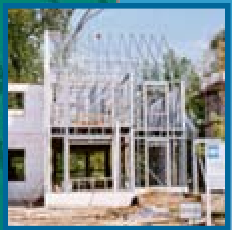

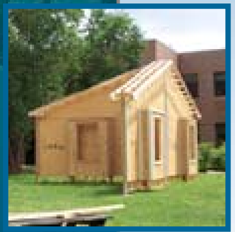

# We Want That!

## A Future Housing Technology Reality Check

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*Dedicated to improving home building since 1964.*

# Outline

- What is it?
- How does it work?
- What has led up to it?
- What is available now?
- What's holding it back?
- What's in the future?

Fuel Cells

Nanotechnology

Photovoltaics

Combined Heat & Power

Advanced Insulation

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# Stationary Fuel Cells

*Source: Ballard Power Systems – www.ballard.com*

**Produces electrical power in the home using hydrogen and oxygen, with only water and heat emitted.**

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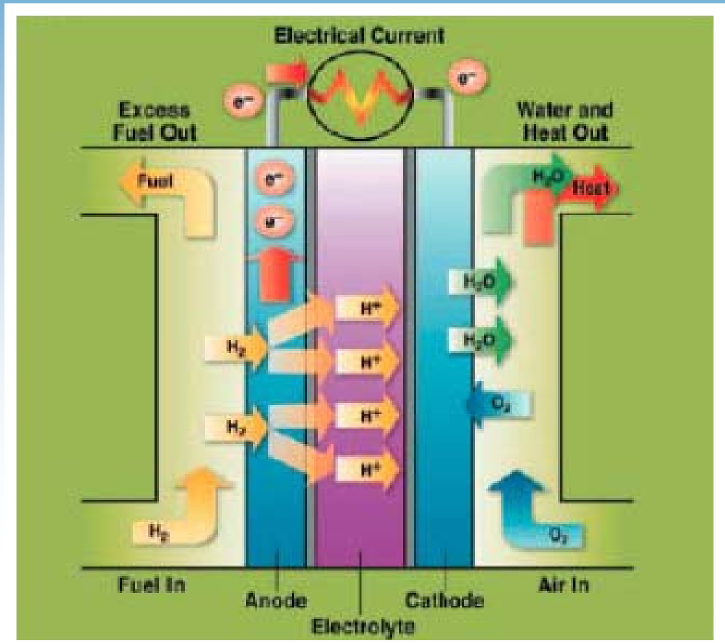
# How Does it Work?

- Several types – PEMFC, PAFC, SOFC
- Hydrogen gas stripped of an electron by catalyst.
- Hydrogen ion passes through to combine with oxygen to produce water, heat.
- Electrons result in electrical potential between cathode & anode.




*Process of a basic PEMFC*

# What Has Led up to It?

- 1838 – Sir William Robert Grove creates the first fuel cell using platinum electrodes in sulfuric acid sealed in separate containers of oxygen and hydrogen.
- 1932 – Francis T. Bacon develops a method using inexpensive nickel electrodes and an alkaline electrolyte. This would later be part of research for British submarines in WWII.
- 1959 – a 5 KW fuel cell was used to power a welding machine.
- 1960's – General Electric and Pratt and Whitney develop fuel cells for use in the Gemini and Apollo space missions
- 1970 -1980's – further research into fuel cells sparked by energy concerns, especially by government and commercial sectors.
- 1990's – commercialization begins on fuel cells in transportation and stationary power generation applications.

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# What's Available Now?

Limited products available for use in homes.

- Capacity: 0.2 to 10 kW*
- Cost:$2500-4000 per kW**
- Efficiency: electrical ~40% (CHP ~70-80%)
- Size: up to freezer chest size*

www.toolbase.org/techfuelcell

*Source: Sanyo Electric Company – www.sanyo.com*

** for residential sized systems. From www.toolbase.org/techfuelcell*

***2006 DOE "Multi-year Research, Development and Demonstration Plan"* and *"Stationary Fuel Cells: Challenges and Opportunities". Research Reports International, May 2006*

# What's Holding it Back?

- **Cost: Currently $2500-4000 per kW (Typical peak demand during the year is 1.4 to 3 kW)***
- **Reliability: 20,000 hour performance has been demonstrated, but longer life is needed (~40,000 hours).**
- **Temperature operating range, when installed outdoors.**
- **Grid Connectivity: Variation in net-metering practices**
- **Infrastructure: Fuel delivery and/or processing**

** Based on 2000 sf house from "Emerging Technologies & Practices, 2004: P1A". American Council for an Energy Efficient Economy.*

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# What’s in the Future?

