTO HIBERNATION.

SUMMER COOLING SYSTEM
A. DAYTIME CIRCULATION: DAMPERS ARE CLOSED AND FANS IN THE ATRIUM ARE TURNED OFF. FRESH AIR IS FILTERED IN WITH NATIVE PLANTS THROUGH THE ALLEY AND FROM THE WATER TABLE. THE STACK CHIMNEY EFFECT FORCES THE COOL AIR DOWN WHERE IT CAN CIRCULATE THROUGH CHAMBERS, AN EVAPORATIVE COOLER AND THE RAISED FLOORING.

B. THE WARM AIR RISES WHERE IT IS VENTED OUT OF THE BUILDING THROUGH DAMPERS IN THE ATRIUM. SEE SECTIONS.

C. NIGHT TIME CIRCULATION: DAMPERS ARE OPENED AND FANS TURNED ON. THE COOL NIGHT AIR TRAVELS OVER THE NATIVE PLANS ON THE ROOF GARDEN, WHICH IS THEN CIRCULATED THROUGH THE BUILDING.

DOMESTIC HOT WATER
LOCATED WITHIN THE TROMBE SYSTEM, IS A CURLY MAZE OF PLASTIC TUBES FILLED WITH WATER. THIS SYSTEM IS SIMILAR TO RADIANT FLOOR HEATING BUT AS A VERTICAL SYSTEM. TIGHTLY WOVEN RECYCLED ALUMINUM PANELS ARE HEATED UP BY THE SUN AND TRANSFER THE HEAT TO THE TUBES. THIS SYSTEM IS THE MAIN CARRIER OF OUR HOT WATER THROUGHOUT THE BUILDING. AFTER THE WATER IS USED, IT IS THEN DISTRIBUTED INTO DENVER'S PURPLE PIPE SYSTEM.

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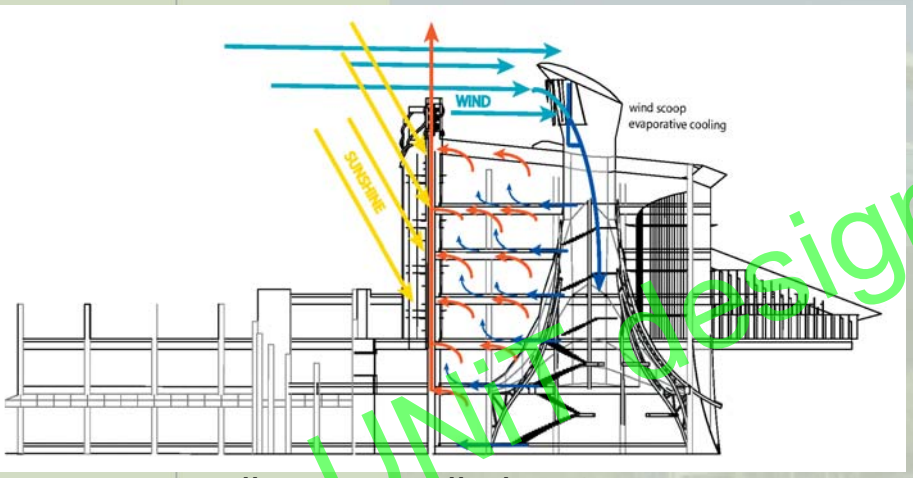
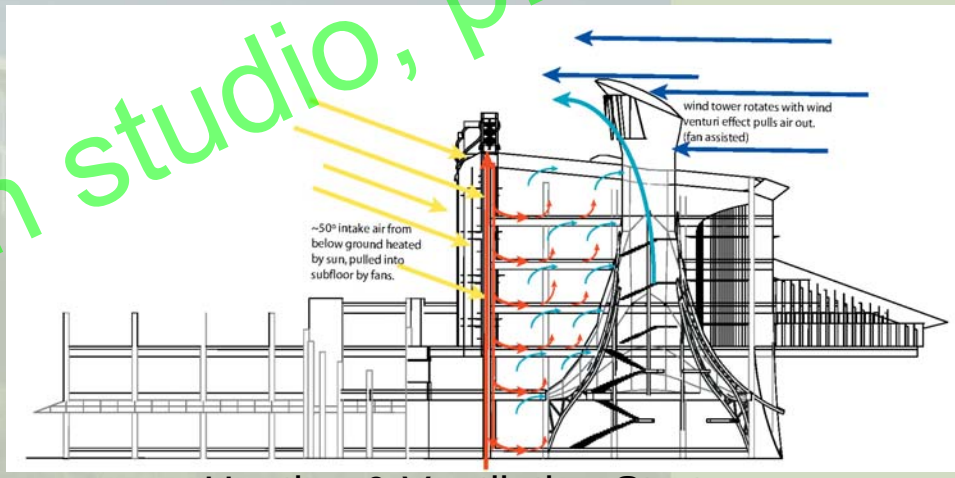
Greenbuilding Studio 2009



