Technology Commercialization Showcase 2008
Buildings Technology Program

Michael McCabe
Buildings Technology Program
http://www.eere.energy.gov/buildings
Email: michael.mccabe@ee.doe.gov
Tel: 202-586-9155

Agenda

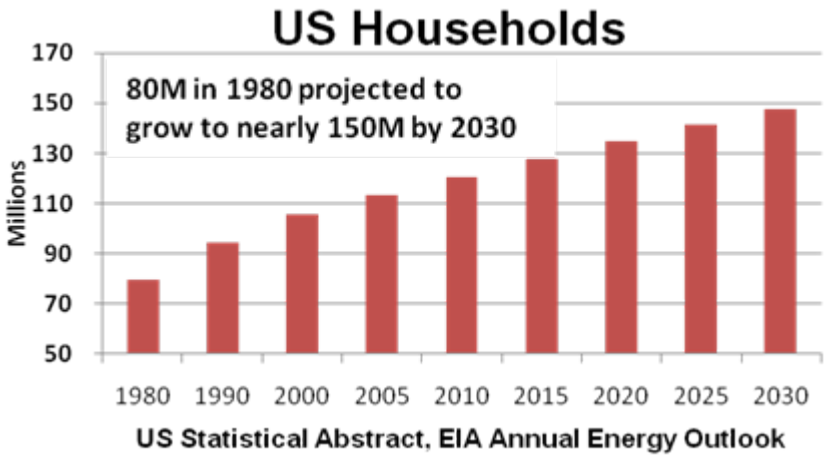
- Buildings Market
- Program Overview
- Technology Commercialization Opportunities
- Unexploited Investment Gaps

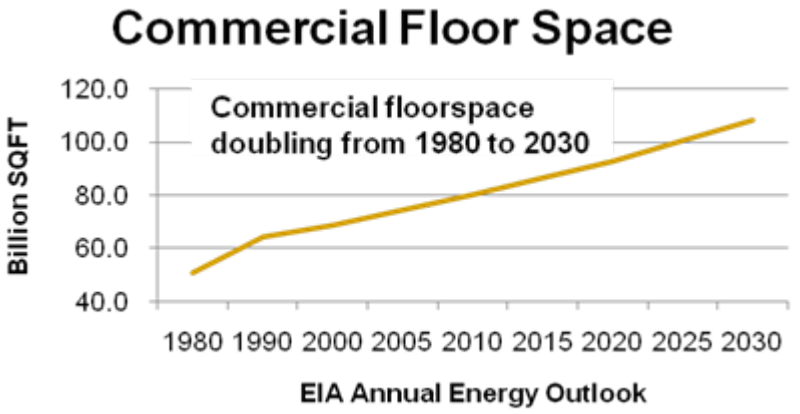
Agenda

- Buildings Market
- Program Overview
- Technology Commercialization Opportunities
- Unexploited Investment Gaps

Energy Use Overview

- Energy uses in buildings include
  - Lighting
  - Heating and Cooling
  - Water Heating
  - Refrigeration &Cooking
  - Computing & other electronics
- Energy use driven by
  - Population (# homes, schools)
  - Economic growth (commercial sqft)
  - Building size (size of homes, offices)
  - Services (e.g., new services like DVRs and cable boxes)
  - Energy prices
  - Efficiency ... focus of this program
- Aggregate energy utility bill for buildings topped $369B in 2005

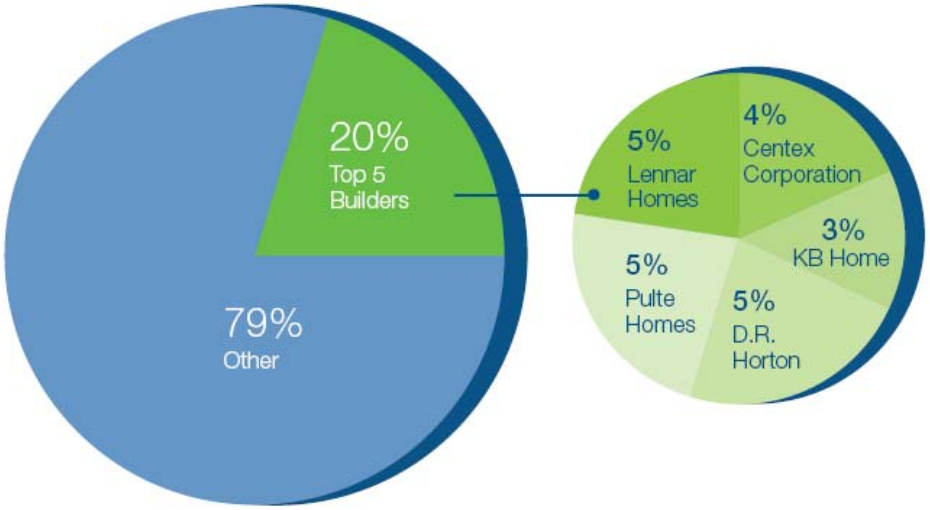


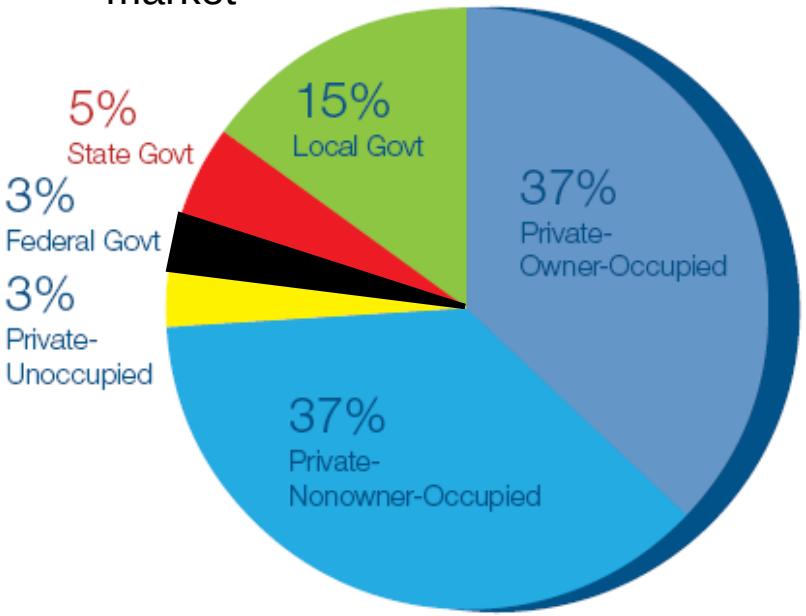


Fragmented Market – Split Ownership

- Residential construction industry consists of nearly 100,000 builders
- Within the new homes market, top 5 builders hold less than 25 percent of the market

