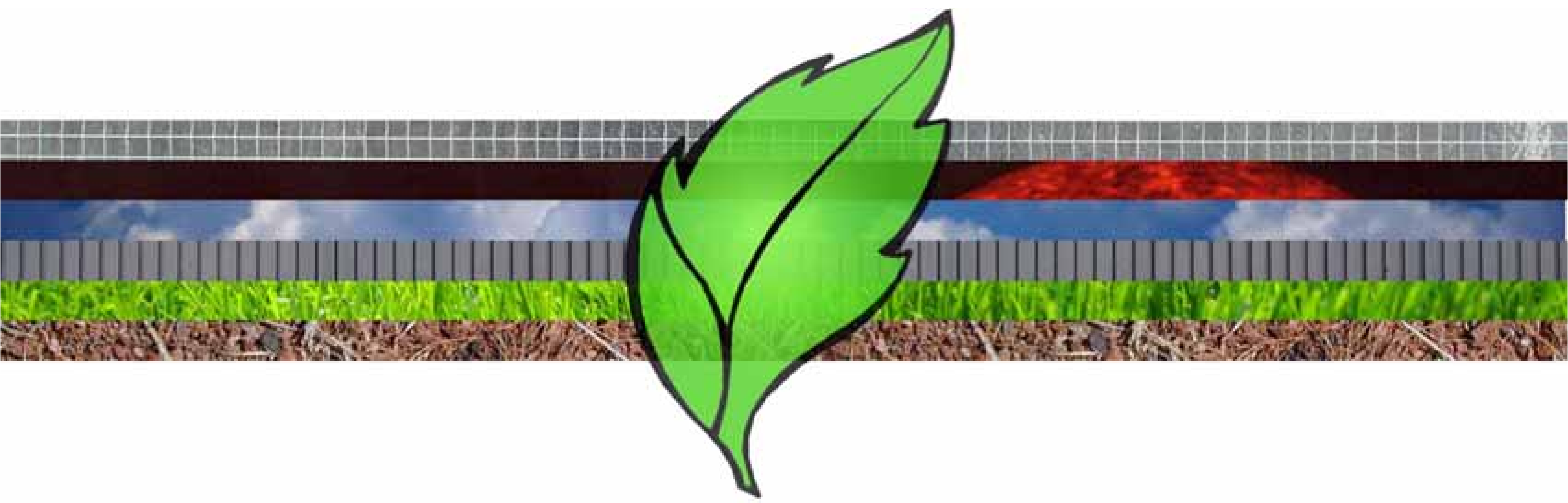
green systems

greenbuilding resource guide



university of colorado, denver
college of architecture
&
planning

fall 2006

Green Systems a greenbuilding resource guide

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GBT Resource Guide: introduction

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Greenbuilding Technology Resource Guide

This resource guide provides an in depth analysis of cutting edge greenbuilding technology and green systems. The topics covered in this guide and the research presented will be a valuable resource for architects, students, and clients interested in understanding, learning and utilizing such concepts and systems.

This resource guide is the second volume in a continuing research, documentation and developement guide of green building materials and systems. Specifically, Tthis guide [Green Systems] focuses on the newest and latest trends, research and technology related to building design integrated green systems.

The format of the guide was based on Transmaterial, a catalog of materials, products and processes
that redefine the physical environment, developed by Blaine Brownell
website: http://transstudio.com

Overview

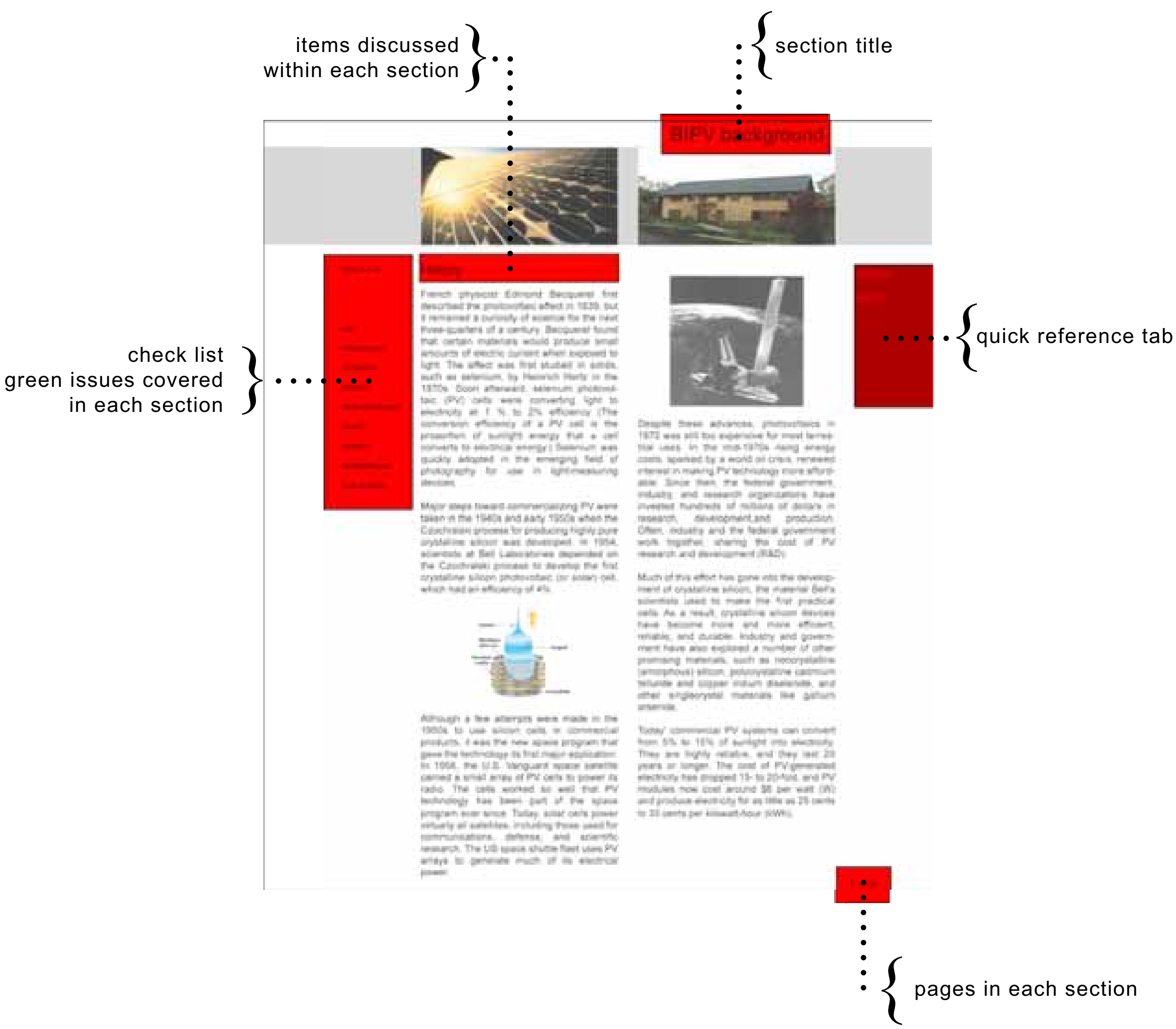
This Resource Guide is a compilation of the research and work of 21 architecture graduate students at the University of Colorado's College of Architecture and Planning. It was developed as part of the Greenbuilding Technology seminar during the fall of 2006. This seminar is an upper level graduate seminar focused on the examination and research of the latest cutting edge technology and data available on green systems and materials. The information contained in this guide will cover topics in greenroofs, anerobic digestion (waste to energy), gasification, wind power, solar power and high performance wall systems. This guide is a continuation of previous geenbuilding technology guides developed in the same seminar from previous years. it respresents an ongoing and continuous body of work concerning greenbuilding technology, cutting edge research and the architectural applications of such technologies.

Course Description

THis course is an upper level graduate seminar comprised of 21 graduate students. Students formed groups of 2-3. Each group explored a specific topic on green building systems. The focus here is not only on the systems themselves, but also on how the systems can be integrated into architectural design. Exploration methods included research, field trips, interviews (with researchers, manufacturers, experts, etc.). Research focused on the latest information availbale and had an emphasis on the most cutting edge technology.

Format

The goal of the GBT guide is to bridge disciplines and expertise into one concise source. As there are many aspects to any one particular topic, the organization here relies on the formatting accompanied by succinct descriptions to educate the reader on the fundamentals of greenbuilding. The format was designed to act as a quick and easy way of communicating the basic “need to know” information with further ways to research and explore the topics within. For example, what does the designer need to know about the subject or technology before he or she starts thinking about considering using it. And on the other hand how can they (the designer) convey that information back to the contractors, developers, and municipal leaders. It aims to demonstrate an unbiased look at greenbuilding materials and related technologies by presenting facts and acting as an educational tool. It can be seen as falling somewhere between the two spectrums of the Transmaterial research and GREENSPEC. It is envisioned that future versions of this prototype might elaborate on the Checklist and concepts behind it to further engage the reader on the set criteria to best gauge performance and environmental concerns.



Disclaimer

Greenbuilding Technology Resource Guide is a resource for current and future materials and technologies. It is intended to serve students, architects, designers, and others interested in learning more about green building. The Green Building Technology Resource Guide, the University of Colorado, Fred Andreas, and the students themselves assume no responsibility for accuracy, completeness or usefulness of the information provided. Users are cautioned to consult with the manufactures and professionals before specifying or recommending any of the products or technologies within.

Green Systems a greenbuilding resource guide

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GREEN ROOFS -

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What is a green roof?

-A roof of a building which is partially or completely covered with vegetation.
-Green roofs are planted over a water-proofing membrane, a root repellent system, drainage system, and filters.
-Vegetative material is often chosen for particular applications and climates

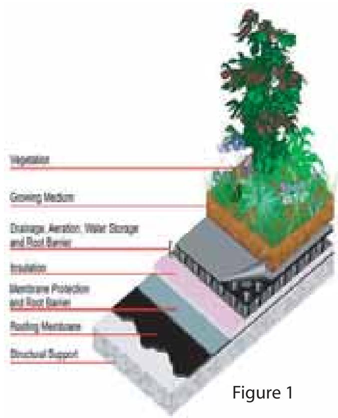


Figure 1

TYPES

INTENSIVE GREEN ROOFS:
-Utilize a variety of plants, including sod, flowers, trees, and shrubs
-Labor-intensive, require irrigation and consistent maintenance
-Requires deeper soil medium of 8-24”
-Generally limited to flat roofs
-Park-like areas which are accessible to the public
-Heavier system (60-200 lbs./s.f. when saturated), requires structural consultation

EXAMPLES OF INTENSIVE GREEN ROOF SYSTEMS:

ROOFTOP GARDENS
-BMW building, Düsseldorf, Germany, 1992

-MAG-Galleries, Geislingen/Steige, Germany, 2002




GREEN ROOFS - TYPES

Types

EXTENSIVE GREEN ROOFS:
-Designed to be self-sustaining
-Require little maintenance after the first year
-As shallow as 2-6” of soil medium
-Generally limited to drought-tolerant plants such as ‘sedums’, herbs, grasses, and mosses
-Usually cannot be walked on, and therefore not accessible to the public
-Lightweight systems which allow for installation on existing roof tops (16-35 lbs./s.f. when saturated)

EXAMPLES OF EXTENSIVE GREEN ROOF SYSTEMS:

ROCKERY GREEN ROOFS
-District Administration Göppingen, Germany, 1991
-Low-growing Sedum species mainly serve as ground cover
-Higher growing perennial plants allow for some creativity and design

SEDUM CARPET GREEN ROOFS
-Norddeutsche Landesbank, Hanover, Germany, 2002
-Low-growing Sedum species mainly serve as ground cover
-Low maintenance

DUO GREEN ROOFS
-Pliensau Funeral House, Esslingen, Germany, 1977
-A thermal insulating green roof system, which eliminates many factors influencing deterioration of roofing membrane.

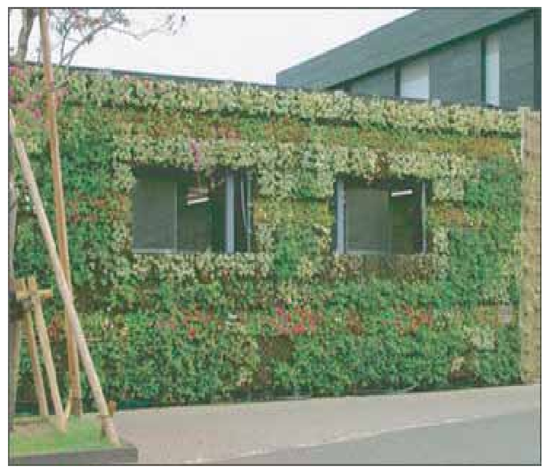

SLOPING GREEN ROOFS
-"Barrel Roof", Vaihing`en/Enz, Germany, 1998

Green Roof Systems

Complete systems
-Can be added to the roof either during or post Construction
-Consists of all the different components including the roof membrane to the plants.
-Highest structural loading which means a higher building cost.
- -Soprema
- -Hydrotech
- -Roofscapes

City of Chicago

Green Wall Panels
-Installation has a low environmental impact
-Safe to install on almost any structure
-Ways to use green wall panels:
- -Exterior or interior walls
- -Company logos
- -Exhibitions/ special events
- -Roof gardens and open space areas



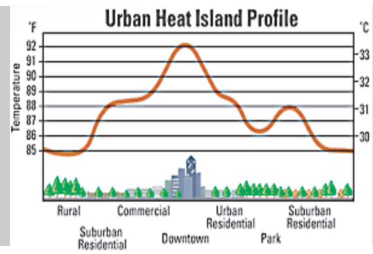
Comparison of Available Green Roof Systems

	Complete Systems	Modular Systems	Pre-cultivated Blankets
Maintenance/repair	difficult	Easy	easy
Installation	more involved installation	quick and easy	quick and easy
System	layer combinations	pre-planted	pre-planted
Weight	high to moderate	moderate	low
Flexibility	high	moderate	low
Companies	Soprema Hydrotech Roofscapes	GreenGrid Green Roof Block	Xero Flor Canada Elevated Landscape Technologies

Firgure 2

Pre-Cultivated Blankets
-Very thin blankets grown off-site.
-Blankets are typically rolled up interlocking tiles that can be placed on any roof.
-Little flexibility in terms of barrier and plant choices.
-very lightweight option.
- -Xero Flor Canada
- -Elevated Landscape Technology

City of Toronto



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Principle benefit of Green Roofs

STORM WATER MITIGATION
LEED Site Selection Credit
6.2: Stormwater Design: 1 pt.
-A green roof can absorb substantial amounts of storm water and delay peak runoff
-Green roofs reduce impervious roof surfaces.
-Encourages infiltration into the root structure of plant material, delaying and retaining peak run off rate during storms.
-Urban surfaces are hard and impermeable and therefore unable to allow natural percolation of water
-Vegetation stores water and returns it to the atmosphere through evapo-transpiration
-A Portland, OR, study found that storm water runoff would be reduced between 11 – 15%

"HEAT ISLAND" EFFECT
-A green roof over 50% of the roof area earns 1 LEED point of Sustainable Site SS Credit 7.2: Heat Island Effect: Roof
-Overheating of urban and suburban areas relative to surrounding countryside
-Due to increased hardscape and dark roofs
-Increases the use of electricity through the use of air conditioners
-Roofs absorb solar radiation and reflect it as heat
-The use of green roofs reduces this heat as well as the distribution of dust throughout the city in the form of smog and green house gasses

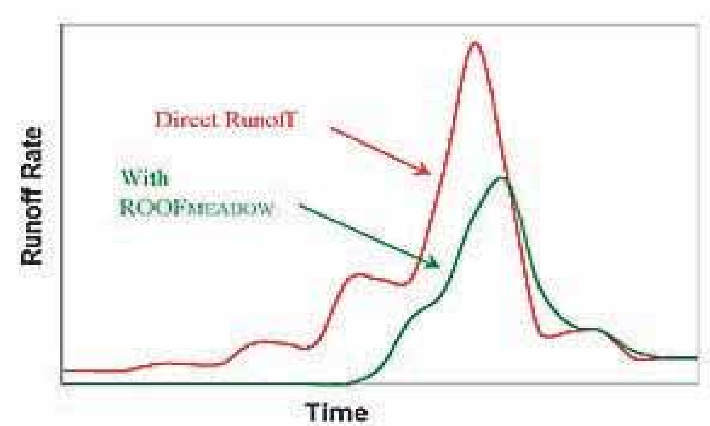


Figure 3: Temperature comparison with and without a green roof

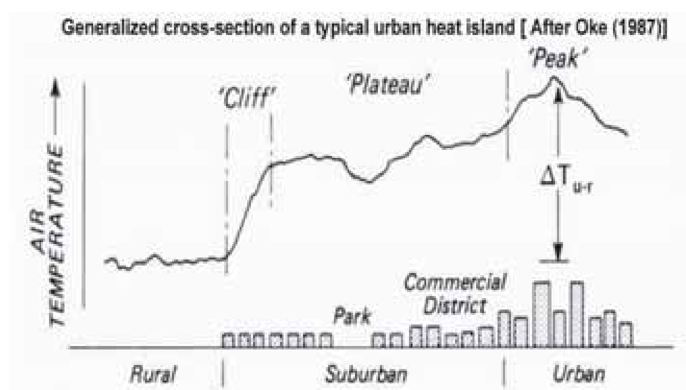
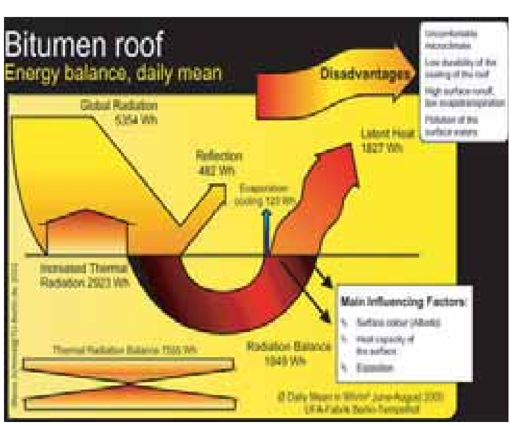


Figure 4: Heat Island Effect



VS.

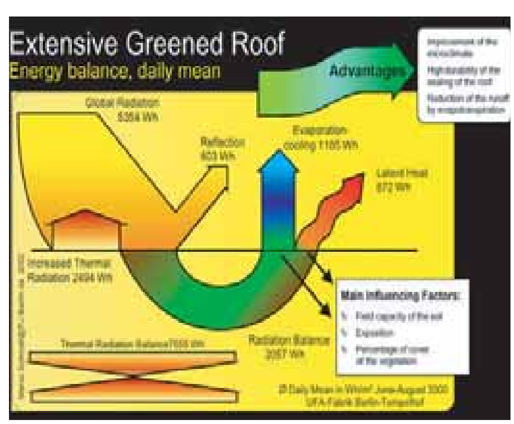
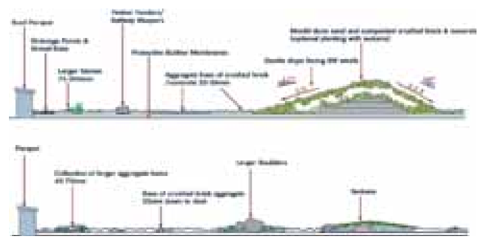


Figure 5

GREEN ROOFS - BENEFITS AND DISADVANTAGES



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Benefits and Disadvantages

BENEFITS:
-Filter pollutants like Carbon Dioxide from the air
-Regulates temperatures throughout the summer and winter
-Lengthen the life of the roof by 2 to 3 times
-LEED points for local materials if expanded shale or scoria are used for growing medium
-Treats Nitrogen pollution in rain
-Negate acid rain effect
-Aesthetic benefits
-Increases habitat in urban environment replacing footprint destroyed with construction
-Reduction of noise through sound absorption rather than sound reflection
-Improved public image of an organization utilizing a green roof
-Reducing energy costs through additional insulative properties
-Increased property value

DISADVANTAGES:
-Increased up-front costs for green roof implementation
-Additional maintenance costs
-Potential for consistent irrigation in arid climates
-Increased weight to the roof, potentially requiring structural considerations
-More difficult to service roof

GREEN ROOFS -

benefits/ disadvantages

group 1

Comparison of Different Types of Green Roofs

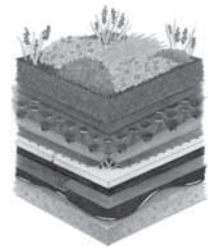
	Intensive	Extensive
Depth of Material	More than 15cm	Less than 15 cm
Accessibility	Accessible	Inaccessible
Fully Saturated Weight	290-967.7 kg/m^3	72.6-169.4 kg/m^3
Plant diversity	High	Low
Cost	High	Low
Maintenance	High	Low

Figure 6

Comparison of Advantages and Disadvantages of Intensive and Extensive Roofs

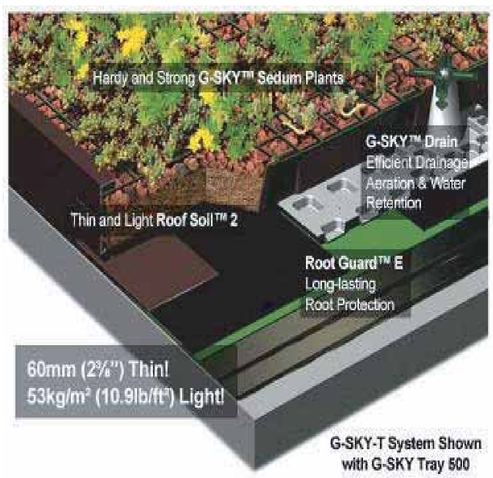
Intensive advantages	Extensive Advantages	Intensive Disadvantages	Extensive Disadvantages
Greater plant diversity and options	Lightweight	High weight loading	Little plant choice
Visually appealing	Low maintenance	Necessary irrigation/drainage systems	No recreational access
Good insulation	Low cost	High cost	Unattractive
Used as open space	Works on older roofs	High maintenance	Less storm water retention
Potential for higher energy savings	Easier to replace	High replacement cost	
More storm water retention	Often no irrigation or drainage system	More expertise required	

Figure 7



Costs

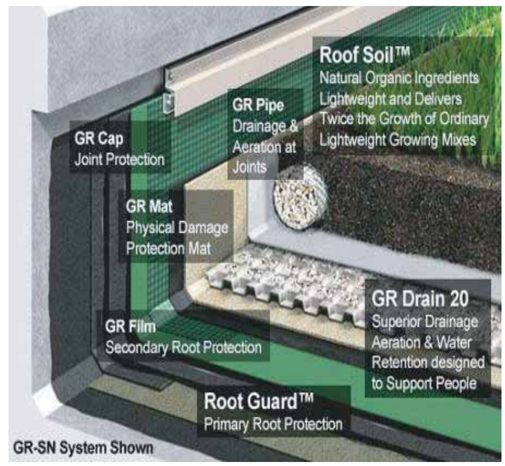
G-Sky Intensive Green Roof System:
- Lightweight and thin
- Maintenance and cost 1/3 of the competitors



System Specification ID	m²	ft²	Notes
G-SKY-T (Tray System)	$125.08	$11.64	Pregrown Sedum Trays, Provides an instant Green Roof. Orders require a 6 month lead time and pre-payment. See 'Terms and Conditions of Sale'.
G-SKY-N (Netting)	$88.04	$8.21	G-SKY Netting high-wind resistant system. 8 different Sedum plant species available. 50 plants/m²
G-SKY-L (Low-Wind)	$58.46	$5.46	G-SKY low-wind resistant system. 11 different Sedum plant species available. 50 plants/m²

Figure 8

Sky Garden Green Roof System:
- Lightweight and easy installation
- Intensive green roof system



GR-SN	Price	
	m²	ft²
GR Filter (+Pin)		

GR Drain 20	$36.47	$3.41
GR Mat		
GR Film		

GR-SC	Price	
	m²	ft²
GR Filter (+Pin)		

GR Drain 20	$30.05	$2.81

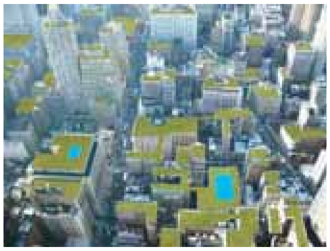
GR Film		

Figure 9

Green Roof & Conventional Roof Costs

	Green Roof	Conventional Roof	Delta
First Cost	$10 - $15	$3 - $9	
Mean	12.50 $/SF	6.00 $/SF	6.50 $/SF
Re-Roofing	$15 - $25	$5 - $20	
Membrane Replacement	0.00 $/SF	3.25 $/SF	-3.25 $/SF
Drainage	0.013 $/SF	0.021 $/SF	0.008 $/SF

Figure 10




Check List

LCA

QUEEN'S UNIVERSITY CAMPUS
A case study was performed to detrmine the financial feasibility of a hypothetical green roof.
-The roof was assumed to cost $70,000
-The building ordinarily would use 90,000kWh of energy for cooling annually, and that the green roof would reduce this usage by 15%.
-The price of electricity was assumed at 11c/kWh, with an annual increase of 7%

The results of the case study showed an NPV of -$33,838 and an ROI of 100%, with a breakeven point of about 21 years.

Capital Investment	$	70,000
Yearly cooling Energy (kWh)		90,000
energy cost year 1 ($/kWh)	$	0.11
energy cost increase		7%
discount rate		8%
% Energy Savings		15%

Year		Energy Price	Energy Cost	Cash Flow	Cumulative Savings
0				-$70,000	
1	$	0.110	$ 9,900.00	$1,485	$1,485
2	$	0.118	$ 10,593.00	$1,589	$3,074
3	$	0.126	$ 11,334.51	$1,700	$4,774
4	$	0.135	$ 12,127.93	$1,819	$6,593
5	$	0.144	$ 12,976.88	$1,947	$8,540
6	$	0.154	$ 13,885.26	$2,083	$10,623
7	$	0.165	$ 14,857.23	$2,229	$12,851
8	$	0.177	$ 15,897.24	$2,385	$15,236
9	$	0.189	$ 17,010.04	$2,552	$17,787
10	$	0.202	$ 18,200.75	$2,730	$20,517
11	$	0.216	$ 19,474.80	$2,921	$23,439
12	$	0.232	$ 20,838.03	$3,126	$26,564
13	$	0.248	$ 22,296.70	$3,345	$29,909
14	$	0.265	$ 23,857.47	$3,579	$33,487
15	$	0.284	$ 25,527.49	$3,829	$37,317
16	$	0.303	$ 27,314.41	$4,097	$41,414
17	$	0.325	$ 29,226.42	$4,384	$45,798
18	$	0.347	$ 31,272.27	$4,691	$50,489
19	$	0.372	$ 33,461.33	$5,019	$55,508
20	$	0.398	$ 35,803.62	$5,371	$60,878
21	$	0.426	$ 38,309.88	$5,746	$66,625
22	$	0.455	$ 40,991.57	$6,149	$72,774
23	$	0.487	$ 43,860.98	$6,579	$79,353
24	$	0.521	$ 46,931.25	$7,040	$86,392
25	$	0.558	$ 50,216.43	$7,532	$93,925
26	$	0.597	$ 53,731.58	$8,060	$101,985
27	$	0.639	$ 57,492.79	$8,624	$110,608
28	$	0.684	$ 61,517.29	$9,228	$119,836
29	$	0.731	$ 65,823.50	$9,874	$129,710
30	$	0.783	$ 70,431.14	$10,565	$140,274
			NPV	-$33,838	
			Saved Sum	$140,274	
			ROI	100%	

Figure 12

LCC

GREEN ROOF FEASABILITY REVIEW
-Prepared by Paladino & Co.
-King county project
-Pacific Northwest, 2004
-220,000 s.f. office building

Table 2: Roof Comparative Life Cycle Analysis

Green Roof		
years		40
discount		2.0%
First Cost	$	(462,500)
Annual maintenance savings	$	500
Annual drainage savings	$	206
Annual energy savings	$	1,125
Subtotal Annual Savings	$	1,831
PV	$	50,094
NPV	$	(412,406)

Future Cost of Roof Replace 1		
years		20
discount		2.0%
Future Cost	$	(81,250)
PV	$	(54,679)
NPV	$	(54,679)

Future Cost of Roof Replace 2		
years		40
discount		2.0%
Future Cost	$	(81,250)
PV	$	(36,797)
NPV	$	(36,797)

Cost of Plant Maintenance	
years	0.0%
discount	0.02
Future Cost	($15,000.00)
PV	($15,000.00)
NPV	($15,000.00)

years	1
discount	0.02
Future Cost	($15,000.00)
PV	($14,705.88)
NPV	($14,705.88)

TCO	($533,588)

Conventional Roof		
years		40
discount		2.0%
First Cost	$	(300,000)
Annual Savings	$	-
PV	$	-
NPV	$	(300,000)

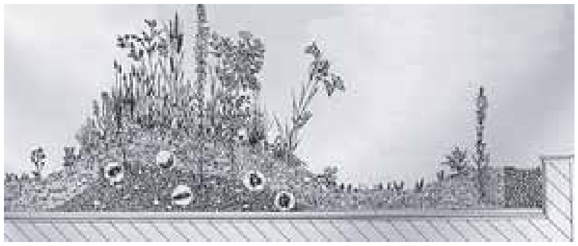
Future Cost of Roof Replace 1		
years		20
discount		2.0%
Future Cost	$	(162,500)
PV	$	(109,358)
NPV	$	(109,358)

Future Cost of Roof Replace 2		
years		40
discount		2.0%
Future Cost	$	(162,500)
PV	$	(73,595)
NPV	$	(73,595)

Overall discount rate	2.0%
Percent of Green Roof	50%

TCO	($482,953)

Figure 11



GREEN ROOFS IN COLORADO

Green roofs have been implemented in Europe for the past 30 years and have slowly caught on in the Maritime climates of the US. In Europe, green roofs are encouraged through local and national governmental incentives. The lack of US acceptance of green roof technology is due to the lack of awareness and understanding of the benefits, as well as the financial up-front costs.

