Incorporating PV in Buildings: A Gathering of Eagles

Introduction and Purpose

Commercial buildings are technically ideal platforms for solar electricity production systems. The simplest application, i.e. **commercial rooftop PV**, involves arrays of photovoltaic modules mounted on flat roof spaces unobstructed by other equipment. Other applications where the PV array is an integrated architectural element, referred to as **building integrated PV (BIPV)**, have also been envisioned and demonstrated, including use of PV materials in skylights, windows, and other vertical and sloped portions of the building envelope. It is simplest to install commercial rooftop PV on existing roofs. Likewise it is simplest to implement BIPV during design and construction of new buildings. The technology for commercial rooftop PV is relatively well-established in parts of the global market, while technology for the most elegant and visionary applications of BIPV remains to be realized commercially.[1]

Because the National Renewable Energy Laboratory (NREL) is involved in creating and transferring renewable energy technology, and because the Sustainable Buildings Industry Council (SBIC) provides a forum and repository for the diverse industries and disciplines involved in sustainable building design and construction, it was natural for the two organizations to join forces to consider opportunities and barriers to widespread incorporation of solar electricity sources in existing and future commercial buildings in the U.S. The two organizations started from a premise that dialog between the existing building industry and its emerging solar electricity sector would lead to more and better integration of solar electricity systems in the nation's buildings.

A one-day meeting ("gathering") was envisioned and held on January 27, 2005, as a starting point for the proposed dialog; the strategy for the day was to bring together leaders ("Eagles") from the mainstream industry, including building owners, designers and constructors, as well as leaders (Eagles) from the industries involved in deploying commercial rooftop PV systems and preparing the way for the more integrated systems of the future. The agenda for this "Gathering of Eagles" started with a situation report on the U.S. PV industry, followed by more specific sessions, dealing first with barriers and opportunities of commercial rooftop PV and then with barriers and opportunities of BIPV. Arrangements were made for these sessions to be professionally facilitated in order to capture specific follow-up actions requiring collaboration between the existing industry and its new solar electricity sector. Specifically, the Eagles were asked to consider and respond to the following strategic questions:

- **Commercial Rooftop PV.** What are the near term opportunities for increasing the amount of rooftop PV on commercial buildings? For example, what can be done to encourage economically viable large-scale PV installations on commercial big-box retail and office park development versus the smaller PV arrays more widely installed for economic and public relations benefits? Should the U.S. look more closely at strategies that are successfully jump-starting the commercial rooftop PV market across Europe? How could such strategies be adapted to U.S. policy and constraints and political preferences?

[1] A notable exception is the award winning apartment building, *The Solaire*, 20 River Terrace, Battery Park City, NY (2003). Here BIPV is skillfully integrated into the façade (Cesar Pelli & Associates).

- **BIPV.** What are the near-term opportunities for increasing the amount of BIPV into commercial buildings? For example, there is a critical need for sustained and purposeful dialog between the building and solar industries. An outcome of this dialog may be an effort to target “plug and play” products that can be conveniently specified by architects and engineers, delivered through traditional building product supply channels, and installed by the traditional building trades. It is well-known that most prior research and development (R&D) addressing BIPV products have been disappointing when measured against its potential deployment. What can be done to encourage sustained and successful research and development towards more integrated products like AC modules and PV integrated insulated glass units?

To ensure that Eagles could spend time referring to rather than generating relevant information, a background paper was prepared that was organized consistent with the meeting agenda, i.e. starting with an overview of the PV industry and market, then summarizing the relevant aspects of commercial rooftop PV systems and their market, and finally highlighting areas where commercial rooftop PV and BIPV differ. The Eagles and invited observers were free to discuss issues raised as the meeting progressed.

The simplicity of the meeting agenda masked the complexities and overlaps of the market, e.g. commercial rooftop PV is evolving steadily in the direction of more integrated systems, and likewise future BIPV applications will likely incorporate technical elements and market experience from on-going commercial rooftop deployment. Further, over time the boundaries between the PV sector and the remainder of the building industry are likely to blur as has occurred when other new technologies have been absorbed and embraced as standard practice.

This paper presents a basic market analysis of solar energy and its use in a specific segment of commercial construction. In addition, the paper incorporates the observations and views of those who participated in the Gathering of Eagles along with proposed actions and recommendations. As energy issues continue to impact the American economy, this timely dialog between various constituencies will, ultimately, lead to the increased use of solar energy solutions in future development and construction projects as one means of reaching energy independence in the new millennium.

Technology and Market Overview

Solar Electricity for Commercial Buildings: Status and Vision

Photovoltaics (PV) do more than offer energy alternatives for this century and the promise of truly renewable energy systems. Commercial building owners who appreciate and/or understand the added value of a truly sustainable energy strategy for new construction today install PV systems in many diverse American climates. Solar energy offers the possibility of a secure and dependable source of energy where commercial interests are vulnerable to failures of the urban/suburban electric grid. A well-planned renewable energy strategy may be worthwhile today due to continued volatility in world energy supplies and economic impacts, which have resulted in higher energy costs. Although the cost of stand-alone and/or roof-mounted and built-in PV (BIPV) has historically been high, increased use and better energy returns have resulted in a reduction in the price of PV. The value of PV systems is gaining worldwide recognition as a major energy source for the coming decades. To reach the level of solar usage in other industrialized nations, the United States must take action now to ensure that renewable energies receive equivalent tax advantages and federal investment subsidies, which are routinely applied to producers of natural gas, nuclear power, and fossil fuels.

A Gathering of Eagles: Public/Private Collaboration to Realize the Vision

The National Renewable Energy Laboratory (NREL) is a leader in the U.S. Department of Energy's (DOE) effort to secure an energy future for the nation that is environmentally and economically sustainable. NREL and DOE sponsored the Gathering of Eagles, which was held on January 27, 2005. The purpose of this meeting was to encourage a greater market share of PV and BIPV in "big-box" retail and other commercial applications throughout the United States.

NREL recognizes that a truly sustainable building can only be achieved through a whole building design approach that includes energy efficiency and renewable energy strategies at its core. The members of the Sustainable Buildings Industry Council (SBIC) share this recognition. SBIC identified and convened two key groups: solar energy manufacturers and solar energy users. SBIC was founded in 1980 as the Passive Solar Industry Council. In addition to representing the solar power industry, SBIC's members include manufacturers of sustainable products, trade associations, architects, engineers, and individual members. The mission of the Council is to promote the design, affordability, energy performance, and environmental soundness of America's homes and buildings while "advancing a 'whole building' approach to design."™

So Many Roofs: Where to Start?

There is significant on-going commercial rooftop PV deployment in the U.S. One major driver is the large unencumbered area of suitable roof space. Two large potential roof "resources" in the U.S. include big-box retail stores and other commercial development throughout the United States

The potential of such commercial buildings as platforms for solar electricity production is significant, leading New Jersey solar advocates to brag that the state has the potential to be the Saudi Arabia of rooftop solar electricity. Bill Jeppesen of RWE Schott Solar estimates an impressive 481 square miles of useable roof space on single story U.S. buildings.[2] At a nominal 100 megawatts (MW) of PV per square mile, this roof space could support an equally impressive nearly 50 gigawatts (GW) of solar electric generating capacity. Total U.S. installed electric generating capacity is less than 1000 GW.

Trends Favoring Solar Energy

With this much potential there must be a catch, or we'd be seeing more solar on commercial buildings. The catch is that most commercial building designers, owners, and developers view solar energy as environmentally correct and one of the major options available to reduce dependence on the electric grid, but they rarely view it as **economically advantageous**. This may be changing—as utility companies continue to

[2] Bill Jeppesen, "Rooftop Solar Power," reFocus (July/August 2004).

increase their rates and the price of producing solar energy decreases—solar power is now comparable, in some energy markets, to energy supplied by the utility power grid. This is true in geographic areas of the United States where traditional utility rates are high and photovoltaic (PV) effective capacities are high.

And yet, there continues to be a "disconnect" between market potential and actual commercial use of solar energy. In the context of new buildings, architects are unsure of the technology and how best to integrate it into an overall design strategy. Developers may believe that the associated costs of solar energy cannot be recouped over the lifespan of the structure. Building owners may be suspicious of the overall reliability of solar energy. So, the question remains: why is the market for solar energy less active in the U.S. than in other industrialized nations, and what can be done to bridge the gap?

Recently (2004-05), the price of oil has risen dramatically due to a number of reasons: continued unrest in the Middle East and other world-wide political upheavals, weather (i.e. hurricanes in Florida), perceived shortages, and the rising demand of manufacturers in economically developing regions such as China, India, and the Pacific Rim. This is also true of natural gas as demand rises in North America while supplies fail to keep pace with increased usage. For example, the price of natural gas recently rose 17% on the New York markets based on the announcement that natural gas supplies were very low as the winter heating season commences.[3]

Many European countries have taken the lead in solar deployment.[4] The U.S. led the way early on in PV conversion technology and still holds its own—now Japan has taken the lead in both technology and manufacturing. As a result, not only will Japan become less dependent on fossil fuel, but also its industry will have a dominant share of markets for PV modules and related manufactured components. In the United States, government investment in renewable energy R&D declined sharply in the early 1980s and has not recovered, as policy attention has focused on encouraging domestic production of oil and gas. Even so, many energy analysts see world oil production at the brink of being eclipsed by demand. Some believe that we are already at this point. Others believe that we will reach the brink within a decade's time. Clearly, there is a need to encourage renewable energies in commercial buildings.

U.S. PV Industry

Capabilities and Limitations

The U.S. PV industry has evolved almost completely independent of the U.S. new building industry. This is true in part because, as a still-emerging industry, it approaches its market opportunistically, and many of its best sales opportunities in industrial nations occur in the context of existing buildings that greatly outnumber "new" buildings in the development, design, and construction phases at a given point in time. The PV industry has developed the competency and strength to sell and install PV systems on existing buildings with little help, attention, and/or encouragement from the commercial building sector. This is true as well for all of the tertiary building services and industries integral to new commercial development: these services and industries are not supporting or encouraging new solar power strategies.

