CONF-9511214--

Designing for the Global Environment

A Symposium
November 2-3, 1995
Atlanta, Georgia

Sponsored by
U.S. Department of Energy

Symposium Administrator:
Saeid L. Sadri, PhD., NCARB, Associate professor
Building Construction Program

College of Architecture
Georgia Institute of Technology

Georgia Tech presents...

Designing for the Global Environment

GT

November 2-3, 1995 ● Atlanta, GA

Sponsored by
College of Architecture,
Building Construction Program
Construction Research Center
U.S. Department of Energy
Moore Space, Inc.
Monsanto Company
Center for Sustainable Technology, Georgia Tech
Endorsed by
The Building Futures Council

Continuing Education
Georgia Institute of Technology
A Unit of the University System of Georgia

Who Should Attend

The Program Targets:

- Architects
- Engineers
- Constructors
- Facilities Managers
- Environmental Engineering Professionals
- Owners
- Developers

Georgia Tech presents...

Designing for the Global Environment

GT

November 2-3, 1995 ● Atlanta, GA

Program Outline

Thursday, November 2, 1995

7:30 a.m. Registration

8:00 a.m. Introductions: Professor Garvin Dreger
Director, Building Construction Program, Georgia Tech
Welcoming Remarks: Dr. Thomas Galloway
Dean, College of Architecture, Georgia Tech

8:15 a.m. **Opening Address: The Honorable Christine A. Ervin**
Assistant Secretary for Energy Efficiency and Renewable Energy, United States Department of Energy

9:00 a.m. **Keynote Speaker: Mr. Paul G. Hawken, Author of "Ecology of Commerce" and President of The Natural Step (USA)**

10:00 a.m. **Break**

10:15 a.m. **POLICY SESSION**

The Importance of Sustainable Buildings and Infrastructure

Creating Sustainable Communities: The Role of Design
Angela Park
Coordinator, Sustainable Communities Task Force
President's Council on Sustainable Developments

U.S. Energy Policies: Will they be responsive to future needs?
John Hemphill
Executive Director, Business Council for a Sustainable Energy Future

11:15 a.m. **Panel Discussion**
Building Sustainable Communities and The Atlanta Empowerment Zone
Moderator:
William S. Becker
Office of the Assistant Secretary for Energy Efficiency and Renewable Energy, U.S. Department of Energy

Panel Members:
Bob Berkebile, BNIM Architects, Kansas City
Hakim Yamini, Atlanta Empowerment Zone Corp., Atlanta
Nancy Skinner, Daybreak International, Chicago
Michael Kinsley, Rocky Mountain Institute, Snowmass, Colorado

Program Outline

12:45 p.m. **Lunch**
Speaker: Mr. William Moss
Senior Vice President for Construction
The Atlanta Committee for the Olympic Games

2:15 p.m. **IMPLEMENTATION SESSION I**

Design Issues

Designing Sustainably
Randolph R. Croxton, AIA
Principal, Croxton Collaborative

AIA's Committee on the Environment, Toward a Sustainable Future
Harry T. Gordon, AIA, principal
Burt Hill Kosar Rittelmann Associates

Application of Finance and Accounting Theory to the Valuation of New Energy and Efficiency Options
Shimon Awerbuch, Ph.D.
Independent Economist

4:00 p.m. **Break**

4:15 p.m. *Redefining 'Energy-Efficient Buildings'*
Amory Lovins
Vice President & Director of Research, Rocky Mountain Institute

A U.S. Manufacturer's Perspective
Harvey Forest, Ph.D.
Solarex, CEO, Photovoltaics, Amoco/Enron Solar

Renewable Energy: Off-the-shelf
Arthur Rudin
President, Sunwize Specialty Products

5:45 p.m. - 7:30 p.m. **Cocktail Reception**

EXHIBIT AREA OPEN ALL DAY

Friday, November 3, 1995

8:15 a.m. **IMPLEMENTATION SESSION II**

Designing Buildings and Infrastructure for Future Generations

Keynote Speaker: Mr. Ted Turner, President and Chairman of the Board, Turner Broadcasting System, Inc.
"The Role of Media in Promoting Sustainable Development"

9:00 a.m. *A Cooler, Cleaner, Less Smoggy Atlanta with Cool Surfaces and Shade Trees*
Arthur H. Rosenfeld
Senior Advisor, Energy Efficiency, U.S. Department of Energy

Designing Against Natural Hazards: A Structural Perspective
Tony Gibbs
Director, Consulting Engineers Partnership, Ltd.

Program Outline

10:00 a.m. **Break**

10:15 a.m. **Earth in the Balance**

The Insurance Industry and Sustainable Construction
Ann Deering
President, Environmental Technologies and Telecommunications

Partnerships: Local Solutions for the Global Environment
Margaret Howard
Executive Director, Global Environmental Options (GEO)

Digital Design and Communication Tools for Sustainable Development
Michael Totten
Director, Center for Renewable Energy & Sustainable Technology (CREST)

Environmental Impacts of Large Events
Ed Augustine
President, Augustine Environmental

12:15 p.m. **Lunch**

2:00 p.m. **IMPLEMENTATION SESSION III**

Changing Perceptions

The Eco-Odyssey of the CEO
Ray Anderson, Chairman and CEO
Interface, Inc.

Promoting Sustainable Energy Strategies in Russia
Robert K. Watson
Director, International Energy Program, Natural Resources Defense Council

Solar Electricity in the Built Environment
Steven J. Strong
President, Solar Design Associates, Inc.

3:30 p.m. **Break**

3:45 p.m. *Factory - Built Integrated Solar Homes, A Progress Report*
Lyle Rawlings
President, Fully Independent Residential Technology, Inc. (T/A F.I.R.S.T., Inc.)

Innovative Strategies for Environmental Sustainability
Shahrokh Rouhani, Ph.D.
Associate Professor, School of Civil and Environmental Engineering, Georgia Tech

Sustainable Technologies
Jorge Vanegas, Ph.D.
Associate Director, Center for Sustainable Technology, Georgia Tech

5:30 p.m. **Concluding Remarks**

EXHIBIT AREA OPEN ALL DAY

Saturday, November 4, 1995

10:00 a.m. - 12:00 a.m. Tour of Sustainable Construction of Olympic Facilities and the Atlanta Empowerment Zone

U. S. Energy Policies: Will They Be Responsive to Future Needs?

John G. Hemphill*

INTRODUCTION

Today, I would like to address head on the question posed to me by the Symposium organizers -- will U. S. energy policies be responsive to future needs? The answer is: I hope they will be. And, in fact, I believe they can be, if we define our goals realistically and pursue reasonable policies that further these goals.

Before I describe what I believe are appropriate and realistic energy policy goals, let me first briefly review past U. S. energy policies. For history can teach us valuable lessons, if we only bother to look.

Early U. S. Energy Policy: A Prescription for Failure.

Our early energy policy goals were too ambitious and our policies inappropriate. Late in 1973, the United States was rudely awakened to the fact that it could longer effectively control world oil prices. And, in fact, that role and responsibility had clearly and unequivocally passed to a small group of countries located in a region of the world known as the Middle East.

Our response was predictable -- it's broke; so let's fix it! With much fanfare, President Nixon created an agency to address the problem and he directed it to proceed immediately to develop a plan for making the United States energy independent. The result was Project Independence, unveiled in November 1974. At the time, our leaders were alarmed by the fact that the U. S. was importing approximately one third of its total oil needs. (Today, approximately half of our needs are met by imports.)

With a plan in hand, the U.S. government began the long and difficult task of devising policies aimed at achieving the illusive oil independence goal. During this time, we got our first glimpse of the political popularity of the gasoline tax and an early reality check concerning the political viability of actions designed to influence consumer energy use that might also inflict personal pain and discomfort in the near term.

The policies we chose to further this goal were as misguided as the goal itself. We used shot guns and nuclear weapons when we should have been using laser guided missiles. The list of failures is large and some energy projects like the Great Plains coal gasification plant were monumental economic failures. At the same time, when you use a shot gun you are bound to score a few hits. We did; I'll come back to them later.

* Executive Director,
Business Council for a Sustainable Energy Future

Energy Policy of the Mid-Eighties: Off the Radar Screen.

In the mid-1980s energy prices crashed. This was good for consumers but it was hell on energy policies aimed at achieving independence from foreign oil. Public support for government action to limit or reduce oil imports disappeared. That goal fell out of favor and off the radar screen.

The problem was not that energy had ceased to be an important factor worthy of government involvement and policy action. The problem was that we were still defining national energy policies in terms of an inappropriate and unrealistic goal -- energy security as defined by the notion of Project Independence.

EVOLUTION IN NATIONAL GOALS

The Nation's attitude toward energy, and its role in meeting broader national goals has matured since the early 1970s. We have come to realize that oil independence as envisioned by Project Independence is not an appropriate or viable national goal and does not make for sound energy policies.

Putting the Horse Before the Cart

We, at last, have come to appreciate that energy is only a commodity -- a strategically important commodity -- but a commodity nonetheless. Energy development and use are important national considerations, not for their own sake, but as an element of national economic growth and environmental quality goals. We have managed to turn things around. We have put the horse before the cart. We have defined new goals and refined old goals in recognition of the strategic role energy plays in advancing our economic and environmental interests.

It's Economic Growth and Environmental Quality, Stupid

Today we recognize that energy development and use decisions are key determinants in economic growth and environmental quality. Energy, or more accurately , the services energy delivers, is a key component of economic growth. Although we see large differences among countries in their energy use per unit of economic production, these differences can be explained by differences in population density, economic development, degree of industrialization and application of technological innovation, to name a few key factors.

The fact remains that regardless of the makeup of a country's economy, energy is and will continue to be an important driver. All else being equal, there is little doubt that a diverse energy resource base that uses domestically derived energy sources to the maximum extent practical enhances a nation's economic vitality by reducing its exposure to and reliance on a single energy source and by strengthening domestic employment opportunities.

The consumption of energy to produce the services that sustain economic growth also often produces pollution, particularly air pollution resulting from the combustion of hydrocarbons. Until recently, the U. S. government's approach to mitigating pollution was limited primarily to regulating emissions coming out of the smoke stack or out of the tailpipe, rather than limiting emissions through the substitution of clean fuels and sources of energy for dirty fuels. The focus has shifted recently to emphasizing flexible approaches to pollution control that use market forces to the extent practical including the substitution of clean-energy sources for dirty ones.

ENERGY POLICY PRINCIPLES

The Business Council for a Sustainable Energy Future is comprised of business leaders from a diverse group of energy industries that share a commitment to environmental quality and economic growth through the development and deployment of non- and low-polluting energy technologies and services. The Business Council recently established six principles that it believes decision makers should apply when formulating energy policies.

1. Policies Should Be Market Based.

Policies to mitigate environmental degradation should be, to the extent possible, market based while taking into account the environmental externalities of energy use. The best policy instruments provide economic incentives to deploy and adopt clean and efficient energy technologies and practices.

The Council believes that this approach best minimizes economic distortions as well as energizes the financial and innovative resources and the organizational assets of industry. The trading of SO2 permits, authorized under the Clean Air Act, is an excellent example of incorporating market forces into environmental regulation without sacrificing environmental quality.

2. Clean-Energy Alternatives Should Receive Recognition.

Policy makers should explicitly recognize the environmental benefits of technologies and services that have the potential to displace high-emission technologies. Cost-effective demand-side and supply-side energy technologies and services should be key components of national plans for addressing environmental and economic development goals.

Business Council members have demonstrated the economic and environmental value of clean-energy technologies. The Sacramento Municipal Utility District (SMUD), for example, has increased its use of renewable energy and energy efficiency to dramatically improve its customer service and financial bottom line. Today SMUD gets nearly half of its energy from renewables and efficiency; by the turn of the century, it expects to satisfy 75 percent of its customer needs through efficiency and clean-energy sources.

3. Energy and Environmental Planning Must be Coordinated.

The planning of energy projects in support of economic growth must explicitly recognize the relative environmental consequences of alternatives. Life-cycle assessments should be used in evaluating alternatives.

Two other Business Council members, the New York Power Authority (NYPA) and United Solar Systems Inc (USSC) are jointly demonstrating the importance of accounting for environmental costs when developing energy projects. NYPA is using a cutting-edge photovoltaic array manufactured by USSC to test photovoltaic performance as a grid-connected power source. Photovoltaics hold great potential for delivering environmentally sustainable, cost-effective power to the electric power grid, especially where transmission upgrades or extension costs are high. NYPA's demonstration promises to serve as a model for energy planners seeking benign alternatives to traditional power sources.

4. Progress Must be Measured and Adjustments Made.

Activities designed to reduce pollution and sustain economic growth must be monitored to insure that results are achieved and to avoid repeating mistakes. Meaningful evaluations also allow programs to be adjusted to improve performance.

The U. S. Department of Energy (DOE) routinely reviews the value and effectiveness of its energy research programs. Energy efficiency and renewable energy programs have repeatedly score at the top of DOE's energy research agenda.

5. Technology Transfer Should be Encouraged.

Economic growth and environmental quality are goals shared by virtually all nations. Coordinated efforts to deploy globally cost-effective, clean-energy technologies and services should be strongly supported.

Once again Business Council members have been working throughout the world making their clean-energy technologies available for meeting the growing energy needs of developing countries. Honeywell Inc. is upgrading the district heating system in Krakow, Poland reducing Krakow's energy costs and air pollution. Enron Corp. is constructing a natural gas pipeline system in Argentina, adding significant clean-energy capacity to fuel Argentina's rapidity expanding economy. Bergey Windpower is providing wind turbines for distributed power applications in Indonesia and Mexico, lowering the cost of delivering electric power services to remote locations.

6. Government Energy Program Assistance Should Support Economic and Environmental Objectives.

Private capital ultimately will determine what types of energy related investments will be made over the long term. Public support, however, can provide important incentives for pursuing sustainable economic growth. The need to pursue such a course of action is particularly critical in the rapidly developing nations of the world.

In this regard, the Business Council is glad to see that public financial institutions such as the World Bank and the U. S. Export-Import Bank have incorporated environmental considerations into their lending criteria.

CONCLUSION

I would like to conclude by pointing out some of what I believe have been and are energy policy successes. Before proceeding with my list, I would like to observe that successes do not come easily or quickly. Many clean-energy opportunities are only now beginning to compete head to head with more traditional energy sources. Others, although showing promise, still have a way to go before they can compete on an equal footing for market share.

Do Not Expect Instant Gratification.

In short, energy policies that meaningfully support economic and environmental goals must have a long-term orientation. We must set meaningful interim milestones for measuring progress and we must continuously challenge the value of programs but we must not expect instant gratification.

And the Winners Are.

The U. S. government, along with state and local governments, has had several energy policy successes measured by their contribution to economic development and environmental quality enhancement. Three examples are:

(1) Research and development of renewable energy has brought down the cost of renewables to the point that wind energy competes favorably with conventional energy sources in electric power generation.

(2) After a rocky start, government natural gas policy which promotes competition has produced a market that is supported by ample supplies at reasonable prices.

(3) Technological innovation, aided by government energy efficiency policies, has resulted in improvements in the efficient use of energy, even in the face of declining energy prices.

In closing, I believe that energy polices that support national economic and environmental goals can and will be responsive to future needs. The challenge for energy policy makers is to design, define and defend energy policies that meet this criteria.

J:\RESAPPS\MISC\GTSPCH.WPD

Collaborative Decision Making for Sustainable Development

By Michael J. Kinsley[1]

For many years, economic development has meant industrial recruitment where business-at-any-cost was preached by a small elite, where civic discord replaced civic discussion, where families made more money but had less to spend, where residents learned to lock their doors, where communities changed from the unique to commonplace and a thousand towns looked alike. But now, scores of communities are saying no to old, worn-out approaches to development and embracing a new kind of development that respects the community and the environment. Created collaboratively by people from all walks of community life, this new approach is called sustainable community economic development.

Though new, sustainable development is based on traditional values of stewardship and working together. Its principles are powerful in their simplicity. Its lessons enrich community decision making. This paper describes these principles and lessons. It introduces a community decision-making process that applies them and suggests the kinds of results you can expect from such a process in your town.

h1 Four Principles of Sustainable Development

Think, for a moment, about the economy of your community. What makes it work? In many ways a local economy is like a bucket that the community would like to keep full. However, the economic buckets of most towns have holes in them. Every time someone buys something from outside the community, dollars leak out.

These leaks can add up to millions of dollars every year. For example, a typical community spends more than twenty percent of its gross income on energy. Eighty percent of those dollars immediately leave the local area. That loss amounts to over $20 million for a typical town or neighborhood of 5,000 people. For cities, the losses can be in the billions.

To balance the dollar drain, money must flow in from outside the local economy. Money comes in when people in other places buy products or services created by local people. Extracted raw materials, harvested crops, or manufactured goods are sold to earn income. Many communities earn money from tourists and other travelers. However it does it, a community must bring in at least as much money as it spends or it will wither and die.

Even if its income and outgoing balance, a local economy that is heavily reliant on only one or two industries may be vulnerable to swings in the national economy.

When a community's basic industry is threatened, the usual response is to call for economic development. Traditionally this has meant one thing: industrial recruitment. Chambers of commerce and development groups across the country talk of bringing in new industry as if it were the only means to improve a local economy.

Many communities have built expensive industrial parks and offered tax breaks, free water, land, and infrastructure to any company willing to relocate there. While some have been able to make this strategy work, many others have found that endless committee meetings, fees for consultants, brochures, and fact-finding tours have resulted in few benefits.

If communities knew the odds they were facing, they would broaden their approach. Each year some 25,000 economic development committees from large and small cities bid for about 500 major plant sitings—a 50-to-1 ratio. It is not uncommon for a competing city to offer benefits worth millions of dollars and still lose the bid. Very few towns or neighborhoods can play in this high-stakes league.

---

[1] Rocky Mountain Institute, Economic Renewal Program, Senior Research Scholar

potential is probably much greater still. It's as if every town in America had an invisible, clean-burning, maintenance-free power plant just waiting to be hooked up to the grid.

Farmers around Fox, Arkansas, are plugging a different of leak. A study by students and faculty of nearby Hendrix College revealed that the college was buying most of its food from distant suppliers, even though the majority of those food items were, or could be, produced locally. The college changed its purchasing policy and is now committed to buying locally, and area farmers are learning how to produce for the college's specific food needs.

To encourage a spirit of leak-plugging, a few communities have even created their own currency. "Ithaca Hours" are a currency that "entitles bearer to receive one hour labor or its negotiated value in goods or services." In Ithaca, New York, that's equivalent to about $10 an hour, the average local wage. Twelve hundred local individuals and businesses of all kinds accept Ithaca Hours, approximately 4,600 of which are in circulation. Management decisions are made by the "municipal reserve board"—anyone who shows up at a bi-monthly potluck.

Lester Prairie, Minnesota, plugs leaks with "Rideshare Bucks," which commuters earn by giving rides to fellow residents. Funded by a state energy grant, the bucks can be redeemed at local retail businesses. In the program's first two years, Lester Prairie commuters saved $600,000 in travel and fuel costs (and in the process prevented 200,000 pounds of carbon dioxide from polluting the atmosphere).

Of course it doesn't necessarily take an official program to plug a leak. Most towns have some sort of barter, or "informal," economy that enables local goods and services to replace imports, albeit without the blessing of the Internal Revenue Service. While the informal economy is virtually ignored by economic developers, its importance was quantified by one researcher who estimated its economic value in Crown Point, New York to be equal to approximately 100 jobs. In a town of less than 2,000, that's a lot of jobs.

h2 Support Existing Business

The economic heart of many communities is small business. Many development experts are convinced that the fastest way to increase jobs and strengthen a community's economy is to encourage existing businesses to become more efficient and successful. Caught up in the dream of high-tech industrial recruitment, many communities overlook local opportunities. But in urban areas, seventy to eighty percent of all commercial growth comes not from the creation of new industries but from internal expansion or modernization of existing businesses.

The Ithaca and Osage examples demonstrate that one way to support existing businesses is to plug the leaks. Ithaca hours are a substantial incentive to patronize local businesses. And, though Osage residents started their energy-saving effort to save money, they also found that lower electric rates had strengthened local businesses. The utility was able to cut its rates by a third because of its cost savings. A 29% reduction in energy costs at Fox River Mills, achieved by installing more efficient electric motors, made possible a plant expansion that nearly tripled jobs.

Alana Probst, a businesswoman in Eugene, Oregon provided an excellent example of supporting existing business and plugging the leaks when, in the early eighties, she asked ten local businesses each to list forty items purchased out of state. She then called other local businesses that might be interested in bidding on items from the list of 400. In its first year, "Oregon Marketplace" created 100 new jobs and $2.5 million in new contracts—not by offering tax breaks or free land or by advertising in industrial recruitment magazines, but simply by connecting local suppliers with local buyers.

The effort has not only boosted local businesses, in some cases it has even created whole new markets. An airline meal company had imported processed chickens all the way from Arkansas, despite a host of chicken growers just outside Eugene. Oregon Marketplace secured a commitment from the airline meal company so that a local bank would loan the growers enough money to build a processing facility.