The leading US cities of green roof research and implementation are Chicago and Portland, where their governments are offering similar incentives of those in Europe. Because the research has been done primarily in maritime climates, extensive green roof systems are designed accordingly with the most suitable plant selection to this climate. There is a lack of technical information that is needed for a successful implementation of a green roof system for arid climates.

The primary benefit of a green roof is storm water management, delaying the peak run-off rate, and lessening the load on storm water infrastructure and sewage treatment. In cities with greater amounts of rainfall, green roofs are very beneficial for this reason. However, in arid climates like Colorado, which receive an average of 15” of rainfall or less a year, storm water management becomes less of a concern; therefore government incentives are not as common. Because of the high amount of solar radiation and lack of rainfall, green roofs which follow the traditional maritime model would have to be irrigated often to survive in Colorado. There is a lack of research on the vegetation that can support a green roof in an arid climate like Colorado, likewise, there are no commercial suppliers providing materials for this system. Succulents such as Sedums, Delosperma, and Sempervivum, as well as cacti and grasses, are hardy, drought-tolerant species that could possibly withstand Colorado’s climate. However, some hybrids of these species cannot endure sub-zero temperatures. This proves that more research must be done to find existing species and create new hybrids which are both drought-resistant and can survive periods of frost. Many of the Prairie grasses are considered drought-tolerant; however, they have deep tap roots which could cause problems with an extensive green roof system. In nature if we look to cliff-dwelling species many have very shallow root systems and can still withstand harsh winds and temperature extremes. These cliff-dwelling plants have naturally acclimated to these conditions through natural selection. The same results can be achieved if more time is spent testing the resistance of species to Colorado’s harsh climate.

The main idea of an extensive green roof system is to provide minimal maintenance and irrigation. For the green roof concept to be realized in climates similar to Colorado, long-term irrigation will likely be needed. Irrigation for the first few seasons is essential for the establishment of root systems. However, maximum plant growth is not desired, and therefore fertilization should be limited.

Green roofs may cost twice as much as conventional roofs, however a green roofs life span is twice as long as a conventional bituminous roof. In Colorado, there is a constant freeze/thaw cycle throughout the winter months, which takes heavy toll on the destruction of conventional roofs. With the implementation of a green roof system, this damage is minimized because of the insulation provided through the vegetation and materials.

In conclusion, green roofs in Colorado will require extensive research and development for the appropriate plant species which can handle extreme temperature shifts and very little precipitation. Until this research has been completed, an un-irrigated green roof in Colorado would be difficult to sustain.

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List of Tables and Charts:

Additional Resources:

Brian Gardiner, RRC, CCS
Austech Roof Consultants, Inc.
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Vancouver Green Roof Research Center:
555 Great Northern Way
Great Northern Way Campus
Vancouver, BC

GASIFICATION DEFINITIONS

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Uses

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DEFINITIONS

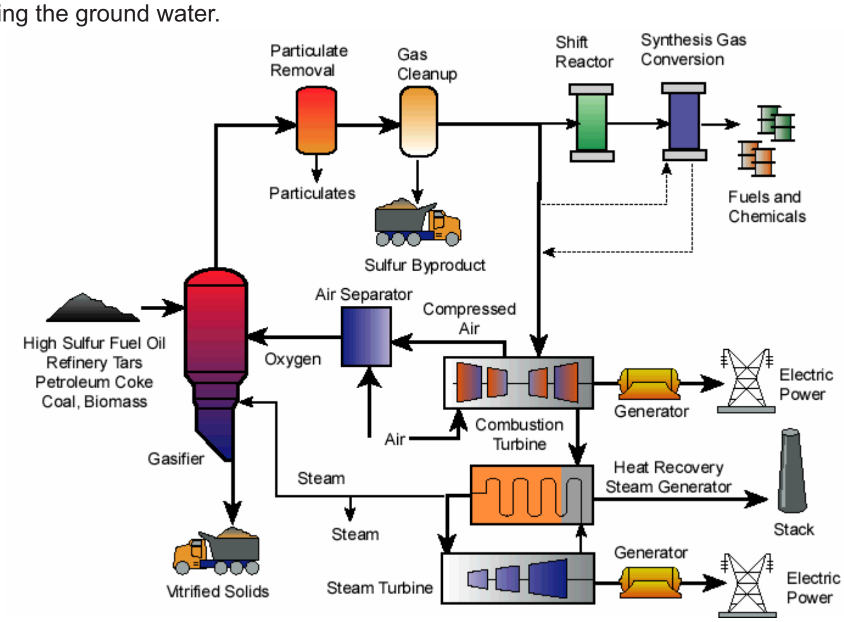
Gasification offers the cleanest, most efficient method available to produce synthesis gas. Virtually any kind of waste can be processed, solid, liquid, or gas, except nuclear material. This includes, municipal solid waste (MSW), auto shredder residue, coal fines, medical waste, hazardous waste, sludge, oily water, tank bottoms, landfill gas, dioxins, PCB's, pesticides, paint, tires, contaminated soil, incinerator ash, etc. The gasification process converts any carbon-containing material into a synthesis gas composed primarily of carbon monoxide and hydrogen. A high efficiency gas turbine burns the clean syngas to produce electricity, and the exhausted heat is recovered to produce steam that powers high efficiency steam turbines. The energy produced by the gasification process is recovered from discarded materials.

The high temperature in the gasifier converts the inorganic materials into a vitrified material resembling coarse sand, which then can be used in construction. Valuable metals are concentrated and recovered for reuse. This process does not generate residual waste, eliminating the need for new landfills, and eliminating the risk of contaminating the ground water.

The gasification plant can be located in an industrial area of the city, dramatically reducing freight costs to a landfill and the total number of garbage trucks. The plant can be located next to the city sewage treatment facility and be used to process sludge. The plant can also be located at existing landfills where it can be used to process landfill gas or to reclaim the ground. Higher efficiencies translate into more economical electric power and potential savings for ratepayers. A more efficient plant also uses less fuel to generate power, and less carbon dioxide is produced, and 99% of the waste produced by gasification can be converted to marketable products. Existing incinerator plants can be retrofitted into the gasification process, which will eliminate the ash disposal and emissions problems of incinerators. The organic material does not burn because there is not enough oxygen. So, air and water emissions are below EPA standards.

LEED

- Water Efficiency
- Energy & Atmosphere
- Construction Waste Management



Fixed-Bed Gasification Process

Uses a bed of fuel that is maintained at a constant-depth by the addition of fuel from the top of the gasifier.

Has a stationary reaction zone typically supported by a grate.

Entrained Flow Gasifiers

Finely pulverized fuel, is gasified within seconds at high temperatures of around 1500 - 1900°C

The quick reaction time allows for a very high throughput, and highly efficient carbon conversion.

Fluidized-Bed Gasifiers

Method of suspending the supplied solids using an upward flow of gasification agent that causes high-velocity, turbulent motion of the reactants.

Thermogenetic Gasification

As part of an integrated plan, as much as 90% of the total waste stream can be diverted from the landfill.

Flexibility in operating rates and fuel types.

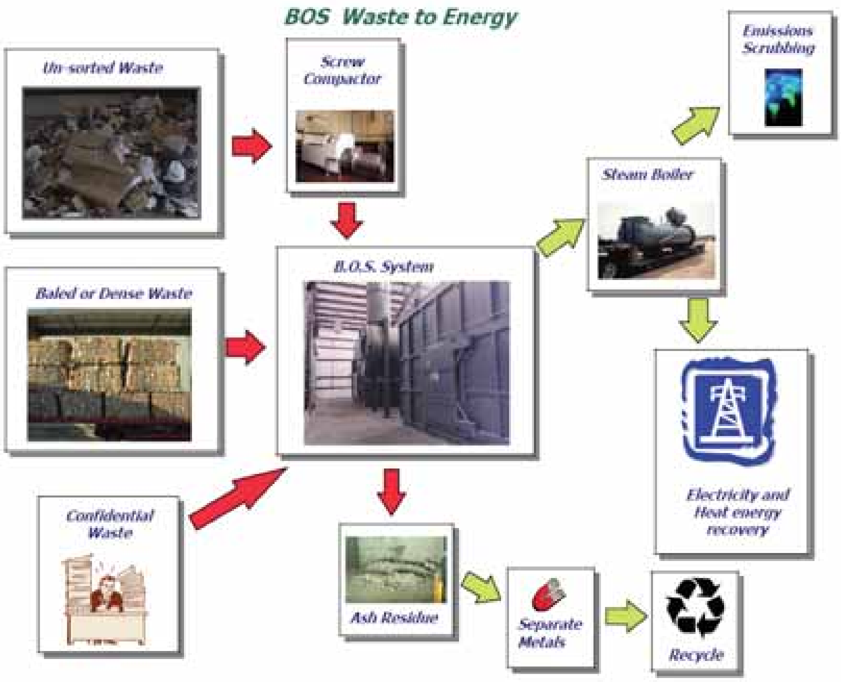
Batch Oxidation System (BOS)

Modular approach to both small and large-scale waste disposal,

Simple system that requires low maintenance and minimal labor.

LEED

- Water Efficiency
- Energy & Atmosphere
- Construction Waste Management



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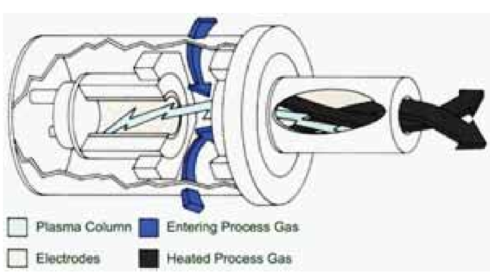
Plasma Gasifiers

Plasma gasification is the gasification of matter in an oxygen-starved environment to decompose waste material into its basic molecular structure. Plasma is considered a 4th state. Electricity is fed to a torch, which has two electrodes, creating an arc. Inert gas is passed through the arc, heating the process gas to internal temperatures as high as 25,000 degrees Fahrenheit. The temperature a few feet from the torch can be as high as 5,000-8000ºF.

Plasma gasification does not combust the waste like an incinerator. The high temperature of the torch can process any type of waste. It breaks down the organic waste into a fuel gas that contains all the chemical and heat energy. The inorganic waste is converted into an inert vitrified glass, and all metals become molten and flow out the bottom of the reactor. There are no tars, furans, ash or any other waste from this process. Plasma reactors can process 20 tons of waste per hour which allows for large bags of waste to be fed directly into the reactor without any sorting.



Plasma Plant Example

Westinghouse Plasma Corporation (WPC) has designed a 300 tpd energy production and vitrification plant for a blend of MSW and industrial waste. The glassy material produced can be sold as a roadbed or construction material and the need and expense to dispose of ash is eliminated.

This new plant can process approximately 300 tpd of 100% MSW. The plant produces approximately 8 MW of electric power. After extensive test campaigns to demonstrate its flexibility, the plant was released to the customer for commercial operation in April 2003.

The slag passed the EPA-mandated Toxicity Characteristic Leachate Procedure (TCLP) requirements.

The plasma torch power for this application ranges from 100 kW to 250 kW per ton/hr of MSW/ASR

Emissions are very much reduced and Dioxins were measured at levels approximately 100 times lower than from an incineration plant (e.g., <0.01 ng/nm3 measured in stack gas).

LEED

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- Energy & Atmosphere
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SMALL SCALE GASIFIERS

These smaller scales gasifiers can range in use from a college campus to a single residence. Like in most technologies as the market increases the devises get smaller and more affordable. With this energy created from waste through gasification, the different scales handle various waste generators to eliminate any more production of (MSW).

LEED

- Water Efficiency
- Energy & Atmosphere
- Construction Waste Management

ENERGOS (ENER•G)

ENERGOS' design remit was to produce an economic solution for a small scale plant with minimum environmental impact. Having achieved this, ENERGOS has helped leading waste and energy companies solving their key problem: How to convert abundant waste resources into environmentally friendly energy with low emissions and attractive economics.

The proven and patented ENERGOS technology is designed to minimize emissions. ENERGOS plants are sized for local applications, converting between 30,000 and 80,000 tonnes pa of household, commercial or industrial waste residue into electricity and/or heat – delivered for local use.

These small scale ENERGOS plants offer a number of benefits:

- Small size of the building designed to reduce visual impact
- Transport of waste is minimized
- Inherently low emissions – at a fraction of EU permitted levels
- Low capital costs
- Fast construction time
- Minimal impact on the local environment
- Integration into regional recycling strategies

Example of built Energos plant

Example of built Energos plant

GASIFICATION USES

SMALL SCALE GASIFIERS

LEED

- Water Efficiency
- Energy & Atmosphere
- Construction Waste Management

HOUSEHOLD GASIFIERS

a company called Community Power Corp. plans on commercializing its line of biomass-fed gasifiers designed for homes, schools and small businesses, especially those in off-grid locations. With this production it is hopeful that this technology will be more readily available.

Models range in size from 5-kW units for home use to 15-kW machines, enough to power a small business. The company is currently demonstrating six gasifiers in off-grid field applications. Those include one 15-kW unit using forest residue to power a greenhouse at North Park High School in Walden, Colo., and a 15-kW gasifier converting a Ruidoso, N.M., wood shaving factory's waste to energy. "The system is perfect for entrepreneurs whose businesses produce biomass residues," They can make the waste pile disappear while offsetting power and heating costs."

Commercial production is the key to making the technology affordable. Making the system modular and standardized so that it can be easily installed in the field will drive the cost per unit down. Walt aims to start making the machines for commercial use in the United States by mid-2005, at an estimated cost of $50,000 for a 20kW unit. If CPC recruits corporate investors and manufacturing partners, the price of each unit is likely to drop more.

The unit converts factory's wood waste into a peak generation of 15 kW.

small modular biomass power system based on downdraft gasifier technology that uses high bulk density fuels. The engine is designed to run for about four or five hours per day to fully charge batteries, and be able to provide 24 hour power.

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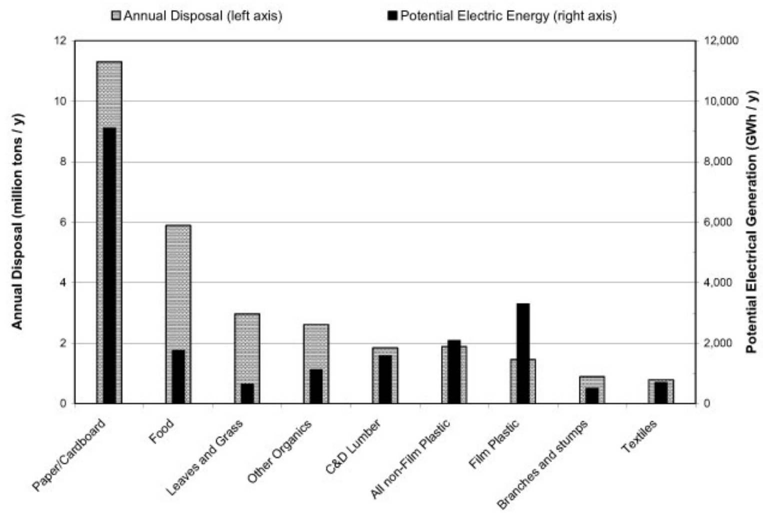
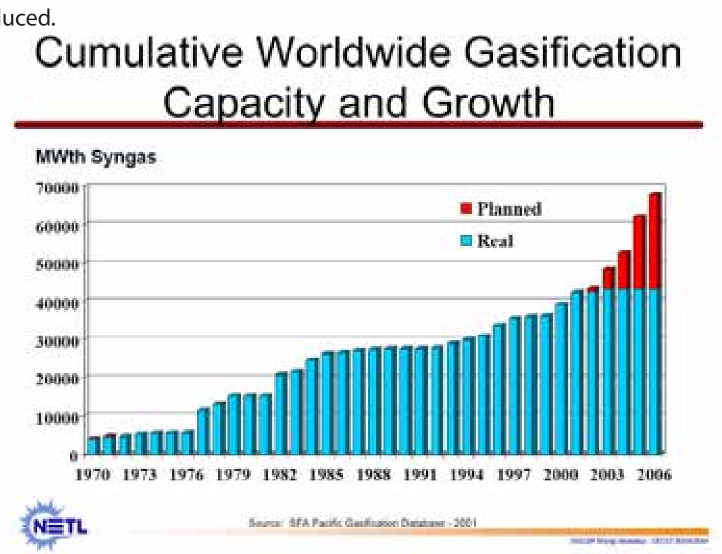
ENERGY POTENTIAL

Almost anything can be put into this waste gasification to produce energy. Of course some things are more efficient and sensible to use. This char gives a brief rundown of common materials and their efficiencies to be put into energy.



As shown in the graph below, we see that gasification is on the move, and has been steadily increasing since the 1970's. We are now just getting to the point where the technology has become efficient and environmentally friendly. The red section indicates a projects what could be if this becomes more mainstream and mass produced.



LEED

- Water Efficiency

- Energy & Atmosphere

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ENERGY RUNDOWN

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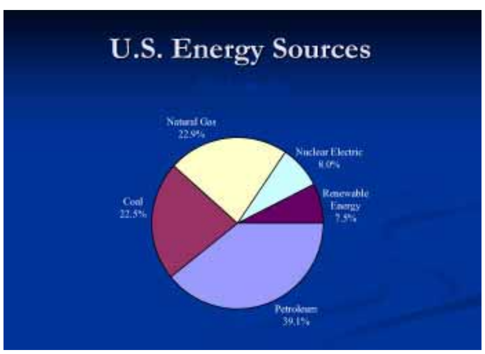
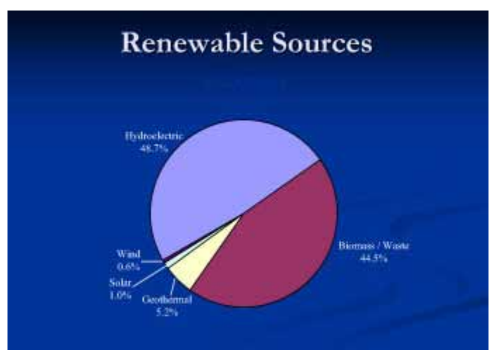
ENERGY USE AND PRODUCTION

	Combustion	Bio-mass Gasifier
Efficiency	60 to 70%	75 to 90%
Economic	Less due to price of fossil fuel increasing.	Net saving 40-50% compared to solid & liquid combustion.
Environment Aspect	Environment Polluting, due to release of CO_2.	Environment Friendly, No chances of emission.
Flame Temp.	1800 º C	1450 º C
Lox, Nox Formation	High due to high flame temperature.	Low due to low flame temperature.
Fuel diversity	LPG, C-9, Kerosene, LDO	Charcoal, Steam coal (Imported), Briquettes
Pay Back Period	-	6 to 7 Months compare to oil.
Start-up	Immediate	Due to chemical reaction initial start-up time is 2 – 3 Hrs.
Shut-down	Immediate	Immediate

U.S. ENERGY SOURCES AND USES





As we can see renewable energy has the potential of being highly more efficient than other forms of power generation. Unfortunately it is one of the most under utilized resources. Out of the renewable energies though we do see biomass and waste being used quite a bit, but some of these techniques can have negative connotations especially with thinking of just regular incineration of garbage. This is where Gasification can lead the way in energy production and also education of the benefits of this use.

BENEFITS OF GASIFICATION

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BENEFITS

Gasification helps conserve valuable water resources, it uses approximately 30-40% less water to produce electric power compared to coal-based generation technologies.

Gasification can readily remove volatile mercury.

Gasification provides the lowest-cost approach for capturing carbon dioxide

There are many different types of gasification processes existing and currently under development.

LEED

- Water Efficiency
- Energy & Atmosphere
- Construction Waste Management

Acceptable Waste Materials

The thermal transformer does not distinguish between types of waste. Materials such as silica, glass, soil, rocks, concrete, metals and any carbon-based waste are all processed the same and require no sorting.

The waste is converted into valuable products, including electricity, ethanol, vitrified glass, metal and sodium bisulfite. Molten metals are separated and recycled. Non-carbon-based materials are vitrified or thermally fused into glass.

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DEFINITIONS

Anaerobic Digestion (AD) is a process whereby organic waste is broken down in a controlled, oxygen free environment by bacteria naturally occurring in the waste material. Methane rich biogas is produced thus facilitating renewable energy generation. As a result, materials that are currently going to landfill can be utilised; natural methane emissions are reduced and conventional generation with its associated carbon emissions is displaced.(2)

- Chicken = 9/10 pound per day = 1 watt of power a day
- Hog = 9 pounds per day = 10 watts of power a day
- Feedlot cow = 90 pounds per day = 100 watts of power a day
- Dairy cow = 140 pounds per day = 162 watts of power a day
- Human = 2.5 pounds per day = 3 watts of power a day

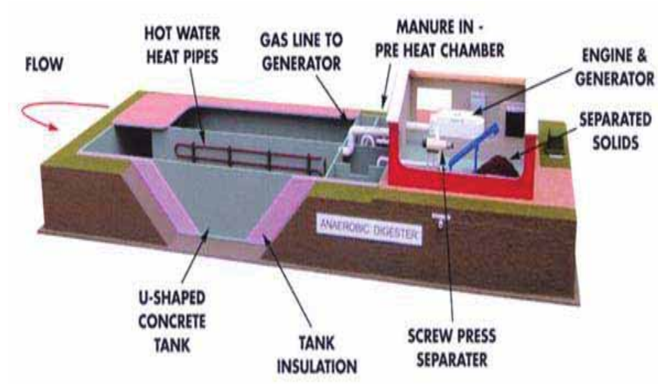
- Estimated total manure produced in the US per year, on animals range from 1.5-2 trillion pounds = 4.7 to 6.3 Gigawatts
- US population could produce 900 Megawatts
- Average size home(2200 sq feet)=720 kWh/month or 1kWh/ each hr
- Generator producing 1 Megawatt can supply 1000 homes
- A Gigawatt (I Million kilowatts) of power will supply 1 Million homes

TYPES

There are a few common types of anaerobic digesters. The most common farm digesters for farms are Open Lagoon, Membrane Covered Lagoon and Heated and Mixed Covered. Open Lagoon is a traditional method of digestion where part of the farm land is converted to a lagoon and waste is held for a period of time. This type of digester has odor and insect problems and need vary large land area. There are little to no operational costs other than final disposal and land can be cheap if the digester is placed in a rural area.

A Membrane Covered Lagoon is similar to an open lagoon in that it is a large pit. It is also the lowest cost to mitigate odor and insect issues. This system has a membrane covering the lagoon that harnesses the methane and control odor issues. Most membrane covered lagoons are designed to contain off gases to be fully utilized for energy and heat recovery. (5)(1)

Heated and Mixed Covered are based on the traditional open lagoon but use the technology of an insulated cover that drastically drops the lagoon size but there are limited examples and vendors because this system can be very unreliable.



Anaerobic digesters can be applied to urban areas. These types of systems include Plug Flow Digesters, Complete Mix and Hybrid Digesters, Fixed Film Digesters, and Upright Cylinder Digesters. All of these digesters are can be modular systems. The plug flow digester has a 20 day holding tank and manure is kept in a liquid state to pass as a "plug" through the vessel. This system lowers the surface area needed but operational costs are greater because the digester must always be heated. (7) There are also large capital costs at inception.

Complete Mix and Hybrid digesters are designed with similar material holding times as plug flow digesters. This system contains a series of tanks that waste passes through during this process. This type of digester begins to be a possible option for individual buildings because the size and shape of the digester can be modified to be incorporated into a building. This digester must also be continually heated but has the option of intermittent operation and is cleaner than previous digesters with a smaller footprint and easy gas production. (14)

Fixed Film digesters use tanks and plastic media to filter the manure form top to bottom. This technology requires well screened material to prevent plugging and is a better system for flushed material.

The newest technology is the Upright Cylinder Digester (UCD). This digester is the most compatible with a building because it can modulate to any shape or size. The UCD is a small diameter tall tank that lowers the time the waste processes in the digester by ¼ of a Plug Flow digester or a complete mix system. The modular tank has a fan that mixes the waste. This increases bacterial contact. This system is a modular approach and can be accommodated to any building system. This system is also mechanically simple compared to other systems so maintenance costs are minimal. This digester can also accommodate co-digestion with off/onsite organics.

Within the UCD digester there are a range of temperature systems. Thermophylic systems operate at a high temperature (50°C–60°C). The micro-organisms rapidly break down organic matter and produce large volumes of biogas. Quick breakdown of waste allows the digester volume to be smaller than other systems (average retention times in the range of 3–5 days). Greater insulation is necessary to maintain the optimum temperature range however more energy will be consumed in heating the system. These systems may be more sensitive to upsets due to temperature variations. (16)However, these systems are more effective in pathogen removal. Larger, centralized systems with excellent temperature control and the need for a higher level of pathogen removal will typically run at thermophylic temperatures. Heat exchangers used to pass the heat from the effluent to the influent are more efficient and economical at the higher temperatures. Mesophylic systems need a longer storage time (retention times of 15–20 days or more) in order for the lower temperature micro-organisms to breakdown organic matter (30°C–38°C). In general, these systems are reported to be more robust when considering temperature upsets. Smaller agricultural systems will operate in this temperature range. Psychrophylic (15°C–25°C) systems running in Quebec and Manitoba have been designed to operate in this temperature range. These systems are very stable and easy to manage. However net gas production and pathogen removal are expected to be lower than for other systems. (3)

Scale of Systems

• Farm-based
• These systems are typically designed for one farm's manure or for the manure from several nearby small farms. They are fairly low cost and often involve a lower level of control or complexity. Farm-based systems have been successfully operated throughout North America. Farm-based system at large farms may come closer to approximating centralized facilities.

• Centralized
• Centralized AD systems are found in Europe. Manure from many farms is hauled to a centralized facility operating with a high biosecurity hauling process. Off-farm materials, such as food processing wastes, are often added to boost gas production. Often the treated manure is transferred to remote field storages to allow for easier handling for land application.(1)

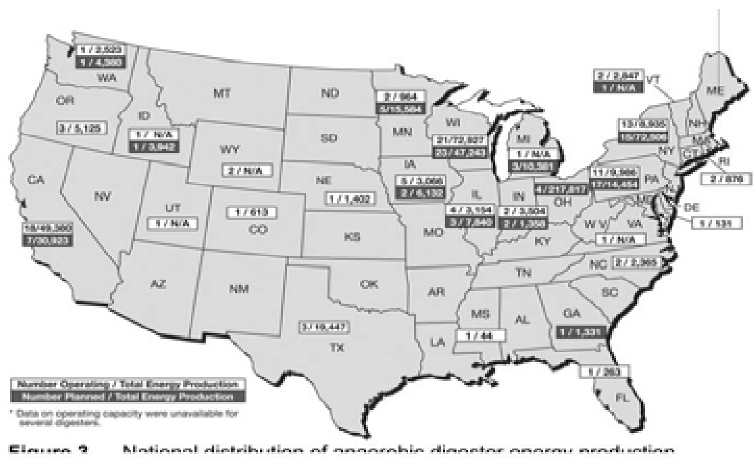
COST

A UCD anaerobic digester for an individual building does not exist at the current time for the commercial market. Thus we can not give an accurate cost to a system. However farm system on average take 8 to 10 years to reach financial payback.(14) In Europe modular UCD systems are being used as mass waste production plants.

Livestock producers can choose from a wide range of waste options provided by a variety of agricultural engineers, vendors, and equipment suppliersThe costs of these can vary greatly, in terms of both initial investment and annual operation and maintenanceFor example, the cost of a typical manure storage facility can range between $60 per Animal Unit (AU) for a typical pond to $300 per AU for an above-ground prefabricated tank. (An AU equals 1,000 pounds live animal weight, or approximately the weight of one beef
cow.) Similarly, an open-air conventional lined lagoon that combines both treatment and storage functions can range between $200 to $400 or more per AU, depending on annual rainfall and process water use at the facility.(4)

PAYBACK ANALYSIS A payback analysis was undertaken to determine the cost effectiveness of generating electricity from digester gas. The following assumptions form the basis of the analysis:

Electricity generated would be used at each wastewater treatment plant to offset energy purchased. Each generating unit would be operated at 90% utilization. Space is available at each wastewater treatment plant to house the generating unit. Heat from the generating unit would be recovered and used to heat the anaero-bic digester. A value of $6/mm BTU was assumed. A preliminary heat mass balance shows the heat recovered should be adequate to heat the digester. A detailed heat mass balance would be required at each facility prior to detailed design. Annual O&M for the microturbine was estimated to be $0.025/KWH and for the reciprocating engines $0.015/KWH. These figures were obtained from the respective manufacturers of this equipment and include gas conditioning O&M. Capital costs were obtained from Capstone and Caterpillar for the microturbine and reciprocating engines, respectively. Costs include the generating unit, gas treatment, compressor, heat recovery and installation.(12) Reciprocating



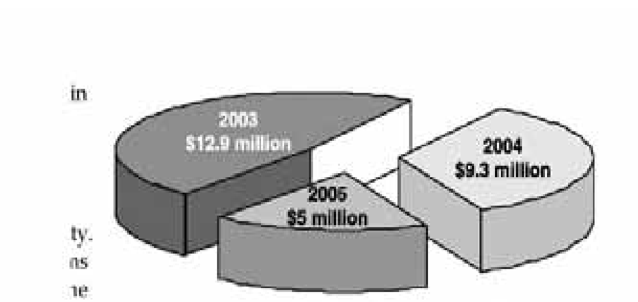


Figure 4. Annual funding for anaerobic digesters.