Cooling & Ventilation Strategy



Heating & Ventilation Strategy

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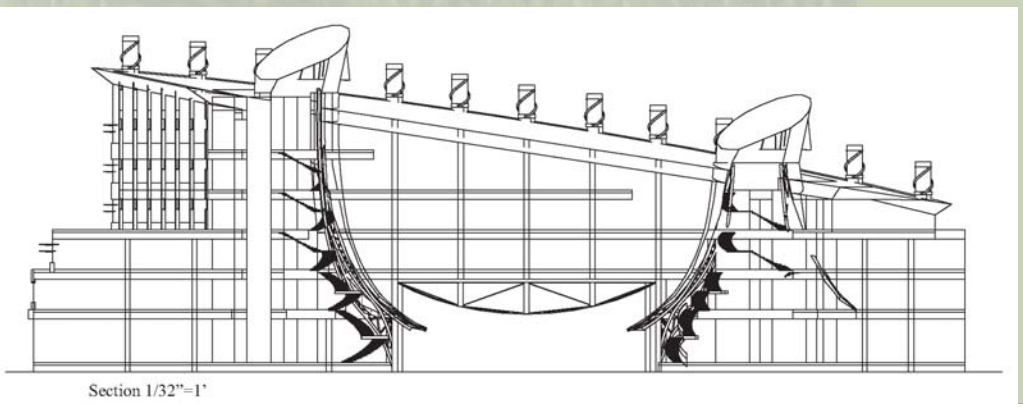

Section 1/32"=1'

Greenbuilding Studio 2009

Resource Guides & Research

Green Systems a greenbuilding resource guide

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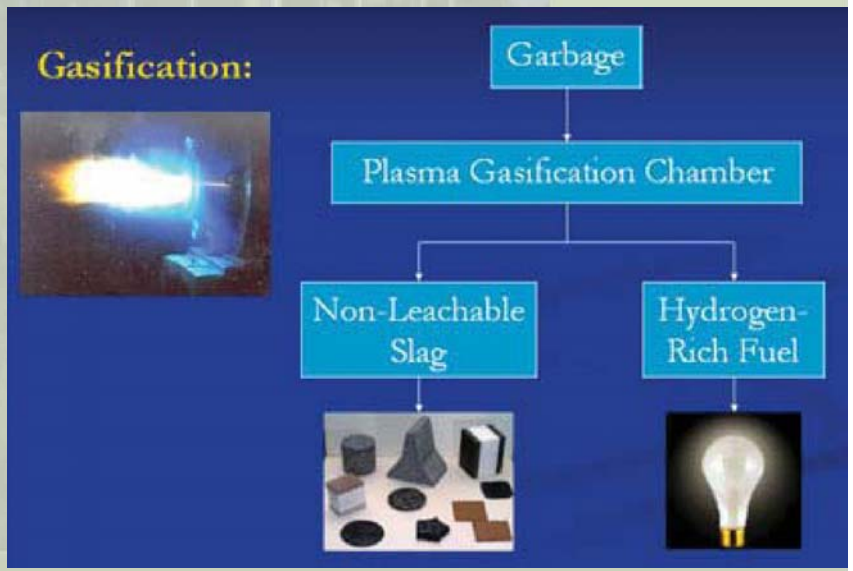
Green Roof Integration



Waste Stream Building Integration

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Translucent Walls

Check List

DMCA

Double Skin Facades

Beijing Swimming Center

ETFE Film

Nanogel

Case Study: Beijing National Swimming Center

Overview:
Architects: PTW Architects

Engineers: ARUP

Status: Under Construction – Ready for October 2007

Use: Swimming Center for the 2008 Summer Olympics

Size: The overall size will be 177x177x31m = 70,000m²

Cost: $100,000,000

Facilities: 2 Olympic Pools, 1 Diving Pool, and a Water Park

Capacity: 6000 Permanent Seats

11000 Additional Temporary Seats for the Olympics

Issue: Building Skin – Using ETFE Film

Beijing Swimming Center. (The Water Cube)