- Target costs are $1500/kw
- U.S. Fuel Cell Council predicts worldwide market for stationary fuel cells could be $10 billion by 2010.*
- Development of hydrogen infrastructure could reduce need for reformer.

** From United States Fuel Cell Council (USFCC) and Allied Business Intelligence, Inc.*

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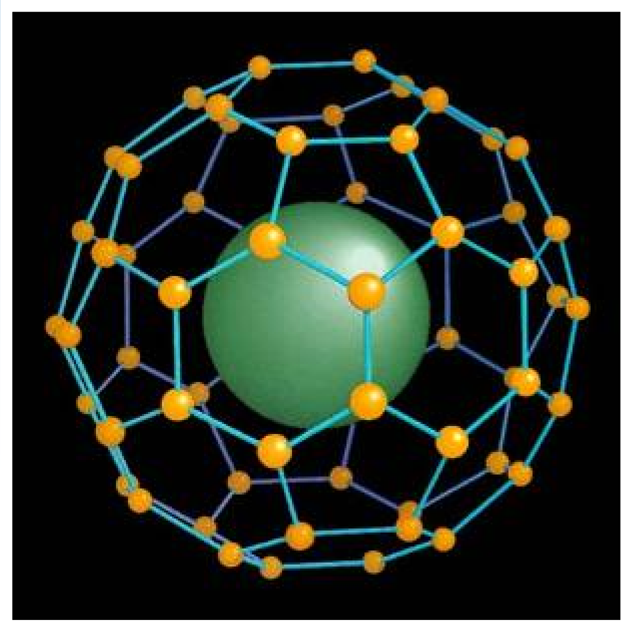
# Nanotechnology in Building Materials



*Fullurene (carbon 60) ball (Source: Institute for Interdisciplinary Research, Universitat Bielefeld)*

*Aerogel block (Source: NASA Jet Propulsion Laboratory)*

**Nano-sized (one-billionth of a meter) particles and structures used to create high performance materials and coatings.**

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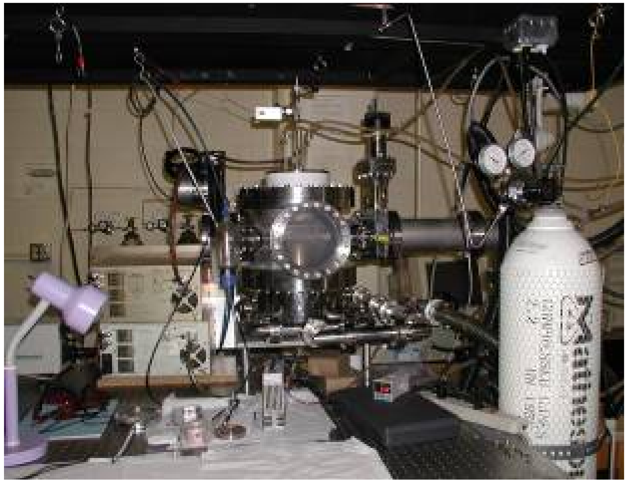
# How Does it Work?

Several methods

- Top down: nanolithography (electron beam, nanoimprint)

- Bottom up: chemical synthesis, self assembly, molecular beam epitaxy

*Electron beam lithography machine at IRC in Nanotechnology at University of Cambridge, England*



*Dual RF Plasma Chemical Vapor Deposition (CVD) system at Michigan Technological University*