Figure 1. Trends in methane reduction and equivalent kilowatt-hours attributed per year to anaerobic digesters – 2000 through 2006.

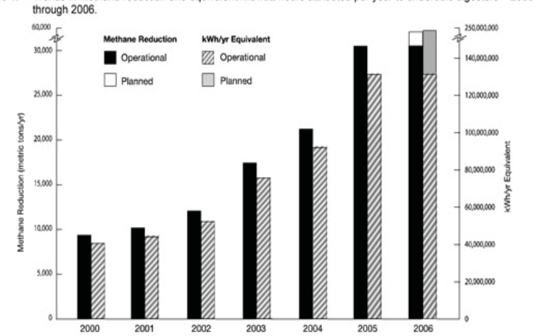
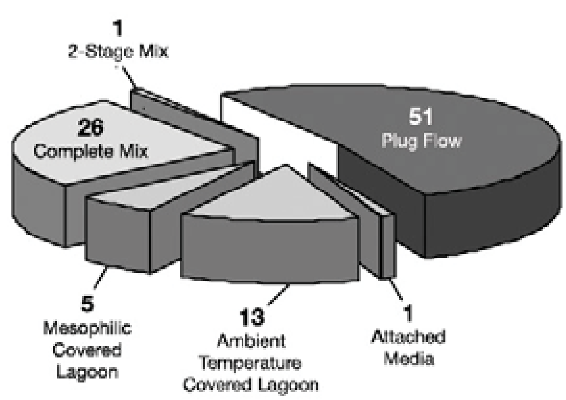


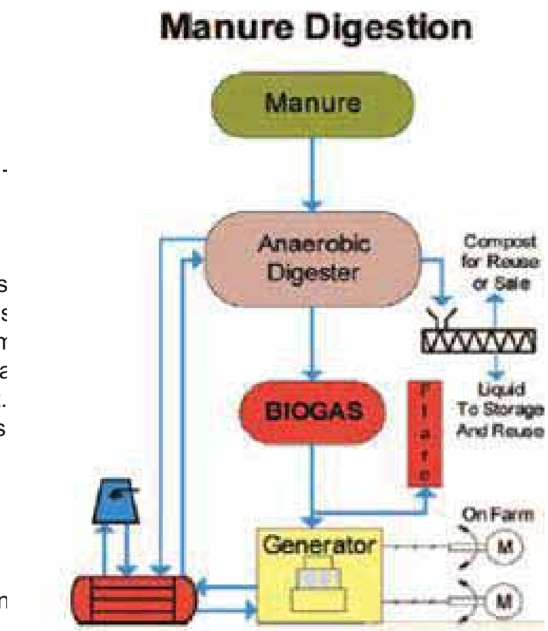
Figure 2. Operating anaerobic digesters by technology*.



*Includes digesters in start-up and construction stage.

(3)(5)(10)

engines were used for generators greater than 120KW. All others are based on microtur-bines. The payback calculation is based upon the following equation: Capital Cost of Cogeneration + Gas Handling Electricity Savings + Heat Recovery Value - O&M Costs to Cogenerate & Scrub Gas Payback was calculated at an electric rate savings at $0.04/KWH. Appendix C shows payback for different size generator options As expected, the payback time is shorter as more electricity is generated due to econom of scale. (9) The longest payback period wa 8 years at $0.04/KWH and one 30 KW unit. The shortest payback period was 4.8 years at $0.04/KWH and generating 613 KW.(8)



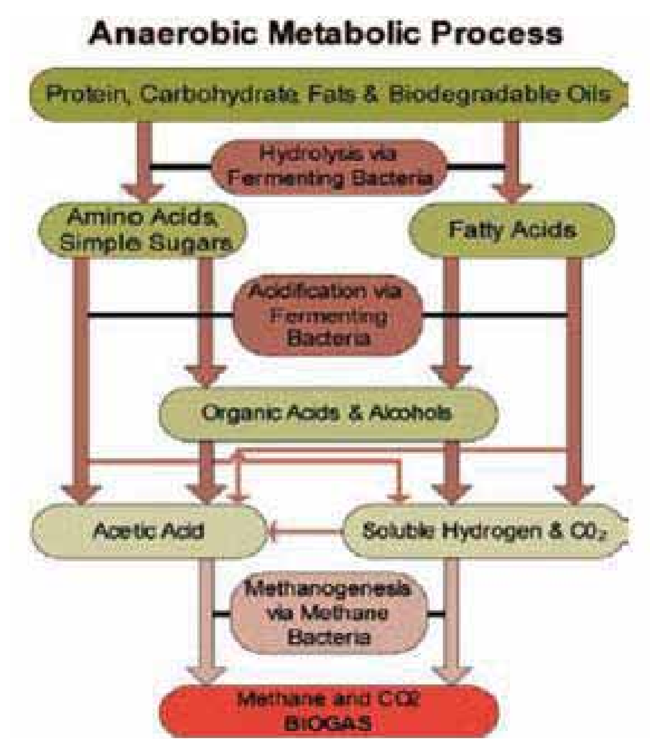
MAINTENANCE

The types of digesters suitable for an urban environment have maintenance costs that are higher than farm based systems. On average the digesters do not require more maintenance than a typical commercial boiler. The maintenance typically includes monitoring methane flow and odor control however UCD systems tend to have lower maintenance than other urban suitable systems.

PROCESS-How it works

Biogas:

- Bio-gas usually contains about 60 to 70 percent methane, 30 to 40 percent carbon dioxide, and other gases, including ammonia, hydrogen sulfide, noxious gases. It also is saturated with water vapor.
- The heat value of the raw gas at typical Colorado atmospheric pressures is about 400 to 600 Btu per cubic foot. In comparison, natural gas has a heat value of 850 Btu per cubic foot and gasoline contains approximately 120,000 Btu per gallon. Partial removal of the impurities may be required. This is not necessarily difficult, but it does complicate the system.(16)



The first step in anaerobic digestion is the decomposition (hydrolysis) of waste. This

step breaks down the organic material to usable-sized molecules such as sugars and amino acids. This is achieved by placing waste into the digester, which mixes the waste, adds air, water, and steam to break-down the waste. The digester is completely sealed to control the temperature, moisture content, and ensures no odor escapes.
The second step converts decomposed matter into fatty acids. The organic waste is now in a liquid that flows into a second digester and naturally occurring microbes break down the fatty acids to produce acetate and other simple alcohols. (9)
Finally, another set of microbes converts the alcohols into methane gas. The methane gas flows towards a double membrane storage tank where it is temporarily stored. From this storage, the biogas is conveyed to the gas engines, where it is converted into electricity.

LIFECYCLE

The LCC and LCA for UCD digesters is looked at from an energy production cycle. It is seen as one of the best options for handling waste products. (2)
The lifespan for a UCD system is fifty years though with good maintenance and upkeep this span could be extended by much more.

EMBODIED ENERGY

The embodied energy costs for anaerobic digestion systems are low. After the system is built all the materials that go into the systems are waste products.

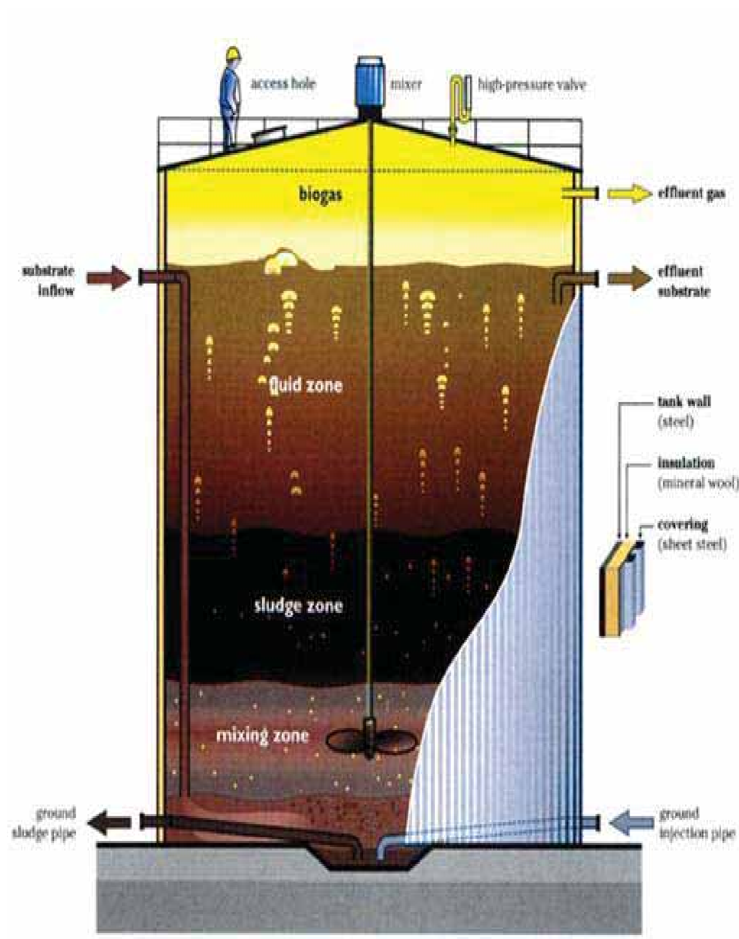
HEALTH

The major health benefit is reducing waste put into landfills as well as reducing and the amount of methane the atmosphere must absorb.

BENEFITS

Odor control. The effluent odor from anaerobic digesters is significantly less than odors from conventional manure management systems. Odor reduction using anaerobic digestion can be very cost-effective when compared to other alternatives such as aeration.

Greenhouse gas reduction. Conventional liquid and slurry manure management practices emit large amounts of methane, a greenhouse gas that contributes to global warming. Biogas recovery systems capture and combust methane, thus reducing greenhouse gas emissions. In addition, by off-setting energy that would otherwise be derived from fossil fuels, biogas recovery and use can help reduce overall quantities of carbon dioxide, another critical greenhouse gas.



■ Ammonia control. Ammonia emissions from livestock manures—especially emissions from anaerobic lagoons used in the treatment and storage of these manures—are a growing environmental concern. To control ammonia emissions, producers can cover manure storage tanks. Because gas handling is not required, the storage structures of anaerobic digester systems, which separate treatment and storage, are smaller and easier to cover than the larger structures of traditional systems.

■ Water quality protection. Anaerobic digestion provides several water quality benefits. When an anaerobic digester system, especially a covered lagoon, is properly managed, phosphorous and metals, such as copper and zinc, will settle out in the process cells, thus reducing phosphorous and metals loadings to surface waters when manure is land-applied. Digester systems, especially heated digesters, isolate and destroy diseasecausing organisms that might otherwise enter surface waters and pose a risk to human and animal health. Anaerobic digestion also helps protect ground water. Synthetic liners provide a high level of groundwater protection for manure management systems. These protective liners are a more affordable option with anaerobic digester systems than with conventional lagoons, because the multiple-cell design of anaerobic digesters requires less volume and, therefore, less lining material is needed. The concrete or steel tanks used in plug flow and complete mix digesters also effectively prevent untreated manure from reaching ground water.

Energy Balance

A properly designed and operated AD system can achieve better energy balance (taking emissions from transport operations into account) than many other forms of energy production. The energy balance relates to the amount of energy consumed in order to produce energy.

Reducing Greenhouse Gases

Methane is a powerful greenhouse. Current disposal practices for slurry and food residues cause methane to be released through natural processes. Anaerobic Digeser exploits the methane production process so that the methane can be used as a fuel. A well-managed anaerobic digester will aim to maximize methane generation, but not release any gas to the atmosphere reducing overall emissions.

Anaerobic Digestion provides an energy source with no net increase in atmospheric carbon. Using fossil fuels for energy production creates carbon dioxide which causes climate change, resulting in a warming of the planet. By replacing energy from fossil fuels, Anaerobic Digestion can reduce overall quantities of carbon dioxide in the atmosphere and reduce dangers of climate change and its potential impacts including sea level rise, storms, drought and flooding.

Reduce the Dependence on Fossil Fuels
The base material for anaerobic digestion is a renewable resource, and does not deplete finite fossil fuels. Energy generated through this process can help reduce the demand for fossil fuels (if used to replace energy from fossil fuels). The use of the fibre and liquor as a contribution to fertilizer regimes can in turn reduce fossil fuel consumption in the production of synthetic fertilizer.
Reduction of land and water pollution
Poor disposal of bio waste can cause land and ground water pollution. AD creates an integrated management system which reduces the likelihood of this happening, and reduces the likelihood of fines being imposed for such pollution.
Reduction of water processing plants
The use of an AD system in a building would greater reduce the demands of the building on the local water treatment facility and therefore allow for smaller water treatment centers to handle the same population base.
Reduction of grid based power needs.
The use of an AD system in a building would greater reduce the demands of the building on the local power plants facility and therefore allow for a smaller power

ANAEROBIC DIGESTION

Check List

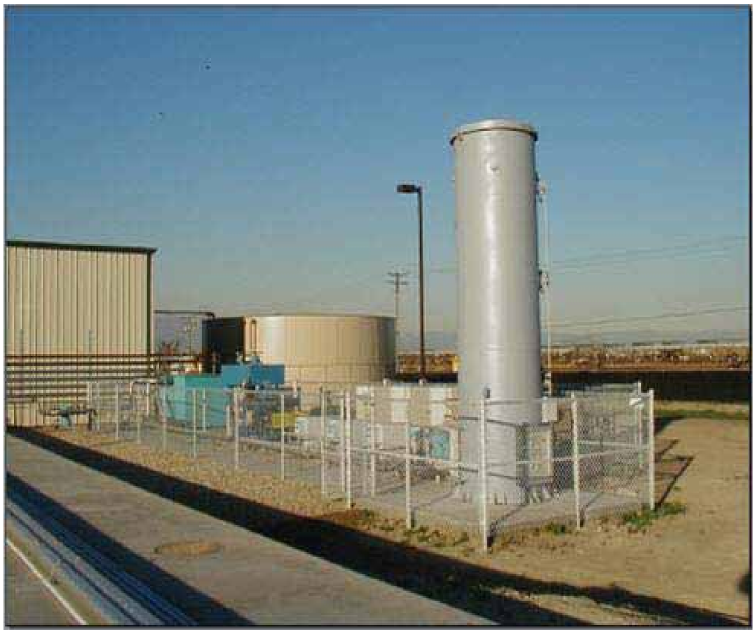
power generation system to handle the same population base.

DISADVANTAGES

Manufacturers
Currently there are no manufacturers producing individual building AD systems. The systems and technology currently in use in farming and in power production for an energy grid.
Building Codes and Laws
Currently all building codes in the United States do not allow for an internal onsite system of this type. In fact the water and waste management systems currently in place do not account for or except this type of system at all.
System Failure
If the system were to fail this would cause several problems, including the loss of material in the system. Concentrated methane leaks and odor problems can occur. Also if the system fails and certain conditions are not met all the material in the UCD will be ruined and require the system to be flushed and new material introduced into the UCD. This will also require the system to be started over.

FINAL ANALYSIS

Anaerobic Digestion with more research will prove to be the most efficient way of handling waste in general and is also a viable energy production method for our future. Though there are not currently systems that are directly made for individual building integration it is a possibility in the near future.



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(3) ANAEROBIC DIGESTER METHANE TO ENERGY A STATEWIDE ASSESSMENT Prepared "Thomas E. Vik" http://www.state.co.us/oemc/programs/agriculture/hog_wastes.htm

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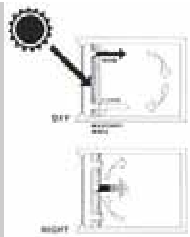
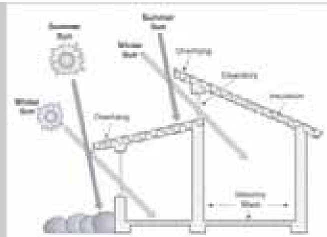
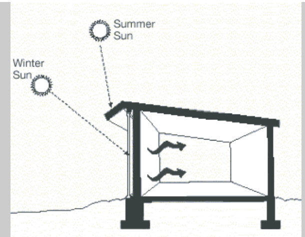
Passive Solar Cooling - Intro



(a) Trombe Wall Diagram



(b) Typical Direct Gain System



(c) Typical Trombe Wall System

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Passive Solar Cooling

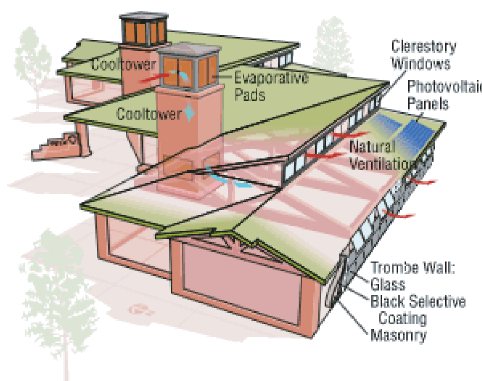
BASICS - The best approach to passively cool a building is by preventing it from gaining heat in the first place. Reducing high heat loads like lighting and appliances and using techniques to prevent the hot summer sun from entering the building are great places to start. In addition proper siting of the building, sizing of the thermal mass and selection of glazing materials are key in providing a good base for passive cooling techniques (Kachadorian, 26). In siting the building North and South elevation areas should be maximized, and shading should be provided that blocks summer sun on the East, South and West. These shading devices should not block summer breezes and shade trees should be placed on the West and South of your building (Schaeffer, 259).

Passive systems are those that use little to no energy in cooling a building. Small electrical draws to power small fans or servos is the only energy used in passive systems. Active systems, however, use pumps fans or other electrical equipment to transfer the sunlight into usable energy. In looking at passive systems evaporative coolers and earth cooling tubes are two ways to cool your building. The research into Computation Fluid Dynamics (CFD) is helping to maximize the usefulness of these technologies.

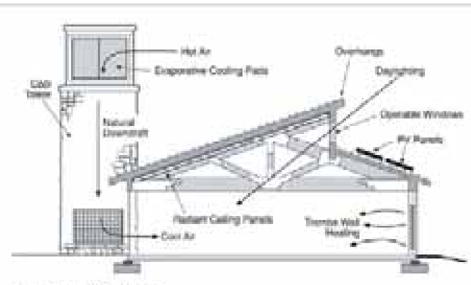
Other Technologies

SOLAR CHIMNEYS - At its most basic, a solar chimney consists of a stack, generally painted black. During the solar day, the chimney is heated and the air inside is warmed, creating an upraft of air in the chimney. This updraft draws air in through the bottom portion of the stack, which can be used to ventilate or cool the building.

The Zion National Park Visitor’s Center in Utah is a great example of a variation on the solar chimney. The Visitor’s Center uses a cooltower coupled with evaporative cooling at the top. This cooltower uses the opposite effect to release cool air through the building; by using evaporative cooling at the top of the stack, the cooled air falls down and exits at openings on the ground level.



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



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

PASSIVE
SOLAR
COOLING

LEED Credits:

Enery & Atmosphere
Indoor Environmental
Quality

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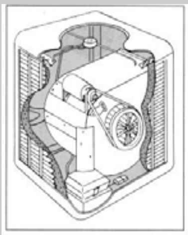
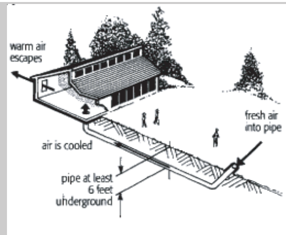
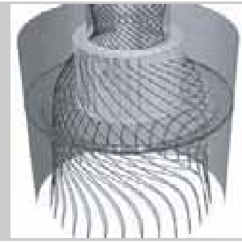
Passive Solar Cooling - Technologies



(f) Evaporative Cooler



(g) Open Loop Earth Cooling Tube



(h) CFD Turbine

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Technologies

EVAPORATIVE COOLERS - Evaporative cooling is the evaporation of a liquid into the surrounding air, which cools the object or liquid it comes into contact with. Evaporative cooling is what happens naturally to your skin when you perspire; your body is compensating for excessive heat through the evaporation of a liquid (sweat) from the top of your skin.

There are three types of evaporative cooling systems: direct systems, indirect systems, and two-Stage evaporative cooler systems. An evaporative cooler is a fan with moistened pads in front of it. Hot, dry outside air is drawn into the system through vents and as it passes through the pads the air is cooled through evaporation. It is then distributed through ducts throughout the building.

The pads are generally made from excelsior, or 'wood wool', which is a wood product made of aspen fibers. More modern materials, such as some plastics and melamine paper, are being used for cooler-pad media. However, wood absorbs some of the water, which allows the wood fibers to cool passing air to a lower temperature than some synthetic materials. The thickness of the cooling pads plays a large part in cooling efficiency, allowing longer air contact. For example, an eight-inch-thick pad will be more efficient than a one-inch-thick pad because of its increased interface.

The water used for wetting the pads is recirculated constantly and is controlled by a 'float' similar to your toilet where the sump must maintain a constant water level.

Two-Stage Evaporative Coolers: The first stage (indirect stage) involves pre-cooling the incoming air through evaporation on the outside using a heat exchanger. The second stage (direct stage) involves passing this pre-cooled air through wetted pads, creating evaporation and further cooling of the air. This air picks up less moisture through the process since cooler air cannot hold as much moisture as warm air. This air now contains 50-70% relative humidity, rather than 80%, making it more suited for climates with higher relative humidity.

EARTH COOLING TUBES - There are 2 types of systems for earth cooling tubes, Open Loop and Closed Loop. Both systems include the use of long underground tubes that allow air to pass through them. Open Loop systems draw the supply air to the building through these underground tubes. Closed Loop systems circulate the air that is already present within the building through these underground tubes. Within the tubes a thermal exchange occurs between the air and the ground. In the summer, heat is transferred to the ground and the air is cooled, in the winter heat is transferred from the ground and the air is warmed.

(i) Earth Cooling Tube about to be placed

CFD - Computational Fluid Dynamics (CFD) is one of the most exciting emerging design technologies for architects and engineers. With CFD, building designers have a tool to predict and quantify how a building will perform in terms of ventilation systems and thermal loads. This can be invaluable in designing passive climate systems for optimal results.

CFD software is becoming more and more refined. It is not hard to imagine CFD technology eventually being incorporated into building information management software as part of a comprehensive software tool.

PASSIVE
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COOLING

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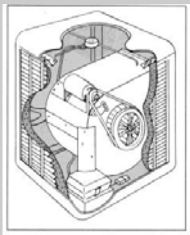

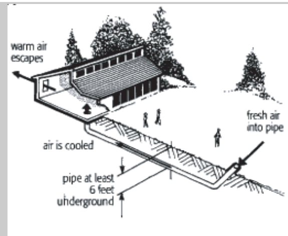

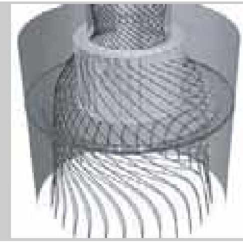

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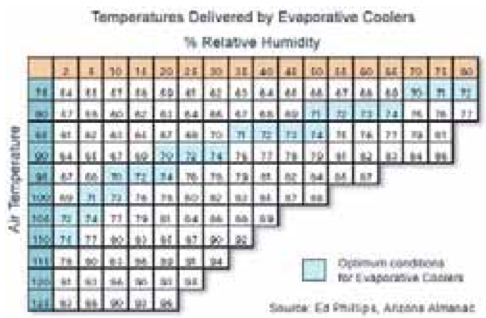
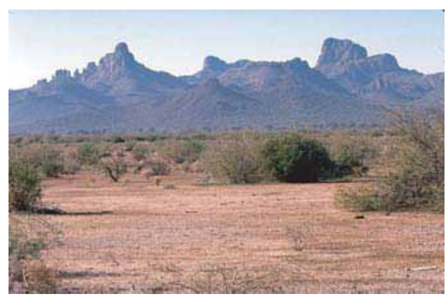
Advantages / Disadvantages

EVAPORATIVE COOLERS - The advantages to evaporative coolers, as opposed to standard air conditioning units, are plenty. Evaporative cooling units do not use or release ozone-depleting refrigerants, commonly found in standard air conditioning units (CFCs & HCFCs), into the atmosphere. These units also use about 1/4 of the energy and cost about 1/4 of the price to operate than standard AC Units. In addition to these benefits, many states offer cash rebates on your energy bills for installing, using and maintaining these systems. For example, in the state of Colorado Xcel Energy offers up to $200 rebate on a system that has an ISR (Industry Standard Rating) Air Flow Rating of at least 2,500 CFM (see bibliography for website). Utah offers up to a $500 rebate depending on type of system and if it is new or retrofitted, while the state of California offers a $300-$600 rebate depending on type of system, with a more efficient/larger system returning a larger rebate.

There are, however, some disadvantages to the system. For example, the system must have hot, dry air to work effectively with very little moisture in the air. This limits its effective use to areas such as the American southwest (Colorado, Utah, Arizona, etc.) Evaporative coolers often consume 3-15 gallons of water per day, which can be tough to naturally attain in these hot, dry climates. Evaporative coolers often use a fan to distribute the air, which means that it ceases to operate in a completely passive manner. However, many of these problems can be alleviated through other sustainable systems. For example, if the evaporative cooler was coupled with a PV array, the array could generate enough energy to run the fan. Also, to negate the water issue, water could be collected and stored to be used later to wet the cooling pads.



(j) Temperatures Delivered by Evaporative Coolers



(k) Evaporative coolers work much more effecively in hot, dry climates, such as the American southwest.

(l) Too much moisture in the air significantl reduces the ability of evaporative coolers to cool air properly.

PASSIVE
SOLAR
COOLING

LEED Credits:

Enery & Atmosphere
Indoor Environmental
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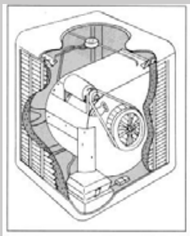

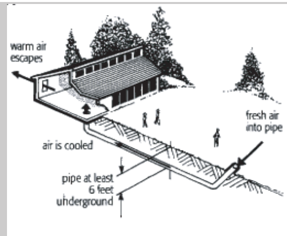

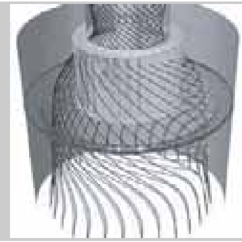

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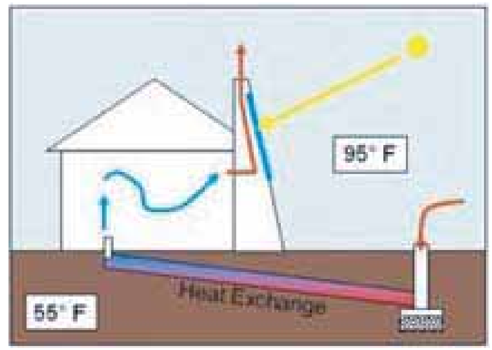
Advantages / Disadvantages

EARTH COOLING TUBES - The effectiveness of earth cooling tubes has long been argued. As a passive system the benefits could be great especially in open loop systems. Advantages to this technology are the constant subterranean temperature of the earth, the low cost of implementation of the system, and the ability to either replace or supplement current system technologies. Disadvantages have been the effectiveness of the technology in warmer more humid climates, the compencity for mold growth and other similar health concerns, and the true effectiveness of the system as a whole.

The biggest use of earth cooling tubes is to reduce the load on the HVAC equipment by beginning the thermal process of the supply air. Because of this thermal exchange the usefullness of earth cooling tubes is low in climates where the soil's temperature does not remain cool at a reasonable depth. However in areas where either it is feasible to bury pipes at great depths (underneath parking garages) or where the earth's temperature does remain constant there usefullness has not been exploited. A couple of reasons are the direct cost to gain ratio of using a system such as this and some of the more tangible issues such as mold growth and other health concerns.

Currogated piping is a technology that has great potential in increasing the use of earth cooling tubes. The use of corrugated pipes will help to increase the efficiency of the cooling tubes by providing more surface area to facilitate this heat transfer. The problem with corrugated piping has been the turbulence that develops in the tubes, which minimizes the flow of air through the pipe. With analysis tools such as CFD, researchers will be able to determine the optimum diameter and length of pipe to facilitate uninterrupted flow through the tubes.



(m) Solar Chimney with Earth Cooling Tubes

(n) LEED-NC Credit Checklist for Indoor Environmental Quality

(n) LEED-NC Credit Checklist for Energy & Atmosphere

(o) Example of plastic corrugated pipe

PASSIVE
SOLAR
COOLING

LEED Credits:

Enery & Atmosphere
Indoor Environmental Quality

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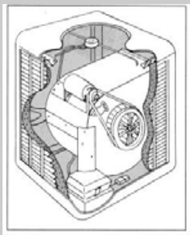

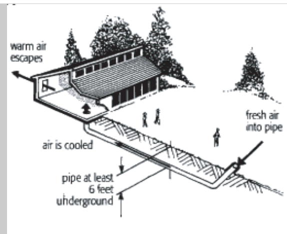

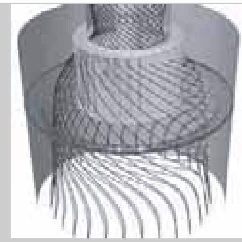

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Advantages / Disadvantages

CFD - The software on the market today - is leaps and bounds beyond what CFD analysis was capable of in the past, but there are still problems with achieving 100% reliability in the predictions. However, reliability levels above 95% are fairly standard, and users can only expect CFD software to become more and more refined.