Industrial recruitment is an attempt to find new ways to pour more money into the community's economic bucket. It can be useful, but it rests on the often unquestioned assumption that new industry is the best, or only, solution to local economic problems.

Sustainable economic development focuses on easier, cheaper, and less risky means to achieve the same end. And while this approach may lack the fanfare and ribbon-cuttings of an industrial recruitment campaign, it typically fosters a deeper kind of community spirit and self-reliance that comes from solving problems locally instead of waiting for salvation to come from outside.

The path to sustainable development is based on four principles.

h2 Plug the Leaks

The lively interchange of commerce is an important part of community vitality. Your days may begin with coffee blended from Africa, Latin America, or Hawaii. You may drive to work in a car bought from Detroit, Japan, or Europe, made from metals mined in dozens of countries. Television brings you news, culture, and sports events from different continents. Almost no part of your life stands alone without commerce from outside your community.

These products of international trade enrich our lives. However, many other imports—notably such necessities as energy, food, water, health care, and housing—can just as easily be supplied locally at no extra cost, and often at a savings. In our analogy of the community bucket, these expenditures are unnecessary leaks; instead of trying to pour more money into a leaky bucket, a town can simply plug some of its leaks. Economic development professionals call this strategy "import substitution," but it is really nothing more than practicing the old adage, "a penny saved is a penny earned," at the community level.

When a community plugs an unnecessary leak, it puts money back into the local economy just as surely as if it had earned it through new industry. Likewise, as individual residents spend and re-spend the money they have saved, the local economic benefit multiplies in the same way it does with new income: more money in circulation creates more value, pays more wages, finances more investments, and ultimately creates more jobs. Unlike income, however, savings are inflation-proof—once you've cut out an expense, you no longer need to keep earning more money to pay for it. Further, money spent on local goods and services often goes to small businesses, the backbone of most local economies.

Self-reliance is an important aspect of any community development strategy in an unpredictable world economy. The more necessities that can produced locally at reasonable prices, the more resilient your local economy will be, and the more able it will be to withstand externally created shocks and changes. Strong local economies are the basis for strong regional, and ultimately national, commerce.

In every community, many goods and services that are purchased out of town are, or could be, produced or marketed locally. Towns have set up programs to lower housing costs, revitalize local agriculture, process wastes more economically, and provide better and less expensive health care.

Even when a commodity can't be produced locally, it can often be used more efficiently to achieve the same net result. For example, Osage, Iowa now saves $1.2 million annually—more than $900 per household—thanks to a series of weatherization and energy-efficiency projects initiated by the local utility and service groups in the early 1980s. Since the start of the program, per capita energy consumption has dropped 25 percent without any reduction in service. Everyone still has comfortable rooms, hot showers, and cold beer; they just spend less money.

The untapped economic potential of energy efficiency is enormous. It has been calculated that the United States could save $200 billion worth of energy annually—and create millions of jobs in the process—simply by being as efficient as Western Europe or Japan. Since those countries aren't as energy-efficient as they could be either, the savings whom rising property values can mean dislocation or bankruptcy. One example is the Wisconsin Farmland Trust, which helps farmers withstand development pressure, produce food while maintaining stewardship of the land, invigorate local agriculture activity, and stimulate farmer-to-farmer cooperation.

h3 Encourage New Local Enterprise

While local leak-plugging and business enhancement are likely to give you the fastest return on investment, the creation of new businesses still plays a vital role.

In any dynamic economy, older businesses will fold and newer ones will be created. In most communities this process is largely unnoticed until business failures outnumber start-ups. However, your community can do a lot to tip the balance toward success. You can encourage start-up businesses that build on local strengths by making the best use of the existing labor force, infrastructure, and resources.

One well-tested method to support the creation and maintenance of small businesses is the business incubator. Though these facilities vary widely from place to place, they generally provide affordable rent, business services, or consulting under one roof. A typical incubator is a cluster of small, affordable-rent offices or shops around central secretarial and computer services. Businesses are often required to move on to other conventional space after a certain period of time, say, two years. They have been developed by private businesses, local governments, and colleges and universities.

Overlooked resources and hidden assets can be the genesis of successful new businesses. A group of women in Colquitt, Georgia wanted to do something about their distressed local economy. They talked about many possibilities, but finally focused their efforts on an unusual local asset, the Mayhaw berry. No one had thought the berry was anything more than a native fruit that residents canned for family use. But one year the group of friends produced a surplus of Mayhaw jelly, hand made labels, and tried to sell it to specialty stores in nearby cities. They sold so many jars that the next year, they moved production out of their homes and into a commercial kitchen. Sales doubled each of the seven following years as they expanded their market to include shops in 36 states. By 1991, the Mayhaw Tree's workforce totaled eight full-time and 32 part-time employees producing a dozen different products.

The Good Faith Community Loan Fund of Pine Bluff, Arkansas, lends small amounts of money to local micro-enterprises. Because the mostly low-income borrowers stand little chance of getting conventional bank loans for their fledgling businesses, the nonprofit fund is putting needed money behind self-employment and new economic activity in depressed regions of rural Arkansas.

h2 Recruit Compatible New Business

In addition to rebuilding the community's existing economy, you may wish to encourage outside businesses to relocate in your community. Recruitment can bring significant rewards, especially if undertaken in a sophisticated way. It can bring in new enterprises to develop underutilized resources and meet needs unfulfilled by existing businesses. However, done without regard for community and environmental values, recruitment can also create serious problems that outweigh benefits.

Incoming companies can bring fresh capital, new jobs, economies of scale, technical expertise, and participation in national or international networks. If these characteristics complement local resources, the new company can bring renewed vigor to your community. Pursuing the first three principles positions a community to recruit wisely. For instance, Wallace Computer Services looked at fifty towns before deciding to move to Osage, Iowa, based in large part on the low electric rates that resulted from the community's energy efficiency program.

In each development effort, ask yourself how you envision your area's future. Will a proposed development or facility be compatible with these goals? Many communities have sought new businesses at any cost, believing that any economic development is positive.

Some might suggest that Oregon Marketplace is an attempt to isolate the area from the national economy; on the contrary, equipment for the facility, unavailable in Oregon, came from a Chicago firm that in turn bought its steel from an Indiana company. Therefore, buying locally made Eugene a stronger trading partner in the national economy, supporting jobs in Eugene, Chicago, and Indiana.

Business networks are one example of how communities can support existing businesses. A bright light in the troubled wood-products industry of Washington state is WoodNet, a network of small to medium-sized wood-products manufacturers that helps members help each other. It finds markets, connects suppliers with buyers, encourages use of waste products, pursues joint manufacturing and purchasing opportunities, creates forums for sharing business ideas, and seeks to stretch the region's dwindling wood supply. WoodNet members make such products as construction and marine products, home furnishings, arts and crafts, garden products, and kitchen wares.

In an otherwise fiercely competitive industry, WoodNet members routinely communicate with each other, tour each other's shops, and enter into flexible relationships. Neighboring businesses often find that they can make what the other needs. Members with similar products and markets meet regularly to share ideas. Acting together, members reduce costs for materials, professional services, and marketing. They gain access to larger markets by jointly manufacturing products no small firm could supply alone. By adding value to its products, WoodNet creates jobs in an industry burdened by limited resource supply.

Some communities are developing their own creative ways to finance local enterprise. According to Professor Cornelia Flora, Director of Sociology at Iowa State University, risk capital was gathered in Oberlin, Kansas from current and past residents at no more than $1,000 per person—very patient capital that no one expected to get back—and invested in a feedlot which later went private. Ivanhoe, Virginia sells deeds to square feet of land in Jubilee Park in order to raise money for sustainable development projects. They have land owners from all over the world! The project creates community pride, develops community capacity, and raises money.

In Great Barrington, Massachusetts, two farmers are now more able to weather the off-season drop in produce sales because their customers are purchasing Farm Preserve Notes. The notes, sold for $9 in the fall and winter, are good for $10 worth of produce in the spring and summer. Everyone benefits: the farmers get winter cash ($9,000 in 1990), consumers get summer discounts, and the community strengthens its local food supply and agricultural economy.

This practice, called Community Supported Agriculture (CSA), generates up-front capital for planting and secures markets for their agricultural products. With CSA, customers become shareholders when farmers sell shares of produce. Shareholder money gets to CSA farmers early in the season and assures CSA members a supply of fresh fruits and vegetables. In addition, consumers who are part of the farm share in the satisfaction, as well as the risks, of agriculture.

Other successful efforts to strengthen local enterprises have focused on counteracting the two most important causes of failure: inexperienced management and inadequate finances. Federally-supported and college-based Small Business Development Centers have supported small businesses by offering classes in such business skills as management and accounting.

Community development corporations lend to businesses, develop commercial and industrial space, and produce housing. Nationally, there are over 2,000 of these locally-based organizations, each targeting its services to lower income people. An excellent example is the Mountain Association for Community Economic Development, operating statewide from Berea, Kentucky, it works on issues of displaced workers, affordable housing, water quality, access to local government, forest products, and micro-enterprise.

Affordable housing, family farming, and neighborhood integration are the work of Community Land Trusts throughout the United States. Communities use CLTs to preserve the availability and affordability of land to low-income residents, farmers, and others to

h2 2. Manage demand rather than merely seeking additional supply. Osage's solutions focused on ratepayers' use of electricity (demand), rather than a new power plant (supply). The solutions to many problems—water and transportation, for instance—are often far less expensive when they address demand rather than simply adding new supply. And there's a bonus: demand-management solutions are not only better for the economy, they're better for the environment.

h2 3. Growth and development are not the same. Growth is expansion, an increase in quantity, while development is an increase in quality. Communities have many opportunities to develop that do not require them to get bigger. They can create jobs, increase income, save money, provide sustenance, and build a stronger community—all of which strengthen the local economy without necessarily requiring its expansion. Osage saved money and created jobs not by getting bigger, but by getting better and smarter through energy efficiency. Sustainable development is a path to a stronger community economy without the problems often associated with town expansion.

h2 4. Seek small solutions. Local chicken processing was just one of many actions taken by Oregon Marketplace. Several attempts to get businesses to buy locally failed, but many succeeded and provided a big win for Eugene. If Eugene instead had sought one big solution, it could have netted one big failure. By pursuing many solutions, its strategy was resilient and durable.

h2 5. Find problem-solvers who care. All too often, communities rely on outsiders for solutions to their problems—for instance, a CEO who might move her company to towns or a government agency head who might provide a grant. In contrast, the people who found and provided the solutions in Eugene all lived there and probably cared about the community. Many understood that a stronger community was in their interest. This not to say that a community shouldn't use outside resources; on the contrary, an effective development strategy taps outside resources. But relying entirely on outsiders places the community's fate in the hands of people who may not have its best interests at heart.

h2 6. Increase the "multiplier effect." When a given dollar that enters a community is then spent outside the community, it's benefit is felt only once. In contrast, if that same dollar is spent in the community again, its benefit is multiplied. It creates more value, pays more wages, finances more investments, and ultimately creates more jobs. Each additional transaction in which the dollar is involved is just as beneficial and creates just as much wealth as a new dollar from the outside.

h2 7. Find hidden local skill and assets. The women of Colquitt identified an underutilized local asset and put it to work. Every community should examine its natural, cultural, and business assets, and the skills of local residents to find new opportunities. Hidden opportunities can even be found in waste: in Rifle, Colorado and Hazleton, Pennsylvania, huge greenhouses keep warm with the waste heat from local power plants.

h2 8. Build social capital. The last lesson comes to us from scores of communities seeking sustainable solutions. Because sustainable development generally requires many small actions by many people, it relies on the participation and support of those people, not just the powerful few. But that support is difficult to obtain unless the community has accumulated social capital—the capacity of a community to work together despite differences, the willingness of residents to volunteer to serve the community and their fellow residents.

Though successful development can result from one person's great idea, a community that sits back and waits for that person to come forward is likely to drift in complacency, hoping things will get better. In contrast, a proactive community sails to success by gathering residents from all walks of life to examine where the community wants to go and how best to get there.

Keeping the community's ship on course requires a crew that works together. But there's dissension in the ranks of most communities. The primary barrier to community success is not the condition of the economy, the price of an important local commodity, the

However, they should add up whether a proposed new industry will bring a *net* benefit. Will the advantages outweigh the costs? Tax breaks, land giveaways, infrastructure upgrades, and other inducements used to attract an outside company will do no good if there is no net gain to the community.

Residents of sleepy Cripple Creek, Colorado, assumed nothing but benefits would accrue from the gambling casinos that moved into town a few years back. Many spent a lot of personal time and money to ensure success of a state ballot question allow gambling in their town. But demands for new public services to the new industry resulted in a 3 1/2 fold increase in property taxes. One local business person could not afford tap fees to new water lines and was forced to run a garden hose down the alley from one casino. Increased taxes and fees forced some residents to leave their own community.

Communities should carefully consider any significant new development to determine if there are hidden costs. For instance, several recent studies have indicated that residential growth usually results in net losses to public coffers, while commercial and industrial expansion may provide net gains but often does not. Revenues from new growth often aren't enough to offset the costs of higher demand for such services as schools, police, fire protection, roads, and sewers. One of the reasons for this dilemma is that local governments usually spread the cost of new public services evenly among all taxpayers, rather than charging it to those who created the cost. The result? Higher taxes for longtime residents, many of whom experience little or no benefit from the growth.

A cautious approach is the cost-effective way to stimulate new business and development. By choosing the most promising and compatible development for your community, you will be able to take your best shot in a range of possibilities. You will be able to make the best use of limited resources and time.

The overarching principle of sustainable development is to do better with what you have; build on your strengths. A community that pursues the principles and heeds the lessons of sustainable development will have a competitive edge if it decides to seek new industry. A community that has plugged its leaks won't be desperate for any economic activity, regardless of whether it fits local conditions. With a reinforced foundation, your community will be a more attractive place for businesses to locate, and you shouldn't have to offer expensive inducements.

Responsible developers are confident moving to places where community values and goals are clearly stated, and local government and businesses collaborate to achieve those goals. They don't mind firm local rules when they are clearly stated and fairly enforced. Whatever direction your community chooses, taking care of what you already have will give your economy the strength to multiply the benefits of any later economic development.

h1 Eight Lessons of Sustainable Development

Sustainable development also illustrates eight important lessons that you can put to work as you strengthen your local economy.

h2 1. Ask why. Before pursuing energy efficiency, Osage leaders started down a more conventional path. The town seemed to be running short of electricity so they considered building an expensive new power plant. But because they were reluctant to raise electric rates to pay for it, Osage leaders asked themselves, "Why build the plant?" The answer: "for more electricity." Unsatisfied, they asked, "Why more electricity?" This time they'd gotten to the underlying reasons: all the uses to which people put electricity. Their solution focused on those uses, helping residents make their electricity go further through home weatherization, efficient lighting, and load-management systems.

The same idea applies to any sort of economic development. To identify underlying goals at the beginning of any community development effort, ask why. Keep asking why a given development proposal is needed in order to ensure that it actually serves the community. You can then pursue many ways to achieve those goals, rather than narrowly focusing your efforts exclusively on such one-size-fits-all solutions as industrial recruitment.

If available, such information as trend analyses, income distribution, tax sources, income and employment by industry, and demographic data, can be offered to participants at this point in the process.

h3 Step Four—Discover Community Economic Opportunities is a challenging exercise that tests participants' creativity. They explore local development opportunities by "making connections," that is, by using an innovative exercise to identify how local assets might solve or fulfill the problems and needs listed in Step Three.

h3 Step Five—Generate Project Ideas, Using What You've Learned, exposes participants to scores of realistic options described in written materials, such as RMI's *Business Opportunities* and *Energy Casebooks* as well as other locally-available sources. Based on the written examples and what participants have learned during the process, they brainstorm ideas for projects they might pursue.

h3 Step Six—Evaluate Project Ideas, begins by refining the project ideas from Step Five. It ends with an evaluation of each project idea for its practicality, sustainability, and compatibility with the community preferred future.

h3 Step Seven—Select Project Ideas: Some of the project ideas will be gems, others will be unrealistic. Some may be huge, others more modest. Though many projects might be sponsored by, say, local government, others would be carried out by a nonprofit group. This step compares projects to one another so that a diverse mix of a few high-potential projects can be chosen.

h3 Step Eight—Develop Projects: Once participants choose the projects they wish to pursue, they set out a course of action for implementing them. Some projects may be carried out by community volunteers, local businesses, and local government. However, other projects (for example, those requiring market or feasibility analyses) will require technical assistance. The community can find that assistance through state or regional government agencies, experts from the state university (*e.g.* extension service), nonprofit non-governmental organizations, or private consultants.

h2 Outcome

The outcome of the process will be a few realistic projects chosen by participants. Because many local residents participated in selecting projects or, at least, followed and understood the selection process, they will feel some ownership in and commitment to them. Participants will chose at least one project that can be implemented quickly and easily to achieve a short-term, measurable success.

The process should also result in a group of community residents and leaders who better understand their economy and are comfortable with economic development. Many influential residents will have participated in genuinely collaborative decision making that may be less contentious than the recent history of local decisions. They will better understand each other and be more willing to work together. This experience may lead to more creative and constructive decisions in the future.

availability of capital, or the quality of marketing; rather it's the inability of residents to work together for the common good. Therefore, the most important goal any community can learn is to build social capital. This guide will help you involve people from all walks of life in your community's development effort. At each step in the process described below, you'll add another building block of social capital to serve as the foundation upon which your community will succeed.

h1 Collaborative Decision Making for Sustainable Development

When an important decision that will shape a community's future is made by an elite group of insiders or by outside experts, community residents who are left out may not stand for it. The result can be delay, distrust, controversy, litigation, or inaction.

In contrast, a community will support decisions made through the collaboration of all local "stakeholders" (representatives of all community interests that have a stake in development). Collaborative decisions are more effective for two reasons: they are based on a wider range of community experience and wisdom, and they are less likely to be opposed and more likely to be supported because participants "own" and are committed to the results.

A community-based approach is not only supported by residents, it's also far less expensive than economic development driven by experts. Most communities have limited access to professional assistance because they are short of money or because they have to borrow experts from universities or government agencies with limited ability to help. Using a decision-making process such as the one described below, communities make the decisions on their own. They then can use their limited consulting budgets for technical assistance if they determine it is needed. They use experts without relying on them.

A community-based approach builds local citizen's economic development skills. Once they have experienced an economic development process first-hand, it no longer seems intimidating or too technical. It becomes comfortable and something they can periodically return to.

h2 Eight Steps

The following is one thoroughly tested means by which a community can take stock of itself and identify development projects through a genuine collaborative process.

h3 Step One—Mobilize the Community: First, ensure that people from all walks of life are involved, not only powerful people but also those who are influential in more subtle ways—for instance, leaders of neighborhood associations and activist groups, or respected teachers. This is the most important step. The success of the rest of the process depends largely on the attention paid to this step.

h3 Step Two—Envision the Community's Preferred Future assembles process participants' values, goals, and perceptions into one list called the preferred future. The list itemizes what the community wants to preserve and what it wants to create. This information becomes the foundation for any decision that the community later makes to develop itself. It is the reasons for development.

Participants are usually surprised to notice how their personal interests intersect with the interests of nearly all other participants, even the ones often regarded as adversaries. Their realization begins the process of building trust among adversaries. The meeting at which exercise this takes place is usually the first public session. It, therefore, often includes a verbal introduction to sustainable development and the process.

h3 Step Three—Identify What You Have to Work With: Before deciding what to do to strengthen the local economy, you need a clear picture of what the community has to work with. This step divides the local economy into several aspects or factors, each of which is examined by a subgroup of participants. Using their own knowledge plus background found in this guide, each subgroup identifies community problems, needs, and assets specific to its factor.

The American Institute of Architects
Committee on The Environment

by Harry T. Gordon, AIA [1]

FORMATION

In response to growing concerns about the impact of the building industry on the global environment, the American Institute of Architects (AIA) formed the **Committee on The Environment** (COTE) in 1990 to increase awareness of the relationship between the designer and the built environment. The COTE is the Institute's forum for the compilation, exchange, and dissemination of environmental information integral to design and the practice of architecture.

MISSION

The mission statement of the AIA Committee on the Environment is:

To Create Sustainable Buildings and Communities by Advancing, Disseminating and Advocating Environmental Knowledge and Values to the Profession, Industry and Public

We have structured our activities around the three processes identified in the mission statement:

Advancement:	To promote research, education, and professional development that advances the knowledge and understanding of sustainable design.
Dissemination:	To create a model information clearinghouse for disseminating knowledge of sustainable design.
Advocacy:	To effect national, regional, and local policies and programs to encourage sustainable design.