---

[3] See the federal government's energy management page: *www.eia.doe.gov*.
[4] Notably, the Swiss and many European Union nations have made great strides in solar power usage.

Thus, lack of mutual project experience and on-going commercial relationships between the PV industry and building purchasers, developers, designers, and planners is one of the most significant barriers to the incorporation of PV in the plans and designs for new commercial buildings. In addition, solar power is not competitive in economies of scale in relation to fossil fuels due to the latter's significant government subsidies. Relative subsidies for solar and traditional sources vary across the U.S.; the playing field has only recently become level in a few states, and demand is not yet at a level to drive major scale economies that can be expected going forward.

Revenue

Based on 103MW of module shipments from U.S. manufacturers in 2003 at prices in the $3/Wdc range and 67MW of system installations having non-module costs assumed to average in the $5/Wdc range, 2003 U.S. PV industry revenues can be roughly estimated in the $650 million range.[5]

Global Market Trends

The U.S. PV manufacturing industry dominated global cell and module manufacturing for the first 20 years of industry growth, accounting for nearly 100% of global cell and module shipments initially and nearly 50% through the mid-1990s. The U.S. industry's share dropped precipitously in recent years as some U.S.-based manufacturing operations have struggled while markets have grown dramatically in Japan, Germany, Switzerland, China, and other major economies, encouraging major capacity expansion in these nations. In recent years, the market for PV on residential and commercial buildings has grown at compound annual growth rates of approximately 30%, driving global market growth. Practically insignificant ten years ago, this market segment now accounts for roughly 60% of all new PV installations globally.[6]

The U.S. PV manufacturing industry now manufactures and ships approximately 15% of product used globally; more noteworthy is the fact that its share continues to decline in the absence of nationally effective on-grid residential and commercial market development programs and subsidies. This is problematic because the United States will continue, in the foreseeable future, to be dependent on fossil fuel imports and it will no longer be competitively positioned to market alternative power equipment and technologies to other nations and cartels. It can be safely predicted that there will be an increase in the total American trade deficit, already at record highs (2005), as the United States continues to rely on vast quantities of foreign oil.

---

[5] PV costs and prices are often indexed to the DC power output of the PV cells and modules. However, in applications connected to the grid, a more meaningful index is the AC power output of the complete system, which can be estimated as roughly 80% of the DC array rating. This accounts for both power conversion losses and the fact that the cells and modules produce less power at outdoor operating temperatures than at the indoor temperature at which they are tested. See, Paul Maycock, "PV Market Update," Renewable Energy World (July-August 2004): 88.

[6] According to the electric utility for Washington, D.C., the costs of fuels, over the past few years have increased as follows: natural gas, 54%; heating oil, 97%; coal,113%; and, gasoline 67%. See, Yolanda Woodlee, "Higher Power Bills A Surprise to Many," Washington Post, 20 January 2005, p. 3 (DE).

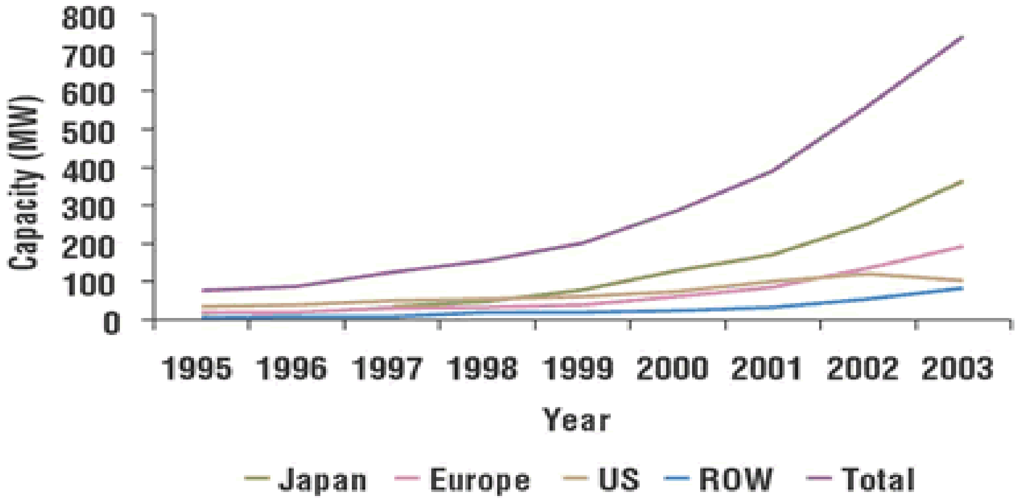

Fig. 1. World PV production in 2003 (MWp-DC) from Renewable Energy World, *ibid*.

U.S. Market and Industry Trends

Market analyst Paul Maycock[7] divides the U.S. market into three major application areas, two of which may be categorized as “stand-alone”, i.e. a battery system relying on PV for daily or periodic recharge is the only source of power. Such applications can include systems typically sized at a kW or less for powering remote buildings, boats, motor homes, travel trailers, vacation cottages, and farms. his also can include an expanding array of commercial and industrial applications requiring secure, highly reliable power, e.g. remote repeaters and amplifiers for telephony, television, and secure communications as well as remote sensors monitoring weather, traffic, pollution, and power for traffic lights and signs and for distributed lighting including parking lots, bus-stops, billboards, and navigation.

Maycock’s “on-grid distributed sector” consists primarily of PV arrays that are mounted on homes and commercial buildings and feed DC electricity to power conversion systems (see definitions, Attachment 1, **inverters**) for conversion to AC electricity at voltages and frequencies suitable for feeding power to building circuits. The split between residential and commercial applications in the U.S. is determined today in part by the funding allocations within incentive programs and the levels of incentives available for different application categories. Allocations and levels, in turn are influenced by the market emphasis and strategies of the most active and aggressive PV retailers. For example, the California Energy Commission estimates that approximately 71.5MW of grid-connected PV systems have been installed with more than half of the total connected in the past two years. Of the total, 10-20% is estimated to be located on commercial sites.[8]

The downstream PV industry in the U.S., i.e. distributors, dealers, and system integrators, is experiencing dramatic but geographically very uneven growth. While federal government-based capacity additions have slowed relative to the rest of the

---

[7] Maycock, *op. cite*.
[8] Jeppesen, 33.

world, incentive programs in California, New Jersey, and other states[9] are being developed and implemented at a somewhat rapid pace. As a result, shipments of applications within the U.S. increased from 24MW in 2000 to 67MW in 2003, such that U.S. market growth has actually kept pace with the rest of the world over the most recent three-year period. Note that California represents the sixth largest economy in the world, and its incentive programs, though commenced later than Japan's and Germany's, have gained momentum and are starting to have an impact on overall global market growth. Most new PV capacity in CA is on homes, but commercial buildings account for a significant share in the range of 10MW per annum.

PV Industry Structure

As suggested above, the U.S. industry structure reflects a value chain that starts with raw material vendors and ends with the building owner or other end user. Companies in the value chain may integrate forward or backward, e.g. module manufacturers may also sell systems and retailers may perform limited value added component assembly and/or provide turn-key installations services. However, industry maturation is driving specify cationialization, e.g. the major manufacturers except for BP Solar have mostly withdrawn from commercial activity involving system integration. Value chain elements include:

Raw materials–provided by suppliers of solar grade silicon, framing materials such as aluminum, glass for module substrates and superstrates, encapsulation materials such as Tedlar and ethyl vinyl acetate, and electronic components for power conversion, charge control, and array protection.

Sub-components–provided by manufacturers of cells for modules and of electronic components for power conversion.

Value added components–provided by fabricators and assemblers of modules and inverters (for on-grid applications), as well as charge controllers and batteries (typically for off-grid installations).

Manufactured systems–provided by system integrators having factory assembly and product packaging capability. These can include OEMs in off-grid products such as electric fence chargers or RV accessories or by companies serving a particular segment of the on-grid market such as residential or commercial rooftop, e.g. PowerLight Corporation, Berkeley, CA.[10]

Distribution and sales–provided by local and regional companies organized to capture volume pricing from manufacturers and serve local and/or regional or national markets for specified applications, e.g. water pumping, residential rooftop.

System engineering and installation–provided by distributors, dealers as well as by contractors in solar or otherwise able to offer solar installation services, e.g. the IBEW provides training to electrical contractors interested in diversifying into solar.

Finance–provided by installers or end-users and now being offered by firms like SunEdison LLC[11] for tax and incentive-advantaged commercial building applications.

---

[9] Massachusetts has funded a number of BIPV projects from its Renewable Trust Fund.
[10] Herein referred to as, PowerLight.
[11] See, *www.sunedison.com*.

Operation and Maintenance–typically provided by the end user but increasingly offered as a service by system integrators and local distributors and installers.

Commercial Rooftop PV Market

PowerLight currently dominates the U.S. market for large commercial building rooftop installations and applications of its manufactured systems are representative of the leading commercial building PV applications. For purposes of understanding current PV industry experience and marketing emphasis, PowerLight's list of case studies can be organized in the following major categories: universities and schools; corporate office[12]; city and county government; other government; manufacturing; national retail[13]; and, wineries and resorts.

Big Box Retail—Rooftops Everywhere

Cities, towns, and rural or exurban areas have changed dramatically over the past decades. The proliferation of discount, general merchandise stores such as Wal-Mart, Target, and K-Mart have had a significant impact on our urban and rural landscapes in almost every conceivable way. Changes in consumer buying habits have, in the past, been linked to changes in the retail marketplace. Many communities are increasingly aware of both the positive and negative impacts of large-scale retail facilities in ways that could not have been imagined even a few years ago.