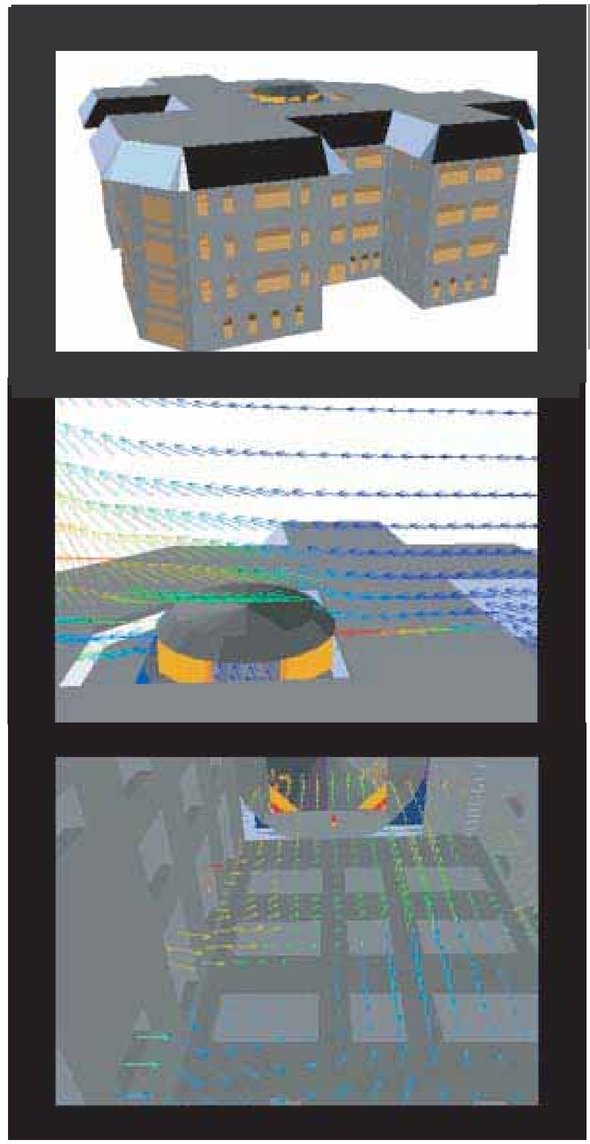
CFD-based predictions are never 100% reliable, because:

- the input data may involve too much guess-work or imprecision;
- the available computer power may be too small for high numerical accuracy (this is often the case);
- the scientific knowledge base may be inadequate (so is this).

The reliability is greater:

- for laminar flows rather than turbulent ones
- for single-phase flows rather than multi-phase flows.

Comparing the predictions of CFD to actual building performance is seldom done due to the high cost of the field tests required to validate the data. The assumptions designers make during the CFD analysis phase are also based on rules of thumb rather than actual building performance in terms of temperature boundary conditions, internal heat gains, and building services operation. However, as the rules of thumb become more accurate and case-specific, much of this discrepancy can be alleviated.



(p,q, & r) Examples of CFD modeling in a building

PASSIVE SOLAR COOLING

LEED Credits:

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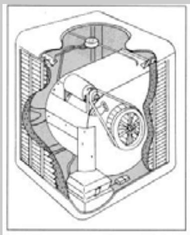
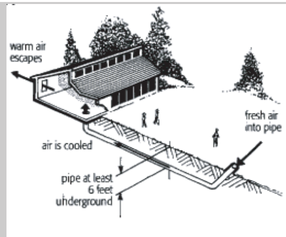
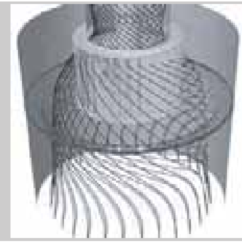






Details

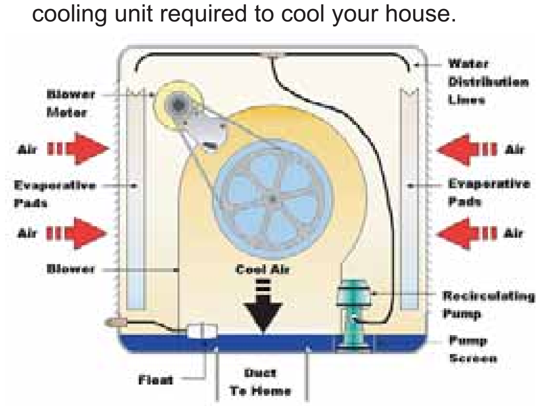
EVAPORATIVE COOLERS - Evaporative cooling systems are quite simple, with the maximum number of stages in the process at two (cooling and distribution of that cooled air throughout the building). This cuts down significantly on equipment and thus reduces the amount of maintenance required. Through this type of cooling process, the air is typically exchanged every 1-3 minutes, thus vastly increasing the indoor air quality (IAQ) of your building. Because it requires fresh air to circulate, these cooling systems allow for (and work better with) natural ventilation, unlike standard AC units which have to work harder to produce the same cool temperature if fresh, outside air is present in your building. Evaporative coolers can be very simple to install, especially when window sill applications are utilized, and they often use less duct work than standard HVAC systems to distribute the cool air.

Rule of Thumb:
Sizing your Evaporative Cooling Unit (formula):

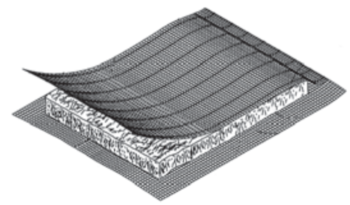
[Size of your house or building or room in Ft.3] / 2 = CFM rating

For example:
You have a 2,000 square ft house with 8 ft ceilings. How large of an evaporative cooling unit do you need (in CFM)?

(2,000 Ft.2) x (8 Ft.) = 16,000 Ft.3
(16,000 Ft.3)/ 2 = 8,000 CFM evaporative cooling unit required to cool your house.



(s) *Diagram of Evap. Cooler*

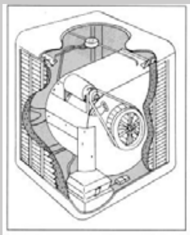


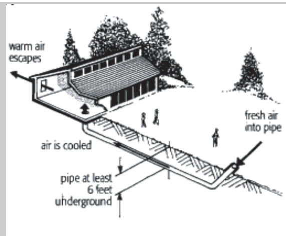
(t) Typical Cooling Pad

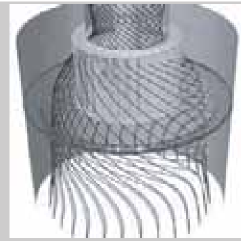
EARTH COOLING TUBES - Health issues that are involved with earth cooling tubes iinclude the ifestation of vermin and insects into the open loop systems. Also the potentially high RH (relative humidity) within earth cooling tubes provides a great breed ing ground for bacteria and mold.

Screens and filters must be placed at the mouth of these systems to prevent infesta tion problems. In order to combat the issue of moisture within the earth cooling tubes, the use of contrete tubing has increased. If the tubes are built out of concrete, the moisture gets transferred into the soil through the material itself. This reduces the RH inside the tubes and reduces the risks of mold growth. If mold happens to develop within the tubes, to prevent these mold spores from entering the building the air must be channeled through filters. By using CFD research we will be able to determine the proper placement and sizing of these filters to impede air flow as little as possible.

In commercial buildings the ability to use larger concrete pipes to serve as the earth cooling tubes not only decreases moisture buildup, but allows for easier maintenance on the system itself. With larger diameter pipes, cleaning crews have an easier time of periodically servicing the system. This not only decreases the health risks but the larger pipes can provide a larger amount of supply air to help facilitate deisred air change levels.







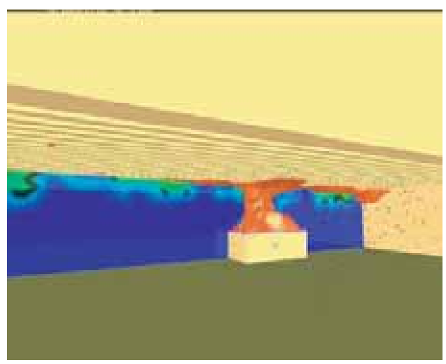
Details

CFD - Furthermore, CFD analysis has been used to accurately predict the spread of smoke and toxins within and without a building, leading to much greater life safety predictions for new and existing buildings. It is also used to show how typically shunned building types – such as double-skinned and naturally ventilated structures – can be built to be just as safe as more traditional approaches, which should start to alter building codes to allow for more naturally ventilated building types.

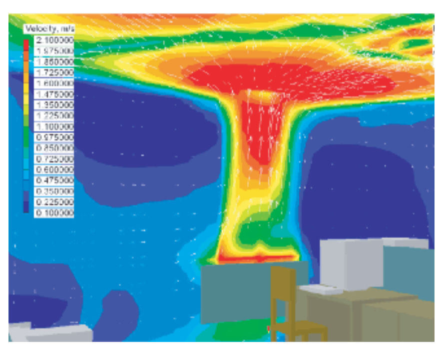
Virtually no information exists on the behavior of a double-skin façade in case of a fire. Usually, for a building with a multistory double-skin façade, smoke from a fire room escaping through the inner façade into the intermediate space between the two skins may accumulate and spread horizontally and/or vertically to other rooms that have openings connected to the intermediate space for the purpose of natural ventilation.

You can use a double-skin façade for smoke control as well as for natural ventilation. It is proved that smoke spread can be prevented with suitable arrangement of openings. Therefore, natural ventilation and smoke control can be realized through one system. Reduced-scale model experiments and CFD analysis were carried out in this research.

In a naturally ventilated building, there are openings with flow paths throughout the whole building, and when a fire occurs, the flow paths for natural ventilation also become paths for smoke to spread to other, non-fire spaces. This is always pointed out as a weakness of naturally ventilated buildings. However, stack ventilation and smoke movement are both driven by the stack effect, which offers us the possibility of using one system to handle these two problems. It has been proven that for a naturally ventilated atrium with a solar chimney on top of the atrium, natural ventilation and smoke control can be realized through the same system.



(u) CFD analysis of a car fire in a parking structure



(v) CFD analysis of a desk fire in an office

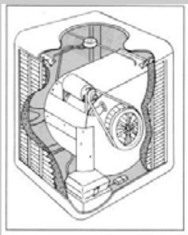
PASSIVE SOLAR COOLING

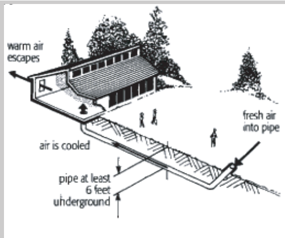
LEED Credits:

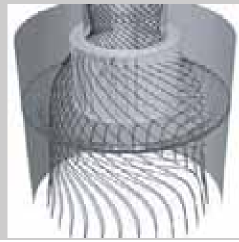
Enery & Atmosphere
Indoor Environmental Quality

Group C1

Passive Solar Cooling Combining Technologies







Cross Technologies

The passive benefits of the earth cooling tubes, evaporative coolers and other passive systems can be maximized with CFD predictions to create the sort of climate gains in buildings unimaginable before CFD technology became as powerful as it is today.

Earth cooling tubes are best used when the air entering the tubes is conditioned somewhat.
If the thermal properties of the supply air can be made more amenable (either warmed in the winter or cooled in the summer) before it enters the bulding, then HVAC systems can be downsized and the energy used can be reduced.
By utilizing cooling tubes, one can directly impact evaporative coolers. CFD prediction tools become almost imperative when maximizing passive systems.

Both the earth cooling tubes and the evaporative coolers use natural resources such as prevailing winds and building siting to create airflow, while active systems utilize pumps or fans.

-

With CFD analysis tools, the proper technique can be determined to maximize the amount of air that can be drawn through the tubes and the maximum benefit of these systems can be determined.

Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

final analysis

Passive Solar Cooling

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Pictures:

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(t) http://upload.wikimedia.org/wikipedia/en/8/88/Excelsior.png
(u) http://www.semf.com.au/images/davey01_0974.jpg
(v) http://www.eere.energy.gov/buildings/energyplus/images/hevacomp_cfd.gif

PASSIVE SOLAR COOLING

LEED Credits:

Enery & Atmosphere
Indoor Environmental Quality

Group C1

Building Mounted Wind Turbines

"Through a combination of new-build with specifically designed wind energy devices and retrofitting of (preferably certified) turbines on existing buildings, it is estimated that the aggregated annual energy production by 2020 from wind turbines in the built environment could be in the range of 1.7-5.0 TWh."(4)

Mounting Type Designations

Building Integrated Wind Turbines (BIWT): Building integrated wind turbines are turbines capable of working close to buildings and exploiting where possible any augmentation that the building causes to the local wind flow. They can be supported independently to the building but will either be accounted for, or be incorporated within, the building design.

Building Mounted Wind Turbines (BUWT): Building mounted wind turbines are physically linked to the building structure. The building is effectively being used as a tower to place the turbine in a desirable wind flow (e.g. on top of a tower block). Whatever the type of building mounted wind turbine employed, the structure must be able to support the turbine both in terms of loads and within noise and vibration constraints.

Building Augmented Wind Turbines (BAWT): Where building mounted wind turbines are integrated in such a way that the building is used to deliberately alter and augment the flow into a turbine. For retrofit applications BAWT's can only be positioned to exploit any augmentation afforded by the existing building. For new build applications the building could be specifically designed to augment the flow through the turbines. The building design may require relatively minor modification of the building shape or the use of rather complex 3-D sculpting of the shape of the building.

Utility- Wind Farm

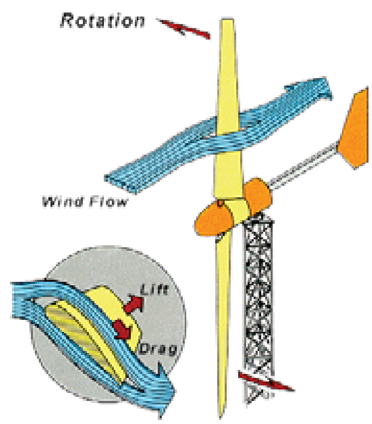
BIWT

BUWT

BAWT

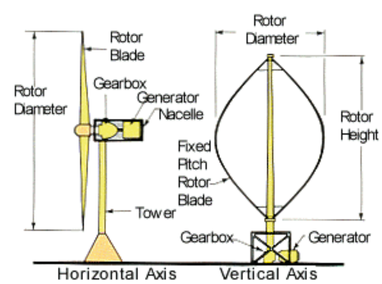
Horizontal-Axis Wind Turbine (HAWT)

A wind turbine in which the axis of the rotor's rotation is parallel to the wind stream and the ground. All grid-connected commercial wind turbines today are built with a propeller-type rotor on a horizontal axis (i.e. a horizontal main shaft). Most horizontal axis turbines built today are two- or three-bladed, although some have fewer or more blades. The purpose of the rotor is to convert the linear motion of the wind into rotational energy that can be used to drive a generator.



Vertical-Axis Wind Turbine (VAWT)

A type of wind turbine in which the axis of rotation is perpendicular to the wind stream and the ground. VAWTs work somewhat like a classical water wheel in which water arrives at a right angle (perpendicular) to the rotational axis (shaft) of the water wheel.



BUWT DEFINITIONS & METHODS

LEED: Energy & Atmosphere, Credit 2

Group B1

Energy in Wind

The first step in understanding wind turbines potential has to do with knowing how much energy can actually be harvested from the wind. Here is a theoretical formula that can help figure out the actual energy potential at any site being studied for wind energy harvesting.

$P_w = 0.5\rho Av$ where P_w = power in the wind (W), ρ = air density (kg/m^3), v = wind speed (m/s), A = swept area of rotor (m^2). The power in the wind increases with the cube of the wind speed, which explains why wind turbines tend to be located at relatively windy sites and the trend towards increased tower height to raise the turbine higher into the air stream. Since the power is also proportional to the swept area, the mean diameter of rotors has also been steadily increasing. (4)

Turbine Power Coefficient

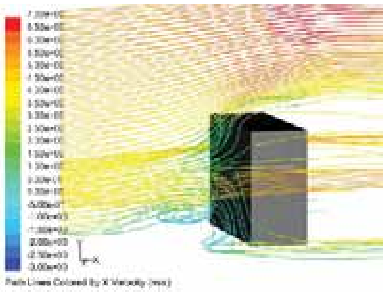
Power produced by a turbine and the power coefficient, C_P The coefficient of power, is the ratio of power from a turbine (P_T) to the power available in the wind and therefore indicates how effective a turbine is at extracting power.

$C_P = P_T / 0.5PAv_1^3$ where C_P for a particular turbine varies with the ratio of rotor speed to wind speed. The ratio of the speed of the rotor tip to the wind speed is called the tip speed ratio, TSR, or, more commonly, λ. A wind turbine is only able to remove some of the power available in the wind because the air needs to continue to pass through the turbine for it to operate, limiting the kinetic energy available for extraction. Using actuator disc theory the theoretical (or Betz) maximum limit on the fraction of power that can be removed from the wind by a non-augmented wind turbine is 16/27 = 0.593 (59.3 %). (4)

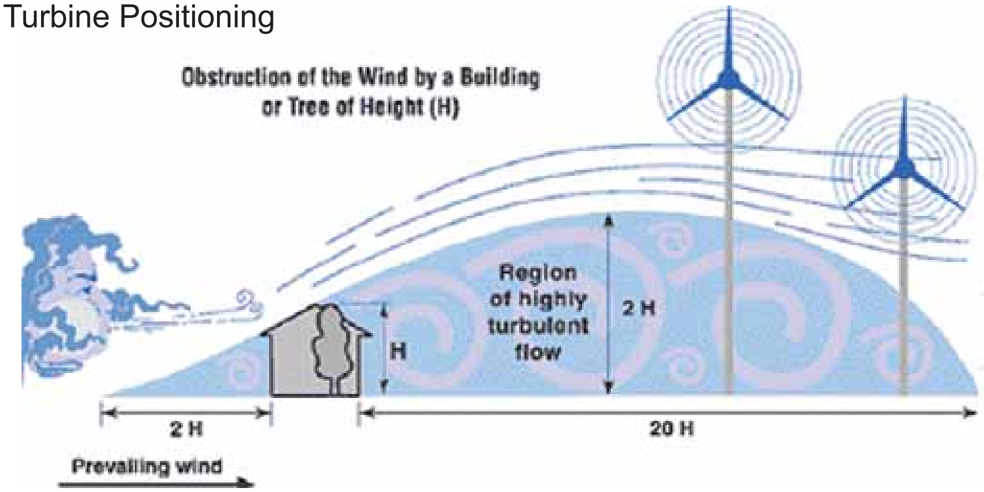
Guidlines For Placing Turbines

To place the turbine at a distance from any obstacle (building etc) of at least ten times the height of the obstacle; or on a tower that is at least twice that height. This avoids locations with excessive gustiness or turbulence, since they will reduce the output from a wind turbine and lead to undue wear and strain on component parts.(2)

Skewed Airflow



Turbine Positioning



Cost

The cost of a wind system has two components: initial installation costs and operating expenses. The initial installation cost includes the purchase price of the complete system (including tower, wiring, utility interconnection or battery storage equipment, power conditioning unit, etc.) plus delivery and installation charges, professional fees and sales tax.

The total installation cost can be expressed as a function of the wind system's rated electrical capacity. A grid-connected residential-scale system (1-10 kW) generally costs between $2,400 and $3,000 per installed kilowatt. That's $24,000-$30,000 for a 10 kW system. A medium-scale, commercial system (10-100 kW) is more cost-effective, costing between $1,500 and $2,500 per kilowatt. Large-scale systems of greater than l00 kW cost in the range of $1,000 to $2,000 per kilowatt, with the lowest costs achieved when multiple units are installed at one location. In general, cost rates decrease as machine capacity increases. For exact figures applicable to you, contact a manufacturer or dealer.

The other cost component, operating expenses, is incurred over the lifetime of the wind system. Operating costs include maintenance and service, insurance and any applicable taxes. A rule of thumb estimate for annual operating expenses is 2% to 3% of the initial system cost. Another estimate is based on the system's energy production and is equivalent 1 to 2 cents per kWh of output (13).

Check List

definitions

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Payback Period

Cost of Installation and Startup:
Residential 5 kW system = $15,000
Residential 50 kW system = $100,000

Annual Cost Savings in Utilities:
Residential $0.06/kWh x 10,000 kWh = $600
Commercial $0.06/kWh x 100,000 kWh = $6,000

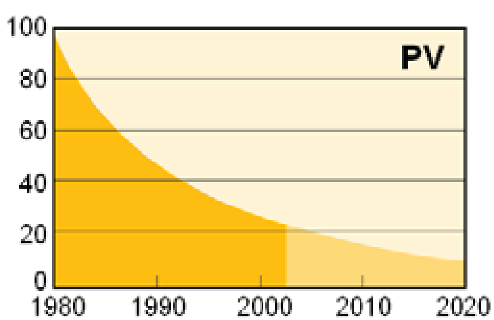
Annual Operating Costs:
Residential $0.01/kWh x 10,000 kWh = $100
Commercial $0.01/kWh x 100,000 kWh = $1,000

Residential Payback Period:
$15,000/($600 - $100) = $15,000/$500 - 30 years

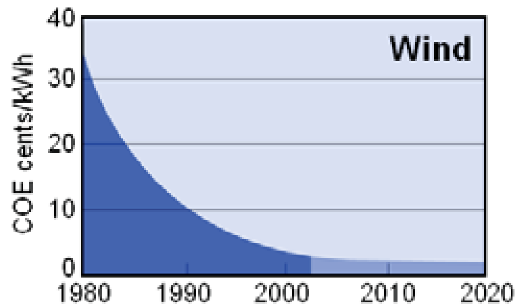
Commercial Payback Period:
$100,000/($6,000 - $1,000) = $100,000/$5,000 - 20 years (13)

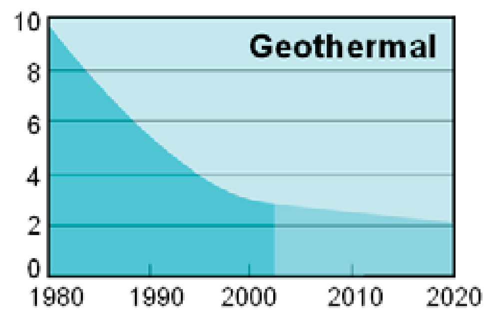
Potential For Price Reduction

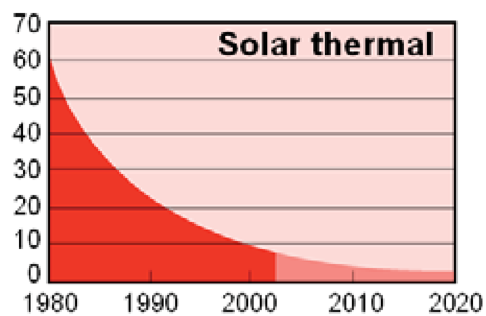
Conventional (large) onshore wind energy continues to fall in price and is forecast by Milborrow to be the cheapest option for electricity generation by 2020, even without taking external costs into consideration. AWEA has also identified further technical improvements which could be made to small turbines. The performance of small turbines can be expected to improve and with it their cost effectiveness. BUWTs can expect to benefit from these falling trends. The main driver for BUWT cost reduction will be mass production supplemented by design improvements and industry maturity. (9)

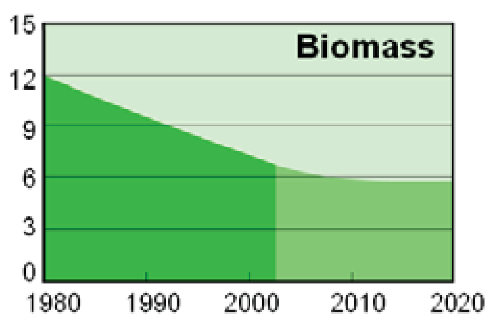


Cents/kWh in constant $2000









BUWT
COST
TRENDS

**LEED:
Energy &
Atmosphere,
Credit 2**

Group B1

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BUWT
COST
ESTIMATES

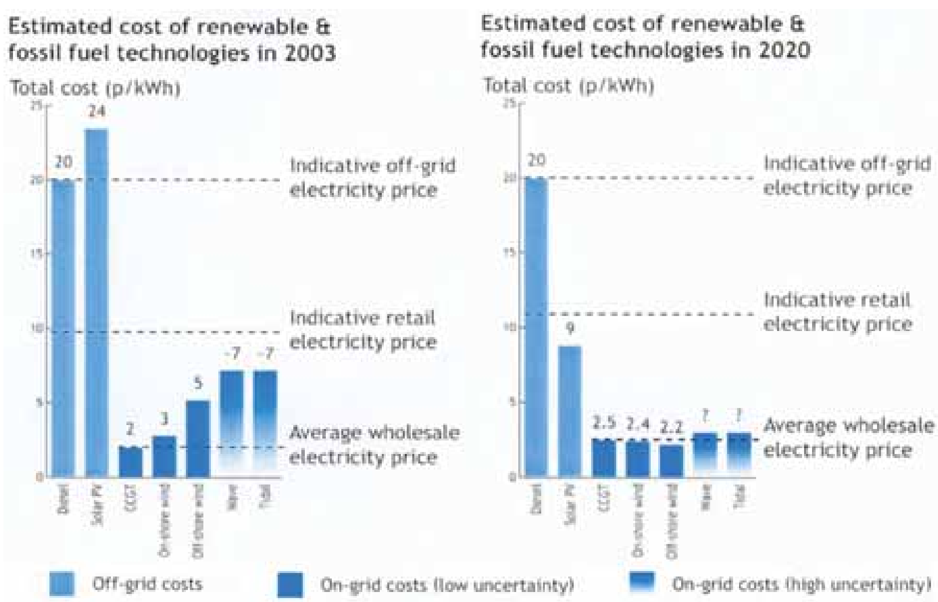
LEED:
Energy & Atmosphere, Credit 2

Group B1

Future Cost Estimates:

The Carbon Trust's report Building Options for UK Renewable Energy surveyed current prices and price predictions to 2020 for on-shore and off-shore wind. The report observed that large on-shore wind is close to being cost competitive today and is likely to be a major contributor to the build up of renewable power capacity over the next ten years. The energy balance/pay back period of wind energy is favourable compared with competing technologies, having been calculated for a large wind turbine to be 1 to 2 months. The CO_2 emitted as during a turbine's construction is related to the energy consumed and thus any CO_2 emission from construction activities is also soon recouped.

Graphs below show that large on-shore wind currently costs 3 pounds/kWh and is forecast to fall to 2.4 p/kWh by 2020. Off-shore wind currently costs 5 p/kWh, but is forecast to be even cheaper than on-shore wind by 2020 at 2.2 p/kWh. (4)



Potential CO_2 Emissions Savings

The overall net potential energy production and hence carbon dioxide emissions savings from BUWTs depends on manufacture and installation rates and the distribution of installations relative to the available wind resource. The baseline net 1% target for retrofitting BUWTs in the domestic sector represents manufacture and installation of turbines on 1% of domestic buildings, i.e. around 250,000 separate units. The 1.5% baseline target for non-domestic buildings represents around 25,000 installations of 20-100 kW units. Finally, the new-build penetration of 5% represents around 7,500 installations per year. Assuming an initial domestic retrofit market of 1250 installations in 2005 and a market growth rate of 30%, the baseline target penetration for domestic properties of 250,000 installations could be reached by 2020. The difference in energy capture and carbon dioxide emissions savings assuming that the installations are concentrated in 4 m/s or 5 m/s wind speed areas. By 2020, these installations could be achieving an annual energy production in the range 1.7-5.0 TWh, depending on local wind speeds, which translates into annual carbon dioxide savings in the range 0.75-2.2 Mt CO_2. In this case, the cumulative carbon dioxide emissions savings to 2020 would be in the range 4.5-13 Mt CO_2. (4)

Making a Decision

1. Evaluating Energy Requirements

The easiest way to determine your present energy usage is to consult all your fuel bills for the previous year. Distinguish between your use of electricity, oil, natural gas and any other fuel that might be reduced or replaced by a wind system. Note how your consumption varies by the month or season so that your energy use pattern can be compared to the availability of winds in your area. Although the fuel bills will not indicate how your energy usage varies with time of day, you should determine this in at least a rough sense to compare with wind availability. When is it the greatest? When is it the least?

2. Evaluating Energy-Efficiency Measures and Other Energy Alternatives

Before considering a wind turbine, you should have already applied sound energy-efficiency measures to your home, farm or business. Doing this will provide a double benefit, because you may not need as large and expensive a wind turbine as you might have thought. You may even be happy enough with your fuel savings to dismiss any further thoughts of buying a wind turbine.

On the other hand, you already may have taken several steps toward energy-efficiency, and the results of your economic evaluation of a wind turbine may prompt you to consider alternative ways of cutting fuel costs. Potentially viable options include solar energy systems, wood stoves and ground source heat pumps. Remaining with your present energy supplier could even be the best buy. Whatever your final decision, it should be based on sound economic principles and be compatible with your energy needs and lifestyle.

3. Evaluating Legal, Social and Environmental Issues

A survey of these issues is crucial to your decision-making, because certain issues can alter or even end your plans for a wind turbine. In general, rural areas will be least affected by these issues.