MAJOR ACCOMPLISHMENTS

Since its inception, the AIA COTE has successfully undertaken major environmental initiatives, including:

- Development and publication of the *Environmental Resource Guide (ERG)*

---

1 Harry Gordon is a Principal of Burt Hill Kosar Rittelmann Associates and Chairman of the AIA Committee on the Environment

Specifically, EDCs educate citizen groups and make resources accessible to them; foster linkages among the community, professionals, and the government; and accelerate the economic, environmental, and energy benefits that can be realized through the adoption of sustainable development principles and practices.

Background.

The environmental design professions—including architects, engineers, landscape designers, and planners—have a longstanding commitment to the quality of life in our urban, suburban, and rural communities. Our talents and services can be best summoned and focused by a national agenda to assist our communities in ways not previously considered and scales not previously envisioned to rebuild a nation of sustainable communities.

The intent of the initiative was to test a process for conducting environmental design assistance teams modeled after the successful "Greening of The White House" and other charrettes to replicate the process freely in communities throughout the country.

Local AIA components, schools of architecture, communities, and related professional organizations participated in the national electronic charrette by teaming up to sponsor proposals for select charrette projects and sites.

Goals.

- Provide a process for design assistance from selected sustainable development experts in federal and state research institutions, universities, trade groups, private organizations, and professional associations.

- Advocate sustainable development among policy makers, regulators, opinion leaders, financiers, and other enablers.

- Help create and deliver education materials for design professionals, builders, general contractors, etc. in the form of technical reports and resources.

- Provide information services, including databases, to help customers locate sustainable materials, equipment, and techniques; find professional firms with sustainable development expertise; link with other projects that have successfully employed sustainable development principles and technologies; and negotiate the maze of relevant public and private programs.

Benefits.

EDCs bring diverse elements of a community together in a demonstration of collaboration for a comprehensive view of the interconnection between economic need, community development, and long-term environmental sustainability.

The *Greening of the White House*, the *Greening of the Pentagon*, and the design assistance provided to the Mississippi floodway communities (Valmeyer, Ill., and Pattonsburg, Mo.) are noteworthy examples of how the AIA has used this model to improve the environmental aspects of buildings and communities. Local AIA components and schools of architecture have similar EDC experience.

Each EDC site used community participants to identify and address the key sustainability issues for their chosen design problem. Three elements are essential to a comprehensive solution: economic opportunity, social equity, and environmental responsibility.

Primary Issues

The environmental focus and emphasis vary depending on the design problem. Samples include:

- Energy: building envelope and windows; lighting and daylighting; plug loads; and heating, cooling, and ventilating systems
- Building Ecology: materials and indoor air quality
- Air, water, and landscaping: site design, aquifer recharge, and parking and walking surfaces
- Waste management: construction and demolition waste, building operations waste, and water and waste nutrient recovery
- Cultural change and behavioral issues: pollution prevention, environmental equity, human factors, and social and community involvement.

- Development and sponsorship of *Building Connections*, a series of three videoconferences, with the theme of *Linking Economy and Ecology for a New Prosperity*. The subjects of the videoconferences were (1) Energy and Resource Efficiencies, (2) Healthy Buildings and Materials, and (3) Sustainable Communities. The videoconferences were seen by over 10,000 people nationwide and the tapes are now available through AIA.

- *AIA World Congress* - The theme for the international conference was *Architecture at the Crossroads: Designing a Sustainable Future.* Held in June 1993 in Chicago, IL, the meeting was the first major international meeting to focus on environmental issues since the Earth Summit held in Rio de Janeiro, Brazil, and was attended by over 10,000 people from 80 countries. The culmination of the World Congress was the signing of the *Declaration of Interdependence*.

- Greening of the White House - the AIA coordinated the efforts of over 100 multi-disciplinary experts to produce a Feasibility Study investigating all opportunities to employ energy saving and environmentally sound technology in all White House facilities and operations (including the Old Executive Office Building). COTE members have also had key roles in the Greening of the Pentagon, the Greening of the Grand Canyon, and other environmental initiatives.

- COTE developed a brochure for building owners, titled, *Healthy, Productive Buildings: A Guide to Environmentally Sustainable Architecture*. The brochure is available from AIA, and addresses site planning, energy use, indoor environment, materials selection, and recycling/waste management.

- Cote sponsors annual International Symposia on environmental topics, drawing speakers and audience on design and environmental topics. The themes of the symposia are:

  - 1991 - Energy, Environment and Architecture
  - 1992 - Designing Healthy Buildings: Indoor Air Quality
  - 1993 - Sustainable Strategies for Communities and Building Materials
  - 1994 - Global Symposium for Sustainable Environments

CURRENT INITIATIVES OF AIA COTE

AIA Environmental Resource Guide

With substantial support from the U.S. EPA, AIA initiated the *Environmental Resource Guide* (ERG) project in 1990. The book has two components. The first

ENVIRONMENTAL RESOURCE GUIDE

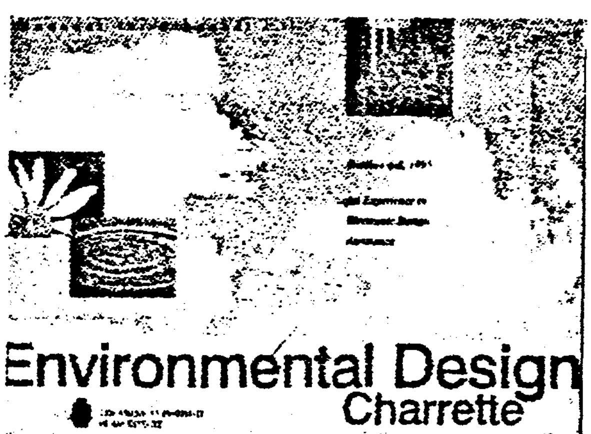
includes research and development of information, and the second involves the dissemination of information through the ERG which was first published in 1992.

Throughout the project's planning and development, the AIA COTE has provided overall guidance and has served as a valuable technical resource. In 1994, the AIA formed the ERG Steering Committee to bring a greater focus to the effort and serve as the ERG's advisory body. The ERG is now being published by John Wiley & Sons under an agreement with AIA Press.

The primary goal of the ERG is to help design professionals make environmentally informed choices for the selection of materials for use in building components, assemblies and systems. Generally there are alternative materials available for any given architectural application and each alternative carries environnmental burdens and may offer environmental benefits. The ERG addresses these issues along with other design considerations. However, the ERG does not tell which product of material to use. Instead, it presents information to enable architects, designers, and specifiers to make better environemental selections to use materials more wisely.

Environmental Design Charrettes

In October 1995, AIA hosted a national event with 15 separate communities simultaneously holding design charrettes throughout the United States, linked via electronic communications. The primary objective of this event was to demonstrate the effectiveness of the environmental design charrette process in raising the public and professional awareness of and involvement in environmental design projects at the building, community, and bioregional scale.



AIA EDC Request for Proposals

An Environmental design charrette (EDCs) is an intensive short-term workshop that is part of a longer, multi-disciplinary project study. The EDC process is a publicly visible way to address the sustainable environmental design issues of economic opportunity, social equity, and environmental responsibility in the planning and design of buildings, communities, and regions.

THE APPLICATION OF FINANCE AND ACCOUNTING THEORY TO THE VALUATION OF NEW ENERGY AND EFFICIENCY OPTIONS

Shimon Awerbuch, Ph.D.
Independent Economist
Nashua, NH 03062

New, renewable energy and energy efficiency technologies are often passive and capital intensive— attributes they share with computer-integrated-manufacturing (CIM), robotics, computer-aided-design (CAD) and similar manufacturing process technologies. The experience in manufacturing over the last two decades indicates that traditional accounting-based procedures for valuing such new technologies significantly understate their benefits [Awerbuch 1993(a)]. This problem is caused by:

i) The use of discounted-cash-flow valuation procedures which ignore risk differentials of new versus old technology forms [Awerbuch 1993(c)];

ii) The reliance on antiquated cost accounting systems that were developed to support a previous era of *active, expense-intensive* technology [Awerbuch, 1993(b)];

iii) The use of cash-flow-based valuation procedures which ignore important managerial options created by new technology forms, including *quality, capability and flexibility* options;

iv) The failure to recognize that new technology changes the way things are done, e.g.: the way buildings are designed, thus reducing cost in ways not anticipated.

The cost of producing energy or energy savings with new technologies is usually estimated using traditional, engineering-oriented discounted cash flow models developed over fifty years ago. Estimating the cost of renewables-based energy or savings, however, is not trivial; traditional engineering procedures fail to reflect risk and other important costs and should not be used.[1]

Traditional engineering-cost models further assume that the benefits and costs can be represented by a stream of direct cash flows. The benefits of passive energy and energy saving technologies however often do not stem from direct cost reductions but are related to overhead reductions and managerial options. As a result, traditional costing procedures cannot 'see' the value of new technology [e.g. Kaplan, 1986].

This presentation highlights recent research which extends project valuation principles first developed in manufacturing, where American firms in particular recognized that their

[1] For example, commercial real estate developers may value incremental energy efficiency outlays as well as the potential energy savings at some arbitrary discount rate such as the mortgage rate or the owner's cost of capital, which is consistent with traditional engineering cost approaches. The mortgage rate, however, reflects the *lender's* risks which are a function of the systematic market risks associated with rent levels, as modified (e.g. reduced) by expense outlays for building maintenance and fuel.

When evaluating a specific expense outlay, e.g. energy, a very different discount rate is needed— one that reflects the risk of that outlay alone. This can be seen intuitively: suppose the building owner could contract with a service to provide fuel deliveries over a long period, say 20 years, in return for a fixed up-front payment. The fuel provider would try to assess the market risk of future fuel price fluctuations and develop a market-based present value for the delivery contract. This present value would have nothing to do with the building owner's mortgage rate or overall cost of capital.

existing accounting and capital budgeting procedures were leading to the rejection of new, innovative processes. The research to date has included the application of:

> i) Capital market theory as a basis for valuing investments in renewable energy and energy efficiency; this approach reflects financial (systematic) risk differentials between the benefits or costs of various technological options. Properly adjusted for such risk differentials, the empirical results suggest that PV and other solar technologies are considerably more cost effective than previously thought.
>
> ii) Portfolio theory to illustrate how higher cost/lower risk renewables/efficiency technologies may be used to reduce risk without increasing cost for a portfolio energy options; in this context the "stand-alone" cost of a particular technology is less important than its contribution to the overall cost of an energy portfolio, relative its risk contribution to that portfolio.
>
> iii) Activity-based-costing (ABC) concepts to better understand the full costs of renewables/efficiency as compared to traditional options.

In addition, the research illustrates how reliance on the engineering oriented *levelized energy cost* (e.g. $/kWh) distorts intertemporal benefit/cost streams thus improperly back-loading energy costs to future cohorts. The addition of environmental externality issues serves to heighten this result.

REFERENCES

Awerbuch, Shimon "Chapter 1: New Economic Cost Perspectives for Solar Technologies," *Advances in Solar Energy, An Annual Review of Research and Development*, Karl W. Boer, (Editor), Volume 10, Denver: American Solar Energy Society, September 1995.

Awerbuch, Shimon "Risk-Adjusted IRP: It's Easy!!!," *The Electricity Journal*, March 1995.

Awerbuch, Shimon "Do Consumers Discount the Future Correctly? A Market-based Valuation of Fuel Switching," (with William Deehan), ***Energy Policy***, Volume 23, No. 1 (January) 1995.

Awerbuch, Shimon (1993a) "Measuring the Costs of Photovoltaics in an Electric Utility Planning Framework," *Progress in Photovoltaics: Research and Applications*, Volume 1 No. 2, (April) 1993; Chichester: John Wiley and Sons.

Awerbuch, Shimon, (1993b) "We Do Not Have the Measurement Concepts Necessary To Correctly Implement IRP: A Synthesis and Research Agenda," NARUC Renewables Meeting, Savannah, October 1993.

Awerbuch, Shimon, (1993c) "The Role of Risk and Discount Rates in Integrated Resource Planning" *The Electricity Journal*, Volume 6, No. 3, (April) 1993.

Kaplan, Robert, *Measures of Manufacturing Excellence*, Boston: Harvard Business School Press, 1990.

Applying Finance and Accounting Theory to the Valuation of New Energy and Efficiency Options

------

Shimon Awerbuch, Ph.D.
Independent Economist

Designing the Global Environment

Georgia Institute of Technology
Atlanta: November 2, 1995

Traditional Cost Approaches No Longer Work: How Not to Evaluate Solar/Efficiency Options:

The Legacy of Manufacturing:

- **Simplistic, Accounting-Based Benefit-Cost Techniques Cannot Properly Value New Technology**

- **Such Techniques Have a Dismal Record for Picking Winners:**

1960's:	*Computers*	"Armies of Clerks are Cheaper"
1980's:	*Robotics*	"Not Yet Cost-Effective"
1980's:	*CAD*	"Engineers Are Cheaper"

These Same Techniques Say Solar/Renewables are 'Not Yet Cost Effective'

Traditional Cost Approaches No Longer Work
Example: Valuing Computer-Aided-Design (CAD)

- **Analyses Based on Naive Benefit-Cost:**

    -- Engineering Salaries Saved Vs. CAD-Station Outlays

- **Analyses Did Not Value CAD's "Intangible" Benefits:**

Frequent product redesign	→	No obsolete product/inventory;
Rapid response/throughput	→	More varied product line;
Complementary benefits	→	Reduce CIM set-up costs;

CAD Helps The Firm Retain Customers--
Not Save Engineering Salaries

Valuing Solar/Efficiency Technologies— Main Ideas

- **Traditional Engineering-Based Valuation Approaches Were Conceived in A Different Technological Era**

  -- Didn't Work in Manufacturing, Won't Work for Passive Solar/Efficiency Options

- **New Value Concepts Must Be Conceived In Order to Fully Understand Renewable/Efficiency Technologies**

- **Meanwhile... Solar/Renewables Seem Cost Effective When Valued Using Modern Capital Asset Valuation:**

  -- Reflect Technology's Financial Risk

    -Market-Based Discounting Using *Capital Asset Pricing Model*

  -- Portfolio Effects

Valuing Solar/Efficiency Using Modern Capital Asset Valuation

- **Individual Benefit/Cost Streams Must be Valued (Discounted) at CAPM-Derived Risk-Adjusted Discount Rates**

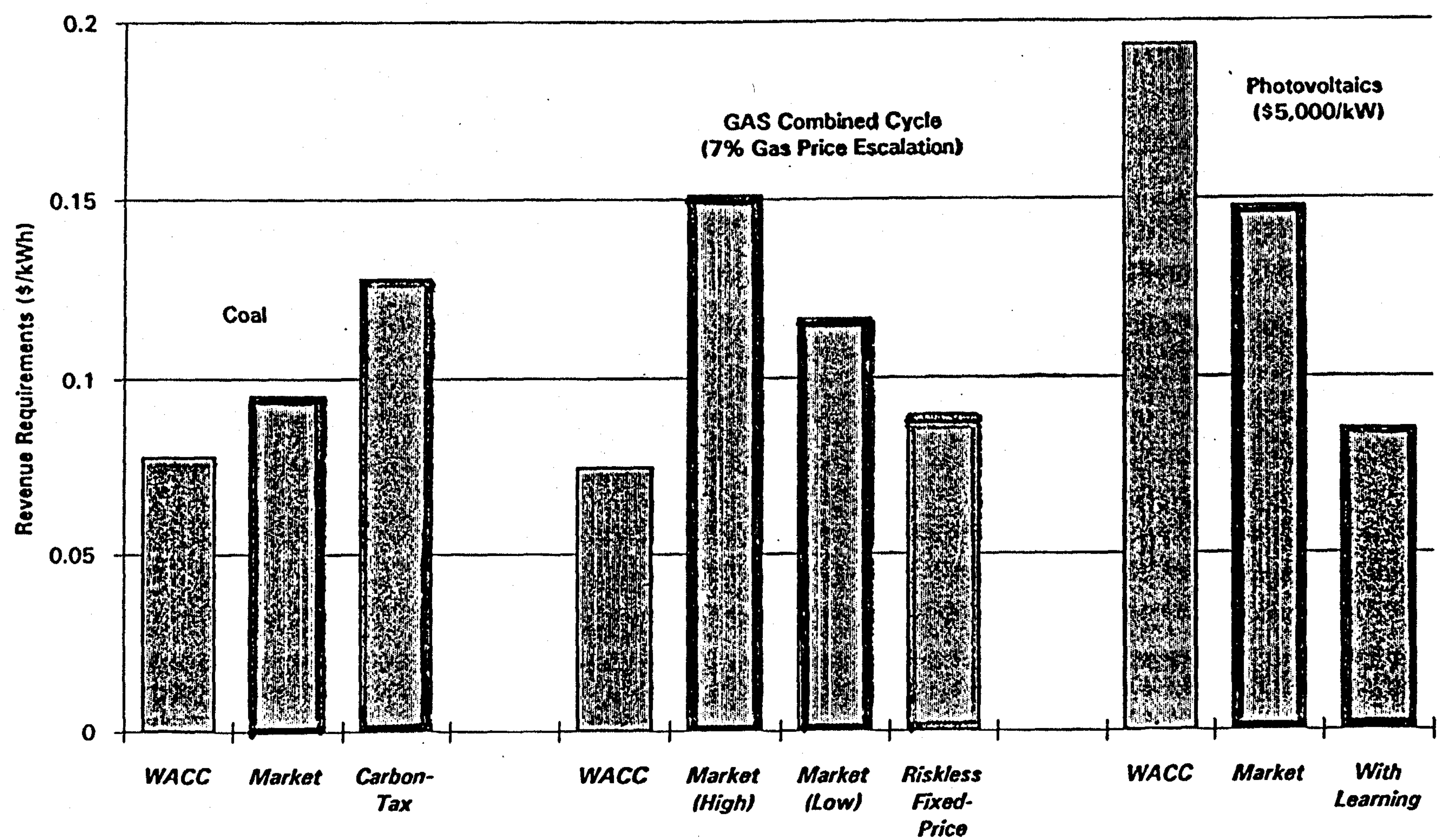
-- Mortgage & Similar Rates Reflect Overall Risk of *Net Cash Flows*
-- "Safe" Benefits Have *Higher* Present Values Than Risky Ones

> *Which Benefit Is More Valuable?*
> *i) $1000 annual interest stream from a Junk Bond*
> *ii) $1000 annual interest stream from a T-bond?*

-- "Safe" Costs Have *Lower* Present Values

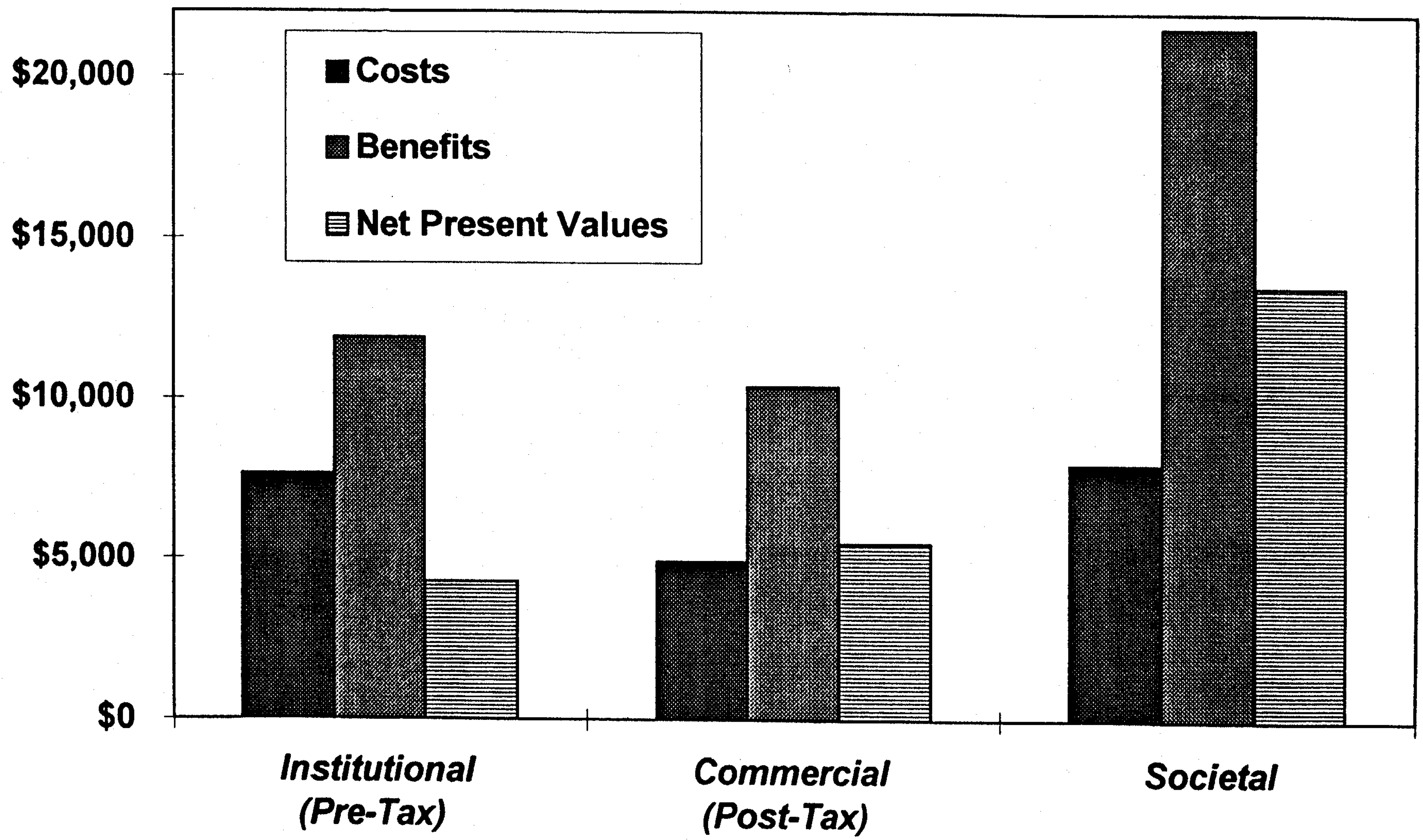
> *Which Cost Stream Is More Desirable?*
> *i) $1000 monthly "risky" utility bill?*
> *ii)$1000 monthly "riskless" outlay for PV-based electricity?*