What is big-box retail? Big-box retail facilities are large industrial-style buildings or stores with footprints that generally range from 20,000 square feet to 200,000 square feet. While most big-boxes operate as a single story structure, they typically have a three-story mass that stands more than 30 feet tall.[14] Big-box retail stores are usually differentiated from individual anchor stores that are an integral design strategy for most suburban and exurban shopping malls. Big-box stores are better defined/explained and understood though their product categories. For example, book retailers like Barnes & Noble typically range from 25,000 to 50,000 square feet. In the category of general merchandise (i.e. Wal-Mart) and specialized merchandise (i.e. Home Depot), big-box retail stores range from 80,000 square feet to 150,000+ square feet. Big-box stores have acres of rooftops, which are suitable, in many cases, for commercial rooftop PV. However, because big-box retail stores are designed for relatively short projected life spans, these roofs may not be capable of structurally supporting additional equipment/machinery, as well as installers and technicians.

Obtaining information and statistics is difficult and time-consuming at-best. Most retailers are reticent to share hard data on store construction/expansion unless required by government agencies such as, the U.S. Department of Commerce. SunEdison contributed a summary, based on data obtained from the National Retail Federation, of big-box retailers including information on number of stores, geographic locations, interest in solar power, etc. (see Attachment 2). The table is an interesting snapshot of the total number of big-box stores by brand with the potential for solar power generation through rooftop PV.

---

[12] This category includes low-rise office parks in suburban and exurban locations.
[13] National retail includes large "big-box" stores, e.g. grocery and home improvement stores.
[14] State of New Jersey, Office of Planning, *Creating Communities of Place*. New Jersey, December 1995.

Big-Box Retail—Market Potential[15]

Big expanses of unused space—rooftops of big buildings! It's true that air-conditioning systems and cellular towers litter rooftops. But, while cellular accounts for 11 percent of total income on the largest buildings, large big- box buildings are not ideal for cellular. They are usually surrounded by parking lots, so no trees or large buildings can obscure sunlight. Aesthetics are not an issue on these building rooftops, so they are ideal for photovoltaics.

In 2003, the top 100 retailers carried out $1,308,457,454,000 worth of business. Warehouse and wholesale clubs were 6.5 percent, supercenters (big box stores) were 10.6 percent, and supermarkets were 19.6% with medium size stores (i.e. Sears, JC Penny) were 3.1 percent.

The top tier has Wal-Mart, the largest with 4,688 stores; Walgreens has 4,227 stores; Kroger with 3,744 stores; and Albertsons with 2,305 stores. The next tier is Sears with 1,992 stores; Safeway with 1,817 stores; and Home Depot's 1,707 stores followed by Target with 1,553 stores; and K-Mart having 1,511 stores. Office supply stores, also considered big-box, are primarily Staples with 1,559 stores and Office Depot with 1,089 stores. Nationwide, there are nearly 600 Wal-Mart Supercenters, Sam's Clubs and Neighborhood Markets. In 1995, Wal-Mart Stores, 239 Supercenters, 433 Sam's Clubs, and 276 international stores had sales of $93.6 billion.[16]

Wal-Mart presents as a fascinating case study for the use of PV/BIPV:

<u>Wal-Mart Supercenters</u>

- 183,106 square feet (average)
- Stores range in size from 108k square feet to 241k square feet
- ½ of each roof equals 450 kW output on average x 400 Supercenters = 180k kW

<u>Sam's Clubs</u>

- 122,107 square feet (average)
- Stores range in size between 90k and 160k square feet of building area
- Half of each roof equals 300 kW on average x 300 stores or 90k kWs

<u>Wal-Mart Stores</u>

- 95,262 square feet (average)
- Stores range in size from 30k square feet to 155k square feet
- Half of each roof equals 235 kW on average x 1900 stores or 446,500 kWh

Assuming only half the roof space of approximately 60% of the stores in each size class, Wal-Mart alone could produce 716,500 kWs or 716 MWs of output midday equaling about one nuclear power plant alone. This is a conservative output estimate assuming 1 kW per 200 square feet, which is on the low side, half the roofs (more likely 70% would be free), and probably 80% of the stores could easily accommodate commercial rooftop PV.

---

[15] "Big-Box Retail—Market Potential" was submitted by Scott Sklar, The Stella Group, Ltd.
[16] Most data on Wal-Mart obtained from the National Retail Federation: *www.nrf.com*.

Cost Effective Onsite PV Solutions for Big Box Retailers[17]
It was determined that there should be a streamlined way for installing PV on the rooftops of large big-box retail stores. PowerLight submitted the following methodology:

1. Develop an acceptable framework for valuing commercial PV systems for big-box retailers including avoided energy, image/PR,[18] environmental credits, faster permitting, etc.;
2. Determine ways that PV installations on big-box retail sites could be implemented more cost-effectively by, for example, design standardization;
3. Apply the value framework and creative cost savings ideas to actual sites under management of the participating big-box retailers to help them prioritize sites for possible PV installations.

The process described above for focusing on a single type of commercial customer can then be replicated for other customer types such as hospitality, office buildings etc.

Office Parks—Mushrooming Exurbia
The exurbs are booming: places, for example, like the Interstate-4 corridor in central Florida; Loudoun County, Virginia; and, Henderson, Nevada are experiencing growth rates far greater than in any urban center in America.

In a manner not seen since the onset of the Industrial Revolution, technology is reshaping the landscape of American life. There is a debate afoot as to whether computer networks and the Internet are revolutionizing productivity, but there can be no argument about whether they are revolutionizing the organization of space. Just as the railroad, telegraph, and mass-production factory produced the manufacturing cities and towns of the industrial economy, the rise of the digital economy is creating a new geography of economic life. The U.S., notes well-known author and educator, Witold Rybczynski,[19] is decentralizing faster than any other society in history: fifteen of the largest twenty-five cities have lost four million people since 1965, while the nation’s total population has risen by sixty million. But while the large "vertical cities" have lost population, mid-sized horizontal cities better adapted to the automobile and better able to offer a quality of life comparable to the suburbs have grown rapidly.

The trend toward economic dispersion and virtualized business seems virtually unstoppable. Estimated at $43 billion in the 1990s, electronic business-to-business transactions grew to more than $1.3 trillion in 2003. To some, this shift to cyberspace—the increasingly global nature of business and ever more sophisticated telecommunications technologies—has made it easier for companies and elites to ignore their responsibilities to a particular city or place. These abrogated responsibilities include regional planning, sufficient infrastructure, reliable and renewable sources of energy, and sufficient, affordable housing. Now, this notion of a "placeless" and "foot-loose" world may be further exacerbated by the development of virtual companies and distributed work. In some ways, the problems of ever-increasing office development may be solved by on-going economic change and upheaval. Nevertheless, the sheer amount

[17] Contributed by Janice Lin, PowerLight Corporation.
[18] Regarding PR for big- box retail, some manufacturers have been asked NOT to publicize some high-profile PV installations. Thus, the level of PR is really dependent on the customer site and corporate policy.
[19] See Witold Rybczynski in the Wharton Real Estate Review (Fall 1997).

of suburban rooftop space available for PV on current and planned commercial office space is considerable.

For the past 20 years, in many metropolitan areas, the majority of construction, in particular in office development, occurred in suburban areas. In cities like Dallas, Atlanta, and Washington, D.C., where beltways around the city were built, office development followed to such an extent that conglomerations of office towers rival, if not outpace, downtowns. So much suburban office development has occurred, especially in the 1970s through the 1990s, that on a national basis, suburban vacancy rates have consistently ranked higher when compared to downtown vacancy rates. This year, as in the past three years, the suburban vacancy rate has been over 10%, while the downtown vacancy rate has averaged about 5%.

Over the past several decades, low-rise office parks or campuses have become widely built outside of major urban centers. Conversely, as business has shifted beyond suburban areas into exurbia, this development model has become increasingly followed as the United States has moved from a manufacturing-based economy to a service- and information-based economy. People in established suburbs are moving out to vast sprawling exurbs that have broken free of the gravitational pull of the cities and now exist in their own world far beyond. Ninety percent of the office space built in America in the 1990s was built in suburbia, usually in low office parks along the interstates. We now have a growing group of people who not only do not work in cities, they do not commute to cities or go to the movies in cities or have any contact with urban life. We now have these huge, sprawling communities with no center. A case in point: Mesa, Arizona, has more people than St. Louis or Minneapolis.

The Washington, D.C. metropolitan area is an example of this type of office development. Although the city center continues to enjoy low vacancy rates, new office space in the form of office parks is being planned and constructed in the suburban and exurban areas surrounding Washington, D.C.[20] For example, the entire amount of new office construction in the metropolitan area is 10.22 million square feet. In outer ring areas and exurbia, this translates to low-density office parks for many corporations and start-ups interested in operations space outside of the urban center. Many office parks feature ancillary development including shops, motels/hotels, and other services. The extensive construction of office parks requires the necessary expansion of transportation, infrastructure, and housing, which may not occur in tandem with on-going development. Needless to say, the electric grid can be overburdened as suburban and exurban areas are constructed practically overnight. Many of these office park developments feature flat roofs ideal for PV with façades readily adaptable to BIPV.

According to McGraw-Hill Construction, the seasonally adjusted amount of new construction during 2004 in the United States was more than $570 billion: “Total construction continues to move at a healthy pace, and it’s now virtually certain that full year growth for 2004 will exceed the 5% gain in 2003.”[21] Although nonresidential building fell slightly during mid-2004, it stood at a seasonally adjusted rate if $157.7 billion. However, office construction experienced a gain of 9%, hotel construction 8%, with development consisting of several high profile projects in the biggest urban areas (New

[20] “Local Real Estate Trends,” Washington Post, 13 December 2004, p. 1, 3(E).
[21] Robert A. Murray, vice president of economic affairs for McGraw-Hill Construction, quoted at: *www.construction.com*.