Top 5 Builders' Percent of New Home Closings



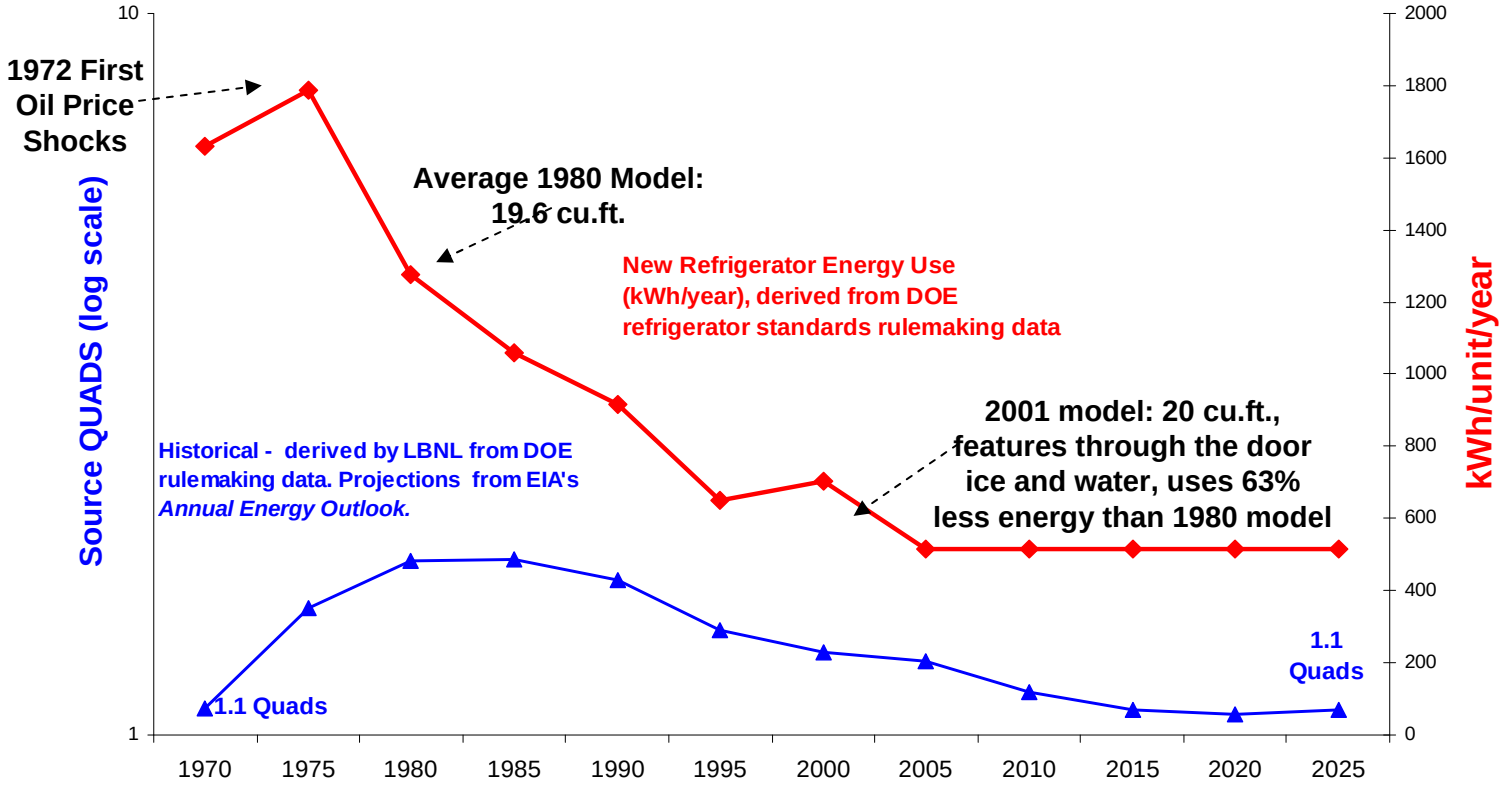


Commercial Building Ownership and Occupancy (Non-Mall Buildings)

- Private sector owns 76% of commercial floor-space, split evenly between owner- and non-owner occupied
- The government owns 24 percent, dominated by local ownership, principally schools

Past successes -- Large and Sustained Savings

Advanced Refrigeration "…one of the last half-century's more remarkable technological achievements in the energy field: a **reduction** of more than **two-thirds** in the average electricity consumption over 25 years, even as average unit sizes increased, performance improved,…DOE was an early and effective leader, …" ("Energy Research at DOE: Was it Worth It", National Research Council



Agenda

- Buildings Market
- Program Overview
- Technology Commercialization Opportunities
- Unexploited Investment Gaps

Program Overview: Mission and Goals

Mission

- Develop technologies, techniques, and tools for making buildings more energy efficient, productive, and affordable through:
  - R&D, demonstration, and deployment
  - Improving efficiency of components, equipment, and their effective integration with buildings
  - Development of building energy codes and equipment standards
  - Integration of renewable energy systems

Goal

- Marketable net-zero-energy buildings focusing on:
  - Reducing energy demand
  - Successful integration of renewable energy technologies

Program Overview: R&D and Technology Integration

- Residential Integration
- Commercial Integration
- Emerging Technologies
  - Solid State Lighting
  - Space Conditioning and Refrigeration
  - Thermal Envelope
  - Windows
  - Analysis Tools and Design Strategies

Thermal Envelope

•High R Walls and Roofs (60-70%)

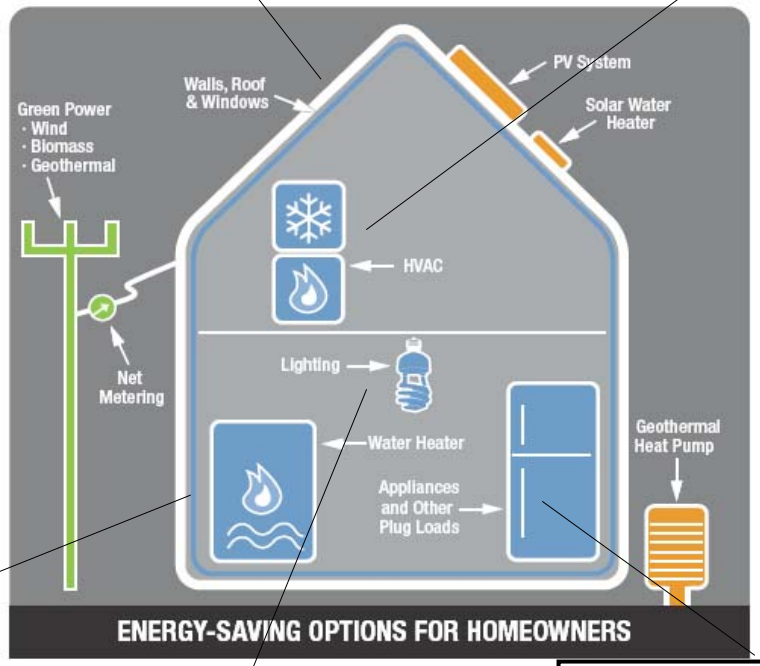
• Smart Insulation and Vapor Barriers (70-80%)

Windows

•R-10 Dynamic Super Window (70-80%)

Space Conditioning and Refrigeration

•Integrated, low capacity heat pump. (60-70%)



Domestic Hot Water

• Engineered Hot Water Distribution (40-50%)

•Integration, low capacity heat pump (60-70%)

Lighting

•Solid State Lighting

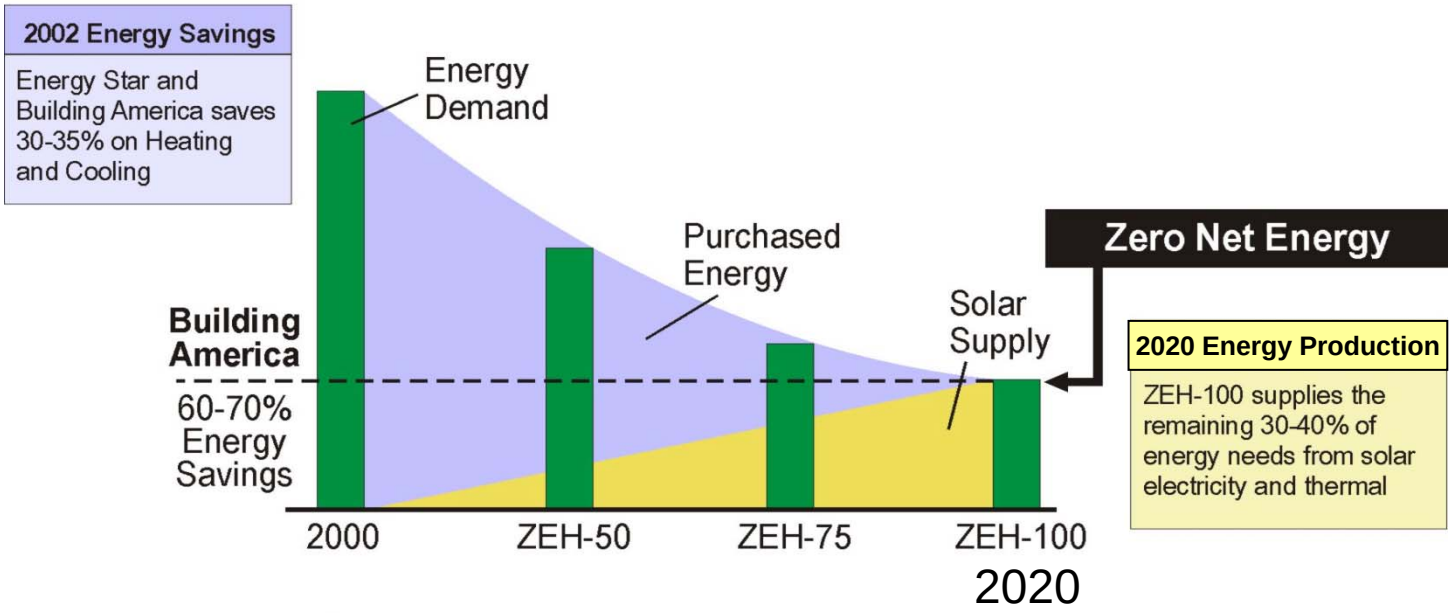
Appliances and Other Plug Loads

• Whole House Energy Control Standard

• 10-30% Misc. Electric Savings (40-50%)

