HIGH TECH GREEN

NET ZERO ENERGY AND CARBON STRATEGIES

Vol 4. - 09/10

university of colorado

college of architecture and planning

GREEN BUILDING RESOURCE GUIDE

Fred Andreas - AIA, LEED AP BD+C

Table of Contents

Introduction to the GBT Resource Guide

College of Architecture and Planning, University of Colorado Denver
Instructor: Fred Andreas, AIA, Assistant Professor Adjunct

Greenbuilding Technology Resource Guide

This Resource Guide provides an in depth analysis of Zero Net Energy strategies and technologies. The topics covered in the guide serve as a valuable resource for architects, engineers, designers, builders, clients, and students interested in understanding and utilizing these concepts and systems. The ZNE Guide is the fourth volume in a continuing research, documentation, and development guide of green building materials and systems and follows Green Materials (Vol.1), Green Systems (Vol.2), and Residential (Vol.3). This volume focuses on cutting edge technology, research, and trends showcasing zero net energy building strategies.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 http://transstudio.com.

Overview

This Resource Guide was developed during the spring terms of 2009 and 2010 at the University of Colorado's College of Architecture and Planning. It is a compilation of work by 24 graduate students in the Green Building Technology Seminar. This seminar is an upper level graduate seminar focused on the examination and research of the latest cutting edge technology and data available on high tech green systems and materials. The information contained in this guide covers topics such as smart grids, building automated systems, and building integrated energy generation. 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.

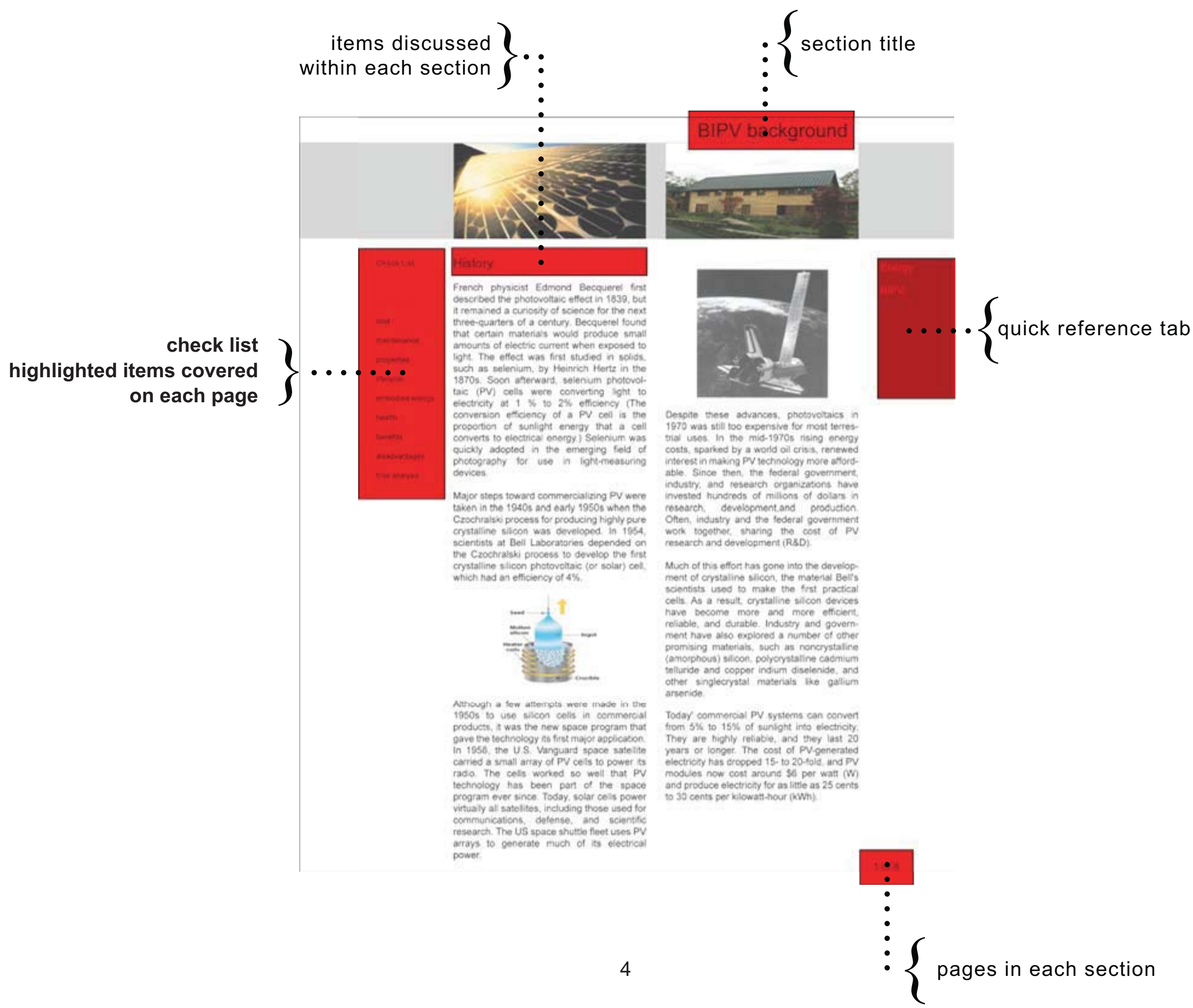
The Green Building Tech Course

The seminar investigated alternative, greenbuilding approaches that include all aspects of greenbuilding design, including materials, equipment, systems, methods, resources, and cutting edge research. 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.

User Guide

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.

Photovoltaics: Embodied Energy & New Technology




Check List

definition

cost

maintenance

properties

lifecycle

embodied energy

health

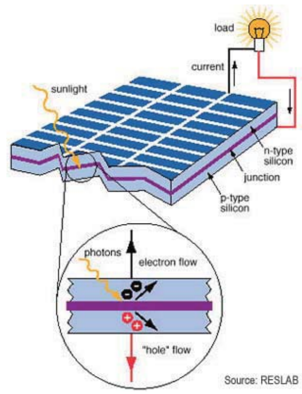
benefits

disadvantages

final analysis

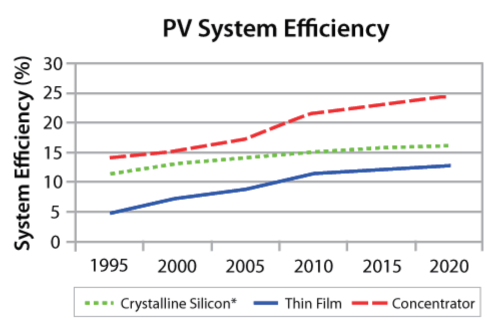
1st Generation

Crystalline silicon photovoltaic (PV) technology was first developed more than 50 years ago at Bell Labs in New Jersey based on silicon wafers, and is known as 1st generation solar technology. Silicon-based technology is technically proven and reliable, and has succeeded in achieving market penetration, primarily in off-grid remote areas and in grid-connected applications where sufficient subsidies are available to offset its high cost. There are several inherent limitations to this 1st generation, however. Silicon wafers are fragile, making processing difficult and limiting potential applications. The process is very labor and energy intensive, and manufacturing plant capital costs are high, limiting scale-up potential. And because materials represent more than 60% of manufacturing costs and silicon supply is finite, the long term potential for cost reduction is insufficient to deliver broadly affordable energy.



2nd Generation

To simplify manufacturing and reduce costs, a 2nd generation known as thin film technologies was developed. These technologies are typically made by depositing a thin layer of photo-active material onto glass or a flexible substrate, including metal foils, and they commonly use amorphous silicon (a-Si), copper indium gallium diselenide (CIGS), or cadmium telluride (CdTe) as the semiconductor. Thin film PV is less subject to breakage when manufactured on a flexible foil. However, the promise of low cost power has not been realized, and efficiency remains lower than that of 1st generation solar. Some questions also remain about the toxic legacy of the materials, both in manufacturing and at the end of life.



PV

New Techonlogy

Thin Film

How is CdTe PV different from other PV technologies?

- Superior light absorption properties that result in higher output compared to traditional silicon modules, under cloudy and diffuse light conditions such as dawn and dusk.
- A low-temperature coefficient that results in better performance compared to traditional silicon modules at higher temperatures.
- Enhanced suitability for high-volume, low-cost module production.

Key Product Design Features

Front (Substrate) and Back (Cover) **Glass**

Laminated glass sheets are heat-strengthened to withstand handling and thermally induced stresses, while avoiding breakage over the 25+ year module life.

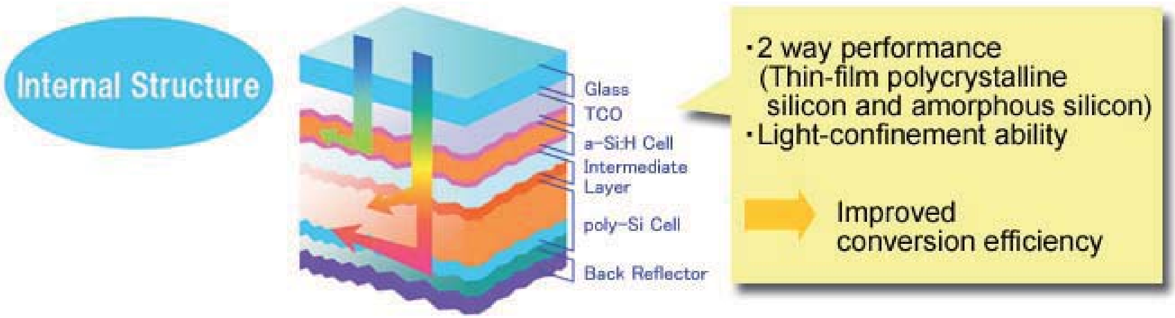
Semiconductor

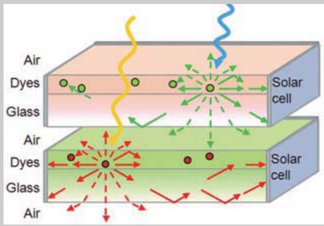
CdTe compound semiconductor material forms the active photovoltaic cells, which convert sunlight into electricity.

Laminate Material

Used to bond the cover glass to the substrate, sealing the photovoltaic device from the environment.

Amorphous silicon (a-Si), a type of thin-film photovoltaic (PV) technology, is experiencing a dramatic growth curve worldwide and offers a compelling business opportunity in power generation, building-integrated solutions and consumer applications. Thin-film PV solutions are the most rapidly growing portion of the PV landscape with approximately 23 percent of the overall PV market in 2008 and a-Si represents the largest component at over 50 percent of the overall TFPV market production in 2008. Amorphous silicon is well positioned to become low-cost PV solution of choice for many applications in the eight-year time frame covered in this report. Lower cost per kWh is the main driver for the shift from crystalline silicon PV to thin-film PV, as well as the increasing acceptance of a-Si thin-film PV for new applications.

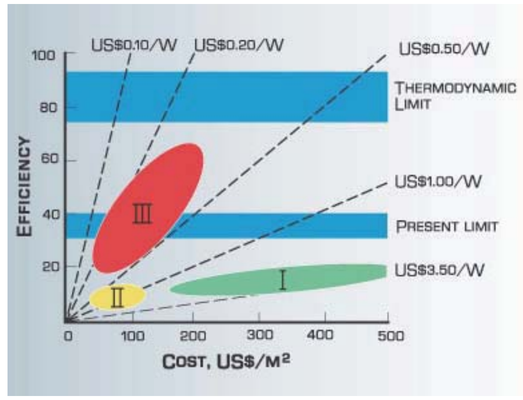




3rd Generation

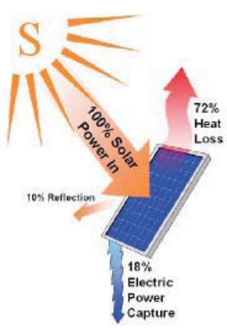
It has been estimated that 3rd generation solar technologies will achieve higher efficiencies and lower costs than 1st or 2nd generation technologies (Green, M., Third Generation Photovoltaics, Advanced Solar Energy Conversion). Today, the 3rd generation approaches being investigated include dye-sensitized titania solar cells, organic photovoltaics, tandem cells, and materials that generate multiple electron-hole pairs. To maximize performance, Konarka scientists have been involved in research efforts in all of these areas, including novel combinations of these approaches.

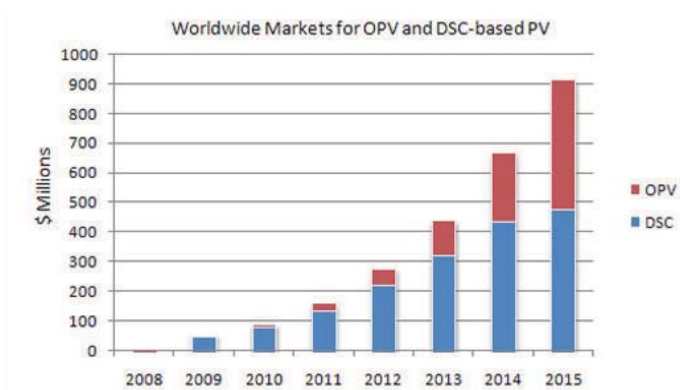
The term "organic PV" (OPV) is frequently used somewhat ambiguously to cover organic/inorganic hybrid materials (notably dye sensitized cells, DSCs) as well as "pure" organic materials. That such materials can exhibit photoelectric effects has been known for many years, and there are apparently a wide range of materials that are candidates for OPV systems, but as indicated above it is only very recently that these materials have been seen as anything other than (one of the many) curiosities of materials science.
But for OPV to move beyond the curiosity category, it must be shown to do something.



NanoMarkets, a leading industry analyst firm, announced 9 march 2009 the release of its report, "Organic Photovoltaic Materials Markets: 2009-2016". The report projects that sales of materials for both "pure" organic solar cells (OPV) and hybrid organic/inorganic dye-sensitized solar cells (DSC), are expected to reach almost $600 million ($US) by 2016.

"The three main areas where OPV is expected to eventually outperform more traditional approaches to PV are (1) very low-costs, (2) enhanced ability to operate in dim light, (3) integration of PV capabilities in building materials and fabrics, and (4) the ability to be printed on flexible substrates," according to the report.





Check List

definition

cost

maintenance

properties

lifecycle

embodied energy

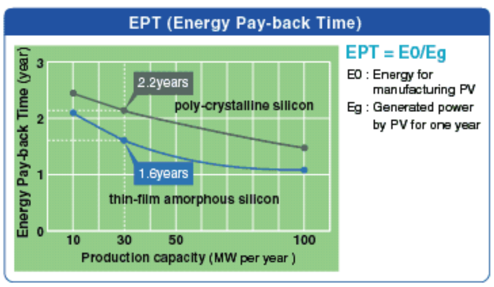
health

benefits

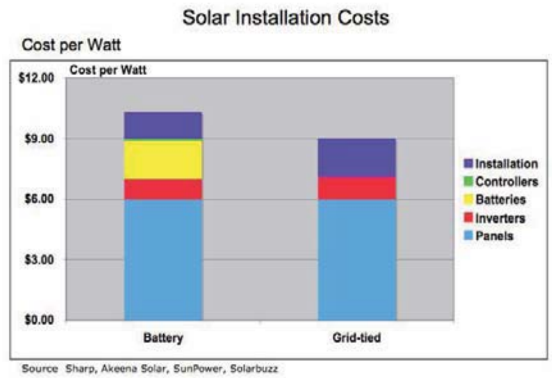
disadvantages

final analysis

EPT is the time a PV module to "pay back" the energy used in its manufacture by its own power generation. The EPT of amorphous-Si PV is 1.6 years, which is approximately 6 months shorter than that of crystalline silicon PV (2.2 years). EPT is one of the most important aspects when evaluating the ecological benefit of PV systems.



The Energy Pay Back Time is defined by EPBT = Einput/Esaved, where Einput is the energy input during the module life cycle (which includes the energy requirement for manufacturing, installation, energy use during operation, and energy needed for decommissioning) and Esaved the annual energy savings due to electricity generated by the PV module. For PV power systems the EPBT depends on a number of factors: cell technology, type of encapsulation, frame and array support, module size & efficiency, PV system application type (autonomous or grid-connected) and, finally, PV system performance as determined by irradiation and the performance ratio. EPBT is also affected by factors that do not directly relate to the characteristics of the PV power system itself: conversion efficiency of the electricity supply system and energy requirements of materials like glass, aluminum etc.



Grid-tied solar appears lower but battery systems that provide backup power given that the sun does not always shine.

As illustrated in Figure 1, the panels represent a significant cost of installation, but the labor and support brackets for the PV panels are significant as well. While thin film PV enjoys significantly lower panel costs and is easier to install, the supporting brackets are sometimes more expensive. As prices for silicon fall, the cost disparity between thin film and silicon PV will narrow.

The tilt of the installation directly affects the Energy Payback Time and the specific CO2 emissions, as they would other parameters which affect the power output (inverter overall efficiency, panel orientation, shading, etc.).

Emissions are dominated by the energy use during PV production. Around 95 % of this energy is electricity. From this figure is important to realise that the environmental performance of PV power systems heavily depends on the energy efficiency of PV system manufacturing and on the performance of the energy system itself, electricity production in particular. The choice of energy conversion efficiency is very important when the manufacturing and the installation of modules are performed in different countries, due to difference in the electricity supply mix.

Engery Pay-back

New Techonlogy

Photovoltaics: Embodied Energy & New Technology

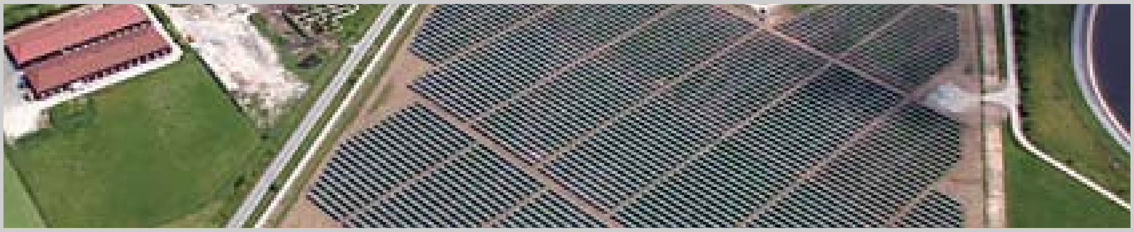
Zero Energy Media Wall - is a groundbreaking project applying sustainable and digital media technology to the curtain wall of Xicui entertainment complex in Beijing, near the site of the 2008 Olympics. Featuring the largest color LED display worldwide and the first photovoltaic system integrated into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

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

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

Solar Art

New Techonlogy



Check List

definition

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

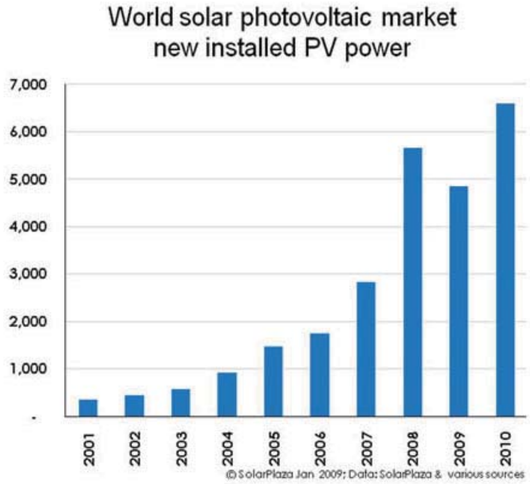
final analysis

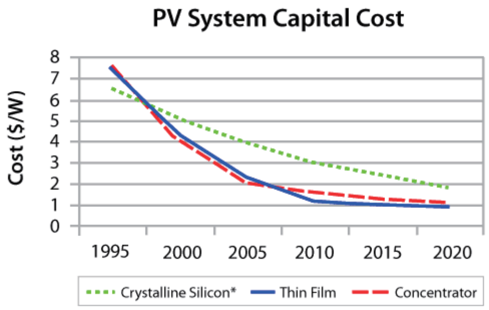
Long-term perspective still very good

The long-term perspectives for the global solar energy market remain great, however. Module prices are declining and industry members expect prices to fall further during 2009. It will bring solar energy closer to the stage where government support is no longer needed.

And, above all, the long-term market drivers that push solar energy will remain in place:

Oil prices are expected to increase when economic recovery returns due to supply limitation.
An increasing number of countries have started CO2 reduction plans, including renewable energy support programs.
Continuously growing electric power demand is being pushed by economic growth in Western countries and Asian rising stars such as India and China.
Continuously decreasing cost of solar modules makes solar energy attractive as a reliable energy source in a growing number of market segments.
Growing interest for electrified transportation (automotive industry opting for electric cars) will stimulate decentralized electricity production.





PV

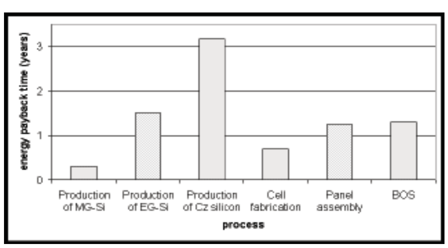
New Techonlogy

HIgh Performance Photovoltaics

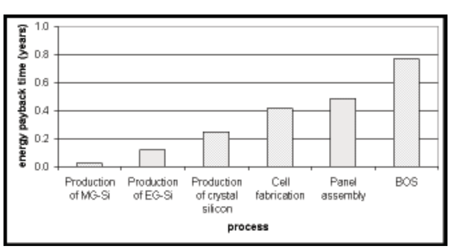
In past years, Embodied Energy (the amount of energy used to collect materials, create panels, and ship to final destination) was upwards of 30 years. With a projected lifespan of 25-30 years, this energy cost made PVs more energy intensive than they would eventually replace. This has recently changed. Researchers have been studying the use of "High Performance Photovoltaics." This includes some of the newest cutting edge materials, technologies, and use of photovoltaics - all with varying levels of efficiency.

Building Integrated Photovoltaics

Building Integrated Photovoltaics have come the furthest on an efficiency standpoint in recent years. In 2000, BIPVs were averaging 20 years to pay back. As of early 2009, depending on the panel, an average payback varies from two years to nine years. The higher efficiency panels typically utilize Thin Film Technology, while the old fashioned Crystalline Silicon Panels (although much more advanced) have a much lower efficiency.



Crystalline Silicon Solar Cells Embodied Energy Payback in Precious Years



Crystalline Silicon Solar Cells Embodied Energy Payback in 2009

Solar Tracking

The ability for a PV panel to follow the sun enhances its capacity to produce energy. Tests comparing a stationary panel versus the same panel on a tracking system show a 25% increase in efficiency. This can be done in several ways:

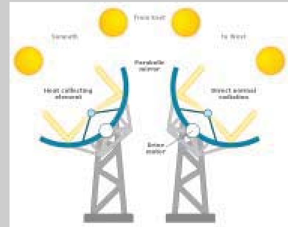
Polar Tracking - one axis rotates parallel to the rotation of the earth

Horizontal Axle Tracking - panel pivots on axis connected to pylon (limited movement)

Vertical Axle Tracking - panel pivots about a vertical axle (very uncommon)

Altitude-Azimuth - panel moves in two directions to locate specific location of sun. These complicated movements require advanced computer technologies (most efficient)

Photovoltaics: Embodied Energy & New Technology



Check List

definition

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

final analysis

Concentrated Photovoltaics

As stated by EMCORE, the leading producer of CPVs, "a Concentrated Photovoltaics approach offers an effective, practical way to keep solar cell conversion efficiencies high while keeping semiconductor material costs down." These PVs are incredibly efficient - roughly 25% overall compared to an industry standard ranging from 8%-15%. EMCORE also boasts the lowest carbon footprint in the production of photovoltaics, utilizing a 95% recyclable product.

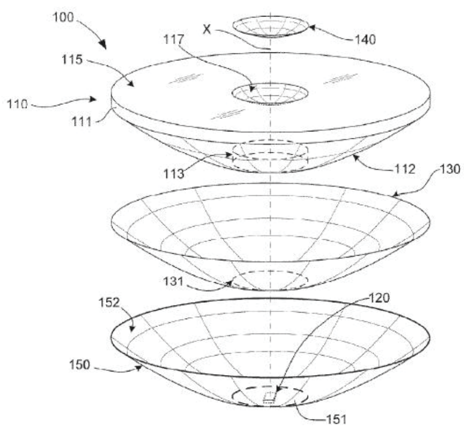


FIG. 1

Concentrated Photovoltaics use a system of mirrors to focus the sun's energy to a small PV panel - roughly 1/500th the size of a typical PV panel. This allows each cell to produce the same amount of energy as an entire silicon panel. A typical CPV panel consists of several cells - thus producing the large amounts of energy.

CPVs require tracking systems to operate efficiently. This increases the overall cost of the product, also increasing the embodied energy. Concentrated Photovoltaics still payback their production energy in roughly two years.

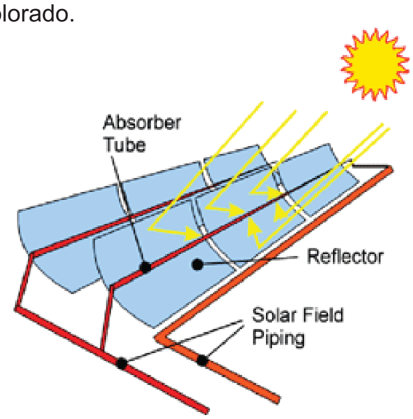
One downfall to CPVs is their lack of ability to handle heat. Mirrors and sunlight produce mass amounts of heat - which can easily destroy the delicate PV panel inside. More research is required to determine adequate ways to deal with this. The current recommendation is ventilation.

Parabolic Trough Photovoltaics

Parabolic Troughs utilize many of the same concepts of Concentrated Photovoltaics - a similar tracking system, similar use of bouncing light, and thus a similar high output of energy.

Unlike CPVs, Parabolic Troughs use a significant amount of PV material. This increase in material (and thus cost) is balanced by the Parabolic Trough's unique ability to use the heat produced by the panel. These panels gain energy through the photovoltaic cells and through the pipes of water / steam running through the troughs. The heat bounced off the panel is absorbed by the tube, warming the water to produce steam. This then goes to a separate system where additional energy is extracted.

Parabolic Troughs, like CPVs, typically take two years to produce their embodied energy. They have, however, been around significantly longer than CPVs and are more reliable. Because of this, fields of Parabolic Troughs have been installed across the South West United States - in areas such as Arizona, New Mexico, Nevada, and Colorado.



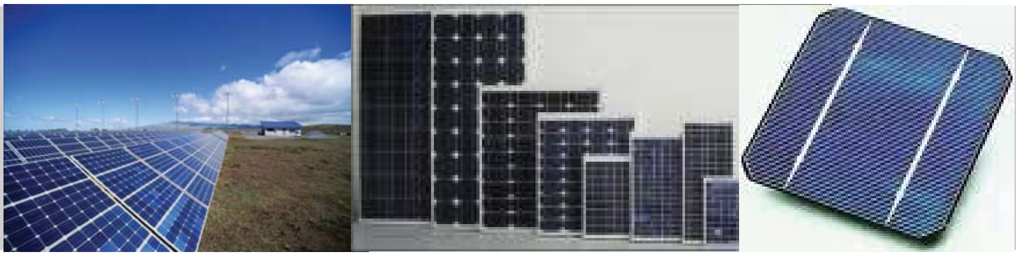
Photovoltaic
Efficiency
Energy

Check List

Works Referenced

http://www.parc.com/research/projects/cleantech/cpv.html
http://www.solfocus.com/en/technology/
http://en.wikipedia.org/wiki/Fresnel_lens
http://www.isuzuglass.com/development/cpv.html
http://solar.anu.edu.au/research/linearconc.php
http://www.parc.com/research/publications/files/5706.pdf
http://www.energybulletin.net/node/17219
http://ecotopia.com/apollo2/pvepbtoz.htm
http://corenewable.wordpress.com/2008/08/26/solar-panels-sure-would-look-good-atop-bends-rei/
http://www.solarsystem.pk/solartracker.html
http://www.nrel.gov/csp/troughnet/solar_field.html
http://www.radiantandhydronics.com/CDA/Archives/BNP_GUID_9-5-2006_A_10000000000000267639
http://www.solargenix.com/pdf/CSPDOEJUNE2003.pdf
http://earth2tech.com/2008/07/31/13-startups-working-on-solar-concentrating-pv/
http://www.pv-tech.org/
http://www.solarbuzz.com/StatsGrowth.htm
http://www.konarka.com/index.php/site/tech_solar/

Advances in Photovoltaic Technology



Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

diadvantages

final analysis

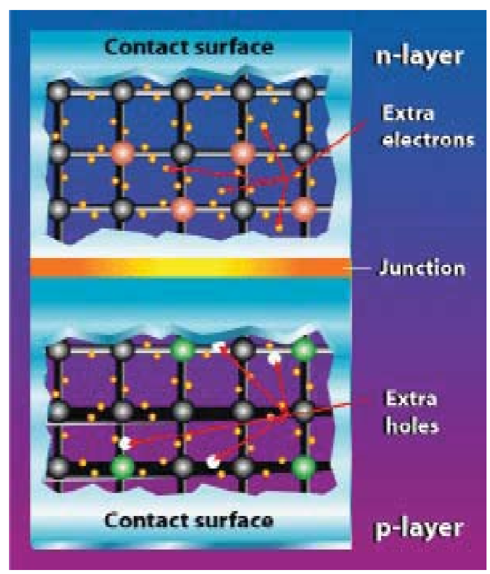
Since solar energy is clean, abundant and renewable it is one of the most promising energy sources of the future. Photovoltaics are devices which capture the energy of the sun and convert it to electricity.

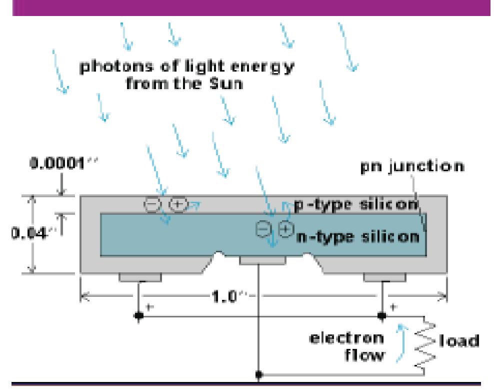
A photovoltaic cell is that a semi-conductor electrical junction device which absorbs the radiant energy of the sun and converts it into electrical energy. Since the first PV technology was utilized in the 1950's to produce electricity the challenge has been to create a PV cell which is both efficient and inexpensive.

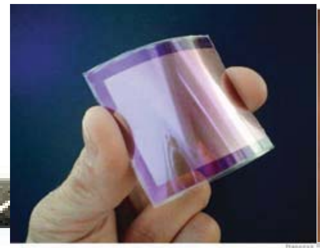
Current commercial photovoltaic cells are dominantly based on crystalline silicon technologies, with efficiencies of about 12% for the best available devices.

There have been three generations of development in the production of solar cells. The first generation was based off of Crystalline Silicon (c-Si). These cells have good efficiency ratings however they are expensive to produce and are fragile.

The second generation of PV consisted mainly of thin film technologies. Thin film consists of the photoactive layer being deposited onto glass or a flexible substrate. Semi-conductors used for thin-film include amorphous silicon (a-SI), copper indium gallium diselenide (CIGS), and cadmium telluride (CdTe). Thin film is far less fragile than the first generation of c-Si cells, however, cost comparisons have yet to be reached and efficiencies are catching up but are not yet comparable to c-SI cells.







Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

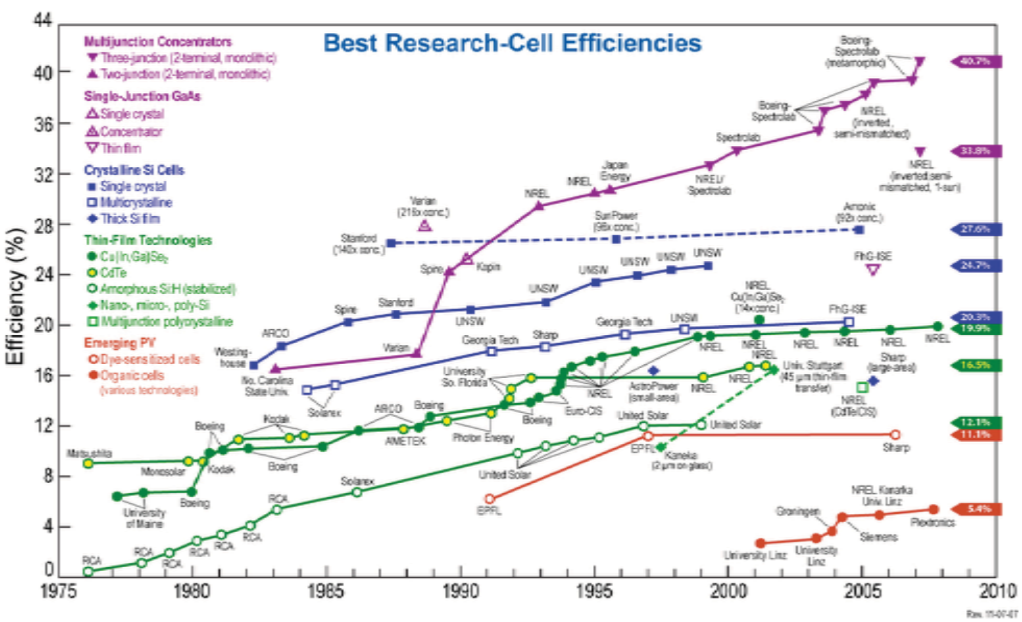
diadvantages

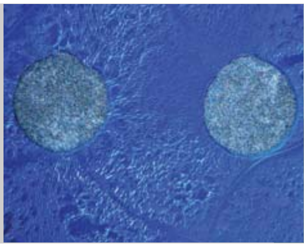
final analysis

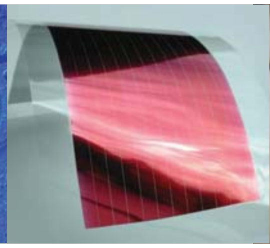
The third generation of PV research is extremely promising. Third generation PV consists of : organic photovoltaics—where the semi-conductor used is an organic material-hybrid cells—which use both organic and inorganic materials, and dye-sensitized solar cells (DSSC) which mimic the process of photosynthesis.

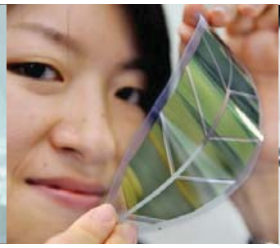
Organic PV takes off on the first two generations of PV but with an organic semi-conductor.

The research for this chapter will focus on OPV and DSC technologies as well as the integration of these technologiys as well as silicon based technologies in Building Integrasted Photovoltaic systems (BIPV).









OPV

Check List

- definitions
- cost
- maintenance
- properties
- lifecycle
- embodied energy
- health
- benefits
- diadvantages
- final analysis

Conventional silicon solar cells contrain hazardous materials such as sulfer dioxide, nitrogen oxide and lead, and Cadmium. For now OPV occupies the high ground, in that the materials that it uses are "organic" and therfor degrade without leaving behind harmful by products.

What makes the OPV safe also is what makes it's lifecycle short. The challenge to the life of the OPV is the degredation of the organic polymers. The degredation is caused by exposure to oxygen, humidity, atmosphere, temperature, and light intensity.

Currently the expected life of OPV cells is around 2-3 years (20,000 hrs.) but with continued research the industry expects that in 10 years the average life of the OPV cell will be up around 15 years long.

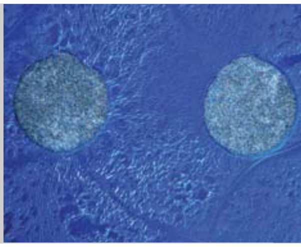
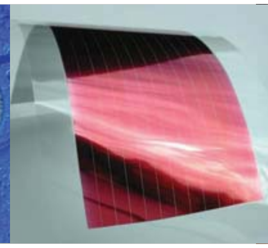
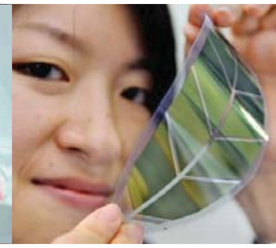
Currently the maintenance involved with solar cells of all types including OPV is cleaning the surface to allow optimum light penetration to the substrates. However, recent developments in nanotechnology have revealed self cleanineg polymers that, in several years, can be applied to surfaces such as solar pannels thus greatly decreasing the need for cleaning.

Disadvantages of OPV technology is that it is still in development and acording to many has a while to go before it is competitive with traditional forms of solar paower collection.

Often the optical bandgap is too high and the band offset between donor & acceptor is not yet optimized. Additionally the charge transfer, transport, and recombination not optimized

Exciton harvesting is of fundamental importance for the efficient operation of organic photovoltaic devices. The quantum efficiencies of many organic and hybrid organic- inorganic devices are still limited by low exciton harvesting efficiencies. This problem is most apparent in planar heterostructures that suffer from a direct tradeoff between light absorption and exciton harvesting.

Durability, as well as, stability, deterioration and low efficiencies are also issues which are still being worked out.


OPV

Check List

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

The advantages of OPV is that there is an abundance of materials and the manufacturing process is simplified. Organic semi-conductors can be dissolved and applied as solutions, whereas inorganic semi-conductors can not. Organic semi-conductors also have a high absorption coefficient which is crucial in producing efficiency in a cell. As OPV is still being developed, comparable efficiencies have yet to be achieved.

Organic based solar cells have the potential to bring about a major breakthrough in reducing the cost of PV cells. In fact, organic semiconductors are relatively inexpensive and can be deposited on flexible substrates in high-throughput roll-to-roll coating machines, leading to low fabrication and installation costs and to a large variety of potential applications that are not appropriate for flat panels.

Currently the cost of solar electricity is of the order of $0.4/kWh, roughly ten times higher than electricity from natural gas.

Although the evolution of the solar energy market since the early 1980's shows a ~23% reduction in the cost of solar panels with each doubling cumulative installed capacity, new photovoltaic concepts and materials are still required to make solar technologies competitive on the energy market and to foster their deployment at a large scale.

Preliminary estimate of OSC costs show that OSC has the potential to reduce the cost of PV electricity by fourfold. However, much work remains to be done on understanding the particular processes for producing OSC and the capital and labor costs associated with them.

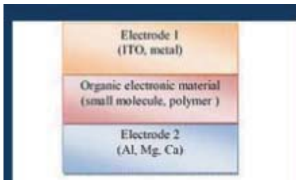


Fig 2. sketch of single layer organic photovoltaic cell

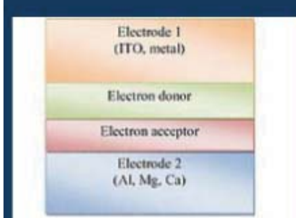


Fig 3 sketch of multilayer organic photovoltaic cell

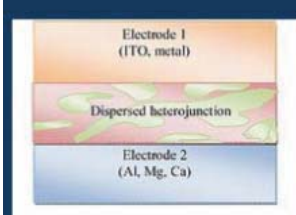
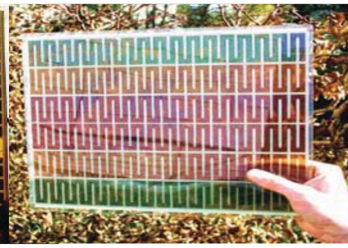
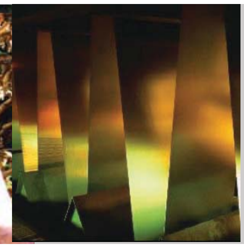


Fig 4 sketch of dispersed junction photovoltaic cell





DSSC

Check List

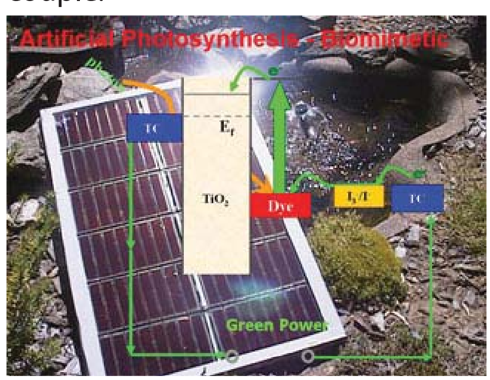
- definitions
- cost
- maintenance
- properties
- lifecycle
- embodied energy
- health
- benefits
- diadvantages

Dye-Sensitized solar cells are also called "Graetzel cells" after Michael Graetzel who discovered them in 1991. This type of cell is based upon the principle of photosynthesis—the bio-chemical process by which plants convert light energy into carbohydrate. They are a type of thin-film cell, but rather than utilizing a semi-conductor layer to absorb light-light absorption occurs in an organic dye—TiO2. In a traditional silicon solar cell, silicon is divided and one side is doped to be a p-type and one side an n-type. This forms a p-n junction which is what creates the electron transfer when light is shone onto it. By contrast, in a DSSC cell, a dye absorbs the light which excites an electron to the higher part of the molecule and from there the energy transfers to the TiO2 (the semi-conductor) where the energy is then collected on a transparent conducting surface.