York, Chicago) and new office campuses in suburbia, in the south and west. Notably, electric utility construction was down, by August 2004, 28% from 2003, a sign that the lessons of the recent blackout have not translated into electric utility infrastructure upgrades.[22]

Commercial Rooftop PV Systems

System Size

There are a number of factors other than building electricity consumption that influences the sizing of commercial rooftop PV projects. Generally, there is an incentive to make the PV system as large as possible within the constraints of roof area and incentive structure. Generic upper limits are determined either by usable roof area or by annual building electricity consumption. A rule of thumb is that about a kW of peak power and 1000 to 2000kWh annually (depending on location of building and mounting scheme) can be expected from ten square meters of suitable roof. The average size of a commercial rooftop PV installation continues to increase in the U.S. and other regional markets. But there are limits on a building-by-building basis, including both roof area limitations and incentive rules that sometimes have eligibility criteria relating to system size. Such installations are increasingly economically driven. Some PV project costs related to project development and financing, permitting, design, procurement, and installation, are relatively insensitive to project scale; it is natural in the context of a cost-effective project to spread these costs over as large a base of economic benefits as possible. Also, if incentives result in a profitable project for investors, sizing and design choices are driven by need to extract as much profit from a given roof.

Net-Metering and “Feed-In” Arrangements

Whereas in Europe utilities are required by law to purchase independently produced solar electricity at prices considerably higher than even their retail rates, in the U.S., typical net metering laws only obligate utilities to accept solar electricity production exceeding the building’s consumption to the point that annual net purchases from the utility are zero. Any feed-in beyond that is accepted at the utility’s (typically very low) marginal generation costs.[23] Obviously, there is little incentive to install solar power systems that can generate more electricity than needed for daily business operations if there is no means to profit from selling excess electric production back to the local power grid.

[22] *Ibid.*
[23] See, *www.awea.org/faq/netbdef.html* for a detailed discussion of net-metering.

Fig. 2. PV installation by PowerLight for Target Corporation in Southern California (image supplied by PowerLight).

Project Example: Whole Foods Market® Edgewater, New Jersey[24]

<table>
<tr><td>Application Type: BP Solar EnergyMax™ Roof System
Location: 905 River Road, Edgewater, NJ 07020
Project Completion: May 2004
Project Size: 125 kW (peak)
Electricity Production: 125,000 kW hours per year</td><td></td></tr>
<tr><td colspan="2">Project description
Whole Foods Market, Inc., has become the first major food retailer in the Northeast to introduce solar energy as a power source at its Edgewater, NJ store. Covering 14,000 square feet on the store's roof, the system will meet more than 20 percent of the Edgewater store's needs. The State of New Jersey and the New Jersey Board of Public Utilities (BPU) through the New Jersey Clean Energy Program, provided a $500,000 rebate on the cost of the system. System owner A-Net Energy through BP Solar partner, SunEdison, covered the rest of the cost. Whole Foods Market in return agreed to purchase energy produced by the BP Solar electric system over a 20-year period at a pre-determined rate. In sum, Whole Foods Market received a guaranteed cost of electricity from clean solar power with no capital investment required.</td></tr>
</table>

[24] Source: BP Solar web site: *www.bpsolar.com*.

Commercial Rooftop PV Economic Model and Financing Options

The basic parameters of commercial rooftop PV economics and finance are system installed cost and annual electricity production.

System Installed Cost

Installed cost of course depends on local construction costs and solar competencies. More importantly, it depends on array mounting and orientation details overall project scale and timing. Scale dependency and timing are roughly quantified in the following tables. In summary, the installed costs of commercial rooftop PV systems can vary from as low as $5000/kWac[25] to as much as $10000/kWac with project scale. The costs of projects of all sizes are expected to continue on the well-established downward path based on technology improvements and economies of higher volume component manufacture. Clean Edge has recently provided a generic forecast for module and installed costs that appear to be consistent with experience and relatively conservative assumptions. Again, this landscape may change radically if geo-political conditions result in significant price spikes in the cost of fossil fuels.

Table 1: Current and Projected PV Costs — 2003-2010[26]

	2003	2004	2005	2006	2007	2008	2009	2010
Installed System Cost (per watt)	$6.40	$6.00	$5.76	$5.54	$5.20	$4.88	$4.68	$4.50
Cost per kilowatt-hour	17–29¢	16–27¢	15–26¢	15–25¢	14–24¢	13–22¢	13–21¢	12–20¢
Costs shown are installed prices without subsidies for large-scale, grid-connected industrial systems and low-cost residential systems. Source: Clean Edge, Inc.								

Scale Economies

Commercial PV/BIPV project costs are not independent of project scale. Taking a 500kWac project having an installed cost of $3,000,000 as a baseline, the effects of project scale are suggested in the table below.

[25] Kilowatt hours alternating current (kWac).

[26] From the Clean Edge web site, *www.cleanedge.com*: “Costs per kWh projections are based on both commercial and residential financing options and do not include tax credits, subsidies, and other incentives likely available to end users which can lower costs significantly. Today’s large-scale systems can clock in at around 10 cents per kWh for direct-user costs, when one considers subsidies and tax credits in places like California.This compares favorably to electricity rates averaging 8 to 12 cents per kWh in the U.S. (and often much higher in CA), and rates hovering closer to 20 cents per kWh in such places as Japan and Europe.”

Table 2: Scale Economies–Commercial Rooftop PV System Costs, Current Year[27]

System Size (kWac):		50-100	100-250	250-500
Modules		3	3	3
Power Conversion		.8	.75	.5
Installation	($/kWac)	1.5	1.25	1
Direct Engineering and Procurement		1.5	1	.5
Indirect		2.2	1.5	1
Total		9	7.5	6

Module prices are assumed to be roughly the same, since relatively large customers for projects of this size purchase them in bulk. Installed DC to AC power conversion and grid interconnection costs are assumed to range from $500/kWac for inverters rated at >100kW to >$1000/kWac for inverters in the 50kW range and smaller.[28] Installation costs would vary inversely with project scale, reflecting the influence of both fixed and area related costs. Direct engineering and procurement costs would be relatively independent of project size, and indirect costs related to overhead and profit would scale roughly with direct costs.

Avoided Grid Electricity Purchases

In the commercial rooftop PV economic model avoided electricity purchases represent a cost saving attributable to the PV system, a form of virtual revenue. Commercial electricity prices vary regionally but are typically the sum of multiple components that are captured in the form of “fixed charges,” reflecting the cost of operating and fueling the utility system on a continuous basis, and “demand charges,” reflecting the incremental cost of meeting demand during higher usage periods. Currently commercial building owners pay an annual average rate of around $0.1/kWh, which may reflect fixed charges as low as $0.05/kWh and demand charges as high as $0.20/kWh during peak demand periods. In locations where the utilities experience a peak demand in the summer daytime hours, the avoided costs attributable to a commercial rooftop PV system will be higher than in other locations because of the good match between solar electricity delivery and building energy usage. A good match is illustrated in the Fig. 3, below.

[27] Source: En-Strat Associates LLC. See, *www.en-strat.com*.
[28] Miguel Alonso Abella and F. Chenlo, “Choosing the Right Inverter (for grid connected PV systems),” Renewable Energy World (March-April 2004), 136.

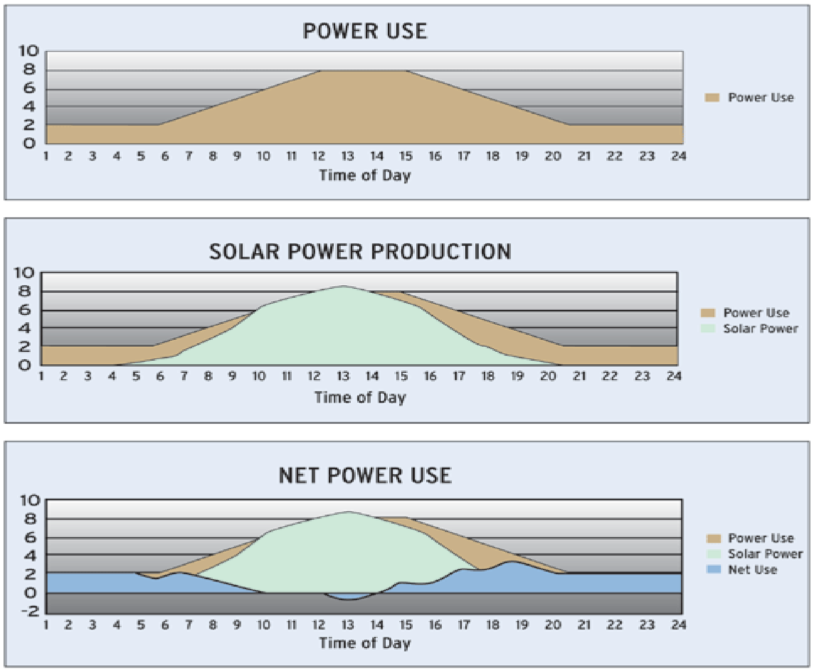

Fig. 3. Illustration of load leveling by a commercial rooftop PV system[29]

Other Economic Factors

Other key parameters of first order commercial PV economics and finance include:

- Annual electricity production in the range of 1000-2000 kWh/kW depending on location and array orientation
- Average annual O&M costs in the range of 1% of the initial project cost
- System performance warranty of up to 10 years at 90% of initial performance
- Economic life estimated at 30 years
- Capital charge rate, typically in the range of 6-10%, based on a mix of equity and debt consistent with project risk and financial model

Financing options

Financing options and choices can be the difference between an economically attractive project and a clearly unattractive project. They depend on system ownership by one of the following:

- Corporate owner
- Public agency owner
- Third party investor

Financing often hinges on incentives, which, as noted above, vary widely from state to state; restrictions apply. Typically they come in the form of a rebate of a portion of the installed cost and/or a form of tax abatement such as a tax credit or permission to accelerate depreciation for income tax purposes:

[29] Lynn Merrill, "Solar Power Rising," Distributed Energy, (Nov/Dec 2003).