Residential Integration Goal: Net Zero Energy Homes

Net Zero Energy Homes



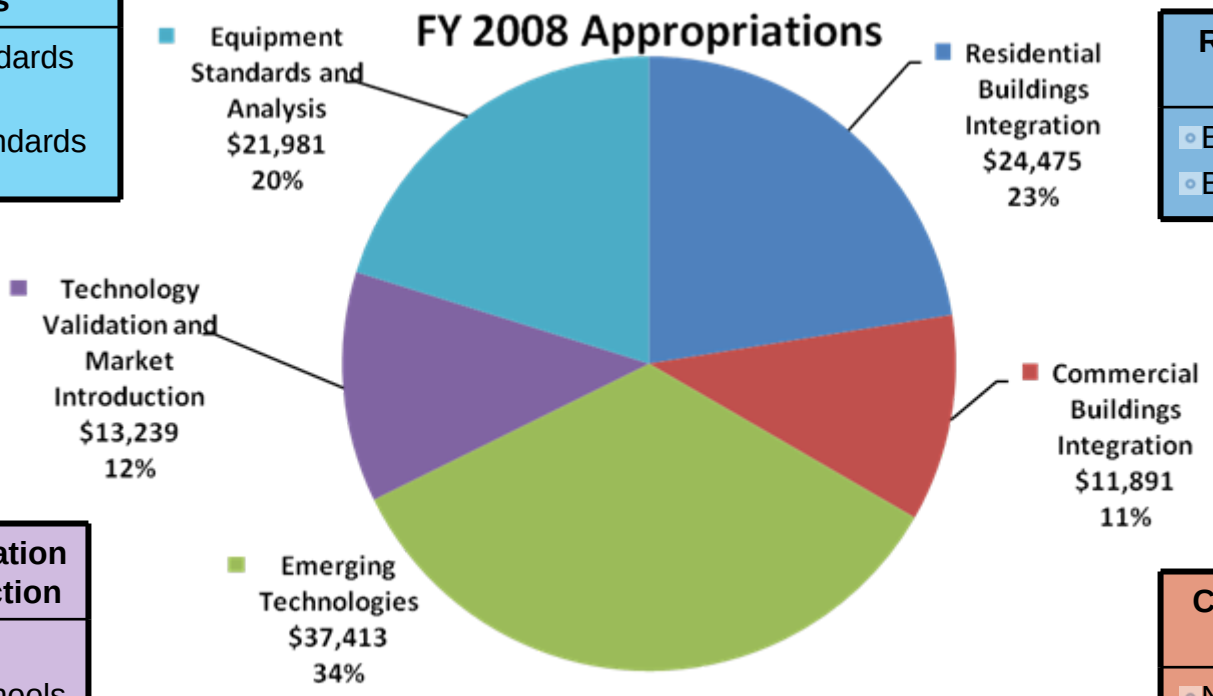
ZEH-100 Saves 100% of Traditional Household Energy Use

Ultimate goal is Net Zero Energy Homes that generate and use energy so efficiently that they are capable of generating as much energy as they consume over the course of a year.

Technology Funding Breakdown

Equipment Standards & Analysis

- Appliance Standards
- Commercial Equipment Standards



Residential Building Integration

- Building America
- Builders Challenge

Technology Validation & Market Introduction

- Energy Star
- Energy Smart Schools
- Energy Smart Homes
- Solar Decathlon

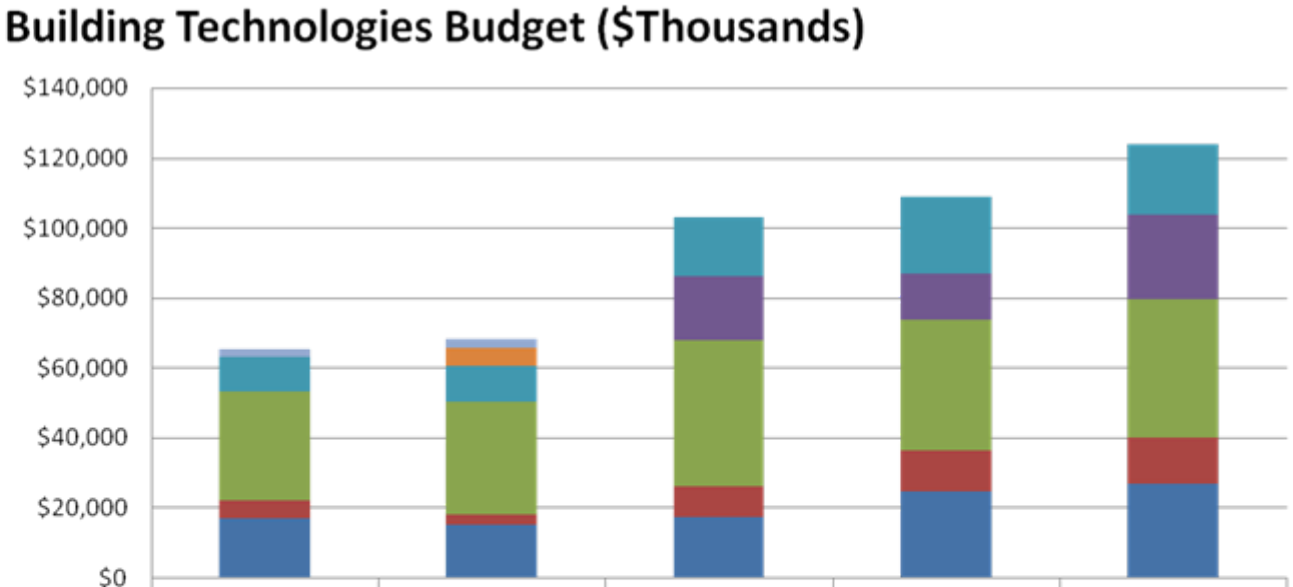
Emerging Technologies

- Lighting R&D, $23,937
- Space Conditioning and Refrigeration R&D, $2,819
- Building Envelope R&D, $7,054
- Analysis Tools and Design Strategies, $2,660
- Solar Heating and Cooling, $0
- SBIR/STTR $943

Commercial Building Integration

- National Energy Alliances
- National Accounts
- Integrating Technologies
  - Sensors & Controls
  - IAQ

Historical Budget



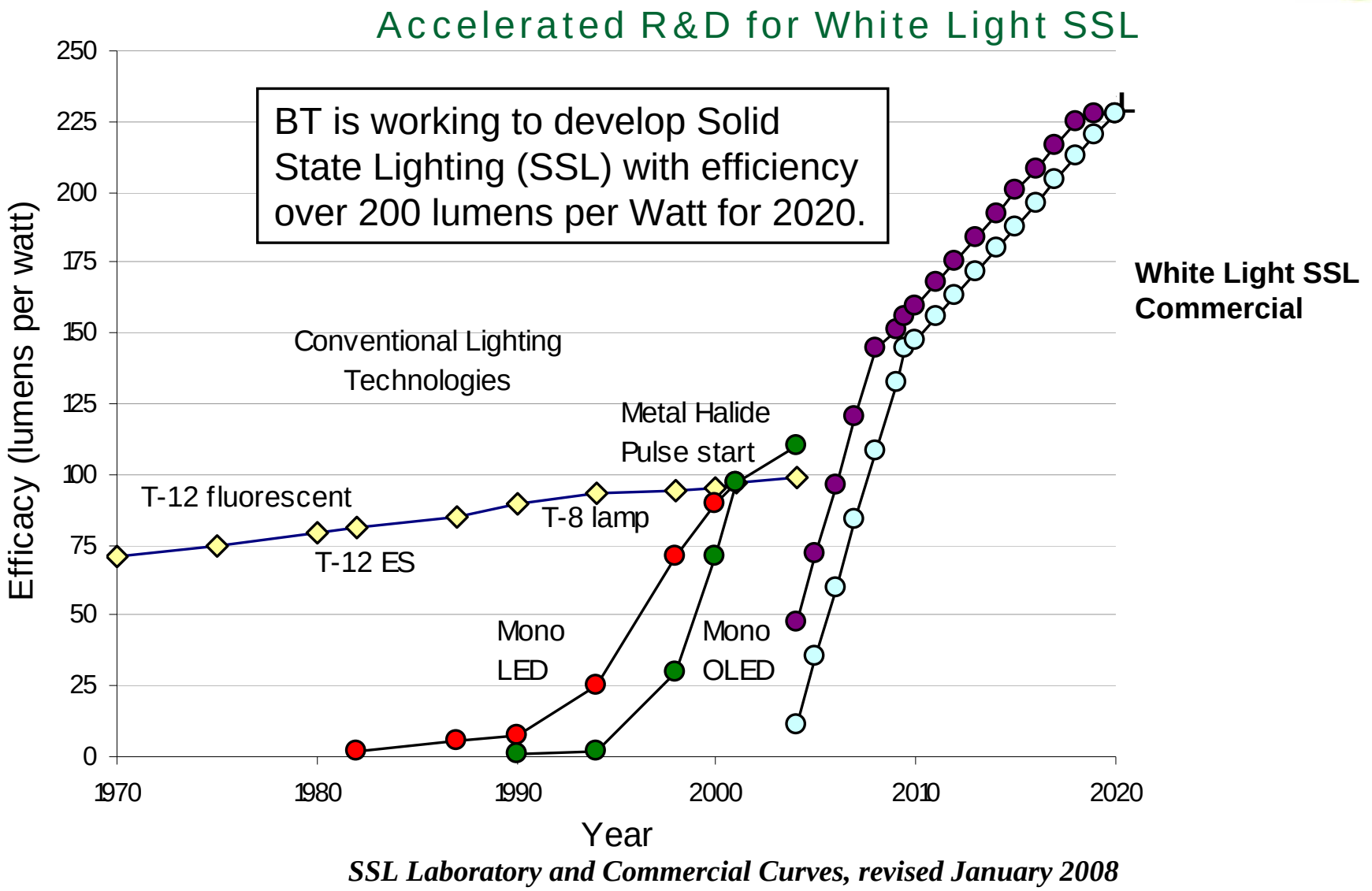
	FY 2005 Appropriations	FY 2006 Appropriations	FY 2007 Appropriations	FY 2008 Appropriations	FY 2009 Request
Other	$1,972	$2,475	$0	$0	$0
Congressionally Directed Activities	$0	$5,346	$0	$0	$0
Equipment Standards and Analysis	$10,147	$10,153	$16,925	$21,981	$20,000
Technology Validation and Market Introduction	$0	$0	$18,249	$13,239	$24,400
Emerging Technologies	$31,124	$32,289	$41,840	$37,413	$39,465
Commercial Buildings Integration	$5,125	$3,069	$8,699	$11,891	$13,000
Residential Buildings Integration	$16,787	$14,858	$17,270	$24,475	$26,900