Levelized Revenue Requirements Excluding Overheads & Indirect Costs: WACC-Based and Market-Based Results



Shimon Awerbuch, Nahsua NH

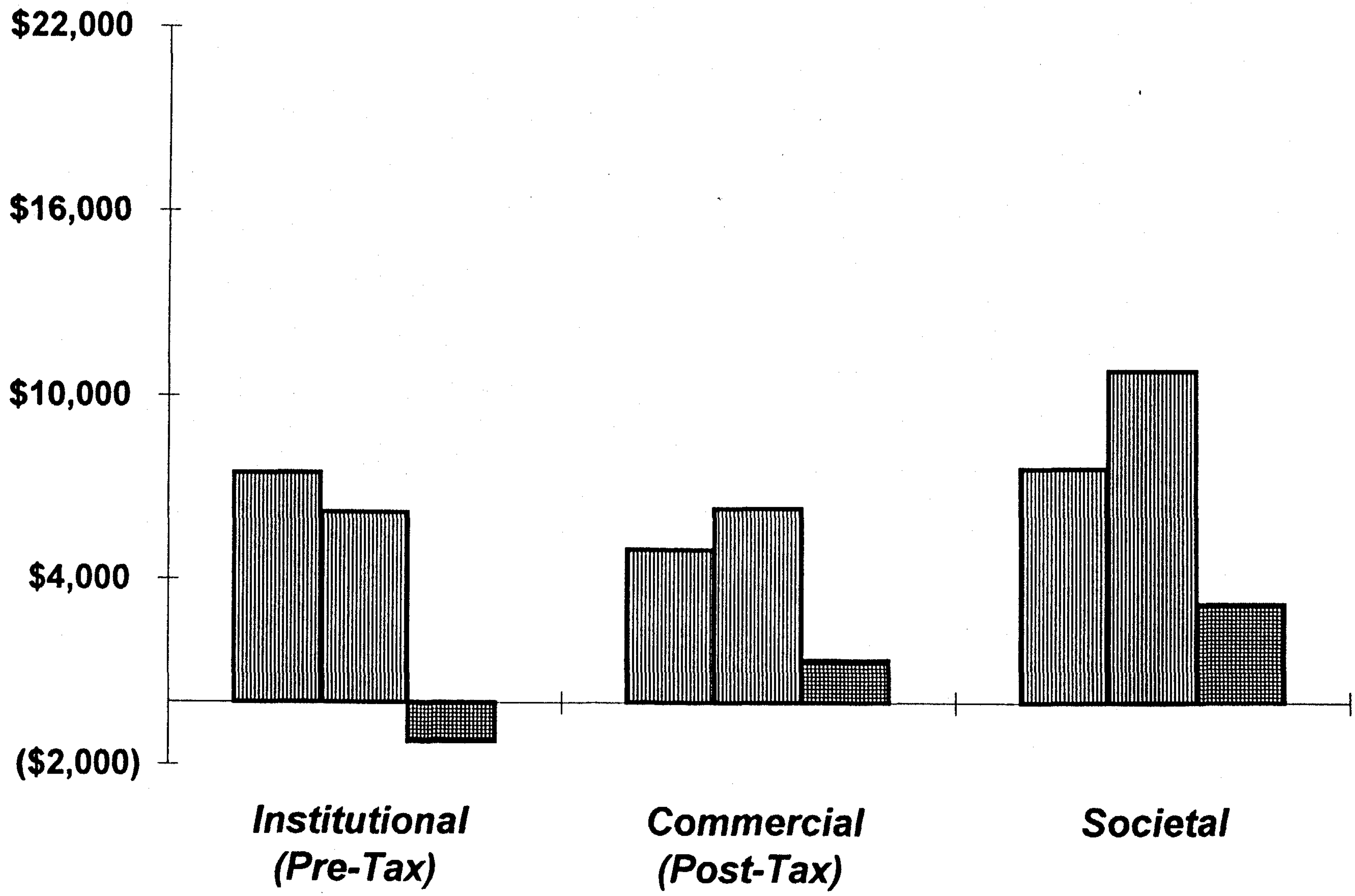
Present Value Costs and Benefits per kW of PV-Augmented Uninterruptable Power Supply



Shimon Awerbuch Ph.D. Nashua, NH

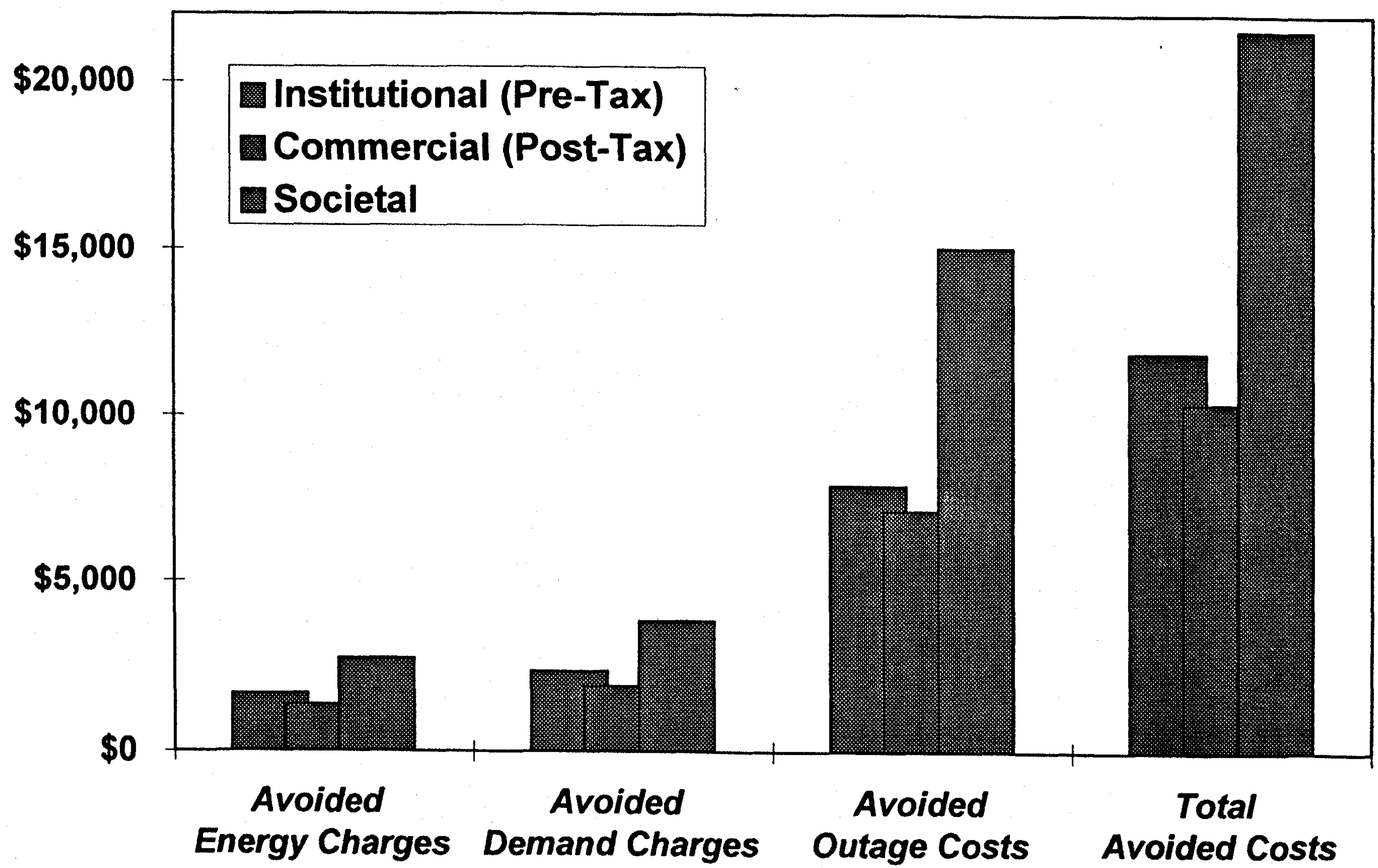
Present Value Costs and Benefits per kW of PV-Augmented Uninterruptable Power Supply

All Benefits/Costs Discounted at Same Rate



Shimor ..verbuch Ph.D. Nashua, NH

Avoided Energy, Demand and Outage Costs per kW of PV-Augmented UPS



Portfolio Effects

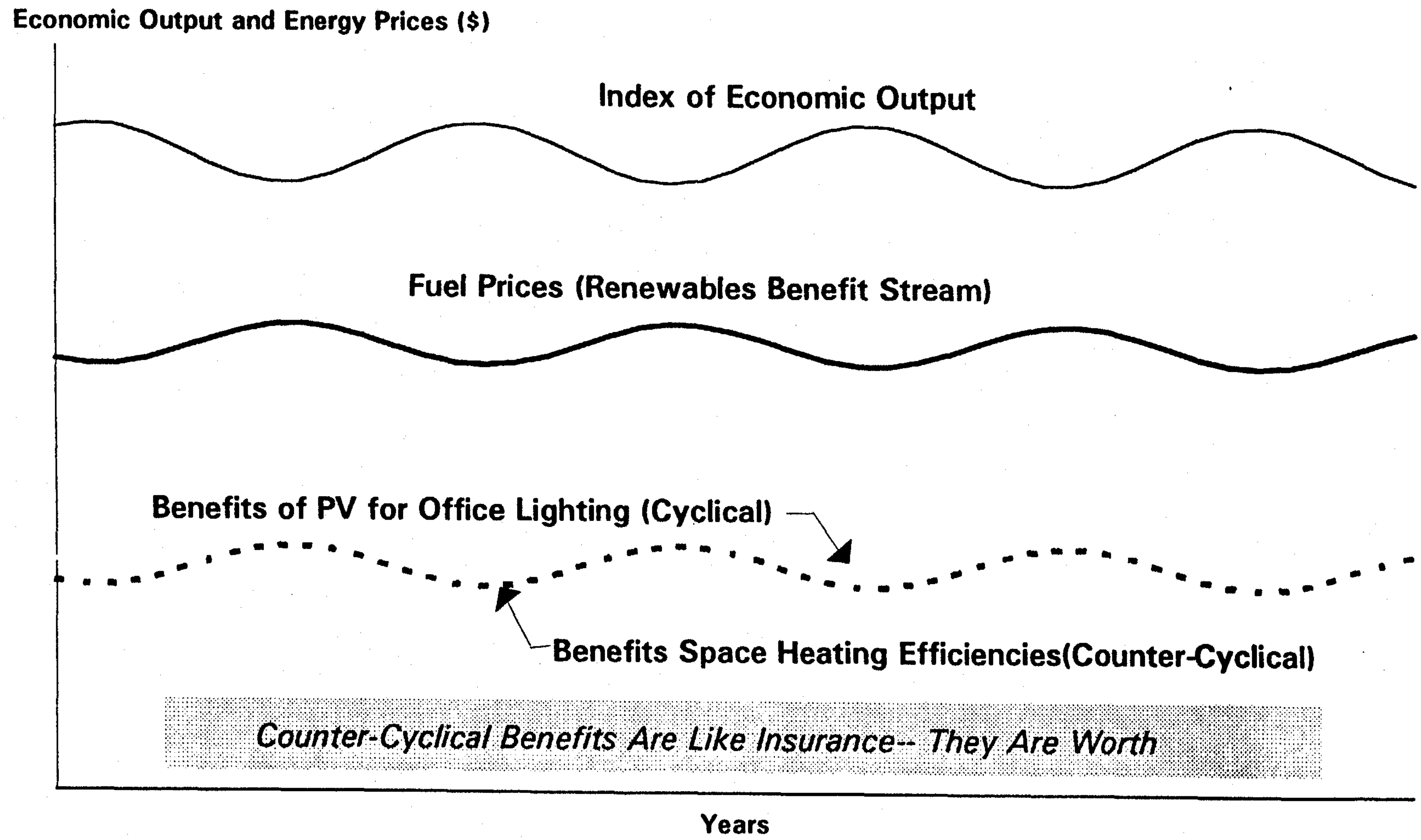
- **An Energy Alternative's "Stand Alone" Costs Are Probably Not Very Meaningful**

  -- Evaluate the Technology's Contribution to Portfolio Cost Relative to its Contribution to Portfolio Cost

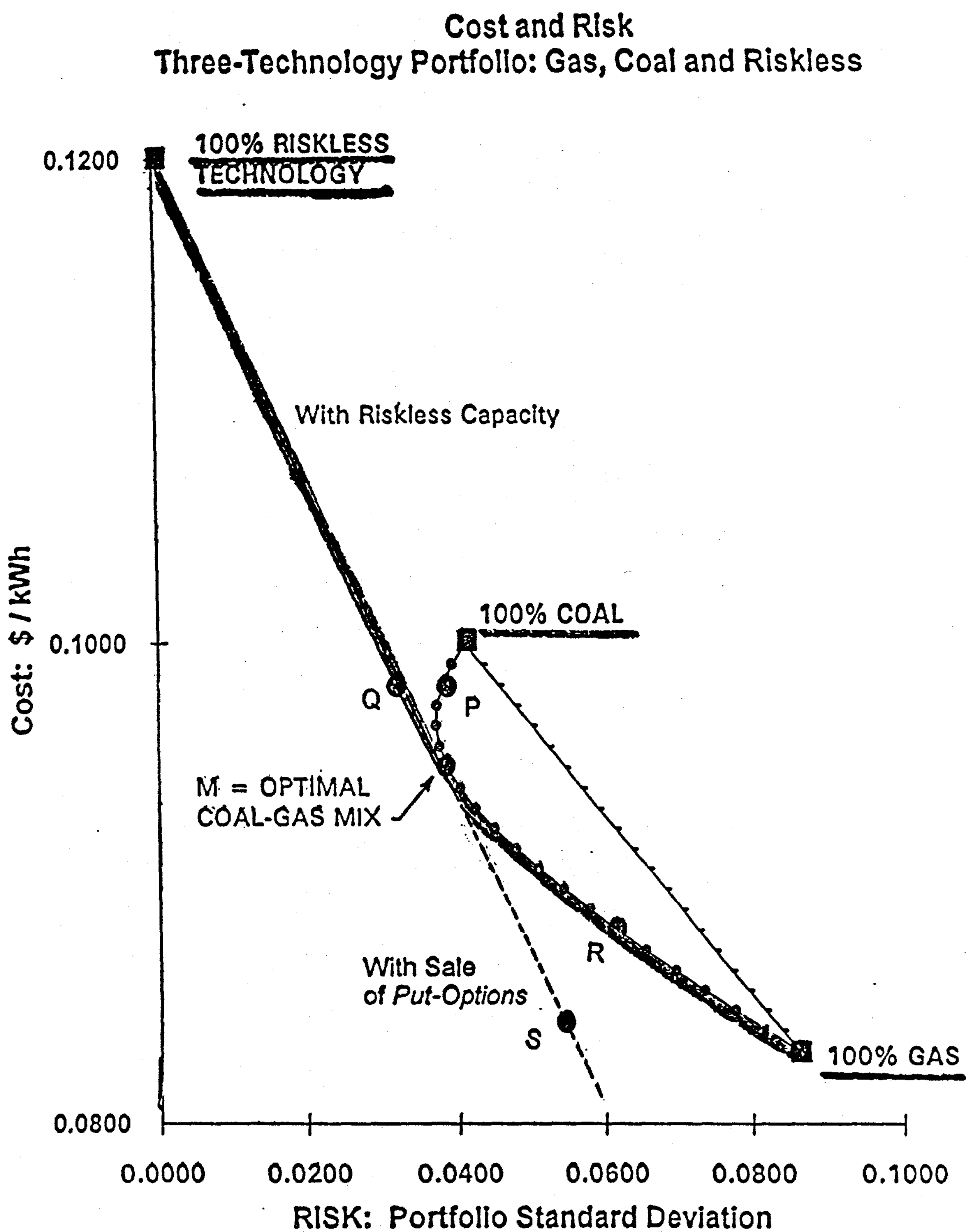
- **Renewables/Efficiency Options Can Enhance the Performance of an Energy Portfolio**

  -- Reduce Financial Risk or Cost or Both

Diversified Renewables/Efficiency Portfolios With Countercyclical Benefits



Shimon Awerbuch, Ph.D. • Nashua, NH 03062 • 603 891 1342



Shimon Awerbuch, Ph.D. Nashua, NH

Portfolio-Theory Implications for Solar/Efficiency Options

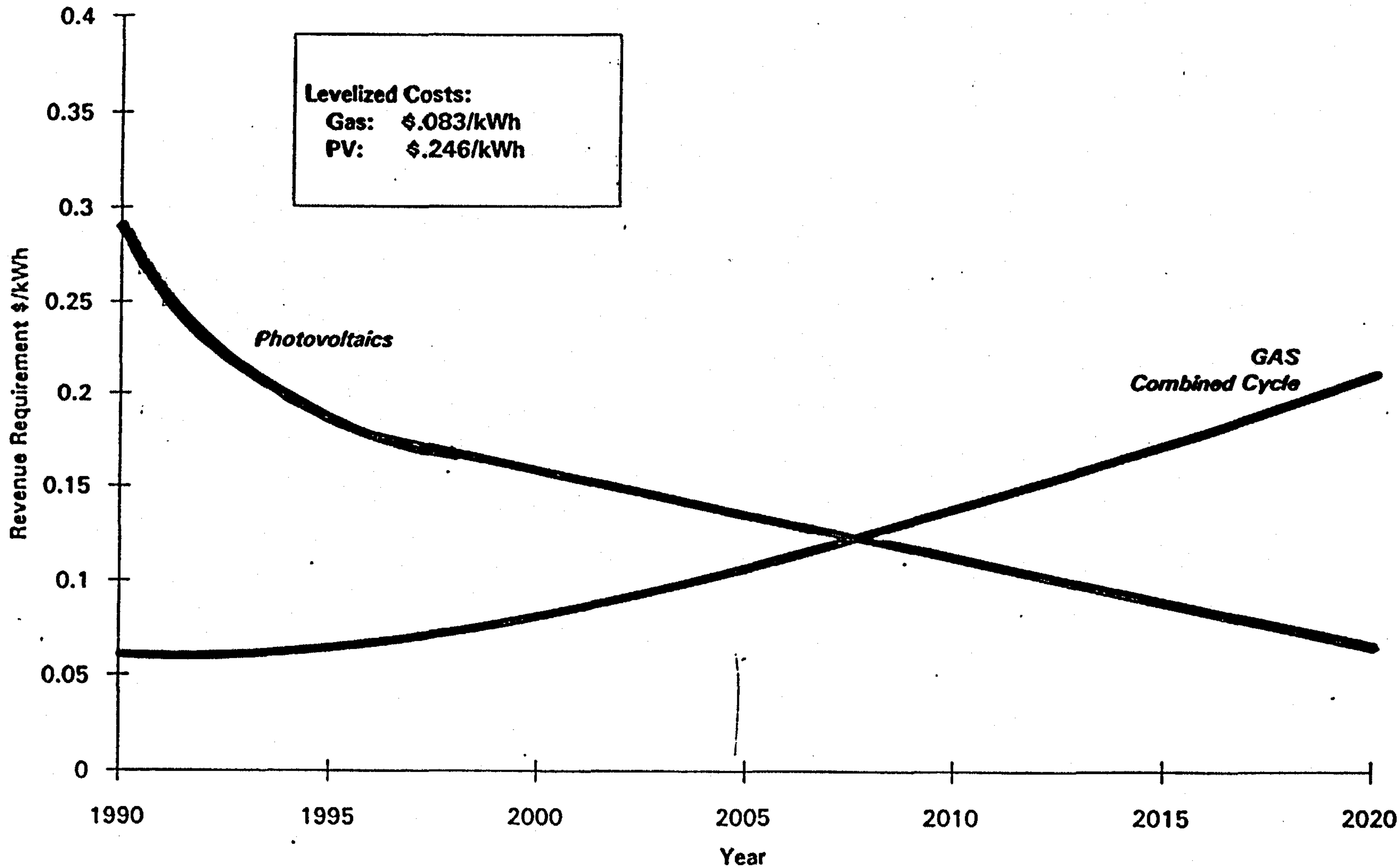
- **Theory: Financial Portfolios Must Include Low-Yielding US Treasury Bills**