Contact the local zoning board, town clerk, or building inspector to identify applicable zoning ordinances and building permit requirements. Liability coverage and insurance needs should be discussed with an insurance agent. To avoid unforeseen public objections to the sight of a wind turbine in the neighborhood, discuss your intentions with neighbors. Obtain a title search to determine if prior agreements or easements exist which would prevent a wind turbine from being installed on your property.

4. Evaluating Wind Resources

Taking wind measurements for at least three months, and preferably a year or longer, is the best way to determine your wind conditions, especially if the data is also compared with those collected at a nearby IEC wind monitoring station. The necessary instruments can be purchased, rented or provided as part of a site evaluation study performed by a hired consultant or wind turbine dealer. A wind turbine site should experience wind speeds averaging no less than 12 mph, for economic viability. This average wind speed is required for most applications.

Before investing in measurements, however, decide if your site has the potential for having sufficient winds. Consult the wind index and also evaluate your site's elevation relative to the surrounding terrain and its access to the prevailing winds. Look at vegetative indicators. Remember that the power in the wind is a function of the cube of the speed. A 10% error in a wind speed estimate can mean a 33% error in a wind power calculation.

5. Determining Wind System Application

If you have already decided what a wind turbine will provide (electricity, for example), then you should next determine an appropriate machine size, or generating capacity.As a rule of thumb, a wind turbine should be sized to supply anywhere between 25 and

Making a Decision (Continued)

75% of your electrical demand. How much you are willing to spend on a system also will affect size selection.

If you have not yet decided what fuel source to displace, the previous steps should give you a clue. Try to match fuel consumption to wind availability. Seasonal winds are strongest in winter and early spring, and daily winds usually peak during the afternoon. If you are considering storing the electricity, as with batteries, then the daily variation in winds is less important.

Most people choose electricity as the wind turbine's product. Interconnection of the wind system with the utility grid eliminates the need for separate storage and provides the convenience of unlimited back-up power from an existing energy source. If you are only looking for alternative energy sources for hot water or space heating, there are other alternatives that should be considered for their practicality and cost-effectiveness. Active and passive solar systems, and wood stoves or furnaces might be better suited for such heating needs.

6. Shopping for a Wind System

Once you have decided how wind energy will work for you, you should examine the wind turbine products and accessories available on the market. If you haven't already, this is the time to contact one or more dealers to discuss your particular interests and get preliminary cost estimates. Choosing a good wind dealer is probably just as important as selecting a good wind system, because most dealers service what they sell. Dealers should provide you with references. Don't hesitate to demand excellence. You should be as particular about service and maintenance of your wind machine as you are for your automobile.

As you narrow your choices to just a few machines, compare wind turbine warran ties and note differences between those provided by the manufacturer and those offered by the dealer. Inquire whether the dealer's warranty is transferable or assumable by the manufacturer should the dealer go out of business. Compare the maintenance requirements of machines. Higher maintenance means higher annual costs.

7. Determine the Requirements for Utility Interconnection

If you plan to interconnect the wind system with the utility's power lines, you must first contact the local utility office. The utility in turn should provide you with a written description of its costs and conditions involved with interconnection, such as double-metering. Determine the need for safety and power conditioning devices, additional monthly service and demand charges, buy-back rates and electrical inspection of the installation. Be prepared to submit a detailed schematic diagram of the planned wind system.

8. Evaluating Wind System Economics

This is the time to evaluate the financial consequences of your pending decision. The initial costs and annual expenses of wind turbine ownership must be weighed against the benefits of long-term fuel cost savings. Wind Energy Economics discusses the variety of costs and savings pertinent to you. Most of them can be incorporated into the simple pay-back method of economic analysis to determine the pay-back period of your investment and the cost per kilowatt-hour of wind turbine-generated electricity.

Remember that wind energy systems qualify for a 1.5 cents per kWh energy production Federal tax credit for energy sold during the first 10 years of operation if the system is placed in service before December 2001. Additionally, the Iowa Energy Center's Alternate Energy Revolving Loan Program may help to offset start-up costs. (14)

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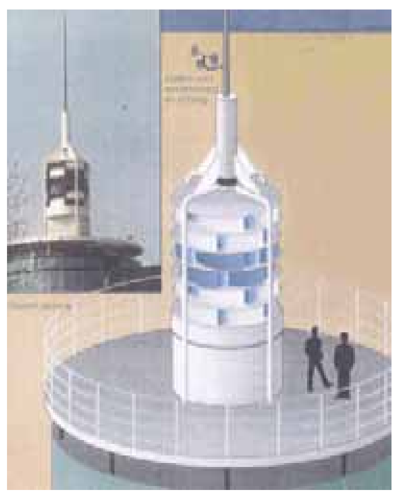
Concerns

Concern by some Small Wind manufacturers and practitioners: The founder of the US company Bergey turbines, Mike Bergey, does not recommend mounting turbines on buildings and wishes “people would stop asking us about mounting turbines on buildings”. Bergey turbines have been mounted on the Green Building in Dublin and encountered problems: the blades cracked – probably due to turbulence loading – and were replaced with new ones by Proven. This highlights the imperative need for BUWTs to be designed and tested to be intrinsically robust for high wind shear and turbulent environments. Charlie Robb of Element Engineering advises that wind turbines should NEVER be mounted on buildings because of:

- Likely very poor performance due to turbulence.
- Transmitted noise through building structures.
- Little thought is ever given to building structural issues.
- Most importantly: ANY wind turbine can break down for an unexpected reason whether properly maintained or not, and sometimes the failure can be catastrophic. It is not possible to make an unguarded rotating machine completely safe in the event of a catastrophic failure. If a building-mounted wind turbine falls down or disintegrates there is a serious risk to people and property. (However, it should be pointed out that rotating fans, for applications such as air conditioning, are already often mounted on buildings within suitably designed enclosures and with appropriate safety control features.)
- Because of this; fitting a turbine to a building is likely to increase the building’s insurance premium. This could be high in the early years of development of this technology as fitting turbines to buildings presents a largely unknown risk. (4)

Point of Reference

Morey Wolfson, an energy consultant also warns that a person interested in purchasing wind turbines should be sure to receive hard numbers from the manufacturers. The information given to a purchaser should not be given by a company on a “we believe” or a “our calculations show” manner. In other words be sure that the numbers that they give you should not be inflated for marketing purposes.(15)



BUWT CONCERNS

LEED: Energy & Atmosphere, Credit 2

Group B1

FINAL ANALYSIS

Architects such as Norman Foster and Skidmore, Owings & Merrill LLP have begun conceptually designing BAWT's which harness and funnel winds into turbines attached directly to the structure of a building. These efforts negate the notion that little structural design is put into mounting turbines on structures. The benefits of designing a turbine into the form of a building gives the opportunity to catch and use the turbulent wind flows created around buildings specifically at the rooflines. By placing turbines within the building structure the idea is that the vibration and noise issues will be lessened as well as moving the turbines high in the air hopefully away from obstruction.

In conclusion, Building Mounted Turbines seem very feasible in the future, however current technology does not have all the answers. With research teams such as Imperial College and the National Wind Technology Center great strides are being taken and manufacturers are starting to research and develop new BUWT technologies. Designers are starting to exploit this new technology as not only an eye catching style of design, but also providing an example of how designers can start taking steps to improve our buildings energy efficiency. Although there are many concerns with wind power, it is defiantly advancing at an exponential rate and will continue to do so making it more economical, competitive and attractive in the future. As more research is completed and designs improved building mounted wind turbines will definitely be a priceless technology incorporated into our future buildings reducing the need for fossil fuel energy in the future.

"Although a few small conventional wind turbines have been mounted to buildings in the past, the year 2004 saw the emergence of specifically marketed BUWT technology. A thorough search to locate all BUWT technologies, both past and present, was undertaken. It is noteworthy that manufacturers in many countries were contacted, including the UK, The Netherlands, USA, Germany, Finland, Canada, Italy, Japan, France, Czech Republic, New Zealand, Mexico, and Denmark In total 41 organizations were identified as having a BUWT concept under development with 13 claiming to have commercial turbines already in operation." (4)

BUWT
FINAL
ANALYSIS

**LEED:
Energy &
Atmosphere,
Credit 2**

Group B1

Small Wind Turbine Vendors:

Abundant Renewable Energy
22700 NE Mountain Top Road
Newberg, Oregon 97132, USA
T: 503.538.8298
F: 503.538.8782
www.abundantre.com

Aerotecture International, Inc.
2035 South Racine Avenue
Chicago, IL 60608
T: 312.829.3240
F: 312.829.3241
www.aerotecture.com

Bergey Windpower Co.
2200 Industrial Blvd.
Norman, Ok 73069 USA
T: 405.364.4212
F: 405.364.2078
www.bergey.com

Energy Maintenance Service
129 Main Avenue
PO Box 158
Gary, SD 57237
T: 605.272.5398
F: 605.272.5402
www.energyms.com

Entegrity Wind Systems
PO Box 832
Charlottetown, PE C1A 7L9
T: 902.368.7171
www.entegritywind.com

Lorax Energy
4 Airport Road
Block Island, RI 02807
T: 401.466.2883
F: 401.466.2909
www.lorax-energy.com

Northern Power Systems
Headquarters:
182 Mad River Park
Waitsfield, VT 05673
T: 802.496.2955
F: 802.496.2953
www.northernpower.com

Solar Wind Works
P.O. Box 2511
Truckee, CA 96160 USA
T: 530.582.4503
F: 530.582.4603
www.solarwindworks.com

Southwest Windpower Co.
1801 W. Route 66
Flagstaff, AZ 86001 USA
T: 928.779.9463
F: 928.779.1485
www.windenergy.com

Wind Turbine Industries Corp.
16801 Industrial Circle S.E.
Prior Lake, Minnesota 55372 USA
T: 952.447.6064
F: 952.447.6050
www.windturbine.net

Large Wind Turbine Vendors:

USA

GE Wind Energy
www.gepower.com

The Wind Turbine Company
www.windturbinecompany.com

Europe

ACSA - Aerogeneradores Canarias
http://www.acsaeolica.com/en/productos_aerogeneradores.htm

Enercon
http://www.enercon.de/en/_home.htm

Vestas
http://www.vestas.com/vestas/northern_europe/da-DK/

Lagerway
http://www.lagerwey.nl/

Nordex
http://www.nordex-online.com/en/

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Group B1

MAGNETIC LEVITATION WIND POWER GENERATION

Check List

history

mechanics

properties

research

potential

final analysis

HISTORY

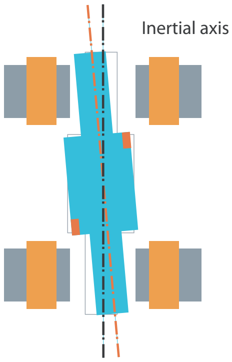
MAGNETIC LEVITAION (MAGLEV):
The process by which magnetic repulsion forces are utilized to cause an object to hover. In a properly designed magnetic field an objects movement and levitation can be controlled.

DEVELOPMENT
This technology is decades old. research in the field of magnetism erupted following World War II.

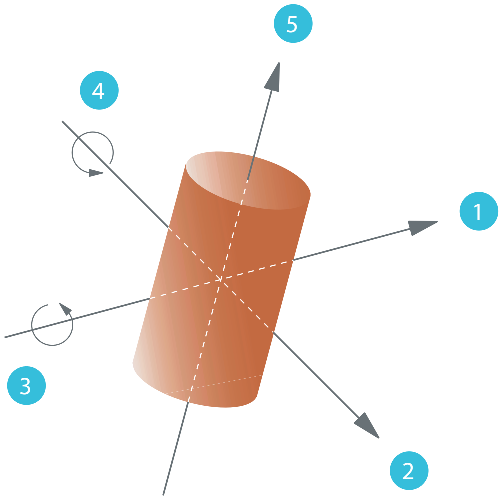
The most well known adaptation of Maglev is its use in the transportation industry with super high speed trains. These trainshover over a magnetic track, and are pulled along by oscillating magnetic/electric currents. These trains benefited from no track friction which allowed for an increased ability to accelerate, allowed for tracks which could be built at steeper grades, and a more efficient transportation system. A maglev system essentially eliminates friction in the members involved. However, at high speeds the majority of friction comes in the from of wind resistance.

In more recent years, other technological developments have incorporated the friction reducing principles of maglev, such as the advent of the magnetic bearing which support moving machinery without physical contact. Futhermore, magnetic bearings are able to operate at very high speeds, require no lubrication, and can operate in a vacuum. Application of this technology has proven fruitful in machine tool operation, petrolium refining, natural gas pipelines, and now electric power generation. (wikipedia.com)

Magnetic Bearings (photo from wikipedia.com)



Rotor Control Diagram
Magnetic bearings are able to compensates in real time for any imbalance. (Lacotech)



5-Axis Control
A 5-axis magnetic bearing provides control of the rotor at high speeds. (Lacotech)

MAGLEV
WIND POWER

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MECHANICS

HOW DOES THIS APPLY TO WIND POWER?
Traditionally, to draw more power from the wind, a wind turbine needs a larger blade. The amount of energy transfered is related to the area of the blade. This is due to the Power Density Calculation which states the rate at which energy passes through a unit of area during a period of time The Power is a cubic function of speed (V), double the speed and the power increases eight times.

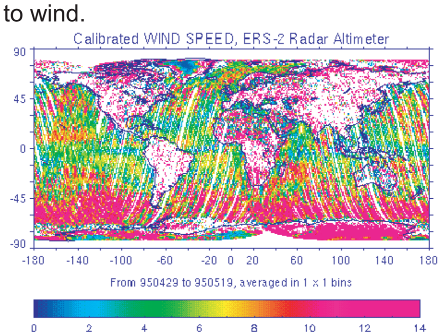
$$Wpd = 1/2p*V_3$$

Thus the larger the rotor area the more power a turbine can harness; doubling the swept area doubles the power available to it. (Gipe)

This is obvious in wind farms that have giant wind turbine. Now, instead of producing a larger blade to get more power from the wind, maglev has recently been incorporated into wind power generators to reduce friction and thereby increase efficiency.

The heart of a wind generator is the electric dynamo which converts rotational energy (the spinning of the turbine from the wind source) into an A/C electric current.

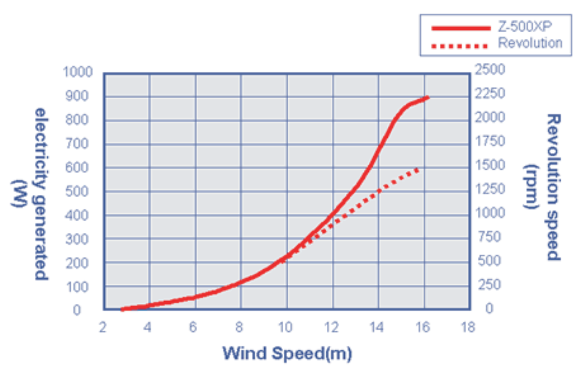
Maglev technology is applied between the rotating drive shaft and the fixed base of the machine. Thus magnetic repulsion levitates the shaft within the servomotor, taking the place of ball bearings thus reducing friction and increasing sensitivity to wind.



WHAT GOOD IS THIS?
when Magnetic Levitation takes the place of the ball bearings in a wind turbine results are as follows: less energy is lost to internal friction and more energy is converted into electricity, the turbine will operate at lower speeds, the mechanical parts have a longer life-span due to less friction, and there are lower maintenance and operational costs throughout the life of the machine.

The inefficiency of a normal wind generator (which happens mainly in the gears, shafts, and bearings) is not very big at moderate to high wind speeds. Dr. Faludi further explains:

“According to a paper by California Wind Energy Collaborative at UC Davis, the average wind turbine's drive train is 87-89% efficient from peak wind speeds down to less than half peak wind speed. However, below roughly a third of peak wind speed, things go rapidly downhill, and by about a quarter of peak wind speed, efficiencies are wallowing sadly in the 30-40% range...Granted a study by NREL found the main losses in a wind turbine's drive train is lubrication oil, churning, particularly at low speed. Using magnetic bearings (if they world at low speeds) would eliminate the need for such lubrication, and so would remove the drive train's biggest inefficiency.”



MAGNETIC LEVITATION WIND POWER GENERATION



Check List

history

mechanics

properties

research

potential

final analysis

PROPERTIES

MAGLEV
WIND POWER

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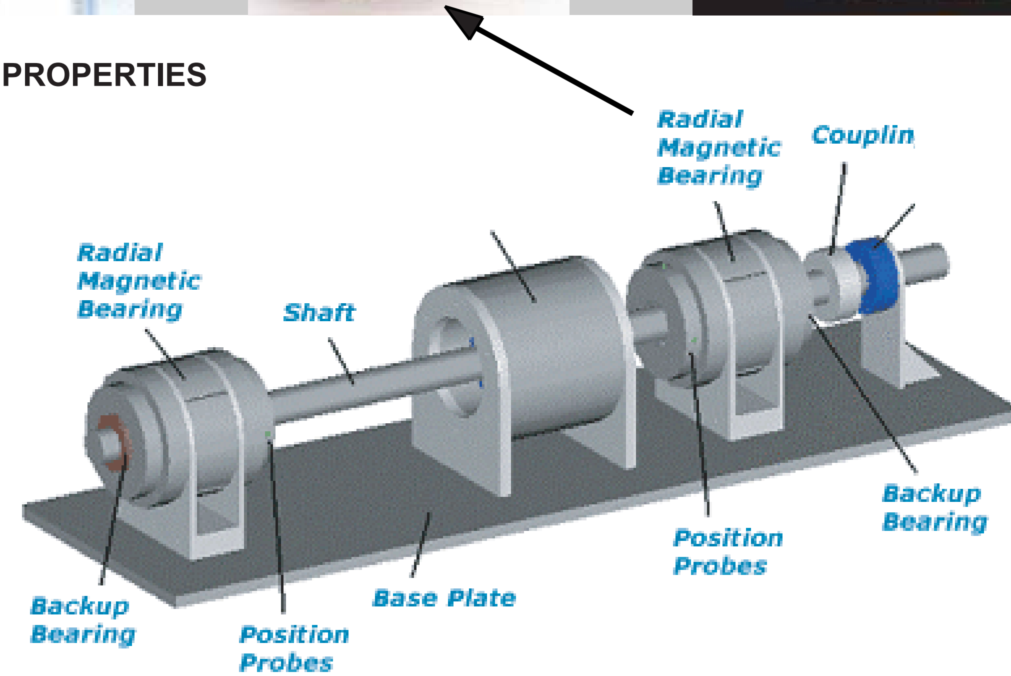

(image from www.airex.com)

MAGNETIC BEARINGS
A maglev wind turbine with electro-magnetic bearings can be understoof by the schematic diagram above. Generally there are two Radial Magnetic Bearing houses where the levitation forces are produced to act upon the shaft.
Position probes are located outside each of these houses to detect shaft motion. This data is analysed by a computer which responds by adjusting the magnetic forces to keep the machine in balance.
As a safety feature, levitated shafts are equiped with emergency backup bearings, of the traditional type, which are able to engage in the event of a magnetic failure. Futhermore, there is also a breaking mechanism to begin decelerating the system in such an emergency. The Backup bearings in existing maglev machines are designed to withstand repeated impact of the shaft and are able to operate the machine at full load for a significant amount of time.

Magnetic Bearing
(image from www.sti.nasa.gov)

MAGNETIC LEVITATION WIND POWER GENERATION

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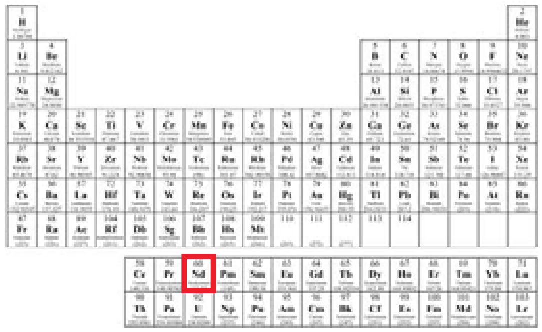
PROPERTIES

NEODYMIUM
Atomic Number: 60
Atomic Weight: 144.24

The famous Chinese breakthrough with a Maglev wind power generator claims not to use electromagets, but powerful neodymium iron boron ($Nd_2Fe_{14}B$) permanent magnets. These are in fact the most powerful naturally occurring magnets on the planet. These have proven highly useful in everything from automobile, computer hard drive, spaceship, and wind turbine. (www.neodymiummagnets.info)

PERIOD TABLE OF THE ELEMENTS



BENEFITS
- Resistant to Demagnetization
- High Energy for its size
- Good in ambient Temperature
- Moderately Priced
- Should be coated to reduce oxidization

MAGLEV WIND POWER

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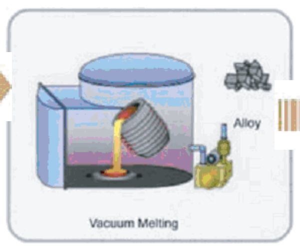
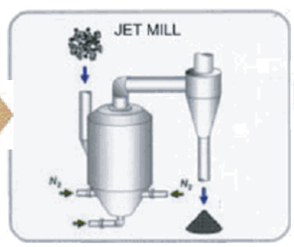
PRODUCTION FLOW DIAGRAM (www.neodymiummagnets.info)

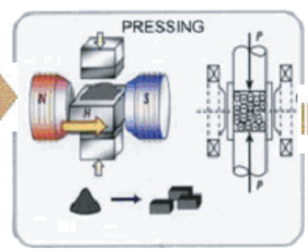
CRUCIBLE



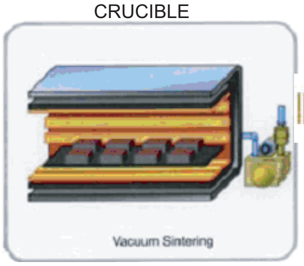
VACUUM MELTING



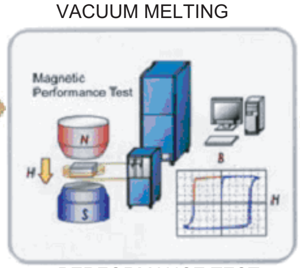
JET MILL



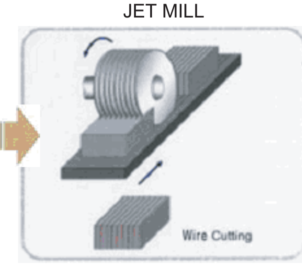
PRESSING



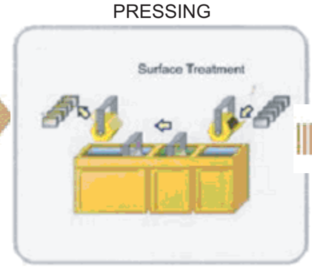
VACUUM STINTERING



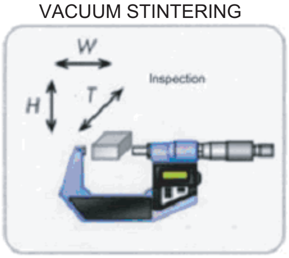
PERFORMANCE TEST



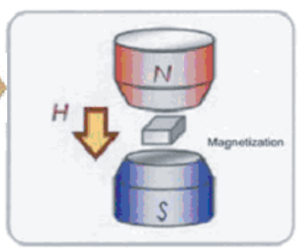
WIRE CUTTING



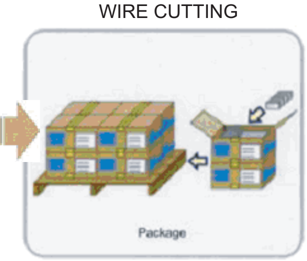
SURFACE TREATMENT



INSPECTION



MAGNETIZATION



PACKAGE

RESEARCH

CHINESE MAGLEV PROTOTYPE

Although Spain and Germany have been the “front runners” in wind power, the most significant breakthrough of the decade has come from China.

A maglev wind-power generation prototype was developed by the Guangzhou Energy Research Institute under China's Academy of Sciences and by Guangzhou Zhongke Hengyuan Energy Science & Technology Co., Ltd. According to Zijun Li, this generator is being regarded as “a key breakthrough in the evolution of wind power technology- and a notable advance in independent intellectual property rights in China.” (Zijun Li) It was first unveiled at the Wind Power Exhibition in Beijing in the summer of 2006. These scientists claim that this generator has a 20% higher electrical output yield when compared to traditional wind turbines. It can harness electricity with wind speeds starting as low as 1.5 meters per second, which is approximately 4 miles per hour.

This is expected to add 1000 hours of additional wind generation time at a typical wind farm. Furthermore, this opens up new wind power generating opportunities in areas previously regarded as low wind-speed areas. The hope is to be able to provide power to places unconnected to the grid, which is most of rural China. Currently 70 million households scattered throughout the Chinese countryside do not have reliable electricity. This could also be used to power other low wind speed areas such as mountain regions, observatories, islands, and television transfer stations.

The Chinese maglev generator is further claimed to decrease operational expenses of wind farms by as much as 50%. The maglev generator makes use of permanent magnets (the strongest of all know magnets) which are neodymium rich, and the strongest natural magnet on earth. China is believed to have a large amount of these rare earth deposits which could be exploited for magnet production.

In a possibly related story, the Chinese are planning to open a second rare earth magnetic alloy plant in Ganzhou, Jiangxi Province, in the latter half of 2007. The new plant will produce up to 2,000 tons/year of neodymium (Nd)-based alloys for high-performance magnets. (http://www.eetasia.com)

A BLOCK OF NEODYMIUM

CHINESE WIND FARMS

MAGNETIC LEVITATION WIND POWER GENERATION

RESEARCH

MAG-WIND GENERATOR
One local industry prototype of note is the Mag-Wind generator. This is a magnetic levitation wind-power generator designed for use in residential and commercial applications.

It is a simpler design which entails 4'-0" high X 4'-0" diameter turbine oriented around a vertical shaft; the base of the turbine hovers above the base plate of the machine. Except for minor resistance from the guide which keeps the turbine in place, the Mag-Wind generator is a frictionless system. This makes the generator, according to Charles from the MagWind company, "very efficient in harnessing wind power even at lower wind speeds." (Charles). According to the Mag-wind, "If we put 10,000 wind turbines onto roofs in a city, on a windy day, that could produce 50 megawatts of electricity, which could replace a coal fired or other fossil-fueled power generating plant." (Mag-wind)

Although this type of generator can be used on flat roofs, it is designed to be installed at the peak of a pitched residential roof top because it utilizes the roof pitch to direct and accelerate the wind towards the turbine. The Magwind generator is almost totally silent, so disturbing the neighbors is not a concern.

MAGLEV WIND POWER

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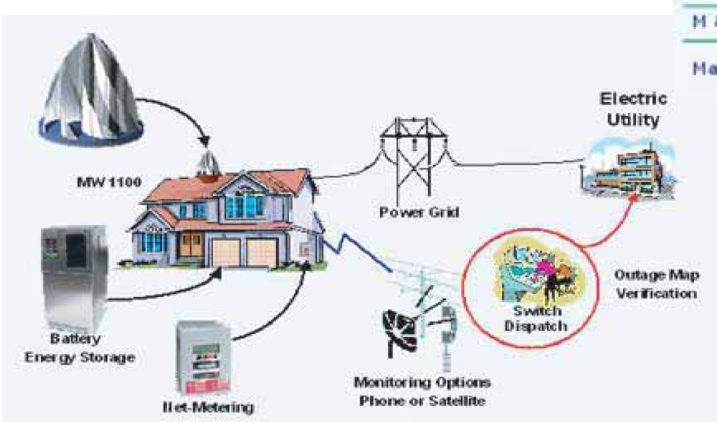
Although there are currently only two full scale and fully functioning units in Ontario and Texas, this prototype will be ready for mass production in the spring of 2007.

According to Mag-wind, specifically the Mag-Wind 1100 model has:
- A productivity rate of 1100kWh per month in a 13 mph average wind
- Wind Cut-in speed of less than 5 mph.
- Wind Top speed: greater than 100 mph.
- Economics: Fully burdened cost over 10 years is 3.5 cents per kW.
- ROI: If current bill is $300 per month or more, then ROI is 3 years or less.

If this technology proves effective, zero net energy (residential) buildings might become more common.

Technology	MAG-WIND	HAWT	Solar
Productivity / $	High	Medium	Low
Economic Model	3.5 ¢ kW	5.5¢ kW	8.0 ¢ kW
ROI	3 yrs	15 yrs	20 yrs
Space Requirements	Rooftop 5 sqf	Rural 1 acre	Rooftop 50 sqf
Noise Pollution	None	High	None
M & O	Minimum	Medium	Minimum
Market Obstacles	Certification	Economics, Space	Economics, Low Productivity

Mag-Wind Specs



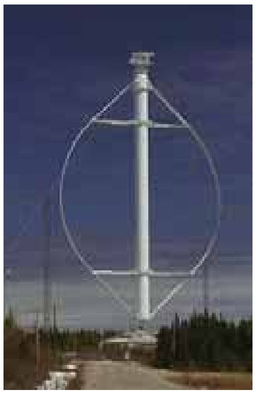
RESEARCH

TATAR VERTICAL AXIS PROTOTYPE
Another breakthrough has been achieved by retired professor and freelance inventor, Frank Tatar. By investing his own $1.2 Million, he has designed, built, and patented (with patent # 4725194) a magnetic levitation vertical axis windmill.