BT Program Initiatives

Research & Development

- **Solid State Lighting**
- Technology Validation and Market Introduction
- **Builders Challenge**
- ASHRAE Advanced Design Guides
- Technology Transfer and Application Centers
- Energy Smart Schools
- Commercial Lighting
- Energy Smart Hospitals

BT Program Initiatives: Solid State Lighting (SSL)



SSL Laboratory and Commercial Curves, revised January 2008

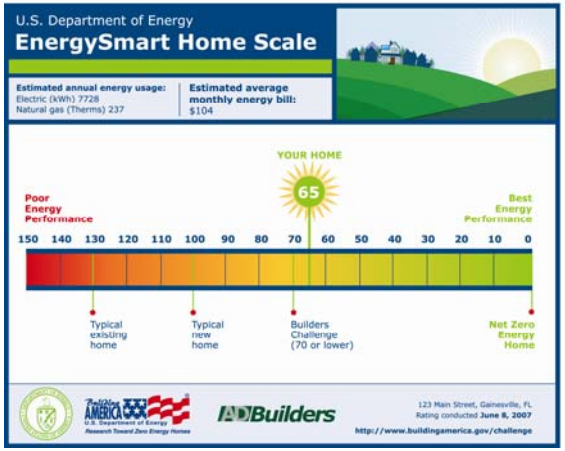
BT Program Initiatives: SSL Today

- LEDs are commercially active in a limited market and limited range of applications (niche markets in general illumination)
- LEDs are cost-effective in colored-light applications
  - Exit signs, traffic signals, advertising signage, airport taxiway lights
  - Energy bill mandates LED exit signs and traffic signals
- LEDs are starting to compete in white-light applications
  - Airplane reading lights, directional / task lighting
- High-brightness LEDs represented **~$3.7 billion market in 2004**
  - Top three applications are mobile appliances (40%), signs (23%) and automotive (18%)
- OLEDs focus on display applications and not general illumination

Source: Energy Savings Estimates of Light Emitting Diodes in Niche Lighting Applications, Navigant Consulting, November 2003; KOPTI presentation 2004.

BT Program Initiatives: Builders Challenge

- DOE Secretary Bodman posts E-Scale at International Builders Show
- Challenge to build 220,000 high performance homes by 2012
- To qualify homes must be between 70 and 0 on the EnergySmart Home Scale as well as meet quality criteria
- Energy performance threshold of 70 chosen because:
  - Cost neutral with readily available materials
  - Meets EPACT Federal Tax Credit in most regions



Agenda

- Program Overview
- Buildings Market
- Technology Commercialization Opportunities
- Unexploited Investment Gaps

Building Technology Commercialization Opportunities

Lighting

- Novel Growth Technique for Large Diameter AlN Single Crystal
- Dimming Electronic Ballast (DEB) and Control Systems Coupled with Unique Power Line Communications System

HVAC

- Integrated Liquid-Desiccant/Vapor-Compression AC
- Solar Powered Liquid-Desiccant Heating/Cooling System
- Low-Cost Remote Automated Wireless Diagnostic Monitoring and Demand Response System for Packaged Air Conditioners and Heat Pumps

Windows

- Electrochromic Windows
- Highly Insulating Windows: Multiple Glazings and Coatings

Other

- Tabbed Fin Heat Exchanger

Lighting: Novel Growth Technique for LED Crystal

Description

- Novel, physical vapor transport (PVT) technique to grow large diameter, high quality AlN bulk single crystals as substrates for LED

Impact

- Greater price-performance characteristics for certain applications, in variety of fields
- Cost at early stages not main driver because current technology has not achieved higher efficacy (150 - 200 lumens/watt) for general illumination

Technology Readiness

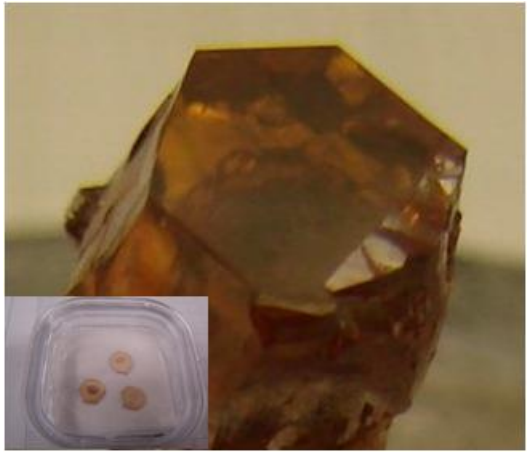
- Crystal growth process developed, work needed to increase size and reduce defects
- Initial price premium of $4-$6K for 2” wafer

Estimated Time to Market

- Product will be introduced Q1 2009

Financing Required

- $2 - $5 million requirement for equipment, facility and personnel expansion

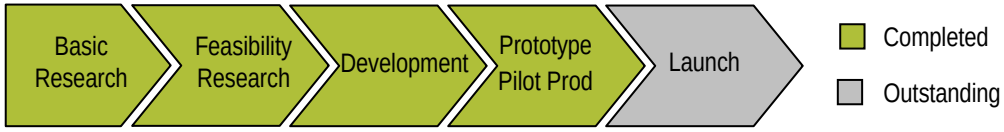


Andrew Timmerman

Business Officer, Fairfield Crystal Technology

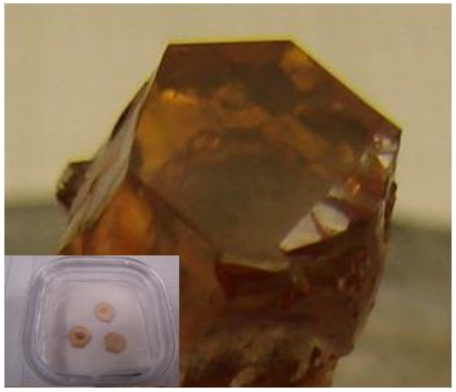
860-354-2111

atimmerman@fairfieldcrystal.com

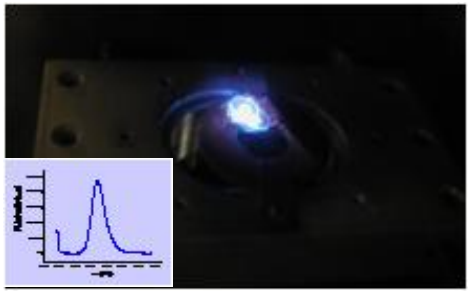


Novel Growth Technique for Large Diameter AlN Single Crystal

- Problem: Nitride-based, high-brightness, UV, visible, and white light emitting diodes are candidates for replacing incandescent and fluorescent lights in general illumination. Poor crystalline quality prevents higher efficiency. Aluminum-nitride (AlN) single crystal shown to have same crystal structure and close lattice match to group III-nitride epilayers, and can be grown in bulk single crystal form.
- Description: Develop novel, physical vapor transport (PVT) technique to grow large diameter, high quality AlN bulk single crystals, which can be used as substrates for growth of high quality nitride LED epitaxial layers.
- Impact: Significant improvements light output efficiencies have made GaN-based LEDs most promising contender for future general illumination application. High brightness LEDs have tremendous energy saving potential, long life time, compactness, and potential cost savings.
- Technology Status: SBIR Project
  - Phase I, PVT technique for AlN single crystal growth studied to understand effect of crucible/insulation set-up, used for PVT growth. Protective TaC coatings on graphite crucibles fabricated and tested, and crystal growth process developed, defects and impurities characterized, and AlN crystal boules fabricated into wafers.
  - Phase II, Develop aluminum nitride substrates suitable for growth of high quality nitride epitaxial layers, leading to fabrication of high brightness LEDs for general lighting applications. AlN wafers and epi-ready AlN substrates will be fabricated from aluminum nitride crystal boules. III-nitride epi-layers will be grown on aluminum nitride substrates, using a metal-organic chemical vapor deposition technique.
- Financing Required: $2 - $5 million requirement for equipment, facility and personnel expansion
- Contact Information
  - Fairfield Crystal Technology, New Milford, CT 06776, 860-354-2111
  - Dr. Shaoping Wang, Principal Investigator, swang@fairfieldcrystal.com
  - Andrew Timmerman, Bus. Officer, atimmerman@fairfieldcrystal.com



7mm AlN single crystal boule and
Insert - three epi-ready AlN wafers



GaN/InGaN quantum well LED structures grown on Fairfield Crystal AlN substrates show a strong blue emission at a peak wavelength of about 465nm.