State Incentives[30]

- California: 50% installed cost rebate and additional 15% state tax credit
- Massachusetts: 75% installed cost rebate
- New Jersey: 60% installed cost rebate
- New York: 70-80% installed cost grant

Federal Incentives

- 10% Federal Tax Credit
- 5-year Accelerated Depreciation

Excellent work has been done (with NREL financial support) to understand how regional variations in the economic parameters and incentives outlined above affect commercial rooftop PV financial viability. Determining the breakeven electricity price is an indicator of commercial rooftop PV economic viability. The following map refers to the ranges of commercial rooftop PV electricity costs as an indication of when and in which states commercial rooftop PV will be in the competitive range versus grid electricity.[31]

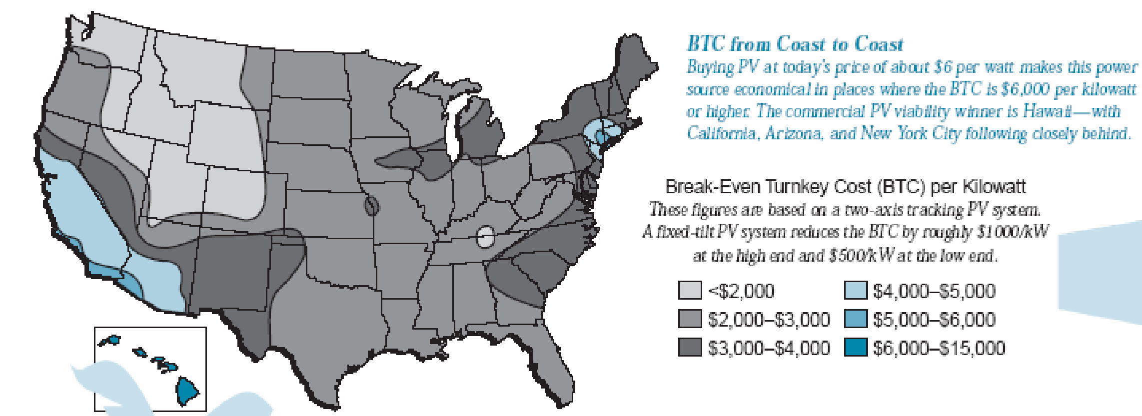

Fig. 4. Valuation of Demand-Side Commercial PV Systems in the United States

Private financing options

Typical commercial PV projects leverage both tax incentives and first cost offsets available from state clean energy funds. If a building owner has good credit and low borrowing costs, plus tax obligations that can be reduced by investing in solar, then in certain states, a rooftop solar project can be an attractive investment at today's installed system prices. If the building owner prefers to conserve capital or cannot fully exploit tax-leveraging opportunities, companies in commercial rooftop PV project finance are emerging. These companies broker low risk deals between companies interested in hosting commercial rooftop PV projects and investors interested in long-term investments having modest but predictable tax-leveraged returns. [32] These companies essentially provide solar energy services that include financing, design, construction, commissioning, and operations and maintenance (O&M).

---

[30] A comprehensive database of state incentives for renewable energy is available at: *www.dsireusa.org*.

[31] Source: Richard Perez (ASRC, The University at Albany), Howard Wenger (Pacific Energy Group), and Christy Herig (NREL): "Valuation of Demand-Side Commercial PV Systems in the United States," (1998).

[32] SunEdison (*www.sunedison.com)* is an example of this type of company.

Public financing
For public agencies having access to low-risk tax-exempt bond funding, basic PV project economics can be equivalent to tax leveraged privately financed projects provided the agency has access to the same state incentives as private building owners.

Current BIPV Solutions for Commercial Buildings

Dimensions of Building Integration
PV building integration can best be viewed as a continuum. At one extreme are PV applications in which the building serves only as a platform for the array and the energy produced is fed directly into the local grid with only incidental effect on building electricity supply and/or demand. At the other extreme is the vision of PV as a multi-functional element of the building envelope seamlessly supplying power to building circuits while integrated into fenestration or façade elements of the building so completely that the appearance and traditional functionality of these elements is not compromised at all and may be enhanced in terms of optical impact, performance, color, shade, and texture.

From a scientific view applications are limited only by the imagination of the architect and technical resources available to create the envisioned solution. From a building design view, applications are limited by engineering and construction budgets and the availability of products qualified for service in the envisioned application. From a product supplier view, applications are limited by the existence of a profitable market for the envisioned solution. Current BIPV applications fall into two categories:

Economically Driven Applications
The degree of integration is sacrificed in order to make use of mass produced and fully qualified components. Use of such components is currently the key to projects that are either fully or marginally cost-effective in the U.S.

Architecturally Driven Applications
These have costs and less attractive energy economics due to customization costs related to the use of low volume components produced to a non-standard and related to the custom engineering and installation costs occasioned by their use. Such applications may also incur higher operating and maintenance costs and/or lower energy productivity due to quality compromises in component production, incomplete product qualification, sub-optimal radiation capture, etc.

Both application categories are quite active, overseas; however, they are served through market channels that can differ greatly depending on the degree of integration. As noted above, existing buildings provide the most favorable context for economically driven applications, while new buildings provide greater flexibility to consider non-economic attributes. New building projects in which PV is to be architecturally integrated typically require the attention of a PV system integrator in custom applications (versus repetitive applications of the same basic array layout and mounting scheme). For example, Solar Design Associates[33] has a well-earned virtual monopoly in the U.S. in delivering this service. Some larger architectural firms are developing some of the expertise required, but the relative scarcity of customer requirements for BIPV in the U.S. is holding others back.

[33] See, *www.solardesign.com*.

More generally, PV applications to existing buildings involve a different and often much simpler design and construction process than PV application to new buildings. Even the simplest and least integrated application to a new building will require not just the involvement of the owner and a solar contractor but, also close and extended coordination among the architect, engineering consultants, the general contractor and various sub-contractors, e.g. (at a minimum) electrical and roofing. When customized PV applications or new PV products are specified, even the involvement of a PV designer and specifier does not always insure against miscommunication among primary and lower tier equipment and component vendors.

Examples of Commercial BIPV Applications

Roof Integration Examples

Figs. 5 and 6. Views of 2.3MWp Floridae exhibition area sunroof (views from above and below), Haarlemmereerpolder, Netherlands[34]

[34] Examples from: www.pvresources.com/en/top25bipv.php.

Fenestration Integration Example

Fig. 7. 325kWp Glass Roof Integrated BIPV System at Lehrter Station, Berlin, Germany[35]

Façade Integration Example

Fig. 8. 11.5kWp BIPV façade on a residential building, *The Solaire*, at 20 River Terrace in Battery Park City, New York. Solar Design Associates (SDA) was retained to work with the architects and engineers to define the options for BIPV at *The Solaire*. SDA responsibilities included conceptual design, computer performance analysis, component specificationification, design development, construction documents and specificationifications, coordination of the electrical and architectural design, assistance with component sourcing and utility interconnection requirements. The project was the first high-rise residential tower in the U.S. to incorporate BIPV.[36]

[35] PREDAC Consortium web site: *www.cler.org/predac/article.php3?id_article=511*.
[36] Anthony O. Pereira and Jorn Jurgens, Case Studies for Building Integrated Photovoltaic (BIPV) Facades in the United States, RIO 2 – World Climate and Energy Event, 1-5 December 2003, *www.rio3.com/proceedings/RIO3_447_A_O_Pereira.pdf*. Steven Winter Associates (CT) consulted on the building's "green" systems.

Commercial BIPV Economic Model and Financing Options

In principle, the commercial BIPV economic model should not differ significantly from the commercial rooftop PV economic model, but parameter ranges will be wider. Installed BIPV costs are only available anecdotally and sometimes only the cost of the entire building is cited with an indication that its costs including PV is within the range of comparable buildings with PV. BIPV installed system costs are available for two recent large scale (100kWp and 325kWp) BIPV projects in Germany and fall in the range of 1250-1650 euros per kW or, depending on the exchange rate, roughly twice the cost of comparably sized commercial rooftop systems.[37]

The same financing options available for commercial rooftop PV might be applied to commercial BIPV. Realistically, at this time, commercial BIPV projects are mostly completed during construction of new buildings and their budgets and economics are likely to reflect trade-offs among project cost and performance and the image and functionality requirements of the owner. Likewise, some costs related to the PV application may be difficult to isolate from costs of other systems or the building as a whole. Therefore, owner financing is likely to be the norm whether the building is privately owned or publicly owned.

Emerging BIPV Solutions for Commercial Buildings: Increasing Integration

Dimensions of integration and future possibilities include:

Electrical

Typically integration occurs at the building's main electrical panel, where the array DC output is fed through a DC to AC conversion/power conditioning system either on the building side of the utility meter or the utility side. When the utility grid is shut down, no power flows from the array. The next logical step in integration would be to have the array or portions of the array power circuits. This in turn makes more sense if there are provisions for energy storage that allow the array to reliably power the most critical building loads. A step in this direction has been taken in the context of a recent project in which the array powers lighting throughout the building.

An eventual step may be the incorporation of power conversion and/or energy storage at the module or sub-array level. Unsuccessful attempts were made during the 90s pursuing the vision of an "AC module" suitable for building and roof integration. The lack of a profitable entry point for this product at the time, coupled with product development set-backs, resulted in abandonment of U.S. based product development efforts. As the market for PV in new commercial buildings strengthens and grows, this may encourage more persistent and successful development and commercialization attempts. The concept of multi-string inverters provides an intermediate solution between string inverters and AC modules.[38]

---

[37] PREDAC consortium web site, *op. cite*.
[38] See, *www.solarelecricpower.org/SEPA_Member_News/.*

Pioneering project (installed in 2002) using 35kW PV array to directly power in-store DC lighting in a Whole Foods store in Berkeley, Calif.[39]

Roofing

PowerLight's success with a product integrating PV modules with insulating and protective tiles covering roof membranes has encouraged competitors to develop alternative solutions. The ultimate solution could be a membrane incorporating PV. Likewise, Uni-Solar's offering of products compatible with standing seam roofs is also likely to encourage generically similar solutions.