To date the company Dyesol has demonstrated the highest yet peak effi cency of 11% in converting sunlight to electricity usign the DSSC technology. They have under-taken the approch of Biomimicry t in developing there tecnology

Plant leaves are tiny factories in which sunlight absorbed in the leaf by chlorophyll converts carbon dioxide gas and water into carbohydrates (glucose) and oxygen, thus providing for the energy requirements of the plant.

Artificial photosynthesis is the term given to the concept whereby the leaf structure is replaced by a porous titania nano-structure, and the chlorophyll is replaced by a long-life dye. The energy circuit is completed by a redox couple.



DSSC

Check List

With regards to cost he current goal for DSSC manufacturers is to develop materials with a maximum cost of 70 US$/m2.

Analysis indicates that such a goal can be reached with the materials known today. At an anticipated 7% DSC effi ciency, this corresponds to $1/Wp. Further cost reductions at the materials level are anticipated for largerscale manufacturing.

Some of the features of DSC have been examined through various tests in the laboratory and in the fi eld under different scenarios likely to be encountered in practical applications. Advantages include robustness, constant charging voltage output at all light levels, temperature tolerance, improved performance in 'normal' solar conditions up to ~60ºC, less angular dependence, camoufl age capability, customizable visual characteristics, low energy payback time, low-cost, good demonstrated prototype performance and long-term stability, all which make DSC technology interesting for many applications.

As mentioned previously in the OPV section the DSSC's are safe but are therfore also subject to degredation which therefor limits there life expectency. Researchers in have developed methods for replacign the dye after it's useful life has been reachd thereby also bringing down the cost of the solar cells over time.

Solaris Nanosciences sees that the DSSCs which are based on low cost materials and simple construction, have to date suffered from limited operating lifetimes due to the degradation of the sensitizer dyes.

As a result they have developed completely rechargeable DSSC creating the lowest manufacturing cost, long-life photovoltaic system in the world.

Nontoxic chemical process allows the degraded dye in already installed DSSCs to be removed and replaced with new dye, restoring the performance of the original solar cell.

"Our materials can boost the absorption of sensitizing dyes by several orders of magnitude; potentially making DSCs more effi cient than silicon at drastically reduced manufacturing costs." Solaris Nanosciences

DSSC

Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

diadvantages

final analysis

Advantages of DSSC Technology:

Less sensitive to angle of incidence of radiation

Performs over wider range of light conditions.

Low sensitivity to ambient temperature changes.

Less sensitive to shadowing – can be diode free.

Incorporated into buildings instead of conventional glass panels and as coatings on steel.

Bifacial – absorbs light from both faces

Production through common low cost processing equipment.

DSC modules have lower embodied energy compared to silicon based solar cells.

The TiO2 is a very thin layer which makes it very cheap to produce the cell.

The typical effi ciency of a DSC versus a silicon solar cell: 6-11% versus 8-30% of a silicon solar cell. DSC's do not compare very well with their silicon counterparts on a pure energy/sq meter basis but they are superiour on cost/sq meter.
Solar energy installations account for less than 0.01% of total global primary energy demand. The major reason has traditionally been cost.

Current research shows that the OPV and DSSC tecnologies are coming along at a surprising rate and although there efficiencies may never outmatch those of the silicon based solar cells the lower costs, low impact of enviromenet as well as health and safety, as well as there wide range of uses as building materials make them promising for future applications.

Check List

- definitions
- cost
- maintenance
- properties
- lifecycle
- embodied energy
- health
- benefits
- diadvantages
- final analysis

Solar Energy Marketplace and BIPV:

Photovoltaics is one of the fastest growing market segments in the world today.

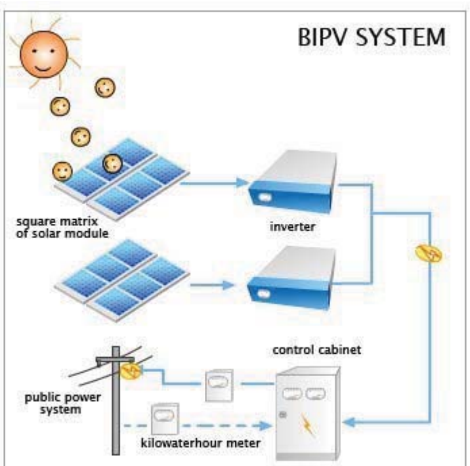
Over 50% of all energy used is in buildings.

Solar power is the most effective energy generator for the built environment for BIPV.

BIPV reduces the carbon footprint for buildings, providing electricity with minimal distribution losses

BIPV offers secure power for buildings, and provides high profi le renewable energy
at a low added cost

First and second generation solar are only useful for roofs due to their high dependence on direct and directed light, however third generation solar can be used to replace walls as a building product



Benefits of BIPV:

Aesthetically pleasing.

The product is easy and less expensive to install.

Less roof penetration, ensuring your roof warranty is still valid.

Low/no maintenance required.

Ideal for off-grid applications.

Lasting performance.

The next few pages will introduce several companies producing BIPV products and several case studies of build, in preocess, or proposed buildings using BIPV technologies.

Building Integrated Photovoltaic (BIPV) technology from Everlight Solar Power Systems uses solar cells to convert solar energy into electricity, and is designed to be building integrated. TAccording to Everflight the attractiveness of BIPV is that it is a sustainable energy source that generates energy where you use it.

Replacing conventional building materials, Everlight BIPV joins seamlessly with metal roofing resulting in reduced installation costs and improved aesthetics compared to conventional photovoltaic modules.

BIPV

Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

diadvantages

final analysis

Helioptix has developed an integrated system of solar collection/daylighting/ double glazed building subpanel / shading device.

The solar facade currently installed at the SyracuseCoE HQ is the first building-integrated concentrating photovoltaic system, developed by researchers at Rensselaer Polytechnic Institute with collaborators at Harvard University.

The system tracks the motion of the sun and uses lenses to concentrate sunlight 500 times, generating both electricity and heat, and was developed with funding from NYSERDA, NYSTAR, and the US Department of Energy. It is being tested in collaboration with SyracuseCoE.

Center of Excellence, Syracuse University

Two seperate see through solar products were choosen for the Kanazawa Bus Terminal in Japan.

TSS(Taiyo See-through Solar) is a high performance glass which can generate infinite and clean electric power through photovoltaics. Moreover, the glass functions as a heat shield preventing excessive solar heat gain.

This product can be seen in the interior photo to the right.

Suntech's See Thru Glazing Product chosen to generate clean power and contribute to the design aesthetic that the city envisioned for its terminal were used to form the bus shelters at the terminal, covering over 3000 square meters and making the Kanazawa Terminal the largest thin film photovoltaic glazing project in the world today.

The Suntech installation at Kanazawa saves 86,465 kilowatt hours annually and will reduce 686 tons of carbon over a 20 year period. These panels can be seen in the photo below.

Advances in Photovoltaic Technology

BIPV

Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

diadvantages

final analysis

Taiwan's new Taichung Convention Center will be covered in solar-powered skin that naturally ventilates the structure reducing energy consumption. The skin-a pleated smocking-esque envelope (seen in the image below)--provides a natural air fl ow to the building minimizing air conditioning usage. It also uses a high-tech double photovoltaic
glass to reduce the remaining energy consumption. Part of the pleat is also transparent so that natural light can permeate the interior.

LAVA Architects won a conceptual re-skinning competition. The skin that they envision is a transparent cocoon that acts as a high performance 'micro climate'. The proposal continues

Innovations include: Existing solar energy used to off set energy requirements, water collected from the atmosphere, natural convection draws conditioned air through existing rooms, and vents to the exterior, localized user control of air and temperature, standard computer designed and generated components manufactured off site and cutting edge digital workflow mean cost effective fabrication and installation, and a solar powered light and media strategy embedded into the fabric.

The image is a rendering of the UTS Tower in Sydney with its proposed Eco-Skin.

Konarka--a manfacturer of polymer-based organic photovoltaic's-and Arch Aluminum & Glass are currently working together in a pilot project to create a solar curtain wall at Arch's office building in Tamarac, Florida. Konkara's main product on the market is currently Power Plastic, which is a film which can be applied to any surface to energy independence. It is currently being integrated into products such as small electronics and camping gear with large-scale BIPV projects in the works as soon as efficiencies reach competitive levels.

Konarka's project with Arch is one of the first projects BI-OPV projects. It is thought that the panels will provide 1.5 kilowatts of power to the facility and from this information collected Konarka will be able to advance the BI-OPV market. Konarka believes BI-OPVs can provide tremendous value by replacing conventional building materials.

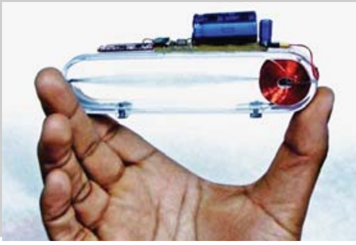
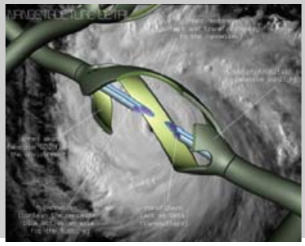
Konarka is also partnering with Air Products to conduct reseach and development on transparent, flexible solar modules for windows and other BIPV applications. They were selected by the National Institute of Standards and Technology (NIST), Advanced Technology Program (ATP) for a $4.7 milliion award to foster new technology developments by U.S. Companies. The technology the companies will be developing is planned to regulate the wavelength of the light passing through the window therefore increasing the amount of energy conserved.

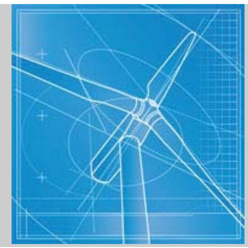
Air products is developing high-conductivity polymers with more efficient charge injection capability in OPV cells thereby improving overall cell electrical performance. Konarka will supplement this by improving their patented transparent, metallic grid electrode techbology in the new cell and module architecture.

It seems liekly, after pereforming this reesearch, that in the near future a large percentage of new construction and remodeling projects will utilize some sort of BIPV that may also integrate wind power, magnetic power generation, along with rainwater collection, food production, etc. to create truly sustainable fully integrated and self sufficient buildings.

bibliography

http://www.sciencedaily.com/releases/2010/04/100406125545.htm
http://www.konarka.com
http://www.dyesol.com
http://www.technologyreview.com/energy/22279/?a=f
http://media.caltech.edu/press_releases/13325
http://www.nanosolar.com
http://www.iset.unikassel.de/pls/w3isetdad/www_iset_new.main_page?p_name=7231006&p_lang=eng
http://www.helioptix.com/HeliOptix_Navigation.html
http://www.sciencedaily.com/releases/2010/04/100409105357.htm
http://www.pvmips.org/
http://www.iset.uni-kassel.de/abt/w3-w/folien/magdeb030901/
http://www.powerfilmsolar.com/
http://www.wired.com/science/discoveries/news/2006/11/72058
http://www.solar.tm/
http://www.suntech-power.com/products/docs/Casestudies
http://www.earchitect.co.uk/sydney/uts_tower_skin.htm/CaseStudy_Kanazawa_17Sep08.pd f?phpMyAdmin=b9f7f7647b32c60f5bb99a3513f000a6
http://www.solenza.co.nz/Solutions/bipv.htm
http://www.dezeen.com/2009/09/25/taichung-convention-center-by-mad/
http://www.everlight-solar.com/en/p_sps02.html
http://gcep.stanford.edu/research/factsheets/organic_photovoltaic.html



Check List

definitions

concept

benefits

disadvantages

possibilities

cost

efficiencies

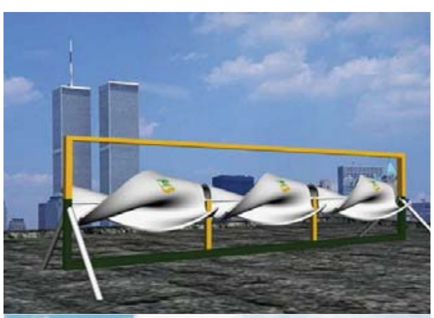
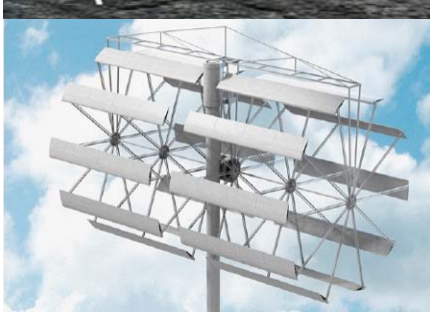
case studies

conclusion

WIND POWER "is the conversion of wind energy into a useful form of energy, such as using wind turbines to make electricity, wind mills for mechanical power, wind pumps for pumping water or drainage, or sails to propel ships."[1]

WIND TURBINE "is a rotary device that extracts energy from the wind. If the mechanical energy is used directly by machinery, such as for pumping water, cutting lumber or grinding stones, the machine is called a windmill. If the mechanical energy is instead converted to electricity, the machine is called a wind generator, wind turbine, wind power unit (WPU), wind energy converter (WEC), or aerogenerator."[1]

ENERGY HARVESTING "(also known as power harvesting or energy scavenging) is the process by which energy is derived from external sources (e.g., solar power, thermal energy, wind energy, salinity gradients, and kinetic energy), captured, and stored."[1]

CONCEPT

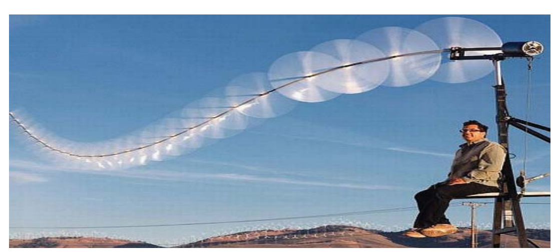
While large scale wind turbines have been designed to very high levels of efficiency, they still inherently posses many problems or disadvantages. All the components are very large and cost a lot of money to fabricate, install, repair and transport, not to mention the large geographical footprint they cover when centralized into wind farms.

These and many other aspects of wind power generation have led people to think smaller. Some small scale approaches have become popular and even been commercialized to micro consumers.

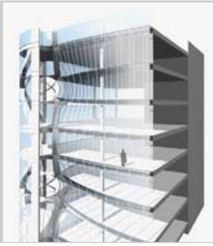
Although these small scale wind technologies are as bold as they are varied, resent data has shown that their efficiencies leave much room for disappointment in certain locations and with certain types of installation.

Thus, given that these inventive machines cost a substantial amount of money, their payback time are not very attractive.

Those are the main reasons why developers and inventors are leaning more toward a micro level, in which the technology could be integrated into building systems, and for a small investment produce a decent amount of electricity.



1 Extracted from Wikipedia



Check List

definitions

concept

benefits

disadvantages

possibilities

cost

efficiencies

case studies

conclusion

BENEFITS OF SMALL WIND TECHNOLOGIES

• Applying (augmenting) small wind turbines such as darrious machines on to buildings provides a good statement of green power and sustainability.

• The creation of some renewable energy through building augmented (BAW) or integrated wind (BIW) systems reduces dependency on the use of fossil fuels.

• Wind Power is a clean power and does not pollute or have any carbon footprint other than that of its manufacturing process and transportation of the equipment before installation.

• There are many incentive programs in which the government pays back or gives tax credits to projects that use a renewable energy source such as wind in buildings.

• LEED points can be gained by using any time of renewable energy system such as wind.


DISADVANTAGES OF SMALL WIND TECHNOLOGIES

• Most small wind technologies are expensive.

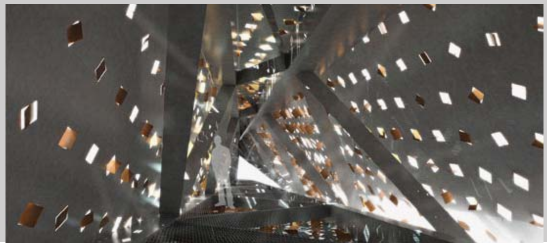
• Due to many different site conditions such as altitude, turbulence, wind path obstruction, drag, etc., most small Building Augmented Wind (BAW) systems have shown to produce much less energy that initially expected.

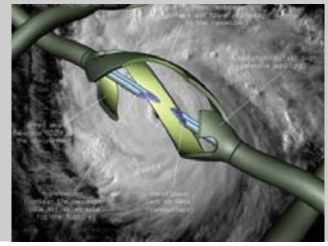
• With a small efficiency rate and a high cost for the equipment, payback times are too long.

• Most small wind systems need constant maintenance and tuning to keep them working decently.

• Small turbines such as darrious machines on poles located on ideal spots of a site are not very cost-effective due to low efficiencies, not to mention those placed on rooftops which are affected by natural turbulence.

• Even medium size Building Integrated Wind (BIW) systems have their drawbacks, such as the noise and vibration created by the turbines, and even if this issue is resolved, there are so many other implications that these buildings would be next to impossible to insure in the US.





Check List

definitions

concept

benefits

disadvantages

possibilities

cost

efficiencies

case studies

conclusion

MICRO WIND

On the Horizon

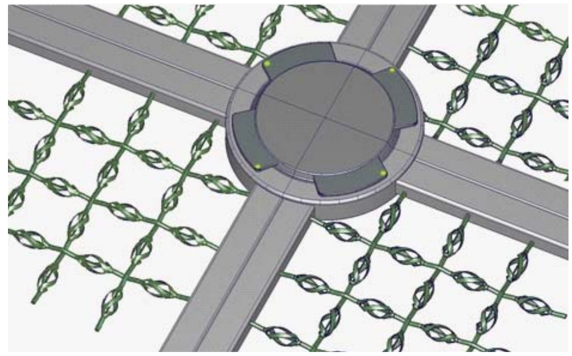
New Generation

If large scale wind farms are good, but too large and remote from the point of use, and if small BAW or BIW are not very cost-effective due to their scale and efficiencies, what then?
Is the answer to just stick to centralized wind farms or to try yet a different scale? Some people think that to be the answer, and in trying to truly integrate wind power technologies into buildings, many have developed ideas that take the scale even smaller. We can call this Micro Wind.

Micro Wind Technologies

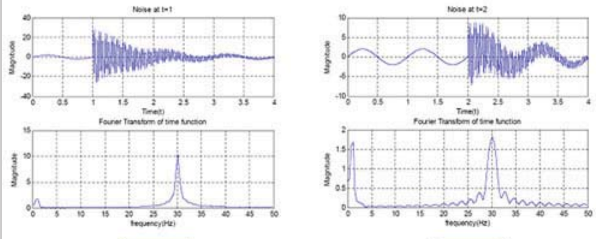
Some developments have just reduce the size of the turbines, and multiplied their numbers.
Others are trying different approaches such as isolating belts and spinning planes that work with magnets to generate electricity.
Yet others are visualizing the future by conceiving a nano level wind turbine that as it is repeated it forms a fabric that can be used as a building's skin, with no friction properties and self-healing capabilities.

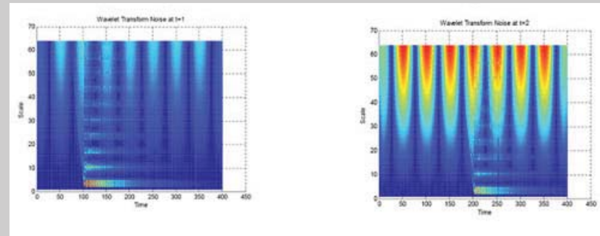
:: The Windcell™, a 1-meter length Windbelt™ generator



List of Known Micro Wind Technologies and Prototypes:

1. Motorwind Micro Turbines
2. Micro Windbelt
3. Micro Wind Skin
4. Nano Vent Skin





Check List

definitions

concept

benefits

disadvantages

possibilities

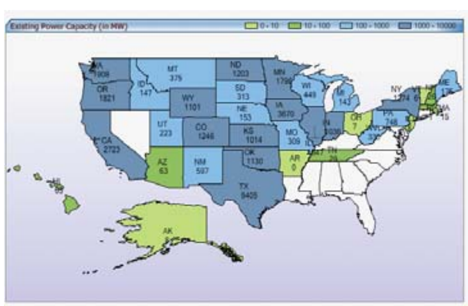
cost

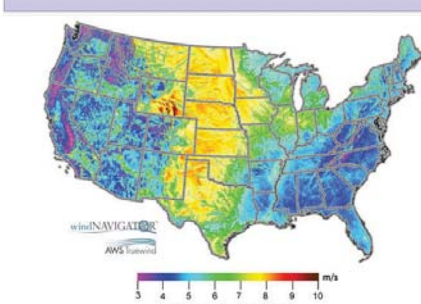
efficiencies

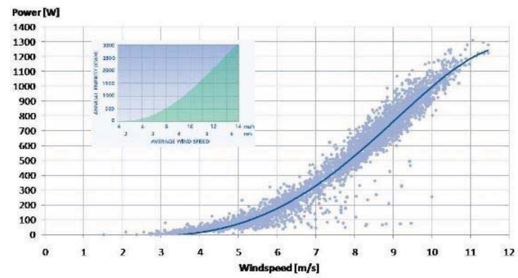
case studies

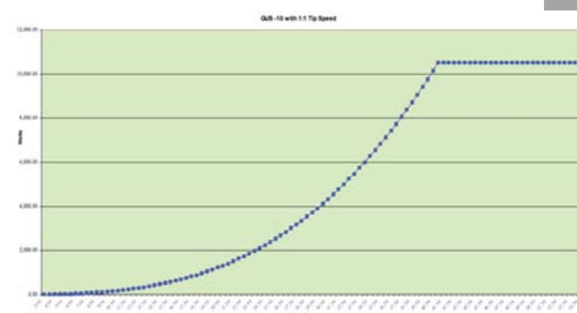
conclusion

Currently, large scale wind production is the cheapest power available. In contrast, small scale augmented wind turbines are produce a power that is more expensive than even photovoltaic energy.
With micro scale systems, however, if they prove to be cheap to mass produce, they would become a reasonably cheap source of energy.
The wind speed factor is obviously a crucial one, and the more wind you get in an area the cheaper the power becomes.
The map below shows that the US is a good candidate, but not all areas of the country have the same potential, as shown in the following maps









The first graph shows the power production results from different small scale wind systems. Notice that the dots follow a pretty steady curve, which means that all systems tested have similar efficiencies, and obviously the higher the wind speed, the higher the wattage produced.
The second graph, however, shows that after a certain wind speed (40-50 MPH) is reached the wattage production flattens out, which means that the machine has reached its potential.

"How does building-integrated wind compare with PV? AeroVironment installations have been running at \$6,500–\$9,000 per kW of installed capacity, which is fairly close to the cost of PV installations, which averaged \$7,600 in 2007, according to a February 2009 report from Lawrence Berkeley National Laboratory. An AeroVironment wind system will deliver, according to Glenney, 750–1,500 kWh annually per kW of rated capacity (depending on the wind resource), while a fixed-pitch, commercial-scale PV system will deliver annually 1,100–1,200 kWh/kW of rated capacity in Boston and 1,400–1,560 kWh/kW in Tucson, according to data provided by Strong.

When you factor in the fact that the PV system is likely to deliver closer to its rated output on a building than the building-integrated wind system, while costing less to maintain, PV is just a better deal."[2]

2 Quote by Alex Wilson: http://www.buildinggreen.com/auth/article.cfm/2009/4/29/The-Folly-of-Building-Integrated-Wind/

Wind Power: Micro Technologies

MOTORWIND MICRO TURBINES

Motorwind micro turbines can work in wind speeds of only 1m/second. Their light weight, small size, and flexible configuration allows them to be installed in both urban and rural environments, for individual or corporate use. Motorwind turbines give users a new option for efficient renewable energy and therefore reducing their impact on the environment.

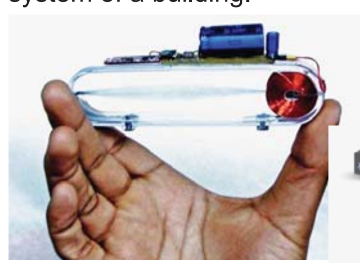
The configuration of these micro turbines allows them to work together as overlapping gears so that if one area of the system receives more wind, the force is distributed throughout so that all turbines spin at the same speed, therefore giving a more even and consistent output.

This system has been tested on prototypes and a school sign, but it seems that it could very well be integrated onto a double skin system of a building.

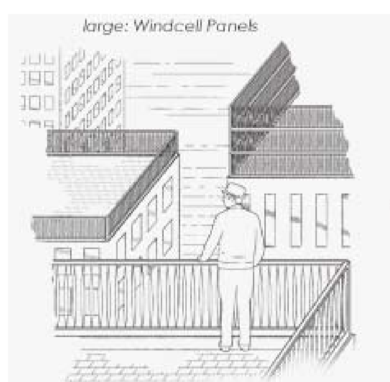
HUMDINGER'S WINDBELT

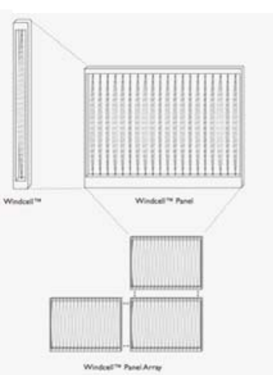
Humdinger has been working on three scales of application for the Windbelt technology. At the smallest scale, the microWindbelt is only roughly 5 inches long and 1 inch tall and can provide power for sensors or small electronics. A larger Windbelt in a 1-meter long frame, called the Windcell, can provide 3 to 5 watts of power, enough for an LED light or other relatively low-power needs. Windcells can also be assembled into panels. A 1 meter square Windcell panel is anticipated to be able to produce up to 100 watts, and have a panel cost of around $1 per watt.

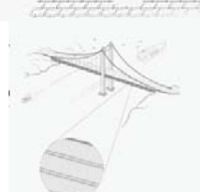
The use of these windbelt panels has been envisioned along the side of bridges or on rooftops, but the ideal would be to integrate them into an interstitial wall system of a building.

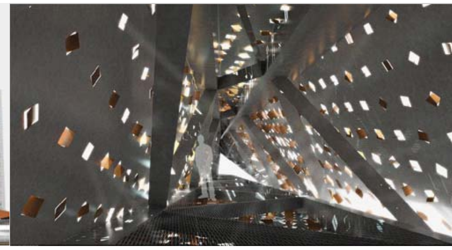


:: The Windcell™, a 1-meter length Windbelt™ generator







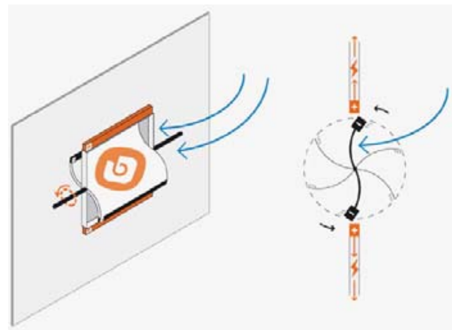



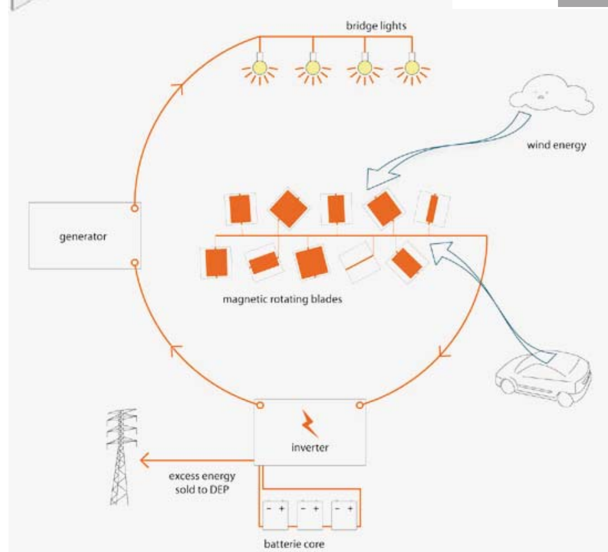

CROSS-WIND BRIDGE: MICRO WIND SKIN

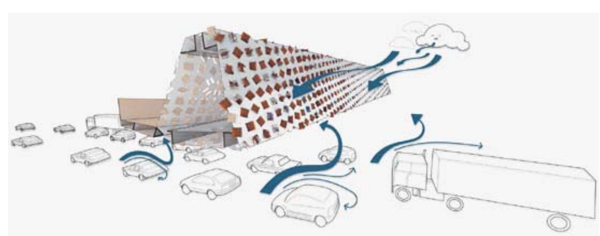
Tiago Barros + Jorge Pereira
Lisbon
2009

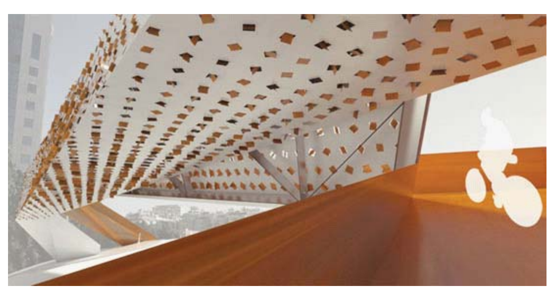
“The cross-wind bridge which is meant to promote the notion of a multipurpose envelope, engineered to capture the wind power from a network of 2,188 light-weight rotating panels. The idea is that drivers who pass under the bridge, will contribute to its ecosystem, increasing the wind velocity by up to 20%, optimizing the rotation of the panels. An induction power system exchanges wind energy through an electro-magnetic band located on each panel. The result of this is a power source which is used to illuminate the bridge by night, which then acts as a responsive 'urban chandelier', visualizing the productive elements that produce its inner light.“[3]

"The cross-wind bridge runs 40m in a south-west / northwest direction over the segunda circular highway in Lisbon. Its paths oblique angles are positioned to optimize Predominant wind directions while providing a tunnel for pedestrians and bikers, Reconnecting and making accessible the remaining paths of Maria Droste Vila split by the highway and engulfed by Telheiral’s residential park. In this context, the bridge will play a formative role in magnetizing sustainable development and turning rural fragments into areas of public green space."[3]









3 http://www.designboom.com/weblog/cat/8/view/7974/tiago-barros-jorge-pereira-cross-wind-bridge.html

Check List

definitions

concept

benefits

disadvantages

possibilities

cost

efficiencies

case studies

conclusion

ECCO ECO LA + ECCO ECO NY

Bureau V
Los Angeles, CA & New York, NY
2009

Ecco Eco LA "is intended to produce brand identity through the production of architecture that is sustainable, memorable, and proactive. Currently in the research and design phase, the project strives to integrate sustainable design elements into an ornamental patterned volume. The signature element of the building is a facade comprised of custom integrated wind turbines that harness energy from passing winds as well as from wind produced by the building's air displacement."[4]

"Ecco Eco NY is a redesign and renovation of an existing structure to house the offices of Ecco Eco, an environmental design initiative. The building is intended to take advantage of sustainable energy sources while providing an iconic presence to the environmental brand. Combining environmental performance with graphic design, the signature element of the project is an intricate patterned facade comprised of custom parabolic solar panels and [wind micro turbines] that produce electricity and improve the urban air quality."[4]

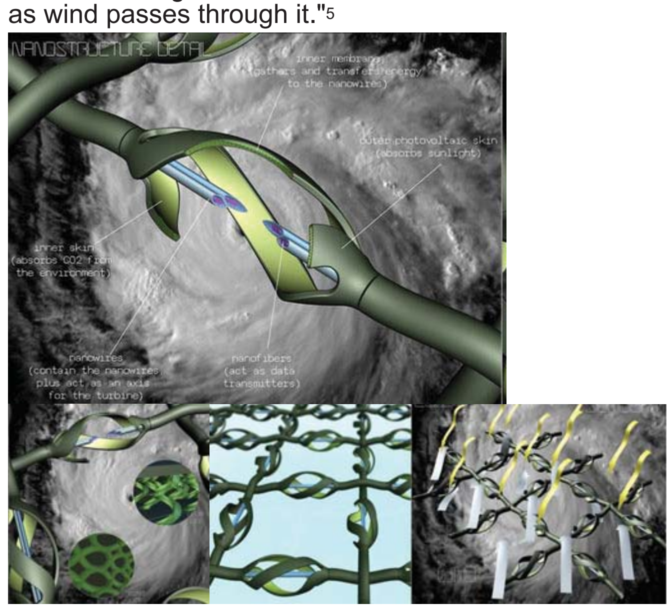
NANO VENT-SKIN

NOS - Agustin Otequi
Mexico, D.F.
2008

"Nano Vent-Skin (NVS) tries to make people think on a smaller scale and apply it to existing buildings, houses and structures (tunnels, road barriers, etc) to generate energy."[5]

"With this approach NVS makes existing objects greener by covering them with a skin made out of micro wind turbines.
It consists of a set of micro turbines (25mmx10,8mm), which generate energy from wind and sunlight."[5]

"The outer skin of the structure absorbs sunlight through an organic photovoltaic skin and transfers it to the nano-fibers inside the nano-wires which then is sent to the storage units at the end of each panel.
Each turbine on the panel generates energy by chemical reactions on each end where it makes contact with the structure. Polarized organisms are responsible for this process on every turbine's turn.
The inner skin of each turbine works as a filter absorbing CO2 from the environment as wind passes through it."[5]

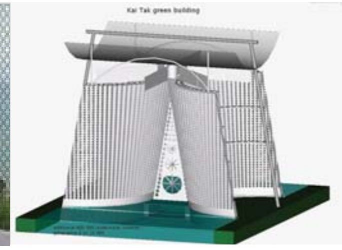


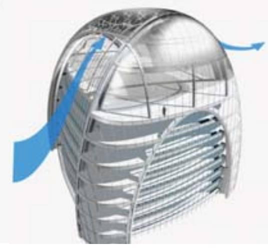
MICRO WIND

Innovating Part 3

4 http://www.bureauv.com/

5 http://www.nos.mx/index_eng.html



Conclusion

• Producing power at the point of use is important because transferring it from a centralized location represents a significant loss of energy.

• Although wind power is generally cheap and therefore very attractive to developers, when it is harnessed by means of small scale turbines it stops being cost-effective.

• The idea of micro level wind technologies can be a positive one if properly integrated into the architecture of buildings, bridges and other community infrastructure.

• Even with the potentially increased efficiency and cost-effectiveness of Building Integrated Micro Wind technologies (when compared to regular small scale augmented systems), the design of buildings must not concentrate on this technology alone. Micro wind must be complemented by others, also integrated systems, such as interstitial wall systems, photovoltaics, magnetic power, passive heating and cooling through solar, natural ventilation and breezes from bodies of water, etc.

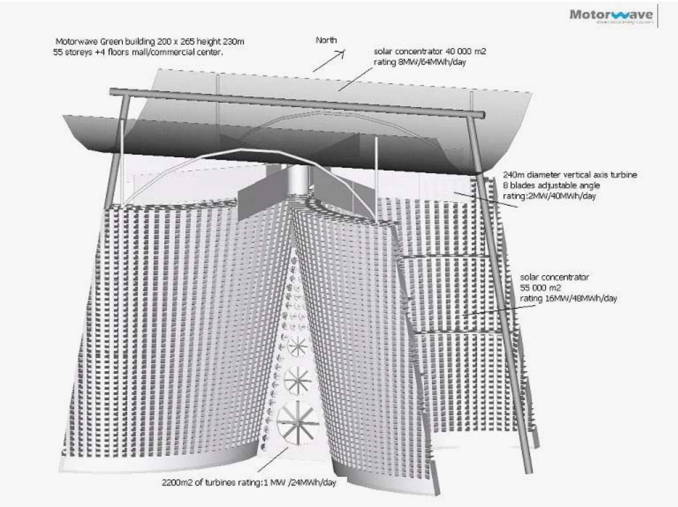
• After looking at all the available building wind technologies. Those that tend to move to the micro and even the nano level seem to be the most promising. This probably due to their ability to be easily reproduced and integrated onto building skins without being too intrusive.

'Solar Ivy' Photovoltaic Leaves also produce electricity by flapping in response to the wind.

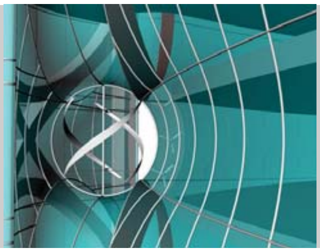
MICRO WIND

The Veredict

'Solar Ivy' Photovoltaic Leaves also produce electricity by flapping in response to the wind.



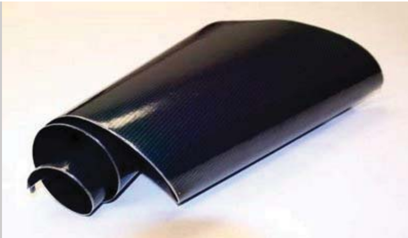
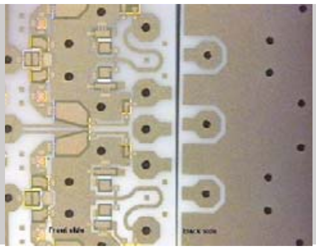
Kai Tak Hypothetical Green Building or X Building

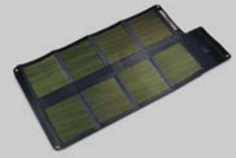


References

1. Floating wind Turbines in the north sea:
http://www.inhabitat.com/2007/07/02/floating-wind-turbines-in-the-north-sea/
2. Turbines on water towers: http://www.inhabitat.com/2009/05/06/optiwind-accelerating-wind-turbine-taps-new-fields/
3. Wind A History:
http://www.mywindpowersystem.com/2009/05/the-most-amazing-wind-turbines-designs/
4. Ten Wind Turbines: http://designapplause.com/2009/ten-wind-turbines/2283/
5. Motor Wave's Motorwind micro turbines: http://www.motorwavegroup.com/new/index1.html
6. Humdinger Windbelt: http://www.humdingerwind.com/
7. Cross-Wind Bridge: http://www.designboom.com/weblog/cat/8/view/7974/tiago-barros-jorge-pereira-cross-wind-bridge.html
8. http://www.bureauv.com/
9. Nano-Vent Skin: http://www.nos.mx/index_eng.html
10. The Magenn Power Air Rotor System (MARS) is a patented high altitude lighter-than-air tethered device that rotates about a horizontal axis in response to wind, efficiently generating clean renewable electrical energy at a lower cost than all competing systems. http://www.magenn.com/technology.php
11. They have the power to provide clean, renewable energy. They have the power to run silently. They have the power to lower your energy bill. But most of all, they have the power to inspire. Windspire vertical wind turbines. http://windspireenergy.com/
Videos: http://windspireenergy.com/video/windspire-energy-2/
12. Largest wind turbine http://www.inhabitat.com/2010/02/16/norway-to-build-the-worlds-largest-wind-turbine/
13. Building Turbines, LLC is an Austin-based start-up company focusing on designing and manufacturing revolutionary wind turbines, for generating electricity. http://buildingturbines.com/
14. http://solarivy.com/
15. http://www.motorwavegroup.com/motorbuilding/index.html
16. Clean Technology Tower: http://www.jetsongreen.com/2008/03/clean-technolog.html

Thin FIlm Technologies



Check List

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

DEFINITIONS

Thin film Photovoltaics (PV)
- low temperature curing inks suitable for front-side grid and bus-bar conductors for thin film technologies such as CI(G)S, Cd Te, DSSC, organic and amorphous silicon;

Electroluminescent (EL) Displays
- a full system of compatible inks for printing EL lamps

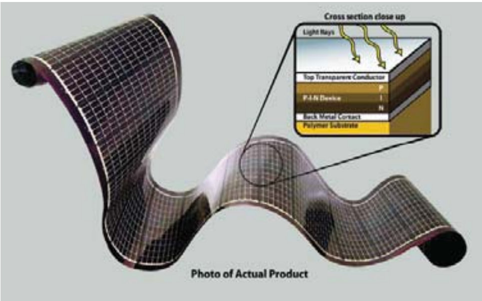
Biosensors
- gold, silver, carbon and custom ink formulations for working and reference electrodes

RFID
- Printed antennae using DuPont MCM silver inks, with widespread usage in ticketing, ski passes, automotive antennae, e-passports and luggage labels

Membrane Touch Switches (MTS)
- full range of silver, carbon and UV dielectric inks

Printed Batteries
- carbon, silver and other custom compositions for printed batteries

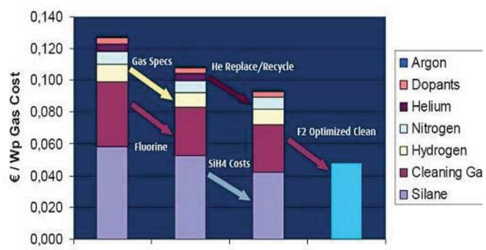
Smart Packaging
- next generation flexographic inks



COST

Although the cost of thin film technology is relatively high right now many people believe that with the advancement and use of such products we will see the cost of such technologies drop below the cost of similar standard technologies in the next 5 years.

Possible Cost Reduction Opportunities
- Reduction of gas costs
- Cost reduction for PECVD chamber cleaning
- Increasing manufacturing line throughput
- Improving cell efficiency



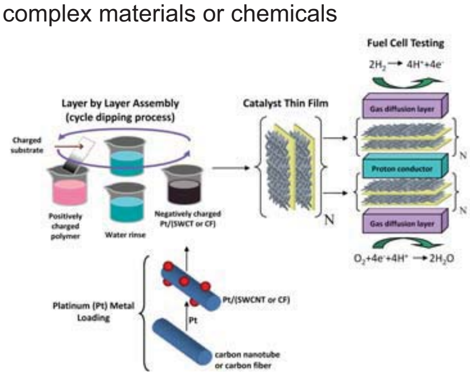
COMPOSITION

There are a number of ways in which these types of materials are formed, below are the three most common with a chart showing how the system is composed.