Novel Growth Technique for Large Diameter AlN Single Crystal

- **Value proposition** is greater price-performance characteristics for certain applications, in variety of technology fields. Increasingly greater performance demanded by end users and nearing limitations of other materials providing opportunities for AlN. Application of interest is high-performance LED markets; improved efficacy for general illumination and blue laser diodes. Additional applications include microcontamination detection, water purification, high frequency communication, scientific analysis and other areas.
- **Potential early markets** are application within high-powered RF devices, which traditionally build on silicon substrates. AlN has been demonstrated to be superior for deep UV light-emitting applications and may ultimately surpass silicon carbide in both cost and performance for high power RF - (AlN) is highly insulating which is attractive for high frequency devices.
- Based on forecast demand for high-brightness LEDs, blue-violet laser diodes, and high-power, high-frequency electronic devices…demand for substrates for GaN devices expected to grow from $340m in 2006 to $880m in 2010. Advanced substrates such as GaN and AlN forecast to be > 50% of market in 2010."
- "Might consider a partner to help in manufacturing the epitaxial layer, but there is not a need for a substrate manufacturer".
- Fairfield will continue to manufacture substrates using patented technology and will be open to licensing technology.

Lighting: Dimming Electronic Ballast and Controls

Description

- Distributed intelligent solution with ballast level sophistication, robust control system and power line communications

Impact

- Adjust levels in response to daylight
- Reduce lighting to occupant preference
- Automatically turnoff when space is vacant
- Responds to electric market signals

Technology Readiness

- Initial product available now, UL approved.
- Consumer cost under $30, competition $100 or more

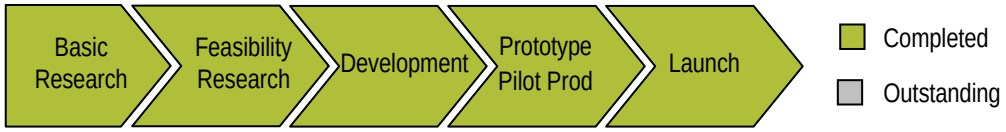
Estimated Time to Market

- Commercial installations Q3/Q4 2008.

Financing Needs

- Raising second round of funding in 2009 of around $10M

Bennett Johnston
VP Business Development, Lumenergi
(415) 388-0165
bennett@lumenergi.com



Dimming Electronic Ballast (DEB) and Control Systems Coupled with Unique Power Line Communications System

- **Problem:** Daily and seasonal electricity demand (load) changes, planned and unplanned outages, and other factors impact electricity reliability and generation costs.
- **Description**: Distributed intelligent solution with ballast level sophistication, robust control system and PPLT power line communications for ease and efficiency.
- **Impact:** Daylighting: Adjusting electric lighting levels in response to increased daylight levels. Task Tuning: Reduce electric lighting levels according to occupant preference. Scheduling: Automatically turnoff lights when space is vacant; building level control or occupancy sensors Load Shedding, Demand Response: Reduce electric lighting levels in response to electric market signals
- **IP position:** 28 patents issued or in process. Owned by Lumenergi.
- **Financing Needs:** Raising second round of funding in 2009 of around $10M.
- **Status:** Commercial Products Dimming Electronic Ballasts (DEBs) Lighting Management Control System (LMCS) Passive Power Line Communications path (PPLC)

Bennett Johnston
VP Business Development, Lumenergi
(415) 388-0165
bennett@lumenergi.com

LUMEnergi™

Dimming Electronic Ballast (DEB) and Control Systems Coupled with Unique Power Line Communications System

- The architectural dimming sub-market is ~$150M/year. Existing market is >$1B/year. The market size is 60-62 million new units, and 1.2 billion unit retrofit in the US. Worldwide market: 2.5 times US.
- Production engineering for mass production including tooling, cost reduction engineering is underway. First commercial installations will begin in 3Q/4Q 2008.
- Initial product in discrete version is available now. UL approved. Lumenergi product costs under $30 to the user competition $100 or more. The value proposition to builders or owners is very high ROI, low first costs (i.e. initial payback well under two years without utility or tax incentives) no maintenance, no liability.
- Looking for trade allies and additional manufacturers. Currently have two manufacturing facilities in China and plans for mass production with multi-billion dollar highly capable plants and vendor financing. Would like to speak with additional manufacturers in South America and EU if appropriate.
- Lumenergi licenses and manufacturers products. Software code is contained in a One Write Chip for additional IP protection, which is very difficult - if not impossible -to copy and allows us an extraordinary measure of control over the products.

HVAC: Integrated Liquid-Desiccant/Vapor-Compression AC

Description

- Advanced liquid-desiccant technology combined with vapor-compression AC

Impact

- Provides > 2X dehumidification of conventional system
- Reduces compressor power by 24% or more
- Easy to install
- Expected to have slightly lower cost (e.g., 15%) to manufacturer than other ACs designed specifically for humidity control

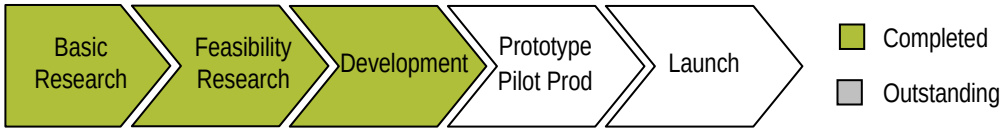
Technology Readiness

- Proof-of-Concept model of liquid-desiccant AC successfully tested
- Two-ton breadboard model designed and fabricated

Estimated Time to Market

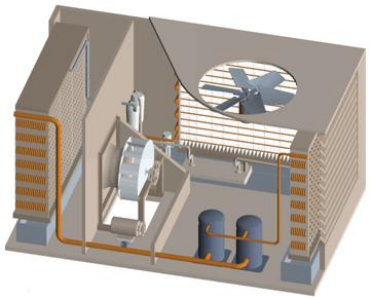
- Now looking for a manufacturing partner. Discussions in very early stage with one potential partner

Andrew Lowenstein
AIL Research, Inc.
(609) 799-2605 x40
ail@ailr.com



Integrated Liquid-Desiccant/Vapor-Compression AC

- **Problem:** ACs are poor at controlling indoor humidity. High humidity can create health problems and lead to mold and mildew. Energy wasted overcooling buildings.
- **Description:** Incorporate advanced liquid-desiccant technology into an electric vapor-compression air conditioner that: (1) provides more than twice the dehumidification of a conventional system, (2) reduces compressor power by 24% or more, and (3) is easy to install on a residence or commercial building.
- **Impact:** High efficiency AC that provides superior dehumidification would restore healthy indoor conditions while significantly reducing energy use. Independent control of temperature and humidity within homes would address problems of poor indoor air quality, mold and mildew growth, and the waste of energy from over-cooling. Technology also should be applicable to commercial rooftop AC market.
- **IP position:** Owned by AIL Research, Inc.
- **Status:** SBIR Project
  - Phase I: Proof-of-Concept model of liquid-desiccant AC successfully tested
  - Phase II: Two-ton breadboard model designed and fabricated. Goals of doubling the dehumidification and decreasing compressor power by 25% (compared to conventional AC) successfully demonstrated.



Andrew Lowenstein
AIL Research, Inc.
(609) 799-2605 x40
ail@ailr.com

Integrated Liquid-Desiccant/Vapor-Compression AC

- U.S. sales of air conditioners that specialize in humidity control is now estimated at $300M/year with significant growth. Most sales are in humid eastern half of U.S.
- Additional technical work needed to map performance over all possible operating conditions. Manufacturable prototypes must be designed, fabricated and field tested.
- The LDVC needs to be implemented and tested as a manufacturable prototype.
- Second important application replaces liquid desiccant with water, which converts LDVC into a very high EER AC with evaporatively cooled condenser. Tests in 2008 proved high efficiency.
- LDVC could be available in 2010 (following beta tests in 2009).
- LDVC AC expected to have slightly lower cost (e.g., 15%) to manufacturer than other ACs designed specifically for humidity control. It will be able to be sold for a premium since it will have a moderately higher efficiency.
- Both LDAC and the LDVC address indoor humidity problems and allow buildings to be better ventilated. Occupant productivity could be important benefits.
- Difficult to compare cost to conventional technology since manufacturable prototype not yet designed and built.
- Compared to other ACs specifically designed for humidity control, will have lower operating costs and a smaller size. Compared to low efficiency ACs, higher first cost, but reasonable payback (<5 years)
- Important early market is high growth HVAC market for Dedicated Outdoor Air Systems (ACs that dehumidify and cool ventilation air in humid climates). Specific applications include natatoriums, health care facilities, theaters, supermarkets and where either ventilation rates are high or indoor humidity must be kept low. Version with evaporatively cooled condenser meets needs for AC in western U.S. (as defined by the Western Cooling Challenge for hot, dry climates).
- Looking for manufacturing partner . Discussions in very early stage with one potential partner.
- IP play most likely be a joint venture with a manufacturing partner in which AILR stays closely involved with the initial set up of manufacturing facilities and the marketing/sales organization.