Cladding

Standard framed modules and unframed laminates are used routinely as cladding or are mounted over weather barrier materials on the vertical faces of commercial buildings. Various attachment and custom framing schemes are employed and there is on-going innovation. Uni-Solar's standing seam roof solution can also be used for cladding PV roof shingles by Uni-Solar, Atlantis and others can as well. Shingle product offerings are intended primarily for single-family home rooftops and may be augmented by PV roofing systems from major building industry players. GE, for example, having acquired a solar manufacturing capability, is in the process of dusting off the vision for PV roof shingles that it pursued during the early days of terrestrial solar technology development in the U.S. The residential market is represents a large share of the total PV market and is growing rapidly, so it is easy to imaging variations of these integrated, packaged systems crossing over and being employed in cladding applications. Longer term, the hope is that flexible cells and modules, perhaps even coatings that incorporate PV will be available for cladding applications, adding further to the choices available to building owners and architects.

Fenestration

Most modules use glass for structural and cell encapsulation purposes. It is logical to ask how such products could be used in fenestration systems. Products currently available, both standard and custom, involve adjusting cell spacing or removing part of the active PV film to vary light transmission. Laminated between two layers of glass these cell configurations can be customized for use as both windows and skylights.

---

[39] Source: *www.princetonenergysystems.com/projects-WholeFoods.htm.*

Meanwhile, efforts in the U.S. started in the mid-90s to incorporate PV modules in conventional curtain wall framing systems. These efforts evolved to target the incorporation of PV materials in the insulating glass units that serve as window components of these curtain wall systems. The technical and product qualification challenges of this application were not completely overcome. As with AC modules, a growing market for PV in new commercial buildings strengthens would encourage more persistent and successful development and commercialization attempts. The converse is also true.

Barriers to Commercial PV/BIPV Development

Arguably, the greatest barrier to commercial PV/BIPV market development is the lack of active dialog between PV/BIPV specifiers and the remainder of the building industry. As discussed above, most practical experience with solar energy on commercial buildings in the U.S. is generated in the context of retrofit applications, whereas the focus of the architectural and allied building design professions is on new projects. Credible efforts (tutorial and overview reports and presentations) to fill the gap are numerous but often do not shed much light on the practical concerns of project feasibility and implementation.

Barriers to Commercial Rooftop PV and BIPV

Solar Resource

Perception Except in “sun-belt” states the local or regional solar resource is insufficient.

Reality There is no solar resource that can be said to be “unsuitable” for commercial PV/BIPV. Indeed, the two most active commercial PV/BIPV markets globally, Germany and Japan, have solar resources more typical of the U.S. northeast than of the U.S. southwest. However, there are clearly areas of the U.S. where the solar resource is of significantly higher quality, i.e. the best resources may result in twice the annual electricity production by a given PV solution than the worst. This issue has some important sub-texts. For example, in northern states, the summer time radiation impinging on a given flat roof surface will be lower than in southern states.[40] Conversely, in northern states, the winter time radiation impinging on a vertical south-facing surface will be higher than in southern states.

Product Service

Perception Once the PV system is installed it becomes the building facility manager’s “problem.”

Reality Upon completion of proper and successful commissioning, PV systems, like other major building systems, can be expected to provide at least five to ten years of trouble-free service. Turnkey rooftop PV systems typically come with suitable warranties, and in any event, the leading PV industry players are well aware of the need to respond promptly and effectively to any system problems that arise. Their trouble-identification and trouble-shooting capabilities are in some cases quite sophisticated and based on remote data collection and monitoring. Customized systems involving non-

[40] For rooftop solutions, array performance can be accommodated by tilting the array.

standard components require more owner attention to warranties and maintenance planning. On the other hand, the strength of the local service infrastructure depends on the level of local market activity, so the matter of how service will be provided merits up-front attention. There is a reasonable expectation that the strength of the PV/BIPV service infrastructure will steadily increase with overall market growth into the foreseeable future.

Barriers (primarily) to Commercial Rooftop PV

Warranties

Perception There is a lack of “investment grade” system performance and warranties.

Reality Commercial PV/BIPV projects can be attractive to conservative investors, i.e. predictable annual energy production offsetting purchases from the grid at volatile prices and escalating rates. However, few solar contractors are willing and even fewer are able to credibly deliver system performance warranties covering typical term of energy project financing, i.e. 10 years. Regarding willingness, while the performance of some system components, i.e. modules, is warranted for 25 years, the performance of the least reliable components, i.e. inverters, is typically not. Regarding ability, a warranty is no better than the future balance sheet of the company offering it, and with notable exceptions, e.g. BP Solar and PowerLight, relevant solar industry balance sheets do not reflect a track record of sustained, stable, and/or profitable operations. This almost rules out third party financing of projects involving customized components or installation methods.

Grid Connection

Perception The local electric utility may either facilitate or oppose obstacles to commercial PV/BIPV.

Reality PV/BIPV is not yet incorporated into most utility company business models, and a particular local utility’s posture of helpfulness, obstruction or neutrality will depend significantly on its dialog with economic regulators, esp. state public utility commissions. Most utilities in the U.S. are highly motivated to satisfy and retain profitable commercial customers in an increasingly competitive business environment, so the level of interest and commitment of the commercial building owner to using PV/BIPV can be influential in determining the local utility’s posture.

Barriers (primarily) to BIPV

Sub-optimal Scale

Perception Solar energy systems have about the same cost per unit of energy delivered whether large or small.

Reality We can detect a trend in the U.S. that small projects of either type are funded for purpose of image; large projects are funded to capture an economic return. Because small project incur the same indirect costs as large projects, they deliver relatively less attractive economic returns. Over the past several years, the typical size range for commercial rooftop PV projects has steadily grown from the tens of kW in the 90s to the hundreds of kW currently.

Limited Opportunities for Integration

Perception The building envelope may be dictated by other criteria and may therefore be unsuitable for “cost-effective” solar.

Reality There is practically no building envelope that cannot accommodate PV; however, the cost of mounting and supporting PV in certain cases can be significant. In the case of custom solutions prepared by the project architect or engineer, a number of proven and low cost attachment methods are available commercially. The market reach of their suppliers at this time is practically limited to customers who specify and install solar arrays. Validation of product suitability may require extra effort. There is an opportunity for cross transfer of solutions between the solar industry and building industry players.

Degraded Aesthetics

Perception Solar arrays may detract from a building’s appearance and/or involve conflicts between architects and engineers.

Reality The aesthetic and economic of a solar array may involve trade-offs. Fortunately, there are an increasing number of useful tools for first order optimization. At the same time, the devil tends to be in the details. Weather barrier penetrations, array attachment and support and internal and grid interconnection are just the more obvious areas where purely aesthetic choices can have engineering and economic implications.

Schedule Risk

Perception Including PV in a new building project requires more trades/services and may result in additional scheduled construction time or delays.

Reality Schedule impacts and delay risks depend significantly on the extent to which the PV solution is “packaged” vs. “custom”. Packaged solutions, e.g. PowerLight Corporation’s PowerGuard commercial rooftop solution are well documented and do not present the general contractor with exceptional integration or scheduling issues. Custom solutions involving non-standard components and/or custom attachment techniques, do in fact require specified design and construction supervision but in most cases are within the capability of basic construction trades and services.

Project Complexity

Perception Because PV systems involve DC electricity, PV projects complicate the building electrical system design, installation and grid interconnection.

Reality For commercial rooftop PV installations, integration of DC circuits is handled by the solar integration/installation contractor(s), while integration of DC and AC power sources typically occurs at the grid interface and involves routine installation of packaged power conversion and grid interface units. DC circuits for collection of solar electricity and delivery to the power conversion unit(s) do require incremental design and installation attention and can be an area of discomfort for electrical contractors lacking prior experience with DC systems.

Opportunities for Commercial PV/BIPV

Market Context – The Evolving U.S. Electricity Market

Drivers for Commercial PV/BIPV development exist at two levels, i.e. those that motivate building owner interest and those that drive investment. Concerns about grid electricity price and reliability, the need to create a favorable corporate image, and the possibility of operating restrictions related to local pollution events can all motivate interest.

Investment, however, tends to be driven by economic considerations, including incentive programs and favorable tax treatment as well as on the long-term cost of grid electricity. There is a range of reasons why on-site power generation is of value to commercial buildings, and many of them make economic sense without subsidy. Obviously, all are related to local energy rates, regulations, energy loads, local regulatory framework, emissions and pollution requirements, and the need to maintain certain functions.

The United States is one of leading digital economies in the world. In the last 20 years, the major controls of industry have been encapsulated in “smart-chips” and are tied to extensive computer networks. Days of the old manual switching gear are gone. By definition, these new controls need greater electric power quality than in the past. The surges, swells, and transients in the electric grid were imperceptible 20 years ago, but now can wreak havoc on sophisticated electronic equipment—literally frying controls and burning-out computers. Surge protectors are now a multi-billion dollar business, but they have limited capabilities except for the most errant electric surges. Electric utilities, for the most part, either deny there is a problem, or have convinced state public utility commissions that the consumer should bear this burden as the cost of doing business. Electric power from photovoltaics does not have these perturbations and energy stored in batteries has a more even power quality. Many large businesses are actually using battery banks and photovoltaics (in some cases small fuel cells) to power dedicated electric circuits for sensitive controls, computers, and sensors, which include cash registers and electronic credit card readers or swipes.