  -- T-Bills Are More Costly -- i.e. Lower Yielding,
  Yet *Increase* Portfolio Return at Any Given Level of Risk

  -- Similarly, Photovoltaics (PV) and Low-Risk Efficiency Options Can Reduce Cost/Risk of an Energy Portfolio

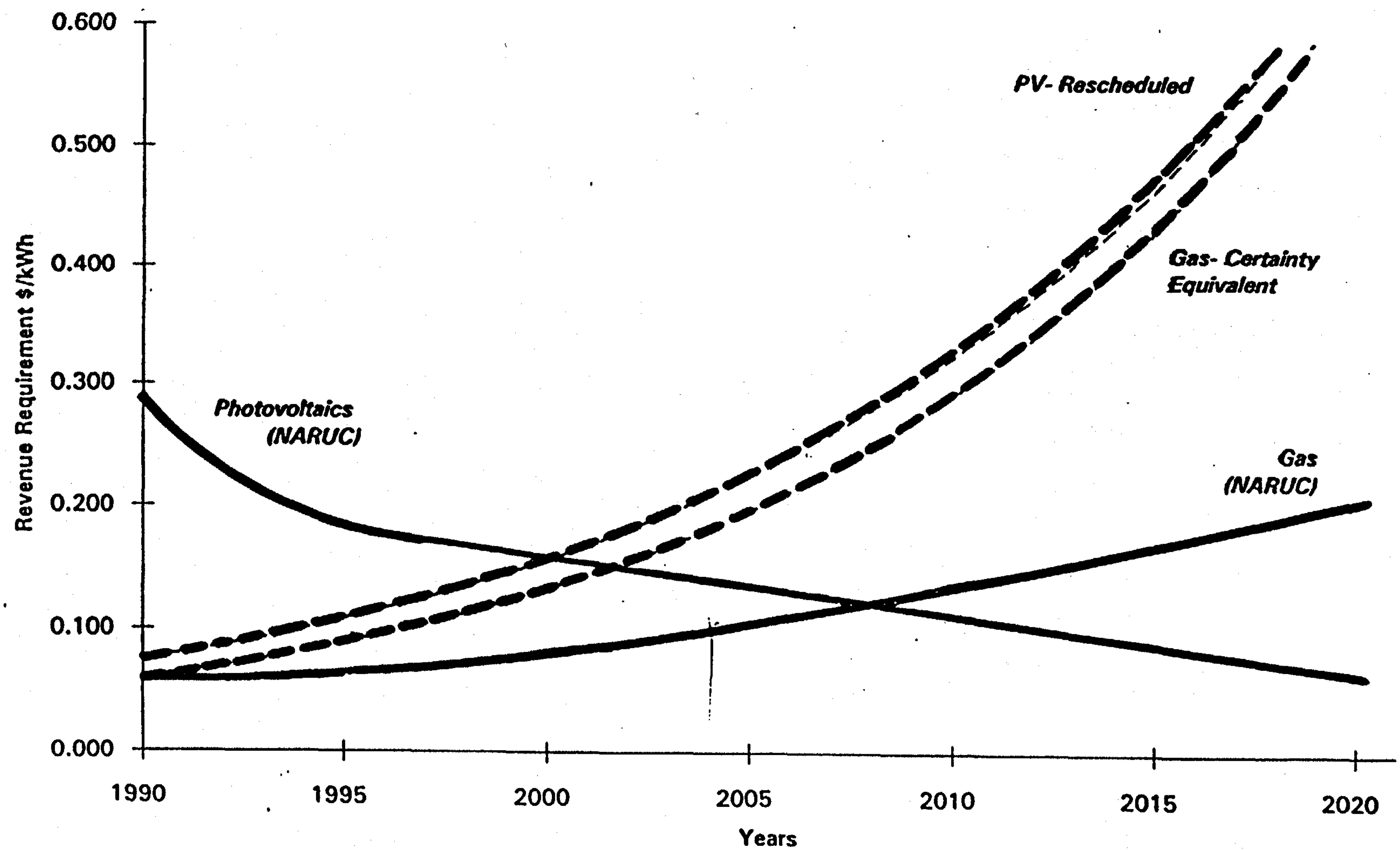
If Financial Investors Applied Valuation Techniques Used for Energy Technologies They Would Only Invest in Junk Bonds!!

Direct Utility Revenue Requirements
(Source: NARUC, 1990)



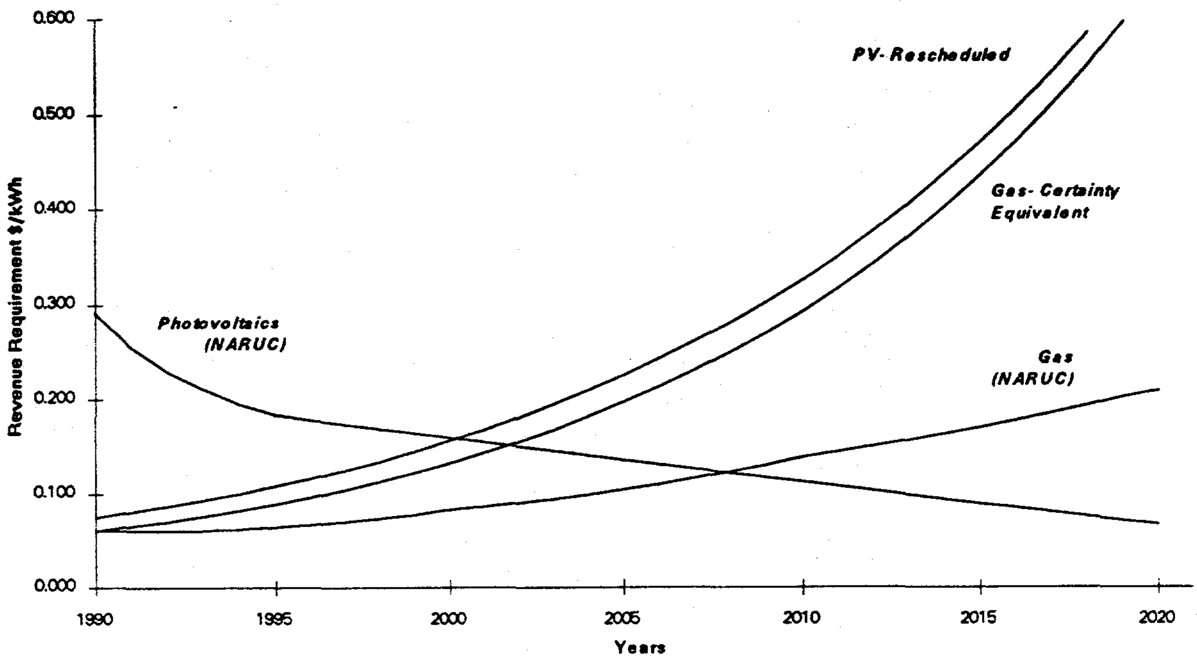
Shimon Awerbuch, Ph.D. Nashua, NH 03062

Direct Revenue Requirements and Certainty Equivalents for PV and Gas



Shimon Awerbuch, Ph.D. Nashua, NH 03062

Direct Revenue Requirements and Certainty Equivalents for PV and Gas



- **Fossil Fuel Usage Saddles Future Cohorts With Rising Fuel and Environmental Costs**

- **Should We Alter Our Compact With the Future?**

Perhaps It Would be a Lesser Evil to Shift Capital Recovery on Solar/Renewables to the Future

Synopsis: Valuing Solar Energy Technology

- **The Previous Results are Based on Established Finance and Accounting Concepts**
  -- Suggest Renewables are Quite Cost-Effective

- **But There is More: Valuing Renewables Requires A Richer Accounting Vocabulary**

  -- Innovative Cost and Value Concepts Were Developed for the "New Manufacturing"
    - *Quality*, *Flexibility*, *Strategic/Capability Options*

  -- Standard Accounting Cannot 'See' Resulting Cost Reductions

  -- Similar Measures Must be Developed for Building Efficiency in Order to More Fully Explain Value

Synopsis: A Richer Accounting Vocabulary (Continued)

- **Today's Cost & Value Measures Conceived in Context of 19th Century Organizations and Technology**

- **Learning How to Fully Exploit Renewables/Efficiency is Non-Trivial**
  -- Ex: 1950's Office Environment Couldn't Exploit Word Processing

Renewables Are as Much a Substitute for Steam Plants as Computers Were a "Substitute" for Typewriters & Calculators

- **Solar/Efficiency Options are Often *Passive, Capital-Intensive and Infinitely-Durable* -- This Affects Cost Accounting Ideas**

  -- Asset Replacement Not Driven by 'Wear & Tear'
  -- Costs Not Readily 'Metered' -- 'Matching' Cost & Output Difficult

How Do You Value A Fax Machine With the Standard Accounting-Based DCF Model?

The Moral:

1. Fully Understanding Solar & Efficiency Technologies Requires

i) The Integration of Modern Financial Valuation Models

ii) The Development of New Accounting Concepts and Valuation Insights and Measures;

These Can Be Gained Only From Practical Experience-- As it was In Manufacturing;

2. Trying to Understand Renewables Using Today's Accounting Valuation Vocabulary Is Roughly Equivalent to Trying to Appreciate Shakespeare by 'Listening' to a Morse-Code Rendition of *Hamlet*.

DESIGNING FOR THE GLOBAL ENVIRONMENT: A U.S. Manufacturer's Perspective

Harvey Forest, Ph.D.
President and CEO, Photovoltaics
Amoco/Enron Solar

November 2, 1995

Designing for the Global Environment: A U.S. Manufacturer's Perspective

Introduction

I'm very pleased to be invited to speak today at the Georgia Institute of Technology. As many of you know, Georgia Tech is one of only two Centers of Excellence in Photovoltaic Research and Education designated by the Department of Energy. Solarex has a long relationship with Georgia Tech in cooperative research in photovoltaics and recently has had the pleasure to return some of the fruits of that research to Georgia Tech in the form of almost 3000 large area PV modules to be installed on the roof of the new Aquatic Center. We are very proud to have been selected by Georgia Tech, Gaston-Thacker/Whiting-Turner, and the U.S. DOE to supply this 340 kW array, the largest of its kind in the world. This system, located on a highly visible facility that will be the site of the 1996 Olympic swimming and diving events, is a showcase for the PV technology steadfastly developed by U.S. industry with the support of DOE over the last 20 years. It is hoped that this system will serve as a model for sustainable energy to the nations of the world present at the Olympics and viewing it on their TV screens.

Sustainability from a Business Perspective

More than 20 years have passed since the founding of Solarex and the beginning of the terrestrial PV industry in 1973. During this time many companies have entered and departed the PV business. Many of these were household names and corporate titans, such as Exxon, ARCO, Shell, Motorola, Mobil, Westinghouse, and most recently, Texas Instruments. Solarex is left alone as the only major PV manufacturer whose ownership and main manufacturing base are in the United States. Although no individual or firm has complete control of its destiny, this survival is not simply a matter of good luck, and the lessons of the last 20 years provide insight into the meaning of sustainability to a business.

A number factors have made it difficult for PV companies to become profitable. At its most basic level photovoltaics represents one of the great dreams of mankind: a limitless supply of clean energy. This dream is only slightly removed from ideas such as perpetual motion, turning base metals into gold, and the fountain of youth. Looked at this way, it is easy to see why people have spent their lives and companies have spent fortunes trying to achieve it. Put into the more prosaic language of the modern corporation, if low-cost PV can be produced, the market is almost limitless.

This potential has enticed many companies to enter the industry and has driven companies to spend enormous sums without the prospect of a near-term return. A common scenario which repeats every year or two is the entrance into the market of a new major corporate entity, perhaps an oil company or an electronics giant, who has acquired a PV technology either through in-house research and development or through acquisition of a typically bankrupt PV company. During the first few years, the new entity really does not worry about operating losses which are viewed as an "investment." This allows products to be sold for much less than they would be sold for if the company had to support itself. Any company trying to compete in such an environment as a self-sustaining business faces a very difficult challenge. Compounding this problem for PV is that it is a very beneficial product socially. This is true not only because of the environmentally clean way in which the energy is produced, but also because the applications of PV are often humanitarian activities such as providing clean water in villages, providing refrigeration to remote medical clinics or providing small lighting systems for homes in rural areas. In many of these applications there is an expectation that the system will be sold at little or no profit because of the worthiness of the use. We do try to help out worthy causes when we can, including donating products for disaster relief or educational purposes, but this can only be done on a limited basis in the overall context of a profitable business. The reality is that rent must be paid, payroll must be met, and the shareholders ultimately must make a return on their investment. This can happen only if the basic business proposition is sound: that is, that the product provides a true value, an economic benefit to the buyer, in excess of what it costs. This positive economic benefit is what makes a business sustainable. Fortunately, there are many applications of photovoltaics where the value exceeds today's costs and we have been able to build our current business around these applications.

PV Economics: Today and Tomorrow

Today's PV market is about 70 MW worldwide with revenues of about $350 million at the level of the manufacturers. At the retail level the value of PV systems including all components and installation approaches $1 billion. Since the late 1980s the market growth rate has averaged 17% per year. This growth has been fueled by falling PV prices in real dollar terms and growing acceptance and knowledge of how to use PV by prospective end-users. With the exception of a smattering of heavily subsidized demonstration programs, today's market is entirely for remote off-grid applications. These are divided into four segments as shown on this graph (figure 1). As you can see, the lion's share of current business is in the industrial area, primarily for remote telecommunications power supply. The next largest segment is for remote habitation, a very broad category that includes everything includes everything from vacation cabins in Scandinavia and off-grid residences in the Western U.S. to basic home lighting kits for less developed countries. In industrial countries, a substantial market also exists for small systems on boats and RVs which make up the bulk of the consumer segment. The remainder of the market is for grid interactive systems, a segment which has grown rapidly in the last year. Although not yet economic in this segment, PV sales are being driven by subsidized market development efforts in Japan, Europe, and the U.S.

Solarex shipped throughout the world in 1994 as shown on the following graph (figure 2). About 2/3 of our sales were exports with about half shipping to the Western hemisphere. Since 2/3 of our sales are to authorized distributors, these figures do not reflect entirely the end-use destination for the product. The next graph (figure 3) shows the even broader spread of distribution at the end user level. A substantially higher fraction of the product is used in Africa and Asia than the point of original shipment would indicate. This reflects the lower level of electrical infrastructure present in these regions which creates a stronger demand for PV. The poor financial condition of many LDCs means that much of this equipment is donated by NGOs or Western governments, and it is often bundled with application equipment such as lamps or refrigerators in the donor country. In some of these countries a fledgling commercial market is developing with local entrepreneurs selling PV systems. Though expensive in up front costs, a PV lighting system often has a payback as short as one or two years when compared to alternatives such as kerosene lamps.

These markets continue to grow at a rate of 15 to 20% per year and are the basis for today's PV industry. A fundamental question is whether this growth will lead eventually to the kind of volumes and prices that will allow the widespread use of PV in grid-connected applications. The economic domains for selected power technologies are presented on this diagram (figure 4). PV clearly competes with batteries, thermoelectric generators, and diesel generators up to several kW in size. PV is also beginning to compete with traditional utility sources. The next graph (figure 5) shows the classic diffusion model for PV. As PV prices decline, PV competes with larger and less costly sources of generation. This model presents a seamless flow of growth in volume driven by lower prices. In reality, each of these price segments requires a different marketing approach and has different barriers. This has limited the ability of the PV industry to develop the intermediate price markets.

Many of the intermediate price applications are in developing countries and involve rural electrification in one way or another. These can be small, individual lighting systems on each home, standalone water pumping systems, or mini-grid systems to electrify a village. The costs, a PV lighting system often has a payback as short as one or two years when compared to alternatives such as kerosene lamps.

These markets continue to grow at a rate of 15 to 20% per year and are the basis for today's PV industry. A fundamental question is whether this growth will lead eventually to the kind of volumes and prices that will allow the widespread use of PV in grid-connected applications. The economic domains for selected power technologies are presented on this table (figure 4). PV clearly competes with batteries, thermoelectric generators, and diesel generators up to several kW in size. PV is also beginning to compete with traditional utility sources. The next table (figure 5) shows the classic diffusion model for PV. As PV prices decline, PV competes with larger and less costly sources of generation. In reality, each of these price segments requires a different marketing approach and has different barriers. This has limited the ability of the PV industry to develop the intermediate price markets.

Many of the intermediate price applications are in developing countries and involve rural electrification in one way or another. These can be small, individual lighting systems on each home, standalone water pumping systems, or mini-grid systems to electrify a village. The potential demand in this segment is enormous. This table (figure6) shows the electricity consumption per capita for various countries. The

20-fold difference in electricity use per capita between India and Western Europe shows the kind of growth in electric generation capacity that will be required as this country's economy develops. Population growth alone will fuel large needs for new generation, and much of this population will be in remote rural areas. It is estimated that 2 billion people do not have access to the electrical grid. A small amount of electricity for household lighting, portable electronics, or medical refrigeration for vaccines can make a large difference in the quality of life for these people. These needs are often best supplied by PV. The cost of installing the grid and the relatively low electricity use per capita also make it unlikely that the grid will be installed anytime soon in the remote rural parts of most LDCs. PV is the only way for these people to obtain a small reliable source of electricity in the near term. It has been estimated that a market potential of 70 GW--1000 times the industry's current annual production--exists in this segment at PV system prices of $4-5/Watt. This is only marginally below today's levels for large quantity purchases.

Given this scenario, can these markets provide a bridge to the even larger grid connected markets? They probably will help to some extent but substantial barriers exist. Most of the countries that need PV do not have the hard currency to pay for it. Many of these countries are already on a strict financial austerity regimen imposed by banking authorities to allow for payment on existing loans from the industrial countries. Some, such as China, have growing economies and even surpluses with the West, but this not the case in the poorest and most rural countries. This problem is linked directly to one of the biggest problems for PV in any of its applications: high initial cost. PV devices require no fuel and no maintenance. Although batteries and other system components require some service, PV systems are far more capital-intensive than alternatives, such as diesel engine generators which are relatively cheap to purchase but require large ongoing fuel and maintenance expenses. This means that cost effective financing is the key to selling PV. This is difficult not only because of the poor availability of hard currency loans but also because of the small size of PV systems. Even entire projects of several million dollars (large to the PV industry) are too small to interest most financial institutions. This problem is even worse at the level of individual users who may need only a few hundred dollars to buy a PV system for their home. A few institutions have stepped forward with small-scale loan programs of this type, but they will need to be widespread to facilitate the sales of PV in many countries.

Lack of financing is only one form of the lack of market infrastructure that impedes market growth in many countries. Many localities do not have distributors and dealers capable of properly designing and installing PV systems. Of course this is one of those "chicken and egg" problems, where since there is no existing market, no one sets up a business to serve it. The cycle can be broken by programs from donor agencies that involve local businesses in the installation and servicing of the systems, but these are usually too sporadic to allow embryonic enterprises to survive and prosper.

Finally, many of these countries have heavily protected markets. This keeps local prices substantially above world market levels and impedes market development, in many cases making the systems unaffordable to the population that needs them the most.

Although some of these conditions are improving, it remains to be seen whether these markets can ever develop sufficiently to provide the large volume business the PV industry needs to achieve major cost reductions.

The Utility Photovoltaic Group (UPVG) has analyzed these markets and determined that a more secure path is needed to ensure the commercial market for PV. Their studies indicate that PV does not achieve a "self-sustaining" market in grid connected applications until a price level of about $3.00/Watt AC is attained. The applications that become cost effective at these levels are best described as distributed grid applications. These are PV systems on commercial or residential rooftops, integrated into buildings, or installed at substations. As might be expected, these markets are highly elastic, with residential applications becoming cost effective at an earlier point than commercial systems due to the generally higher electric rates paid by residential customers and the relatively low costs of financing available through home mortgages. This graph (figure 7) shows the relative size of the commercial and residential markets at various system prices. At prices below $3.00/W AC, market sizes are in the gigawatts.