Chemical deposition
- fluid precursor undergoes a chemical change at a solid surface, leaving a solid layer

Physical deposition
- uses mechanical or thermodynamic means to produce a thin film of solid. An everyday example is the formation of frost.

Other deposition processes
- normally rely on a mixture of these two methods required to imprint some more complex materials or chemicals



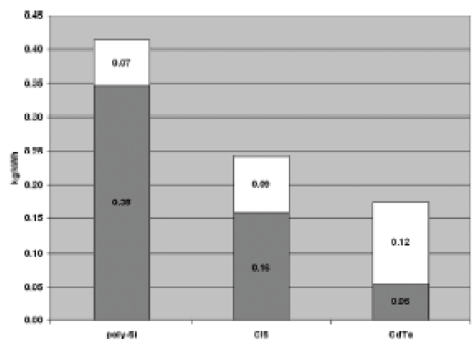
Thin Film Technologies
Kevin Nguyen
Maciek Gesikowski

Energy and life cycle assessment of thin film CdTe photovoltaic modules.

In reference to the study performed by (NREL) National Renewable Energy Laboratory the energy and life cycle of CdTe modules takes in to the account the following :

-Raw material flow.

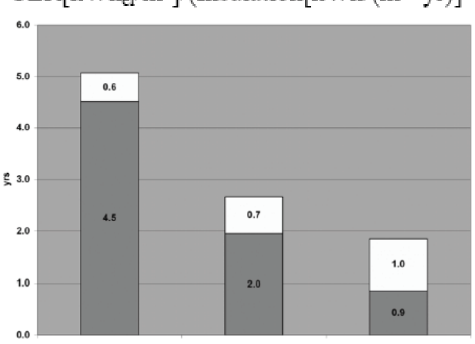
This method looks at material resource depletion and incorporates the amount of raw material per unit of delivered service (kWh).



-Energy analysis using energy pay back time.

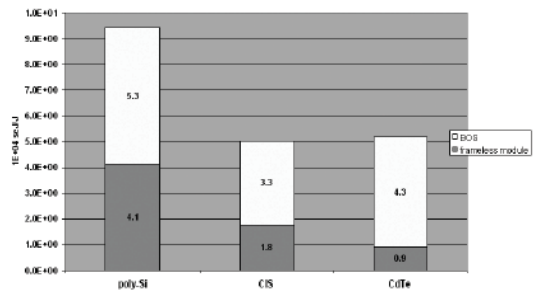
Energy pay back time for CdTe wafer technology is 0.9 years. The method takes into account the total amount of fossil fuels used by this process.
The Energy Pay Back Time is calculated as follows:

$$GER[kWh_{el}/m^2]/(Insulation[kWh/(m^2*yr)]*\eta$$

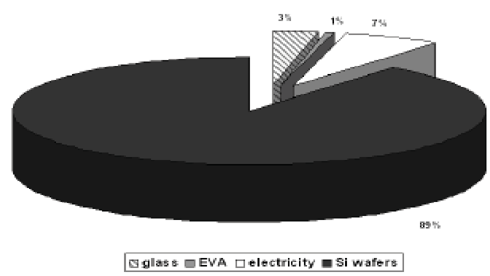


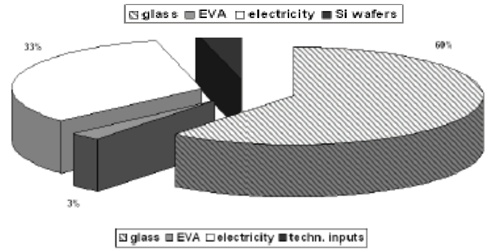
-Enegery analysis using solar transformity.

This method is trying to consider the total amount of indirect environmental support provided to the biosphere to the system.
To express this relationship the units of solar equivalent Joule per Joule of electricity produced are used [seJ/J].



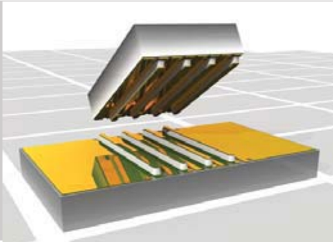
-Environmental impact using CdTe modules versus Si modules.

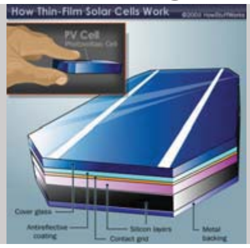




Conclusion:
-CdTe technology is a product with the least impact on the environment:
-CdTe uses the least amount of raw material
-CdTe has the fastest pay back time of 0.9yrs.
-CdTe needs the least of solar support for Joule to Joule produce.
-CdTe has the smallest impact during manufacturing process.
-Least CO2's emitted per kWh.
-Lest Eco Toxicity potential.

Thin FIlm Technologies





Thin Film Technologies

Kevin Nguyen

Maciek Gesikowski

Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

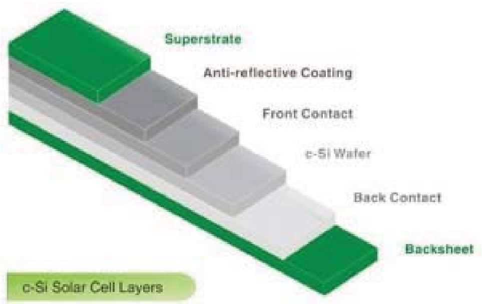
disadvantages

final analysis

BIO-SOLAR

- Bio-based materials from renewable plant sources to reduce the cost and environmental impact of thin film PV

- BioBacksheetTM is a premium-grade backsheet consisting of a cellulosic film combined with a highly water resistant and high dielectric strength nylon film made from castor beans, used as a replacement for the extremely popular crystalline silicone backers that are very popular today



PV-TV

- Size: 980mm long and 950mm wide, come in a standard depth of 10mm thick

- Light Transmission: allows 10% light transmission, which is optimal for allowing light in while keeping the environment comfortable

- Solar: can generate 3.8 watts of electricity per square foot, an above-average level of efficiency

- TV: this system can be used to project full color images onto the panels… although they do not work well when there is competing light.

THIN FILM BATTERY

- All solid state construction

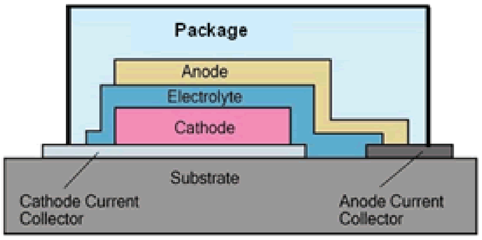
- Can be operated at high and low temperatures (tests have been conducted between -20°C and 140°C)

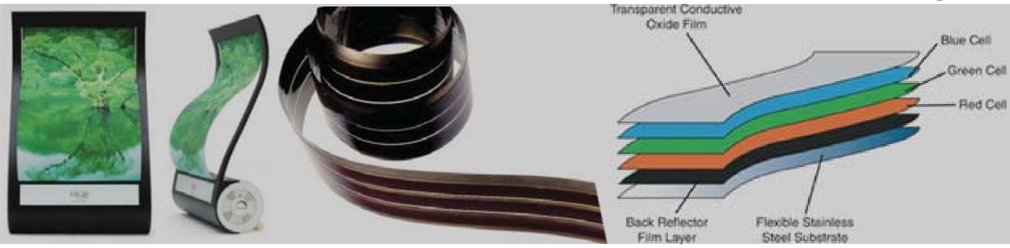
- Can be made in any shape or size

- Cost does not increase with reduction in size (constant $/cm2)

- Completely safe under all operating conditions.

- Dupont is the leader in developing technology to print the necessary parts onto a thin layer, allowing increase in production and decrease in cost





RESOURCES

- http://www2.dupont.com/MCM/en_US/news_events/event20081119.html
Analysis and press release for DuPont Microcircuit Materials Printed Electronics Silver Conductive Ink a more cost effective solution for, Thin film Photovoltaic, Electroluminescent, Biosensors, RFID, Membrane Touch Switches, Smart Packaging, and Printed Batteries.

- http://www.freepatentsonline.com
Used to develop information on a number of different US patents that allowed us to see what was available in this particular area of technology as well as a look into what is being worked on a great source as a starter to find the newest technology.

- http://energypriorities.com/entries/2006/05/xsunx_power_glass_bipv.php
'Thin Film Could Soon Make Solar Glass and Facades a Practical Power Source' an article that looks at the possible solutions for thin glazing solutions and will hopefully begin to bring the use of thin glazing to a more mass population discussing greater efficiencies and ease of use.

- http://www.mhi.co.jp/power/e_a-si/
Mitsubishi thin film PV panel, this resource is for one of the main producers of thin film PV and provides and analysis of two different ways of obtaining the product and the efficiency differences between them

- http://www.toolbase.org/Technology-Inventory/Windows/switchable-glazing-windows
Skylight solar glass technologies allow for more efficient roof cavities that have higher R – Value coefficient therefore better thermal efficiency.

- http://cat.inist.fr/?aModele=afficheN&cpsidt=2373388
Angular selective films which respond to sun radiation in particular angular reflective environment.

- "Printed and Thin Film Photovoltaics and Batteries", Dr Harry Zervos and Dr Bruce Kahn
- Although this book is not available locally the abstract and other information available through the publisher has allowed us to understand some key aspects to thin film development.

- http://www.pvresources.com/en/bipven.php
- looks at some examples of the use of clear PV material and how the assembly can workwithin a building envelope

- http://www.ertex-solar.at/cms/startseiteeng
Ertex soloar has a few completed projects within Germany and other European countries they seem to be at the forefront of melding the ideas of technology and design.

http://www.greenenergyforearth.com/2009/03/11/biosolar-to commercialize-biobacksheet-for-thin-film-photovoltaic-modules-2/
-Bio-based materials from renewable plant sources to reduce the cost and environmental impact of thin film PV

http://www.nrel.gov/pv/thin_film/docs/20theuropvscbarcelona4cv114_raugei.pdf
- information on energy and life cylcle of thin fil PV materials

Thin Film
Technologies

Kevin Nguyen

Maciek Gesikowski

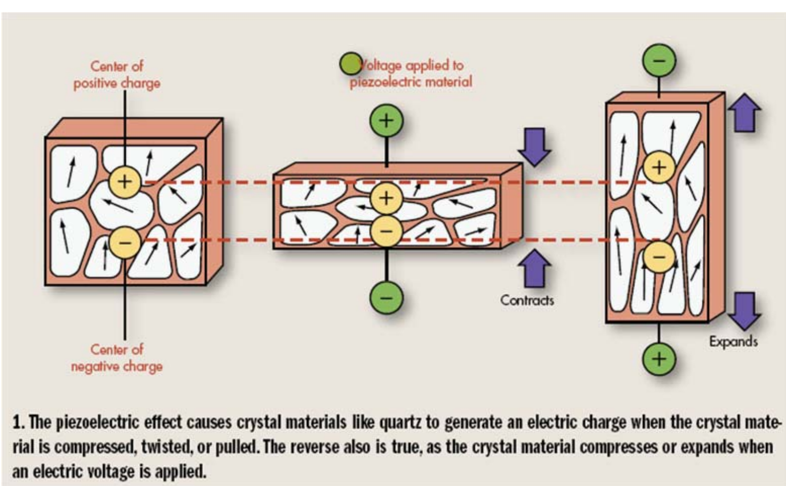
Harvesting Kinetic Vibrational Energy

DEFINITIONS

Kinetic Energy
Energy available as a result of motion that varies directly in proportion to an object's mass and the square of its velocity; when an object has kinetic energy, the elements of the object that are moving are elements within the object such as waves, atoms, electrons, and molecules of that object.

Vibrational Kinetic Energy
Kinetic energy that is caused when an object is vibrating, or experiencing vibrational movement.

Piezoelectricity
The generation of electricity or of electric polarity in dielectric crystals subjected to mechanical stress, or the generation of stress in such crystals subjected to an applied voltage. Piezoelectricity is a naturally occurring phenomenon exhibited by certain materials that generate an electric field when deformed. When a force is applied, an electric gradient is created which generates a voltage across the material. When the material is integrated into a circuit, this voltage will create a DC current.



Piezoelectric

Battery
A device containing an electric cell or series of electric cells storing energy that can be converted into electrical power.

Regenerative Brake
Energy recovery mechanism that reduces vehicle speed by converting some of its kinetic energy and/or potential energy into a useful form of energy instead of dissipating it as heat as in a conventional brake (typically used in railway systems and hybrid vehicles).

Regenerative Brake System

Energy Harvesting
Process by which energy is derived from external sources (solar, thermal, wind, salinity gradients, and **kinetic**), captured and stored, in order to power local devices.

Energy storage
The ability to convert energy into other forms, such as heat or chemical reaction, so that it can be retrieved for later use.

Sub Floor Kinetic Energy Harvesting

Caitlin Jones

Alyssa Manny

TECHNOLOGIES

Flooring Integrated Systems

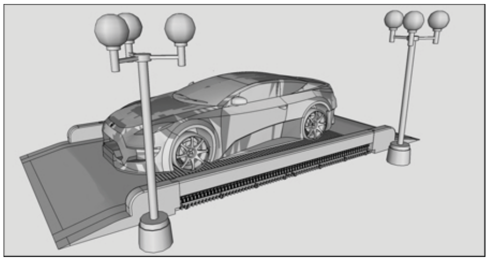
- Pavegen
- KinergyPower
- Innowattech
- POWERLeap
- Crowd Farm

Pavegen

Pavegen in public traffic zone

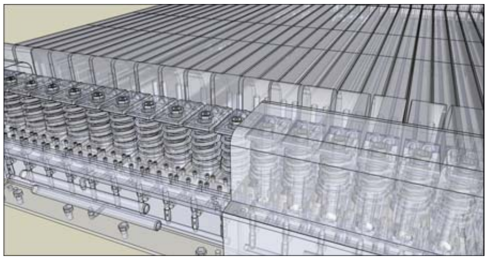
Paving slabs harvest kinetic energy in high footfall environments through piezoelectronics, converting the energy into electricity. Each slab depresses 5 mm under the weight of a passing pedestrian, and stores energy within the slab itself. Pavegen slabs glow to indicate to the user that they have created energy, though only 5 % of total energy created goes to its illumination. Excess energy can be used to power pedestrian lighting, information displays, street lights, and many other applications.

KinergyPower



section of fabric

KinergyPower utilizes a roadway “fabric” comprised of hydraulic pistons. When a vehicle rolls over and compresses the series of hydraulic pistons, the compression can be used to force hydraulic fluid through the system. KinergyPower uses this motion and transforms the captured hydraulic pressure into the power to run a hydraulic generator unit which produces electricity. KinergyPower is an energy system that captures kinetic energy from the weight and momentum of decelerating traffic and converts it into clean, reliable, renewable electricity.



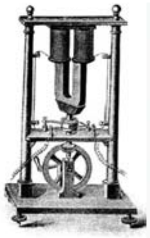
hydraulic pistons

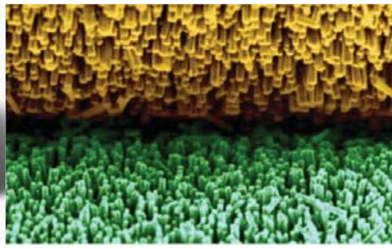
Where KinergyPower Comes From:

When a car is being operated, not all the energy generated from the fuel it uses goes to running the car. In fact, some energy is used and other energy is lost. Idling, braking, and accessories (i.e., radios, heaters, etc) all require some amount of the vehicle’s energy.

When a vehicle is in operation, the energy that it uses is expended as follows:

62.4% is used to propel the vehicle
17.2% is used in idling or standing by
5.8% goes to braking
5.6% Driveline losses (engine lubrication, etc)





Check List

definitions

technologies
flooring
textiles
BAS

benefits

disadvantages

final analysis

bibliography

About KinergyPower, continued...

4.2% Rolling resistance
2.6% Aerodynamic Resistance due to the design of the vehicle
2.2% from Accessory use within the vehicle

Source: www.fueleconomy.gov/feg/atv.shtml

KinergyPower harvests its energy from *rolling resistance*, and the *deceleration* and *braking processes*.

Facts:

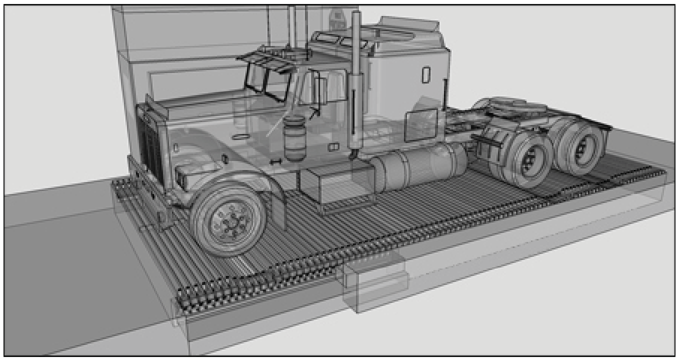
KinergyPower Energy Carpet installed on *50 meters* and traveled on by *250 cars a day or 10 trucks a day for one year* will **produce enough electricity to power one home for one year.**

A Bus Depot with traffic level of *1000 buses* can harvest enough electricity to **power 31 homes for one year.**

The same KinergyPower Carpet placed in the path of *10,000* ***trucks*** *per day* will **produce 1232kWh.**

One KinergyPower Carpet placed to receive *10,000 vehicles per day* will **produce 51kWh.**

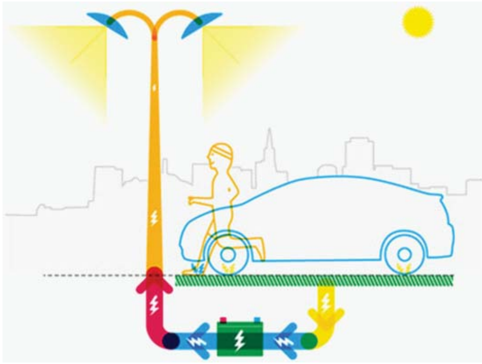
detail of hydraulic fabric



Innowattech

The Innowattech Piezo Electric Generator (IPEG™) have unique abilities to harvest energy from weight, motion, vibration and temperature changes. They are specific generators for roadways, railways, runways and pedestrians, and are embedded at a depth of about 5 cm; the area where the compression stressis maximal.The external load results in the deformation in both the asphalt layer covering the generators and the generators.The deformation of the generator and the shortening of the piezoelectric columns embedded in the generators, generate charges on the piezoelectric columns that are the source for the electric energy. IPEG™ have a potential to generate an average of 200 kWh per hour for the highway with traffic of 600 heavy trucks/buses per hour on average.

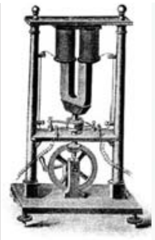
POWERLeap

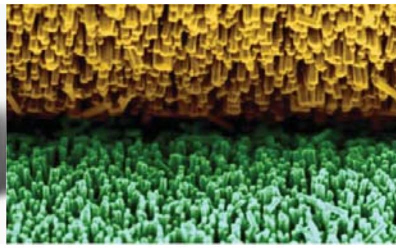


A flooring solution that produces electricity through conversion of wasted kinetic energy from pedestrian and vehicular traffic in urban areas. The electricity generated from the system can be stored and used in a wide variety of applications to create a self-sustaining closed loop system. In large installations the electricity can also be fed back into the grid. Furthermore, POWERleap generators can be used as a sensor network to provide an intelligent environment that improves power efficiency within a space.

Caitlin Jones

Alyssa Manny





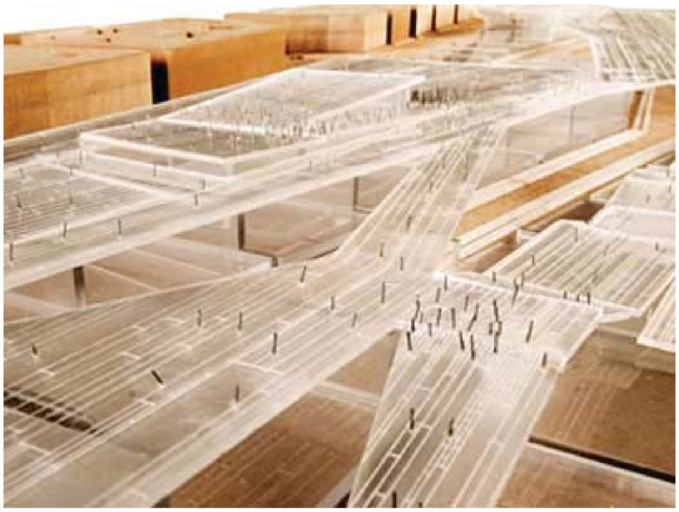
Caitlin Jones

Alyssa Manny

Crowd Farm

Two graduate students at MIT's School of Architecture and Planning want to harvest the energy of human movement in urban settings, like commuters in a train station or fans at a concert. James Graham and Thaddeus Jusczyk, both M.Arch candidates, would turn the mechanical energy of people walking or jumping into a source of electricity. A responsive sub-flooring system made up of blocks that depress slightly under the force of human steps would be installed beneath the station's main lobby. The slippage of the blocks against one another as people walked would generate power through the principle of the dynamo, a device that converts the energy of motion into that of an electric current. The electric current generated by the Crowd Farm could then be used for educational purposes, such as lighting up a sign about energy. "We want people to understand the direct relationship between their movement and the energy produced," says Jusczyk. A single human step can only power two 60W light bulbs for one flickering second. But get a crowd in motion, multiply that single step by 28,527 steps, for example, and the result is enough energy to power a moving train for one second.

model by Graham and Jusczyk



TECHNOLOGIES, continued:

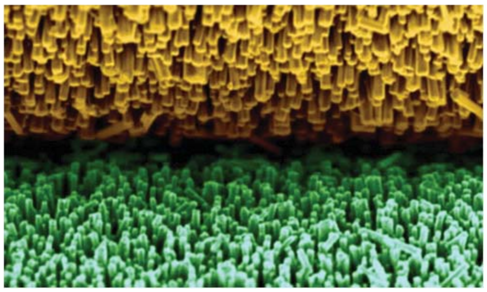
Textiles

- Carpet Fibers
- Piezo-Rubber
- Nanofibers
- Soft House

Carpet Fibers

Yong Qin and colleagues have developed fabrics made of specially coated fibers that produce electricity through the piezoelectric effect. The fibers consist of two intertwined strands of Kevlar. On one of the strands they grow a forest of radially aligned bare zinc-oxide nanowires, and on the other a similar coverage but of gold-coated nanowires. Stretching one of the strands back and forth along the length of the second strand causes the nanowires to rub against each other. This rubbing causes the bare zinc-oxide nanowires to bend, which, owing to the piezoelectric characteristics of the oxide, causes a separation of charge to develop across the diameter of each wire. As this happens, the rectifying metal-semiconductor junctions that form at the points of contact between the opposing sets of nanowires allow only negative charge to pass from the bare nanowires to the gold-coated nanowires. This, in turn, generates a voltage across the two strands. From a single double-stranded fiber, the authors generate peak closed-circuit currents of around 5 pA.

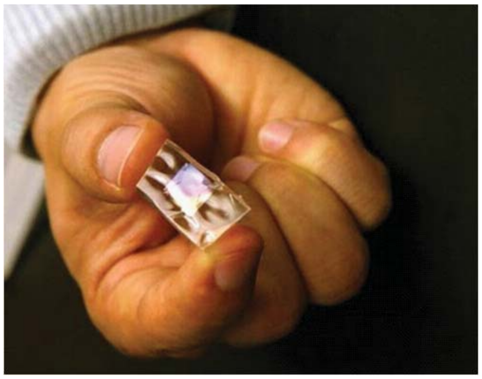
continued on page 5



Carpet Fibers, continued:

By entangling multiple strands together — which increases the area of contact between opposing nanowires — this current can be increased by a factor of up to 50, an average output current of 200 pA for a six-stranded bundle. Reducing the core resistance of the strands by depositing a conducting layer between the nanowires improves the output of their double-stranded fibers by three orders of magnitude. One of the advantages of Qin and colleagues' fiber-based generators — compared with previously reported schemes for generating electricity with piezoelectric nanowires — is that they operate at low frequency, which means they can produce power from a wider range of sources of mechanical vibration, such as that generated by someone's physical movement. The flexibility and low-temperature growth conditions of the system are other advantages. By weaving these fibers into a 'power shirt', the authors estimate that up to 20–80 mW of power could be generated by one square metre of fabric — comparable to the power used by a personal music player.

Piezo-Rubber



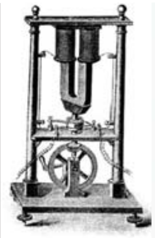
There has been recent development of flexible, biocompatible rubber films for use in implantable or wearable energy harvesting systems: nano-sized ribbons of lead zirconate titanate (PZT) — each strand about 1/50,000th the width of a human hair — to ribbons of flexible silicone rubber. PZT is one of the most efficient piezoelectric materials developed to date and can convert 80 percent of mechanical energy into electricity. The combination resulted in a super-thin film they call 'piezo-rubber' that seems to be an excellent candidate for scavenging energy from body movements. The development of a method for integrating highly efficient energy conversion materials onto stretchable, biocompatible rubbers could yield breakthroughs in implantable or wearable energy harvesting systems. Being electromechanically coupled, piezoelectric crystals represent a particularly interesting subset of smart materials that function as sensors/actuators, bioMEMS devices, and energy converters. Yet, the crystallization of these materials generally requires high temperatures for maximally efficient performance, rendering them incompatible with temperature-sensitive plastics and rubbers. Limitations to such materials may be overcome by presenting a process for transferring crystalline piezoelectric nanothick ribbons of lead zirconate titanate from host substrates onto flexible rubbers over macroscopic areas. Fundamental characterization of the ribbons by piezoforce microscopy indicates that their electromechanical energy conversion metrics are among the highest reported on a flexible medium, meaning they are efficient.

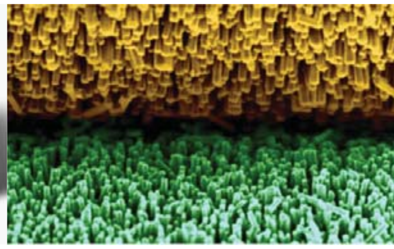
Nanofibers

Researchers and engineers at UC-Berkeley have created nanofibers that could be woven into clothing and harvest energy from the wearer's movements. These nano-sized generators have "piezoelectric" properties that allow them to convert into electricity the energy created through mechanical stress, stretches and twists. This technology could eventually lead to wearable “smart clothes” that could power hand-held electronics through ordinary body movements. Because the nanofibers are made from organic polyvinylidene fluoride, or PVDF, they are flexible and relatively easy and cheap to manufacture. The tiny nanogenerators have diameters as small as 500 nanometers, or about 100 times thinner than a human hair and one-tenth the width of common cloth fibers.

Caitlin Jones

Alyssa Manny





Check List

definitions

technologies
flooring
textiles
BAS

benefits

disadvantages

final analysis

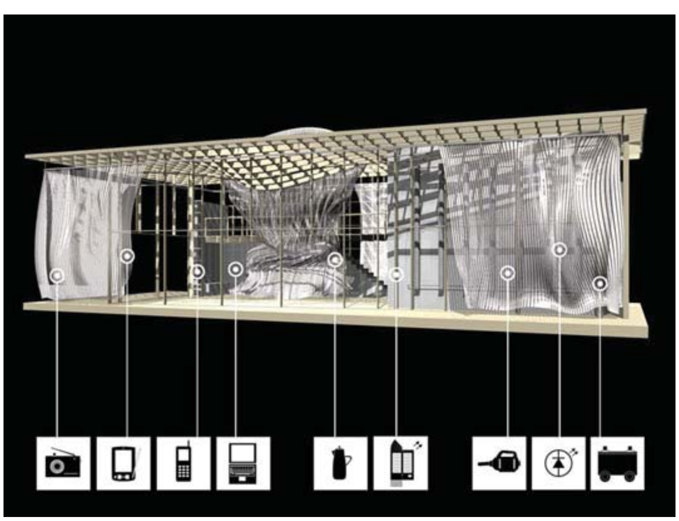
bibliography

continued from page 5:

The researchers repeatedly tugged and tweaked the nanofibers, generating electrical outputs ranging from 5 to 30 millivolts and 0.5 to 3 nanoamps. The researchers report no noticeable degradation after stretching and releasing the nanofibers for 100 minutes at a frequency of 0.5 hertz (cycles per second), meaning they have potential in not only efficiency, but also longevity.

Soft House

Kennedy & Violich Architecture took a radical first step in designing the Soft House, replacing many of the hard wall surfaces of a standard prefabricated house with movable curtains that contain embedded nanotechnology and thin-film photovoltaics. The research team found that these technologies would enable a 1,200-square-foot house to generate enough energy to meet fully half of its own daily requirements (as much as 16 kilowatts of direct current, or DC, power). Textiles have been a fixture of architecture and design for their ability to define and modify a space. The thin-film photovoltaic textiles are essentially solar panels created from organic photovoltaics.



TECHNOLOGIES, continued:

Building Automated Systems

- Fluxxlab
  - Powerslide
  - Revolution Door
  - Door Dynamo
- inDOOR Energy Harvester
- ReRev
- Regenerative Elevator Brakes

Fluxxlab

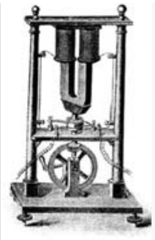
Fluxxlab's work to date has been focused on sustainable energy harvesting, specifically in the form of converting small amounts of human energy into electricity.

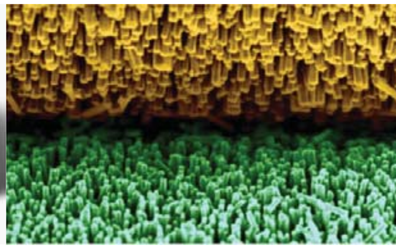
Powerslide

Powerslide is an innovative product that turns the sliding motion of common building components such as sliding doors, windows, and drawers into a source of energy. The device uses an integral alternator designed for each application to harness and locally redistribute the energy. By harvesting the residual energy of human effort and converting it to light, the Powerslide directly communicates a single person's contribution to an energy cycle possible through the metabolic relationship between people, technology and architecture.

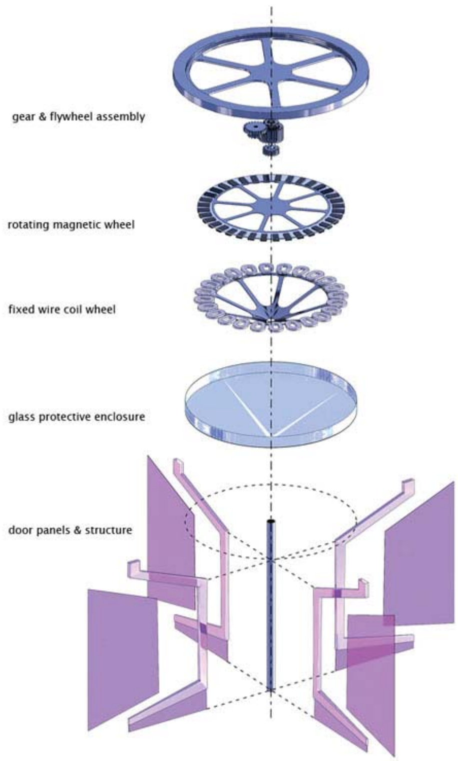
Door Dynamo

The Door Dynamo is comprised of a modified door closer coupled with a "hacked" flashlight dynamo by use of an integrating gear. This assembly can be added to any existing or new door to harness a small amount of energy when users enter or exit. In the exhibition display version, the energy harnessed is used for a light display that shows users the relationship between metabolic and mechanical energy.



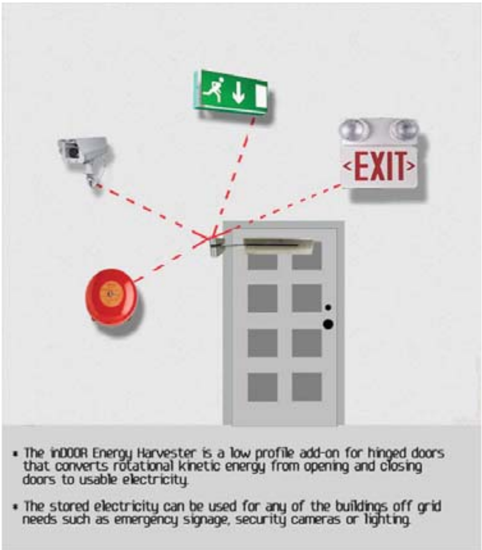


Revolution Door



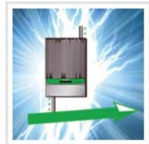
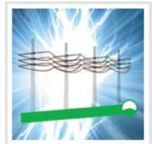
The Revolution Door is a modified revolving door comprised of three parts - a redesigned central core replacing that of any existing or new revolving door, a mechanical/electrical system that harnesses human energy and redistributes electricity to an output, and an output device that maps the harnessed energy. By mechanically harvesting a negligible amount of human energy and converting it to a tangible display through the use of a generator, the Revolution Door will directly communicate a single person's contribution to an energy cycle possible through the metabolic relationship between people, technology, and architecture.

inDOOR Energy Harvester



The inDOOR Energy Harvester is a low cost, low profile mechanism that converts rotational kinetic energy from opening and closing a door to usable electricity. It contains a circuit to store this electricity, measure what is produced and dynamically graph and monitor its progress from a website. The stored electricity can then be used for any of the buildings off grid needs, such as emergency sign-age, cameras or lighting.

ReRev

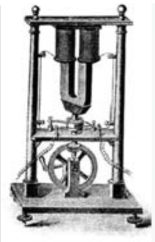




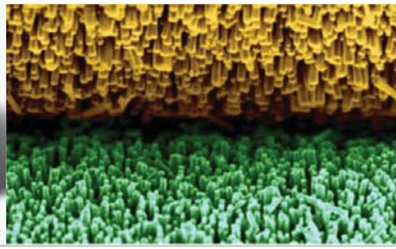
ReRev is a retrofit technology for existing exercise machines in which the kinetic motion of aerobic exercise is captured to convert otherwise wasted energy into productive renewable energy that feeds back into the building's electrical system. The ReRev technology is in the inverters, which act much like solar inverters in that they take DC powergenerated by the elliptical machines and convert it to AC power that is fed back onto the utility grid.

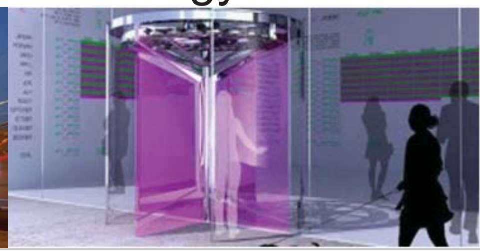
Harvesting Kinetic Vibrational Energy

Caitlin Jones

Alyssa Manny







Regenerative Elevator Brakes

The physical principle of all regenerative elevator brakes is to convert electrical energy into potential energy that is stored in the load (car plus counterweights), which was lifted up. Since the range of travel of elevators is limited, it is obvious that half the time the elevator is going up, and half the time it is going down. Thus, in 50% of all elevator moves, the motor acts as a generator and gives back the potential energy. Typically this potential energy is changed into heat by dynamic braking resistors. Consider the number of moves an elevator makes each year, and you will easily understand how a regenerative converter could save significant energy in these applications. Regeneration occurs in an AC variable frequency drive system when the load overhauls the motor. This can occur when trying to decelerate the load, or when some external force causes the motor to overhaul, causing the motor to act like a generator. The energy contained in the rotating equipment flows into the drive, and is manifested as increased DC bus voltage in the inverter. This “over voltage” is traditionally wasted as heat by means of dynamic braking resistors. With rising electric power costs and increasing “green” awareness, there is an increasing demand for a way to recover that wasted energy. It is now economically feasible to accomplish this with regenerative converter units, which transform the DC regenerative electrical energy into fixed frequency utility electric power.

graphic depicting trend of regenerative power

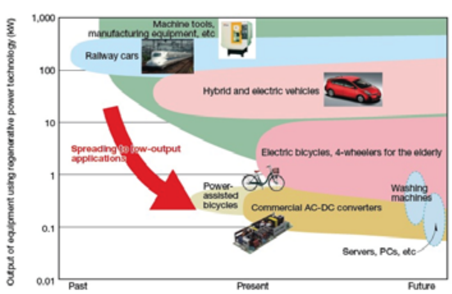


Fig 1 Regenerative Power Spreads to Low-Output Equipment Regenerative power technology was developed to reuse the power from high-output motors, over 100kW, used in trains, machine tools and the like. Today the technology is being used in lower-output equipment such as hybrid cars, power-assisted bicycles and AC-DC converters.

BENEFITS

The current kinetic energy harvesting technologies include piezoelectrics, dynamos and regenerative brakes, all of which have produced successes in laboratory and field studies. Beyond successful initial trials, however, other benefits include a cost-free and regenerative supply, educational possibilities and a reduced need for foreign oil in energy production. The most promising benefit to harvesting kinetic and vibrational energy is the fact that the energy source is constantly available and completely free of charge. The natural world is set-up on a system of navigation and a propensity for movement, whether to satisfy life-sustaining necessities, or merely for pleasure and entertainment. Technology and innovation predict that we as humans will always be looking for ways to accentuate our daily lives with methodologies of ease and comfort. Couple that fact with providing a technology that could inevitably reduce a cost of living from energy consumption, and you have a fruitful concept.

Initial installations of kinetic energy harvesting systems have provided a tangible educational link between human movement and their capability of producing energy. Products such as Pavegen, POWERLeap and and the Revolution Door have all utilized illumination to add public awareness and directly communicate a user’s impact on their environment, and their individual capacity for energy production through typical daily routines. The potential of harvesting kinetic and vibrational energy as a powerful renewable resource comes from the fact that people don’t have to alter their lives in order to contribute to the grid. Simple everyday movements and motions would be able to power the world around us.The bottom line within development of all renewable technologies goes without being said: the inevitable need to reduce our national (and global) dependence on crude oil. Harvesting kinetic and vibrational energy would tap into a system already set in place: a wealth of energy converted in to electrical power rather than dissipating as heat. The possibilities are literally endless.

Caitlin Jones

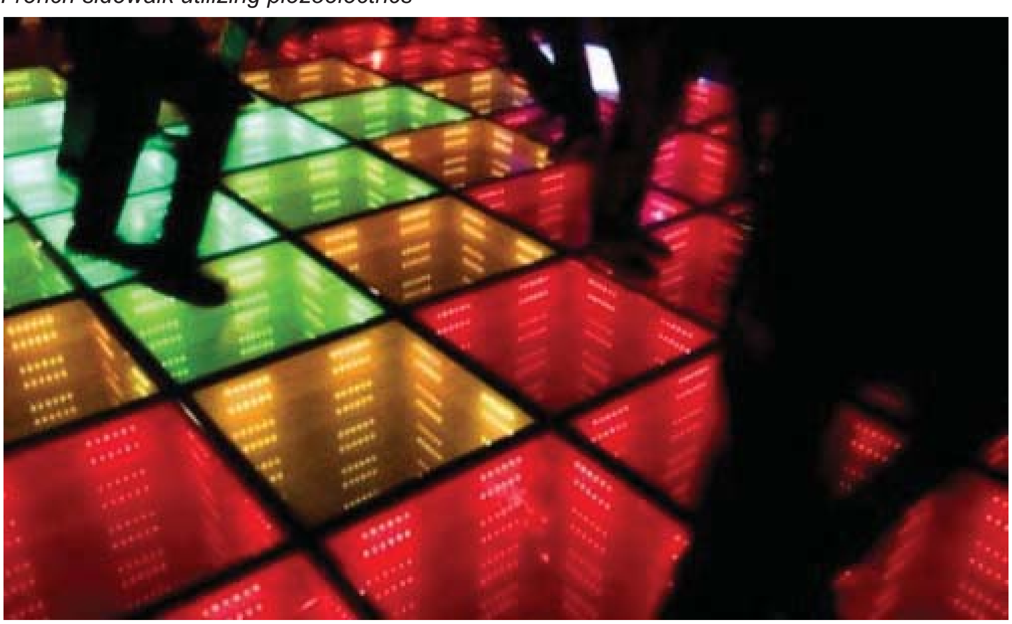
Alyssa Manny

DISADVANTAGES

As Newton described in his laws of physics, energy can neither be created nor destroyed. While every person in this world contributes to the metabolism of potential energy into kinetic, few technologies exist that can then translate such kinetic energy into potential electrical energy. The technologies that do exist work on either small or large scales, are expensive to manufacture and manipulate, and are relatively inefficient in terms of the material scale.

Piezoelectrics and dynamos work extremely well in harvesting kinetic energy, but only on a relatively micro scale. They are currently successful in powering small applications, such as cell phones, laptops and pedestrian lighting installations, but their technology has yet to be expanded into macro-scale building integrated applications. Regenerative brakes, on the other hand, are typically utilized in large motor systems such as elevators and hybrid cars, but offer few other possibilities for building integrated systems.