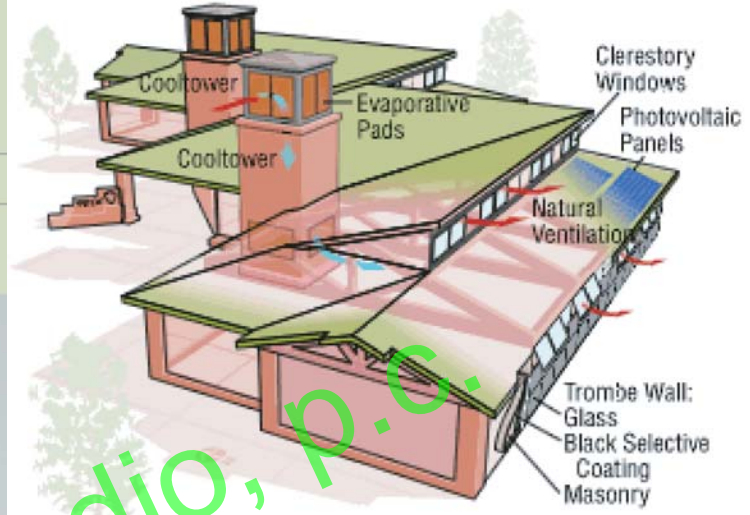
Translucent Walls

LEED Credits:
EA Credit 1
EQ Credit 8.1

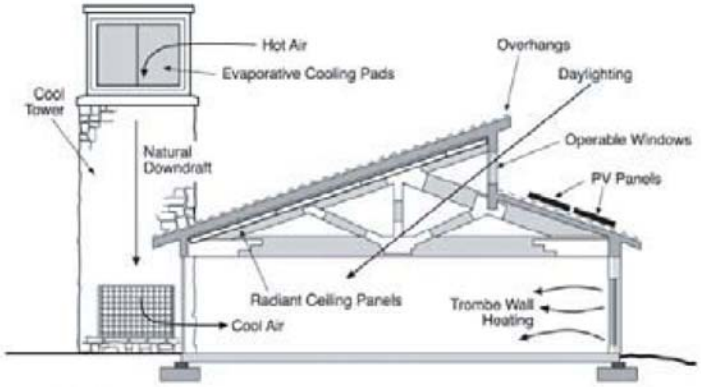
Skin:
Facts:
-1,0760,000 Square feet of ETFE film cover the building.
-4,000 Bubbles of various sizes.
-Designed to react to lighting and projection.
-This state-of-the-art material provides a cost-effective cladding solution
-Extremely low energy consumption during manufacturing process of ETFE
-Complete system weighs between 50 -90% less than systems of other materials.
-The entire system can be recycled.

Energy:
The Beijing National Swimming Center (The Water Cube) is designed to act as a greenhouse

- 90% of the ambient solar energy will be used to passively heat the building and pools.
- Will reduce the energy consumption in the building by 30%.
- 55% savings on lighting energy during the day
- Heat recovery system integrated into the design.
- Heat loads are minimized in the summer, and maximized in the winter by ventilating the heat out of the wall cavity in the summer and containing it in the winter.



(d) Diagram of Zion National Park Visitor's Center Sustainable Systems - Note the cooltower with evapoative cooling pads



Source: NREL and NPS drawings.

(e) Diagram of Zion National Park Visitor's Center cooltower with evapoative cooling pads

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Photovoltaics: Embodied Energy & New Technology