HVAC: Solar Powered Liquid-Desiccant Heating/Cooling System AC

Description

- Solar-powered air conditioner, which runs on heat, that is exceptionally well suited to controlling indoor humidity

Impact

- Hedge against higher energy costs and improves health & comfort through humidity control, increased ventilation

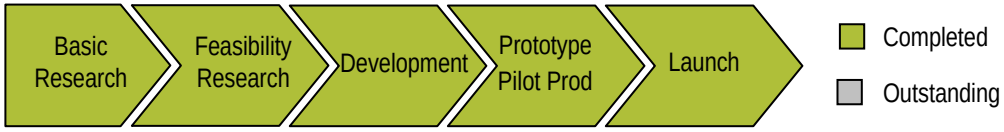
Technology Readiness

- Two beta prototypes now operating on hot water from gas-fired boilers
- One will be converted to solar in 2008.
- Another solar unit will be installed in Florida in late 2008
- Unit running on waste heat from micro-turbine will be installed in late 2008
- No significant technical work remains

Estimated Time to Market

- Limited commercial sales begin in 2008

Andrew Lowenstein
AIL Research, Inc.
(609) 799-2605 x40
ail@ailr.com



Solar Powered Liquid-Desiccant Heating/Cooling System

- **Problem:** Conventional air conditioning consumes a large amount of energy contributing to overloaded electrical grids, air pollution and global warming.
- **Description:** A solar-powered air conditioner, which runs on heat, that is exceptionally well suited to controlling indoor humidity
- **Impact:** A competitive liquid-desiccant air conditioner should significantly reduce energy use for cooling and reduce emissions of greenhouse gases and other pollutants. Technology should also allow our schools, homes, offices and other buildings to be better ventilated without the deleterious effects of high indoor humidity.
- **IP position:** Owned by AIL Research, Inc.
- **Status:** SBIR Project
  - Phase I: The solar liquid-desiccant air conditioner was designed and a strategy for its commercialization identified. Computer modeling showed that, with tax credits now available, the solar air conditioner could have a payback of less than ten years.
  - Phase II and III: Two beta prototypes are now operating on hot water from gas-fired boilers, one of which will be converted to solar in 2008. Second solar unit will be installed in Florida in late 2008, and a unit running on waste heat from a microturbine will also be installed in late 2008

Solar Powered Liquid-Desiccant Heating/Cooling (LDAC) System

- Conventional ACs that specialize on humidity control are ~$2,400/ton. Solar LDAC cost ~$5,500/ton w/o 30% federal investment tax credit, and $3,850/ton w/ credit. Higher first cost recouped in 6-12 years at today's energy prices.
- The value proposition to builders or owners is that it provides buyer with hedge against higher future energy costs and improves health and comfort through better humidity control and increased ventilation.
- Important early market is high growth HVAC market for Dedicated Outdoor Air Systems (ACs dehumidify and cool ventilation air in humid climates). Also regions w/ drier climates and high solar availability where LDAC can operate as desiccant assisted indirect evaporative cooler. If utilities allowed to meet RPS through reduced load, then solar LDAC could be part of utility programs.
- U.S. sales of ACs specialized in humidity control ~$300/yr w/ significant growth.
- Looking for manufacturing partner for LDAC (applied as either gas-fired unit or solar-powered unit). Discussions in very early stage with two potential partners.
- IP play will most likely be a joint venture with partner where AILR stays closely involved with initial set up of manufacturing facilities and the marketing/sales organization.

HVAC: Automated Wireless Diagnostic Monitoring & Demand Response System for ACs & Heat Pumps

Description

- System automatically detects and diagnoses faults
- Service providers deliver timely maintenance based on actual equipment condition

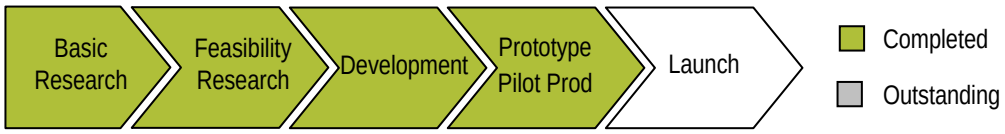
Impact

- Technology lowers total life cycle operating cost of equipment
- Make equipment “demand responsive” when electricity prices and grid instability develops
- Certain states like CA and NY are considering mandating diagnostics and demand response in building codes

Technology Readiness

- A manufacturing partner is needed

Srinivas Katipamula
PNNL
(509) 372-4281|
Srinivas.Katipamula@pnl.gov



Low-Cost Remote Automated Wireless Diagnostic Monitoring and Demand Response System for Packaged Air Conditioners and Heat Pumps

- **Problem:** AC and heat pump packaged units are some of the most neglected of equipment in buildings. Often serviced only once or twice per year or run until failure. Often running at degraded efficiency, thus increasing energy costs for building owners.
- **Description:** System automatically detects and diagnoses faults in the monitored equipment to help service providers deliver maintenance service in a timely manner on the basis of actual equipment condition. Results are transmitted to a network operations center and accessible via the web. System enables electric load shedding in response utility calls for demand response.
- **Impact:** Can be used on packaged air conditioners and heat pumps used widely on small and other low-rise commercial buildings, which represent over 50% of US commercial buildings
- **IP Position:** PNNL patent on air-side HVAC diagnostics
- **Technology Status:** No system with similar capabilities is currently on the market. DOE development work was performed in collaboration with an industry partner, which has indicated interest in commercialization of this technology, provided the cost can be reduced.

Srinivas Katipamula
PNNL
(509) 372-4281|
Srinivas.Katipamula@pnl.gov

Low-Cost Remote Automated Wireless Diagnostic Monitoring & Demand Response System for Packaged Air Conditioners and Heat Pumps

- The primary technical barrier is reduced hardware and installation costs to deploy the automated remote diagnostics and automated remote demand response capabilities.
- The development and testing cycle of the reduced cost hardware is 12 to 18 months after funds are received.
- The conventional approach to maintenance is run until failure or scheduled maintenance, replacement at failure, addressing issues based on occupant complaints, and simply paying higher energy costs when systems are running in degraded condition. This type of condition-based maintenance is not traditional but can lead to longer equipment life and reduced energy and maintenance costs.
- The technology would lower the total life cycle operating cost of the equipment and also make the equipment “demand responsive” when a market for demand response to electricity prices and grid instability develops (already available in some areas of California and the northeast).
- Certain States like CA and NY are considering mandating (as part of building energy codes) diagnostics and demand response.
- The market is regional. 50% of commercial buildings have packaged equipment that will benefit from the technology. Although the technology can be applied to residential-sized units, the reduced cost may still be too high for residential application.
- A manufacturing partner is needed.
- PNNL will license the software that will work in combination with the hardware to be developed by the manufacturing partner.

Windows: Electrochromic Windows

Description

- Electrochromic (EC) glass is electronically tintable glass that can be switched from clear to darkly tinted at the push of a button

Impact

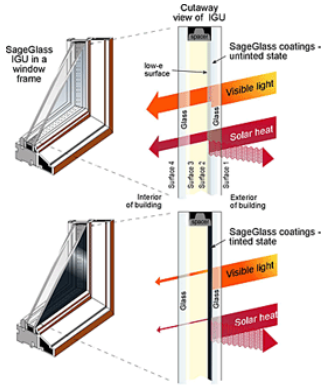
- EC glass can be operated manually or integrated into an automated building management system

Technology Readiness

- Currently available in dimensions up to 42.5“ by 60"

Estimated Time to Market

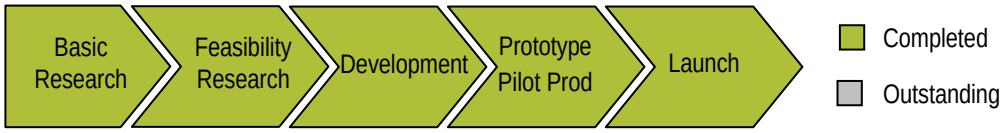
- In the market since 2004 and highly competitive at volume production
- In discussions for expanding both production and distribution



Layers of metal oxides are applied to conventional glass and then fabricated into insulating glass unit (IGU).