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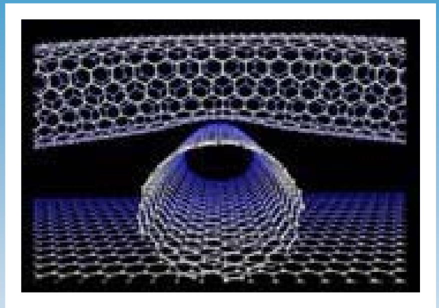
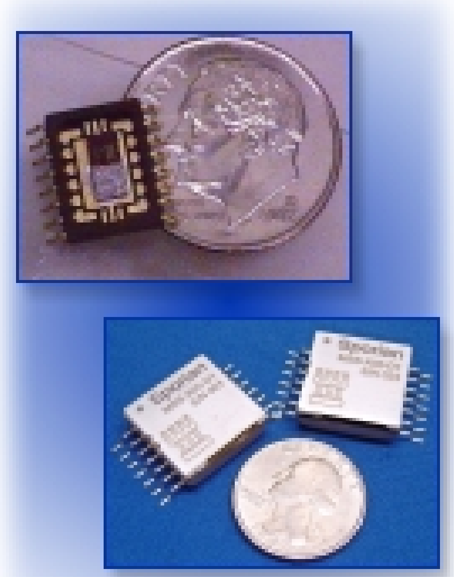
# Types

- Titanium Dioxide – anti-microbial, sanitizing properties
- Carbon Nanotubes – directional thermal and electrical conductivity, very high strength
- Carbon Buckyballs – material encapsulation
- Aerogel – porous, low density, highly insulative
- MEMS – micro-machines





*Top: Carbon nanotube models (from Molecular Foundry at Berkeley National Laboratory)*

*Bottom: Sensors for physical property measurement from Sporian Microsyctems, Inc.*

# What Has Led up to It?

- 1590s – Hans and Zaccharius Jannsen create the first microscope, allowing things to be seen on a very small scale.
- Late 17th century - Antony Van Leeuwenhoek and Robert Hooke created microscopes that could see down to a cellular level.
- Late 1800s to early 1900s – advances in quantum theory allowed for physics to be understood at a very small scale, which allowed for very significant techniques at the smallest level
- 1952 – carbon nanotubes discovered in Russia
- 1982 – The scanning tunneling microscope allows for three dimensional viewing at the atom scale.

# What's Available Now?

- Concrete Admixtures – (i.e. nano-silica) Increased strength, self-compacting
- Insulation – (aerogel) Higher R value in a smaller space
- Glass Coatings – (titanium dioxide) Self-cleaning and hydrophilic coatings in glass
- Various Products – Anti-microbial, sanitizing admixtures
- Micro-Sensors – Real-time temperature, stress, humidity, etc. measurement

# What's Holding it Back?

- **Cost: eg Carbon Nanotubes cost $25-1300 per gram***
- **Health Concerns: Effect of various nanomaterials on environment and humans unknown**
- **Production Technology – Develop equipment to apply to products on a mass scale.**
- **Production Capacity – More production needed to meet large application needs.**

** Mann, Surinder. "Nanotechnology and Construction". Institute of Nanotechnology. November 2006.*

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# What's in the Future?

- **Heavy R&D investment by federal labs and research universities**
  - **US government funding in 2007 is $1.2 billion***
  - **Extensive programs in Europe and Japan**
- **Health issues under study at multiple universities through EPA Toxic Control Act grant program ($5 million in 2006, $22 million to date)**
- **Production capacity expanding for many materials.**

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# Combined Heat and Power (CHP)

WhisperGen Micro CHP unit above counter (Source: Micro Power, http://www.micropower.co.uk)

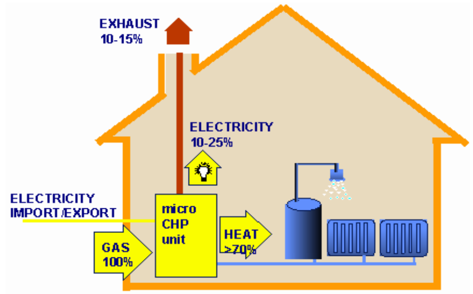
CHP Warm air Furnace system from Honda (Source: Newport Partners LLC, http://www.newportpartnersllc.com/technologies/mchp.html)

**A device that generates both heat and electricity on site for use in the home**

# How Does it Work?

## Typically in a residence:

- Fuel drives an engine that runs a generator for electricity, then waste heat is used to heat water or air coil
- Stirling, internal combustion engines and Rankine engines used
- Fuel can be propane, natural gas, biomass
- Fuel cells also used as waste heat can be captured from chemical reactions


**Top: Transmission losses for electricity (Source: DOE Energy Efficiency and Renewable Energy (EERE),** [http://www.eere.energy.gov/femp/technologies/derchp_chpbasics.cfm](http://www.eere.energy.gov/femp/technologies/derchp_chpbasics.cfm)

**Bottom: Micro CHP in a house (Source: *“Meeting 21st Century Residential Energy Needs”. United States Department of Energy, Energy Efficiency and Renewable Energy Program. December 2003.)***

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# What Has Led up to It?