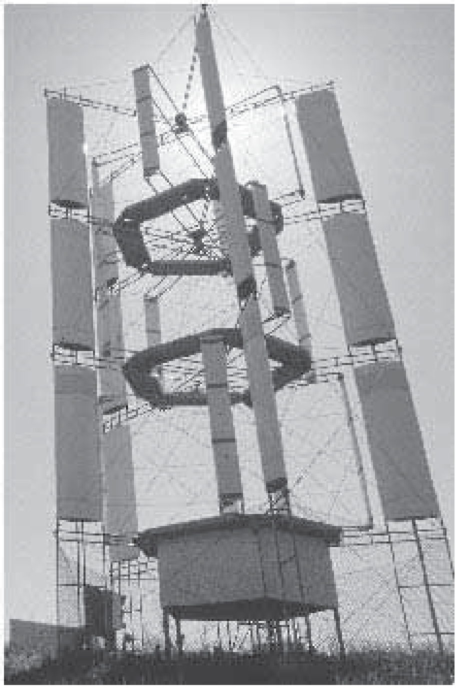
His design is a 20'-0" tall turbine of wind collecting panels that floats over a bed of neodymium iron boron magnets. This product boasts a lower environmental impact than taller horizontal projects, and thus could be incorporated more closely into an urban setting. The finished product, which is 40' high by 20' in diameter, looks like a typical corn silo, and has a potentially broader aesthetic appeal than gigantic wind farm turbines. Professor Tatar believe the Vertical Axis design has greater versatility in architectural design than the more massive horizontal axis turbines present at large wind farms.

His turbine also revolves at lower wind speeds and generates power more consistently as a result.

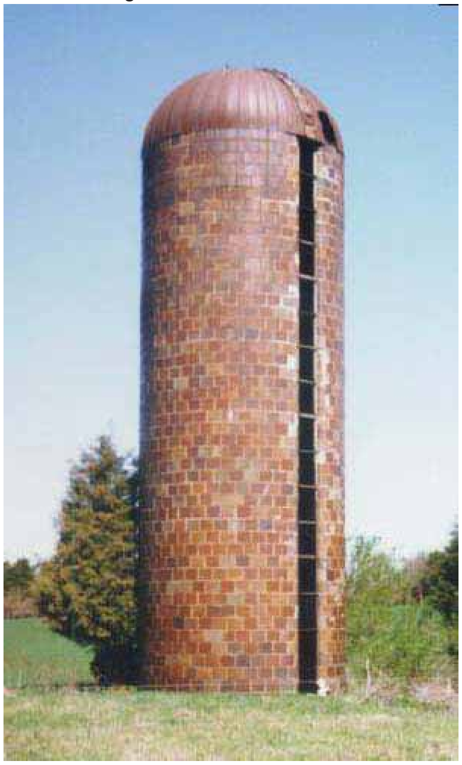
According to Tatar, these wind machines, "operate on less wind than propeller turbines...and could be used at industrial and commercial sites to provide on-site power without having the environmental impacts of the taller 'horizontal axis' projects." (Ploetz 1)



(image from Paul Gipe, "Wind Power")



A Maglev Vertical Axis Wind Turbine



A grain silo

POTENTIAL

HIGHWAY WIND POWER

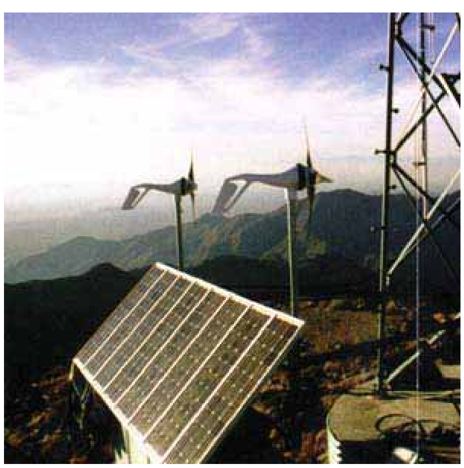
Small Maglev generators could potentially be used along heavily traveled roadways to generate electricity from wind created by the passing traffic. This energy could be stored, during the day, and then be used, at night, to power street lights or illuminate signage.

OTHER POSSIBLE APPLICATIONS

Further possibilities include the ability to upgrade or replace existing wind turbines with Maglev generators to increase efficiency and life duration. The feasible area for power production expands dramatically if significant power can be yielded by 10 mph winds or less.

SOLAR CHIMNEY

Solar towers are also prototypical hyper modern electric generating machines. The idea behind them is to use a large arrays of translucent panels spread over large areas to heat large quantities of air, then to allow the thermo-currents of air to rise upwards and to funnel them into a large tower, as the air travels and gains speed it passes through electric generating turbines. If these turbines made use of maglev technology, the system of arrays could be downsized in the order of 20% and yield the same power output. This would make smaller solar towers feasible, or larger ones more powerful.

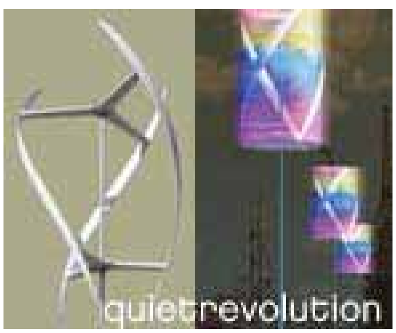


A likely development will be the coupling of Photovoltaic Panels with Wind Power Turbines, especially since peak wind hours are seldom in sync with peak cooling electrical production demand.

COMPUTER RENDERING OF A SOLAR CHIMNEY

FINAL ANALYSIS

HOW MIGHT THIS AFFECT ARCHITECTURE?
The advent of maglev technology in the arena of wind power generation could hold the key to hundreds of innovations. The refinement of this technology will doubtlessly produce a greater diversity of ind power applications. Wind power could become as viable as photo voltaic power generation, appearing everywhere from individual residences to large power producing arrays; everywhere from remote locations to commercial buildings or freeways in urban centers.



ADVANTAGES
As previously discussed, the obvious advantage with maglev wind power generation, is that it produces more power than traditional turbines, and harnesses power from lower wind speeds. Other bonuses include the longevity of these machines and reductions of maintenance costs. Furthermore, because of the reduction of interior friction, they are also quieter in operation.

DISADVANTAGES
One drawback to maglev wind technology is that it is brand new, and thus extremely expensive. According to an NREL study, “motor efficiency outweighted drive train efficiency, so fancy maglev bearings won't do you any good if you don't also have the best motor you can buy.” (Faludi) So, this will only mean higher costs for the motor. The maglev generators typically use permanent magnets which are made of expensive rare earth metals. According to the McCaig in his book, Permanent Magnets in Theory & Practice,

“The term rare-earth' is misleading. The rare-earth elements were until recently rare and expensive, but the reason was that they were difficult and expensive to separate and refine, not that the earths from which they were obtained were scarce.” (McCaig 123)

The wonderful claims of this revolutionary idea have not been tested over time, and have not been “field verified” either. Doubtless, there will be some refinement and fine tuning to be done. At worst, there could be major setbacks or design impediments which are not yet apparent.

CONCLUSION
Regardless, Maglev technology has merit as an idea and opens up many new opportunities for creativity and design. It further encourages us to dream of ways to incorporate power generation into the built environment.

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Other Useful Web Pages:
http://www.mag-wind.com/wind-energy-faq.php
http://www.worldwatch.org/node/4217
http://www.renewableenergyaccess.com/rea/news/chinawatch/story?id=45422
http://jcwinnie.biz/wordpress/?p=1707
http://peswiki.com/index.php/Directory:MagLev_Wind_Power_Generator#How_it_Works
http://www.worldchanging.com/archives/004708.html
http://www.treehugger.com/files/2006/07/china_unveils_w.php
http://www.windtech-international.com/content/view/661/2/
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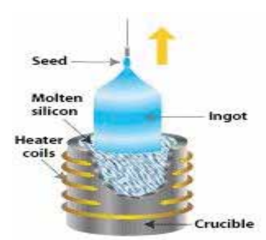
BIPV background

History

French physicist Edmond Becquerel first described the photovoltaic effect in 1839, but it remained a curiosity of science for the next three-quarters of a century. Becquerel found that certain materials would produce small amounts of electric current when exposed to light. The effect was first studied in solids, such as selenium, by Heinrich Hertz in the 1870s. Soon afterward, selenium photovoltaic (PV) cells were converting light to electricity at 1 % to 2% efficiency (The conversion efficiency of a PV cell is the proportion of sunlight energy that a cell converts to electrical energy.) Selenium was quickly adopted in the emerging field of photography for use in light-measuring devices.

Major steps toward commercializing PV were taken in the 1940s and early 1950s when the Czochralski process for producing highly pure crystalline silicon was developed. In 1954, scientists at Bell Laboratories depended on the Czochralski process to develop the first crystalline silicon photovoltaic (or solar) cell, which had an efficiency of 4%.



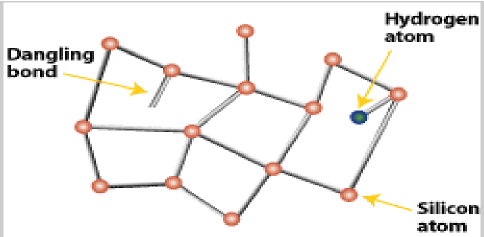
Although a few attempts were made in the 1950s to use silicon cells in commercial products, it was the new space program that gave the technology its first major application. In 1958, the U.S. Vanguard space satellite carried a small array of PV cells to power its radio. The cells worked so well that PV technology has been part of the space program ever since. Today, solar cells power virtually all satellites, including those used for communications, defense, and scientific research. The US space shuttle fleet uses PV arrays to generate much of its electrical power.

Despite these advances, photovoltaics in 1970 was still too expensive for most terrestrial uses. In the mid-1970s rising energy costs, sparked by a world oil crisis, renewed interest in making PV technology more affordable. Since then, the federal government, industry, and research organizations have invested hundreds of millions of dollars in research, development,and production. Often, industry and the federal government work together, sharing the cost of PV research and development (R&D).

Much of this effort has gone into the development of crystalline silicon, the material Bell's scientists used to make the first practical cells. As a result, crystalline silicon devices have become more and more efficient, reliable, and durable. Industry and government have also explored a number of other promising materials, such as noncrystalline (amorphous) silicon, polycrystalline cadmium telluride and copper indium diselenide, and other singlecrystal materials like gallium arsenide.

Today' commercial PV systems can convert from 5% to 15% of sunlight into electricity. They are highly reliable, and they last 20 years or longer. The cost of PV-generated electricity has dropped 15- to 20-fold, and PV modules now cost around $6 per watt (W) and produce electricity for as little as 25 cents to 30 cents per kilowatt-hour (kWh).

Silicon



Background

Silicon is used to make some the earliest photovoltaic (PV) devices. Itis still the most popular material for solar cells. Outranked only by oxygen, silicon is also the second-most abundant element in the Earth's crust. However, to be useful as a semiconductor material in solar cells, silicon must be refined to a purity of 99.9999%.

In single-crystal silicon, the molecular structure—which is the arrangement of atoms in the material—is uniform, because the entire structure is grown from the same crystal. This uniformity is ideal for transferring electrons efficiently through the material. To make an effective PV cell, however, silicon has to be "doped" with other elements to make it n-type and p-type.

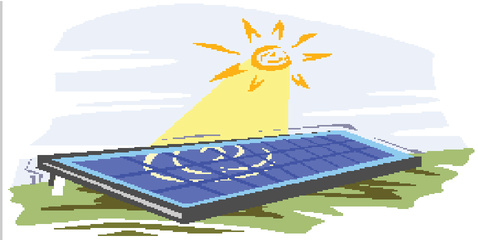
n-type silicon

Silicon that has been doped with phosphorus gas to turn it into a material that contains extra electrons that it will release easily.

P-type silicon

P-type silicon is doped with boron gas to turn it into a material that contains holes that accept a free electron easily. Although "n" and "p" imply negative and positive, n-type and p-type silicon are in an "in-between" stage that has the inclination to readily become more negative and positive.

Semicrystalline silicon, in contrast, consists of several smaller crystals or grains, which introduce boundaries. These boundaries impede the flow of electrons and encourage them to recombine with holes to reduce the power output of the solar cell. However, semicrystalline silicon is much less expensive to produce than single-crystalline silicon. So researchers are working on other ways to minimize the effects of grain boundaries.



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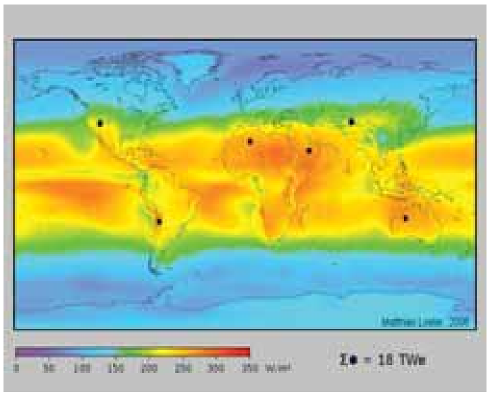
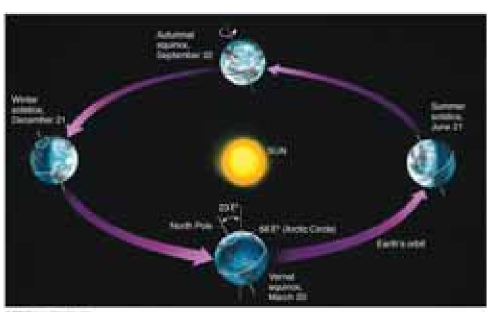
sun zones

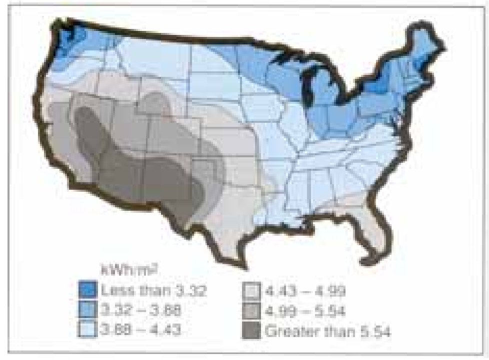
When sunlight reaches Earth, it is distributed unevenly in different regions. Not surprisingly, the areas near the equator receive more solar radiation than anywhere else on Earth.



Sunlight varies with the seasons, as the rotational axis of the Earth shifts to lengthen and shorten days as the seasons change. The amount of solar energy falling per square meter on Yuma, Arizona, in June, for example, is typically about nine times greater than that falling on Caribou, Maine, in December. The quantity of sunlight reaching any region is also affected by the time of day, the climate (especially the cloud cover, which scatters the sun's rays), and the air pollution in that region. These climatic factors all affect the amount of solar energy that is available to PV systems.



regional benefits



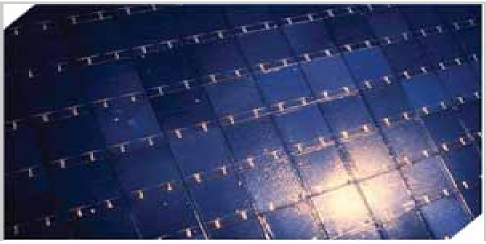
Boulder, CO

Station Identification	
City:	Boulder
State:	CO
Latitude:	40.02° N
Longitude:	105.25° W
Elevation:	1634 m
PV System Specifications	
DC Rating:	4.00 kW
DC to AC Derate Factor:	0.770
AC Rating:	3.08 kW
Array Type:	Fixed Tilt
Array Tilt:	40.0°
Array Azimuth:	180.0°
Energy Specifications	
Cost of Electricity:	8.4 ¢/kWh

Results			
Month	Solar Radiation (kWh/m²/day)	AC Energy (kWh)	Energy Value ($)
1	4.43	427	35.87
2	4.89	418	35.11
3	6.05	564	47.38
4	6.09	529	44.44
5	5.99	523	43.93
6	6.08	501	42.08
7	6.06	502	42.17
8	6.24	518	43.51
9	6.25	516	43.34
10	5.67	503	42.25
11	4.60	420	35.28
12	4.29	413	34.69
Year	5.56	5834	490.06

Energy

BIPV



advantages

* The 122 petawatts of sunlight reaching the earth's surface is plentiful compared to the 13 terawatts of average power consumed by humans. Additionally, solar electric generation has the highest power density (global mean of 170 W/m2) among renewable energies.

* Solar power is pollution free during use. Production end wastes and emissions are manageable using existing pollution controls. End-of-use recycling technologies are under development.

* Facilities can operate with little maintenance or intervention after initial setup.

* Solar electric generation is economically competitive where grid connection or fuel transport is difficult, costly or impossible. Examples include satellites, island communities, remote locations and ocean vessels.

* When grid connected, solar electric generation can displace the highest cost electricity during times of peak demand (in most climatic regions), can reduce grid loading, and can eliminate the need for local battery power for use in times of darkness and high local demand; such application is encouraged by net metering. Time-of-use net metering can be highly favorable to small photovoltaic systems.

* Grid connected solar electricity can be used locally thus minimizing transmission/distribution losses (approximately 7.2%).

* Once the initial capital cost of building a solar power plant has been spent, operating costs are low when compared to existing power technologies.

disadvantages

* Solar cells are costly, requiring a large initial capital investment.

* Limited power density: Average daily insolation in the contiguous U.S. is 3-9 kWh/m2 usable by 7-17.7% efficient solar panels.

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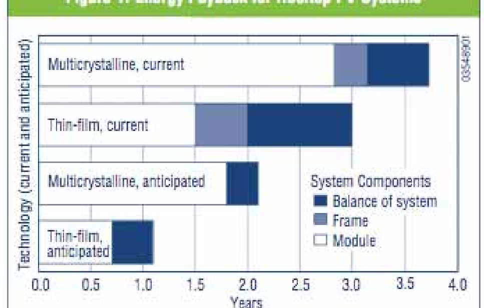
declining costs

Declining manufacturing costs (dropping at 3 to 5% a year in recent years) are expanding the range of cost-effective uses.

The average lowest retail cost of a large photovoltaic array declined from \$7.50 to \$4 per watt between 1990 and 2005. With many jurisdictions now giving tax and rebate incentives, solar electric power can now pay for itself in five to ten years in many places.

energy payback

Figure 1. Energy Payback for Rooftop PV Systems



Reaping the environmental benefits of solar energy requires spending energy to make the PV system. But as this graphic shows, the investment is small. Assuming 30-year system life, PV systems will provide a net gain of 26 to 29 years of pollution-free and greenhouse-gas-free electrical generation.

Energy

BIPV

PV power chart

The table below shows the total cost in US cents per kWh of electricity generated by a photovoltaic system. The row headings on the left show the total cost, per peak kilowatt (kWp), of a photovoltaic installation. The column headings across the top refer to the annual energy output in kWh expected from each installed kWp. This varies by geographic region because of different levels of insolation and it also depends on the overall efficiency of the PV system. The calculated values within the table reflect the total cost in cents per kWh produced. They assume a 4% cost of capital, 1% operating and maintenance cost, and depreciation of the capital outlay over 20 years. (Normally, photovoltaic modules have 25 years' warranty, but they should be fully functional even after 30-40 years.)

20 years	2400 kWh/kW_p	2200 kWh/kW_p	2000 kWh/kW_p	1800 kWh/kW_p	1600 kWh/kW_p	1400 kWh/kW_p	1200 kWh/kW_p	1000 kWh/kW_p	800 kWh/kW_p
200 $\$/kW_p$	0.8	0.9	1.0	1.1	1.3	1.4	1.7	2.0	2.5
600 $\$/kW_p$	2.5	2.7	3.0	3.3	3.8	4.3	5.0	6.0	7.5
1000 $\$/kW_p$	4.2	4.5	5.0	5.6	6.3	7.1	8.3	10.0	12.5
1400 $\$/kW_p$	5.8	6.4	7.0	7.8	8.8	10.0	11.7	14.0	17.5
1800 $\$/kW_p$	7.5	8.2	9.0	10.0	11.3	12.9	15.0	18.0	22.5
2200 $\$/kW_p$	9.2	10.0	11.0	12.2	13.8	15.7	18.3	22.0	27.5
2600 $\$/kW_p$	10.8	11.8	13.0	14.4	16.3	18.6	21.7	26.0	32.5
3000 $\$/kW_p$	12.5	13.6	15.0	16.7	18.8	21.4	25.0	30.0	37.5
3400 $\$/kW_p$	14.2	15.5	17.0	18.9	21.3	24.3	28.3	34.0	42.5
3800 $\$/kW_p$	15.8	17.3	19.0	21.1	23.8	27.1	31.7	38.0	47.5
4200 $\$/kW_p$	17.5	19.1	21.0	23.3	26.3	30.0	35.0	42.0	52.5
4600 $\$/kW_p$	19.2	20.9	23.0	25.6	28.8	32.9	38.3	46.0	57.5
5000 $\$/kW_p$	20.8	22.7	25.0	27.8	31.3	35.7	41.7	50.0	62.5



Generations

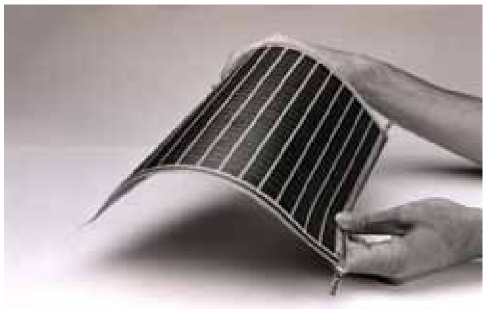
First

The first generation photovoltaic, consists of a large-area, single layer p-n junction diode, which is capable of generating usable electrical energy from light sources with the wavelengths of solar light. These cells are typically made using silicon wafer. First generation photovoltaic cells (also known as silicon wafer-based solar cells) are the dominant technology in the commercial production of solar cells, accounting for more than 86% of the solar cell market.

Second

The second generation of photovoltaic materials is based on the use of thin-film deposits of semiconductors. These devices were initially designed to be high-efficiency, multiple junction photovoltaic cells. Later, the advantage of using a thin-film of material was noted, reducing the mass of material required for cell design. This contributed to a prediction of greatly reduced costs for thin film solar cells. Currently (2006) there are different technologies/semiconductor materials under investigation or in mass production, such as amorphous silicon, poly-crystalline silicon, micro-crystalline silicon, cadmium telluride, copper indium selenide/sulfide. Typically, the efficiencies of thin-film solar cells are lower compared to bulk silicon (wafer-based) solar cells, but manufacturing costs are also lower, so that a lower price in terms of $/watt of electrical output can be achieved. Another advantage of the reduced mass is that less support is needed when placing panels on rooftops and it allows fitting panels on light materials or flexible materials, even textiles.

cells. Currently (2006) there are different technologies/semiconductor materials under investigation or in mass production, such as amorphous silicon, poly-crystalline silicon, micro-crystalline silicon, cadmium telluride, copper indium selenide/sulfide. Typically, the efficiencies of thin-film solar cells are lower compared to bulk silicon (wafer-based) solar



Third

Third generation photovoltaics are very different from the other two, broadly defined as semiconductor devices which do not rely on a traditional p-n junction to separate photogenerated charge carriers. These new devices include photoelectrochemical cells, Polymer solar cells, and nanocrystal solar cells.

thin film technology

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types

-amorphous silicon (a-Si)
-copper indium diselenide (CIS)
-copper indium gallenium diselenide (CIGS)
-cadmium telluride (CdTe)

basic concept

- uses less material
- thinner (10 μm thick compared with 200- to 300-μm layers for crystalline-silicon cells)
- cheaper to produce
- flexible (textile applications)
- more durable

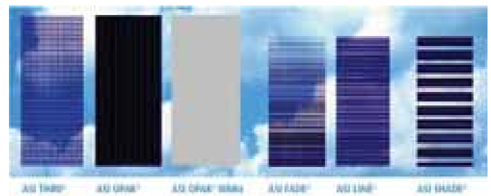
example products

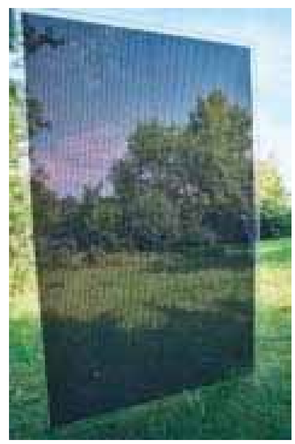
photovol glass
MSK corp

- transparent
- 10% light transmittance
- 3.8 watts of electricity per square foot (40.85 W/m2)
- ~ $ 45 sf ($ 484 m2)
- ~ $ 12 per watt

exmaple products

Schott
ASI glass system





Fabric applications

power shade
Power FIlm

Energy

BIPV

availability

There are two basic commercial PV module technologies available on the market today:

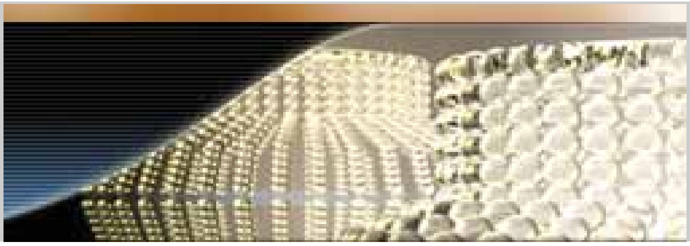
1. *Thick Crystal Products* - includes solar cells made from crystalline silicon either as single or poly-crystalline wafers and deliver about 10-12 watts per ft_of PV array (under full sun).

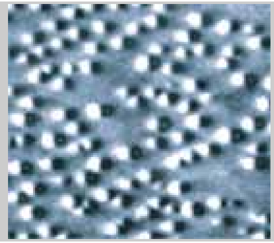
2. *Thin-Film Products* typically incorporate very thin layers of photovoltaicly active material placed on a glass superstrate or a metal substrate using vacuum-deposition manufacturing techniques similar to those employed in the coating of architectural glass. Presently, commercial thin-film materials deliver about 4-5 watts per ft_of PV array area (under full sun). Thin-film technologies hold out the promise of lower costs due to much lower requirements for active materials and energy in their production when compared to thick-crystal products.

samples of commercially available thin film systems

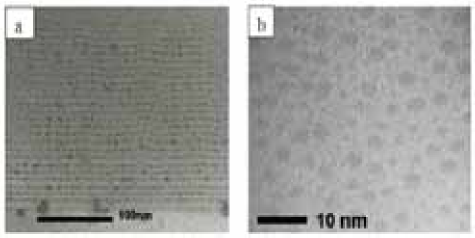
Company	Material	Area (cm2)	Efficiency (%)	Power (W)
Solar Cells Inc.	CdTe	7,200	8.4	60.3
Solar Cells Inc.	CdTe	6,693	8.6	57.7
APS	a-Si/a-Si	11,522	4.6	53.0
Siemens Solar	CIS	3,832	11.2 *,**	43.1
Siemens Solar	CIS	3,859	10.2	39.3
BP Solar	CdTe	4,540	8.4 *,***	38.2
ECD	a-Si/a-Si/a-SiGe	3,906	7.8	30.6
Golden Photon	CdTe	3,528	7.7	27.5
Solarex	a-Si/a-SiGe	3,432	7.8 *	26.9
USSC	a-Si/a-Si	3,676	6.2	22.8
Fuji	a-Si/a-Si	1,200	8.9	10.7
Siemens Solar	CIS	938	11.1	10.4
Matsushita Batt.	CdTe	1,200	8.7 *	10.0
USSC	a-Si/a-SiGe/a-SiGe	903	10.2	9.2
BP Solar	CdTe	706	10.1 *	7.1
Energy PV	CIGS	741	8.1 *,**	6
ISET	CIS	845	6.9	508

Note: After preliminary light-soaking for a-Si
*Not measured at NREL **Unencapsulated ***Not monolithic





quantum dot technology



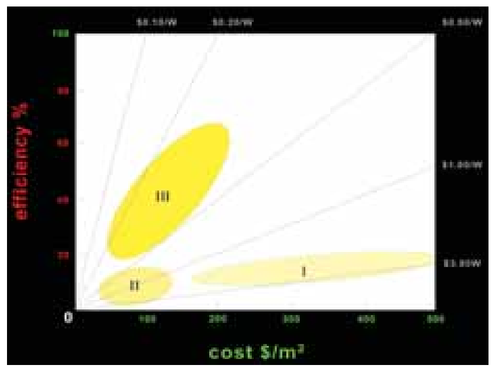
basic concept

- theoretical limit of 95%
- cheaper and safer to produce
- expected cost of $1/W
- non crystalline (can be used on a greater selection of substrates…. glass, plastics, steel….)
- can be used in solution (dyes and paints)

The Third Generation of Solar Cells

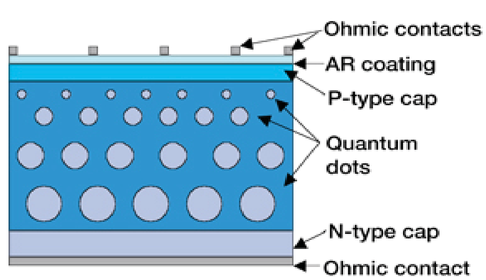
The Carnot limit on the conversion of sunlight to electricity is 95% as opposed to the theoretical upper limit of 33% for a standard solar cell. This suggests that the performance of solar cells could be improved 2-3 times if different concepts were used to produce a third generation of high efficiency, low-cost solar cell technologies. A variety of advanced approaches to third generation solar cells are under investigation, but the best scenario would involve a low-cost semiconductor material that could have its bandgap tuned for optimal performance allowing the manufacturer to control the absorptive properties of the solar cell. Evident Technologies product line of quantum dots have been designed for exactly this type of tunability, and provide industry with an ideal opportunity to develop market competitive PV solar cells.