In the commercial building sector, there is an application that could improve significantly the overall system economics: the direct integration of PV into the exterior skin of the building. In this application, PV laminates made to the standards of architectural glass are substituted directly for the glass, metal, or stone materials which would normally be integrated into building curtain walls. This application is very attractive economically because both the PV laminates and the building curtain wall provide dual functions. The PV laminates take the place of building materials which would otherwise be needed to cover the exterior of the building. These materials presently range in price from $5 to $40 per square foot. The upper reaches of this range is about the price of today's PV modules. Even taking an average of perhaps $10 per square foot gives a credit of $1.00/W against the cost of the PV system. The curtain wall structure serves the function of the module frame and mounting hardware, eliminating these from the cost of the PV system. This is worth about another $0.50/W. Adding these together gives a cost benefit of at least $1.50/W and perhaps more if comparisons are made to higher value building materials. Adding the $3.00/W "threshold" price gives a total of $4.50/W as an approximate break-even price for building integrated PV. This is only about 20% below recent large volume prices for grid connected PV systems. This kind of price level will almost certainly be achieved in the next couple of years, making building-integrated PV one of the largest potential near-term applications for grid connected PV. Solarex is presently working with Kawneer, an Atlanta-based major manufacturer of curtain walls, to develop and market products specifically for this application. An innovation that we are developing actively to help drive this market is the AC module. By incorporating a small inverter right at the module, substantial savings can be made in the system wiring and switchgear which will all be standard, universally available AC equipment that can be installed by any electrician. The relatively large production volume possible for these small inverters should also reduce the overall cost of the units.

As interesting as the building integrated markets are, there is another distributed grid PV application that has even larger potential: transmission and distribution support. In these systems, modest-sized PV arrays ranging from 100 to 500 kW output are located at substations. These arrays provide power at the distribution voltage taking the peak load (typically on hot summer days) off of transformers and feeder circuits. Recent analysis done by a Midwestern utility showed that on some feeders the value of the PV systems was as high as $5.00/W, although this value can vary substantially from feeder to feeder even within the same utility. Although this application clearly could have near-term economics favorable to PV, utilities are also finding other low-tech solutions (such as diesel engines that run during peak loads at substations) that may be less expensive than PV. For this reason, it is not clear that PV will be quickly adopted for this application even at $3.00/W AC system prices.

Although all of these applications show large potential they are markets that are only at the earliest stages of development. Even if PV prices were at $3.00/W today, it might take years to generate the large sales volume, a minimum of 10 MW, needed to commercialize a new low cost PV technology. This is the classic volume-price conundrum that has confronted the PV industry for years. Fortunately, Solarex has recently begun a relationship which solves this basic problem.

Amoco/Enron and the Solar Farm Business

In January of this year, Solarex entered into a strategic partnership with the Enron Corporation. Solarex, formerly a wholly owned subsidiary of Amoco, is now owned by Amoco/Enron Solar, a partnership that is held equally by Amoco and Enron. Enron is a major natural gas distribution company and is also a major developer of independent power producer (IPP) projects. If you'll pardon the use of an overworked word in business, there truly is a strong synergy in this relationship. Enron brings substantial financial resources into the venture but of equal significance is the market access they are providing through their IPP expertise. A business unit similar to Solarex, Amoco/Enron Solar Power Development Group (AESPD), has been established to commercialize an entirely new application for PV--the solar farm. Solar farms will be large arrays of PV, typically 100 MW, taking about 800 acres of land on average. These farms will be operated as IPPs: AESPD will own these projects and sell power to the local utility. By guaranteeing a large, long-term market for a large volume of PV, the relationship with AESPD will allow Solarex to commercialize a new, low cost PV technology: tandem junction thin film silicon. While thin film, sometimes called amorphous silicon PV, has been heralded for years as a potential low cost PV technology, it has not been commercialized successfully for grid connected applications until now. A few weeks ago I had the pleasure of breaking ground for our new 10 MW tandem thin film silicon plant near Williamsburg, Virginia. We believe that this technology, which will produce fully monolithic 8 square foot modules with an output over 60 watts in a continuous in-line process, will give us the low costs necessary to bring PV into widespread application. If we achieve our objectives, our production will increase more than tenfold over the next 10 years.

Global warming is a phenomenon that has been recently almost universally acknowledged by the scientific community. Experts differ on the severity of the rise in global temperature that is already beginning and the extent of its effects, but its existence is no longer in question. This chart (figure 8) shows the relationship between carbon emissions and global temperatures. Will solar farms have a measurable impact on the global environment? In one year, one 100 MW solar farm will generate 200 million kWh of electricity. Compared with the combustion of coal, this will prevent the emission of 177 thousand metric tons of CO_2. Although this is small in comparison to the total U.S. CO_2 emissions of over 1.3 billion metric tons per year, it is a meaningful start. To quote a Chinese proverb, "the journey of a thousand miles begins with a single step." Amoco/Enron Solar is planning to begin the construction of many solar farm projects over the next ten years, laying the groundwork for the PV industry to make a significant contribution to our energy mix and a significant reduction in environmental impacts that would be generated otherwise.

Conclusions: Technology is Not Enough

You have now seen our vision of "PV Heaven": seemingly limitless amounts of low-cost PV playing a major role in the world's energy and environmental picture. Let me now bring you back to Earth. Twenty years of effort and billions of dollars in investment have brought our industry to the brink of widespread application, but it is not there yet. Numerous technology development programs that are critical to achieving the next round of cost reductions are partially funded by DOE. Many of these programs have been targeted for elimination by Congress. These cost-shared programs have generated substantial performance improvements and cost reductions of PV. Companies like Solarex have invested heavily in these programs and need for DOE to follow through on its commitments. Failure to follow through now could result in much slower progress, at best, and at worst, the transfer of these technologies to overseas competitors just at the moment of broad commercial application. It would be a technological disaster for the U.S. if PV follows the now-famous "VCR path"-- U.S. developed technology that ends up being manufactured overseas. Europe and Japan both are supporting PV to an equal or greater degree than the U.S. and have been more consistent over the years. Continued support of activities such as cost-shared R&D and the encouragement of utilities to become involved in PV is essential if the industry is to maintain the forward momentum established in the last few years.

With a few more years of investment by both the government and private sector, PV can be a technology that is cost effective for many grid connected applications. But, technology alone is not enough for commercial success. Ultimately, what energy sources we use is a public policy decision. Conventional energy sources are heavily subsidized in many ways, from the billions spent every year by DOE on the nuclear industry for waste storage and clean-up to the hundred billion dollar cost of the Gulf war. If PV is to be assimilated rapidly into our energy mix we will need incentives to level the playing field.

One such incentive, so-called "green pricing," is based on the willingness of some utility customers to pay a marginally higher bill each month (typically $10 to $15) in return for receiving some of their electricity from a "green" source, normally a PV array which can be mounted on the customer's roof or possibly at a central site. The extra price helps pay for the PV arrays. A program of this type, called PV Pioneers, is currently being run by the Sacramento Municipal Utility District (SMUD). In some communities that strongly support renewable energy, a similar scheme can be applied to the entire rate base. In these so-called rate-based incentives, a small surcharge (say one-half cent per kilowatt-hour) is applied to all of the electricity sold by a utility and the proceeds of this surcharge are used to buy PV.

An incentive that requires no specific investment in PV by the utility is the adoption of net metering. This is a change in the rules governing what the utility company must pay for excess electricity generated by PV installed on a user's premises. Normally, a utility is obligated to pay only the so-called "avoided cost of generation" for the electricity generated by a ratepayer's PV array. This is a very low rate because it covers only those costs the utility avoided by not having to generate that additional kWh. The ratepayer, on the other hand, pays full retail price for electricity purchased from the utility. The ratepayer typically needs two meters to properly keep track of the electricity bought from and sold to the utility company. Net metering eliminates this by allowing the single meter to spin backward when the PV array generates more electricity than is being used on the premises. The customer is effectively selling electricity at the same price at which he buys it. This greatly enhances the value of a PV system to the user.

These incentives can go a long way toward leveling the playing field for PV, but for PV to truly compete with bulk power generation such as coal and nuclear, environmental externalities must be taken into account. These are the costs borne by society for various types of generation including the effects of pollution and other harmful by-products not included in the costs typically accounted for by the generator. Estimates of these costs vary widely, which has been a substantial obstacle in getting policymakers, such as PUCs, to include them in their analysis of the costs of various generation options. One estimate is shown on this chart (figure 9). These figures are in line with several recent studies which indicate that the value of these social costs are on the order of one-half the direct cost of generation. If these costs are included, PV electricity produced by our proposed solar farm in Nevada at a price of 5.5 cents per kWh would be directly competitive with coal-fired plants generating electricity at 2.25 cents per kWh. Clearly, changing our decisionmaking process to include this factor could have a major impact in accelerating the rate of adoption of PV for large-scale power generation.

I hope by now that I've convinced you to share my enthusiasm for Photovoltaics. I encourage you now to take an active part in this dynamic new technology. First, as architects, engineers, and businessmen, you can catch the wave of PV commercialization by incorporating PV into your building designs and looking for those applications where PV is a sound economic choice today. You have the opportunity to be the vanguard of our energy future. More fundamentally, I ask that in your role as citizens, you actively petition our governments at all levels to adopt public policy which supports and encourages this potentially strategic technology. The world's energy future is truly in your hands. Thank you.

Figures

SOLAREX SHIPMENTS BY APPLICATION

Total Shipments	
Industrial	40%
Remote Habitation	26%
Grid Connected	17%
Consumer	17%

Figure 1

SOLAREX SHIPMENTS BY REGION

Total Shipments	
North America	39%
Latin America	10%
Europe	13%
Africa/Middle East	11%
Asia	14%
Australia	13%

Figure 2

WORLDWIDE CONSUMPTION

Total Consumption	
North America	17%
Latin America	10%
Europe	24%
Africa/Middle East	24%
Asia	20%
Australia	5%

Figure 3

ECONOMIC DOMAINS FOR SELECTED TECHNOLOGIES

Power Source	Continuous Load Range	Electricity Cost Range
Batteries	<1W to 30W	>$1000 to $30/kWh
Thermo-Electric Generators	10W to 800W	$20 to $3/kWh
Diesel Generators	100W to 1mW	$10 to $0.20/kWh
Remote PV - 1995	<1W to 100kW	$10 to $0.35/kWh
Utility PV - 1995	100kW to 100mW	$0.50 to $0.07/kWh
Traditional Utility Sources	1mW to 1gW	$0.30 to $0.02/kWh

Figure 4

PV DIFFUSION MODEL

Application	Penetration	Electricity Cost Range
Space Satellites	Yes	$100 to $30/kWh
Off-Grid	Yes	$20 to $0.50/kWh
Building Integrated	Partial	$0.50 to $0.05/kWh
T and D Grid Support	Partial	$0.25 to $0.05/kWh
Peaking Power	Partial	$0.20 to $0.05/kWh

Figure 5

GLOBAL POWER DEMAND

	Electricity (Billion kWh)	GDP ($US Billion)	Population (Millions)	GDP Per Capita ($/Person)	Electricity per Capita (kWh/person)
India	315	1,340	903	1,500	349
China	813	2,717	1,178	2,306	690
Brazil	242	817	157	5,203	1,541
U.K.	328	962	58	16,586	5,655
Germany	530	1,338	81	16,518	6,543
Japan	900	2,514	125	20,112	7,200
U.S.	3,350	6,379	258	24,725	12,984

Figure 6

RESIDENTIAL AND COMMERCIAL PENETRATION OF PV

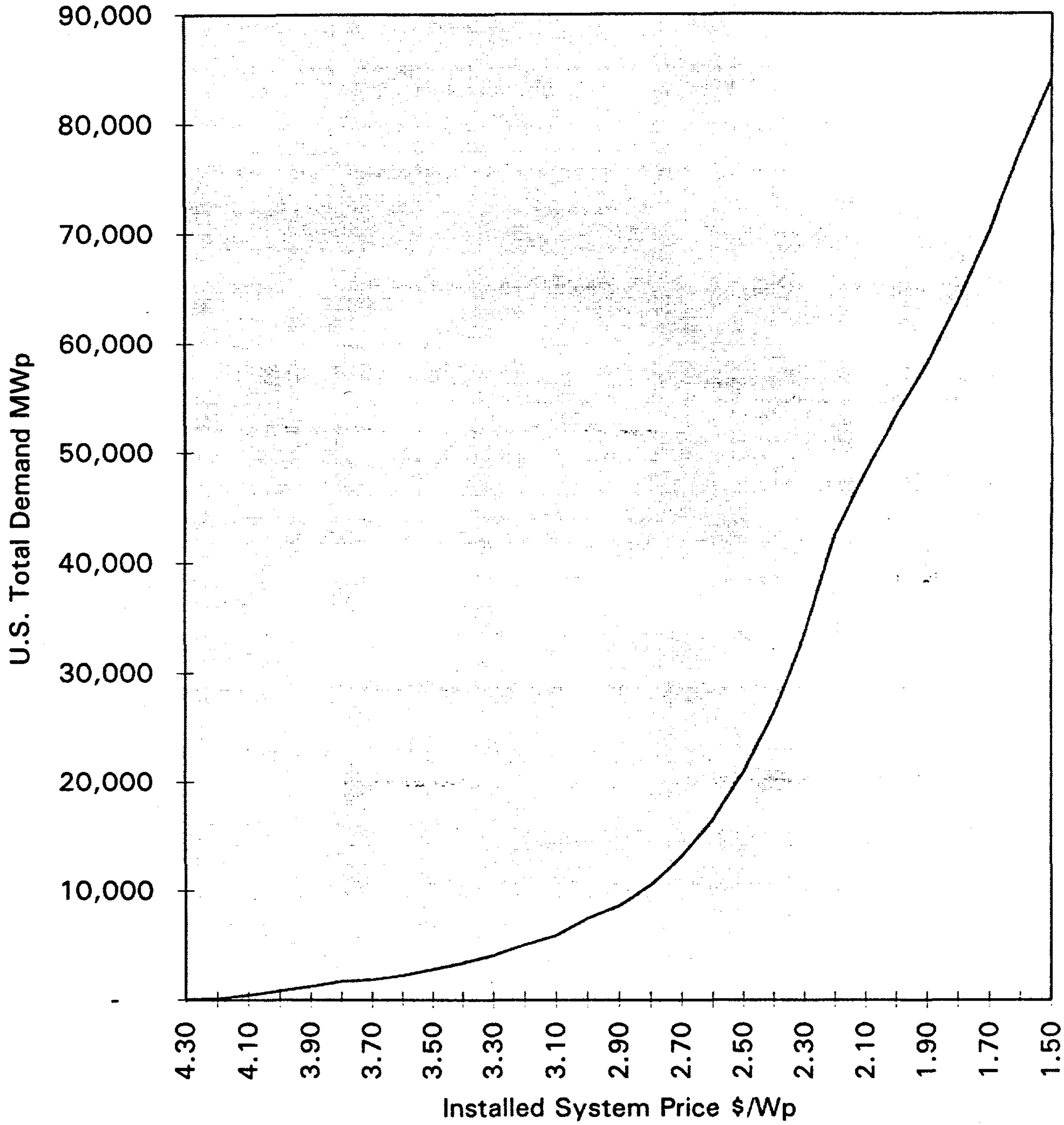


Figure 7

Source: UPVG Publication

THE GREENHOUSE EFFECT

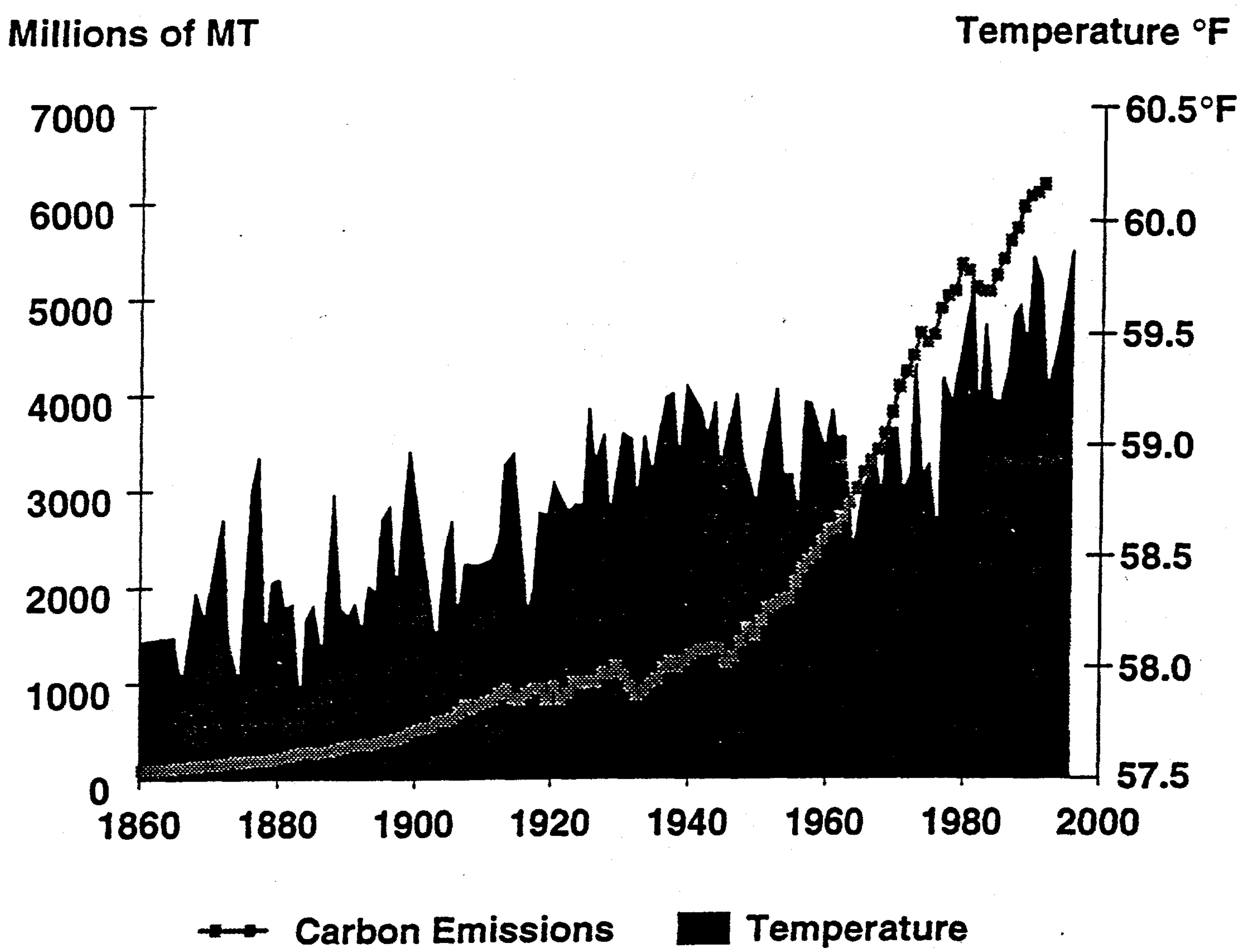


Figure 8

SOCIAL COSTS OF CARBON EMISSIONS

Coal Case

Cost ¢/kWh			
	Cost $/lb	Solar	Coal
NO_x	3.40	0	.62
SO_x	.78	0	.06
CO_2	.01	0	2.57
Total		0	3.25

The Social Cost of Using Coal
vs. Solar is Significant...3.25 ¢/kWh

Figure 9

DRAFT
October 23, 1995

Direct and Indirect Savings: Magnitudes and Implementation Policies

Arthur H. Rosenfeld, Joseph J. Romm [1]
Hashem Akbari, Haider Taha [2]
Alan Lloyd [3]

Abstract

A "Cool Communities" strategy of lighter-colored reroofs and resurfaced pavements and shade trees can directly lower annual air conditioning bills in Los Angeles by ~\$200M, cool the Basin by 3 C°, save indirectly \$160M more in air conditioning, and reduce smog by ~10%, worth another \$360M, for a total savings of \$0.7B.

To implement these savings, we call for ratings and labels for cool materials, buildings performance standards, utility programs, and an extension of the RECLAIM smog offset trading market to include credit for cool surfaces and trees.

Generalized to the US, total annual savings will be ~\$10B. Many more utilities can participate, and EPA (Environmental Protection Agency) can include cool materials and trees in its proposed regional "open market smog offset trading credits."

Key Words: Heat Islands, Cool Communities, savings, implementation, policy, smog, ozone, incentives, etc.

Outline of the Science and Economics

This special issue on cooling buildings and communities covers many different savings from switching to cooler surfaces and planting trees. The aim of this paper is to compare them all, via three tables, and then to discuss some policies that could achieve these savings. The preceding papers describe three different sorts of savings:

1. Direct Cooling (Table 2). Cool roofs and trees which directly shade buildings ("shade trees") reduce summer air conditioning (a/c) loads, thus saving mainly electricity and thus money—about \$220M/year—in the Los Angeles basin. Switching from a hot dark roof to a cool white or light roof involves a small heating penalty, which we address in our discussion of Table 2.