Most businesses require being fully operational if they are to stay profitable. In the retail trades, many make their profits in the last six weeks of the year. In different regions of the country, outages are experienced often due to intense weather patterns (hurricanes, floods, tornadoes, and thunderstorms), old distribution grid, changes in local development patterns which stress existing electric distribution feeder lines, and accidents (due to traffic, human error, and even customers). Battery banks for backing up computers, transmitters, refrigeration, and electronic controls and security systems are already used routinely in the marketplace. Photovoltaics systems are in many cases used to charge battery banks by day and extend the useful life of the battery banks even after the electric grid goes down for an extended period.

Another end-use driver for photovoltaics is to offset high electric rates. Electric rates most vary in the commercial sector and are expressed as peak power rates, usage rates known as demand charges, and ratchet rates, which are peak extremes in price, which extend that rate for the entire month. In most cases, high electric rates come during middy times during the warmer months when air-conditioning load commands most of the electric grid capacity. Photovoltaics is said to have natural capacity because the technology produces optimally at this very time the higher rates occur—midday spring through summer. Photovoltaics systems atop of buildings can be sized to offset a particular demand, peak usage, or ratchet rate and can be tied to battery banks and other distributed generation and energy efficiency technologies to assure that the amount produced completely offsets the higher rate.

Regulatory regimes in many states promote green electric power, renewable energy portfolio of new electric generation, and lower emissions or emission offsets. Each of these regimes creates certain market niches. The earliest environmental drivers are local emissions permitting for siting or enlarging a facility where the company wishes to accelerate permitting. Use of energy efficiency and clean energy, such as photovoltaics is usually weighed quite favorably. Similarly, efforts to show offsets of emissions of either diesel or coal for electric power through incorporation of photovoltaics, is an allowable option under the State Implementation Plans (SIPs) in complying with Clean Air Act requirements. State Public Utility Commissions have developed green pricing approaches where the electrons are designated as green and willing customers would be charged a premium rate for the electric power. In some cases, utilities have programs to install actual photovoltaics systems on buildings for a similar effect. And more recently, eleven states have mandatory renewable energy portfolio standard targets, including the two biggest states--California and New York, and more recently by ballot, Colorado. In some states such as Arizona and Colorado, photovoltaics are an actual requirement within the portfolio, while in other states the lowest priced portfolio energy supplier is encouraged.

As states begin to adopt standards for interconnection to the electric utility grid, many states are adopting the concept of net metering: the entity is credited for the electric power generated but not used. The IRS has agreed that utility rebates, or credits, are not treated as income. While many commercial entities are open and functioning midday, some businesses and institutional buildings have lower usage midday in summer months, and do achieve a considerable net-metered credit.

Aside from required programs, businesses have attempted to resort to branding themselves green to attract customers or to exemplify themselves as good public citizens. A large number of photovoltaics systems have been installed for boasting rights, which many businesses believe draws in customers and retains customer loyalty.

A smaller subset of business customers purchase photovoltaics as either a complete hedge against higher electricity prices, or because of intense dislike of electric utility providers: areas such as Southern California or Long Island that have extremely high energy prices and have experienced many brownouts have invested in photovoltaics. Many business customers have strong premonitions that these price fluctuations and power outages will occur again. Additionally, some businesses have had poor service or customer relationships with their electric provider and thus try to minimize costs or interaction as much as possible. This customer class represents a small percentage of end users, but a definitive one.

Finally, as states announce Renewable Energy Portfolio Standards, net metering, System Benefit Trust Fund grant programs (such as California Governor Schwarzenegger’s announced “million solar roofs program”), and green power initiatives—a bandwagon effect occurs by the commercial, industrial, and business sectors to utilize photovoltaics. As mixed-use developments and green industrial parks become more prevalent, photovoltaics is also seen as absolutely essential for inclusion.

There is Good Reason for Market Interest

High Electricity Rates and Potential Rate Volatility and Escalation

In times when price stability of grid electricity supply is threatened, energy users are motivated to explore alternatives. For example, there was, a significant localized upsurge in retail PV sales leads in the context of the California electricity crisis, and some of these leads were converted into sales, either immediately, in the context of existing incentives, or subsequently in the context of changes to the state incentive programs. The creation of competitive markets for electricity has forced commercial electricity users in some areas to take a more active interest in managing their near and long term electricity costs, and this, too, has motivated serious inquiries regarding commercial PV/BIPV.

High Quality Solar Resource

The PV industry has learned over time that market interest in commercial PV/BIPV tends to be highest in areas where the solar resource is obviously excellent. In the past, this was not a significant driver for commercial PV/BIPV in the U.S., because, in the absence of incentives, few inquiries could be converted into actual purchases. Now, “sunbelt” states are among the leaders in creating mechanisms to encourage PV deployment and create indigenous solar retail and manufacturing jobs.

Threats To Business Continuity

When reliability of grid electricity supply is threatened, energy users are motivated to explore alternatives. For example, there was an upsurge in inquiries about PV during the Y2K build-up and in the aftermath of the northeast black-out. The retail PV industry has learned how to respond opportunistically when public concern is temporarily heightened and “stand-alone” PV solutions are feasible in all size ranges. However, commercial building PV offerings typically deliver cost-savings but not reliability. The most important reason is that incentive programs apply to cost of solar electricity production but not to the incremental cost of adding storage for purposes of reliability and flexible dispatch. Also, solar electricity retailers cannot offer the same warranties and service commitments for energy storage as for basic solar electricity production systems; in addition, market volume for related components and subsystems is limited, resulting in weaker product offerings and aftermarket support from component suppliers.

Hedge Against Operating Restrictions

Environmental regulation in the U.S., particularly in the context of the Bush administration’s Clear Skies initiative, has evolved toward identification of air pollution “non-attainment” areas and pollution “caps” on these areas under which rights to pollute can be sold, purchased or traded. In these cases solar can provide a hedge against costs and/or operating restrictions that could result from regulatory action to address continuing “non-attainment.”

Image

Building owners may or may not be concerned about corporate or personal image, and if they are, many image creation and enhancement tactics are available to them that involve primarily marketing and PR expenditures. Visible application of solar technology can serve as symbolic evidence of concern for the environment. Often, however, the image benefits can be captured via small and operationally insignificant installations. Standards like LEED® award “image points” on a more rigorous basis, so the process of LEED® certification can lead to more meaningful solar applications.

Investment is Becoming More Rewarding

Profit

Private sector building owners are concerned with making a profit. Their investments need to generate life-cycle revenues that more than offset life cycle costs. A new building per se is not profitable but its costs and benefits are determinants of profitability. The profitability of a commercial PV system installed on an existing building is easier to quantify. Elements of “virtual” revenue potential include cost offsets, i.e. reduction in utility energy costs and demand charges. As discussed earlier, these core elements may be augmented by the potential to feed power into the grid at “incentive” prices and the potential to sell “green tags” and carbon credits to companies needing carbon offsets or to companies marketing green power.

Standards

The emergence of rating systems like LEED® creates a new driver, especially potent for new buildings, for not only consideration of solar electricity but for investment as well. In some cases including solar may be the most cost-effective way to score the requisite points to capture a particular targeted rating.

Conclusions, Recommendations, and Potential Action Items

Conclusions

The group[41] reached an interesting “conclusion” that it is time to redefine WHO IS THE CUSTOMER for PV these days. In the past the PV industry was marketing mostly to energy providers. Hence, the PV industry doesn't really understand much about the buildings industry or the specific needs of building owners. Attendees agreed that it was important to increase the dialogue between these two industries.

One way to do this is to facilitate presentations between the two groups at their respective events, conferences, etc. Another action item was to dramatically increase the information (i.e. public relations) that goes out to the building industry about PV. For example, a better marketing job might allow us to begin to work with big-box retail and hospitality industry concerns to see if we can move beyond them being just “receptive” to PV. This may happen if someone presents PV to them in a more proactive way, which may create more demand for it in their new buildings.

There is a need to identify exactly how some of the potential “new” customers (i.e. Wal-Mart, Target, and Marriott) can become vocal advocates for better PV policy, or more R&D or more incentives, etc. Is there an opportunity to work together with DOE and/or decision makers to make solar a more attractive option?

The meeting attendees on the buildings side (owners of big-box retail and representatives from the hospitality industry) and those from the PV side (manufacturers, consultants, suppliers, supporting industries) both agreed that creating some type of

[41] “A Gathering of Eagles” convened on January 27, 2005, at Marriott International, Bethesda, MD.

electronic information portal would be a good place to start to connect information for these two industry groups. It was clear that right now the two industries don't know the basics about each others' business models. It was suggested that SBIC might be a logical forum for facilitating information exchange between these groups and the Whole Building Design Guide (*www.wbdg.org*) might be an appropriate existing platform/web site which the U.S. Department of Energy supports.[42]

Potential Action Items
If a portal (web-based database) is developed, it could logically be divided into two phases.

Phase 1: INFORMATION TRANSFER between the two industries:

- *Identify all the economic drivers clearly for big-box retail owner and hospitality building owners*. These are extremely complex and are often a major barrier. Those mentioned include: installed costs, capacity, avoided electrical costs, incentives, cost of capital, tax liabilities, term of debt, inter-connection costs, tax credits, and investment return.
- *Identify types and availability of third party financing for rooftop PV*. This type of financing, as opposed to more traditional owner financing, is a critical new product that could have a big impact.
- *Create a simple spreadsheet to help owners calculate what their specific "payback" might be*. It will vary widely depending on location, available subsidies, etc. Include a checklist so owners can determine all of their costs for externalities (as much as possible).
- *Identify all state-by-state mandates that require the use of photovoltaics*.
- *Identify state-by-state incentives, interconnection regulations and definitions and make them accessible through the portal*. Users could link to the Clean Power Estimator[43] and the DSIRE database.[44]
- *Develop case studies written for the "new" PV audience and post them.*
- *If rooftop PV on new buildings is a priority, find the actual decision makers and work more closely with them*. For example, we could form a consortium with glass manufacturers, the fenestration industry, and the roofing industry.[45]
- Release information about PV and construction issues through existing networks.