By working on the nanometer scale, Evident's quantum dots exploit the quantum properties of materials, helping to overcome the limitations of traditional semiconductor devices. In the case of PV solar cells, Evident's quantum dot semiconductors are unique in their ability to inexpensively capture a large percentage of the sun's energy while retaining great versatility of form quantum dots can be made into flexible sheets, put into liquid form, or made to be transparent. The relative low cost and high performance of quantum dots vis-à-vis bulk silicon semiconductor material and thin films allows dots to theoretically achieve the third generation goal of ~60% efficiency and $100 or less per square meter of paneling necessary to make PV solar cells economically competitive.



Stability and Lifetime

Quantum dots can be prepared with a protective shell which increases stability and yields longer lasting solar cells without degradation in performance. This represents an advantage over traditional semiconductor devices, which do not have protective molecular shells to guard against the harmful effects of the sun, and therefore must be replaced more often, driving up material costs.



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ABE FUTURE

Imagine heat radiating from the walls of your home on a cold winter night, or the glass in your home's windows emitting cool temperatures on a scorching summer afternoon. Now imagine these systems operating on an endless supply of affordable energy – the sun" (Renssaler Polytech Institute).

Intelligent skin systems are emerging into the building environment in a positive way. By improving the active skin of the building, green technologies can provide for optimized energy performance, as well as, on-site renewable energy for the buildings they inhabit. Active Building Envelopes/Photovoltaic (ABE/PV) systems will impact the building community in economics, integration and aesthetics.

With a $300,000 grant from the National Science Foundation to fund the research, Steven Van Dessel and his team are exploring the likelihood of heating and cooling systems that would increase efficiency and adaptability by reducing the current technologies to a micrometer scale.

The Active Building Envelope system uses a Photovoltaic system to collect and convert sunlight into electricity, then sends the solar energy that has been captured as electricity to a series of thermoelectric heat pumps. These heat pumps are integrated into the building's walls, windows and roof. Dessel's ABE system also stores energy for future uses when it is possible that little or no sunlight would be available (Van Dessel).

ABE systems will optimize energy performance for the future. The use of thin-film photovoltaic cells and ABE systems to harvest solar energy is an alternative to the use of fossil fuels and therefore, ABE systems can make a significant impact on the world's dependency on them, while also lowering greenhouse gases. The future of their designed systems is headed in a direction that will optimize a building's energy performance by responding to its outside conditions. It will also lower operating costs over the lifetime of the building by harvesting and using energy captured by the sun

Cheick List

ABE AND TE HVAC SYSTEMS

Such improvements will result in a decrease of waste and possibly eliminating a building's cooling equipment altogether. ABE technology seeks to address problems with conventional energy sources that are located off-site, which bring about air, water and land pollution as a result of energy generation and transportation. If we assume that traditional heating and cooling equipment for a commercial building uses about 30% of the building's operating costs, then ABE systems are focusing on lowering that percentage. Thin-film systems are being developed by a few different researcher teams right now, but what makes Van Dessel's system different from theirs is the fact that they are developing technologies that work at a micrometer scale, at a cost that is a fraction of the price when compared to others, and that Van Dessel's ABE system is one with thermoelectric device incorporation. One of Van Dessel's main focuses was to use "off-the-shelf components", which are constantly growing in number and shrinking in price. Thin Film PV systems also have shorter energy paybacks as the compare to current flat plate modules.

In Fig. 1, "Thermal insulation" and "Thermal Mass" denote the external and the internal layers of the ABE wall, respectively. The TE units are dispersed inside the openings that are provided in the insulating layer. Each TE unit consists of two heat sinks. As shown in Fig. 1, the internal heat sink either absorbs or dissipates heat to the thermal mass layer. The external heat sink either absorbs or dissipates heat to the air, through natural or forced convection. To explore the feasibility of the ABE system, a preliminary feasibility analysis was performed on a model of a generic enclosure [1]. The next section summarizes this feasibility analysis.

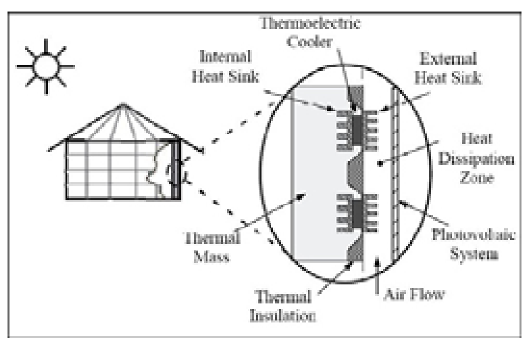
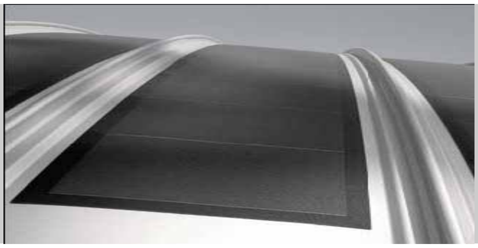


Figure 1: Active Building Envelope (ABE) system



THE VAN DESSEL SYSTEM

Figure 2 shows the top view of the generic enclosure (1m×1m×1m) that was used for exploring the preliminary feasibility of the ABE system. It was assumed that the heat transfer from the external environment into the enclosure (or the reverse) would be through the ABE wall only.

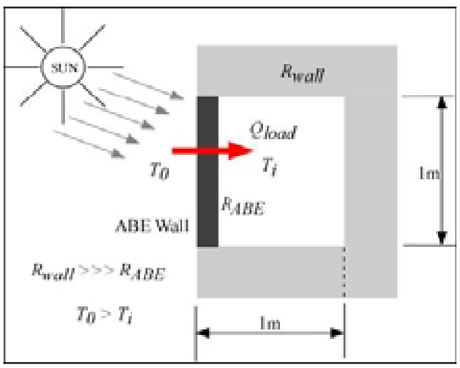


Figure 2: Schematic of a generic enclosure with single ABE wall

Figure 3 shows the relation between the total input power and the number of TE units used in different ABE configurations. We can learn from Fig. 3 that the total input power for the ABE system decreases as the number of TE units per ABE wall increases. However, decrease in the input power is less pronounced beyond 6 TE units per wall, for the generic enclosure considered in the preliminary feasibility analysis.

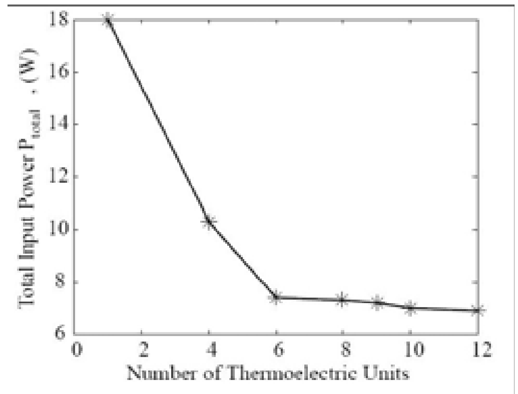


Figure 3: Total input power for different configurations of ABE system

Photograph of generic testing enclosure

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As shown in Fig. 4, when current flows through the junction of two dissimilar conductors (also called thermocouple), heat is either liberated or absorbed (depending on the direction of the current) at that junction. This phenomenon is known as the Peltier effect and it results in lowering the temperature at the heat-absorbing junction, and simultaneously increasing the temperature at the heat-releasing junction [4] (Van Dessel).

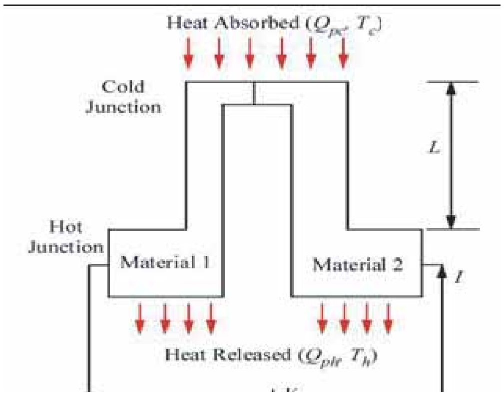
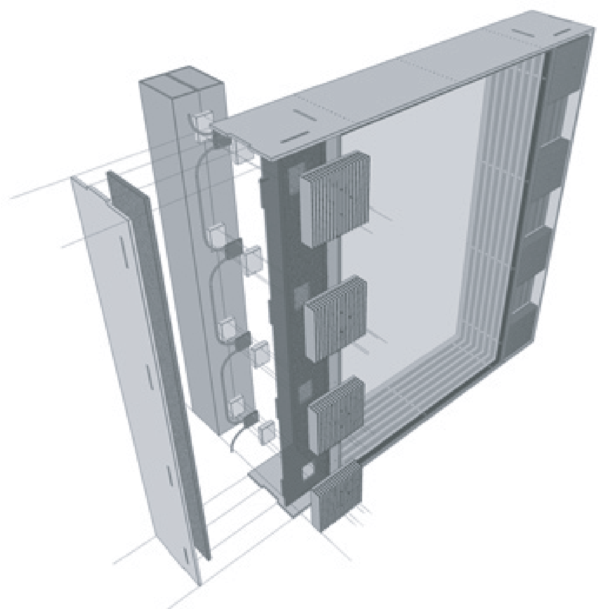
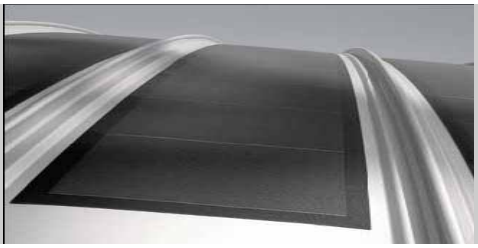


Figure 4: Schematic of a thermocouple



Exploded axonometric drawing of an ABE assembly



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Photovoltaic Collectors

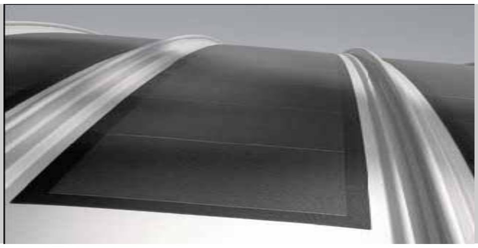
BIPV

Largely supported by government, Building Integrated PV (BIPV) technology is rapidly growing and gaining investors, who are excited about the idea of flexible skins that could be applied to a variety of building materials. By storing the sun's energy and utilizing it for building use, dependency on traditional systems will dwindle.

United Solar Ovonic Corporation and First Solar are two of the major manufactures of thin film PV systems. United Solar is the leading manufacturer currently producing at a capacity of 28MW, with plans to expand to 300MW by 2010. There is a growing demand for this current technology compared to silicon systems because they are more affordable to produce and output higher electricity per rated power (kWh/KW). Thin film systems are creating a high demand for the development of micro-scale and nano-technology. Because the technology is being developed as the system is being perfected, the progress of the start-up has been a little slow, but is quickly gaining attention and demand. The building industry is catching on.

Future manufacturing of thin films offers advantages because of continuous, low-cost production techniques, low installation costs, and short energy payback among other reasons.

Flexible Photovoltaic Laminate



Cheick List

BIPV

The energy payback metric indicates how long it takes a PV panel to produce an amount of energy equivalent to what it took to manufacture the module, from raw materials extraction to the energy used to operate the manufacturing equipment. Finally, studies have shown that, unlike silicon cells, thin film PV cells do not exhibit significant degradation in performance when the cell temperatures rise and the output from thin film PV systems is less affected by shading and overcast conditions.

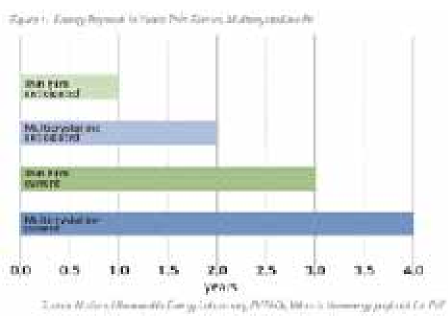


Figure 1 below illustrating energy payback in years, comparing thin film and multicrystalline PV systems

Alwitra Evalon Solar

A single ply roofing membrane system created by Alwitra, using the Alwitra Evalon Solar product

The ThyssenKrupp-Solartec product, a metal pan with insulation layer, 1 m wide and up to 24 meter long

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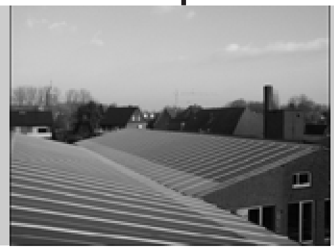

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BIPV

With the development of flexible photovoltaic laminates United Solar Ovonic contributes remarkably to the evolution of building integrated photovoltaic systems. With the possible integration of flexible PV elements into standard building and roofing elements new options for BIPV applications are created, which lead to increased product reliability, product security and reduction of total system costs.

Kalzip AluPlusSolar: a system made from aluminium standing seam profiles, which can be used as well in a rounded shape

roofing membrane system created by Solar Integrated, using the Sarnafil roofing membrane

CSI 13650

Photovoltaic Collectors

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New Mexico State University in conjunction with WFU
Dr. Seamus Curran
Assistant Professor in Nanotechnology
James Dewald

Announced at the Santa Fe workshop on Nanoengineered materials and macro molecular technologies
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http://lesowww.epfl.ch

The Centre for Window and Cladding Technology at the University of Bath, UK conducted a study called Integrated Building Control (IBC) to develop a window with automated vents and shading. Self-adaptive control strategies were applied to the window in order to moderate the environment in the room but allow for the needs of the occupant.
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ADVANCED WINDOW WALL SYSTEMS




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Topics Covered

Window strategies: short term, long term
Window Options:
Dynamic Shading Technics
Integrated Window-Wall Systems
Switchable Glazing
- Photochromics
- Thermochromics
- Liquid Crystals
- Suspended Particle Displays

Electrochromics

Definitions

Windows are no longer just windows. Glazing must become an active, integral part of building climate, energy, information, and structural systems.

Building integration - structural power, and data interconnection between the window and the rest of the building

Information display - passive active, or interactive display of text or images

Energy supply and conservation - annual or, ideally, instantaneous net provider of energy to the building.

Environmental harmony - minimal negative environmental impacts over the product life cycle

Enhanced traditional features improved window characteristics.

Introduction

The US Department of Energy (DOE), in collaboration with window industry participants, has spearheaded a major movement toward energy efficiency in glazing products. This new generation of glazing represents the need for responsive, controllable, and active smart windows that cohesively interact with building and occupant needs. In an age when completely glazed facades are en vogue, the need to approach glazing holistically is more important than ever. A Window is not merely a window anymore. Instead, a Window now represents a strategy for transparency by which a building skin can, through some mechanism, provide a suitable interior atmosphere while also limiting energy use and respecting environmental consequences. Glazed skins have now accepted new responsibilities as "advanced window wall systems".

Since the 1970's the popularity of Low-e windows in the residential market has risen steadily to a point where now their use consumes nearly 40% of the total windows sold for residential use in the United States. [1] Residential heating costs alone have surpassed $1.5billion, the windows themselves accounting for nearly $30 billion in lifetime energy savings. However even with substantial energy-cost savings, windows continue to augment the nearly $265 billion spent in the US toward annual building energy costs. [1]

Wall systems continue to evolve in an attempt to meet the challenges of attaining the ultimate goal of Zero Net Energy (ZNE) use in the building. This paper will attempt to bring clarity to just some of the many technical solutions available to create energy-efficient, transparent wall systems.

INTRO

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ADVANCED WINDOW WALL SYSTEMS

Short-Term Strategies

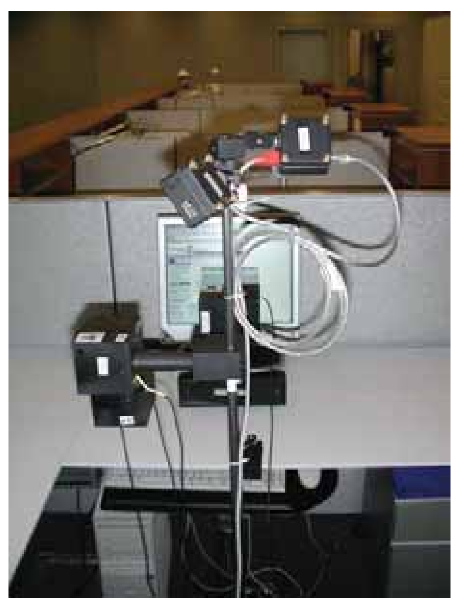
Short-Term Strategies are used as a way of solving energy issues in a immediate way. These strategies are often used for buildings that exist. The strategies are traditional and include individual occupants operating window shades manually upon request of a building systems supervisor. Also motorized shading devices (interior and exterior) are operated automatically by building systems supervisor in response to a load event. With these systems lighting is limited. These Short-term strategies recognize a need for a dynamic wall system

Long-Term Strategies

These strategies are used in new or renovated buildings. Usually more costly and at the same time more effective. Some of these strategies include shading devices that are automated and integrated with lighting controls to reduce cooling and lighting loads. Switch able windows (e.g., electrochromics <EC>) are integrated with delighting scheme to reduce cooling loads. Other strategies that deal more with the design of the building include a double envelope facades with automated venting operations to reduce cooling loads. Also integrated with lighting controls.
Cooling of thermal mass using nighttime ventilation through windows.

Convincing the Consumer

a. A Greater initial investment is inherent to most developing technologies. However, studies have shown that the initial costs of these advanced systems could be compensated by savings in decreased chiller sizes and the elimination of additional shading devices. Studies value these savings between \$3-\$15/m^2. Annual savings could be recognized in energy savings, carbon emissions, and/or heating and cooling costs that have been predicted to reduce peak loads by nearly 20-30% in most commercial buildings.
b. Automation and building system integration reduces the role of the individual occupant and allows for building efficiency by allowing for the collaboration of the building systems.
c. Improved performance and new technological advances will materialize as cost savings. Over the last couple decades glazing U-values have decreased from about



Energy Saving Strategies

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Dynamic Shading Techniques

Motorized Blind System
These systems refer to a well-established method of utilizing Venetian blind systems for glare elimination and solar gain control. The latest products incorporate the blinds between two panes of glass which helps eliminate maintenance problems. These systems can be fitted with sensors and automation controls that increase usefulness.

Disadvantage
Difficult to find appropriate balance between the light levels and solar gain.

Motorized Shade System

Motorized Shade Systems are also referred to as Roller Shade Systems. The fabric utilized here as the shading medium incorporates a wide range of optical and solar properties. This technology has less optical control than does the previous blinds system, but layering of different fabrics makes an attempt to solve this problem.

Disadvantage
Yet again, this solution does not afford high levels of transparency.

Integrated Window-Wall System

In an attempt to improve upon energy losses through window frames and wall assemblies, Lawrence Berkeley National Laboratory's Windows and Daylighting Group has developed what they refer to as an Integrated Window-Wall System (IWS). This approach attempts to create an all-inclusive wall of paneled construction that incorporates operable windows, recessed night insulation, and integral solar shading. The wall framing anchors the window sash resulting in a non-frame window assembly. Sun shades and concealed night insulation can be deployed to block heat gain or, double thermal resistance to approximately R12. [4]

WINDOW OPTIONS

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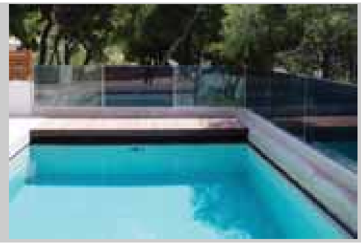
ADVANCED WINDOW WALL SYSTEMS



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Photochromic

Photochromic glazing darkens when exposed to direct sunlight (most commonly used in sunglasses).

Disadvantage
Wall systems utilizing this technology could not introduce efficient solar gain during cold months of the year. On sunny, cold days these windows would darken and shade the interior, effectively eliminating any heat gain.

Thermochromic

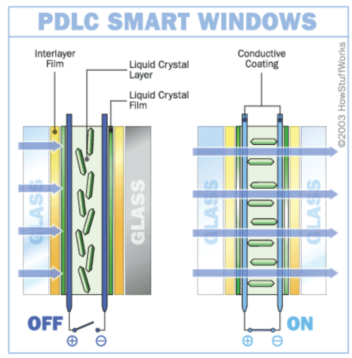
Thermochromic material reacts to heat changes.

Disadvantage
While more effective in controlling solar gain than photochromics, visual attributes can be obscured or completely eliminated. Can not be controlled in any way

Liquid Crystals

Liquid Crystal units require a small electrical charge in order to change there translucency. When the charge is applied, the liquid crystals align parallel to one another thereby allowing light into the interior space. Conversely, when the charge is eliminated the liquid crystals randomly arrange themselves and sufficiently absorb the light.

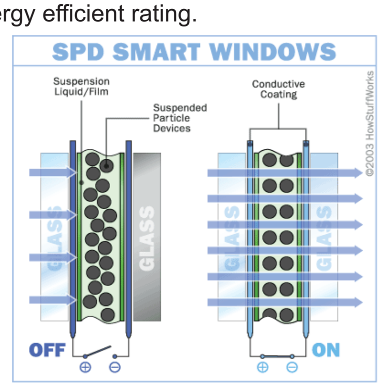
Disadvantage
This technology provides for transparent or opaque stages with no intermediary situations. The resulting uncontrollability of this technology makes it a less attractive option when compared to other smart glazing techniques. Also, the LCD windows do not control heat gain; therefore they are typically specified for interior use only.



Suspended Particle Display

SPD windows use varied amounts of electrical charges to maintain control of allowed or blocked light. The SPD assembly consists of these parts: [5]
* Two panels of glass (or sometimes plastic)
* Millions of suspended particle devices
* A conductive material (usually a film) that coats the glass or plastic panes
* A system of liquid suspension for the freely floating SPD particles to sit in
* Mechanism of control

Disadvantage
Organic-based materials used in fabrication are not durable in exterior applications.
The 50-100V alternating current the window requires to maintain tinting is not an optimal energy efficient rating.



Switchable Glazing

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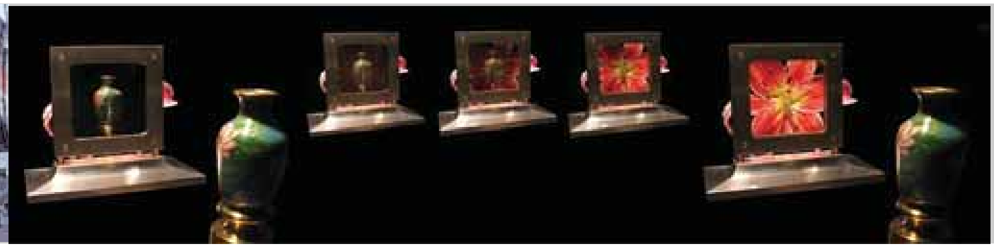

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Electrochromic (EC) Window Assembly

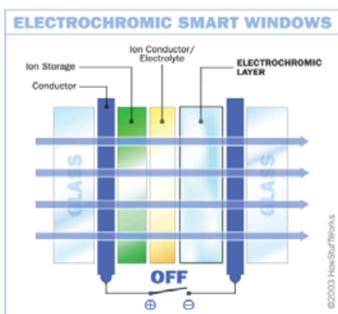
2 Glass or Plastic Panels

2 Conducting Oxide Layers

An Ion Conductor

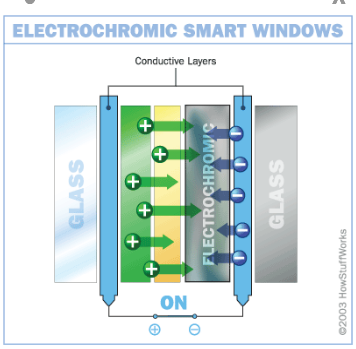
2 Electrochromic Layers
Oxide-reaction
Transitional-Metal

Ion Storage Space



The Electrochromic layer typically consists of Tungsten Oxide (WO3).

$$WO_3 + xM^+ + xe^- \quad M_xWO_3$$



Oxide-Reaction

A small electrical charge is applied releasing ions through the conducting layer and into the electrochromic layer. These ions alter the optical properties of the WO3 causing it to absorb light. The result is a darkening of the window. The opposite is true when the voltage direction is reversed, the window bleaches.

The Electrochromic layer typically consists of Tungsten Oxide (WO3).

Transitional-Metal Hydride Electrochromic Window

Electrochromic layer consists of a rare earth metal Nickel-Magnesium (Ni-Mg).

Naturally Ni-Mg is virtually opaque and reflective.

When voltage is applied to window unit, hydrogen gas is released into the electrochromic layer causing the Ni-Mg to turn transparent.

Different from oxide-reaction EC window in that the Ni-Mg EC window reflects heat and light instead of absorbing them.

Range of transmissibility predicted to be 10x's greater than that of the absorptive materials in oxide-reaction EC windows.

Electrochromic Windows

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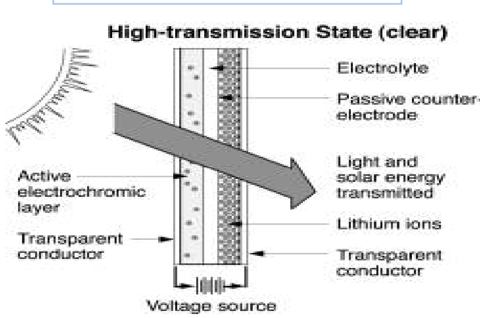
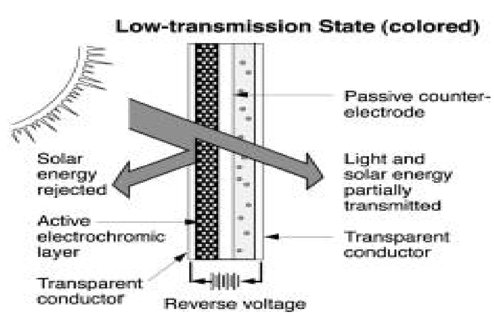


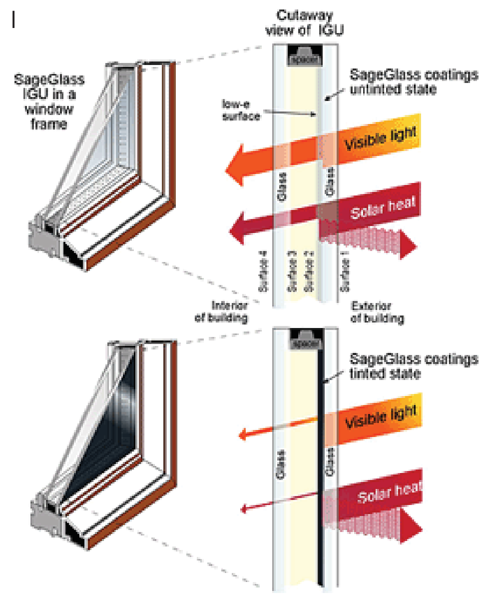


Equipment

Available Glass Sizes: Current sizes available up to 42.5” x 60”.
Outboard lite: ¼” tempered, clear glass.
Inboard lite: Laminated or heat-treated
Spacer: Stainless steel with wall thickness of 0.008”
Seal: Dual seal system – gray silicone and polyisobutylene.
Airspace: ½” argon-filled
Minimum Edge Clearance: 3”
V-shape Channel: Necessary to route wires and conductors down through wall system.

Provided by Sage Electrochromics, Inc.

I



EC Equipment and Controls

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Controls

EC windows can be networked to wall-mounted controllers or to individual PCs.

Manual or automated controls available.

Individual panes of glass can be controlled separately.

Occupants can control glare, solar gain, and daylighting throughout the day.\

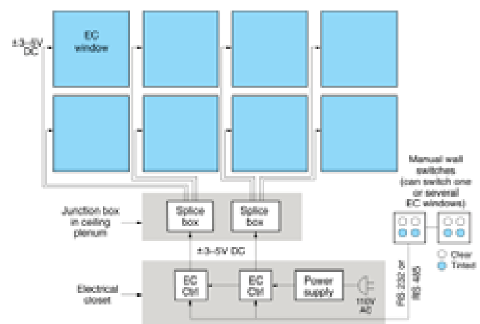


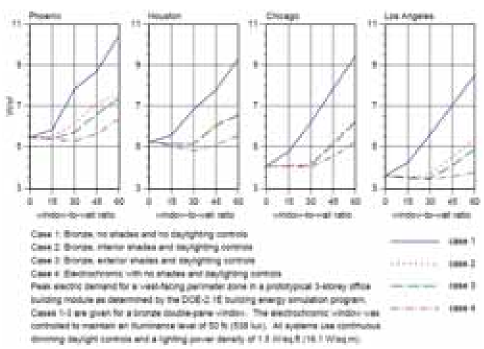
Figure 13. Diagram of a large installation of EC windows with manually-operated wall switches and EC controllers located in an electrical closet.

Controllability contributes to EC system appeal. A typical wall-mounted controller is sold with each system. The controller adjusts the voltage levels and direction as it is sent through the window unit. This controller can allow for manual or automated management of glass tinting levels: 1) fully tinted or bleached, or with an advanced controller 2) a full range of intermediate settings. For networked systems the level of control can be narrowed to a specific room or office by integrating glass control into a typical PC desktop user. The following illustration diagrams the integration of controllability into an EC window system.

Electricity Consumptions

Virtually a “passive” system. Minimal voltage required to maintain “darken” state.

“It takes less electricity to power and control 1,500ft² of SageGlass® glazing per day than it does to power a 60-watt incandescent light bulb.”



California Energy Commission
Berkeley Test Results

Average daily energy use savings of nearly 10-23% compared to conventional high-transmittance window (Tv=0.06)

44% savings realized (reference case had no daylighting controls).