French sidewalk utilizing piezoelectrics



FINAL ANALYSIS

There is so much possibility in the world of harvesting kinetic and vibrational energy in terms of powering entire buildings. Imagine the power generation from harvesting every step on every stair, ascension and descension of every elevator, every computer stroke, every push of a light switch, every swing of a door, all vibrations down a pedestrian hallway, etc. With the combined technologies of piezoelectronics, dynamos and regenerative brakes, it is possible that every built object in the world could function on its on energy metabolic processes.

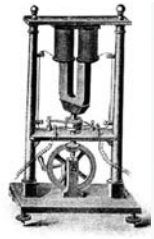
With the continual integration of piezoelectronics into smart fibers and smart materials, it is also possible to believe that with every low-frequency human movement/vibration, we could potentially work towards harnessing energy that could power every gizmo and gadget that we hold onto daily.

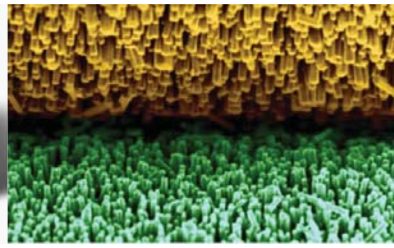
The technologies of piezoelectronics, dynamos and regenerative brakes will continue to progress wherever there is a market for them. The next step will be to re-examine battery storage cells in order to reduce their embodied energy and provide a viable means for storing energy long-term.

Harvesting Kinetic Vibrational Energy

Caitlin Jones

Alyssa Manny





Check List

definitions

technologies

benefits

disadvantages

final analysis

bibliography

BIBLIOGRAPHY & ADDITIONAL RESOURCES

Energy harvesting: Rubbed the right way
http://www.nature.com/nphys/journal/v4/n3/full/nphys906.html

Journal of Science article with technology for fibers mentioned above
http://www.nature.com/nature/journal/v451/n7180/full/nature06601.html

University of Michigan
http://www.engin.umich.edu/newscenter/pressReleases/20100303131438hev/

The harvesting of energy from gym equipment is finally being implemented by a company in Florida called ReRev:
http://rerev.com/

Power harvesting systems for door swings:
http://www.indoorharvesting.com

Research at Duke and Princeton have explore piezoelectric material, and possible applications for it.
http://news.duke.edu/2009/10/eharvest.html

Piezo-Rubber
http://nanopatentsandinnovations.blogspot.com/2010/02/piezo-rubber-super-thin-films-harvest.html

Full article on technology of piezoelectronics on rubber
http://pubs.acs.org/stoken/presspac/presspac/full/10.1021/nl903377u?cookieSet=1

Energy Harvesting Fiber
http://www.greenbiz.com/news/2010/02/17/nanofibers-developed-energy-producing-clothes

UC_Berkeley news article about nanofiber technology
http://berkeley.edu/news/media/releases/2010/02/12_electric_nanofibers.shtml

Microgenerator converts kinetic energy from the vibration of the equipment running at mains frequency into electrical energy.
http://news.thomasnet.com/fullstory/487414

Perpetuum provides global leadership in vibration energy harvesting.
http://www.perpetuum.com/

Soft House Project
http://www.inhabitat.com/2008/06/12/solar-harvesting-textiles-energize-soft-house/

Solar Textiles
http://www.greenlaunches.com/alternative-energy/solar-fiber-for-photovoltaic-textiles.php

A hybrid energy harvester (solar + mechanical):
http://www.technologyreview.com/energy/22410/?a=f

Energy converter for linear motion
http://www.enocean.com/enocean_module/eco-100/

Piezoelectric Ceramics: Science Meets Pottery
http://electronicdesign.com/article/components/piezoelectric-ceramics-science-meets-pottery18095.aspx

Energy-Generating Floors to Power Tokyo Subways
http://www.inhabitat.com/2008/12/11/tokyo-subway-stations-get-piezoelectric-floors/

MIT Architecture and Planning, “The Crowd Farm”
Energy produced by human movement through mass transit and community sectors
http://web.mit.edu/newsoffice/2007/crowdfarm-0725.html

Dynamo research
http://en.wikipedia.org/wiki/dynamo

Case study of harnessing kinetic energy from revolving doors (Fluxxlab) and elevators
http://www.greenheating.org/alternative-energy/harvesting-energy-from-humans/

Opposition article of harnessing kinetic energy due to its inefficiency (Cnet)
http://news.cnet.com/8301-13512_3-9779334-23.html

Capability of piezoelectronics to transform interactive devices into energy generation
www.thedailytechlog.com/tag/piezoelectic

POWERleap
Company dedicated to generation of power from pedestrian and vehicular traffic
www.powerleap.net

Pavegen
www.pavegen.com

Biomechanical Engery Harvesting
http://www.time.com/time/specials/packages/article/0,28804,1852747_1854195_1854172,00.html

Energy Harvesting Overview
http://en.wikipedia.org/wiki/Energy_harvesting#Biomechanical_harvesting

Energy Harvesting and Ultra Low Power Devices
http://www.ti.com/corp/docs/landing/cc430/graphics/slyy018_20081031.pdf

Harnessing Kinetic Energy
http://www.technologyreview.com/Energy/19777/?a=f

Vibration Energy Harvesting Devices
http://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=04283437

Consumer Products Using Kinetic Energy
http://agreenliving.org/tag/kinetic-energy/

KinergyPower
http://www.kinergypower.com/index.shtml

Kinetic Energy and the Energy Crisis
http://www2.electronicproducts.com/Can_kinetic_energy_solve_our_energy_crisis--article-iccn00-aug2006-html.aspx

Regenerative Brake Overview
http://en.wikipedia.org/wiki/Regenerative_brake

APEC Conference Presenters
http://www.apec-conf.org/content/view/273/244/

A Green Workout
http://www.thechicecologist.com/2008/11/a-great-green-workout-create-your-own-energy-at-the-gym/

The Green Micro Gym
http://thegreenmicrogym.com/

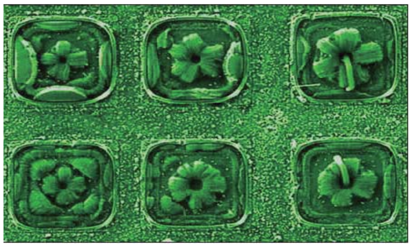
Energy Harvesting Sidwalks
http://hubpages.com/hub/Piezoelectric-Energy-Harvesting

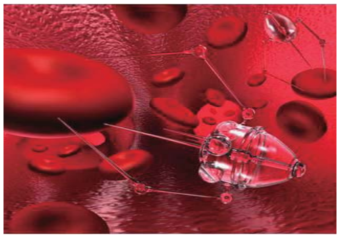
Energy Harvesting in Roads
http://www.allcarselectric.com/blog/1037173_innowattech-in-
road-energy-harvester-uses-tiny-generators-to-capture-2000-watts-per-hour

Energy harvesting vibration sources for microsystems applications
http://eprints.ecs.soton.ac.uk/13645/1/MST_review_paper.pdf

Benefits of regenerative brakes and energy converters in elevator systems
http://www.hitachi-america.us/supportingdocs/forbus/isd/white_papers/vfd/Hitachi_Regen_White_Paper_Final.pdf

Nanotechnology & Advanced Window Systems





Check List

definition

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

final analysis

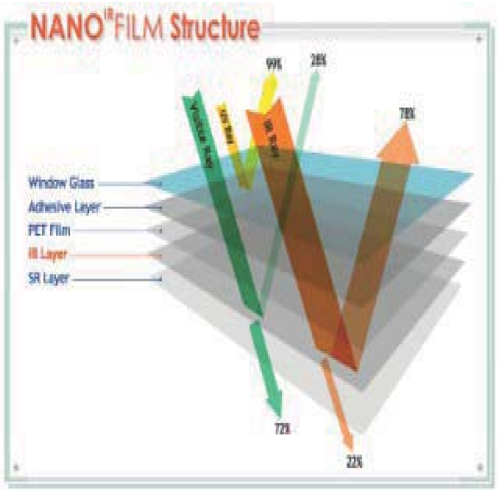
History

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

The best options that have been available to architects and builders for energy-efficient windows have been limited at best. Different glazings designed to reduce solar heat gain work for a building's efficiency during warmer temperatures, but in colder months work against it. Louvered building facades or window treatments allow natural light into a space without solar heat gain, but do not offer unobstructed views to the outside. So ideally, the perfect window would allow heat in during colder climates and block heat during warmer climates… all on its own. [3]

Solar Control Glass: The earliest form of energy-efficient windows. This includes Reflective glass and Low-E glass (both of which use metallic coatings). [8]

Smart Windows: The most current evolution in solar control glass.



Existing Smart Window Technologies
(refer to- Vol. II *Green Systems*, p.83)

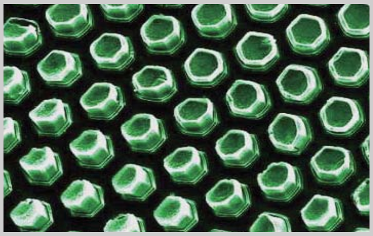
Thermochromics: heat causes window film to darken

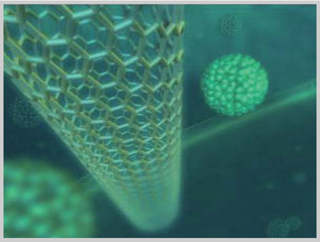
Photochromics: light causes window film to darken

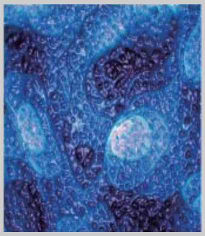
Liquid Crystals: an electric chargecauses liquid crystals to align/disalign in order to change translucency

Suspended Particle Displays: an electric charge causes a reaction between an organic film and freely floating particles in liquid suspension in order to change translucency

Electrochromics: an electric charge causes layers to react and change translucency. This system requires wiring and external control panels. [14]







Nanotech

Check List

definition

cost

maintenance

properties

lifecycle

energy

health

benefits

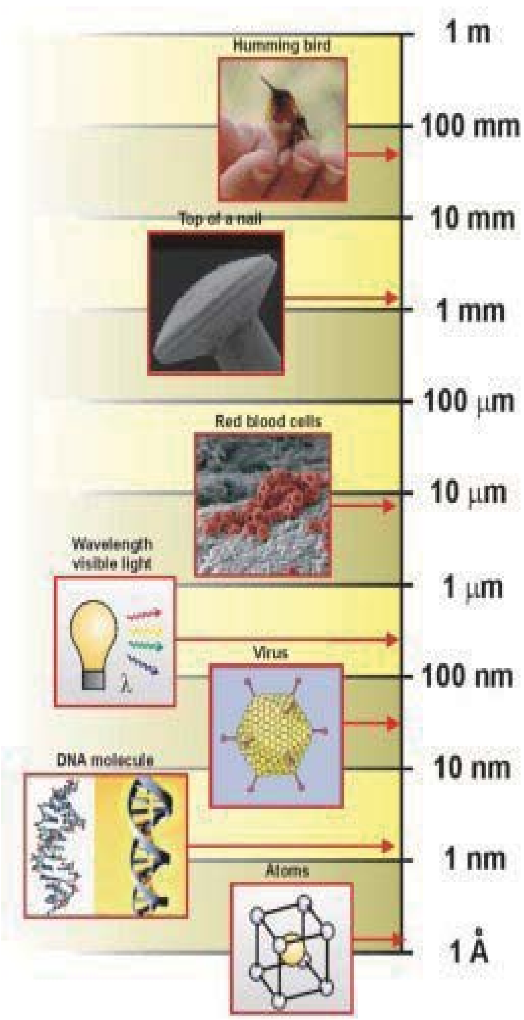
disadvantages

final analysis

One of the most current scientific technologies contributing to advancements in Smart Window design is nanotechnology.

Nanotechnology is the engineering of functional systems at the molecular scale.

The term *nanotechnology* was popularized in the 1980's, but the idea was envisioned as early as 1959 by renowned physicist Richard Feynman.



Nanotechnology is a general-purpose technology

In its advanced form nanotechnology will have significant impact on almost all industries and all areas of society. It will offer better built, longer lasting, cleaner, safer and smarter products for communications, for medicine, for transportation, for agriculture, for architecture, and for industry in general. [17]

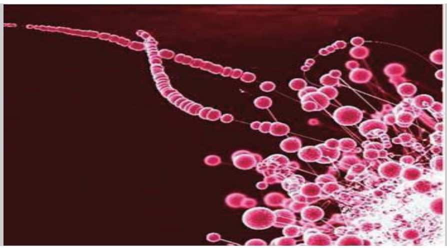
How has Nanotechnology begun make an impact on the Smart Windows industry?

Nano-Ceramic Window Film:
Advanced ceramics have historically been used by NASA to thermally protect the Space Shuttle Orbiter. Now, because of nanotechnology, they are being used by window film suppliers in the manufacture of solar control window film.

Nano-ceramic particles are created when microscopic compounds are formed between metallic and nonmetallic elemtns, both with strong phsyical and chemical bonds. One such compound commonly used in the manufacture of window film is Titanium and Nitrogen, TiN, a smart ceramic for solar control. [6]

"I want to build a billion tiny factories, models of each other, which are manufacturing simultaneously. . . The principles of physics, as far as I can see, do not speak against the possibility of maneuvering things atom by atom. It is not an attempt to violate any laws; it is something, in principle, that can be done; but in practice, it has not been done because we are too big."

- Richard Feynman



Check List

definition

cost

maintenance

properties

lifecycle

energy

health

benefits

disadvantages

final analysis

Next-Gen Smart Materials

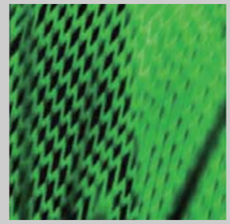
Various aspects of smart materials (including quantum dots, thermochromics, electrochromic materials, and various kinds of fiber-based circuitry) are under investigation in labs all over the world. Major players include (but are by no means limited to) IBM, Nippon Telehone and Telegraph, Fujitsu, Delft University, MIT, Harvard, Stanford, Princeton, Cornell, CalTech, and The University of California at Santa Barbara. Wellstone(TM), Wafflestone(TM), and Gridwell(TM).

Next-Gen Electrochromics

The Department of Energy (DOE) is in the early stages of research on next-generation electrochromic coatings. Conventional electrochromic coatings are composed of thick layers, making them costly to manufacture. They are also absorptive, which increases thermal stress. Next-generation research will investigate the use of a newly discovered material, reflective transition metal hydrides, to create simple gasochromic windows that may overcome these limitations, enabling higher performance and lower cost. Other smart window technologies, such as suspended particle devices, also will be monitored as potentially promising alternatives to electrochromics.

Polymers that Change Color with Chemical or Electronic Stimulus:

This is one example of a Next-Gen Electrochromic technology. Researchers at A*Star and Nanyang Technological University have created the first azulene-based electrochromic device—a material that changes color instantly and reversibly through electricity—by spinning the polymers into thin films and sandwiching them between transparent electrodes. This discovery will lead to a new smart window that can change from clear to opaque, or change different colors to desire different visual effects. This technology is being toyed with in sunglasses and ski goggles.



Phase-Change Material Window Film:

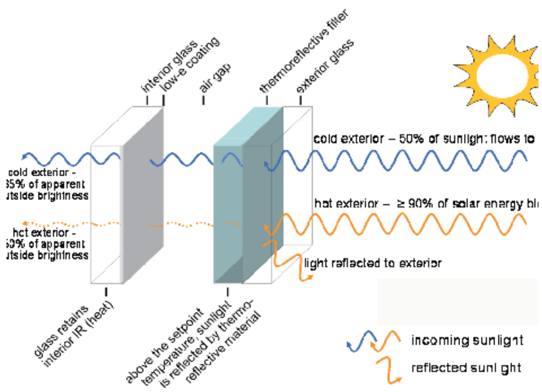
One of the most intriguing advancements of nanotechnology is currently taking place in the *thermochromic* smart window category. These windows reduce energy costs by up to 50 percent in most buildings.

Programmable Matter

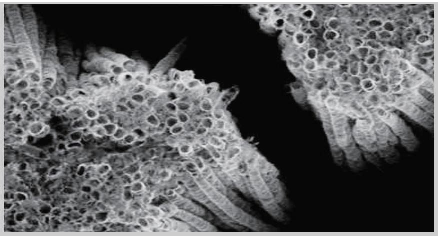
Programmable Matter(TM) is the nano-engineered material material that is the backbone behind these thermochromic advancements which can be called Phase-Change Material Window Film.

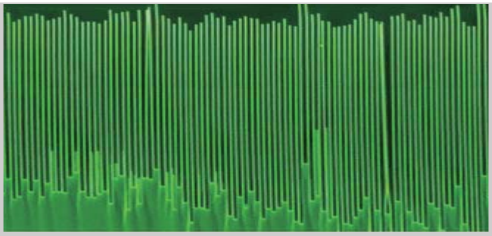
Single-electron transistors, a form of quantum dot, were first proposed by A.A. Likharev in 1984 and constructed by Gerald Dolan and Theodore Fulton at Bell Laboratories in 1987. The first semiconductor SET, a type of quantum dot sometimes referred to as a designer atom, was invented by Marc Kastner and John Scott-Thomas at MIT in 1989. The term "artificial atom" was coined by Kastner in 1993.

However, Wil McCarthy (an ex-NASA engineer and now President and Co-Founder of Ravenbrick LLC) was the first to use the term *Programmable Matter(TM)* in connection with quantum dots, and to propose a mechanism for the precise, 3D control of large numbers of quantum dots inside a bulk material. [8]



A Programmable Matter(TM) smart material is any bulk substance whose physical properties can be adjusted in real time through the application of light, voltage, electric or magnetic fields, etc. Primitive forms may allow only limited adjustment of one or two traits (e.g., the "photodarkening" or "photochromic" materials found in light-sensitive sunglasses), but there are theoretical forms which, using known principles of electronics, should be capable of emulating a broad range of naturally occurring materials, or of exhibiting unnatural properties which cannot be produced by other means. [15]





Check List

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

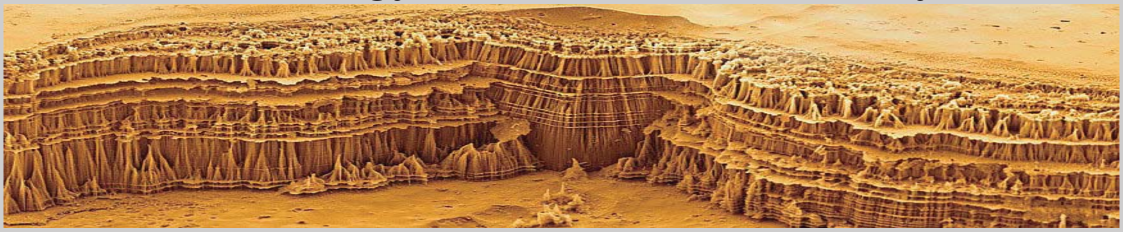
Phase-

Change

The Phase-Change Material Window FIlm can be literally programmed before installation along several parameters. This includes what temperature the phase change occurs, what portion of the light spectrum is blocked, and what level of diffusivity is desired. It is technically possible to adust the temperature change point to a precision of 0.1 degrees C, but for practical purposed a product will be developed to change at one "sweet spot," such as 80 degrees F, or different "sweet spots" desired for specific geographic regions. [4]

How the Phase-Change Filter Works:

The opacity can come two different ways: by darkening or by whitening. In the former case, the phase changes causes the film to block most of the light and, in the latter case, the phase change instead causes the film to diffuse the light. It's the only technology of its kind in the industry. It will react to the heat from the sun outdoors during the summer. Less sunlight indoors means that the interior would stay cooler, which lessens the energy usage and price of the cooling load. The filters work just as good at keeping the structure warm in the winter. [1]



Benefits

Typically [other products are] electrochromic, which are driven by electrical power. The programmable matter is active-passive. It's active in the sense that it does the change, and it's passive in the sense that it does it without having any moving parts. [15]

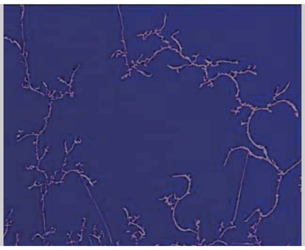
The phase change film exemplifies:

- Significantly reduced heating and cooling costs, the greatest energy consumers in commercial buildings.
- A fully automatic transition, free from wires or activation devices.
- Easy to install on new windows or retrofit to existing ones.
- Affordability, particularly compared with current smart windows.
- A quantifiable and short-term ROI which can be easily determined for any specific building.
- Aesthetic appeal, enabling the use of natural sunlight in building design.
- Improved temperature and light-glare comfort for people in the building. [20]

Disadvantages:
Researchers studied the impact of nanoparticles used in the field of nanotechnology on the environment.

The goal is to understand and predict the possible effects of nanotechnology on the environment. These new technologies could thus be developed accordingly, in anticipation of possible adverse effects.

Nanotechnology & Advanced Window Systems



Check List

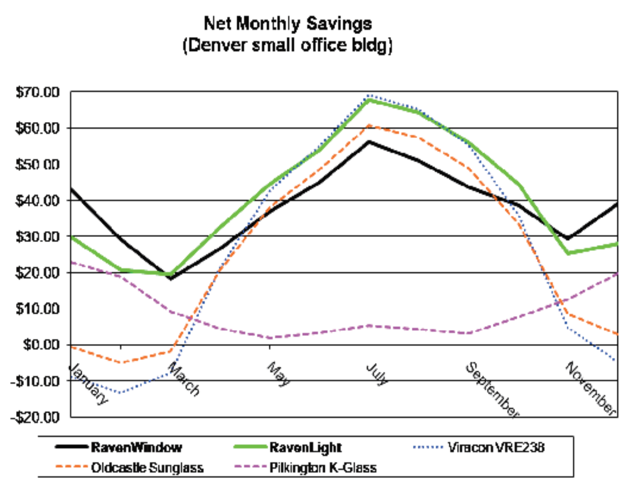
definition
cost
maintenance
properties
lifecycle
energy
health
benefits
disadvantages
final analysis

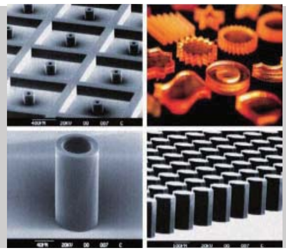
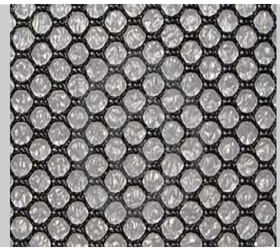
Efficiency

Product	Denver Residential	Denver Commercial
RavenLight	11-13 years	5-7 years
RavenWindow	11-13 years	5-7 years
RavenWindow-ER	12-15 years	5-8 years

Energy usage / Net monthly savings:

Thermochromic ROI Summary
Thermoreflective filter w/ pyrolytic low-E
Building #1: Residential
Two-story residence, 3,487 ft2 floor space per story, 20% windowed exterior
(total window area = 992 ft2)
Building #2: Large Office
12-story office building 46,941 ft2 floor space per story, 40% windowed exterior
(total window area = 38,301 ft2)
Assuming \$25 / ft2 retail cost for thermoreflective filter
(vs. estimated manufactured cost of < \$16)
Assuming \$0.12 / kWh electricity
(vs. 2008 peak of \$0.16)
Assuming20% annual energy price inflation
(vs. 25% average for 2003-2007) [1]

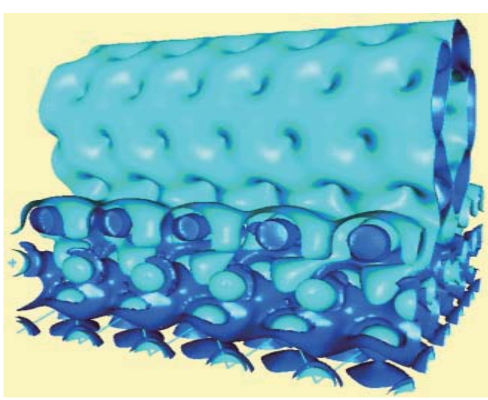


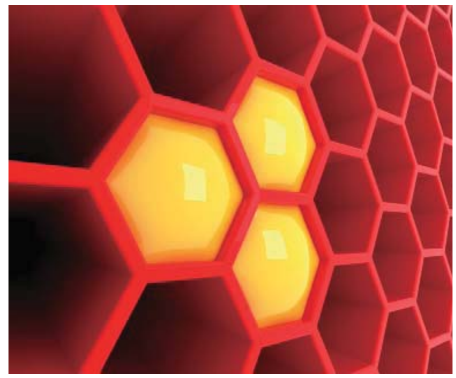




Microblinds and Optical Lithography

The National Research Council of Canada (Ottawa, ON, CA) scientists have developed a microblind system for smart windows that can be used to let light or heat through a window or keep them out. These microblinds work in a very simliar way to the Phase-Change windows, in that they block heat in the summer but allow transmission of heat in the winter to warm the space. The microblinds could even be used to make window displays.

The microblinds are patterned by standard optical lithography. Optical lithography is a technology that behaves in a similar way to traditional lithography, but it takes place on a soft material at a very small scale and is patterned by lasers. The blinds can be patterned onto a layer and added to a window, or can be patterned directly onto the glass. This technology is nothing new, but the nano-industry actively developing this technology to create new and exciting materials. [13]

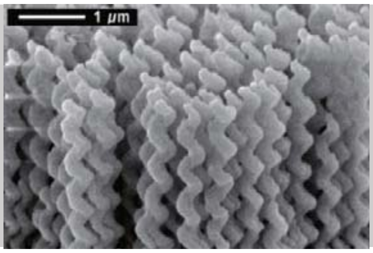


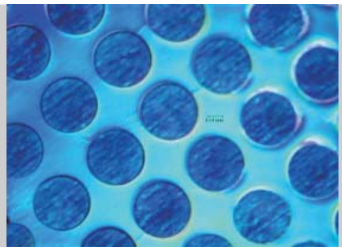


How it Works?

A microblind system has an array of overhanging stressed microblinds, each having an anchor portion attached a substrate and a mobile portion. They are stimulated by electrostatic forces and can curl up or down to allow or block light. The blinds can either be actuated by an automatic system, or by the user.

There are several different embodiments of the microblinds, and they are generally very similar. One embodiment is created by depositing and patterning a number of layers on a clean substrate - preferably glass. The substrate could also be platic (roll or foil) that could be installed later between two panes of glass. It could also be an illuminated translucent panel for use a sign or billboard. [12]

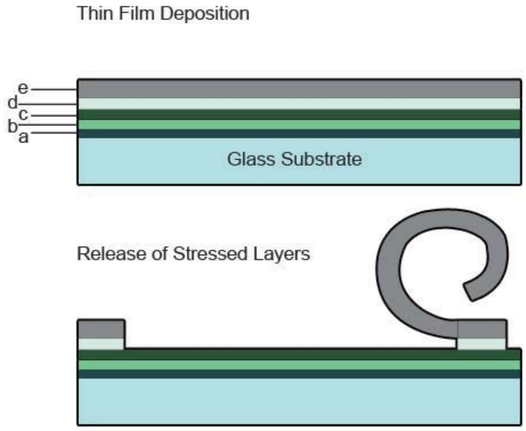




Check List

cross section:

a) a transitional layer
b) a transparent conducting layer
c) an insulating layer
d) a release-sacrifical-anchoring layer
e) a reflective, resilient and stressed layer

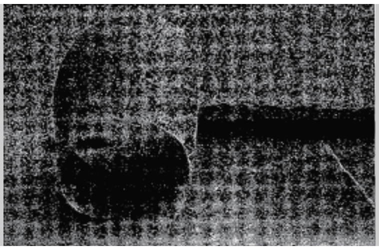


A clean deposition of a diffusion barrier, adhesion promoter and insulator layer is added on the substrate (layer a). This is followed by the deposition of a transparent conducting layer that is reliable, cheap, and transparent in the visible spectrum to allow solar heat gain when blinds are open. Being hard is also advantageous (layer b). The next step is the deposition of another insulator layer that is a polymer and will keep the leakage between layer 'b' and 'e' very low (layer c). Next the release-sacrificial-anchor layer is applied. It should give a very strong contact or anchoring point for the microblinds (layer d). The final layer modulates the light through window and should have controlled optical properties like transmission and reflection (layer e). This final layer must be very thin, and the stress is very important. The stress is what can make the microblinds curl.

What Effect can be Produced by Manipulating the Solar Transmission?

The blinds can either be completely open (to allow all light and heat), completely closed (to allow shaded light and no heat), or partially opened to obtain effects in between the open and closed states. This is called a "grey level" and can be obtained in a few ways. First, the different rows and columns of microblinds could be a viariety of geometric shapes (circles, squares, trapezoids). Each shape would require a different voltage to activate it. Therefore when applying a voltage V to the entire smart window area, onl the second and third columns (for example) of microblinds will be opened. Second, the grely levels could be achieved by switching hte microblinds between states at a speed high enough to be undetected by users (like how a tv or computer screen produces images).

Nanotechnology & Advanced Window Systems



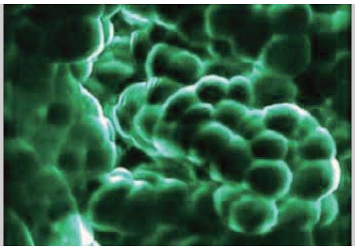
The Future:

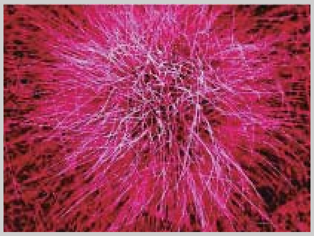
Initial nanotechnology influenced improvements to smart materials will be relatively simple changes to existing technologies. The future however holds possibilities for extremely complex solutions for producing not only smart materials but ones that are highly intelligent.

These new materials may incorporate nanosensors, nanocomputers and nanomachines into their structure. This will enable them to respond directly to their environment rather than make simple changes caused by the environment. As an example materials may be able to shape shift. The current emerging technology of surface treatments for a wall that allows it to change colour might be impressive now, but what if the wall material could change itself to produce a window where and when required.

In the future with the microblind system, there could be extra functionality. Regular windows could thus become displays to the inside users when there is light outside or to outside viewers when the illumination inside the building is sufficiently higher than the ambient outside light (such as at night time). Even without addressing the microblinds, big commercial buildings could be come a temporary billboard at night time.

In the future at Ravenbrick, (for example), they are anticipating a RavenSkin Smart Wall System. Think of it as a thermal battery. McCarthy (head of Ravenbrick) says its possible to build an entire wall, composed of basically the same reversible phase-change material used in the window film, that would absorb sunlight and other ambient thermal energy during the day, and then gradually release heat in the evening. The wall, for example, could be constructed of material that would gradually reverse a sun-induced phase change and release its heat energy at, say, 72°F.





Works Referenced

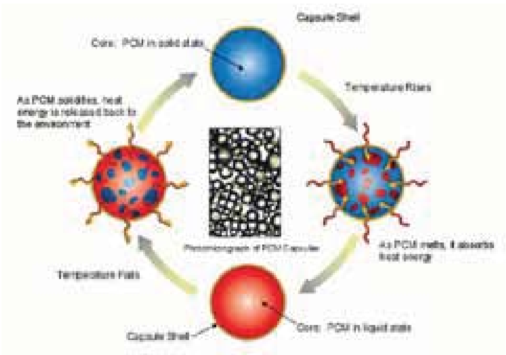
1.Ravenbrick- Cole Porter
2. Prof. Patrick Teuffel, Dr. Ing.
P.Teuffel@tudelft.nl
Department: Building Technology-Architectural Engineering, Delft University
3. http://www.nanotech-now.com
4.http://www.nanowerk.com/spotlight/spotid=1007
5.Alternative - Nano Ceramic Window Films
http://www.spec-net.com.au/press/1008/wfa_011008.htm
6.company using Nano Ceramic Window Films
http://www.huperoptikusa.com/
7.Pleotint, Inc. http://www.pleotint.com/default.aspa
8..http://current.com/1mg564c
9.http://ceramics.org/ceramictechtoday/materials-innovations/ravenbrick-nifty-thrifty-nonelectric-smart-windows-and-smart-walls/
10.NanoUltra Super Hydrophilic Window Technology
http://www.youtube.com/watch?v=fJdE6R9aVNY
11.Video about nanotechnology materials
http://www.bnl.gov/cfn/movie/
12.Argon National Laboratories Electronic & Magnetic Materials & Devices
http://nano.anl.gov/research/electronics.html
13.NREL http://www.nrel.gov/
14.RNL global design http://www.rnldesign.com/
15.temperature sensitive tiles
http://inventables.blogspot.com/2009/12/inventables-most-popular-material-2009.html
16.ceramic nano filters
http://www.spec-net.com.au/press/1008/wfa_011008.htm
17.center for responsible nanotechnology
http://www.crnano.org/whatis.htm
18. "Research into artificial atoms could lead to one startling endpoint: programmable matter that changes its makeup at the flip of a switch."By Wil McCarthy Wired Magazine Issue 9.10 | Oct 2001
19.IBM Research: Nanoscale Science and Technology
http://www.almaden.ibm.com/st/nanoscale_st/
20. United States Department of Energy http://www.energy.gov/
21. Technology Review: Cheaper color changing windows Thin, battery-like films change color when the weather changes. Katherine Bourzac THURSDAY, DECEMBER 03, 2009
22. Nanowerk.com Risks in architectural applications of nanotechnology
http://www.nanowerk.com/spotlight/spotid=1007.php

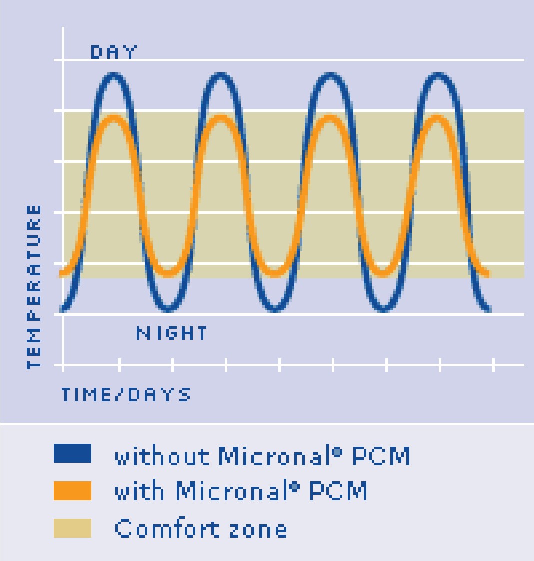
Resources

The Future of **Phase Change Material** in Integrated Apllications

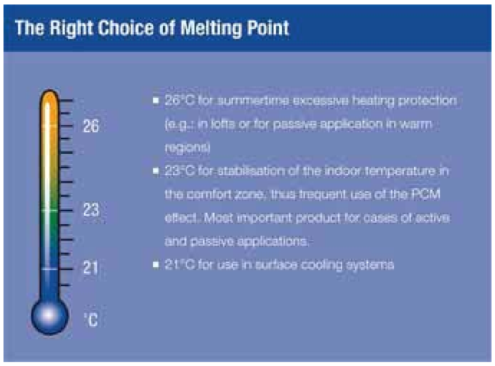
Modern structures of steel and glass have provided opportunities for more daylight, increased ventilation, and improved indoor environmental quality as compared to older buildings of heavy construction. However, the trend to create lighter, frame-oriented structures has introduced the challenge of balancing steeper temperature differentials, owing to a reduction of thermal mass. A heavier building is able to smooth out these temperature swings because traditional building materials, such as masonry, insulate interior spaces from both hot summer days and cold winter nights.

The introduction and development of phase change materials has served to bridge this gap between light construction and thermal consistency. To introduce the concept of phase change materials, hereafter referred to as "PCMs", one can use an ice cube as an analogy. When ice is heated, the temperature stops rising when the ice eventually turns to liquid. If the two phases exist simultaneously, the temperature does not increase; rather, the energy is stored. When ice melts in a drink, it is absorbing the heat around it. When the ice solidifies in the freezer, it releases that heat to its surroundings. During the change of phase, whether solid to liquid or liquid to solid, the ice remains at 32 degrees Farenheit; the energy storage and release goes unnoticed – it is termed latent heat energy.

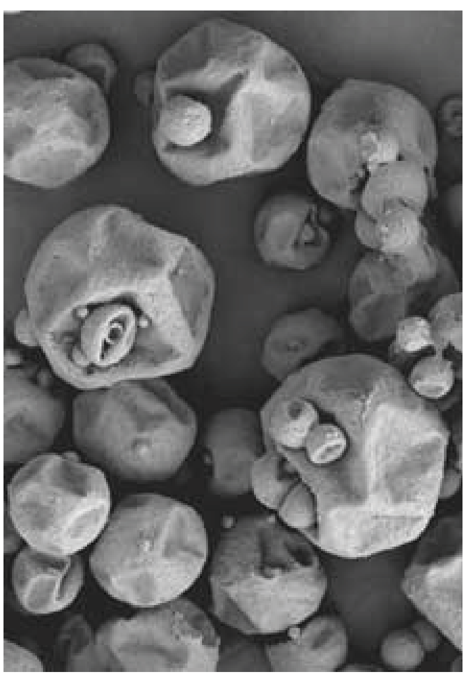




So how does this concept apply to construction? To reduce conventional air conditioning loads and maintain pleasant temperatures during extreme seasonal conditions, the thermal capacity of a building must be increased. With an expected energy requirement in Europe reaching 120 TWh/year this decade, it comes as no surprise that there is an urgent need for innovative, intelligent alternatives to curb energy use in building cooling applications, especially in the commercial sector. Researchers are continually developing and testing new methods and applications for PCMs. Paraffin wax has been found to melt in comfortable room temperatures ranging from 68 to 78 degrees Farenheit. During this phase change, paraffins are able to absorb considerable amounts of heat from their surrounding environment, while insulating that area from thermal gains. At night, when the ambient temperature drops, the paraffin releases its stored energy to the adjacent space and readies itself to repeat the cycle the next day.



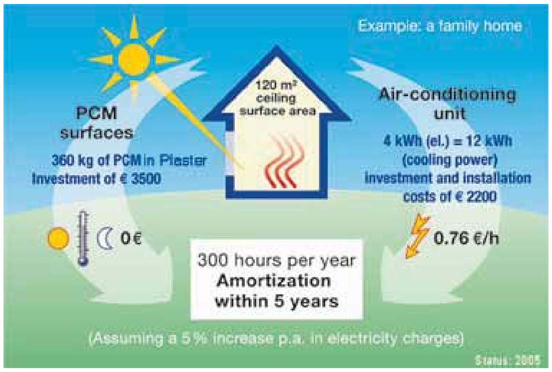
PCMs are now able to be used in a range of conventional building products. For example, a 5/8" thick plaster panel enhanced with PCMs has approximately the same heat capacity as a concrete or brick wall. This combination of lightweight design with high insulating characteristics has promising potential for the building industry, especially in the retrofit/ renovation market where large scale deconstruction and rebuild may not be economically or environmentally feasible.



Going forward, research and the future of PCM in building applications incorporates the thermal characteristics of the technology into the building envelope. While research and development continues for PCM encapsulation methods and products for solid wall and floor material construction including plasters, foams ,and thin masonry, the next step involves transparent, thin layers that allow for optical transmission while minimizing building skin weight and size. The implications for such development are significant as core-dominated, fossil fuel consuming designs will continually give way to skin dominated, naturally driven heating and cooling systems.

COST

The microencapsulation of phase change materials is the only key technology to date which makes it possible to bring PCM´s into building materials within large-scale production processes. This makes possible a new class of intelligent building materials with only small additional effort. While per unit cost for raw materials remains proprietary, consumers have been provided with an end product example in the range of $5,000 for PCM enhanced wall panels for a typical home. Transparent PCM layered products are in the infant stage of testing; thus specific PCM choices and associated costs are not yet established.



MAINTENANCE

Durability is a key factor in the potential of PCMs in more building applications. By using novel microencapsulation methods, in which the PCM component is housed within a solid, protective particle shell, the end result is a very stable composition, regardless of the PCM phase state. The PCM components that would be suitable for construction applications are hydrophobic, thus not susceptible to water uptake. High purity of product ensures a high melting enthalpy with no side products that might have detrimental effects on performance or health. The lack of double chains in the PCM composition protects the product from oxidation. The size of a microcapsule (2-20μm) renders it mechanically indestructible. A testing process of 10,000 cycles revealed no damaged capsules, no composition changes, and the impenetrability and melting heat capacity remained at their starting levels. If a typical home were to have 300 phase changing cycles in a year, the test period reflects a 30 year durability. In a building skin application, modularization of components would augment the overall lifespan and durability of the system. As the PCM has been verified to withstand elemental and climatic flux, replacement and repair would likely be limited to the housing, support structures, and associated construction components.