2. Indirect Cooling (Table 3). In California, before 1930, all cities first cooled as we introduced irrigation and then, in the 1940's, started to heat as we replaced orchards

[1]US Department of Energy
[2]Lawrence Berkeley National Laboratory
[3]South Coast Air Quality Management District

with dark roofs and pavements. Downtown Los Angeles first cooled 3°C, now has climbed back, and, as it grows, continues to warm 1°C every 15 years. One new cool roof will cool only the building below it, but our simulations show that if we modestly cool all the eligible roofs, roads, and parking lots in Los Angeles, we will offset half the present heat island. And if we plant two trees per house, we will offset the other half. This 3°C cooling will save Los Angeles another $160M/year in reduced utility bills

3. Smog (ozone) Reduction through Indirect Cooling (Table 4). Air pollution in Los Angeles is a severe problem, estimated to cost the community $10B/year in medical costs and lost time from work. Of this, perhaps $7B is related to particulates, which is partly scavenged by trees, but which we will barely address here. But the rest, "smog," is ozone (O_3), a highly oxidizing and irritating gas which is formed by a temperature-sensitive reaction between two precursors: organic gases (called VOCs (volatile organic compounds) or ROGs—they are both manmade and biogenic) and oxides of nitrogen (NOx, which is a product of combustion). It is difficult to disentangle the medical and lost work time costs of particulates and O_3, but a reasonable guess for O_3 is $3B/year.

As a measure of temperature sensitivity, we note that in the winter there are plenty of precursors and plenty of necessary ultraviolet light above the basin, but no smog. Ozone begins to exceed the National Ambient Air Quality Standard (NAAQS) of 120 ppbv (parts per billion by volume) when the daily maximum temperature hits about 22°C, and O_3 often reaches 240 ppbv by 32°C. Restated, ozone goes from acceptable to terrible in just 10-15°C. Of that small range, our manmade heat island has already used up 3°C. Our cool communities strategy can just cancel the present 3°C heat island, and our simulations show a 12% reduction in population-weighted O_3 "exceedance" above the more conservative California standard of 90 ppbv. A $3B annual ozone externality, multiplied by a 12% savings, should be worth $360M.

Outline of Possible Policies for Implementation

After each table, we discuss implementation, of which we give an overview here.

1. Direct Cooling. To make a market for cool roofs we need ratings, labels, data bases, marketing, and publicity. We recommend waiting until a roof needs normal "reroofing" (refinishing or replacement), at which stage it costs little or nothing to switch to a cool color. But for building owners who are about to reroof, utilities and others should have vigorous programs to inform them that they can save 10 to 40% of their a/c bill by choosing properly. Indeed, in California, if a utility program saves a customer $1, its stockholders earn 10¢, so incentives can be profitable to the utility.

To make a market for shade trees we must rank trees by their biogenic emissions (more testing and labeling). Some trees emit unacceptable amounts of gases which are a precursor to smog. The more pungent the tree, the more likely it is to cause a smog problem, in fact to do more harm than good. So we need programs to encourage home owners to plant the right trees.

2. Indirect Cooling. Cool roofs, with a return on investment of less than one year from direct cooling, should be a relatively simple "sell." Cool pavements cool the city only indirectly and are more of a "tragedy of the commons," even though for LA they offer annual savings of $40M of cooling and $90M of avoided ozone. We note that this tragedy of the commons holds even around the Mediterranean Sea, where traditionally building are white-washed and often have white roofs, yet cities and villages often have dark, sometimes asphalt, streets and parking lots.

Table 3 shows us how to convert annual utility bill savings of $40M/year to a present value of $50/100 sq. meter (1076 sq. ft.) of pavement, which still merits a utility incentive program. Table 3 also shows that a large tree in Los Angeles has a present value of indirect cooling savings of $50 (plus $75 more if it directly shades windows). Many utilities already have tree-planting programs, and more should start them.

3. Smog Reduction. How do Los Angelinos capture $360 of potential annual savings? We suggest that one answer is to extend "RECLAIM" to cool surfaces and trees. RECLAIM stands for REgional CLean Air Incentive Market, and was started, for NOx only, from stationary sources only, in 1994 by SCAQMD (California's South Coast Air Quality Management District). In an attempt to cap smog, SCAQMD capped annual NOx emissions and is now lowering the cap 8% a year. It has set up a credit trading market, and companies which are out of compliance (or new businesses) must purchase credits from those in compliance. SCAQMD judges RECLAIM to be a success and will propose to extend it to VOC's (the other precursor) and to "area sources" (e.g., motor vehicles), and we suggest that it also give credits for cooling the city. Table 4, line 5, shows that the present value of a cooler roof or pavement is $100/100 sq. meter) and about $100/tree. The actual cost of the cooler material (at time of reroofing or repaving) or the trees should be well under those present values.

Generalization from Los Angeles to Other Hot, Smoggy Regions

So far we have carefully studied only two hot cities. (We have painted roofs and surveyed existing roofs in Sacramento, and our colleagues have painted roofs in Florida. All our meteorological and smog modeling has so far been confined to Los Angeles.) So this paper is written in terms of Los Angeles. The direct savings from cool roofs and trees, however, are applicable to all warm climates. For indirect cooling, we estimate that in many smaller communities it can still offset the (smaller) heat island. For smog, we know that the temperature dependence is universal, and, so probably our 10%-15% estimated reductions will apply to other cities. Finally, we have not modeled the indirect cooling by trees in more humid climates, where evapotranspiration is reduced. Fortunately EPA is planning a workshop on the effectiveness of cool surfaces and vegetation in many hot, smoggy regions of the US.

Discussion of the Tables

First, a comment on language. In the tables we refer to Albedo (a), and also to Reflectivity (R). They are the same—the fraction of solar energy reflected by a surface—but scientists say "albedo" and the roofing industry is more comfortable with "solar reflectance" for its ratings and labels. Apart from metals, the higher a or R, the cooler the roof or pavement. Δa means the increase in albedo of a new roof, reroof, or resurfaced pavement. ΔT means the resulting drop in temperature. Taha likes to refer to the sum of all the roofs and roads which could be made cooler as the "albedo-able" area of the city.

Table 1. Inputs to the Meteorological Model, Temperature and Smog Outputs
(Los Angeles Airshed, source: Taha '95)
Unit area used for roofs and pavements is 100 m^2 = 1076 ft^2.
Trees are counted directly. Area of mature tree is 50 m^2.
Residential roofs are typically 200 m^2 (so ~2 units), M = millions.

1. **Input:**

	Area (km^2)	Units (M)	Δa		Area (km^2)	Units (M)
1. Cool surfaces				2. Trees		
5M homes	1000	10		Shading homes	500	10
Non-res. buildings	250	2.5		Shading non-res. buildings	50	1
All roofs	1250	12.5	0.35		550	11
Pavement	1250	12.5	0.25			
"Albedo-able"	2500	25	0.3			

2. **Output of meteorological model:**
For both cooling and smog, we give the results of the "combined" runs.
In all cases, albedo alone or trees alone contributed 50%, as illustrated under "Cooling."
Cooling: Population-averaged at 2 p.m. ΔT (combined) = 3.0°C
ΔT (albedo only) = 1.5°C, ΔT (trees only) = 1.5°C

3. **Output of smog model:**
Reduction of ozone concentration exceeding 90 ppb: Population-averaged, 8-hour average = 12%

Three different simulations are used the calculate the results compiled is this paper.

To calculate the direct savings from cool roofs and from the shading of individual buildings by trees, Akbari et al. use the DOE-2 program. The results will be presented in Table 2.

The indirect cooling from cool roofs and pavements, and from the evapotranspiration of trees, is calculated by feeding the assumed change in albedo Δa, and the increased "footprint" of 11 million new trees, into a meteorological model (Taha et al.). The model calculates a different cooling for each hour of the day, in about 400 "developed" cells, which together account for almost the entire population of the Basin. But to estimate the savings in a/c bills, we combine the 400 cells into a single population-averaged hourly cooling, which reaches a maximum of 3°C at about 2 p.m., when the temperature itself is a maximum. Table 1 shows Taha's assumed inputs, and Table 3 will show the indirect savings from the 3 C° cooling.

Smog-Related Savings. Finally, the output of the meteorological model is fed into an "airshed" model which, among others things, calculates the rather spotty ozone reduction. The **net** reduction of the ozone (actually the excess over 90 ppbv), population-weighted and averaged over 8 hours, is 12%, but the map is spotty because the now-cooler city causes reduced upwelling of heated air, thus allowing the smog precursors to concentrate in a smaller volume and actually increase the ozone level in a minority of the cells. This reduced upwelling cancels about half the gain that one would guess just from looking at the temperature dependence of the rates of reaction for forming ozone. These results will be addressed in Table 4.

A few comments on Table 1. When thinking about a whole city, the natural unit of area is a square kilometer (0.4 sq. mile), but a home owner thinks much smaller units; we chose 100 m^2 (1076 sq. ft.) and use both in our tables. We take the roof of a typical home to be 200 m^2, and a parking stall is about 30 m^2.

Part 1: Input Col. 1 (Cool Surfaces) shows the areas fed into the meteorological model: 5 million homes, each with 200 m^2 of roof, whose albedo has been increased (at time of reroofing) by 0.35 (e.g., from green with $a = 0.15$, to white shingle or white flat roof, weathered for a few years to $a = 0.5$). In the same run we simulated the resurfacing of comparable area of roads and parking lots, switching from asphalt ($a = 0.05$) to cement or clear asphaltic material. Normally the pavement industry pays no attention to the color of the aggregate, which represents most of the volume of the final concrete, but if we begin to use white aggregate, the final roadway will weather to an albedo of 0.3 to 0.35, so an albedo increase of at least 0.25 over traditional asphalt paving. There is a slight increase in cost, which is discussed by Pomerantz (this issue). Again, Taha uses the word "albedo-able" for the combination of roofs and roads, and in his model has increased the average albedo of these impermeable surfaces by 0.3.

Input Col. 2 (Trees) accounts for planting 11 million trees and gives them 15-20 years to grow to a "footprint" of 50 m^2 (about 500 sq. ft.).

Timing: We are not proposing that building owners take any action before their roof or parking lots need normal maintenance, typically 20 years for residential shingles, 5 years for a well-maintained flat roof, 5-10 years for a parking lot or road. At that time, the cooler replacement roof or parking will cost little; we have estimates from a manufacturer of shingles of \$50/house.

Thus our base case runs are for current conditions, but our changes are really 15-20 years off in the future.

Part 2. Cooling Output. Taha et al. have modeled the cooling from "albedo only," "trees only," and both "combined." The results are additive, so henceforth we quote the combined result but attribute half the savings to each strategy.

Part 3. Ozone Reduction. The airshed model shows concentration reductions of about 10%, but a considerable uncertainty here is how to *count* the gain in air quality. People don't seem to be bothered by low concentrations of ozone, say below 50 ppbv. The NAAQS is 120 ppbv, but will probably drop, and the California standard is 90 ppbv. Air quality is usually measured as its "exceedance" above one of these two standards, and of course the higher the threshold, the higher the percentage reduction in ozone and the more effective the strategy appears to be. Taha's paper on the modeling gives the percent reduction above several different thresholds, but here we just take one relatively conservative measure, the exceedance above 90 ppbv.

Table 2. Utility Bill Savings for Los Angeles in 2015

For roof albedo, $\Delta a = \Delta R = 0.35$ (e.g. green, R=0.15; weathered white R = 0.5)

Units: roofs, 100 m^2 = 1076ft^2; trees, 50 m^2 = mature tree.

	Unit savings "U" or LA-wide savings "LA"		A.	B.	C.	D.
			Cool roof			Shade Trees
			Homes		Office	
			Old	New	New	
1	U	Unit area (m^2)	100	100	100	50
2	U	Net utility bill ($/yr)	28	18	50	~10
3	U	20-yr eff. present value (yrs)	15	15	5	7.5
4	U	Life-cycle bill ($)	420	270	250	~75
5		Los Angeles area (km^2)	550	450	250	550
6		LA Number of units (m)	5.5	4.5	2.5	11
7	LA	LA Theory (Lines 2*6) ($M/yr)	150	80	125	110
8	LA	LA Theory: all 4 col. combined	$465M/yr			
9	LA	LA Real: scaled from Sacramento study. ($M/yr)	90		40	90
10	LA	LA Real, all col. combined	$220M/yr			

Line 2 gives the net annual utility bill savings for typical customers. "Net" means electric bill savings from a/c, slightly offset by an increase in the winter bill for gas heat. Old homes (Col. A) have uninsulated attics; new homes (Col. B) have R-19 attic insulation. Office buildings save more than homes because the a/c runs longer hours.

Line 3 is included so that we can calculate the present value (PV) of the stream of savings of Line 2. We assume that a residential shingle roof lasts 20 years, a flat commercial roof is refinished (so could change color) every 5 years, and urban trees live only 20 years. We calculate the PV (in 1995 $) using a (low) 3% real discount rate. [The California Energy Commission has adopted this low "intergenerational" discount rate for its Title-24 Building Energy Performance Standards.] For a 20-year tree, the present value in Col. D is 7.5, not 15 (as for a 20-year roof). This difference is because a tree grows slowly, so its savings are out in the discounted future. We assume the tree is half grown after 10 years. Then a 3% real discount yields the tabulated value of 7.5. This argument applies to all three savings tables.

Line 4 (Line 2 x Line 3) then gives the present value of a building owner's decision to change roof color or plant a tree. Now we extend very crudely the annual savings of Line 2 to all of Los Angeles.

Lines 5 and 6 give the number of units (5 million homes—55% of them old, and 11 million trees).

Line 7, called "LA Theory," gives the product of Line 2 and Line 6, which constitutes an upper limit for annual Los Angeles savings. It is only an upper limit (to give some idea of the savings potential) because we wrongly assume that all 5 million homes are eligible for cooler roofs and that all non-residential roofs are above air-conditioned offices. We will do this better in Line 9.

Line 8 is the sum of the upper limits of all four columns of Line 7.

Line 9 is our "real" estimate of Los Angeles savings. It is scaled up to Los Angeles from a realistic study of Sacramento, taking into account the actual albedo of Sacramento roofs and the roof color and a/c demand of non-residential space. [M. Pomerantz et al., 1995]

Line 10, entitled "LA Real," is the final sum: $220 million per year. This is less than half the $465 million upper limit.

Before we can discuss utility incentives, we must address the indirect savings of Table 3.

Table 3. Indirect A/C Savings from a 3 C° Cooling

			A. Roofs and pavements	B. Trees	C. Combined
1	LA	Cooling, pop.-averaged (ΔT, 2p.m.) (°C)	1.5	1.5	3
2	LA	Annual electricity (BkWh/yr)	0.8	0.8	1.6
3	LA	Annual electricity bill ($M/yr)	80	80	160
4		Number of units	25	11	
5	U	Unit annual bill ($/yr)	3.2	7.3	
6	U	Eff. (present value) years	15	7.5	
7	U	Life cycle savings/unit ($)	50	55	

Tables 3 and 4 are, in logic, "upside down" from Table 2. In Table 2, we were interested in the direct savings to a building owner, and the Los Angeles-wide estimates are incidental, included only so that we can compare direct and indirect effects. In Table 3, the reverse is true. The primary input to the table is the 3 C° cooling output from the meteorological model. We then use utility data to convert the 3 C° cooling to avoided peak power (Los Angeles-wide) and then to avoided electricity bills (Los Angeles-wide). Only then do we divide by the number of roofs or area of roads in Los Angeles to get unit annual savings.

Now we discuss this sequence of steps in slightly more detail.

Line 1 shows the 3 C° cooling, apportioned half to cooler surfaces (the model does not distinguish between roofs and pavements), half to trees.

Line 2 is best explained with the help of **Fig. 1**, which gives data from the major utility, SCE (Southern California Edison), on the temperature dependence of air-conditioning demand. Figure 1 shows a slope of 360 MW/C°. Combined with the other utility, LADWP (Los Angeles Department of Water and Power), the slope is 540 MW/C°, so 3 C° of cooling drops a/c demand by 1.6 GW. We estimate that this 1.6 GW is avoided for about 1000 hours/year, for a saving of 1.6 BkWh, which we estimate to be worth about $160 M/year.

Next we want to apportion line 2 to individual units of cool surface.

Line 4 gives the number of units of cool surface and trees in the Basin.

Line 5 gives the annual electricity bill savings, per 100 m^2, or per tree.

Line 6 gives the number of effective (present value) years for cool surfaces (*cf* Table 3, line 3).

Line 7 gives the life cycle savings per 100 m^2, or per tree.

Now we can compare Direct/Indirect savings. Remember that the direct savings were calculated for a roof that was an attractive candidate for an incentive (green—>white, $\Delta a = 0.35$), whereas indirect savings are from a mix of roofs and pavements, averaging $\Delta a = 0.3$. [In his paper in this issue, Pomerantz suggests that with proper incentives parking lots can achieve $\Delta a = 0.5$.]

For roofs the direct effect wins. Thus, for homes: direct (old or new) / indirect = (28 or 18) / 3. But for trees, direct and indirect are comparable (10 / 7).

Incentives to Save Air Conditioning

For a utility which is planning an incentive program, we can now summarize the savings.

1. Roofs. 90% of the savings are direct, so use Table 2 or refer to the four papers in this issue on high albedo and energy use. [Akbari et al., Bretz et al., Parker et al., Simpson et al.]

2. Pavements (indirect only). Line 6 gives the present value of 100 m^2 of cooler surface: $50. Note that once its color has changed, a residential roof or roadway will likely stay cooler for 20 years. However, this is not guaranteed for a flat roof on a commercial building (which should be refinished every 5 years), so a utility incentive should require an agreement that the coolness gained is permanent.

3. Trees. Even though 11 million trees contribute only $90M out of a total of $220M of direct savings, single trees are too good to be true: $75/tree for direct savings + $55 indirect (plus, see Table 4, $100 from ozone reduction). By "too good to be true," we mean that trees are cheap—roughly $1/(height in feet), and we recommend an 8-foot tree that costs ~$10. But, as we said earlier, even if it survives, its shade benefits are ten years off. We leave our utility friends the pleasant task of designing a rebate program for a tree that costs $10 but is worth $200 to society and $75 (in shade) directly to the home or building owner.

We hope the numbers in Tables 2 and 3 speak for themselves. In a hot, metropolitan area like Los Angeles (10 million people), annual savings in 20 years can reach $360M ($36/capita) with ~1 year payback time.

In California and New England, where "collaboratives" have rewritten utility profit rules, utility stockholders can share with customers about 10% of societal energy savings. This should be an additional motivation for utilities to cool their communities.

Table 4. Savings from a 12% (Exceedance) Reduction in Smog

Indirect smog-related savings from 12% reduction in the O_3 "exceedance" above 90 ppb, taking the O_3 externality (medical and lost-work days) as \$3B/yr.

			A.	B.	C.
			Roofs and pavements	Trees	Combined
1	LA	Pop.-weighted 8-hr reduction	6%	6%	12%
2	LA	LA-wide annual saving (\$M/yr)	180	180	360
3		Number of units in LA (M)	25M	11M	
4	U	Unit societal savings (\$/yr)	7.2	15	
5	U	Eff. (present value) years	15	7.5	
6	U	Unit life-cycle savings (\$)	100	100	

We have already explained in our Outline why we apportion \$3B to the annual ozone cost to peoples' health and productivity. And we discussed why we picked exceedance ($[O_3]$ - 90) ppbv as our way to scale cost reduction.

Line 2. We can now understand why the Los Angeles-wide annual savings are \$360M and are apportioned equally between roofs and pavements (Col. A) and trees (Col. B).

Line 4 gives the unit societal annual savings. We see that a 200 m^2 roof and 1 tree are both worth \$15.

Line 5 gives the familiar present value expressed in equivalent years.

Line 6 gives the present values of avoided smog, \$100 each per 100 m^2 of lighter surface and per tree.

Next we address two air quality savings that are not on Table 4.

1. Trees as adsorbers of particulates. Of the \$10B annual health/productivity cost of air pollution in Los Angeles, at least half appears to be from particulates—we will say \$5B—and particulates stick to leaves. We are looking into this effect but want to point out that every 1% of filtration is worth \$50M/year.

2. NOx reduction from decreased peak power generated in the Los Angeles Basin. Even though peak power will drop by 3.8 GW, and some peak power is generated and produces NOx within the Basin, Taha calculates that decreased peak power will reduce smog by about only 1%.

Incentives to Reduce Smog

We have proposed that the utilities be society's agents to lower a/c bills. For smog reduction, in our outline, we nominated SCAQMD, and in particular suggested that their RECLAIM offset credit trading market be extended to include temperature reduction measures.

However, RECLAIM is only a financial market; it can deal with individual buildings or parking lots only through agents. For roofs and trees (which save a/c), we naturally suggest bringing in the utilities. For public roads, RECLAIM could deal with local governments. For parking lots we suggest the asphalt resurfacing industry.

Asphalt resurfacers do not currently consider themselves as thermal polluters, but in our view they are, and so are eligible to start trading in a market which, in steady state, should command \$100-200 per 100 m^2 for an albedo change of 0.25 to 0.5. A typical parking space (with its share of access road) occupies ~ 30 m^2, so should be worth \$30-60. This should roughly offset the surcost of the lighter aggregate and the clear binder.