Phase 2: COLLABORATIVE ACTIONS between the two industries:

- Comment on the new LEED® 2.2 Rating System. An important next step that perhaps SBIC could take on is to increase the LEED® points awarded for onsite PV.
- *As a pilot program, help one industry partner green their existing plans and specifications* (i.e. Marriott's five building types) that do not require any "green" strategies or PV now. Marriott's decision makers are its licensees (not headquarters

[42] Additional funding would be required to expand the WBDG to cover PV/BIPV.
[43] Thomas E. Hoff, Clean Power Research, "Using the Internet to Promote PV and Other Clean Technologies" (*www.clean-power.com/research/customerPV/CleanPowerEstimatorUses.pdf*).
[44] See *www.dsireusa.org*.
[45] This idea has been put forth by NREL in conjunction with Marvin Keshner, at Hewlett Packard (see "Study of Potential Cost Reductions Resulting from Super Large-scale Manufacturing of PV Modules," NREL subcontract number ADJ-3-33631-01). This is a long-term action item.

staff). Thus, there is a large, diverse group to educate: they need assistance on many levels.

- *Customers (either together or as individual companies) could develop a performance specification for their preferred system*. This would require the standardization of size, output desired, weight, etc. so manufacturers can begin to meet their needs. As a corollary action item, the Eagles could create big-box and hospitality industry specifications and/or standards.
- *Eventually, we are going to need a standard certification process* for 1) plug and play PV products and, 2) installation. If solar power is to become a standard feature of new buildings, new solar power customers are going to demand this procedural streamlining consistent with the standard approach to specifying and procuring all other major building systems.[46]
- *Present information at conferences*. One good example is the Edison Electric Institute's National Accounts conference. A number of solar power manufacturers would appreciate suggestions of additional conferences to attend to help bridge the communication gap between the building industry and the PV industry.

[46] The North American Board of Certified Energy Practitioners (NABCEP) has already established a certification standard for smaller PV projects. It may be time to establish a certification process for large-scale projects such as big-box retail stores and office buildings.

Attachment 1. Definitions[47]

Commercial Rooftop PV: PV array, typically large, supported by commercial building roof – offsets building electricity use – eligible for first cost rebates in some states

BIPV: PV array, typically small to medium, integrated in building skin or roof for and eligible for incentives in some states where BIPV is defined as involving: 1) material substitution, e.g. use of PV module in lieu of traditional building materials or component, and/or 2) efficiency gains, e.g. PV array is designed to reduce heat gain.

Antireflection coating: A thin coating of material applied to a crystalline PV surface that reduces light reflection and thus increases solar radiation capture by the PV cell.

Balance of System (BOS): Non-PV components of a BIPV system typically include wiring, disconnects, diodes protecting modules from damage by reverse currents, mounting and attachment hardware, switches, and array power conditioning units, meters, and battery storage equipment.

PV on buildings or rooftop PV: Photovoltaics arrays attached or supported by the building roof and typically connected to an inverter adjacent to the building's main electrical panels.

BIPV—Building-integrated photovoltaics: PV incorporated into a building's skin or structure as an integral part of a structural and/or design as opposed to PV on buildings (see PV on buildings definition, *supra*).[48]

Bypass diode: A diode connected across one or more solar cells in a PV module to protect these cells from thermal destruction in case of total or partial shading of individual cells while other cells are exposed to full light.

Conversion efficiency: Amount of electricity a PV device produces in relation to the amount of light shining on the device, expressed as a percentage. A PV cell's conversion efficiency varies with outside temperature and also slightly with age. Because of minor electrical losses, modules may be less efficient than modules per se, and losses in power conversion result in overall system efficiencies less than the conversion efficiency of the array.

Curtain wall: An exterior wall that provides no structural support.

Encapsulant: Plastic or other material around PV cells that protects them from environmental damage.

Grid-connected: Inter-tied with an electric power utility.

---

[47] Most of the BIPV terminology herein is drawn from: Eiffert, Parina, Ph.D. and Kiss, Gregory J., *Building-Integrated Photovoltaic Designs for Commercial and Instructional Structures, A Sourcebook for Architects*. U.S. Government Printing Office, 2000.

[48] There is no commonly accepted definition of BIPV—every PV array is integrated in some degree as necessitated by a building's design and/or structural components. For purposes of the Eagles meeting, PV that is designed into a new building and serves some structural, aesthetic, or other traditional function other than power generation.

Inverter: Device that transforms direct currant (DC) electricity to alternating-current (AC) electricity.

Module: Commercial PV product containing interconnected solar cells; modules are offered in various standard sizes by high volume manufacturers; sizes and cell configurations for optical effect, etc. can be ordered from manufacturers at premium prices.

Net metering: In the United States, utilities are obligated, generally, to accept solar electricity production temporarily exceeding a building's consumption to the point that annual net purchases from the utility are zero as the utility company compensates the building owner for excess power returned to the grid.[49]

PV array: Group or string of connected PV modules operating as a single unit.

PV laminate: Building component constructed of layers of glass, metal or plastic encapsulating photovoltaic material.

PV solar cell: Device made of semiconductor materials that convert direct or diffuse light into electricity; typical PV cells are made from wafers of crystalline silicone or thin films of silicon and other materials that form light sensitive semiconductor junctions.

Solar insolation: Solar radiation striking a PV array's surface at any given time; it determines the potential electric output of a BIPV system.

Stand-alone: Remote power source separate from an electric utility grid; a stand-alone system typically has a battery storage component.

[49] An increasing number of states require utilities to credit the customer for solar electricity that feeds into the grid against overall purchases up to a zero balance.

Attachment 2. Strategic Questions for the Eagles

What are the near term opportunities for increasing the amount of rooftop PV on commercial buildings? For example, what can be done to encourage larger scale PV installations on commercial big-box retail versus the smaller PV arrays being widely installed for public relations purposes? Should the U.S. look more closely at strategies that are successfully jump-starting the commercial rooftop PV market across Europe? How could such strategies be adapted to U.S. policy and constraints and political preferences?

What are the near term opportunities for increasing the amount of BIPV into commercial buildings? For example, there is a critical need for sustained and purposeful dialog between the building and solar industries. An outcome of this dialog may be an effort to target "plug and play" products that can be conveniently specified by architects and engineers, delivered through traditional building product supply channels, and installed by the traditional building trades. It is well-known that most prior research and development (R&D) addressing BIPV products has been disappointing when measured against its potential deployment. What can be done to encourage sustained and successful research and development toward more integrated products like AC modules and PV integrated insulated glass units?

Attachment 3. Big Box Retail Solar Usage and Solar Power Potential (Source: SunEdison and the National Retail Federation)

Big-Box Retail Solar Usage and Solar Power Potential (prepared by SunEdison)

Rank	Company	Units			Avg Sq ft of Solar per Store	W/ sq. ft.		Total
	(Head-quarters)	2001		Comments		7.7	MWs	859
								% mark.
	Wal-Mart					W/store	kWs	MWs
1	Bentonville, Ark.	4,414	+	America's largest employer	49,799	383,451	169,255	169
	Home Depot			More than a billion				
2	Atlanta	1,348		customers a year	39,728	305,904	41,236	41
	Kroger			Streamlining to				
3	Cincinnati	3,534		vie with Wal-Mart	14,176	109,155	38,575	39
	Sears							
4	Hoffman Estates, Ill.	2,960		What will Lands' End bring?	13,878	106,858	31,630	32
	Target			May be shedding				
5	Minneapolis	1,381	+	department stores	28,503	219,470	30,309	30
	Albertson's			Sold stores;				
6	Boise, Idaho	2,400	+	exited several markets	15,805	121,695	29,207	29
	Kmart			Chapter 11				
7	Troy, Mich.	2,150		magnified problems, miscues	17,222	132,612	28,512	29
	Costco							
8	Issaquah, Wash.	369	+	No.1 in wine sales	94,301	726,117	26,794	27
	Safeway			Old lease				
9	Pleasanton, Calif.	1,773	+	obligations may hurt profits	19,346	148,967	26,412	26
	JCPenney							
	Plano, Texas				8,489	65,366	24,643	25
	Deerfield, Ill.				6,995	53,863	18,960	19
10		3,770	-	Wants to double earnings this year				
	CVS							
13	Woonsocket, R.I.	4,191	+	Says 2002 is a "transition year"	5,307	40,863	17,126	17
	Lowe's			High hopes for				
14	Wilkesboro, N.C.	744	+	non-traditional goods	29,719	228,838	17,026	17
	Best Buy			Expanding in				
15	Minneapolis	1,900		Canada	10,314	79,419	15,090	15
	Federated Dept. Stores			Paid for misstep in non-store				
16	Cincinnati	450	-	selling	21,951	169,024	11,781	11

	Office Depot			**Largest office supplier worldwide**				
24	**Delray Beach, Fla.**	**1,062**	**+**		10,503	80,872	8,589	9
	Staples			**Looking for an upbeat year in 2002**				
27	**Framingham, Mass.**	**1,400**			7,675	59,094	8,273	8
	7-Eleven			**Same-store merchandise sales grew 5.1%**				
29	**Dallas**	**5,829**	**+**		1,697	13,070	7,618	8
	Circuit City			**CarMax figures no longer included**				
	Richmond, Va.				15,368	118,336	7,384	7
30	**Dallas**	**624**	**-**		27,212	209,535	4,736	5
	BJ's Wholesale			**Took a hit from old HomeBase leases**				
40	**Natick, Mass.**	**130**			39,701	305,700	3,974	4
	Barnes & Noble			**Steve Riggio takes over from brother**				
43	**New York**	**1,934**			2,518	19,391	3,750	4
	Borders Group			**Closing smaller Waldenbooks sites**				
	Ann Arbor, Mich.				2,745	21,140	2,609	3
57		**1,234**						
	Whole Foods Markets			**Bought Harry's Farmers Markets in October**	17,479	134,586	1,750	
59	**Austin, Texas**	**130**	**+**		1,006	7,748	1,530	2