PROPERTIES

Current research on PCM for transparent, insulated building skin applications has provided base statistics for optimal configurations, which result in a promising future market potential. Testing has been conducted at the CSEM UAE Innovation Center in the United Arab Emirates using a range of PCM thicknesses under natural ambient temperature conditions. To this point, many PCMs are highly transparent for the visible part of the solar spectrum whereas the infrared part is absorbed within the PCM . However up until now little effort has been made to study the optical transmittance of the materials which would render them suitable for transparent building envelope applications. In testing, the melting point of PCM was chosen to be near the average ambient temperature to simulate the natural daytime environment. Results for tests using a range of PCM thicknesses is shown in Table 2.

Table 1. Thermo-Physical Properties of PCM.

Melting point [b]	31.98°C
Heat of fusion [b]	236.17 kJ/kg°C
Solid specific heat [a]	2.15 kJ/kg.K
Liquid specific heat [a]	2.18 kJ/kg.K
Solid thermal conductivity [a]	0.34 W/m.K
Liquid thermal conductivity [a]	0.15 W/m.K
Density [a]	777 kg/m^3 @ 25°C

a: From literature [1] b: From differential scanning calorimeter measurement

Table 2. Solar Transmittance Measurements for Various Thicknesses under Outdoor Conditions.

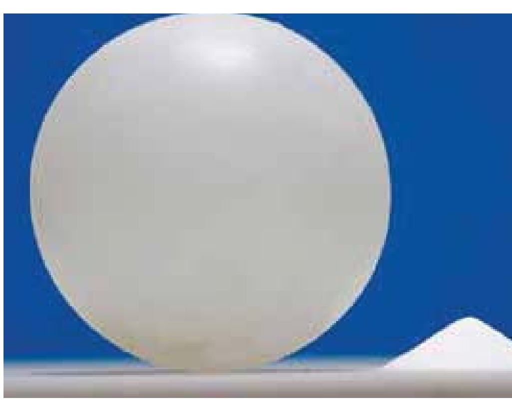
PCM thickness (mm)	Global solar radiation (W/m^2)$^+$	Ambient temperature (°C)$^+$	PCM transmittance (%)$^{+,*}$
4	744.2	38.7	67.6
10	775.3	40.1	65.3
15	786.6	40.6	63.9
20	771.8	38.9	62.9
30	698.8	38.6	59.9

+ These values are averaged values during the different days of measurements
* This value is system transmittance values with PCM layer between two glass covers.

Table 3. Comparison of Solar Transmittance of PCM with Water and Air.

Material	Transmittance @15 mm
PCM	63.9
Water	60.4
Air	74.6

The results of testing also indicate a significant drop (7.7%) in PCM transmittance over the course of a day (Figure 3). This signifies an importance when choosing PCM thickness for different applications, climate regions, and building characteristics.





Check List

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

Phase Change Material

Tests comparing PCMs and water were conducted to measure optical transmittance. Results show that for a layer thickness of 15 mm, PCM has a higher transmittance (63.9%) than water (60.4%) (Table 3). For tests involving PCM thickness as a standalone component, optical transmission ranged from 90.7% for a 4 mm thickness, down to 80.3% for a 30 mm thickness (Table 4). Overall conclusions indicate that high transmittance and low thermal conductivity make PCMs suitable and viable as a transparent insulating medium for building construction applications. Further research is needed to optimize latent heat capacity for all transparent building applications. As the PCM layer requires varying thicknesses and size to achieve necessary thermal characteristics, designers would likely benefit from integrating these components into the building aesthetic, rather than attempt to isolate the function of the skin from the appearance.

LIFECYCLE

A study conducted by BASF estimates that a typical single family home made with plaster that incorporates 360 grams of PCM would cost just under $5,000. This number, owing to variation in location, climate, and building construction characteristics, serves as a basic estimate for the potential of the product. A five year payback does however provide a viable option for use. These plaster panel products are highlighted by National Gypsum, who has an ongoing collaboration with BASF, NREL, and Califonia's Emerging Technologies Coordinating Council. The company is currently testing panels that "liquefy" at 73 degrees Farenheit while storing 22 BTUs per square foot. These panels are estimated to come to market in the next year, provided that testing is successful in four distinct seasons.

As transparent PCM applications are not as far along in the prototype and testing realm, specific costs for production and consumer purchase are not yet known. However, with the aforementioned advantages owing to the stable and durable nature of PCMs, payback is likely to be shortened given proper market saturation.

Tab. 4. Transmittance of PCM Alone.

PCM thickness (mm)	4	10	15	20	30
PCM alone transmittance (%)	90.7	87.5	85.7	84.4	80.3

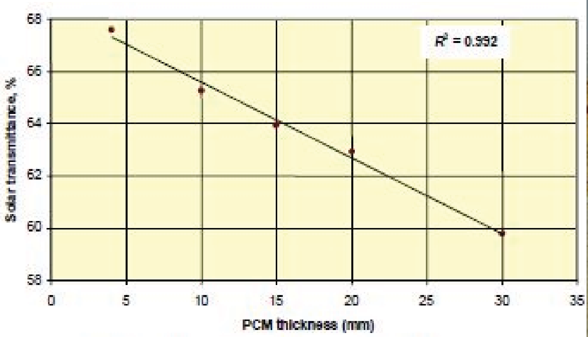
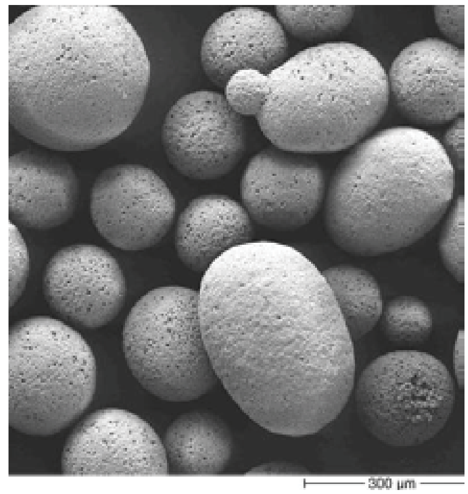


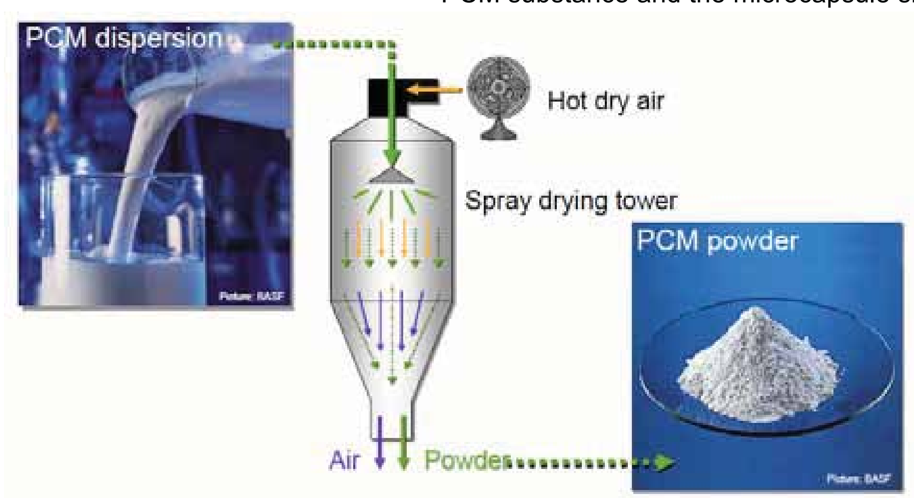
Fig. 2. Variation of Average PCM Solar Transmittance with PCM Thickness.

EMBODIED ENERGY

The production of PCM's is a complex process but not an energy intensive one. Advancements in the containment of PCM's has not only led to increased durability and performance but also a better manufacturing process. The initial PCM of choice was an inorganic hydrated salt solution, but due to chemical instability and poor transitional thermal characteristics anhydrous organic substances (pure wax or paraffins) have become the favored substitutes. The production of PCM's consists of the actual PCM material - wax or paraffin, as well as the encapsulation of the PCM, which is accomplished by adding monomers to the PCM substance causing a polymer shell to form around it. The shell is responsible for protecting the substance from being contaminated, thus preserving the high thermal attributes of the PCM. Once the PCM has been created it can then be applied to the surface of a material, which usually occurs during the manufacturing phase of that material. For instance, plastic must sit in water during production and this is when the PCM's (already contained in microcapsules) are dispersed into water and embedded in the material.



In cases where PCM is being applied to a material that does not use water during manufacturing spray drying the material will get rid of excess water leaving the PCM material in a powder form (which maintains a strong bond with the surface of the material, an example is dry-ready mixed plaster). In general, the process of applying PCM's to the surface of various materials is not an energy intensive one considering PCMs can be dispersed during the normal manufacturing process of a material. The majority of the embodied energy that comes from PCM's tend to be in the initial stages of developing the PCM substance and the microcapsule shell.



HEALTH

The health effects of PCM's on humans are relatively benign. Modern production are formaldehyde-free and made from highly pure waxes. Unlike the inorganic PCM substance used during the 70's and 80's, PCM's today are chemically stable. In addition, recent efforts have focused on developing non-flammable organic PCM's to address the concern of PCM's susceptibility to fire. Lastly, the passive nature of PCM's versus mechanical cooling and heating methods in conventional buildings means less reliance on producing energy, leading to reduction in carbon emissions and cleaner air.

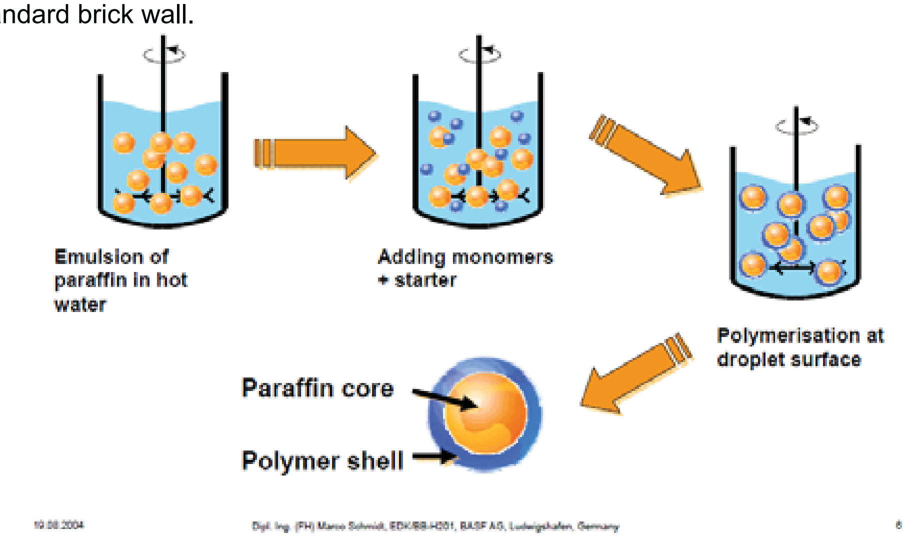
BENEFITS

The benefits of PCM are obvious. Modern construction lacks the thermal mass of older buildings, which were able to regulate indoor climates using their material properties. PCM's provide an opportunity for light-weight buildings to achieve indoor thermal comfort through passive means rather than relying on conventional heating/cooling methods. A layer of PCM plaster 1.5 cm. thick has similar heat capacity properties to a standard brick wall.

The broad range of materials that PCM's can be applied to renders it a flexible element for almost any design. Furthermore, the use of PCM's on transparent surfaces will not only thermally regulate indoor temperatures but will also permit natural daylighting, therefore increasing solar heat gains during cold seasons.

DISADVANTAGES

The disadvantages of using PCM's mostly focus on their slow acceptance in the market place. The easiest application of PCM's to a surface is during the manufacturing phase of a particular material, therefore the use of PCM's must be a design-phase decision and not an afterthought. Until we witness a paradigm shift from centralized heating/cooling to passive building skins that are able to control indoor climate conditions there will continue to be a slow acceptance of PCM's in the market place, consequently causing the price of PCM's to remain disproportionately high and only small-scale production. A common deterrent of older PCM's were their susceptibility to fire and durability but new advancements have addressed both these issues.



Check List

definition

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

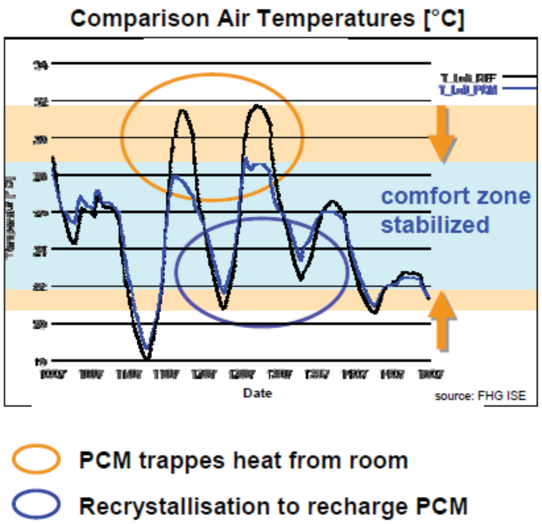
final analysis

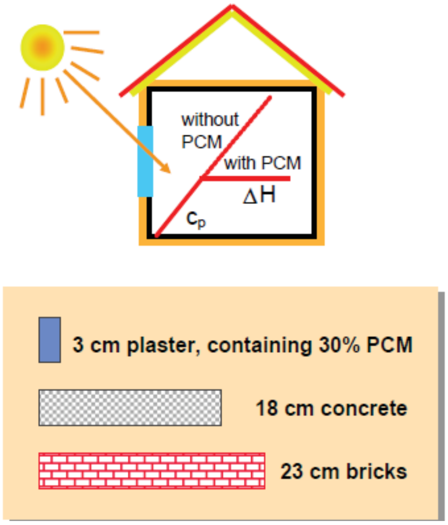
FINAL ANALYSIS

Heating and cooling in buildings consume massive amounts of energy that ultimately leads to environmental degradation. Treating building skins as a source of indoor thermal regulation means less reliance on traditional HVAC systems. PCM's are a great alternative because they respond to the surrounding environmental conditions of a building and passively react by insulating and then releasing heat into interior spaces. As we've discussed the PCM substance and the microcapsules it's contained in have taken enormous strides in terms of technology, the only thing that awaits is its adoption in the market. In instances where PCM's can't solely control indoor temperatures they can greatly reduce the need for AC systems.

The use of PCM's on transparent surfaces is unquestionably the most promising aspect of its future implementation. With its high solar transmittance, low thermal conductivity, and potential for latent heat storage PCM's are able to provide the necessary indoor thermal conditions without consuming much energy. Future

advancements will bridge "smart" glass that controls the amount of light entering a space with phase change materials that store and release latent heat. A building skin that reacts to its environment through passive means will greatly reduce the amount of energy typical buildings require.





Works Cited

<http://www.micronal.de/portal/basf/ien/dt.jsp?setCursor=1_290814>.

<http://www.energiforumdanmark.dk/fileadmin/pr__sentationer/Phase_Change_Material_-_Micronal_-_with_notes.pdf>.

<http://www.fraunhofer.de/en/research-topics/construction/microencapsulated.jsp>.

<http://www.technologyreview.com/energy/24476/page2/>.

<http://jestec.taylors.edu.my/Vol%204%20Issue%203%20September%2009/Vol_4_3_322_327_sharma_jain.pdf>.

<http://www.micronal.de/portal/basf/ien/dt.jsp?setCursor=1_290823>.

<http://www.microteklabs.com/micropcm.html>.

<http://www.rdmag.com/Awards/RD-100-Awards/2009/07/Organic-Thermal-Material-Changes-Phase/>

<http://www.ornl.gov/sci/roofs+walls/AWT/ComputerSimulations/Kosny_PCM%20overviewl.pdf>

<http://nanopatentsandinnovations.blogspot.com/2009/12/fraunhofer-institute-creates.html>

Building Automated Systems (BAS)

By: Audrey Pierce & Alyssa Tharrett

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

Definition

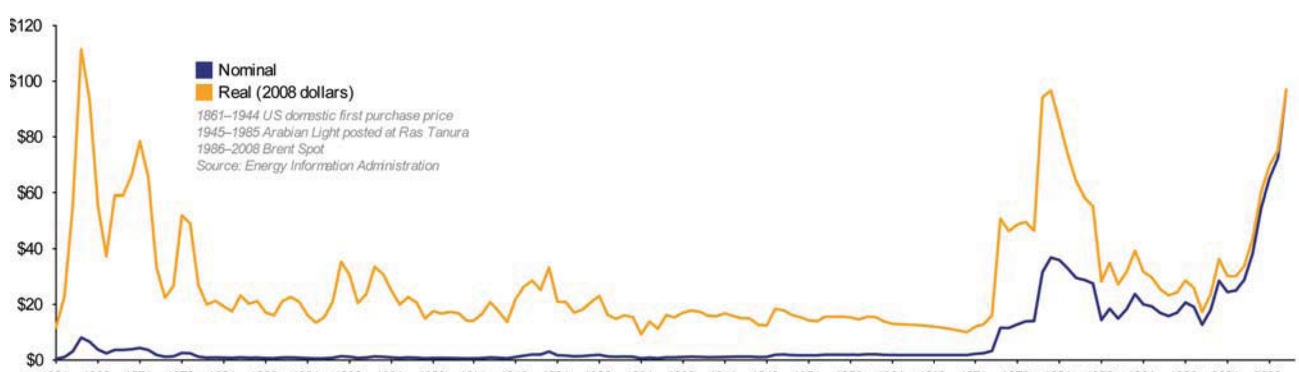
Building Automation Systems (BAS) are energy management system that control and monitor energy use throughout a building at real-time and allows owners and tenants to make better decisions about the building's energy use. Unlike simple building controls, an automation system computes, controls, manages, communicates, programs and processes a variety of functions throughout a building from a single light to an entire ventilation system.

History

In 1973 the OPEC oil embargo sent an astute message to the energy consumers around the world. The price of oil shot up 70% and oil shortages forced countries such as the US to explore energy conservation. Buildings at this time were greatly over designed in the areas of HVAC because energy was cheap, but after the embargo companies and individuals began to see a direct economic hit in their monthly energy bill. Building operators began to look at the first form of building automation in an effort to control the increasing energy bills. Plywood boards covered air inlets, effectively shutting off systems. Energy management system products then began to appear in the market, these products could schedule, cycle and shut off equipment. While these did reduce energy use they also decreased human comfort levels and created major indoor air quality problems.

Throughout the 80's EMS (energy management systems) evolved but it wasn't until the '90s that the market saw intelligent systems categorized as true building automation that reduced energy use while still maintaining comfort levels.

Today most commercial buildings incorporate basic automation and energy management systems through their HVAC systems. The energy crisis' of decades before have shifted from a purely monetary efficiency of energy to a new moral movement in energy conservation and thus allowed building automation systems to develop into an ever evolving component to the future of sustainability.



Building Automated Systems (BAS)

Cost

The typical cost of an efficient building automation system in a new commercial building is approximately 1-1.5% of the total construction cost. More sophisticated systems currently being produced for intellegent green buildings can cost up to 4% of a building cost.

Savings - Monetary & Productivity

BAS can conservatively save 10% of a buildings operation cost, which can approximate to a 4 year pay back period along with an increase in staff productivity and efficiency. More than 20% of occupants are not satisfied with the comfort of the spaces they habitat.

"Providing improved comfort, both in physical (temperature, lighting, humidity, IAQ) and emotional terms (confidence, convenience, empowerment, assurance) allows occupants to focus on their mission in the building and not spend time focused on the lack of comfort. "

"Why your next project should be an Intelligent Building" by Paul Ehrlich

"In-home energy displays present information on electricity and gas consumption, enabling consumers to monitor and control their energy usage. By making consumers more conscious of their day to day energy consumption, such displays can help change behaviour and promote energy saving habits. National and international experience suggests that such feedback leads to between 5 and 15 percent energy savings"

The Smart Way to Display
Published by Energy Saving Trust ®

Cost vs. Savings Example

Given: 150,000sf building at a construction cost of $175 per square foot.

By investing $4 per SF on building automation in this example a reasonable calculation of energy and operational savings as well as productivity improvement savings can be computed.

Operations and energy savings with a $4 sf investment can give a 4 year return on investment. By calculating in the productivity savings due to occupants satisfaction a 1.7 year return on investment can be reached.

For more detailed information please refer to http://www.automatedbuildings.com/news/may06/articles/ehrlich/060425025140ehrlich.htm

Building Automated Systems (BAS)

definition

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

final analysis

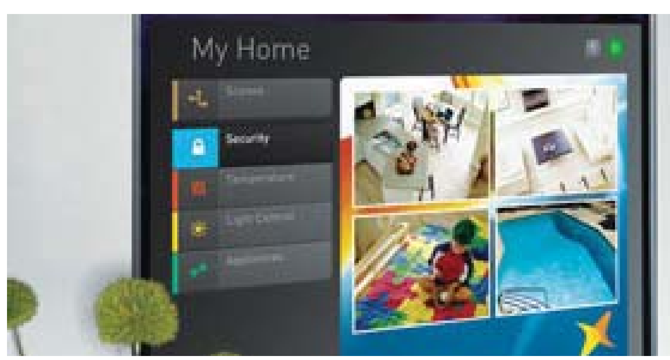
Begin Scene

Fred pulls his fuel guzzling SUV into the driveway after a long day of teaching. As he opens his front door the transmitter attached to his keychain sends a signal to the building automation system at his home. The shades covering the western windows relax to allow a better view of the mountains after an afternoon of protecting the home from unwanted heat gain. The lights in the kitchen begin to glow in anticipation of a home cooked meal and PBS greets Fred from the TV. The thermostat automatically shifts to a comfortable 72 degrees after having a break all day while no one was home. After diner he fills the dishwasher and sets it to start. The appliance's display alerts Fred that his energy consumption is reaching a peak energy demand time period for the day and it will wait to start when the energy demand of the area lowers, thus saving energy use and cost. At the end of the day Fred sits at his computer and reviews the report his home automated system generated. This report points out maintenance issues that have been detected and a populated list of contractors to help. It summarizes his daily energy use and highlight spots of spiked energy consumption along with a list of solutions to avoid spikes in the future. After a restful night's sleep the

shades rise, the coffee pot starts and the rest of Fred's building automation eases him into the day. As Fred drives off his building detects he is gone and shuts down unnecessary appliances and systems. Fred can drive confidently to work in his gas guzzling car, content that his building automation does more for the environment than trading in his SUV for a hybrid car.

End Scene

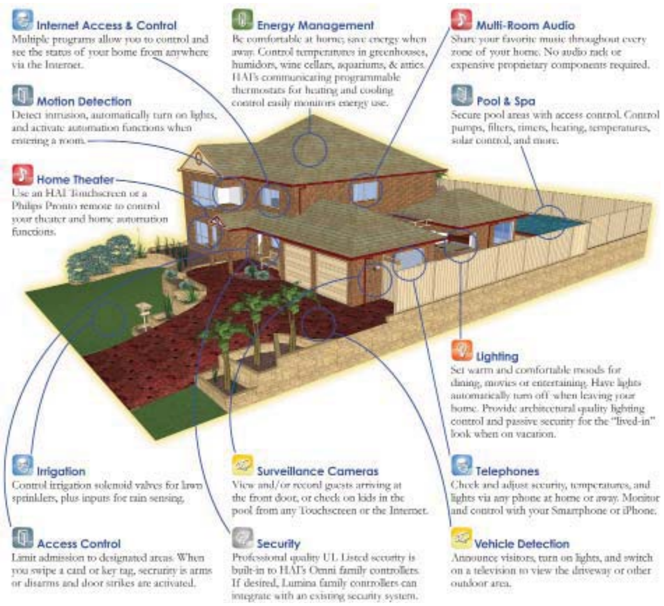
As the allegory implies above, building automated systems can have a large impact on everyday life. There are few divisions of a building that an automated system cannot improve. The next section will list a wide array of systems and controls integrated with a building automated system.



Building Automated Systems (BAS)

Building Automation Systems can control a variety of interfaces throughout a project, including:

- Heating
- Ventilation
- Cooling
- Lighting
- Appliances
- Facades/Louvers
- Water
- Gas
- Operation & maintenance
- Logging & monitoring energy data
- CO2 monitoring
- Diagnosis
- Security systems and biometric access
- Paging devices
- Shutters/blinds
- Power supply
- Sanitation
- Multimedia
- Telephones
- Elevators
- Payroll/accounting
- Facility management



The previously listed systems can be controlled through many different preferences, including:

- Energy data communication
- Individual personal preference
- Time of day
- Humidity
- Number of occupants
- Indoor/Outdoor temperature
- Solar thermal load
- Motion

Evolving BAS controls now allow for:

- Remote & Web-based (wireless control)
- Smart Grid compatible with Smart Meters
- 2-way communication with energy grids
- Real-time maintenance monitoring & solutions
- Open platform software

The Fénix Garden Hotel uses a new building automation system that integrates HVAC, fire safety, and solar energy systems through a single interface.

Building Automated Systems (BAS)

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

BAS
IT Backbone
& IPv6

Information Technology of BAS

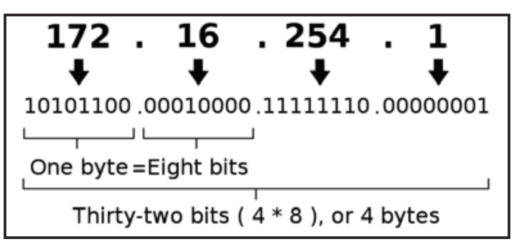
For the last eight years, leaders in the BAS industry have been persistently redefining the way BAS technologies communicate with each other. It is no longer about creating a BAS product that operates autonomously from its competion, but rather have the capability to integrate itself in BAS systems other than its own. Integration is an important factor that is helping pave the way for the latest, greatest building automation systems of tomorrow.

Two new emerging technologies, which address the integration issue and which will revolutionize the building automation industry, are Internet protocol version 6 (IPv6) and cloud computing. Both of these technologies will change how the industry thinks about communication. The reason is that improvements in wireless technologies are providing BAS leaders the opportunity to develop innovative BAS solutions that can help fulfill the increasing demand to communicate better with our buildings from a new perspective.

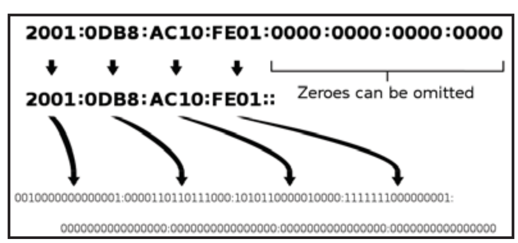
IPv6

Internet protocol is nothing more than a set of rules that govern the way data is transmitted over the Internet. It is nonetheless the backbone of all web-based building automation systems that are being used today.

The current Internet protocol version 4 (IPv4), however, has its limitations that hinder the advancements of BAS technologies. The major problem with the existing IPv4 is that it is running out of IP addresses. Although IPv4 which is 32-bit, has a little over four billion Internet addresses, it does not have the capacity to allocate unused IP addresses to every device used in existing and or that will be used in future edifices. Keep in mind that our mission is to communicate better with our buildings and the most effective way to accomplish this is by assigning unique IP addresses to dampers, temperature sensors, and other commonly found building gadgets that will eventually be, if they have not already been automated. The next generation of Internet protocols, that is IPv6, which is a 128-bit address, does just that. Aside from its other inherent benefits as listed on the next page, its ability to provide a vastly larger address



A sample of an IPv4 address in a dotted-decimal notation.



A sample of an IPv6 address in a hexadecimal notation.

space than the current IPv4 allows a better, systematic, hierarchical allocation of addresses and efficient route aggregation. According to wikipedia, "Renumbering an existing network for a new connectivity provider with different routing prefixes is a major [undertaking] with IPv4. With IPv6, however, changing the prefix announced by a few routers can in principle renumber an entire network since the host identifiers...can be independently self-configured by a host." This enables BAS designers to utilize IPv6 to expand their building automated systems to include devices (e.g., actuators and switches)for better control over energy consumption and usage.

How does IPv6 differ from its predecessor?

- Larger IP address space
- Jumbograms
- Stateless address autocon-figuration
- Multicast
- Mandatory network layer security
- Simplified processing by routers
- Options extensibility

Larger IP address space:

- 3.4×10^{38} addresses or
- approximately 5×10^{28} addresses for each of the roughly 6.5 billion people alive in 2006 or
- the same number of IP addresses per person as the number of atoms in a metric ton of carbon

Jumbograms:

- IPv6 supports data packets that exceed the size limits of IPv4

Stateless address autoconfiguration:

IPv6 hosts can configure themselves automatically when connected to a routed IPv6 network using ICMPv6 router discovery messages

Multicast:

- Has the ability to send a single packet to multiple destinations

Mandatory network layer security:

- It is no longer optional, but mandatory to have an IP security or protocol for IP encryption and authentication

Simplified processing by routers:

- Simplier IPv6 packet header
- IPv6 routers are no longer expected to perform fragmentation, leaving the IPv6 hosts to do the job
- IPv6 routers are no longer expected to recompute a checksum when header fields change
- IPv6 routers are no longer expected to compute the time a packet has spent in a queue

Options extensibility:

- Unlike IPv4, IPv6 headers can easily be extendable to support future services for QoS, security, mobility, etc. without a redesign of the basic protocol

For more detailed information please refer to http://en.wikipedia.org/wiki/IPv6

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

Cloud Computing

The actual benefit of IPv6 comes with the next emerging technology, cloud programming. At its most basic level, the cloud is simply the Internet. It is not a new concept by any means. In fact, it has been around since the 1980s, but have only been popularized in recent years due to the technological advancements it has made; it has gotten cheaper, it utilizes more sophisticated remote software, and it is easier to store, edit, and share information than emailing files. Some familiar examples of cloud-based applications are Yahoo Mail, GMail, and Hotmail.

For the BAS industry, however, this is "new" technology that is going to help change the way buildings operate in the future as the desire for net-zero energy edifices become more prevalent and obtainable. The market will shift from using proprietary to open source standards where key companies contribute to making compatible BAS products at an economical rate. This is essential to the implementation of cloud computing.

The cloud has so much to offer. Once building devices have their own unique

> "Cloud computing is here, and growing, and quite useful. It will only get better and better."
>
> "PC Use Increasingly Basks Under the Cloud"
> by Walter Mossberg

IP addresses, owners will be able to better communicate with their buildings via the cloud, running complex algorithms to produce detailed reports remotely from a cell phone perhaps or directly from a hardwired interface, on power consumption changes in real time.

Furthermore, with the cloud in place, building automation systems will be able to run applications and store necessary data on servers miles from the premises. The option is there to be managed by IT specialists if necessary.

The cloud also becomes a tool to allow BAS infrastructures to expand easily as information requirements increase.

On top of that, the cloud will be able to analyze the system with one month's data and update the code in the local device based on possible failure scenarios. It is a self-healing system that translates to money saved.

When there is enough data stored, the cloud will be able to calculate predictions for the future and will alert the user for possible break downs.

Last, but not least, playing back individual device performances would be like watching a movie; it would be visually easier to identify problematic areas rather than interpreting points on charts.

Building Automated Systems (BAS)

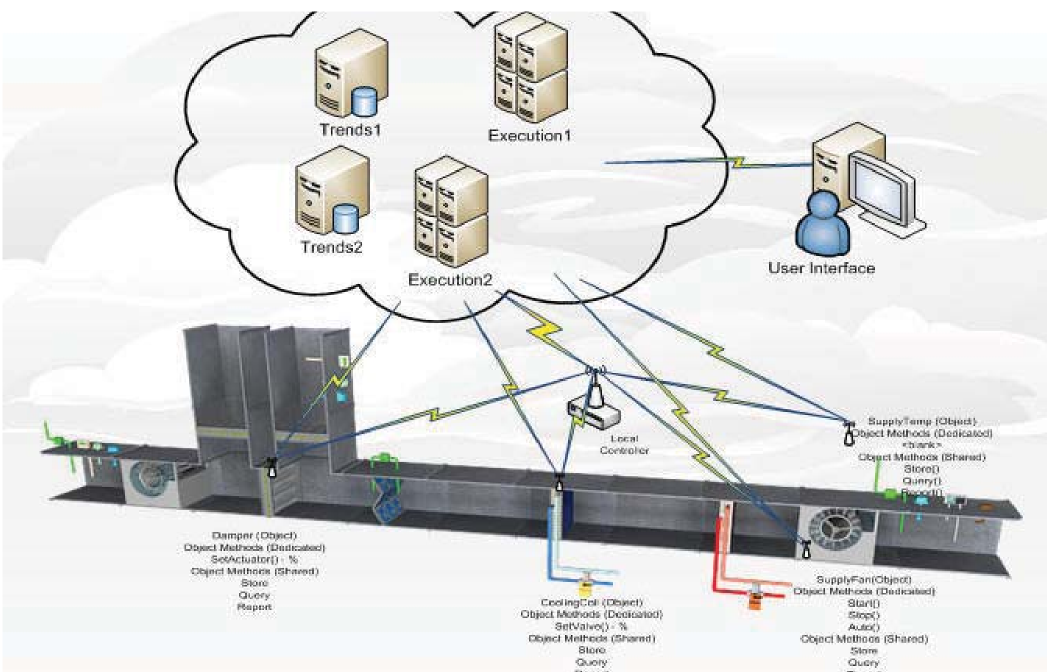



definition
cost
maintenance
properties
lifecycle
embodied energy
health
benefits
disadvantages
final analysis

BAS
IT Backbone
& Cloud Computing

"Here is a scenario of an air handling unit controlled by the cloud. The air handling unit has a supply temperature and it has methods stored in the sensor. The sensor has a mini computer that is capable of simple calculations and able to communicate to the cloud or the local controller. The local controller consists of wireless connectivity devices and is located close to the specific air handling unit or units. It does not require input output cards as every device communicates via IPv6. The local controller is programmed to run the air handling unit optimally. It's main purpose is the calculate PID loops, starts and stops, etc. The local controller's application is automatically updated by the cloud. Every device on the network such as temperature sensors can connect to the cloud for simple executions such as storing trend data and also can initiate a query from the cloud and can return the value to the cloud, to the local device and to the local user interface. This will enable the programmer to have vast possibilities for their applications. The cloud can automatically calculate different variables such as power consumption changes from the cloud database and can generate reports for the whole life time of the building. That much data can be used to optimize the building to its fullest extents."

"Future of Building Automation with IP Version 6 & Cloud Networking"
by Alper Uzmezler



This is a graphic depiction of how the cloud would interact with the user, the local controller, and various building devices connected to the BAS system.

Building Automated Systems (BAS)

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

Smart Meters

Electricity metering is undergoing its greatest transformation since the first meter was installed more than 120 year ago. Advanced metering infrastructure (AMI), integrating two-way communications with energy measurement, is on the front lines of utility Smart Grid deployments, promising major energy savings by changing how and when customers use electricity...More than 250 million smart meters will be installed worldwide by 2015."

PikeResearch

Smart meters play a vital role in monitoring energy production and consumption of net-zero energy buildings. They are much more advanced than traditional meters, whether electrical or gas, that we know of today (see chart on page 11). They are nonetheless the epicenter for smart grids, a two-way, near real time communication between users and utility companies that facilitates the increase reliability of electric services while providing insight into a building's energy use patterns and a means for returning renewable energy back to the grid. Other major features include remote or automatic load-shedding and load cycling, displaying energy prices and CO_2 emission levels, offering prepaid services through the devices, performing remote updates, providing remote connect and disconnect, and detecting tamperages and outages.

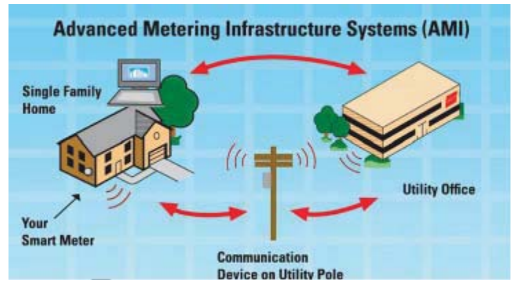
What makes the next generation of smart meters different from current smart meters is that they are able to offer a combination of unique features not found on any smart meter currently available. The next generation of smart meters, which OnStream will be introducing the first of its kind in the UK this summer, can be accessed via cell phones. Their built-in mobile communication technology makes this possible. Their meters will also have the ability to accommodate communication with smart appliances as they become widely available in the market. Additionally, they will use lower levels of electricity to operate than their predecessors as well as featuring a roaming SIM to pick up the strongest mobile network to transmit information wirelessly. Until now, smart meters were restricted to one mobile network, hampering installation of meters if the signal for that network was not strong enough.

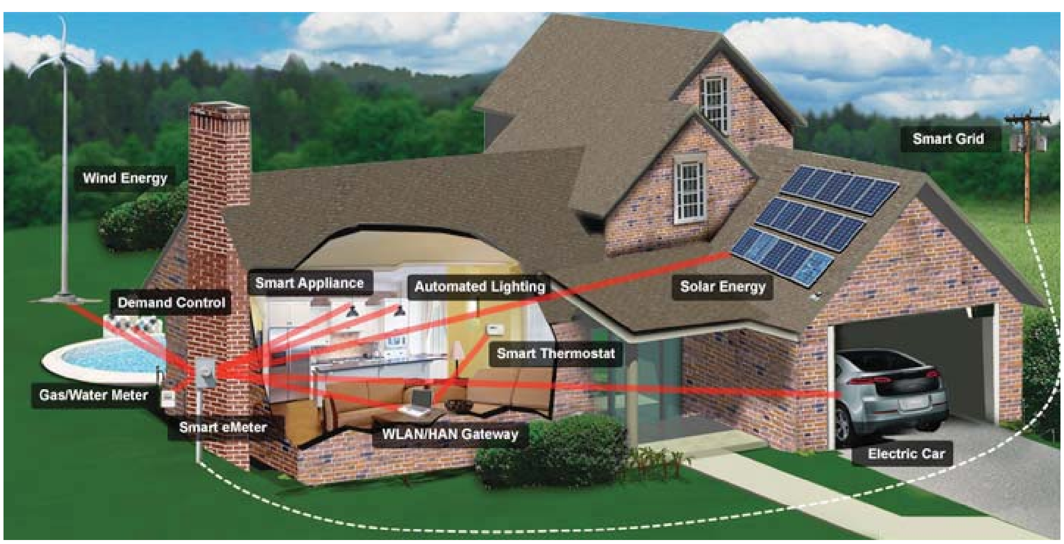
With this new technology about to hit the market in a few months, it is most likely that other major players in the industry such as General Electric (GE), Itron, and Landis+Gyr will follow suit, launching their version of the next generation of smart meters.

BAS technologies including smart meters thermostats, and smart appliances are continuing to move toward wireless communication. Downstream, smart thermostats such as the ones being unveiled this summer by Silverpac called the Silverstat 7, has a mini computer that gives a real-time energy display with a wi-fi interace that can pull electricity usage information from smart meters, or vice versa. General Electric who has signed a patent license agreement with SIPCO and INTUSIQ, licensors of the Essential Wireless Mesh patent portfolio, is another company example that is eager to enter into the "wireless" smart appliance market but have not done so as of yet. But when these products are made available, they too will be able to talk with the new smart meters just discussed.

Silverstat 7

Nonetheless, the point being made here is how smart meters work in the most simpliest form. Smart meters will gather energy usage information over hardwire or wi-fi from such devices such as smart thermostats, smart appliances, and solar and wind technologies, transmit the data upstream through radio technology to the smart grid, and then onto the local utility company. This not only makes it fast and easy to connect, transfer, and disconnect service, but also allow the utility company to shed load during peak usage and pricing periods. How the end consumers benefits is from the information received back from the utility company via the smart meters and displayed on BAS monitors. They are able to view their energy consumption, CO_2 emissions, and energy costs on an incremental basis. It allows them to identify opportunities to save on monthly energy bills.





Building Automated Systems (BAS)

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

BAS
Smart Meters

Comparing Smart & Traditional Meters

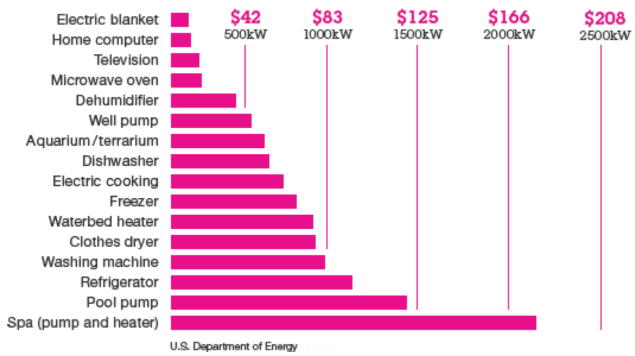
	Newest Smart Meters	Current Smart Meters	Traditional Meters
Easy to read	Yes	Yes	No
Reports outages	Yes	Yes	No
Necessary monthly readings	No	No	Yes
Helps conserve electricity and or gas	Yes	Yes	No
Takes advantage of lower rates	Yes	Yes	No
Ability to automatically adjust central A/C units in the summer	Yes	Yes	No
Ability to communicate with smart grids	Yes	Yes	No
Ability to transmit and receive information wirelessly in both upstream (distribution and transmission assets) as well as downstream applications (automated operation of consumer appliances and smart controls)	Yes	Yes	No
Ability to communicate with smart appliances	Yes	No	No
Mobile communication	Yes	No	No
Restricted to one mobile network	No	Yes	n/a
Level of power consumption used to operate the smart meters	Lower	Higher	Higher

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

Smart Appliances

Cost/Year

How much electricity do your appliances use?