Check List

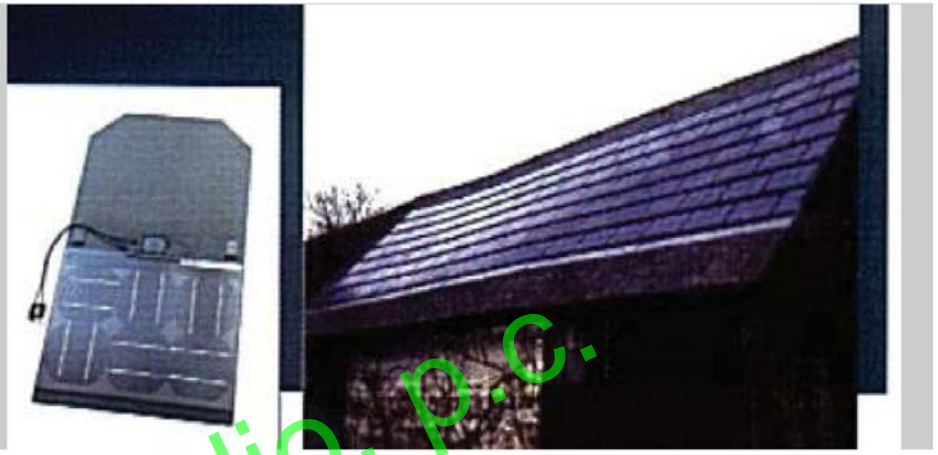
- definition
- cost
- maintenance
- properties
- lifecycle
- **embodied energy**
- health
- benefits
- disadvantages
- final analysis

Zero Energy Media Wall - is a groundbreaking project applying sustainable and digital media technology to the curtain wall of Xicui entertainment complex in Beijing, near the site of the 2008 Olympics. Featuring the largest color LED display worldwide and the first photovoltaic system integrated into a glass curtain wall in China, the building performs as a self-sufficient organic system, harvesting solar energy by day and using it to illuminate the screen after dark, mirroring a day's climatic cycle.

The polycrystalline photovoltaic cells are laminated within the glass of the curtain wall and placed with changing density on the entire building's skin. The density pattern increases building' s performance, allowing natural light when required by interior program, while reducing heat gain and transforming excessive solar radiation into energy for the media wall.

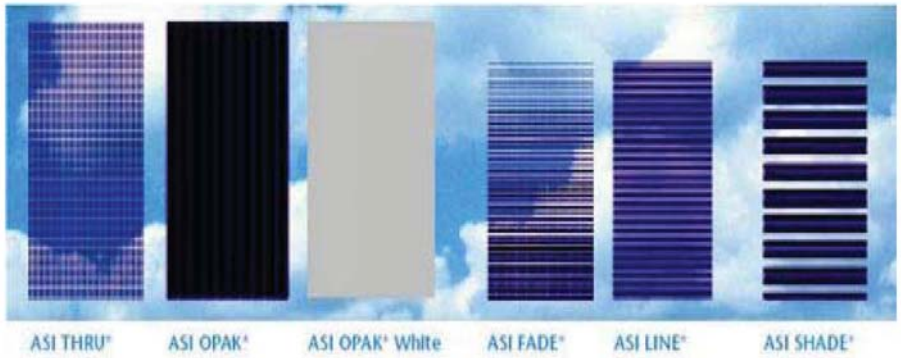
Solar Tree, created by Ross Lovegrove, was developed and produced by Artemide in collaboration with Sharp Solar, world leader in solar cells production. This revolutionary urban lighting project works with the most advanced solar technology respecting not only environmental issues but also cultural and social aspects of today's world. Solar Tree demanded very complex studies and analyses which Artemide has conducted with great commitment and sensitivity regarding ecological demands.
Lovegrove's innovative lighting project, the "Solar Tree," is a solar-powered streetlamp that also serves as a piece of modern art, infusing a bit of nature into the usually gray urban landscape.
Solar trees are able to provide enough light during the night-time even when the sun did not show for as much as four days in a row.

thin film technology



Example Products

Schott
ASI glass system



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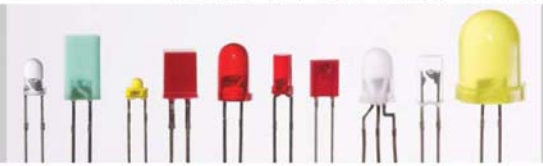
SUSTAINABLE LIGHTING



Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

final analysis

OLED Technology

Organic Roadmap (OLEDs)' [1]