- 1880 – 1st patent is granted to Birdsill Holly in New York for a combined heating and power generation plant.
- Late 1800's to early 1900's – District CHP plants arise in several areas in Europe and the United States
- 1965 to the 1980's – recovery applications to steam turbine technology discovered, leading to efficiency over 60%. Companies realize benefits of using excess heat from electricity for other things
- 1985 – MIT begins planning for a CHP system that will reduce emissions for their needs by 45%. After many utility and legal complications, it was completed by 1995.
- Currently:
  - As of 2006, 30 thousand units are operating in Japan and 80 thousand are on order in UK from one New Zealand Company.
  - 19 systems are currently employed in New England households

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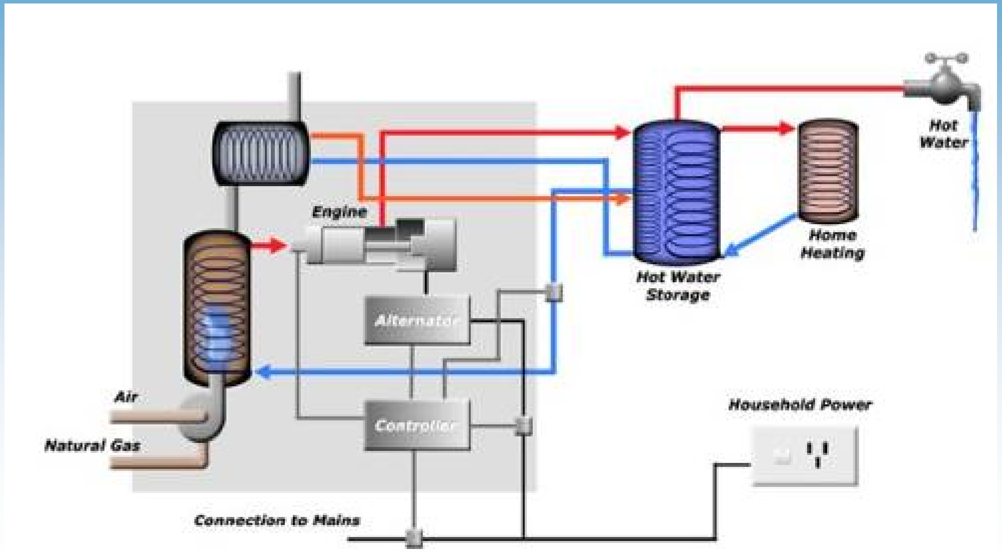
# What's Available Now?




*Example of a Stirling Engine hot water CHP (Source: COGEN Microsystems, http://www.cogenmicro.com/index.htm)*

**Stirling, internal combustion, Rankine, and small turbines are available. Prime mover can be heat (air or hot water) or electricity**

- **Capacity: 1 to 10 kW for home**
- **Cost: House systems are from $13 to $20 thousand "average"** *(It Heats, It Powers, Is it the Future of Home Energy?" Christian Science Monitor, November 14, 2006.)*
- **Efficiency: overall, from 80-90%**
- **Size: from dishwasher to refrigerator size**

# What's Holding it Back?

- Cost can be $10 to $20 thousand dollars for a residential system
- Grid connectivity issues must be addressed
- Because cost effectiveness depends on both heating and power, ways to optimize this across climates need to be addressed
- Ways to minimize the presence of the systems needs to be addressed

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# What's in the Future?

- With spreading adoption in Europe and Asia, prices will likely go down. Additionally, tax reductions there have spurred growth
- Several systems have been installed in the USA, meaning their economics here will be seen, allowing for better insight into their value
- As of 2004 the ACEEE has determined that Micro CHP is a lower priority than other methods for conserving energy, so other technologies may emerge that are more economical than CHP in the USA.*

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** "Emerging Technologies & Practices, 2004: P1A". American Council for an Energy Efficient Economy.*

# Photovoltaics

*1.4 kW PV panel in Baltimore City (Source: Maryland Energy Administration)*

**Using energy from the sun to produce electricity, with new higher efficiency and organic cells.**

# How Does it Work?

- **Sunlight hits a PV cell, which encourages electron movement in a semi-conducting material (typically silicon). This flow is the DC current.**