> "With little or no intelligence to balance loads or monitor power flows, enough electricity is lost annually to power India, Germany, and Canada for an entire year."
>
> IBM

Appliance manufacturers such as General Electric (GE), Whirlpool, Electrolux, and Indesit are currently leading the smart appliance movement. They have jumped on the band wagon early on because there is a lot of potential to capitalize on this market. According to ZPryme, a research and consulting company, the global houshold smart appliance market is projected to grow from $3.06 billion in 2011 to $15.18 billion by 2015 as the smart grid technologies gain traction and momentum in the wider economy. By 2011, the U.S. is expected to have majority of the global market share, accounting for 46.6 percent or $1.43 billion, but is predicted to lose part of it to China as it dips to 36 percent or $5.46 billion by 2015.

- Dishwashers & ranges
- Washers & dryers
- Microwaves & water heaters

Smart appliances, such as the ones listed above, have software integrated into their operations that can communicate with the electric grid, smart meters, and other smart appliances. They can adjust themselves automatically, although they could be overrided, to use less electricity when prices are highest and powering down or delaying operations to avoid using power when other high energy consuming appliances are running. The wireless intergration will further allow the appliances to be controlled from different points whether it be from a web browser, iPhone, or in-home display. They are designed to be fully integrated with building automated systems that will encourage users to efficiently consume and consciously manage their electric usage.

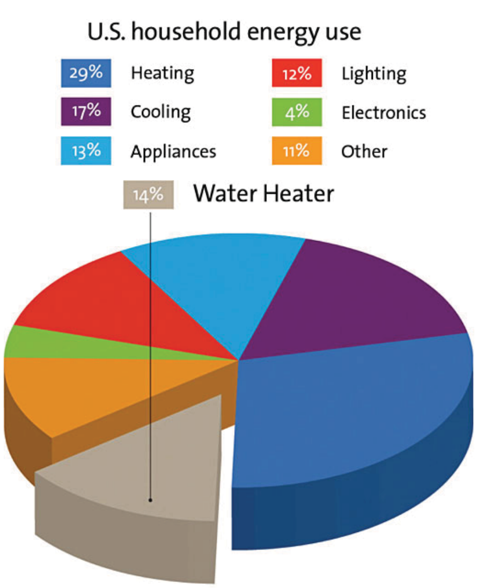
Take, for instance, how current refrigerators operate. The auto defrost cycle, which uses a considerable amount of its electricity, are prompted by factors like door openings. Ideally, You do not want the defrost mode to run during peak periods of pricing. You rather have it run during the night when energy prices are lower. A smart refrigerator, on the other hand, will sense what the cost is and know when it is the appropriate time to run the defrost mode. Now




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

when the energy prices increase, the appliance automatically knows to go into an energy conscious state. When the prices reach its peak demand, it ensures that it is conserving energy as best as it can. This new technology that is still being research in labs is expected to reduce electricity consumption by 15 percent.

Water heaters, the second highest energy user in the home behind heating and cooling, is another less efficient appliance that will eventually be replaced by smart technologies like the ones being developed by GE. The future of water heaters, whether for commercial or residential use, will be electric hybrids. They will operate on the same principle as the smart refrigerators. When the rates are high, these smart water heaters will silently choose the lower rate for their heating mode. They will also be programmable where the user can exchange information about vacation plans and guest schedules in addition to being able to communicate with smart meters and the smart grid. At their most basic level, they will absorb heat from the ambient air and transfer it to the stored water to achieve the desired temperature.



Source: DOE website
www.energystar.gov/index cfm?c=products.pr_pie



In order for the smart appliances to make a huge presence in the market, several conditions will have to be met. It takes a collaborative effort amongst the appliance manufacturers (e.g., GE and Whirlpool), the smart grid integrators (i.e., the software developers such as IBM and Cisco), and the utilities to make this a success. The conditions are listed as follows:

1. Competition. The market needs a variety of small, medium, and large appliance manufacturers competing against one another to make it affordable for the average consumer.

2. Standardization. There needs to be a seamless integration across the smart grid ecosystem. Integrators must communicate with utilities and smart appliance manufacturers in regard to developing smart appliance standards, knowledge transfer, efficiency testing, and the optimization of systems and networks that communicate with smart appliances.

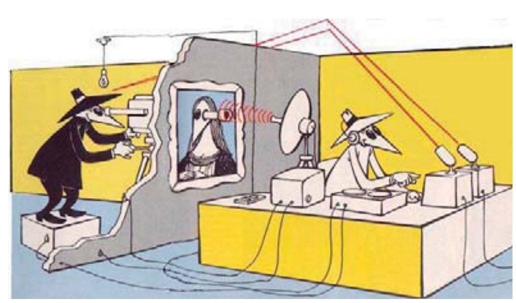
3. Expansion of Smart Grid Infrastructure. The smart appliance growth relies heavily on how quickly the smart grid infrastructure is installed and readily accessible to communities. It is a major undertaking by the utility companies, but they are responsible for building the smart grid infrastructure that will let consumers fully reap the benefits of smart appliances.

"Hackers may manipulate the grid in many wants: they could completely cut power to users, causing a blackout; they could electronically tell the computers that less electricity is needed, thus causing brownout; or they could initiate a denial-of-service attack in which the smart grid is made to attack itself."

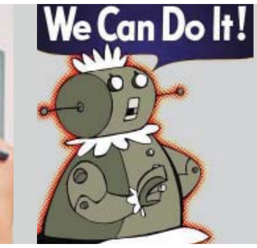
Building Technology and Terrorism
by John J. Fanning

Disadvantages

Arguments over the wide spread implementation of BAS and the Smart Grid focus on privacy and security issues. The fear of terrorism is at the forefront of many people's minds because of the vulnerable network of computers communicating wirelessly in building automated systems. Cases have occurred where hackers compromise a building automation system and wreck havoc for the building. One such instance happened at a small U.S. airport where the hacker turned off the runway landing lights. Other opponents to the BAS & Smart Grid movement believe it will jeopardize their right to privacy under the US Fourth Amendment.



Building Automated Systems (BAS)



definition

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

final analysis

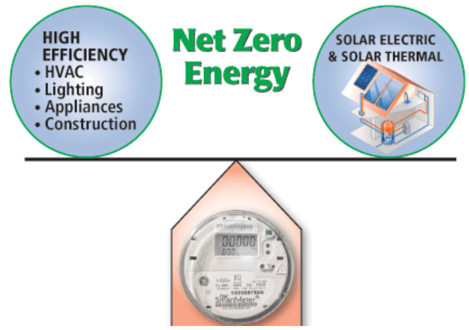
Final Analysis

While building automation originally started as a response to monetary pressure it will continue to develop as a green building tool used towards a zero-net-energy tomorrow.

The first step in building a greener future is education for occupants and builders. Owners should be able to see real time energy usage via smart meters in an effort to reduce consumption. Architects should be equipped with the knowledge to plan and design these intelligent automated systems within each building so they can meet the needs of the future.

A green building cannot exist without intelligence, which is the component BAS brings to a building. The future will be a connection of these intelligent buildings working together within a smart grid that is capable of maintaining equilibrium between energy production and consumption.

BAS is inherently IT based, which is a sector that advances consistently and exponentially, thus providing a bright future to the endless possibilities of building automation.



"Energy, buildings, and the environment are interlinked in a symbiotic relationship, and the results of this interaction can be optimized for maximum gains by convergence of Green and Intelligent building concepts. An intelligent building is one in which the building fabric, space, services and information systems can respond in an efficient manner to the initial and changing demands of the owner, the occupier and be in harmony with the environment. Intelligent buildings not only have energy efficiency but also have safety and telecommunications systems and other required automations propelled by innovations."

Intelligent Green Buildings Of Tomorrow
by Dr. S. V. Ranade

Office Building in Steiermark, Germany
Dynamic facades that adapt automatically to their surroundings could not exist without building automation.

Building Automated Systems (BAS)

Works Referenced

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

http://www.esmagazine.com/CDA/Articles/Column/BNP_GUID_9-5-2006_A_10000000000000271363

http://en.wikipedia.org/wiki/Building_automation

http://www.automatedbuildings.com/news/aug05/articles/ibtpe/ibtpe.htm

Building Automation by H. Merz

"The Smart Way to Display", Published by Energy Saving Trust, 2009

"The Effectiveness of Feedback on Energy Consumption: A Review for Defra of the Literature on Metering, Billing and Direct Displays", by Sarah Darby, April 2006, Environmental Change Institute – University of Oxford

http://highperformancehvac.com/ddc-a-building-automation-systems#ddc_bas_overview

http://news.cnet.com/8301-11128_3-10451082-54.html

http://www.chiefengineer.org/content/content_display.cfm/seqnumber_content/792.htm

http://www.automatedbuildings.com/news/may06/articles/ehrlich/060425025140ehrlich.htm

http://www.green-tech.biz/index.php?option=com_content&view=article&id=52%3Agrenn-buildings&catid=39%3Aconstruction&Itemid=67&showall=1

http://news.cnet.com/greentech/?keyword=Cisco

http://www.alsaonline.com/english/images/WholeHouse.jpg

http://en.wikipedia.org/wiki/IPv6

"Future of Building Automation with IP Version 6 & Cloud Networking," by Alper Uzemezler. http://www.automatedbuildings.com/news/jun09/articles/bas/090519010450bas.htm

"PC Use Increasingly Basks Under the Cloud" by Walter Mossberg. http://www.capecodonline.com/apps/pbcs.dll/article?AID=/20100509/BIZ/5090314/-1/NEWS

BAS

Works Referenced

Building Automated Systems (BAS)

BAS

Works Referenced

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

"Smart Meter Installations to Reach 250 Million Worldwide by 2015" by PikeResearch. http://www.pikeresearch.com/newsroom/smart-meter-installations-to-reach-250-million-worldwide-by-2015

https://www.indianamichiganpower.com/info/projects/SouthBendSmartMeters/HowThey-Work.aspx

http://www.elp.com/index/display/article-display/336510/articles/utility-products/volume-5/issue-8/product-focus/amr-ami/zigbee-smart-energy-technology-spurs-smart-grid-energy-conservation.html

http://climatelab.org/Smart_Meters

http://www.energyandutilities.org.uk/companynews/current/onstream_200410

http://www.peachygreen.com/renewable-energy/smart-thermostat-includes-a-mini-com-puter

http://www.ti.com/corp/docs/landing/smartmetering/index.html

http://continuingeducation.construction.com/article.php?L=134&C=621

http://www.ibm.com/smarterplanet/us/en/smart_grid/ideas/index.html?re=spf

http://ge.geglobalresearch.com/industries/appliances/

http://www.zpryme.com/SmartGridInsights/2010_Smart_Appliance_Report_Zpryme_Smart_Grid_Insights.pdf

http://news.cnet.com/8301-11128_3-10286278-54.html

http://continuingeducation.construction.com/article.php?L=134&C=621

Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

final analysis

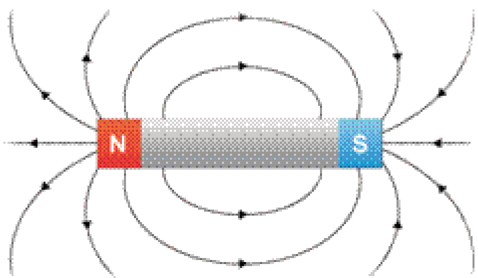
Magnetic Systems

Roberto Pesce

Fabian Baumann

History and Background.

The magnetic properties of natural ferric ferrite were first described by Greek philosophers around 600 BC. While William Gilbert in the 1600s and Benjamin Franklin in the 1700s both did significant work dealing with electricity, one of the most important discovery was made in 1855 by Michael Faraday: electromagnetic induction. His work dealt with how electric currents work and many inventions of the first half of the 20th century were based on his experiments.

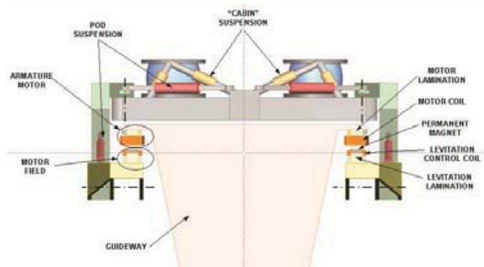


Applications of magnetic properties:

- Medical/Pharmaceutical
- Magnetic Levitation
    - Levitating Trains
    - Wind Turbines
- Magnetic Bearings
    - Permanent Magnetic Motors
    - Chillers
- Adiabatic Demagnetization
    - Cooling Systems
- Magnetic Separation
    - Water Treatment

Magnetic Levitation:

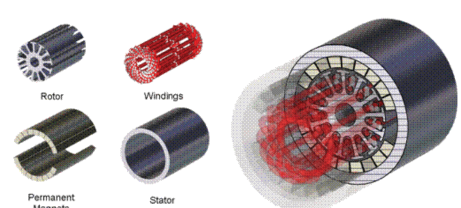
Magnetic Levitation (MagLev) is a is a system of transportation that suspends, guides and propels vehicles - predominantly trains - using magnetic levitation properties from a very large number of magnets for lift and propulsion. This method has the potential to be faster, quieter and smoother than wheeled systems.



The track creates a travelling magnetic field beneath the train, which lifts the cars and propels them at 300-plus mph. The train's on-board systems are powered by induction from the track (only the section of track under the train is energized).

Magnetic Motors:

In permanent magnetic motors the magnetic flux is created by a series of permanent magnets inserted directly onto the rotor (IPM). The use of permanent magnets minimizes rotor losses, the temperature rise is consequently smaller, creating a significant improvement in the overall efficiency of the machine. This type of motor works as a matter of course with a variable speed drive.



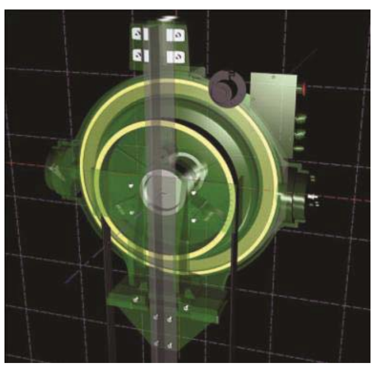




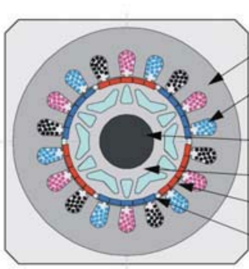

Magnetic Systems in Elevators.

Elevators using Permanent Magnet Synchronous Motors:

PMSM elevators are already in use today and present many advantages, such as a simplified mechanical system for the lift, improved comfort, reduced noise and vibration, and energy savings. The compactness of PMSMs allow for the elimination of the machine room, above or adjacent to the hoist way. The motor and control systems can be mounted within the hoist way itself. Also, elevator machine rooms are areas where substantial air leakage and heat loss from the building occurs.



The System, use axial flux motors which results in a very compact, light, and as flat as possible motor which can be wall mounted within the reduced room available in the hoist way. These motors, are very similar in operation to the more common radial flux designs. The stator produces a constant rotating magnetic field to which the rotor aligns itself at synchronous speed. Permanent magnets are affixed to a disc shaped rotor, whereas the stator has a three-phase toroidal winding. The sheave is integrated in the rotor to achieve greater compactness.

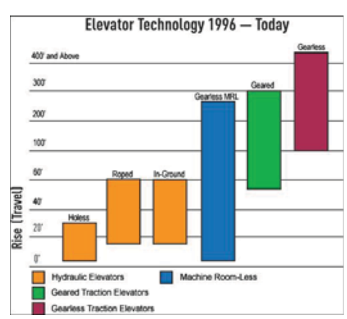


Item	Hydraulic	Traction 2 speed	EcoDisc
Speed (m/s)	0.63	1.0	1.0
Load (kg)	630	630	630
Motor output power (kW)	11	5.5	3.7
Main fuse size (A)	50	35	16
Typical energy consumption (kWh/y)	7000	5000	1535
Carbon footprint (kg CO_2/year)	2090	1550	745
Oil requirements (l)	200	3.5	0
Thermal losses (kW)***	3.8	3.0	0,8
Elevator Machinery Weight (kg)	650	430	230
Typical machine-room area (m^2)	5	12	0

Benefits:
- Energy saving up to 60% v/s hydraulic
- Very low Power consumption
- High Efficiency PM Motor Technology
- Ride Quality
- Gearless Traction Elevator Performance
- Smooth Ride
- Quiet – Noiseless Operation
- Environmentally Responsible
- No Hydraulic Oils – Zero Spill Risk
- No hot oils smell
- Building Efficiency
- Recover Machine Room Space
- Machine Room Less Space
  (reduce construction costs)
- Flexible Layout

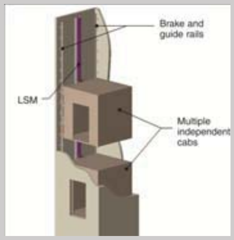
Disadvantages:
- May require case-by-case approval by local code authorities that have not adopted the latest national ASME elevator safety code
- Core dimensions and installation requirements vary according manufacturer

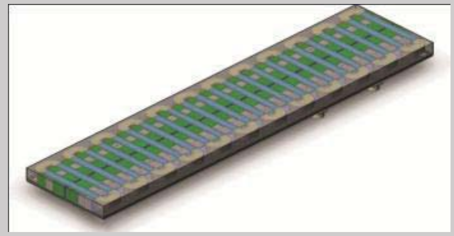
Still relatively new in U.S.



Roberto Pesce

Fabian Baumann





Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

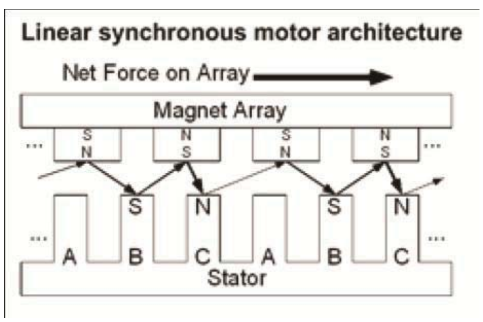
final analysis

Roberto Pesce

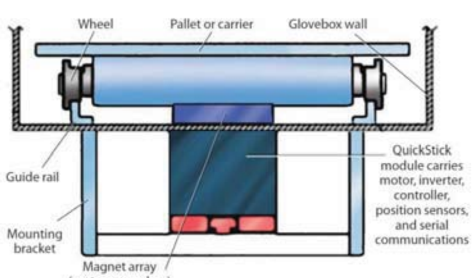
Fabian Baumann

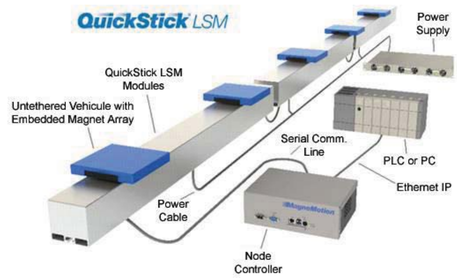
Elevators using Linear Synchronous Motors

The Magnemotion company has been developing for several years the Linear Synchronous Motor System, which is basically pallets moved on a track by magnetic fields. Similar to the Maglev Train Technology, where the LSM produce the movement of the magnets using the properties created by the magnetic field (attraction and repulsion).



All motor components, controls, and position sensors are build into the stationary motor segments in the track. The pallets themselves have no powered components so there is no need for complicated electrical and control connections or cabling, and they are able to carry loads as heavy as several tons up to 4 m/s.
Pallets, also, can be equipped with a range of support including flanged or groove guide wheels, and rollers on rails, depending on payload sizes, speed, weight, and number of pallets in the system.
Bidirectional system of any size or complexity can be constructed combining QuickStick modules. The system has not traditional power-transmission parts, so maintenance in low.

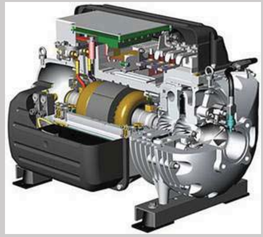




Currently, the system is being tested in diagonal and vertical directions with the goal of creating an elevator system supported by electromagnetic fields.

For elevator applications, an important property of the LSM is the individual stator segment that operates with low-duty cycle. This means, the system could be able to get a much higher thrust than one might infer by scaling the force capabilities of rotary motors. So, they could be able to overload LSM without affecting reliability.

Benefits:
- Eliminates ropes and counterweights
- Higher speed at no higher cost
- Motor efficiency over 85%
- Multiple cabs in a simple hoistway
- Switch cabs between adjacent hoistway
- Energy generated by a descending cab can be used by an ascending cab, can be stored in a battery or can be returned to the mains
- System is less costly when cabs are operated at relatively high speeds, because stator duty cycle is low

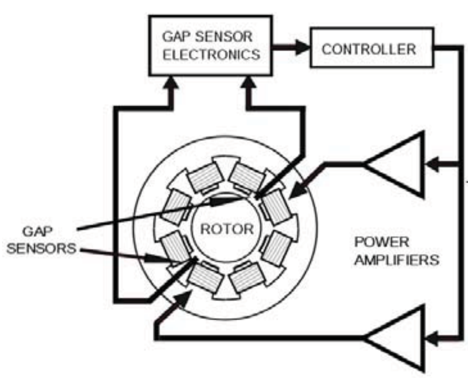


Magnetic Cooling Systems

Chillers based on Magentic Levitation Technology:

The MagLev Chiller is the first sustainable compressor design in the air conditioning industry. It runs on a virtually friction-free compressor, which eliminates heat and reduces energy consumption.

The principle of operation of a magnetic bearing is an electro magnetic device, which maintains the relative position of a rotating assembly (rotor) with respect to a stationary part (stator). The electro magnetic forces implemented for this are controlled by an electronic control cabinet. An active Magnetic Bearing is, therefore, made up of three distinct parts:
- The bearing itself
- The electronic Control System
- The Auxiliary bearings

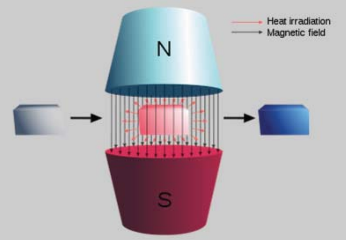


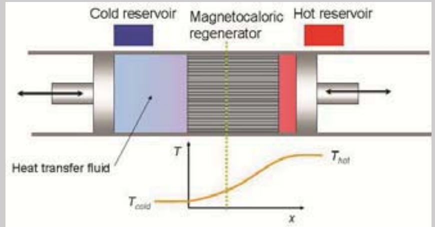
Because the MagLev Chiller's shaft and compressor turbine spins suspended and centered in an electromagnetic field, there is no friction, no wear on surfaces, and no oil contamination of the unit's heat exchange surfaces. The chiller's oil-free design eliminates oil maintenance, its costs, and environmental damage caused by oil use and disposal. In addition, the units at the U.S. Mission in Geneva will be air cooled as opposed to water cooled, eliminating wasteful water consumption, the need for a cooling tower, the need for hazardous biocides and anticorrosion chemicals, and associated sewer costs.

Benefits:
Can reduce energy used for air conditioning by up to 30%
Minimal refrigerant charge is safer for the environment and less costly
Significantly quieter operation than a full-sized chiller
Oil-free refrigerant system means that oil cannot make its way onto the heat transfer surfaces and degenerate the efficiency of the system
Required electrical startup current for MagLev compressor is just 2 amps v/s a full size compressor requiring 500-600 amps
A MagLev compressor's weight is one-third of what a conventional compressor of similar capacity would be. It requires significantly less material and energy to manufacturer a MagLev compressor, adding positively to your carbon footprint reduction process
Fully functional internal computer provides high level monitoring and diagnostics

Roberto Pesce

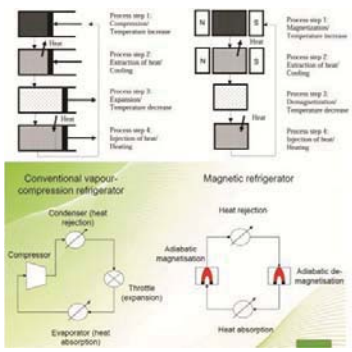
Fabian Baumann





Magnetic Refrigeration:

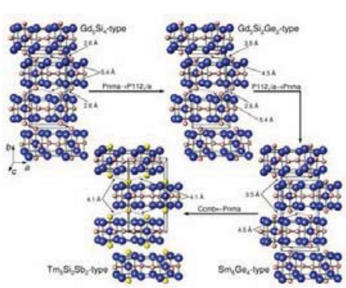
Magnetic refrigeration is a cooling technology based on the magnetocaloric effect (Thermodynamic properties of magnetic materials). This system is an alternative to the vapor-compression technology and it getting more attention because it is a high efficiency and environmental friendly technique, because is avoiding the ozone-depletion or global warming gases and it does not use chlorofluorocarbons.



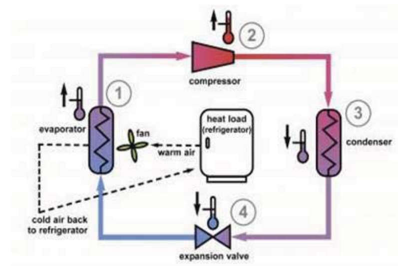
There are two essential points to make this system work:
- Material w/large MCE
- High Magnetic Field created by Magnetic Sources

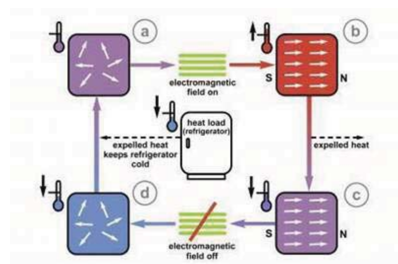
Magnetocaloric Effect

The magnetocaloric effect is the property of some materials to change its temperature when they are exposed to a changing magnetic field. Gadolinium (Gd), was the first material discovered with magnetocaloric properties. Since then, several other materials and Gadolinium alloys have been studied.

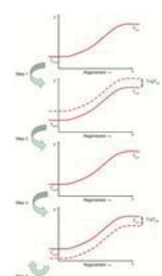


A magnetic cooling system follows a cycle similar to the traditional refrigeration cycle, only there is no working fluid - just magnetocalorics and a magnetic field.





A magnetocaloric material heats up when magnetized (b); if cooled and then demagnetized (c), its temperature drops dramatically (d).

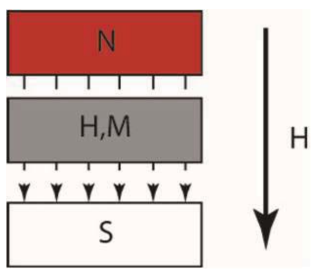


The AMR (Active Magnetic Refrigeration) cycle is analogous to the conventional gas system.
The magnetocaloric regenerator is placed in the middle of the refrigerator surrounded by heat transfer fluid. In one end of the regenerator bed a cold reservoir is placed and a hot reservoir is placed in the other end.
Pistons in each end can move the heat transfer fluid through the regenerator.
The figure inserted at the bottom show the temperature profile through the refrigerator at steady-state.

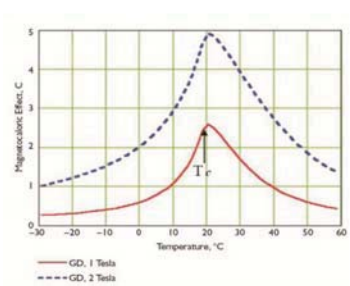
Roberto Pesce

Fabian Baumann

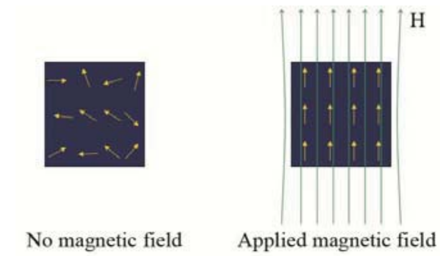
The cycle starts with a temperature gradient along the regenerator. In step 1 the AMR is magnetized, the temperature in the regenerator is increased and the gradient is “lifted” upwards. In step 2 the fluid is shifted from left to right and the hot fluid is moved out to the hot reservoir where heat is rejected, resulting in a new temperature distribution. In step 3 the AMR is demagnetized shifting the gradient “downwards”. Finally, in step 4 the fluid is shifted from right to left letting the cold fluid absorb heat from the cold reservoir; this returns the AMR to its original temperature distribution.



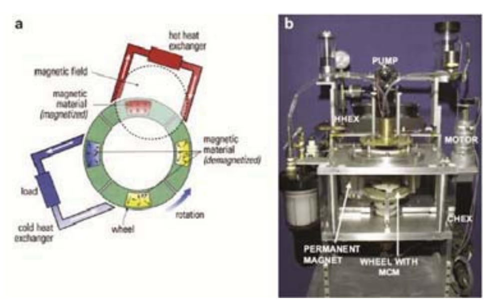
The thermodynamic system consists of the magnetic sample (grey area) and the magnet (red and white area), the arrow denotes the direction and strength of the magnetic field. Within the sample the total magnetic field is increased due to the magnetization of the sample.



The relationship between the temperature dependence of the magnetization and the magnetocaloric effect. The magnetocaloric effect is largest around the Curie temperature where the material experiences a phase transition. The adiabatic temperature change will have a positive peak and the isothermal entropy change will have a negative peak.



Magnetic refrigeration could be competitive with conventional gas compression refrigerators operating below ambient temperatures, with a five-year payback for large scale building air conditioning or supermarket chillers or food processing plants (refrigeration and freezing).
The energy savings by replacing a conventional gas-cycle (Freon or ammonia) refrigeration unit with a magnetic refrigerator were estimated to be 30% along with the elimination of Freon or ammonia, as an added environmental benefit Work on the magnetic refrigeration device a rotary, room temperature, permanent magnet, magnetic refrigerator began in 1998 at Astronautics Corporation of America (ACA). In the meanwhile Ames Laboratory (AL) entered into a three year with ACA to assist ACA to bring this apparatus, called a laboratory demonstration magnetic refrigerator.



Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

final analysis

References.

- MAGNETIC FIELDS
http://en.wikipedia.org/wiki/Magnetic_field magnetic fields

- MAGNETIC WIND TURBINES
http://www.windturbinesnow.com/magnetic-wind-turbines.htm

- MAGNETIC MOTORS
http://www.lynxmotiontechnology.com/introtosema1.htm
http://labs.ee.psu.edu/labs/powerlab/papers/energy_00154.pdf
http://www.freescale.com/webapp/sps/site/application.jsp?code=APLPMSYNCMO
Permanent Magnet Synchronous Motor:
http://www.engineerlive.com/Asia-PacificEngineer/Power_Transmission/Internal_permanent_magnets/15627/

- MAGNETIC LEVITATION
http://en.wikipedia.org/wiki/Maglev_(transport)
http://www.howstuffworks.com/maglev-train.htm
http://hacknmod.com/hack/electromagnetic-train-levitation/
University of Sherbrooke developed a scale model train that levitates
http://www.o-keating.com/hsr/maglev.htm

- USE IN ELEVATORS
http://www.toshiba-elevator.co.jp/elv/infoeng/pressrelease/20060117e.jsp
http://www.kone.com/corporate/en/Pages/default.aspx
http://www.edcmag.com/Articles/Feature_Article/ea8554b329697010VgnVCM100000f932a8c0__
http://rebar.ecn.purdue.edu/ect/links/technologies/mechanical/ecosystem.aspx
http://machinedesign.com/article/mechanical-systems-go-high-tech-0307
http://www.magnemotion.com/

- MAGNETIC COOLING SYSTEMS
http://geneva.usmission.gov/2009/04/02/maglev/
http://www.multistack.com/pressroom/documents/StateMagazineArticle.pdf
http://www.sciencedaily.com/releases/2009/05/090515083822.htm
http://newenergyandfuel.com/http:/newenergyandfuel/com/2009/05/25/progress-update-on-magnetic-refrigeration/
http://www.nrel.gov/docs/fy01osti/26785.pdf
http://www.ameslab.gov/news/Inquiry/fall97/bigchill.html
http://www.absoluteastronomy.com/topics/Magnetic_refrigeration
http://projects.bre.co.uk/cool/magnetic.htm
http://findarticles.com/p/articles/mi_m1272/is_n2625_v125/ai_19496180/
http://www.youtube.com/watch?v=eOgh1Gaelzs

- LOOKING TOWARDS THE FUTURE
Magnetic Motorcycle:
http://www.youtube.com/watch?v=NUXhJZZRUIg
UK Magnet Technology:
http://www.youtube.com/watch?v=Obw6qSZdsd4
The Space Elevator:
http://www.spaceelevator.com/
http://via-venture.over-blog.com/article-4864116.html
Magnetic Generators and Motors:
http://peswiki.com/index.php/Directory:Magnet_Motors

Magnetic Systems

Roberto Pesce

Fabian Baumann

SUSTAINABLE LIGHTING



What makes lighting “sustainable”?

The International Association of Lighting Designers (IALD) defined sustainable lighting in 2001 as:
Lighting design that meets the qualitative needs of the visual environment with the least impact on the physical environment

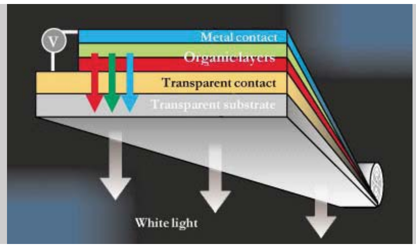
Sustainable Approach to Lighting Design

IALD’s sustainable approach to lighting design includes:
• Collaborating with other design disciplines to further green building practices
• Maximizing the use of daylighting
• Minimizing the use of energy
• Avoiding skyward illumination
• Ensuring system durability and maintainability
• Encouraging environmentally responsible manufacturing processes
• Advocating the development and use of renewable energy and other sustainable building materials and technologies

http://www.archlighting.com/industry-news.asp?articleID=452970&sectionID=0

Current Leading Contenders in Sustainable Lighting

Solid State Lighting
Fiber Optics
Hybrid Solar Lighting



Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

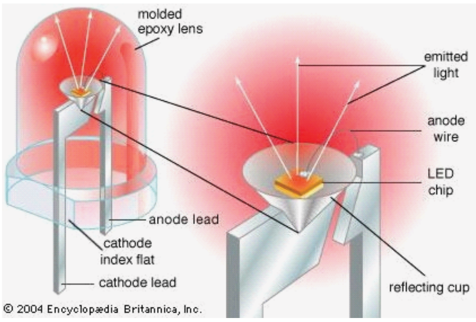
benefits

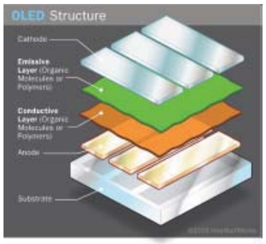
disadvantages

final analysis

SOLID STATE LIGHTING (SSL)

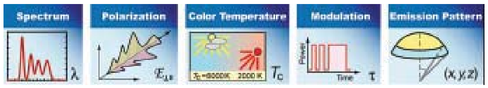
The three major types of solid state lighting technology are LED, OLED, and PLED. LED is silicon based, OLED is organic based with organic molecules in the emissive and conductive layers, PLED is similar to OLED technology but utilizes polymers for the emissive and conductive layers.

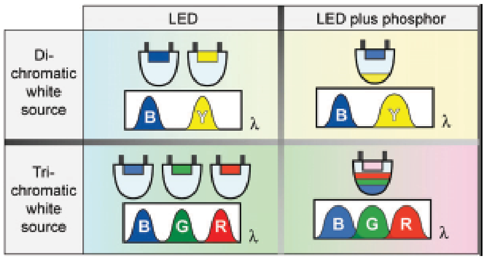




Controllable Features of SSL

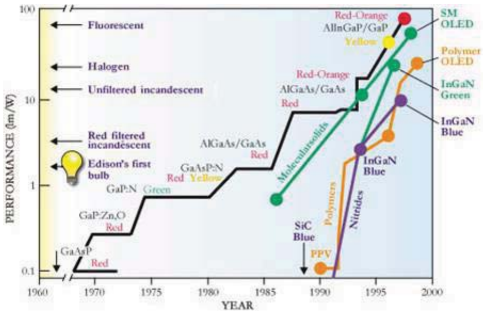
Solid state lighting sources have many features which are, in contrast to conventional lighting sources, can be controlled and tuned with high accuracy. These controllabe features include, spectrum, polarization, color temperature, modulation, and emission pattern.





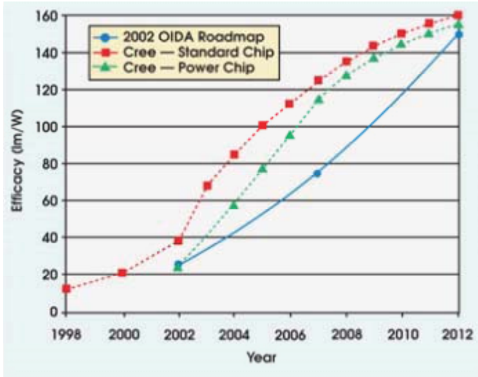
There are four main approaches to achieving white light from LED sources. Two or thee LED's are combined to produce white light or a single LED will be coated with various phosphor layers to produce white light.

Historical Progression



1907 - Round discovers light from SiC crystal
1921 - Lossew Rediscovers effect
1962 - Holonyak/GE produce 1st LED \$260
1963 - Light from Organic Crystals (OLEDs)
1968 - Red LEDs
1971 - Yellow, Green, Amber LEDs
1990 - AlInGaP LED, Large increase in
effectiveness & efficacy
1993 - Blue/Green InGaN LED
2003 - White LED, 34% Quantum Efficiency

Future

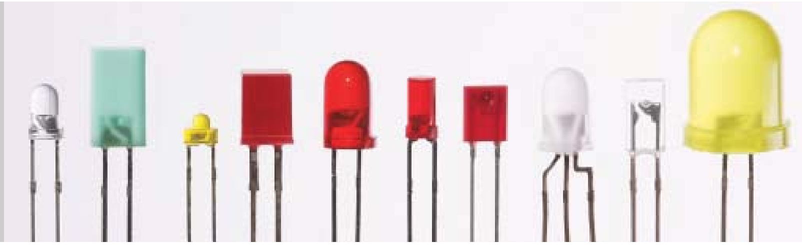


The efficacy of LEDs will increase rabidly through 2012, spurring widespread adoption.

LED technology roughly follows Morre's Law for computer technology, indicating that LED's will double in brightness and decrease to half the previous cost every 18 to 24 months.

SOLID STATE

Types
Features
Progression
Future



Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

final analysis

OLED Technology

Organic Roadmap (OLED)[19]

Attribute	State of the Art	Target	Comments
Luminous Efficacy (lm/W) and Brightness (cd/m^2)	White: 20, 1080	White: 150,	Combines electrical to optical power conversion with the ability of the human eye to detect. The real idea is to match emitted light with this response curve. *Is 200 lm/W really necessary?*
Lifetime (khrs to 50% depreciation)	10	>100	Big challenge for OLEDs as they suffer a "steady, monotonous, irritating" degradation.
Flux/Lamp (lm/lamp)	Depends upon size	Depends upon size	OLEDs have an inherent advantage in that they are manufactured in "sheets" and therefore emit diffuse light.
Purchase Cost ($/m^2)	>120	30	Combined with ownership to be competitive with fluorescent lamps.
Ownership Costs ($/Mlm-hr)	16.00	0.63	Cost of ownership = cost of capital + cost of operating. SSL is expected to overtake incandescent in 2005 and fluorescent in 2010. Note that at the limit, all costs are driven by operating costs. *What if operating costs were minimal?*
Color Rendering (CRI)	75	>90	Again, here the tradeoffs of quality vs. flexibility will be important.
			But, if the light is very flexible and has the ability to integrate with other materials, how important is CRI?
Color Temperature (CT) (°K)	3900	3900	Similar to LEDs – color temperature is addressable by combining different colors.

Organic SSL Advantages and Challenges

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

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

OLED Future

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

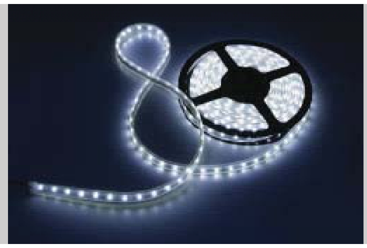
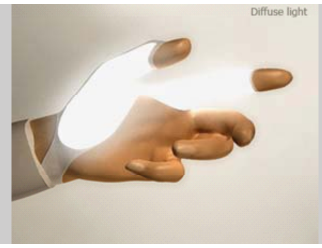
Edward A Dowdell, "Technology Migration and Distribution: A Case Study of the Solid State Lighting Industry,"

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

SOLID STATE

OLEDs
Roadmap
Advantages
Challenges
Future



Check List

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

SOLID STATE

Global Benefits
Resources

Global Benefits

Table 2. Global benefits enabled by solid-state lighting technology over a period of 10 years. The first numeric value in each box of the table represents the annual US numeric value. The US uses about 1/4 of the world's energy.