Attribute	State of the Art	Target	Comments
Luminous Efficacy (lm/W) and Brightness (cd/m²)	White: 20, 1000	White: 150,	Combines electrical to optical power conversion with the ability of the human eye to detect. The real idea is to match emitted light with this response curve. *Is 200 lm/W really necessary?*
Lifetime (khrs to 50% depreciation)	10	>100	Big challenge for OLEDs as they suffer a "steady, monotonous, irritating" degradation.
Flux/Lamp (lm/lamp)	Depends upon size	Depends upon size	OLEDs have an inherent advantage in that they are manufactured in "sheets" and therefore emit diffuse light.
Purchase Cost ($/m²)	>120	30	Combined with ownership to be competitive with fluorescent lamps.
Ownership Costs ($/Mlm·hr)	16.00	0.63	Cost of ownership = cost of capital + cost of operating. SSL is expected to overtake incandescent in 2005 and fluorescent in 2010. Note that at the limit, all costs are driven by operating costs. *What if operating costs were minimal?*
Color Rendering (CRI)	75	>90	Again, hint the tradeoffs of quality vs. flexibility will be important.
			But, if the light is very flexible and has the ability to integrate with other materials, how important is CRI?
Color Temperature (CT) (°K)	3900	3900	Similar to LEDs – color temperature is addressable by combining different colors.

Organic SSL Advantages and Challenges

Organic LED Advantage	Comment
Simple and elegant	Light, designed by nature.
Flexibility. Thin.	OLEDs are amorphous and bendable. Embeddable in glass, metal and silicon.
Cool operation.	Safe. As with displays, these light emitters are cool to touch and harmless.
Transparent.	Transparent to their own radiation. Allows monochrome layers to be manufactured to create white light.
Small sizes. Lightweight.	Flexible form factors, no luminaries.
Environmental advantages	No mercury (0.5% of mercury released in 1999 from lighting). Ability to free over 125 GW of power (125 large power plants) and reduce CO_2 emissions by 200 million tons per year. Advantages are offset by losses in SSL manufacturing process.
Low turn on voltages	3 volts and lower.
Color Changing Capability	Using RGB emitters and intensity control, programmers can control lighting color and CRI.
Highly efficient electron to photon conversion	80% efficiencies have been demonstrated.

Organic LED Challenge	Comment
Lifetime	About one order of magnitude increase is needed to *compete with traditional lighting.*
More brightness	Relatively dim.
Packaging and encapsulation	OLEDs are very sensitive (darken) to moisture (they are a better indicator than currently available moisture detectors).
Edge emission	Much of the light "leaks" out of the edges of the package.
Color and color rendering	Multiple methods exist to generate white light. Unclear which will prevail.
Efficiency	Needs to be increased to 40% from 5%.
Manufacturing costs	Need to continue to decrease.
Materials	Increased stability.
Processing	Drive toward bulk roll processing.

OLED Future

"And, with thin-film flexible organic materials, computational circuits may dissolve into the products they control. Why have separate silicon driver circuits for an OLED display when the computer itself can be integrated into the display? Although it is unclear whether small molecule or polymer technologies (or both) will prevail, organic circuits are becoming a reality. 19 The only hanging question is in which lighting applications they will begin to disrupt first."

Edward A Dowdell, "Technology Migration and Distribution: A Case Study of the Solid State Lighting Industry."

http://dspace.mit.edu/handle/1721.1/29743?show=full

SOLID STATE

OLEDs
Roadmap
Advantages
Challenges
Future

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MICROGRID & SMART GRID TECHNOLOGY

Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

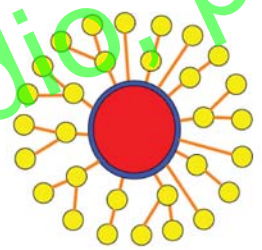
benefits

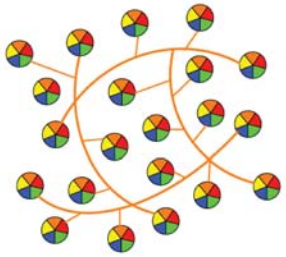
disadvantages

final analysis

PROPERTIES

A large Utility Grid has five basic components: Generation, Distribution, Consumption, Management, and potentially some level of Storage. A Microgrid has all of the same components in a much smaller more localized package.





Current Grid

Micro- Grids

Generation Distribution Management Storage Consumption

GENERATION

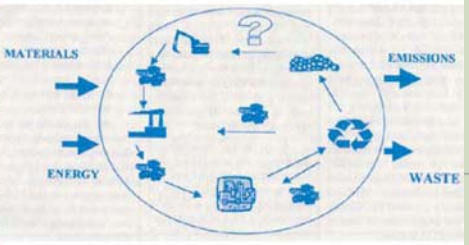
A micro-grid may have single or multiple sources of internal energy generation. These will ideally be sustainable technologies such as, solar, wind, biomass, micro-hydro, etc... but may be supplemented by diesel, or natural gas based generation. The use of imported energy sources like fossil fuels will probably be eliminated over time due to cost and reliability issues. Generation sources will not only provide energy but information regarding their status, efficiency, capacity and history.