Thin film solar arrays
(Source: Renewable Energy World,
http://www.earthscan.co.uk/news/article/mps/
UAN/640/v/3/sp/332598698879332119362

- **Concentrator cells have been developed that can produce high efficiencies by concentrating more energy into a smaller panel area**
- **Organic and thin film are being developed to get more efficiency and lower cost per area of PV**
- **Alternative materials are under development offering new options for the next generation of PV.**

# What Has Led up to It?

- 1839 – Photovoltaic effect discovered in France by Edmund Becquerel
- 1883 - Charles Fritts described the first solar cells made from selenium wafers
- 1900's to 1950's – quantum mechanics and other development lead to discovery of new materials and how they react to light, leading to the launch of the first solar powered satellites in the late 1950's. Cells are from 5% to14% conversion efficient.
- 1980 – First thin film solar cell to reach 10% conversion efficiency
- 1985 – 20% efficiency reached in Australia for silicon
- 1994 – NREL reaches 30% efficiency using a concentrator cell
- 2000s – more research expanding into organic PV is happening. It will likely be cheaper to produce these systems, but current efficiency is around 5%, with hopes of increasing.

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# What's Available Now?

- Mono and Polycrystalline Silicon
  - Most common form highest efficiency
  - 12-18% electrical efficiency
  - Wafer form
- Thin Film Silicon
  - Spray-applied to substrate
  - 6-8% electrical efficiency
  - Often used in integrated products (glazing, roofing, etc)
- Cadmium Telluride (CdTe)
  - Alternative material becoming available
  - 6-10% electrical efficiency

Residential systems range from 1-8kW and cost $12-20k per system (before incentives)

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# What's Holding it Back?

- Cost – currently $6-10 per watt ($12-20k per system)
  - 25-35 cents/kWH (15 cents/kWH needed to be competitive)
  - Incentives can cust system cost in half
- Production Capacity
  - Silicon manufacturers at capacity for last 5 years
- Efficiency
  - Efficiencies above 20% have been achieved in labs, but have not yet appeared in products.
- Consumer Acceptance
  - Aesthetics have traditionally been a problem
  - New low-profile units, and integrated products helping

** Based on 2000 sf house from "Emerging Technologies & Practices, 2004: P1A". American Council for an Energy Efficient Economy.*

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# What’s in the Future?

- **Higher efficiency**
- **More product integration**
- **Alternative colors**
- **More alternative materials**
- **Emphasis on PV generation with overall energy efficiency.**
- **Battery improvements that allow more use of battery backups in residential applications**

**Visit “What’s New Under the Sun” Friday at 11:00 in South 330 for more information.**

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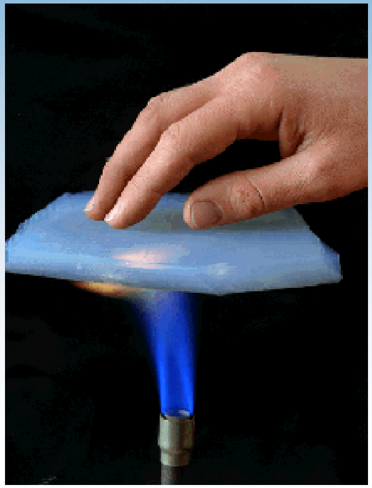
# Advanced Insulation



*Lawrence Berkley National Laboratories – http://eetd.lbl.gov/ECS/aerogels/aerogels.htm*

**Extremely thermal high insulation values and even energy storage in a limited space to improve the energy efficiency of homes, their systems, and appliances.**

# What Has Led up to It?

- 1892 – vacuum flask invented by James Dewar, showing the effectiveness of a vacuum in insulating the contents.
- 1931 – aerogel created by Steven Kistler at the College of the Pacific in California.
- 1980's – after decades of manufacturing and makeup refinement, aerogels were used as Cherenkov radiation detectors. Researchers at Lawrence Livermore National Laboratory create extremely low density silica areogel, at 0.003 g/cm3.
- Early 1990's – aerogel used in space shuttle experiments to collect cosmic dust.
- 1994 – various companies and laboratories form a partnership to commercialize aerogel uses.