Windows darken when voltage is applied

Neil Sbar
SAGE Electrochromics, Inc.
(507) 331-4904
nsbar@sage-ec.com



Electrochromic Windows

- **Problem:** Energy lost through inefficient windows accounts for 30% of building heating and cooling energy. Low-E coatings revolutionized markets in 1980s but now “stuck” at that performance level.
  - Current product sales ~ $40B/yr US; (x5 globally)
  - Current U.S. annual heating energy cost ~ $30B/yr
  - New generation of technologies needed for heat loss reduction; potential to create “zero net energy windows”
- **Description:** Electrochromic (EC) glass is electronically tintable glass that can be switched from clear to darkly tinted (and from darkly tinted to clear) at the push of a button. EC glass can be operated manually or integrated into an automated building management system.
- **Impact:** In contrast to traditional fixed “static” windows, EC smart glass can be either automatically or manually adjusted as desired: darkened to minimize solar heat gain in summer (while still preserving the external view) and lightened to a near-clear state to augment residential heating in winter and provide natural lighting year round. By regulating solar heat in this manner, EC smart windows can reduce the demand for building heating and cooling energy and lower peak electricity demand in most parts of the country. **Opportunity for building energy savings from EC dynamic glazings ~2x low-e savings**.
- **Status:**
  - SAGE, founded in 1989, opened its first commercial production facility in 2005 and currently manufactures EC smart glass under the SageGlass® brand, for sale to select window and skylight OEMs.
  - SageGlass products are currently available in dimensions up to 42.5" wide (or tall) and 60" tall (or wide)

Neil Sbar
SAGE Electrochromics, Inc.
(507) 331-4904
nsbar@sage-ec.com

Electrochromic Windows

- SageGlass has been in the market since 2004, today we are growing production capacity and market awareness and presence
- The product is on the market now, and highly competitive at volume production
- The value proposition to builders or owners is energy saving and glare control without loss of view
- Markets are in both commercial and residential construction windows, as well as certain transportation window applications
- The glass and window industry is a large global business
- SAGE is in discussions for expanding both production and distribution
- SAGE has large and strong IP position as well as growing portfolio of manufacturing trade secrets

Windows: Highly Insulating, Multiple Glazings &Coatings

Description

- Windows with multiple glazing layers, including rigid plastic or thin glass center layer, Low-E coatings, optimized optical properties, and low conductance gas fills

Impact

- Create a highly insulating product that can for most U.S climates

Technology Readiness

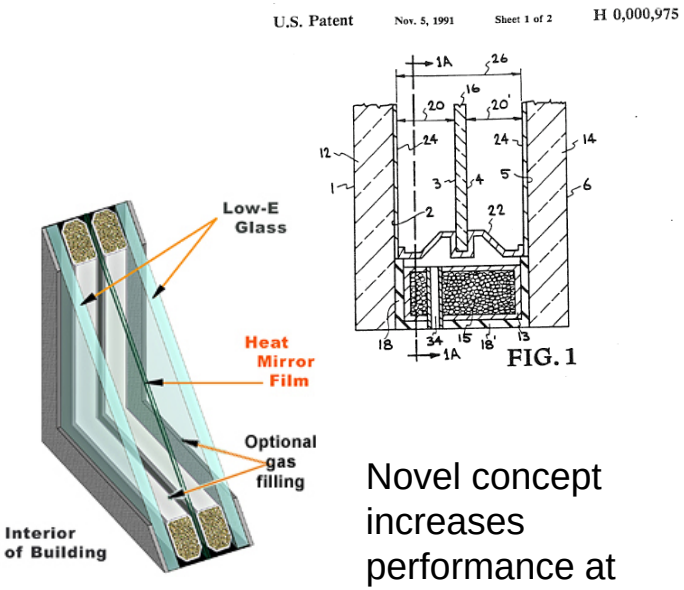
- Basic concepts proven with extensive simulation and lab testing of prototypes
- Needs materials and design optimization with manufacturing cost in mind

Estimated Time to Market

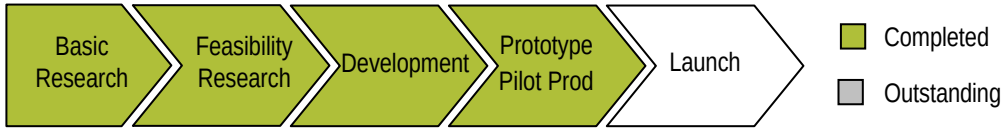
- Could be brought to market 12-18 months

Financing Needs

- $5-10M for R&D
- Tooling and manufacturing costs will be additional



Novel concept increases performance at lower cost



Stephen Selkowitz
Lawrence Berkeley National Lab
(510) 486-5064
seselkowitz@lbl.gov

Highly Insulating Windows: Multiple Glazings and Coatings

- **Problem:** Windows influence 20-50% of building energy use, Low-E coatings revolutionized markets in 1980s but now "stuck" at that performance level
  - Current product sales ~ $40B/yr US; (x5 globally)
  - Current U.S. annual heating energy cost ~$30B/yr
  - New generation of technologies needed for heat loss reduction; potential to create "zero net energy windows"
- **Description:** Goal is to create a highly insulating product that can become a mainstream product in most U.S climates
  - Near term solution for cost-effectiveness
  - Multiple glazing layers, including rigid plastic or thin glass center layer
  - Low-E coatings with optimized optical properties
  - Low conductance gas fills, e.g. krypton to reduce gap size
- Financing Needs: $5-10M for R&D. Tooling and manufacturing costs will be additional
- **Impact:** This technology package could effectively reduce the $30B cost to "0" while providing purchasers with significant economic and related benefits
  - Energy and peak demand savings
  - Smaller heating and cooling systems
  - Electric load peak benefits
  - Occupant comfort and amenity with large windows; occupants want views
- **IP position:** LBNL published basic approaches in 1990s so cannot be controlled by others; opportunities for new IP for manufacturing process
- **Status:** Basic concepts proven with extensive simulation and lab testing of prototypes
  - Builds on existing underlying low-E technology and gas fills so minimizes risk and start up costs
  - Needs materials and design optimization with manufacturing cost in mind
  - Lab prototypes of new solutions exist; new investment could accelerate progress to market; market advantage to first mover
  - Interest from window manufacturers if cost and performance target met

Highly Insulating Windows: Multiple Glazings and Coatings

- Engineering development to minimize manufacturing costs is needed to get to a marketable product. Additional materials for use as rigid center. Some window manufacturers may redesign frames to go with the improved glazing.
- A product could be brought to market in 12-18 months
- The projected cost would be an additional $3-$5/sf for insulating glass unit; this new glazing could add 10- 25% to cost of complete window.
- The value proposition to builders or owners is saves energy, reduces peak demand, reduces heating and cooling system size and simplifies system - e.g. not necessary to run ducts to the perimeter of the building. Ability to place windows on "bad" side of a house, e.g. north; possibly better acoustics.
- High end housing which values quality of space and indoor environment, owners wanting a "green home", off-grid or zero energy home, ~50% of windows sold are for replacements and could provide good market opportunities since owner is often directly involved in the decision making. If EnergyStar tightens its requirements and becomes effective in 2009 this could also move the early market.
- Potential market is very large if cost is low enough, e.g. in the US: 50 million units per year for residential; more for commercial. Initial markets probably in cold northern and north central, (Plus all of Canada) but hot sunbelt, e.g. Arizona, Las Vegas may be good markets also.
- Need a manufacturing partner: investor could develop new manufacturing company or partner with existing insulating glass manufacturer or with key supplier of components. Also need to sell to or partner with a window manufacturer to incorporate the insulating unit in the frame; window manufacturer could play a role in manufacture as well.
- Engineering design was initially published and made public so that it could not be captured by any single firm. Stronger play may be development and patenting of novel manufacturing processes
- A related opaque insulating material, gas filled panels, based on this glazing work, was patented and licensed to several firms making building insulation and insulation for shipping containers.

Other: Tabbed Fin Heat Exchanger

Description

- Tabbed fin heat exchanger is a new type of air to liquid plate fin heat exchanger that reduces the electric power required to run fans

Impact

- Heat transfer per unit fan power was increased by 15-19% over state of the art heat exchanger design

Technology Readiness

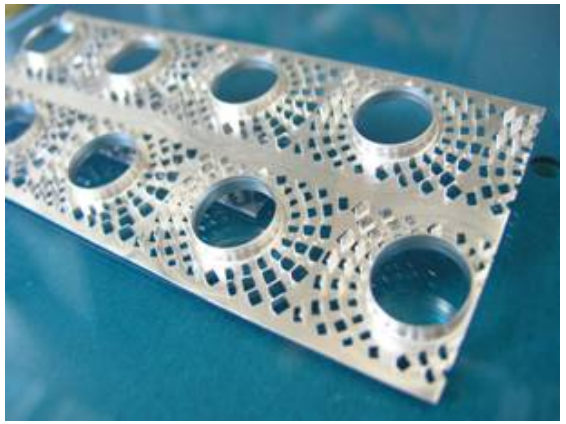
- Has gone through 3 iterations to improve its performance
- More work needed to determine a process to manufacture and possibly improve design for ease of manufacture