More savings could be realized if windows were controlled based on occupancy.
(e.g. unoccupied building : Tv=minimum)

Peak Load Reductions

EC windows realize load reductions due to solar gain as high as 26% provided window was fully tinted (SHGC = 0.09)

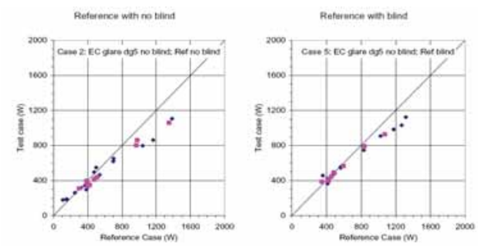


Figure 17. Field measured hourly peak cooling load due to heat gains from window and lights for the single-zone EC system controlled by glare (Tv=0.05) compared to the reference case with (right) or without (left) fully-lowered Venetian blinds (45° slat angle). Peak loads occurred above the 800-1000 W level for both the reference and test (EC window) cases. [Lee et al. 2006]

Reductions realized as energy savings

The two-for-one benefit inherent to these EC windows is that the building occupant gets the benefits of two windows for the price of one. While in the summer months the user appreciates the shading capabilities of the window as well as its 0.09 SHGC, during the winter the visible transmittance can be increased up to 62% and the SHGC increased to 0.48. The following summarizes the U.S. Department of Energy’s report stating that electronically tinted windows are capable of significantly decreasing building operational costs by providing exceptional reductions in solar heat gain.
40% savings on energy bills
20% savings on operating costs
24% reduction in peak demand
25% decrease in the size of HVAC systems

Table 6: Annual Energy Savings Potential of Commercial Window Technologies

Window Type	Energy Savings over Current Stock			
	Heat, quads	Cool, quads	Lighting, quads	Total, quads
Sales (Business as usual)	0.03	0.17	-	0.20
Low-e	0.33	0.32	-	0.65
Dynamic Low-e	0.45	0.53	-	0.98
Triple Pane Low-e	0.71	0.31	-	1.02
High-R Dynamic	1.10	0.52	-	1.62
Integrated Facades	1.10	0.52	1.0	2.62

Stock use is 0.85 quads Heating, 0.54 quads Cooling. See Table 2.

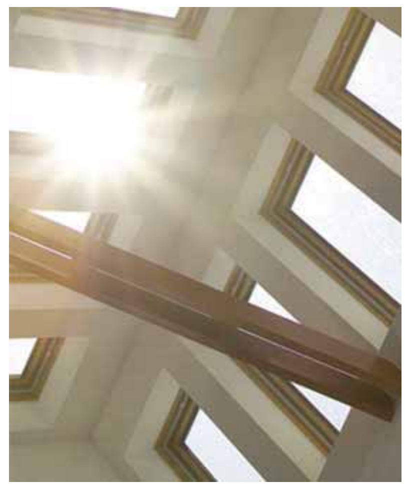
Economics

The continuing development of smart windows brings with it persisted challenges that face both manufacturer and consumer alike. EC product manufacturers in particular must find new ways to either comply with the current production and construction standards, or instead transform the market and requirements required for advanced window wall systems. As an educated market swings, so will the prices and associated costs for products adjust and adapt in a favorable manner.

Currently, prices for dynamic windows are high due to a lack of consumer demand for mass production and the additional specialty costs related to transportation, installation, and maintenance. Windows are not readily associated with cost savings by the occupants of a building; cost savings are more visually apparent in utility and energy bills. The experience of the consumer is the essential market component that must quickly be altered.

Dynamic windows may make this necessary alteration in perception possible. As more buildings are integrated with these EC window units, the more consumers will be able to physically experience the advantages. While the economic savings of installing these windows will be realized to the consumer of the time, the immediate impacts of glare control, natural daylighting, and thermal and visual comfort will quickly increase consumer demand for this technology. As demand rises the cost per unit will decrease. Prices for this EC window technology currently range from $65 to $100 per square foot; the projected goal is to reduce this premium to nearly $10 per square foot. [2]

Sage Electrochromics, Inc. is the leading producer of EC windows in the market today. The company has installed its SageGlass® units into what is considered a case study in progress, the Desert Medical facility in Palm Desert, California. SageGlass® is utilized in operating rooms as well as office space. This product can offer varying degrees of light transmittance while negating the need for maintenance-heavy shades and blinds.

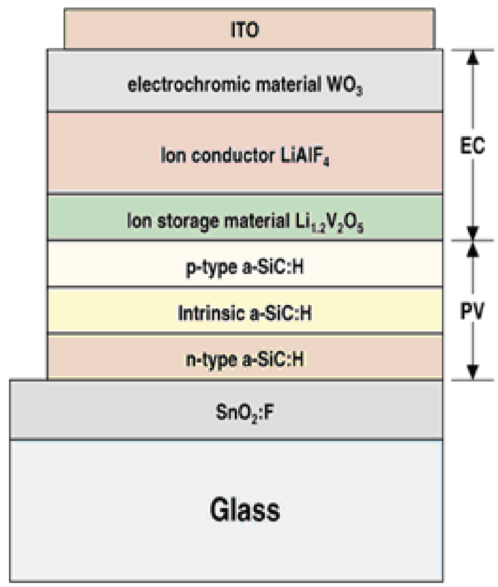


Sage Electrochromics, Inc

Photovoltaic-Powered EC Devices (PV-EC)

The National Renewable Energy Laboratory (NREL) is in the process of developing a prototype EC window that utilizes photovoltaic-generated energy to power the switching/tinting process. A photovoltaic (PV) film is attached to the ion storage layer of the EC window. This film harnesses energy from sunlight to generate the necessary voltage to darken the electrochromic layer. An additional contact layer positioned between the PV film and the EC layer could be wired to a battery that could power the EC window in the absence of sunlight.

Incorporating this technology into building design is yet another step toward an integrated wall system that can detect conditions and then react appropriately.

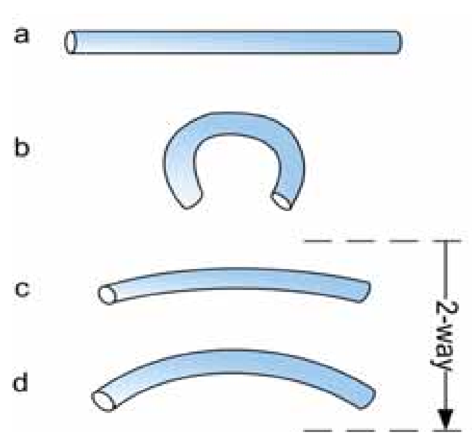


Lawrence Berkeley National Laboratory

Shape Memory Alloys (SMA)

Shape Memory Alloy (SMA) is a term used to describe a particular metal that can “remember” its geometry and return to its original condition after being deformed. The typical types of SMA’s are copper-zinc-aluminum, copper-aluminum-nickel, and nickel-titanium (NiTi) alloys. NiTi alloys are superior mechanically and in terms of durability. Heat acts as the catalyst by which these extraordinary metals deform in a controlled manner. The two-way effect of these alloys allows the metal to change into two different shapes, the changes occurring once at high temperature and then returning to its original state at a low temperature.

Although mainstream, architectural applications have not yet been published, SMA use in architectural functions has already begun. Delta Metal has investigated the use of SMA material in the passive operation of greenhouse windows. [12] As the heat within the greenhouse increases, the SMA actuators respond by changing shape and opening the windows. When sufficient heat has been released the temperature within the space will fall and the actuators will again react by returning to their original state, thereby closing the windows.



www.wikepedia.com

Check List

definitions
cost
maintenance
properties
lifecycle
embodied energy
health
benefits
disadvantages
final analysis

Window Industry Initiative

The U.S. Department of Energy's Office of Building Technology, State and Community Programs (BTS), in cooperation with the window manufacturing industry, has developed a "window technology roadmap". [13] The initiative identifies the goals and strategies for the window industry over the next 20 years. The purpose of this strategic plan is to support the industry's crucial needs with government funding and resources. It will serve as a guide for collaboration between industry professionals, laboratory testing facilities, and government entities in an effort to accomplish the Vision of the initiative.

This Vision is sustained by six elements that articulate future concerns, goals and trends that will effect successfully accomplishing the 20-year initiative:

1. Windows as an integral part of the building system
2. Active, smart glass and windows
3. Informed consumers at all levels
4. More glass and windows used in buildings
5. Windows as an environmental solution
6. Windows as an energy source [13]

Final Analysis

Clearly glazing plays a much larger role in the operation of not only a building's skin, but also its mechanical functions. Windows are not merely holes in the wall anymore but rather a resource by which occupants maintain a connection to the outside, and the building itself can sustain a comfortable interior environment efficiently and responsibly. This evolution in glazing started as a single window, then to an advanced window wall system, and now must continue to progress into a working "appliance in the wall," an integrated system with needs, reactions, and consequences.

Electrochromic windows provide us with the appliance necessary to move forward in this conversation of building integration and green design. Future technological advancements (e.g. PV-EC and SMA) can contribute to a new Roadmap of Design by which an architect's perspective might change. A building, a site, and a community would no longer be separated, but instead united as an integrated piece of the landscape and the urban fabric.

Future Windows

Leed

EA Credit 1
IEQ Credit 6-8

Vision

"In 2020, consumers recognize windows as affordable 'appliances in the wall' that are active and interactive parts of a true building system. Windows offer added value by providing energy, entertainment, and information with enhanced comfort, lighting, security, and aesthetics, in harmony with the natural environment."

U.S. Department of Energy
"Window Industry RoadMap"

Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

final analysis

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Internet Resources

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•www.nrel.gov National Renewable Energy Laboratory (Golden, CO)
•http://eetd.lbl.gov Lawrence Berkeley National Laboratory (Berkeley, CA)
•www.sandia.gov Sandia National Laboratory
•www.howstuffworks.com Explanation and comparison of different smart window technologies
•www.greenbuildingpages.com/links/weblinks_lab.html Comprehensive “Green” resource site
•http://gaia.lbl.gov/hpbf/main.html Case studies through University of California
•http://murphyjahn.com/english/frameset_intro.hrm MurphyJahn Architects
•www.eu-swift.de/#Overview Overview of Swift campaign in Europe
•http://www.permasteelisa.com Permasteelisa Group, curtain wall experts.
•http://www.ultimateniti.com Ultimate NiTi technologies
•http://www.nitinol.com NDC – Nitinol Devices and Components
•http://www.unlv.edu/labs/neatl University of Nevada, Las Vegas – Natural Energies Advanced Technologies Laboratory.
•http://www.refr-spd.com Research Frontiers, Inc.
•http://www.sggprivalite.com/home/bottom.html Saint-Gobain Glass Vision: Priva-Lite.
•http://www.conservationcenter.org/e_main.htm Energy Center of the Rockies – Colorado.
•http://www.consumerenergycenter.org Consumer Energy Center – California Energy Commission

Energy Stratigies

Leed

EA Credit 1
IEQ Credit 6-8

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• Interview with Paul R. Tufts, Civil Engineer.

• Interview with Brian Tufts, Material Science Engineer.

Check List

DMCA

Double Skin Facades

Beijing Swimming Center

ETFE Film

Nanogel

Case Study: Denver Museum of Contemporary Art

Overview:

Owner:
Denver Museum of Contemporary Art

Design Architect:
Adjaye Associates

Architect of Record:
Davis Partnership

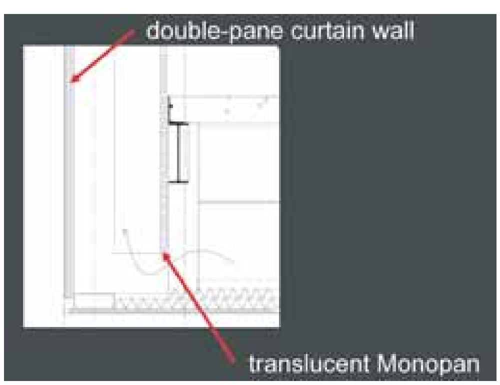
Mechanical Engineers:
M-E Engineers

LEED Consultant and Energy Analysis:
Enermodal Engineering

Square Footage: 27,000

Status: Under Construction

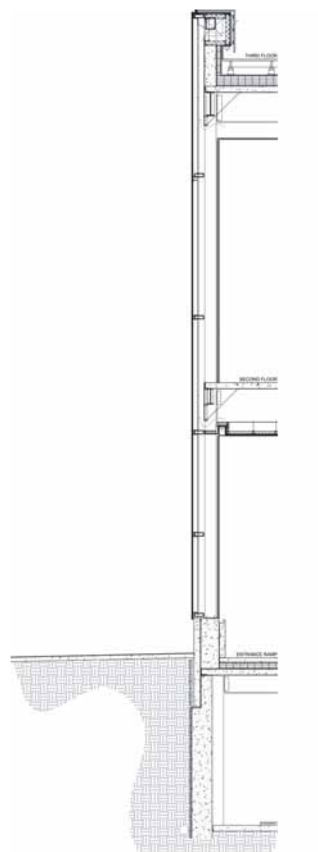
Exterior rendering of DMCA at night.



Close-up of the Double Skin Facade wall section

Double Skin Facade

- DSF covers approximately 50% of the buildings exterior envelope
- Cavity mechanically exhausts air from plenum space to outdoors
- Design driven by architect
- Translucent Monopan diffuses light and heat evenly through interior space.
- DSF gives precise control over solar gain and airflow – Whole building becomes a mechanical system



TYPICAL WALL SECTION -
DENVER MUSEUM OF CONTEMPORARY ART

Translucent Walls

LEED Credits:
EA Credit 1
EQ Credit 8.1

Check List

DMCA

Double Skin Facade

Beijing Swimming Center

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DMCA - Double Skin Facade

Energy Analysis of Double Skin Facade:

One southeast-facing zone from an eQuest model was analyzed using Energy Plus to determine effects of the Double Skin Facade (DSF) on heating and cooling loads.

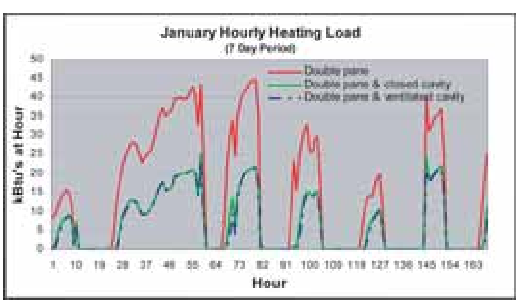
Base Case: No cavity is used for the baseline case. Glazing is **double pane insulating glazing** as proposed for exterior facade.

Model A: Closed cavity model consists of exterior double pane insulating glazing and interior glazing as translucent Monopan. Closed cavity with no airflow **functions largely as a triple pane glazing.**

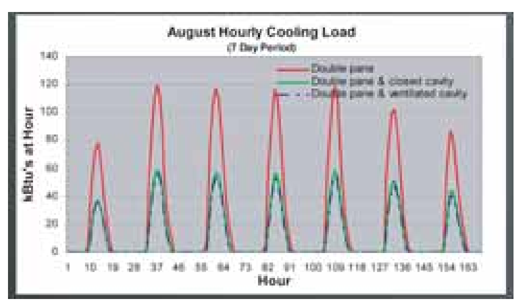
Model B: **DSF with cavity and airflow** consists of exterior double pane insulating glazing and interior glazing as translucent Monopan. Air is taken from the interior zone into the cavity zone at a rate of 293 cfm.

Results: DSF with closed cavity reduces daily and peak demands in approximately half. Introducing airflow through the cavity saves an additional 2-3%. During summer months, the lower effective SHGC of DSF due to translucent Monopan reduces these peaks. In winter months, the cavity plenum with moderate air temperatures reduces heat transfer through the

		Baseline	Model A		Model B	
August	Average Cavity Temp. (F)	98	107		104	
		Load	Load	% Red.	Load	% Red.
	Peak Cooling Load per Window Area (Btu/h-ft^2)	70	35	50%	33	53%
	Average Daily Space Cooling Load (kBtu)	557	258	54%	241	57%
January	Average Cavity Temp. (F)	45	89		92	
		Load	Load	% Red.	Load	% Red.
	Peak Heating Load per Window Area (Btu/h-ft^2)	26	15	44%	14	47%
	Average Daily Space Heating Load (kBtu)	347	158	55%	148	57%



Energy analysis of winter heating loads.



Energy analysis of summer cooling loads.

Translucent Walls

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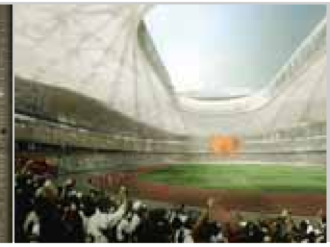


DMCA - Double Skin Facade

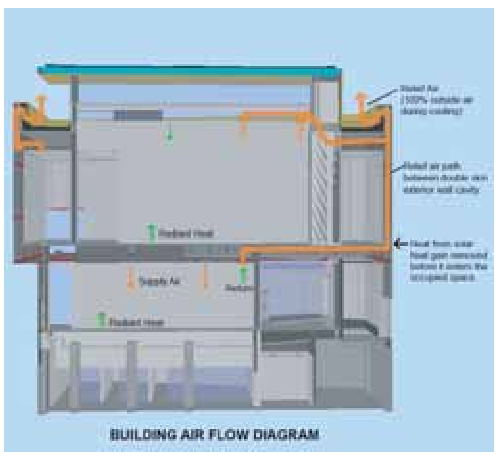
Buildings Overall Energy Conservation

- Lighting system improved 20% over ASHRAE standard due to increased diffused daylight from the translucent wall system.

- Demand controlled ventilation

- Exhaust air relief through DSF

- In-Floor Radiant Heating with VAV dedicated outdoor air systems.



Energy analysis of winter heating loads.

Interior rendering showing translucent Monopan system.

DSF Conclusion

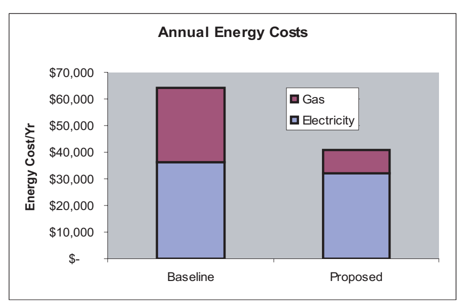
- Annual Energy Cost Savings are 37%

- Greatest savings are from radiant heating, dedicated outdoor air system coupled with demand control ventilation.

- Huge savings compared to baseline, but only 3% savings due to DSF over triple glazing system with no air flow.

- The whole HVAC system, however, is well integrated with the façade resulting in significant overall HVAC annual energy savings.

- Efficiency with translucency becomes an integral component of the system as a whole, but not by itself. Why? It DIFFUSES heat and light more efficiently than standard glazing alone due to reducing hot spots from direct sunlight penetrating the facade.



Projected annual energy costs from energy analysis.

Translucent Walls

LEED Credits:
EA Credit 1
EQ Credit 8.1

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

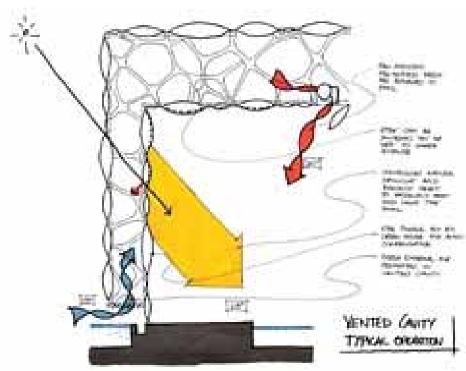
Capacity: 6000 Permanent Seats

11000 Additional Temporary Seats for the Olympics

Issue: Building Skin – Using ETFE Film

Beijing Swimming Center. (The Water Cube)

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.

Translucent Walls

LEED Credits:
EA Credit 1
EQ Credit 8.1

ETFE Foil

Basics:
ETFE or Ethylene TetrafluoroEthylene (Teflon) is a fluorocarbon-based polymer, a kind of plastic. It is designed as a UV stable copolymer material with high corrosion resistance and strength over a wide temperature range. The foil is extremely thin (20 Nanometers). An ETFE foil cushion is made up of at least 2 layers of ETFE, which are sealed with an aluminium extrusion. The more layers of ETFE used the better the insulation properties become. The cushions are inflated with low-pressure air to provide insulation to reisis wind loads.

ETFE weighs 1% of the equivalent sized piece of glass panel and can take up to 400 times its own weight.

Different patterns can be created on the foil to create diffent levels of transparency. By using a checker board pattern on the foil a variable transparency between 5% and 65% can be achieved. A pattern using alternating stripes, where the stripes themselves are 50% transparent create a system that can adjust from 45%-85% transparent. Pressu-reized air is used to inflat and deflat the ETFE cushion. (Figures 1 and 2)

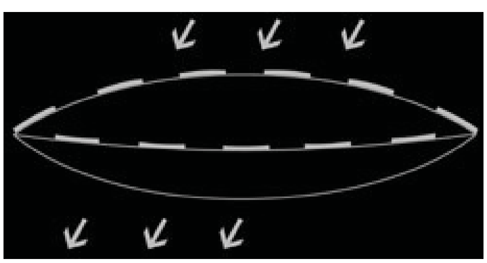


Figure 1. Open/Inflated Cushion.

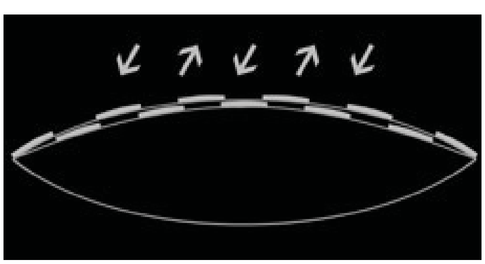


Figure 2. Closed/Deflated Cushion.

The light transmissions properties of the ETFE allow for the growth of plants letting in light wavelenghts around 450nm and 650nm

Ecology:
ETFE is unaffected by air pollution and UV light. It does not become yellow, harden or deteriorate over time with a durablitiy of over 20 years.

The raw material used to make ETFE is not a petrochemical derivative. The production of ETFE happens in water and does not involve the use of any solvents.

ETFE is a highly energy effieient cladding technology due to both is environmental performance (high insulation and optimized solor controll) and its low embodied energy (less than 1% of conventional technologies).

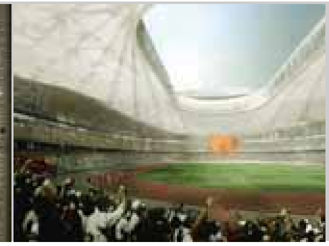
Benefits:
1) This state-of-the-art material provides a cost-effective cladding solution.
2) Extremely low energy consumption during manufacturing process of ETFE.
3) Complete system weighs between 50 -90% less than systems of other materials.
4) ETFE can be completely recycled.
5) ETFE has a high resistance to tearing.

Translucent Walls

LEED Credits:
EA Credit 1
EQ Credit 8.1







Nanogel

Aerogel = Tissue
Nanogel® = Kleenex®

How aerogel is made:

- Aerogel starts as a silica dioxide gel, similar to the gelatin dessert you make at home.

- The liquid in the gel is removed without collapsing the gel (normal evaporation causes the gel to collapse).

- Through a process called supercritical drying, the material does not collapse but retains its original size and shape.


Close-up of aerogel in solid block form.

Aerogel Facts:

- A translucent, very lightweight material that is a dry gel principally made from silica (silicon dioxide) and 96% air.

- Theoretically, a block weighing less than a pound could support a weight of half a ton.

- An ounce of aerogel has the surface area of 10 football fields.

- Aerogels real strength is its incredible insulating effects on any kind of energy transfer; thermal, electrical or acoustic.

- A one-inch thick Aerogel window has the same insulation value as 15 panes of glass and trapped air - a conventional window would have to be 10" thick to equal a 1" thick aerogel window.

- Average pore size is 20 nanometers

Aerogel and LEED

- Aerogels are a more efficient, lighter-weight, and less bulky form of insulation than the polyurethane foam currently used to insulate refrigerators.

- Replacing chlorofluorocarbon-propelled refrigerant foams with aerogels would help reduce ozone depletion

- Using aerogel towards LEED:
v2.2: Enhanced Refrigerant Management
V2.1: Ozone Depletion

- Exchanging refrigerant foams with aerogels reportedly would reduce CFC emissions in the U.S. by 16 million pounds per year.

Aerogel Performance Properties

Aerogel is recognized as the most superior insulating material in the world.

Nanogel Thickness		Light Transmission	Solar heat Gain Coefficient	U *	R *
				(btu/hr ft² °F)	
0.5"	13 mm	73%	0.73	0.25	4
1"	25 mm	53%	0.52	0.125	8
1.25"	31 mm	45%	0.43	0.1	10
1.5"	38 mm	39%	0.39	0.08	12
2"	50 mm	28%	0.26	0.06	16
2.5"	64 mm	21%	0.21	0.05	20

* ASTM 1363

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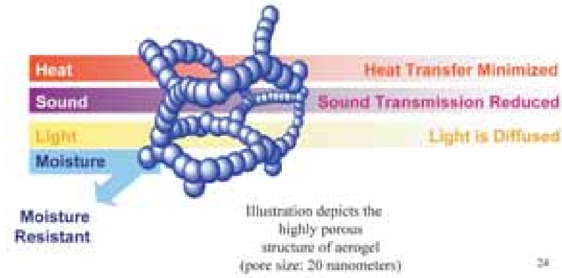
Aerogel's unique combination of properties provide performance benefits unequaled in existing building materials:



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Translucent Walls

LEED Credits:
EA Credit 1
EQ Credit 8.1

Check List

DMCA

Double Skin Facade

Beijing Swimming Center

ETFE Film

Nanogel

Nanogel

Design Benefits:

- Ability to design with more daylight and meet energy codes.
- Ability to improve occupant comfort, heath and productivity.
- Greater capability to optimize building design and aesthetics.

Performance Benefits:

- Exceptional thermal insulation and reduces solar heat gain.
- Reduces excessive sounds and disturbing noise levels.
- Diffuses and disperses high quality daylight within a space.
- Repels moisture and resistant to mold and fungus growth.
- Permanent long term life and product performance.

Green Benefits:

- Reduces building design loads, and conserves energy.
- Reduces emissions to create a healthier built environment.
- Establishes possibilities for earning USGBC LEED points.
- Nanogel is recyclable and can be reused.

Disadvantages:

- Can not be used alone, must be sand- wiched between glass or other material.
- On average, Nanogel costs $16 per square foot depending on thickness.

Current Nanogel Products:

Polycarbonate Glazing System with Aerogel

Comparison based on 16mm polycarbonate panel with and without aerogel	Standard	Aerogel Insulation
Thermal (R-Value*)	R 2.4	R 4.4
Acoustic (STC Value)	19	22
Light Transmission	82%	60%
Solar Heat Gain Coefficient	.83	.60

Polycarbonate Glazing System

The aerogel filled polycarbonate panels are available in clear and opal color

The opal performance to light transmission and solar heat gain are 29% and 0.44 respectively.

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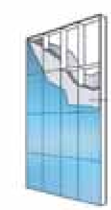
Fiber-Reinforced Panels with Aerogel

	Standard	Aerogel Insulation
Thermal (R-Value*)	R 4.3	R 20
Acoustic (STC Value)	32	35
Light Transmission	20%	20%
Solar Heat Gain Coefficient	0.23	0.10



Fiber Reinforced Daylight System

U-Channel Glass with Aerogel

	Standard	Aerogel Insulation
Thermal (R-Value*)	R 2	R 3.5
Acoustic (STC Value)	42	44
Light Transmission	70%	50%
Solar Heat Gain Coefficient	0.69	0.42

U-Channel Glass

The aerogel filled polycarbonate panels centered in the U-Channel cavity are available in clear and opal color

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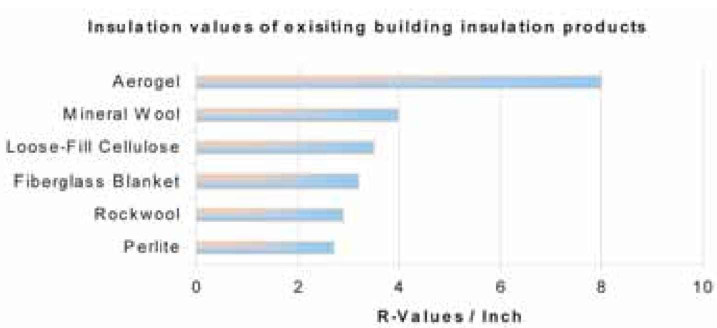

Translucent Walls

LEED Credits:
EA Credit 1
EQ Credit 8.1

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www.ptw.com.au

www.covertex.com

www.foiltecna.com

http://www.fluon.jp/fluon/english/products/etfe_film/index.shtml

Credits

Assistant Professor Adjunct
Fred Andreas, AIA

GBT : Green Systems Project Groups

Green Roofs
Natalie Kerlakian
Jordan Vaughn

Gasification
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Jeff Holtmann

Anaerobic Digestion
Ashley Vlasak
David Needleman

Passive Solar Cooling
Nate Drinkwine
Matt Tynan
Eric Wadsworth

Building Mounted Wind Turbines
Jay Fourniea
Mike Zimski

Magnetic Levitation Wind Power
Andrew Remstad
Christian Allen

Building Intergrated Photovoltaics
Tuong Tran
Alex Madans

Active Building Envelopes
Ali Menke
Josh Voeller

Advanced Wall Systems
Erik Plunkett
Brent Lambeth

Translucent Walls
Joe Murphy
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