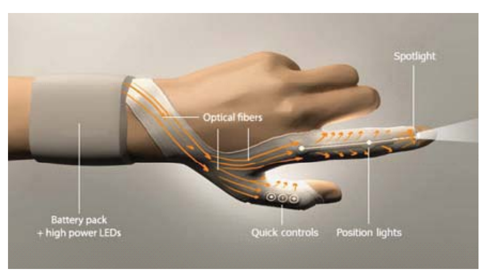
	Savings under '5.5% scenario'	Savings under '11% scenario'
Reduction in total energy consumption	43.01×10^{18} J $\times$ 5.5% $\times 4 \times 10 = 94.62 \times 10^{18}$ J	43.01×10^{18} J $\times$ 11% $\times 4 \times 10 = 189.2 \times 10^{18}$ J
Reduction in electrical energy consumption	228.9 TWh $\times 4 \times 10 =$ 9, 156 TWh $= 32.96 \times 10^{18}$ J	457.8 TWh $\times 4 \times 10 =$ 18, 310 TWh $= 65.92 \times 10^{18}$ J
Financial savings	22.89×10^9 \$ $\times 4 \times 10 = 915.6 \times 10^9$ \$	45.78×10^9 \$ $\times 4 \times 10 = 1,831 \times 10^9$ \$
Reduction in CO_2 emission	133.5 Mt $\times 4 \times 10 =$ 5.340 Gt	267.0 Mt $\times 4 \times 10 =$ 10.68 Gt
Reduction of crude-oil consumption	12.03×10^6 barrels $\times 4 \times 10 = 481.2 \times 10^6$ barrels	24.07×10^6 barrels $\times 4 \times 10 = 962.4 \times 10^6$ barrels
Number of power plants not needed	$35 \times 4 = 140$	$70 \times 4 = 280$
	40% Market Penetration	80% Market Penetration

Resources

Edward A Dowdell, "Technology Migration and Distribution: A Case Study of the Solid State Lighting Industry,"
http://dspace.mit.edu/handle/1721.1/29743?show=full

Schubert, E., Kim, J., Luo, H., Xi, J-Q., "Solid-state lighting – a benevolent technology,"
http://www.iop.org/EJ/abstract/0034-4885/69/12/R01/
http://iopscience.iop.org/0034-4885/69/12/R01/pdf?ejredirect=.iopscience

LED Magazine: Architecture
http://www.ledsmagazine.com/Architecture



LED Magazines Online
http://download.iop.org/led/

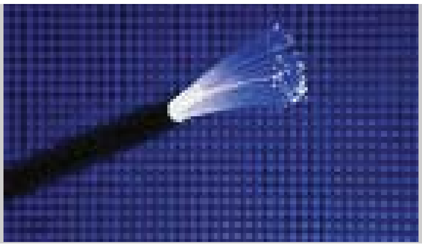
Light Up The World Foundation
http://lutw.org/home.htm

US Dept of Energy/SSL Resources
http://www1.eere.energy.gov/buildings/ssl/index.html

The Promise and Challenge of Solid-State Lighting
http://scitation.aip.org/journals/doc/PHTOAD-ft/vol_54/iss_12/42_1.shtml

SSL Research
http://www.lrc.rpi.edu/programs/solidstate/completedProjects.asp

OLEDs for Europe
http://oled100.eu/homepage.asp


Check List

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

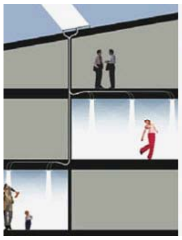
FIBER OPTIC LIGHTING

Benefits

Can be combined with solid state lighting or sunlight sources for energy efficient light distribution. A single light source can be used to illuminate many different areas at once Optic fibers can be used for pinpoint, task, or general illumination. No electricity means light can be piped anywhere with no heat or risk of shock

Future

Fiber optics can be used for data and light transmission. Fiber optics can be used as sensing devices to detect building stability. Can be installed for multiple purposes throughout buildings.





FIBER OPTIC

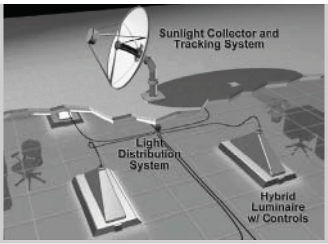
Benefits
Future
Resources

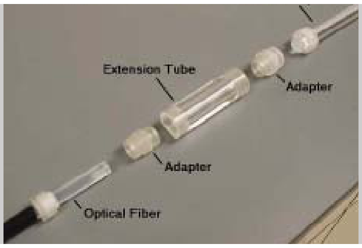
Resources

Natural Lighting: A Proposal for ES2
http://www.watgreen.uwaterloo.ca/projects/library/f04lighting2-natural.pdf

Evaluating the potential for energy savings on lighting by integrating fibre optics in buildings
http://www.sciencedirect.com/science?_ob=ArticleURL&_udi=B6V23-4GV9S86-1&_user=918210&_rdoc=1&_fmt=&_orig=search&_sort=d&view=c&_acct=C000047944&_version=1&_urlVersion=0&_userid=918210&md5=1bc7c0d833d4f23b5e281f7d51b71bbd

Coupling efficiency of polymer optical fiber for light-gathering power in optical fiber daylighting system
http://ieeexplore.ieee.org/xpls/abs_all.jsp?arnumber=1437461
Introduction to Fiber Optics http://books.google.com/books?hl=en&lr=&id=RP2FQw5uSywC&oi=fnd&pg=PP8&dq=fiber+optic+building+lighting+benefits&ots=UaYU8DYhst&sig=jqhsPyOHmQS5_vWVbedldnVafwk#PPA7,M1

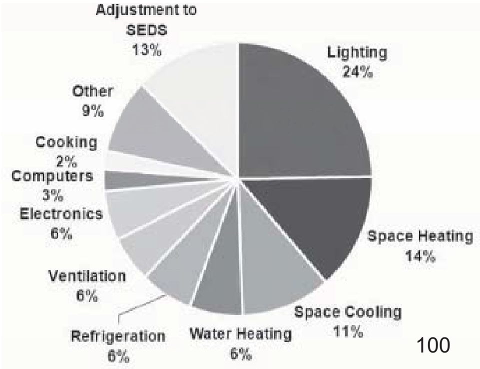




HYBRID SOLAR LIGHTING

A lighting solution that uses basic natural lighting solutions as well as high tech ones and is designed to be flexibly integrated into modern buildings. How does it work? The system uses a roof-mounted solar collector and small fiber optics to transfer sunlight to top floor hybrid fixtures that contain electric lamps. With a control system, the two light sources works in tandem by dimming the electric lights when the sunlight is bright and turning them up as clouds move in or as the sun sets. The result is a dramatic improvement over conventional approaches to bringing sunlight into buildings.

Lighting now accounts for 1/3 of the non-residential electricity usage and is the largest single use of electricity in non-residential buildings.



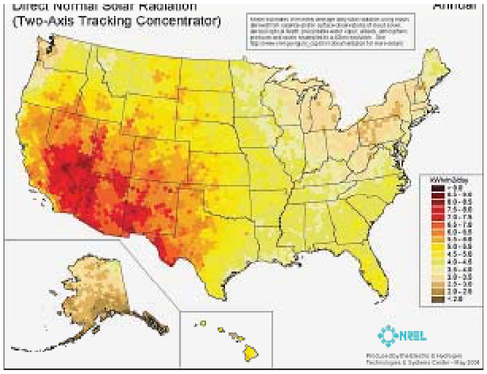
One collector powers 8 to 12 hybrid light fixtures, which can illuminate about 1,000 square feet.

According to Sunlight Direct estimates, one unit can save about 6,000 kilowatt hours per year in lighting and another 2,000 kilowatt hours in reduced cooling needs for a total of 8,000 kilowatt hours per year. For parts of the country where the utility rates are 10 cents per kilowatt hour, savings can total up to $8,000 per system over 10 years.

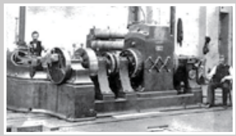
For large floor spaces-10o,000 to 200,000 square feet-this translates into energy cost savings of between $1 million and $2 million over 10 years, according to the company.

Operation and maintenance savings could account for another $300,000 in cost reductions over the same period.

If market projections prove accurate, within five years 5,000 hybrid solar lighting systems could be installed in regions of the nation where solar availability and electricity rates make this technology cost effective, saving 50 million kWh per year. Retail applications are the most likely first market for this technology. The challenge is to reduce the cost from about $12 to $4 per square foot. With larger collectors and other design improvements, researchers say they can achieve that goal. At the current fully installed cost, that translates into about $5-$8 per watt. This is almost twice as cost effective as PV panels, which typically run $10 per watt fully installed," said Morris, noting all costs are before rebates.



Menlo Park Workshop



Pearl Street Station

First Street Lamps

Metering

Compact Fluorescent Light

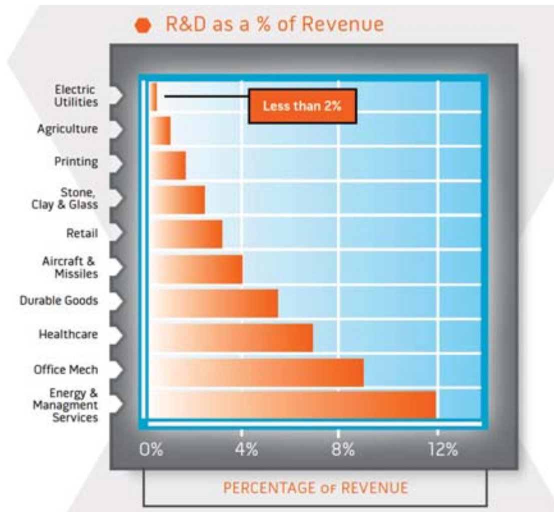
advancements in electricity

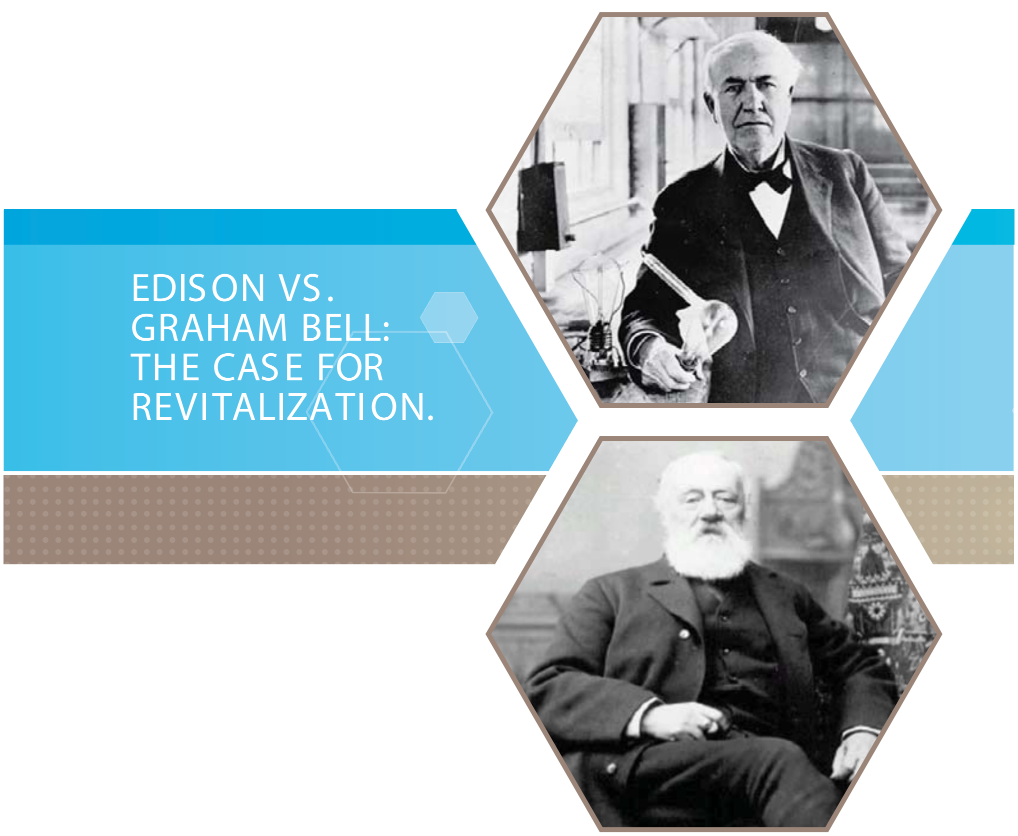
WHY?

The story goes like this:

If Alexander Graham Bell were somehow transported to the 21st Century, he would not begin to recognize the components of modern telephony- cell phones, texting, cell towers, PDAs, etc.- while Thomas Edison, one of the grid's key early architects, would be totally familiar with the grid.

As can be seen in the adjacent graph, spending on electric utilities research & development is among the lowest of all industries.





DEFINITIONS

Micro Grid-

Instead of relying solely on large power plants, a portion of the nation's electricity needs could be met by small generators such as ordinary reciprocating engines, microturbines, fuel cells, and photovoltaic systems. A small network of these generators, each of which typically produce no more than 500 kilowatts, would provide reliable power to anything from a postal sorting facility to a neighborhood.

This microgrid appears to the larger grid as any other customer. It can quickly switch between operating on or off the grid: when the grid offers cheap electricity, the microgrid can purchase it, but if prices rise or in case of a power failure, the microgrid can isolate itself or temporarily shed unimportant equipment during power shortages. This ensures uninterrupted power to critical computers, communications infrastructure, and control systems. It can also inject power into the larger grid to lessen stress on the overall system demands.

Between 60 and 80 percent of the energy consumed by power plants escapes as heat. But with a microgrid, waste heat could feed a small, adjacent heat load such as a water heater. Recovered waste heat could also be used to cool and dehumidify buildings, using thermally activated processes. Cooling buildings places tremendous strain on the power grid, and by sharing this load, it will help both the microgrid and the larger grid.

The latest distributed generators can produce electricity almost as cheaply as huge power plants, especially if benefits such as heat recovery are considered. In addition, recent advances in power electronics, such as inverters that connect small solar generators to the grid, make control of small-scale systems economically feasible for the first time.

There's also the tantalizing possibility of incorporating fuel cell-powered cars into the microgrid. Simply park your car in the garage, plug it in, and supply power to a few homes. Or plug the car into your office and help power the building.

Smart Grid- The smart grid is characterized by a two-way flow of electricity and information, capable of monitoring everything from power plants to customer preferences to individual appliances. It incorporates into the grid distributed computing and communications to deliver real-time information and enable the near-instantaneous balance of supply and demand at the device level.

Micro CHP- This refers to the use of waste heat through co-generation or combined heat and power (CHP). It implies an integrated energy system, which delivers both electricity and useful heat from an energy source (such as natural gas). Unlike electricity, heat, usually in the form of steam or hot water, cannot be easily or economically transported long distances, so CHP systems typically provide heat for local use. Because electricity is more readily transported than heat, generation of heat close to the location of the heat load will usually make more sense than generation of heat close to the electrical load.

Distributed Generation- Distributed generation involves the use of small-scale power generation technologies that are located close to the load being served, capable of lowering costs, improving reliability, reducing emissions, and expanding energy options.

Islanding- During disturbances, the generation and corresponding loads can separate from the distribution system to isolate the microgrid's load from the disturbance (and thereby maintaining high level of service) without harming the transmission grid's integrity. This intentional islanding of generation and loads have the potential to provide a higher local reliability than that provided by the power system as a whole.

Check List

COST

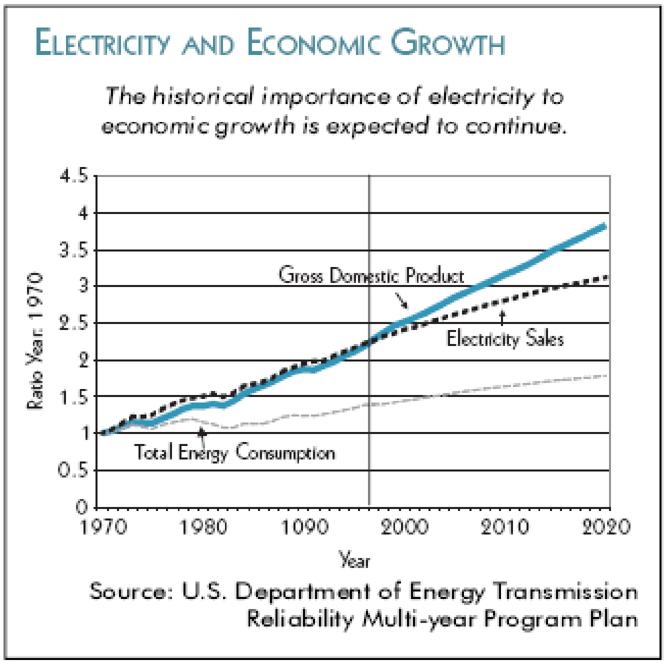
A microgrid can allow for significant cost savings. Energy delivered from the bulk power system often includes costs for things such as transmission losses, congestion pricing and customer service overhead. These costs can exceed the simple generation cost.

Microgrids enable consumers to supply some or all of their own electricity needs. In doing so, consumers can use renewable generation sources. While not all areas of the country have access to equal wind and solar capabilities, a microgrid provides the option to tailor the electricity mix to the consumer's liking. This bottom-up consumer approach can reduce reliance on fossil fuels and lower greenhouse gas emissions. Microgrids encourage efficiency by making the marginal cost of energy more transparent. If the microgrid itself purchases energy from the bulk power producer and then distributes it to the entities within the microgrid, these entities have access to dynamic pricing. The marginal generation costs are more transparent; this enables customers to earn a direct benefit from energy-efficient investments.

They also can provide realtime price signals and automatically adjust electricity usage to most efficiently meet the power needs of each individual consumer.

Wal-Mart has created microgrids for two facilities, one in McKinney, TX, and one in Aurora CO. They draw their energy first from onsite resources then from the grid as a secondary service. (They apply dozens of energy efficiency techniques as well.) Even if you didn't believe any of the other indicators, the fact that penny-pinching Wal-Mart thinks microgrids are cost efficient should tell you that this trend is for real.

The economics of microgeneration is about replacing a small number of large turbines/generators with a large number of small but mass produced generation units. Some of the new energy sources such as solar cells or fuel cells show little economy of scale – the cost of a solar cell array is largely proportional to the number of solar cells – in other words, to the rated power.



EFFICIENCY: If the grid were just 5% more efficient, the energy savings would equate to permanently eliminating the fuel and greenhouse gas emissions from 53 million cars. Consider this, too: If every American household replaced just one incandescent bulbwith a compact fluorescent bulb, the country would conserve enough energy to light 3 million homes and save more than $600 million annually. Clearly, there are terrific opportunities for improvement.

COST (cont.)

Examples of small networks similar to microgrids already exist, and many resemble the early electricity supply networks. An elegant example of a prototype microgrid can be found at the site of a former Mont-Cenis coal mine in Germany's Nordheim-Westfalen. The 12,000 m2 building, which houses a training academy, is powered by a 1MW photovoltaic array integrated into the roof and façade of the glass envelope structure, and by a CHP generator which is fuelled by methane escaping from the disused coal mine. A 1.2MWh battery ensures smooth integration into the local electricity supply, and the heat is used for the academy, surrounding housing and a nearby hospital.

Sacramento Municipal Utility District (SMUD) will field demonstrate a 310-kW load microgrid at the utility's corporate headquarters. For the demonstration, three 100-kW reciprocating engine generators will be coupled with a 12- ton absorption chiller system and an existing 10-kW PV system. Electrical output will be provided to the central utility plant and another building to serve sensitive loads such as the chilled and hot water distribution pumps, controllers, cooling towers and related equipment that need to continue operating during a utility electrical outage. The project is unique in that it will link natural gas fueled internal combustion engines with the PV system.

The design and construction work will begin in 2009 with the actual demonstration beginning in 2010. The demonstration will run for approximately 18 months. The total costs are nearly $3 million.

The electric load of one house(Figure 1) would be difficult to supply by one generating source. The microgrid would supply a much smoother averaged load similar to that shown in Figure 2. The load shown in Figure 3 applies at the national level: for example, a curve of this type would be used by the National Grid to plan generation.

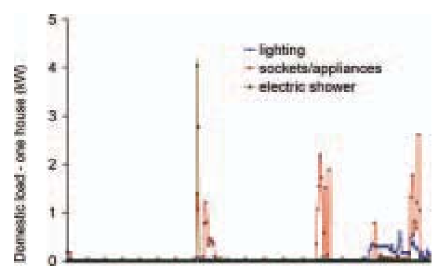


Figure 1

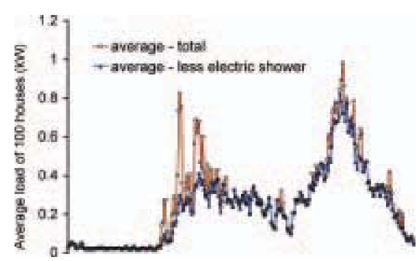


Figure 2

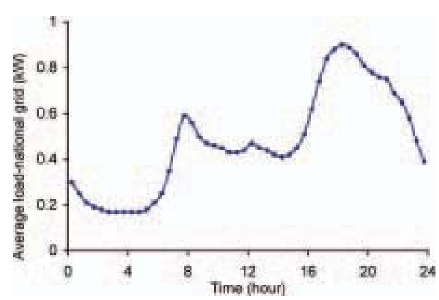


Figure 3

Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

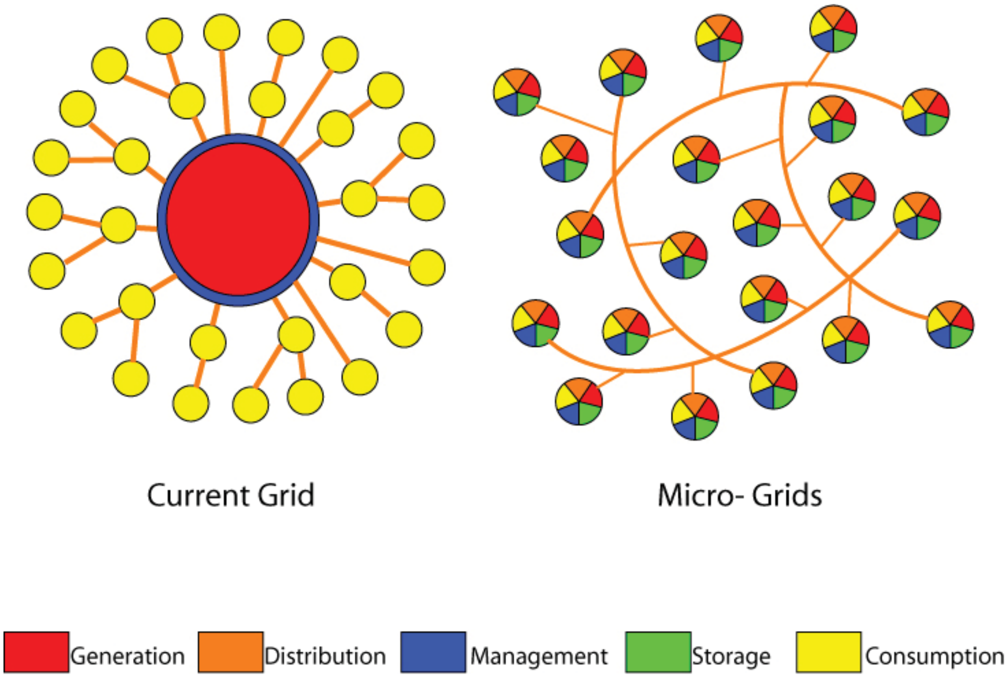
final analysis

MICROGRID
&
SMART GRID
TECHNOLOGY

Properties

PROPERTIES

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



GENERATION

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

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

DISTRIBUTION

The distribution lines within a micro-grid will be optimized for two directional flow of both power and information. They will be networked to move power from the generators to the consumers in the most efficient manner. Micro-grids will also be connected externally to the public utility. This allows for buying and selling of power to the utility while simplifying the utility's system. A micro-grid is interpreted by the utility to be a single power load/source. This connection can be islanded by a smart-switch which allows the system to move seamlessly between grid-connected and island operation modes.

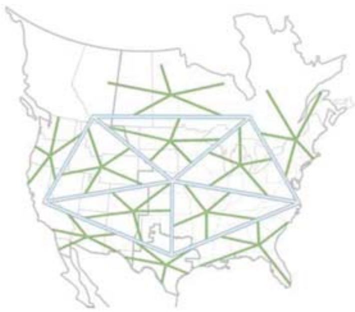
STORAGE

While energy storage is not absolutely necessary for a grid-connected micro-grid it loses the ability to operate as an island, and much of the autonomy related to storage capacity. Without storage power generated will have to be either sold or used immediately. Batteries are, of course, the first thing that comes to mind when thinking of energy storage, and battery banks are a useful component of any micro-grid. There are, however, many other options for energy storage. Batteries use chemical storage of electricity. Other chemical storage opportunities include ultra-capacitors, and electrolysis to form hydrogen for fuel cells. Energy can be stored thermally as heat or cold, in thermal mass or ice storage. Electrical potential can be converted to gravitational potential, pumping water upstream for later use in micro-hydro generation.

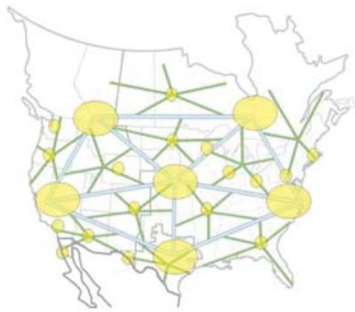
Bronsbergen Microgrid
Zutphen, the Netherlands

208-home residential vacation park
108 homes fit with 315 kW capacity PV
Two battery banks to store excess energy

National Electricity Backbone for Coast-to-Coast Power Exchange



Electricity Backbone Plus Regional Interconnection

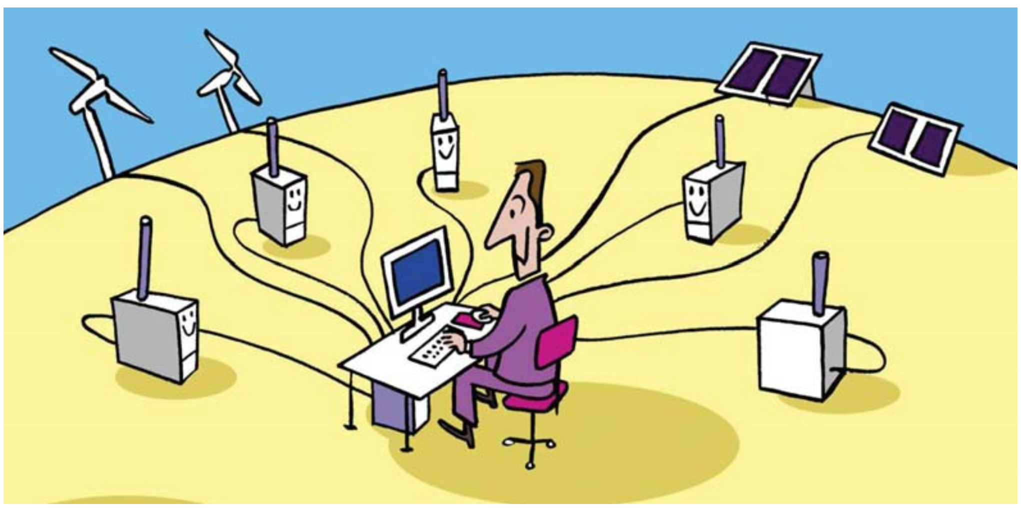


Electricity Backbone, Regional Interconnection, Plus Local Distribution, Mini- and Micro-Grids

MICROGRID & SMART GRID TECHNOLOGY

MANAGEMENT

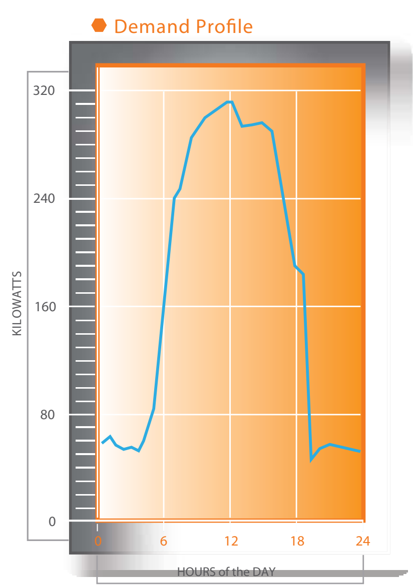
A key component to any micro-grid is the incorporation of smart-grid technologies. The transmission and control of information is necessary for the efficient transmission and control of energy. Information will be communicated both to and from all components in the grid. This will include smart-metering, self-describing appliances, remote, and/or automated, control of generation sources and non-essential loads, building dashboards within homes and businesses and a central neighborhood control center. These intelligent systems will allow residents and businesses to be more intelligent about their consumption of power, syncing their use with real-time information about local production. Some simpler, prototype micro-grids use text messaging to alert consumers to good times to cut back or to use their non-essential appliances.



CONSUMPTION

Another essential part of any future grid system is a reduction of consumption demand. A smart grid with user ownership provides incentives and information to empower and encourage conservation. Micro-grid community members will be encouraged to use energy efficient fixtures and appliances, and to control their consumption in real time with the micro-grid's production and storage capacities.

The diagrams on the following pages illustrate the functional relationships and hierarchy within a smart microgrid. Note that these systems can be far more complex or simple than illustrated here.



Check List

definitions

cost

maintenance

properties

lifecycle

embodied energy

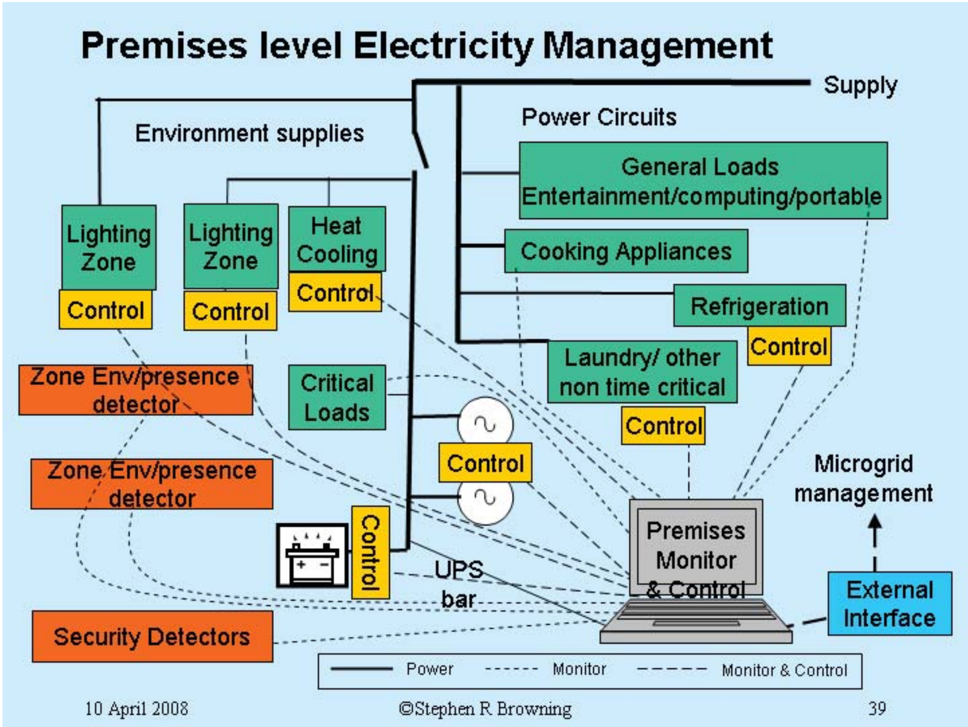
health

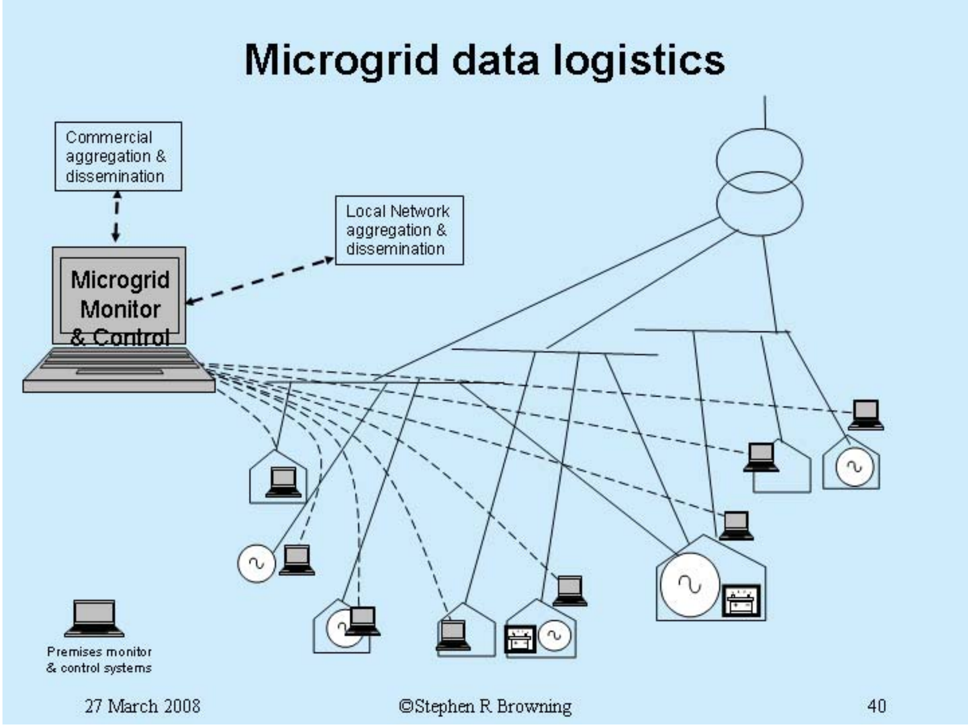
benefits

disadvantages

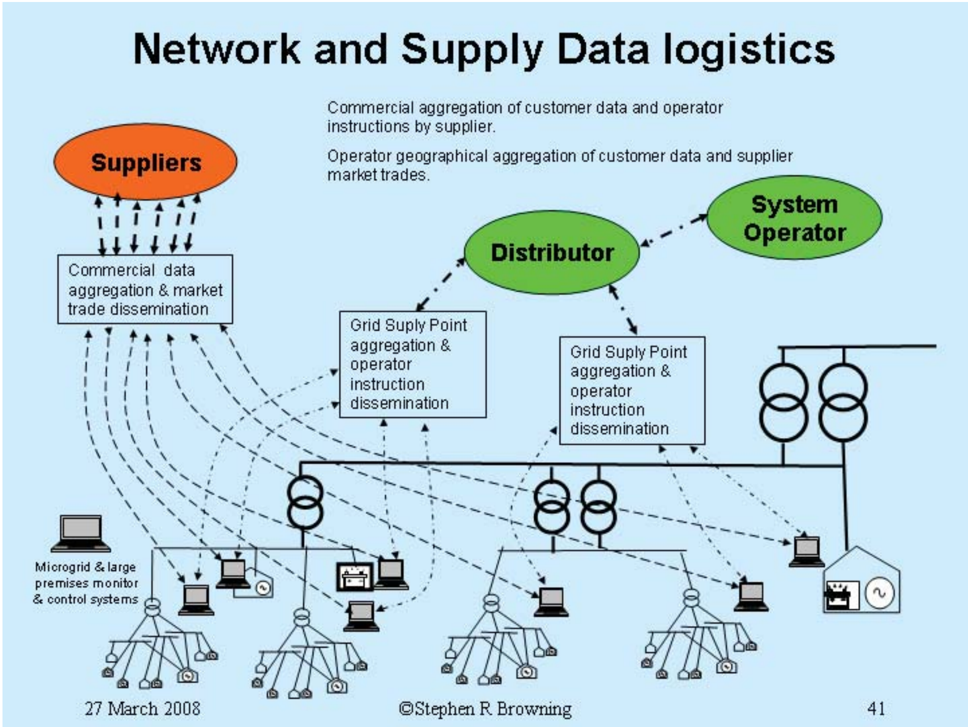
final analysis

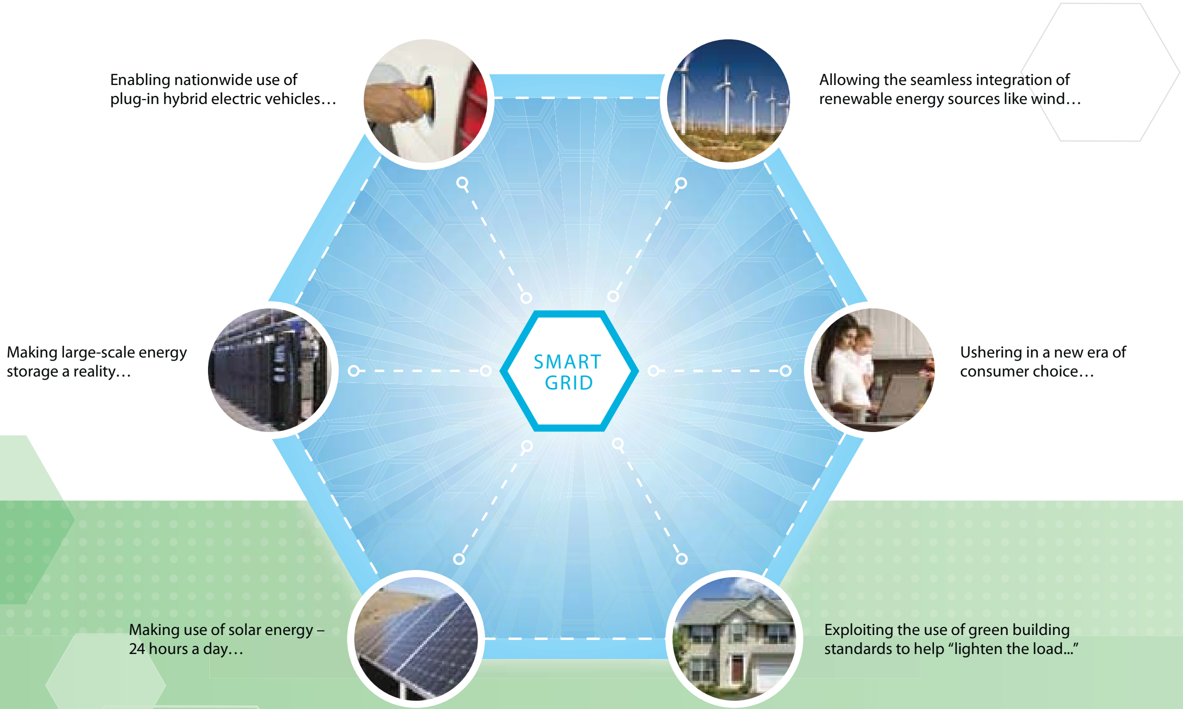
PROPERTIES (cont.)





PROPERTIES (cont.)





BENEFITS

The United States Department of Energy held a 2008 Symposium on Microgrids in Kythnos. The implementation of Microgrid Technology will provide numerous benefits. A number of these benefits include:

- Reduced Cost
- Potential to Spread Savings
- Thermal Energy Savings when CHP Methods are Employed
- Potential for Economic Dispatch of Generation Assets
- Reliability of Service
- Multiple Generation Assets
- Potential Isolation from Local Grid Problems and Disruptions
- Security
- Encouragement of Green Power
- Local Voltage Control
- Voltage and Current Harmonic Improvement
- Optimization of Power Delivery System
- Provide Service Differentiation
- Improved Efficiency through Reduced Transmission Line Loss

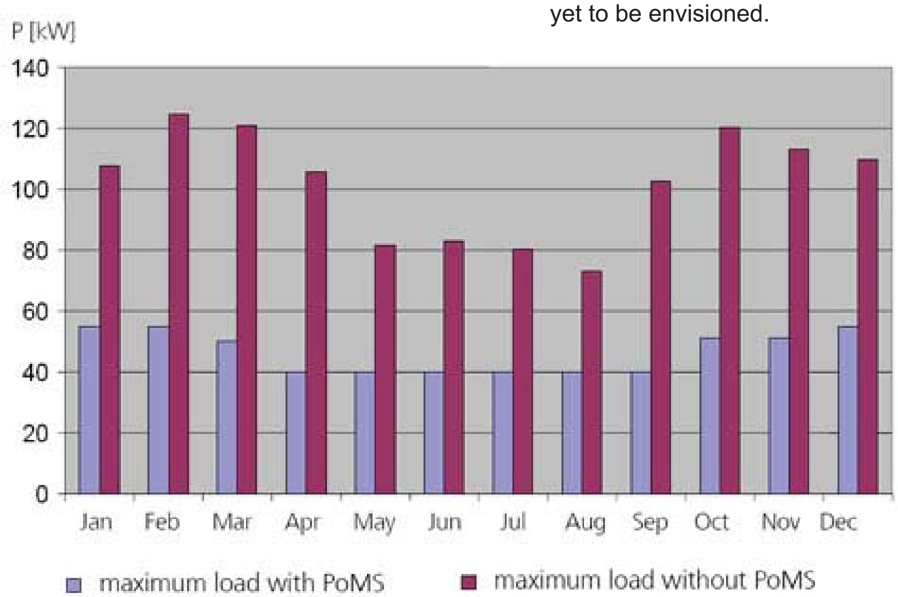
The DoE's "Smart Grid: An Introduction" goes on to discuss the further benefits of the introduction of smart grid technology into the marketplace:

"In the short term, a smarter grid will function more efficiently, enabling it to deliver the level of service we've come to expect more affordably in an era of rising costs, while also offering considerable societal benefits – such as less impact on our environment.