Estimated Time to Market

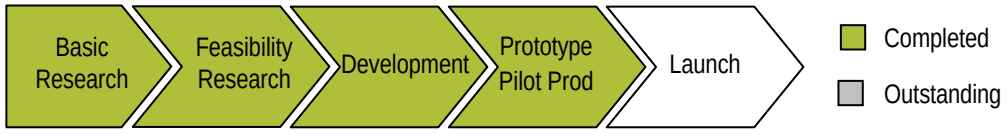
- Ready to commercialize today

Financing Needs

- Money to improve design for manufacturability

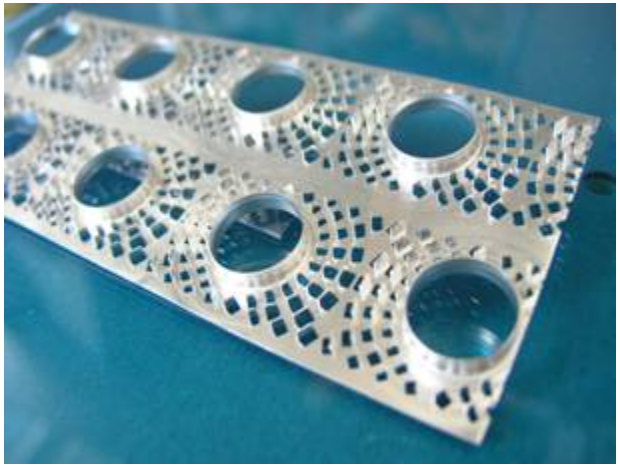


Chuck Kutscher
NREL
303-384-7521
Chuck_Kutscher@nrel.gov



Other: Tabbed Fin Heat Exchanger

- **PROBLEM:** Fan use for heat exchange is used in everything from house hold air conditioners, to large scale air cooled power plants. Energy use from these fans are typically 10-20% of total energy use/production by these systems.
- **DESCRIPTION:** The tabbed fin heat exchanger is a concept born out of the geothermal program in 2003. The driver behind the research was to invent a new type of air to liquid plate fin heat exchanger that reduced the electric power required to run fans.
- **IMPACT:** Energy savings with a 30% improvement in heat exchanger efficiency has the potential to save about 0.04 quads of energy, or $1.2B/yr at retail electric prices of $0.10/kWhr in household AC units alone.
- **IP POSITION:** NREL will license
- **FINANCING NEEDED:** Investment into manufacturing technique and tooling cost.
- **TECHNOLOGY STATUS:** The tabbed fin air cooled heat exchanger has gone through 3 iterations to improve its performance. The 1st generation design actually performed as well as state of the art fin surface types. By the 3rd iteration the heat transfer per unit fan power was increased by 15-19% over state of the art heat exchanger design.



Chuck Kutscher
NREL
303-384-7521
Chuck_Kutscher@nrel.gov

Tabbed Fin Heat Exchanger

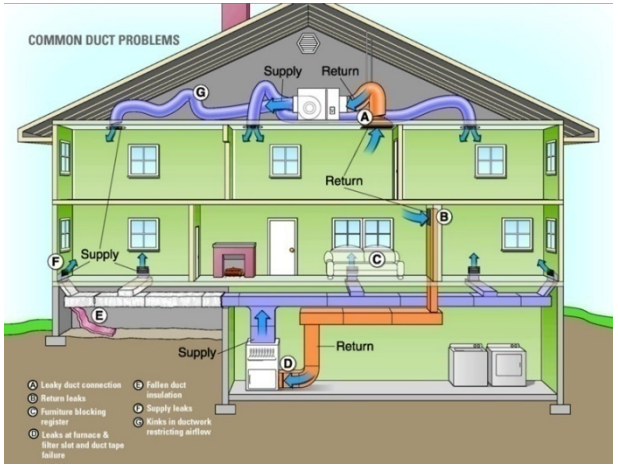
- The Tabbed Fin (T-fin) technology is ready to commercialize today, however additional iteration on the current form will likely see incremental improvements in its performance. Some R&D could go towards the combination of T-fin with louvered or slit fins to further improve performance
- No current production is underway
- More work is needed to determine a process to manufacture the T-fin and possibly improve the design for ease of manufacturing
- More work needed to determine if the technology can be applied to geothermal power plants (large scale air cooling of power plants)
- The cost is expected to be an upfront capital investment (tooling) and each part thereafter to be of equal cost to current SOA technology
- The product already improves upon the state of the art fins. This fin type is the new "state of the art" if it is commercialized
- Potential early/mature markets are high efficiency air conditioning, turbine jacket coolers, and air cooled Geothermal power plants
- Market size is entire air conditioning market in the US
- May need manufacturing partner. Previous partner may still be interested if additional money is allocated to improve design for manufacturability
- NREL will license the technology

Agenda

- Program Overview
- Buildings Market
- Technology Commercialization Opportunities
- Unexploited Investment Gaps

Unexploited Investment Gaps: Home Performance with Energy Star

- Contractors
  - Diagnoses home's energy performance recommendations and estimated costs and savings
- Home owners
  - Motivated by increase in comfort, positive environmental impact and lower energy bills
  - Decision based on credible information
  - Quality assurance program checks participating contractors work to verify it meets established protocol

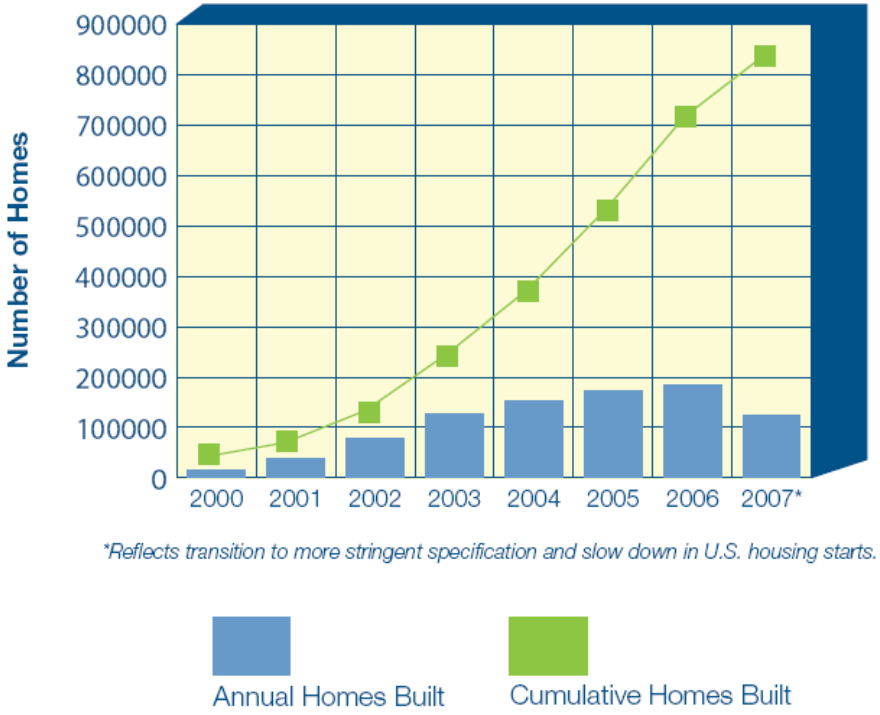


Appendix

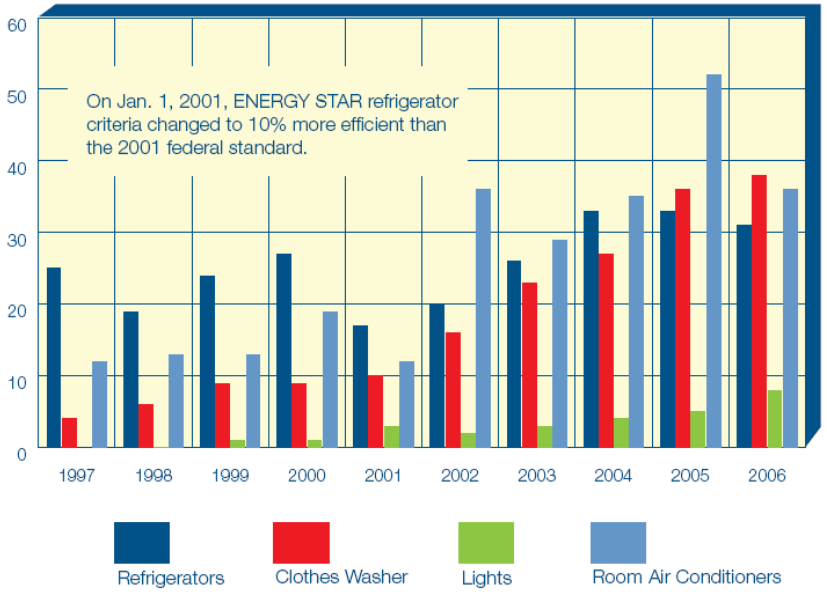
Buildings Market: Efficiency Trends

- Energy efficiency in homes has become more prevalent in the past

ENERGY STAR Homes Constructed



Market Shares of Selected ENERGY STAR Products



market penetration fluctuates with seasons and criteria revisions