# What We're Using Now

| | New U.S. Homes |
|---|---|
| Fiberglass batt | 80% |
| Fiberglass blown behind mesh | 4% |
| Fiberglass blown-on, no mesh | 2% |
| Rockwool batt | 1% |
| Cellulose blown behind mesh | 2% |
| Cellulose blown-on, no mesh | 6% |
| Foam Plastic | 2% |
| Other | 3% |
| TOTAL | 100% |

Source: 2004 Annual Builder Practices Survey

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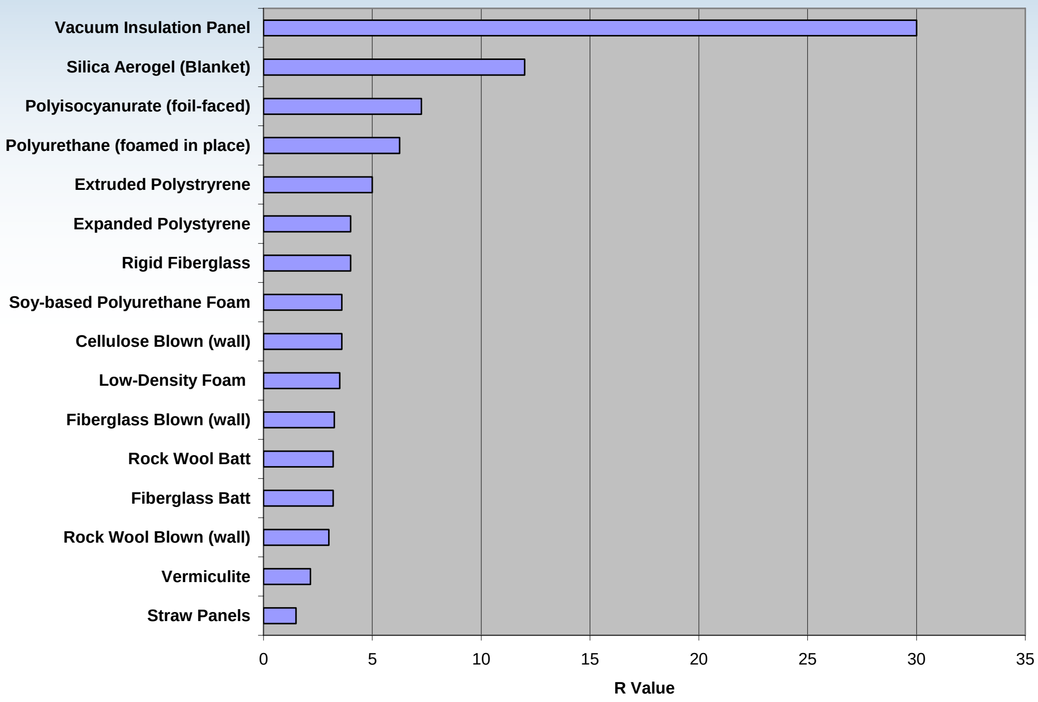
# What’s Available Now?

- Spray foam products now on market and gaining popularity.
- Aerogel coming onto the market in specialty applications and likely to increase.
- Vacuum insulated panels available on appliances and being studied for other applications

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# What's Holding it Back?

- Cost: Currently $3-5 /sf for vacuum panels and aerogel (depending on packaging). Monolithic aerogel blocks can cost even more.
- Durability: Some VIP seals degrade over time and can be punctured
- Brittleness: Aerogels are extremely strong, but also very brittle
- Health Studies: More information is needed on the affect of aerogel particulates
- Production: Much more production capacity of aerogel is needed to reduce the price.
- Process advances needed to produce larger, cheaper monolithic aerogel blocks.

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# What's in the Future?

- Spray foam will likely continue to develop and become more cost effective and common.
- Aerogel will appear in additional products and possibly wall insulation and window.
- Phase change materials have the potential to be overlayed on existing insulations.
- Developments in VIPs (such as the use of cells) have the potential to improve durability.

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# Path Top Ten

- Mold resistant gypsum
- Solar Water heating
- Recycled concrete substitutes and aggregates
- CHP
- Horizontal Axis Washer/Dryer
- Hydrophilic, impact resistant windows
- Super-Sized ICFs
- Induction cooktops
- GPS for land development
- Permeable pavers and pavement

**Visit the PATH/DOE Booth in the Federal Commons for more information at W3659.**

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# Thank you!


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