Longer term, expect the Smart Grid to spur the kind of transformation that the internet has already brought to the way we live, work, play and learn."

A smarter grid applies technologies, tools and techniques available now to bring knowledge to power – knowledge capable of making the grid work far more efficiently...

- Ensuring its reliability to degrees never before possible.
- Maintaining its affordability.
- Reinforcing our global competitiveness.
- Fully accommodating renewable and traditional energy sources.
- Potentially reducing our carbon footprint.
- Introducing advancements and efficiencies yet to be envisioned.



Am Steinweg Microgrid Stutensee, Germany Residential Microgrid

Chart to left represents the maximum power via the MS/LS transformer with (blue) and without (purple) energy management system as provided by smartgrid technology

DISADVANTAGES

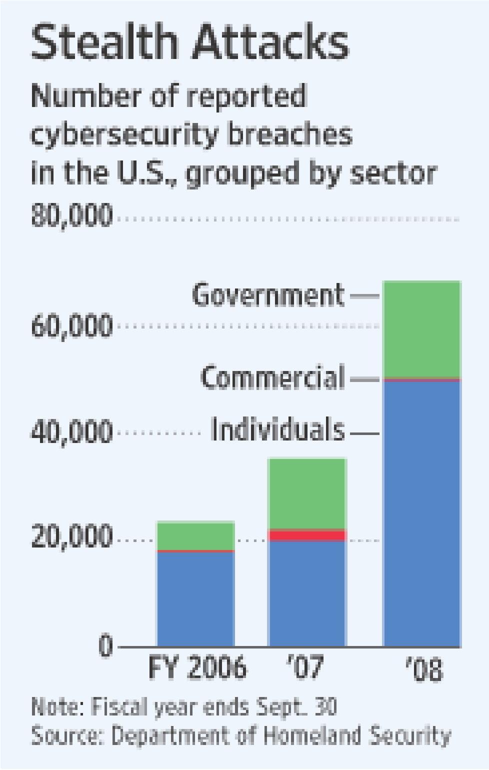
While there are numerous advantages to micro grid technology, there are some disadvantages to consider:

The most obvious disadvantage is the associated startup cost. Connecting a local microgrid into the larger grid requires transformers to regulate the frequency and transfer of electricity to protect both grids from power surges and other potentially damaging fluctuations. This initial investment is necessary but is an obstacle to consider.

Additionally, the development of successful microgrids will require more smaller-scale energy production. This means investment in technologies such as solar panels, wind turbines, building-integrated photovoltaics, aerobic + anaerobic digestion, and other technologies. Some companies offer incentives to assist customers with these purchases and the development of carbon credits and tax credits may offer new opportunities to overcome this challenge.

Microgrid development costs may be offset and managed by local utilities or may be outsourced for local management and maintenance. Current technology and development in the industry leans toward centrally-sourced management to control and enhance the efficiency of microgrids through the use of smart grid technology. There are many good reasons for this, but any networked grid with a centralized control brings to bear unique security risks. Although the technology can be used to achieve greater regional power production, stability, and availability, it also opens a new venue for sabotage and disruption. One of the greatest strengths of a simple microgrid network is the innate system security that accompanies de-centralized power production. Currently, we might have security concerns for the safety of a large nuclear or coal-powered plant. A smartgrid infrastructure that is controlled from a centralized network will share the vulnerability of a single target from which to cause massive power disruptions. This may require only a handful of determined hackers located anywhere around the globe rather than a handful of suicide bombers who must pass through physical security to reach their target. This is a very real risk to be considered and one which may ultimately prove extremely challenging to defend against. Hacking and digital sabotage threatens our energy security and will prove more challenging with an extensively-networked system as offered by smartgrids.

According to the Wall Street Journal:
The U.S. electrical grid... includes many thousands of miles of transmission lines, power plants and substations. The flow of power is controlled by local utilities or regional transmission organizations. The growing reliance of utilities on Internet-based communication has increased the vulnerability of control systems to spies and hackers, according to government reports.



FINAL ANALYSIS

Three macro trends are converging to make microgrids inevitable.

1. Security. More and more countries, states, provinces, and cities are facing up to the dangers of terrorism and natural disasters. They are urgently searching for ways to isolate disturbances so they do not turn into cascading blackouts. Military bases are already heading down the microgrid path. So are a few countries (such as Denmark). Even a few cities and business districts are using security from natural and manmade disasters as a motivator to move toward microgrids.

2. Self-reliance. As more and more industries go digital, they are bumping into the requirement for high-quality, interruption-free power. As the CTO of tech giant Oracle once put it: “We don’t worry about the cost of power. We worry about the cost of not having power.” Indeed, interruptions can cost tens or even hundreds of dollars per minute for certain commercial and industrial power users. Sources such as the RAND Institute and the Electric Power Research Institute say outages cost North American businesses $100B per year or more.
As a result, more and more commercial and industrial customers are considering sophisticated backup power and onsite generation and discovering microgrids as the best way to ensure self-reliance.

3. Standards. Until recently, each connection within the microgrid and each interconnection to the larger grid was a “custom” job. As a result, costs were exorbitant. Finally, however, standards are emerging in both areas. The CERTS Initiative (a coalition of national labs, universities and others) is developing plug-and-play specifications for inside the microgrid. And the National Renewable Energy Laboratory is leading the charge to create national interconnection standards. As these standards are proven and penetrate the market, they will bring down costs and installation time.

“The perfect power system will ensure absolute and universal availability of energy in the quantity and quality necessary to meet every consumer’s needs. It is a system that never fails the consumer.”

-Bob Galvin, 2005

Credit to:

http://www.google.com/search?q=microgrid+definition&ie=utf-8&oe=utf-8&aq=t&rls=org.mozilla:en-US:official&client=firefox-a

http://www.google.com/search?q=micro+grid+technology&ie=utf-8&oe=utf-8&aq=t&rls=org.mozilla:en-US:official&client=firefox-a

Ultra-capacitors
http://energystoragedemo.epri.com/cec/microgrid/tech_desc.asp

liquid batteries
http://www.technologyreview.com/energy/22116/page2/
http://www.ecogeek.org/content/view/2607/80/

rapid charge
http://www.treehugger.com/files/2009/03/lithium-ion-battery-breakthrough-mit-fast-charge-seconds-supercapacitors.php

ecogeek how to store that power
http://www.ecogeek.org/content/view/2612/80/

CERTS Microgrid Concept
http://certs.lbl.gov/certs-der-micro.html

BBC News Article 2005
http://news.bbc.co.uk/2/hi/science/nature/4245584.stm

Power Transmission Stuff
http://electricitymagnetism.suite101.com/article.cfm/electric_power_transmission_and_usage

Boulder Smart Grid City (with Excel Energy)
http://smartgridcity.xcelenergy.com/story/index.html
http://www.autobloggreen.com/2008/03/13/boulder-to-become-first-smart-grid-city/

google search results
http://www.google.com/search?hl=en&client=firefox-a&rls=org.mozilla:en-US:official&hs=A9X&ei=EOy7Sf7xA5GUsAPg-vSdAg&sa=X&oi=spell&resnum=0&ct=result&cd=1&q=Smart+Grid+in+Boulder&spell=1

DEFINITION:

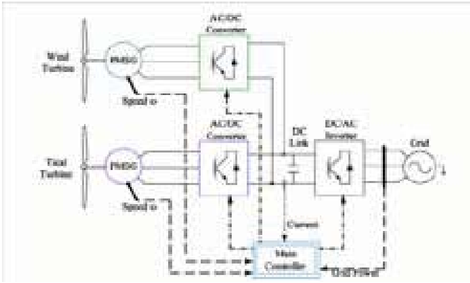
Our Ocean consistently generates large amounts of usable energy in the form of mechanical energy, from the motion of waves and tides, and thermal energy, from the heat of the sun. The constant pull of the moon cycles water in and out with the tides; our forceful winds drive the waves of the ocean; and the heat of the sun creates large differences in temperature between the ocean's surface and deeper waters, providing an abundant and ever-present source of exploitable energy.

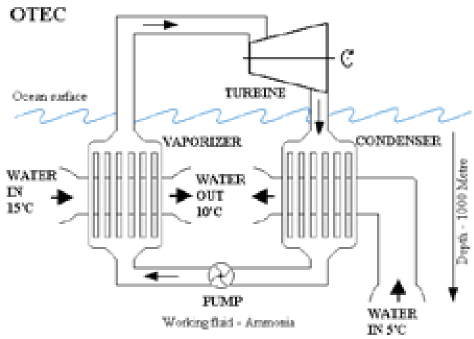
TYPES:

Wave Energy Converters: These systems extract the power of ocean waves and convert it into electricity. Typically, these systems use either a water column or some type of surface or just-below-the-surface buoy to capture the wave power. In addition to oceans, some lakes may offer sufficient wave activity to support wave energy conversion (WEC) technology.

Tidal/Current: These systems capture the energy of ocean currents below the wave surface and convert them into electricity. Typically, these systems rely on underwater turbines, either horizontal or vertical, which rotate in either the ocean current or changing tide (either one-way or bi-directional), similar to an underwater windmill. These technologies can be sized or adapted for ocean and lake use, or non-impounded river sites.

Ocean Thermal Energy Conversion: OTEC generates electricity through the temperature differential between warmer surface water and colder deep ocean water. Of ocean technologies, OTEC has the most limited applicability in the continental United States because it requires a 40-degree temperature differential that is typically available in locations such as Hawaii and other more tropical climates.





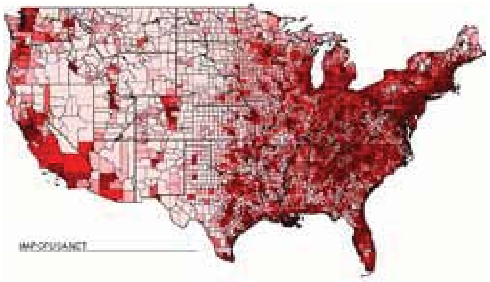
Renewable Ocean Technologies

Brett Van Andel

William Mensching

Market:

Based on the central, geographical location of our nation's current renewable energy resources (wind, solar), and the corresponding proximity of our population along the coast, ocean energy would create a considerable impression in efficiency and cost of current transportation demands on renewable energy.



Any coastal location with yearly averages over 15 kW/m has the potential of creating wave energy at competetive prices. Wave Energy harvesting potential for the United States is 250 million megawatt hours/year or 6.5% of current electrical consumption. It is set to be the next renewable to be fully commercialized.

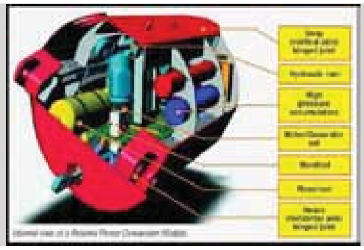
Cost:

Current Cost in UK: 45 cents/kW hour
World Renewable Energy report estimates wave energy at 9 cents / kWhr and tidal at 8 cents / kWhr.
Compare to offshore wind: 3-8 cents
onshore wind: 2.5-7 cents

In comparison, wind energy was much more expensive at this point in its development.

OTEC systems, like tidal and wave systems, have not yet been widely deployed, making estimated costs difficult. Some estimates of power generation costs are as low as 7 cents / kWhr.

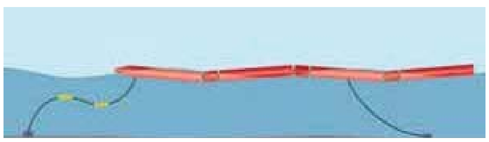


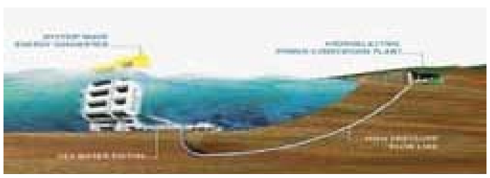


Pelamis Sea Snake:

Scottish Power Renewables, the largest generator and developer of onshore wind power in the UK, has the world's first grid-connected off-shore wave-energy converter. They have now purchased the Pelamis Sea Snake from Pelamis Wave Power, and are planning to deploy three Pelamis wave farms, with a capacity of 50 MW of energy each.

The Sea Snake is composed of semi-submerged cylindrical sections, linked by hinged joints. The waves induce motion in these joints, which is resisted by hydraulic rams, which pump high-pressure fluid through hydraulic motors, driving electrical generators to produce energy.

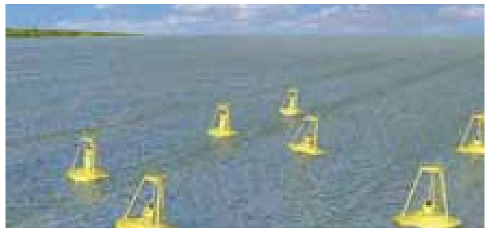




The Oyster:

The Oyster was designed and built by AquaMarine Power (winners of Innovator of the year 2009). It is based around a movable buoyant barrier structure that is mounted on the seabed in depths of 10-12 m (33-40 ft) and pivots like a gate. Hydraulic pistons deliver high pressure water via a pipeline to an onshore electrical turbine.

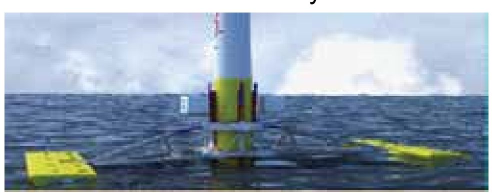
One such prototype is located off of the coast of Scotland (installed 2009), producing 315 kW of energy at a time. Multiple Oyster devices are designed to be deployed in utility-scale wave farms, typically of 100MW or more. The system is expected to provide 1 GW by 2020.



Power Buoy:

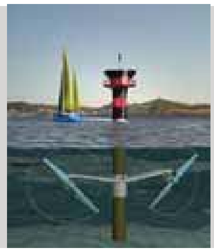
The Power Buoy system, designed and built by Ocean Power Technologies, is currently deployed at testing sites in Oahu, Hawaii, Spain, Scotland, Oregon (nation's first commercial wave-energy station), and England.

OPT designed the Power Buoy, currently located 2.5 miles offshore, to move up and down freely, stroking a mechanical piston that powers a generator. Up to 10 buoys then connect to a power station through an underwater substation pod, which carries the combined electrical output to shore in a single transmission cable. The estimated generation is 4140 MW/yr, with an estimated CO2 savings of 2110 CO2 tons/yr. A single system would occupy 30 acres of ocean. If successful, OPT plans to place an additional 200 Power Buoys.



The Wave Treader:

Green Ocean Energy LTD designed and built this device to attach to the base of oceanic wind turbines. Two floating bodies made of GRP connect to arms, which power hydraulic actuators that in turn power generators. The system has a 500 kW rating, 25-yr design life, and low intrusion to marine ecology. The aim for Round 3 of offshore wInd turbines includes 480 by 2010, and 1000 by 2015, so the market is there.



Check List

definition

market | cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

final analysis

Embodied Energy:

Embodied Energy is the total amount of energy necessary for the entire product lifecycle.

Currently, this innovative field of technology boasts an extensive list of typologies, from attenuators, absorbers, and overtoppers to surge converters, turbines and oscilalating water columns, from countries all over the world.

The field is awaiting the results from each company's deployed products at testing sites worldwide to determine the viability of each product. These results will spur interest from investors and material scientists to better develop the systems that yield the greatest results, ultimately providing the best converters with the lowest possible embodied energy.

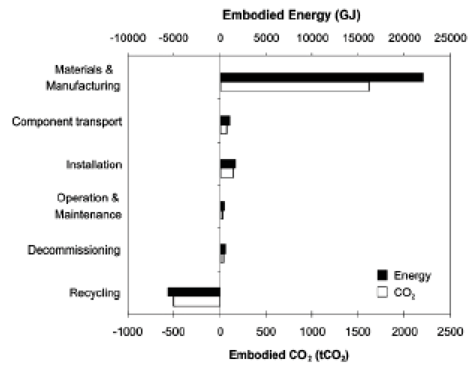
Material	Embodied energy (MJ/kg)	Embodied CO_2 ($kg\,CO_2/kg$)
Aluminium (range: rolled – cast)	150.2–167.5	8.35–9.21
Carbon/glass fibre [19]	200.0	11.2
Cast iron [20]	37.0	3.3
Cement	2.35	0.28
Copper	55.0	4.38
Epoxy resin [21]	137.1	13.8
Nylon 6	120.5	5.5
Paint	80	6.1
Polyethylene/polypropylene	73.7	1.7
Polyurethane foam [21]	102.9	3.9
PVC pipe	67.5	2.5
Stainless steel	51.5	6.15
Steel (range: engineering – rolled plate)	11.7–45.4	0.68–3.19

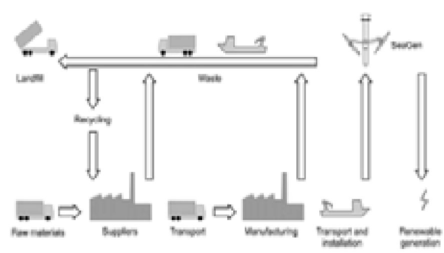
Material usage and carbon for shipping currently make up the majority of embodied energy in these systems' product lifecycles.

Palamis Sea Snake:
293 KJ/kwH and 22.8 g CO2/ kwH.
Energy Payback = 20 months,
CO2 payback = 13 months

Sea Gen Turbine:
214 KJ/kwH and 15g CO2/kwH
Energy Payback = 14 months
CO2 Payback = 8 months

Fossil Fuels:
400-1000g CO2 / kwH





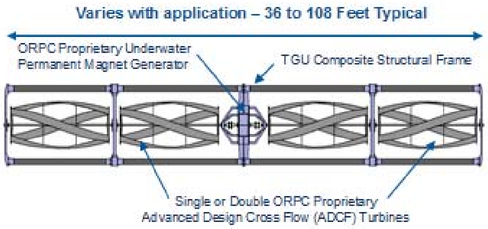
Innovative Technologies:

Currently, a new wave of untouched technology is bypassing the grid to connect directly to its destination. The recent boom in wind and solar energy technologies gave birth to a new and innovative design process, where these technologies directly influence the shape, location, orientation, and many other aspects of the building and environment surrounding it.

Likewise, industry leaders in wave, tidal, and ocean thermal energy are making the leap to integrate these systems directly into the minds and plans of today's architectural designers, paving the way for cutting edge innovation in the design of our landscapes and buildings.

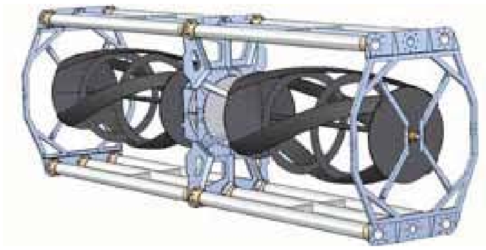
Ocean Renewable Power Company:

ORPC is completing design-work on the RivGen™ Power System, directing its sights on remote communities with no large, centralized power grid. The majority of these communities currently



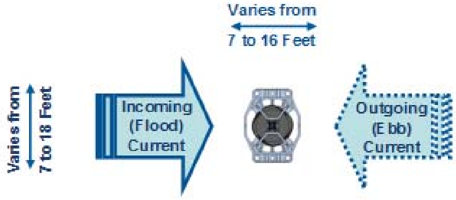
rely on local power distribution grids connected to diesel generators, inevitably leaving an overwhelming carbon footprint. In addition, these generators are steadily increasing in operating cost, requiring expensive fuel to operate.

The RivGen™ system connects directly to these existing diesel-electric grids. It is conditioned so that when the RivGen™ system generates power, the diesel generator automatically turns down or off. This allows the community to access the maximum amount of renewable power, relying on the diesel system as a back-up for emergency or low production times.

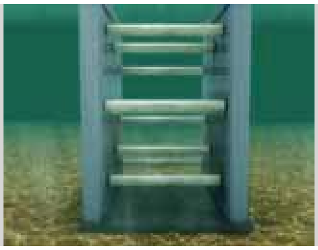


ORPC designed the entire system to fit easily into standard shipping containers, enabling a quick and efficient installation once they arrive on site. Depending on the size and needs of each individual community, the RivGen™ system can include several Turbine Generator Units (TGUs), with each producing 30 kW in a 10 fps current.

The unit works on a similar principle as a wind turbine, where rotating foils



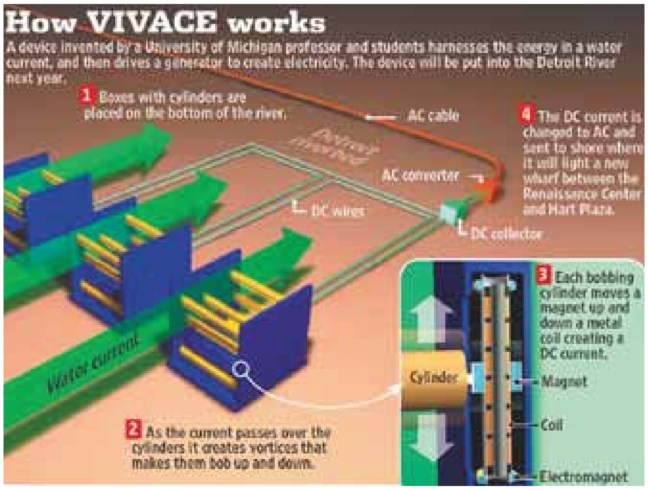
power a central permanent magnet generator. However, because water has a density more than 800 times that of air, the TGUs provide significantly more power at a relatively low current. They are made of corrosion-resistent composites, include no lubricant-demanding gears, and emit nothing into the surrounding water.



Check List

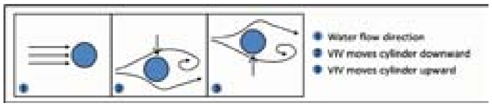
- definition
- market | cost
- maintenance
- **properties**
- lifecycle
- embodied energy
- health
- **benefits**
- disadvantages
- **final analysis**

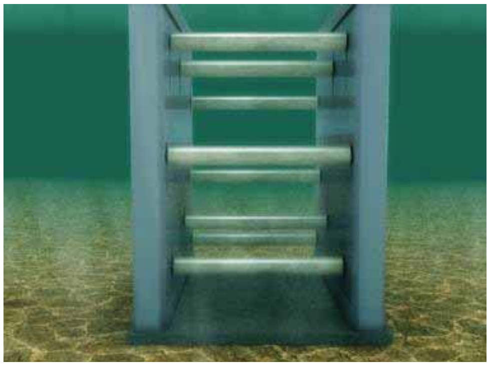
Vortex Hydro Energy:



The VIVACE system, developed by Vortext Hydro Energy, engages, harnesses, and manages Vortex Induced Vibrations (VIV) in its innovative ocean power system.

This phenomenon (VIV) is often the cause of tremendous damage in aero, civil, mechanical, marine, offshore, and nuclear engineering applications. It was the cause of the Tacoma Narrows Bridge disaster in Washington State (1940), where torsional vibrations caused the bridge to collapse. However, VHE has successfully developed a system to control VIVs typically destructive nature.





With no turbines, propellers, or dams, it is unlike any previous ocean or river energy technology. The VIVACE system converts horizontal hydrokinetic energy from currents into cylinder mechanical energy. Electric power generators work to convert this mechanical energy into electricity.

The VIV technology supports that vortices are formed and shed on the downstream side of round bodies in a fluid current. This vortex shedding alternates sides, creating a pressure imbalance, resulting in an oscillatory lift.

Beyond their emergence into this innovative design, Vortex Hydro is installing this system next year in the Detroit riverbed, where it will connect to and light a new wharf between the Renaissance Center and Hart Plaza. This connection opens up the possibilities of purposeful designs that integrate with our available water resources.

Check List

definition

market | cost

maintenance

properties

lifecycle

embodied energy

health

benefits

disadvantages

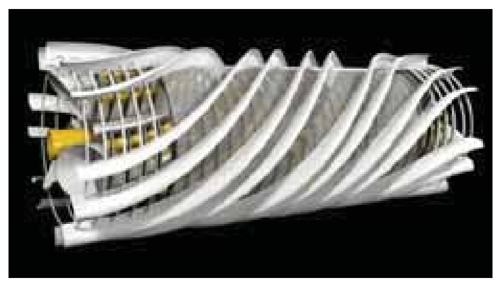
final analysis

GRO Architects:

GRO Architects' submittal for Metropolis Magazine's 2009 Next Generation Design Competition stood out as a notable concept for harnessing the energy from New York City's river waves, while enacting the waterways.

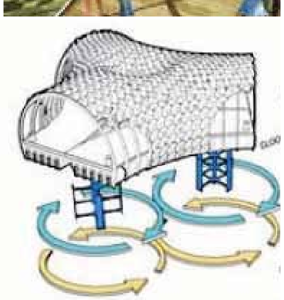
The group designed floating walkways as a retreat from the inner city, which extend from piers, and use the current of the river to spin giant turbines. The power would be silently generated below the public spaces above, utilized by pedestrians for walkways, reflection, and even residential housing.

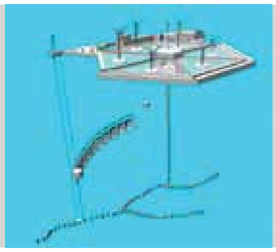
The form has taken on two unique appearances, one more enclosed and the other more open, with two methods of capturing the energy, similar to those mentioned earlier, but integrated into the structure and design.



New Technology Building Integrated:

GRO Architects





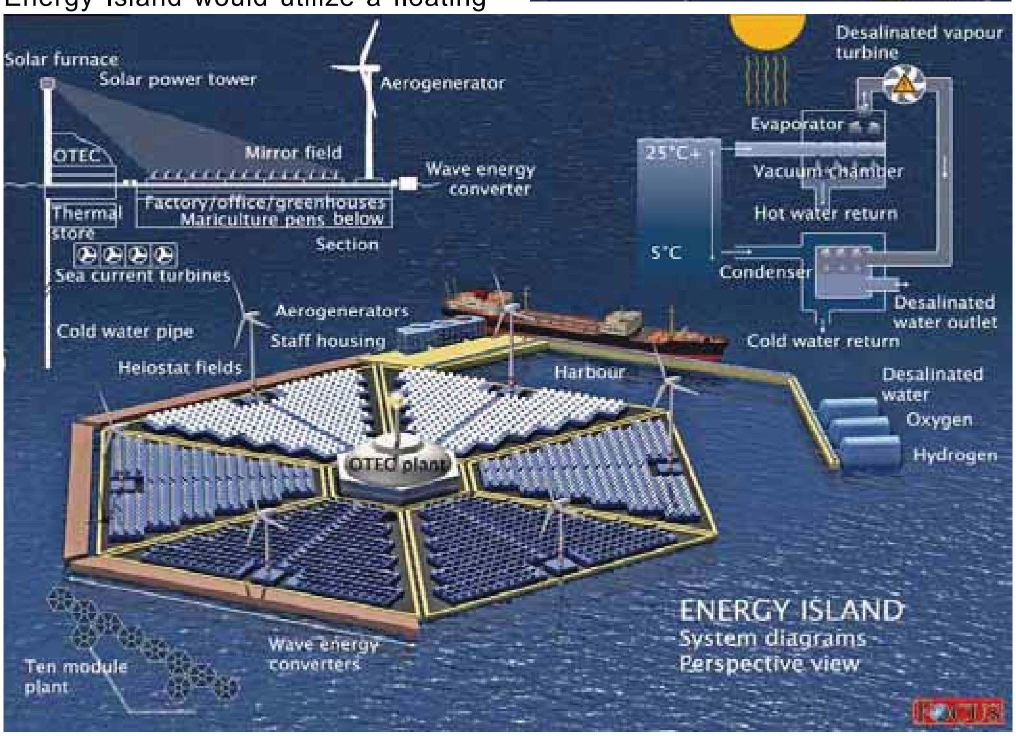
Energy Island:

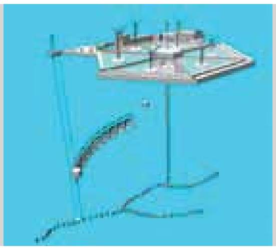
Architects Dominic Michaelis and Alex Michaelis claim that 1/10,000th of the surface of our seas contains enough solar thermal energy to provide for our entire planet's energy needs, as well as sufficient desalinated water for all uses of a population of 7 billion.

Their concept is Energy Island - a unique offshore, manmade structure that produces both power and desalinated water, 24 hours a day, to combat the less efficient and periodical collections from wind, solar, and wave technologies. For every MW of power generated, 2.36 million liters/day of desalinated water will be created. The cold water, where applicable, can also be used for air conditioning, drawn-up high-grade phytoplankton as feed for aquaculture/ fish farms, and carbon credits.

Energy Island would utilize a floating platform with a "twin membrane" design engineered to protect the island from the heavy seas, and provide hydraulic energy from the platform to generate electricity. Further, the island as a whole harvests all useful and available energy sources available, complementing one another for a much greater output. The island captures wave energy on the windward sides, sea currents, solar energy, geothermal energy, and OTEC electricity with seawater desalination.

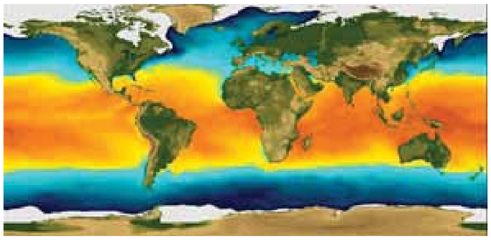
In tropical or subtropical waters around the equatorial belt, the surface waters are 25°C and above, while the water





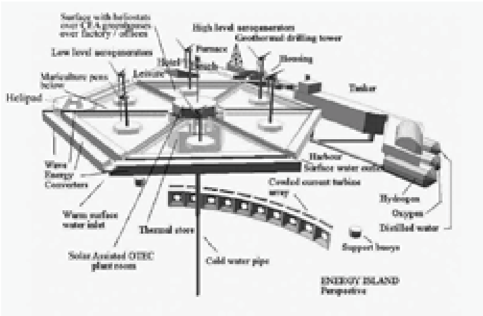
1,000 meters below is a cool 5°C.

An open-cycle OTEC system flash-evaporates solar-heated tropical sea water in a vacuum chamber. The



resulting low-pressure steam drives a turbine-generator, producing electricity. The cold seawater drawn up from the depths then condenses the steam on cold heat exchanger plates, after it has passed through the turbine, producing desalinated water. The closed-cycle system uses the cool water from the depths and the warm surface water to vaporize and condense a working fluid, such as anhydrous ammoniac, which drives a turbine-generator. This system only produces electricity.

The pair of innovators designed the system to expand with multiple Energy

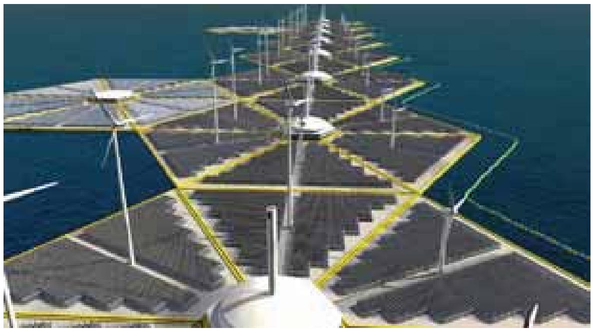


Island modules attaching to one another, with the possibility for leisure and education facilities, or a self-sufficient holiday destination. A set of 8 connected OTEC modules would supply 2000 MWe, or the equivalent of a very large nuclear power station, and 2400 million liters of desalinated water per day, sufficient for 8 million residential houses per day.

The primary environmental concerns are in drawing phytoplankton from the depths and returning the cool water used

to condense the steam just below the particularly warm surface water. These minimal impacts, however concerning, will have to be formally assessed as to their significance, and weighed against the base-loaded, constant-peak OTEC system that, economically speaking, would produce both desalinated water and power at the cost figure of power alone.

Review the reference section on page 11 for links to find out more of the innovation in design of Energy Island, and its possibilities for changing how we design and create living environments in our future.

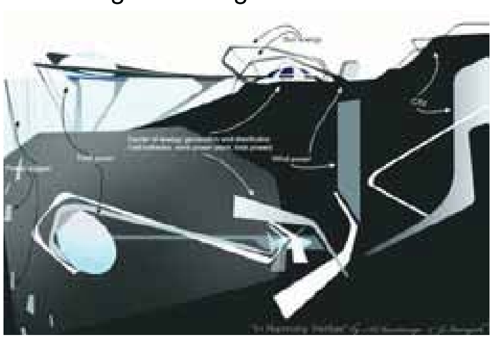


"In Harmony Veritas":

Angela Chanturiya and Yuliya Ivanyuk showcase a hi-tech city in harmony with nature in "In Harmony Veritas". Their innovative concept responds to the call of today's world for more sustainable buildings that generate on-site energy via various renewable systems.

Their small, scientific complex absorbs all of its power from sea and tidal energy below, and solar and wind above. The project explores the complex as an organism that merges with its environment for the betterment of the local ecosystem, placing the building in an examined location where it will harmoniously connect with the nature surrounding it.

Our expanding built environment is responding to the innovative advances in wind and solar energy through building orientation and placement, and likewise, "In Harmony Veritas" responds to these renewables in combination with the flourishing technologies of our oceans.

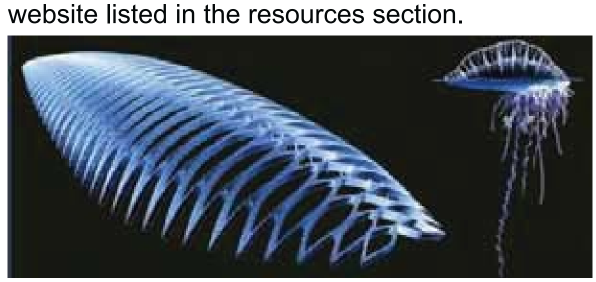


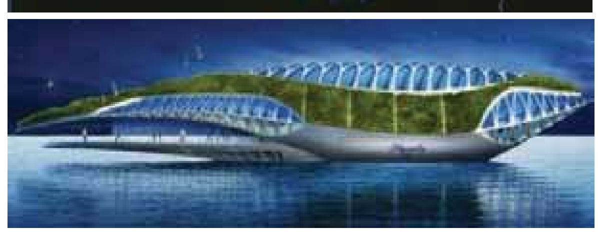
"Physalia":

A much more conceptual approach from Vincent Callebaut Architectures explores an animation of our oceans and waterways in "Physalia", a half aquatic and half earthly amphibious vessel, self-sustainable and fully-integrated with the numerous architectural advances involving water.

The scheme utilizes hydro turbines under its hull, creating hydro-electricity,

water desalination techniques, rainwater recycling, and many more water resource management approaches, aimed to produce energy while purifying the world's waters. Although the majority of Callebaut's architectures have never seen day, the innovative concepts of "Physalia" address the growing concerns within energy, water, population and space. Find our more at Callebaut's website listed in the resources section.





Works Referenced

Anupam, . "Eco Architecture: In Harmony Veritas – A self-sufficient complex in harmony with nature." Ecofriend. Istablogs Network, 10 Dec. 2009. Web. 27 Apr. 2010. <http://www.ecofriend.org/entry/eco-architecture-in-harmony-veritas-a-self-sufficient-complex-in-harmony-with-nature/>.

Aquamarine Power. Making Marine Renewable Energy Mainstream. N.p., 2010. Web. 18 Apr. 2010. <http://www.aquamarinepower.com/>.

Bogdan, Lea. "Flood Harvesting Housing Brings Tidal Power to New York City." Inhabitat. Inhabitat, LLC, 7 Oct. 2009. Web. 27 Apr. 2010. <http://www.inhabitat.com/2009/10/07/energy-harvesting-turbines-for-nyc-get-a-style-update/>.

Callebaut, Vincent. "PHYSALIA, AMPHIBIOUS GARDEN CLEANING EUROPEAN WATERWAYS WATERWAYS 2010 EUROPE." Vincent Callebaut Architectures. N.p., 2010. Web. 27 Apr. 2010. <http://vincent.callebaut.org/page1-img-physalia.html>.

"Energy Island : Information + Images." e-architect. N.p., 2009. Web. 27 Apr. 2010. <http://www.e-architect.co.uk/energy_island.php>.

Heath, Tom BSc,PhD,M.I.Mech.E C. "Realities of Wave Technology." . Wavegen, 2010. Web. 18 Apr. 2010. <http://www.wavegen.co.uk/pdf/art.1727.pdf>.

Loew, Tracy. "Oregon is first U.S. site for a wave-power farm." USA Today, Feb. 2010. Web. 18 Apr. 2010. <http://www.usatoday.com/money/industries/energy/environment/2010-02-16-wave-energy_N.htm>.

McDermott, Matthew. "New Wave Power Device Will Attach to Offshore Wind Turbine." Tree Hugger, 10 Feb. 2009. Web. 18 Apr. 2010. <http://www.treehugger.com/files/2009/02/new-wave-power-device-attaches-to-offshore-wind-turbine-wave-treader.php>.

Morales, Alex. "Wave, Tidal Energy May Power 1.4 Million U.K. Homes (Update2)." Bloomberg Business Week, 4 Mar. 2010. Web. 18 Apr. 2010. <http://www.businessweek.com/news/2010-03-04/wave-tidal-energy-may-power-up-to-1-4-million-u-k-homes-by-2020.html>.

"NJIT architecture team puts forward tidal power scheme for NY." Wave & Tidal Energy News. N.p., 17 July 2009. Web. 27 Apr. 2010. <http://www.wave-tidal-energy.com/home/news-archive/40-general/212-njit-architecture-team-puts-forward-tidal-power-scheme-for-ny>.

Ocean Power Technologies. Making Waves in Power. OPT, 2010. Web. 18 Apr. 2010. <http://www.oceanpowertechnologies.com/profile.htm>.

Ocean Renewable Energy Coalition. Renewable Ocean Energy: Tides, Currents & Waves. 23 October. 2006. Alternative Energy. <http://www.alternative-energy-news.info/renewable-ocean-energy-tides-currents-and-waves/>.

Ocean Renewable Power Company. Tarika Technologies, n.d. Web. 27 Apr. 2010. <http://www.oceanrenewablepower.com/orpcpowersystems.htm>.

Parsons, Sarah. "Tidal Docks Use Waves to Power NYC's Streetlamps." Inhabitat. Inhabitat, LLC, 14 July 2009. Web. 27 Apr. 2010. <http://inhabitat.com/2009/07/14/new-design-uses-waves-to-power-nyc%E2%80%99s-streetlamps/>.

Pelamis Wave Power Ltd. Pelamis Wave Power. N.p., 2010. Web. 18 Apr. 2010. <http://www.pelamiswave.com/index.php>.

South West RDA. Wave Hub. N.p., 2010. Web. 18 Apr. 2010. <http://www.southwestrda.org.uk/working_for_the_region/key_sw_projects/cornwall__the_isles_of_scilly/wave_hub.aspx>.

VAIDYANATHAN, GAYATHRI. "Companies Work to Harness the Power of Waves." The New York Times, 2 Mar. 2010. Web. 18 Apr. 2010. <http://www.nytimes.com/cwire/2010/03/02/02climatewire-companies-work-to-harness-the-power-of-waves-5213.html>.

Voith Hydro. Voith Hydro Wavegen Limited. Voith, 17 Mar. 2010. Web. 18 Apr. 2010. <http://www.wavegen.co.uk/index.html>.

Vortex Hydro Energy. A Breakthrough in Marine Renewable Energy. Voith, 2010. Web. 18 Apr. 2010. <http://www.vortexhydroenergy.com/>.

"Welcome to Energy Island: A world of clean energy and water." Energy Island. Energy Island Ltd., 2009. Web. 27 Apr. 2010. <http://www.energyisland.com/index.html>.

Credits

Assistant Professor Adjunct
Fred Andreas, AIA, LEED AP

GBT Project Groups

Photovoltaics: Embodied Energy & New Technology
Jamie Stadille
Chenyang Xu

Advances In Photovoltaic Technology
Robyn Shaw
Jessica Garfin

Wind Power: Microtechnology
Cesar Cervantes
Jevon Van Vliet

Thin Film Technology
Kevin Nguyen
Maciej Gesikowski

Kinetic Vibrational Energy
Caitlin Jones
Alyssa Manny

Nanotechnology and Advanced Window Systems
Lauren Fowler
Austin Hanson

Phasechange Materials
Robert Best
Benjamin Kallechey

Building Automated Systems
Audrey Pierce
Alyssa Tharrett

Magnetic Systems
Roberto Pesce
Fabian Baumann

Sustainable Lighting
Dara Cunningham
Eric Doner
Christopher Fletcher

Micro Grid & Smart Grid Technology
Susan Grey
AJ Watkins
Roland

Renewable Ocean Technology
William Mensching
Brett Van Andel