Photo Above: Bronsbergen Microgrid, Zutphen, the Netherlands, 108 homes fit with 315 kW capacity PV

MICROGRID & SMART GRID TECHNOLOGY

Properties

LCA - BEES Calculation



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recycling

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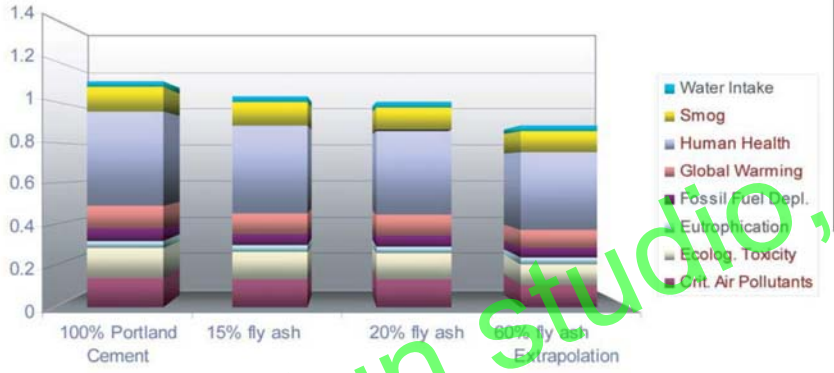
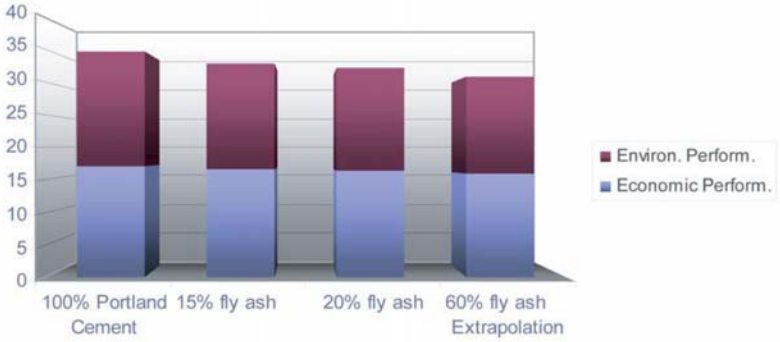


Beam 4ksi Environmental Performance

*Lower Values show better Performances
*Lower Strength Cement shows better performance (comparing to 5ksi)



Beam 4ksi Overall Performance

Environmental and Economic performance are combined into an Overall performance measure. Adding additional fly ash won't increase the cost.

Greener CONCRETE: SCM's

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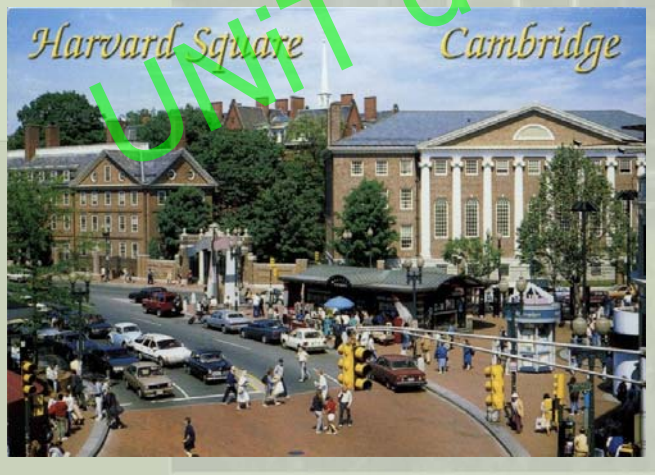
Transit Oriented Districts, TOD



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City of Denver, CDA
The Future of Denver

- **Future growth downtown and TOD**
- **We want to see the downtown continue to grow and thrive.**
- **Investment in TOD areas must be balanced with downtown.**
- **TOD is often missing an option in housing.**
- **Future growth will be spread around the City and will take many forms**
- **High density buildings downtown, mixed use station areas, infill development in established neighborhoods, and Stapleton.**
- **As each FasTrack's line is built, especially the East Corridor to DIA, Downtown becomes a stronger location.**
- **Development at stations near downtown will generate business for downtown from an entertainment perspective**

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