Pomerantz [1995] discusses the probable longer life of cooler pavements. Many of our colleagues (and Shell Oil) believe that cooler roads will last 20-50% longer because of reduced thermal cycling, reduced ultraviolet damage to the cooler binder, and better ability of the cooler, stronger binder to spread the load of tires. We must model and measure the temperature dependence of service life of roofs and pavements but so far have only anecdotes.

Ozone Level and Peak Power in Los Angeles, California

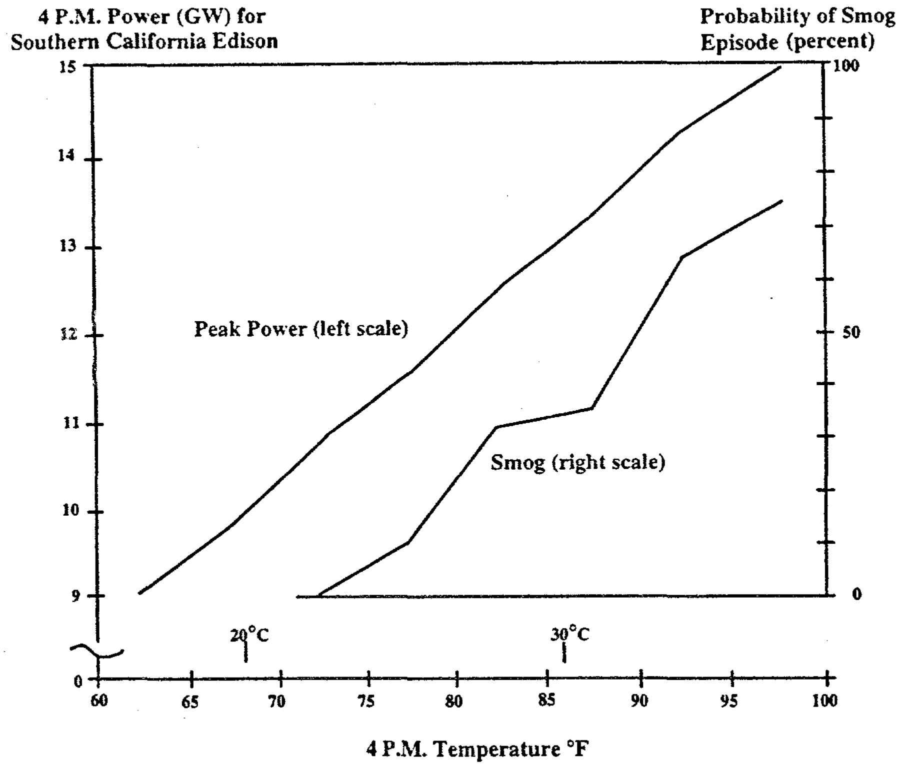


Fig. 1: Ozone levels and peak power for Southern California Edison vs. temperature in Los Angeles, CA. Peak power use rises by 3% for every 1°C rise in temperature. Probability of smog increases by 6% for every 1°C rise in temperature above 72°F (22 °C) [Akbari et al., 1990]. An episode occurs when the ozone concentration is above the National Ambient Air Quality Standard, 120 ppb.

Michael Totten, Director, CREST

Michael Totten is Executive Vice-President of the Washington, DC-based tax-exempt, non-profit organization, the Solar Energy Research and Education Foundation (SEREF), as well as Director of SEREF's primary project, the Center for Renewable Energy and Sustainable Technology (CREST). He has spent the past 20 years in public service fostering ecologically sustainable, economic development policies and opportunities, and is a recognized expert on global energy issues.

Totten conceived CREST's mission of providing **on-line** distance learning resources and information exchanges (via CREST's Internet site, **Solstice**), and **on-disc** interactive multimedia resource tools (via CD-ROM and hard disk storage media). Each month, more than 140,000 people from 65 countries access Solstice to download full-text documents and digitized slides. Totten oversaw the completion of two educational CD-ROM discs on "green technologies" released in 1995: **The Greening of the White House**, and **The Sun's Joules** (about a solar energy-based economy).

For the past dozen years his professional experience has focused on developing public policies around ecologically sustainable economic development opportunities. Previously, Mr. Totten served several years as Senior Associate for Policies, Information and Training at the International Institute for Energy Conservation. During this time he succeeded in convincing the World Bank to finance the $24 million Ilumex energy efficient lighting program in Mexico, the first large-scale utility Demand-Side Management project ever undertaken by the World Bank. The project is expected to save several hundred million dollars in avoided fossil fueled power plant construction, while preventing the release of tens of thousands of tons of greenhouse gases. Totten also organized and conducted training workshops on Integrated Resource Planning for utility managers, government agencies and public interest advocates in Asia, Latin America, Central and Eastern Europe, and Africa.

From 1984 to 1990 Mr. Totten served as Senior Advisor to U.S. Representative Claudine Schneider (R-RI), supporting her leadership role in the U.S. Congress in promoting innovative public policies and market-based incentives to foster sustainable development. Mr. Totten was responsible for drafting one of the most comprehensive bills on climate change, known as the *Global Warming Prevention Act (HR 1078)*, which emphasized substantial support for energy efficiency and renewable energy, pollution prevention and waste reduction, biodiversity preservation, and ecologically sustainable farming and forestry practices. The bill was studied by parliamentarians in over a dozen countries, and was translated into German by the Enquette Commission of the FRG Bundestag, and referred to in their decisionmaking process on actions to slow global climate change.

He has written and spoken extensively about sustainable resource development. His recent publications include *Energy-Wise Options for State and Local Governments*, and the prize-winning Earth Pledge essay, *Bright Ideas* , (http://www.earthpledge.org/epf/totten.html). Totten serves on the boards of several organizations, including Renew America and Environmental Building News. He has a B.A. in Literary Analysis from Yale College.

Digital Design and Communication Tools for Sustainable Development
by Michael Totten[1]

OVERVIEW

There is strong sentiment within the computer and communications industry that the power and speed of mainframe computers will be available at personal computer sizes and prices in the next few years. Coinciding with this is the expectation that large data/information/knowledge resource pools will be available online for download via Internet, CATV/telephone systems, and wireless systems.

From a standing start in the early 1980s, sales of Personal computers have soared to about 50 million per year worldwide, valued at about $74 billion. At the end of 1993, an estimated 176 million personal computers (PC) of all kinds were in use around the world (Haynes 1992). Some industry analysts expect PC sales to exceed several hundred million per year before the end of the decade (Negroponte 1995).

Prices have steadily plummeted to a few percent of what similar computing power cost a few decades ago. Along with the rising number of less expensive Personal computers have been two other phenomenal advancements: 1) constantly larger storage capacity at constantly declining cost; and, 2) faster and more powerful memory and process chips at constantly declining cost.

Compact Disc-Read Only Memory (CD-ROM) Storage Media

Take CD-ROM drives, which computer manufacturers are now including in most desktop computers (selling for well under $1000), as well as in increasing numbers of laptop computers, and are also selling for as little as $100 to plug in to many existing computers. These drives now play interactive multimedia software programs stored on compact discs (CDs) similar to CD Audios, but integrate video clips, sound, graphics, photos, text, spreadsheets, databases, and interactive exercises.

Each CD-ROM disc stores 650 Megabytes (MB) -- the equivalent of 12 library shelves, or 1000 textbooks with 250,000 pages of text, or half a ton of paper. Data compression algorithms allow storage of 72 minutes of compressed full-screen, full-motion video or more than six hours of audio. Once developed, a CD-ROM disc can be duplicated for about one dollar each (compared to $10,000 to photocopy all the information it contains). Discs with 10 to 15 times this storage capacity (10 Gigabytes, GB) are anticipated to be available within the decade.

Hard Drive Storage Media

Hard drives, which transfer data at 10 times or greater the speed of CD-ROM drives, show equally compelling rates of innovation. Inexpensive conventional hard disk drives for desktop Personal computers held 10 MB in the early 1980s, 100 MBs around 1990, and 1,000 MB and larger (1 Gigabyte, GB) drives are now becoming commonplace.

The price of electronic storage has been falling by more than half every two years. In the past 24 months the cost of a 1000 MB hard drive has dropped from $2,000 to $400,

---

[1] Director, Center for Renewable Energy & Sustainable Technology (CREST), Washington, DC email: mpt@crest.org

and in some cases, can be found for as low as $100. Their size also continues to shrink. Sony announced market plans for a detachable, 1,500 MB hard drive just 2 and 1/2 inches in size, that will cost less to produce than current 80 MB hard drives.

"We're probably decades away from any fundamental limit that would inhibit the progress of these technologies," according to Christopher Bajorek, IBM Vice President (Business Week 1994).

Powerful Memory Chips

In short, electronic storage media are getting cheaper by the week, and highly portable. Cheap storage is being combined in desktop and laptop computers with incredibly powerful memory chips that were once the domain of mainframe computers (e.g, Intel's Pentium series, Motorola's PowerPC series, and DEC's Alpha series). What this points to are tremendous new opportunities to do tasks on $1000 to $2000 computers that just a decade ago could only be done on quarter million dollar machines.

At the same time, software trends are increasing programmer productivity and enabling routine reuse of software modules in the manner of integrated circuits. Trends include: object-oriented programming (OOPS), an emerging market for software components, and software agents. One promising result of these powerful software advancements is the emergence of case-based learning tools that enable users to ask "what-if" questions of expert-based reasoning tools, and view answers in multimedia formats (Winslow 1995).

If the 1980s witnessed the adoption of desktop computers for word processing, spreadsheets, and simple database management, the 1990s are witnessing the additional use of these machines for extensive visualization and communication tasks. This could not be more timely, given the need to not only quickly access key information from widely dispersed locations, but to more quickly grasp and understand increasingly complex or complicated issues.

Empirical research indicates that expressing knowledge in multi-sensory ways (e.g., alpha-numerical text and charts augmented with photos, graphics, animations, video, and sound tracks) assists many people in learning faster, as well as absorbing more information, relative to text-only documents. An even more powerful learning process results from digitally cross-linking the multi-sensory information, so that the user can randomly retrieve resources in a manner closer to the intuitive processes of human thinking. In this manner, the user can quickly move to information of increasing or decreasing degrees of complexity and simplicity, as needed.

This **hypermedia** process, as it is increasingly called, is made possible by the digital revolution. Hypermedia is playing an increasingly prominent role in saving millions of dollars at federal agencies like the Department of Defense, where the scores of technical volumes on how to maintenance and repair a complex plane or land vehicle are now accessible on a single CD-ROM. An operator can view a video or blow-up of a difficult procedure, overcoming the limitations of static text and two-dimensional images. The operator can continue to move to greater and greater detail in submenus and cross-linked menus.

These important features -- cost savings and enhanced, more rapid learning -- were highlighted in a report to the Committee on Appropriations by the Department of Defense (DOD) in its congressionally mandated report, Effectiveness and Cost of Interactive business, but rather an enormously valuable economic resource, is only beginning to be widely recognized.

Leap-frog technologies.

There is strong debate as to the time frame in which development of adequate infrastructures in many of the developing countries will occur. Development to date has been hampered by the lack of technicians and managers for the technologies. AID notes in a detailed **Information Plan** (AID 1993) that the implementation of a robust infrastructure in the developing countries will lag that of the developed countries by 50 to 100 years. And that due to the long time frames anticipated, it is likely that mobile radio and cellular systems will be the de facto standard for the next five to ten years. Other industry experts believe it is possible that advanced digital networks will penetrate developing countries at a far faster pace, perhaps within the next several decades.

As a recent World Bank report notes, "The emerging structure of the Global Information Infrastructure presents an extraordinary opportunity for developing countries. The new infrastructure is characterized by a variety of low-cost options for local connections, competing global operators for long-distance services, increasingly digital transmission, and low-cost, reliable, simple network access with increasingly sophisticated terminals....This model for the telecommunications infrastructure allows developing countries to leapfrog the developed world's enormous investment in wired local loops, the most expensive part. Developing countries can provide better service at a much lower cost per subscriber." (Forge 1995)

Another recent World Bank study reports that "The gap between industrial and developing countries in basic telephone service, although still large, is narrowing. In 1988, developing countries had about 75% of the world's population, about 16% of its product, but only about 12% of the telephone main lines. Industrial countries averaged about 32 main lines per 100 inhabitants; developing countries only 1.5 However, between 1969 and 1988, developing countries almost doubled their share of the world's telephone lines, from 7 percent to 12%." (Saunders 1994)

Furthermore, considerable investment in telecommunication lines is planned in the developing world this decade, as the following chart indicates:

1993-2000	Millions of new phone lines	Percent increase in lines	Investment, $ billions
China	35.5	19.3	53.3
Russia	15.5	6.7	23.3
India	9.1	11.2	13.7
Brazil	6.8	6.4	10.2
Mexico	6.3	8.5	9.4
Thailand	4.3	16.7	6.6
Malaysia	3.1	11.9	4.6
Poland	2.7	6.9	4.0
Indonesia	2.6	13.6	3.9

Source: International Telecommunications Union (Business Week 1994)

As reported in **Business Week**'s 1994 special edition on The Information Revolution, "Over the next decade, China plans to pour some $100 billion into telecom equipment, adding 80 million phone lines by the year 2000, four times the number it has

Videodisc Instruction in Defense Training and Education (Fletcher 1990). DOD's meta-analysis reviewed 40 evaluation reports on the use of interactive multimedia in training and instruction, and concluded that it is less expensive than classroom instruction, enables trainees to learn the material more quickly, leads to higher retention rates, and often turns passive learners into active ones. Providing information in a multi-sensory format, and enabling users to swiftly and randomly retrieve information, were singled out as the two most critical aspects of this faster learning process.

Electronic Communication

As remarkable as have been the developments in stand-alone desktop and notebook computing, the marriage of computers with the incredible developments in telecommunications is staggering in its implications. Computer-based telecommunication is already accessible between more than 160 countries. It is proving to cost pennies on the dollar to send and receive information compared to photocopying and mailing documents, faxing, or using the phone or airplane to diffuse materials.

Several tens of millions of computers in more than 100 countries are now linked to the global communication network known as Internet, and the staggering growth of the Internet (20-30% per quarter) is expected to surpass 100 million users by the end of 1995. By the end of this decade the Internet Society anticipates most countries worldwide will have Internet access. The Internet facilitates the exchange of not only electronic mail, news, discussions in online groups, and text- and numerical-based documents, but the display and exchange of graphics, images, sound, video, and software.

Country-to-country variation in access.

The reliability and economics of electronic mail access varies tremendously from country to country, and even within countries (urban vs. rural), due to both technical issues (e.g., the capacity and quality of the telecommunications infrastructure) and public policy issues (e.g., various tariff structures and monopolistic pricing systems). In highly competitive environments, as found throughout North America, an Internet connection can be obtained for as low as $10 per month for text-based access, and for less than $30 per month for audio and visual capabilities. Some innovative pricing schemes recently proposed by electric utilities may drop the cost to a very robust $5 per month.

The spectacular advances in the satellite and cellular radio areas are now offering services in regions not served by the current telecommunications infrastructure. The vigorous pace of implementation makes any figures of merit as to current numbers of installations and services immediately out-of-date.

Most industry analysts see the telecommunications industry poised for revolutionary improvements in data communications networking over the next 24 to 48 months. Analog, digital, satellite, microwave, cellular and fiber-optic technologies offer users the possibility of communicating virtually all forms of voice, data, text and video information over digitally integrated networks of heterogeneous systems at high speeds throughout the industrialized world. These technological advances have forced governments worldwide to think about changing their monopolistic telecommunications markets into competitive ones. Pressure continues for lower international rates, strongly encouraged by, among others, the World Bank in its interaction with recipient developing countries (Talero 1995).

The idea that telecommunication services are not just a necessary cost of doing now. By the end of 1995, each of the 26 provincial capitals except one will have digital switches and optical fiber links to Hong Kong, Singapore, Taiwan and Thailand. 'When a country goes from no infrastructure to the latest, it will leapfrog entire rungs of development,' says John Legere, AT&T's managing director of consumer services for Asia." (Business Week 1994)

Communication Technologies Essential for Designing for the Global Environment.

Achieving high quality design for the global environment (DGE) in as swift a manner as feasibly possible economically, technically, and organizationally, will require, at a minimum, getting the right and most-up-to-date data, information and knowledge to the right people and places in a timely manner.

Many of the activities vital for DGE require that multiple people, located at different sites and institutions, cooperatively work on issues and/or processes. If information necessary to the individuals is limited by the speed of dissemination, then the quality and timeliness of their efforts are reduced. Many of the activities require the passing of control over to another location as actions are taken. If, for example, transmission is via paper forms, for each site that re-enters the same data into yet another system many productive hours are lost performing data entry. This is one of the major observations of the federal government's National Performance Review (NPR), and a key reason why making federal documents electronically accessible is a foundation stone of Executive Branch policy.

The devil is in the details, as the saying goes, and achieving high-quality DGE outcomes will require the exchange of billions of details between millions of people. The details are needed for discussion, education, training, decisionmaking. The powerful, cost-effective tools of knowledge acquisition, creation, visualization and dissemination are vital for fulfilling these needs. Electronic communication helps facilitate the just-in-time, on-demand, at-any-point-and-location demands that people need.

Future Pace of Digital Innovation Getting Faster

As computer pundits often point out, if cars kept pace with the innovations of the computer industry over the past 25 years, one would now be able to purchase a Rolls Royce getting 2,000 miles per gallon for two dollars. Yet, industry experts expect the next five years to outpace the staggering achievements of the past quarter century. Consider a few highlights presented by computer and communication industry experts in a recent volume (Leebaert 1991), where the consistent message was the merging of computing, communications and images, promising distributed networking of "anything, anytime, anywhere," according to Johnson of DEC.

Chip Progress.

Dr. Gelsinger and his colleagues at Intel are working on the Micro 2000 chip available by the end of the decade, the next step towards the "PC on a chip" which, in turn, will be available within a decade or so. The Micro 2000 will be a 64-bit processor with 50 to 100 million transistors per processor (compared to today's -bit processors with 1 million transistors per processor), have a clock speed of 250 Megahertz, and operate at 700 Million Instructions Per Second (MIPS), along with 2 MB cache memory.

Parallelism.

Dr. Gasis at IBM sees "just over the horizon" the use of parallelism via neural networks providing 1000 MIPS or more and one Megabytes per second data rates, with input devices such as keyboards and touch screens giving way to natural-language input, speech and handwriting.

Quantum-Coupled Devices.

Dr. Tennant & Dr. Heilmeier of Texas Instruments see quantum-coupled devices (qcd) replacing transistors over the long-term for even greater developments -- the biggest qcd's are 100 times smaller than today's transistor. Within the next half decade they see the trend from answer systems to insight systems, as a result of easier modeling, simulation and visualization software, and the emergence of common knowledge bases where we can connect" concept streams or cut and past ideas rather than text or pictures." Expert formal knowledge will be available in executable form, not just in textbooks (as, for example, Palladian's Operations Advisor, which allows the use of queuing-theory models of factory operations without having to deal with the mathematics of lambdas, rhos and mus).

Brilliant Expert Knowledge Systems.

Expert knowledge systems will progress from "smart" to "brilliant," possessing the ability to manage their own missions. They will provide direct connection and control over varieties of sensors; perform integration and interpretation of sensor data; employ use of image understanding to combine the outputs of image processing with expectations to better describe what is in a scene and what is happening; be capable of collecting a history of which strategies worked and which ones didn't, and analyze this to improve performance over time; and coordinate the actions of multiple cooperating knowledge systems. Moreover, brilliant knowledge systems will reflect the integration of two information structures: knowledge inference systems with hypermedia browsing systems, offering two distinct ranges on the same spectrum.

Multi-Sensory Computer Interfaces.

Dr. McBride and Dr. Brown of Tandem Computers estimate that by the end of the decade online technology with voice recognition and multimedia presentation will be as pervasive as the telephone today (e.g., allowing us to communicate instantly with many of the earth's inhabitants through an invisible complex network of switches, wires, optical fibers, transoceanic cables, satellites, and microwave links).

Daisy-Chained Jukeboxes.

Dr. Olafsson of Sony sees revolutionary opportunities with write-once and rewritable CD-ROM discs and daisy-chained jukeboxes (containing a dozen plus CDs). Sony's High Capacity write-once system, for example, stores 6,550 Megabytes (MB) on a single 12 inch optical disk at the very low cost of five cents per MB. Up to seven jukeboxes can be daisy-chained giving the user access to 2.2 Terabytes (information equal to 2.2 million floppy disks). Optical disks are an excellent medium for the enormous amount of data created by simulation software. They should prove very valuable for collecting and storing real-time sensor data for imaging, analysis and simulation applications.

All rewritable optical disks will be interchangeable among different operating systems. Images and data will be pulled off disks in a jukebox quickly and easily, and downloaded to smaller media for distribution to a variety of end-users. Integrated with Local Area Networks (LAN) on fiber optic connections, Personal computers will essentially have access to the processing power, data-transmission rates and mass storage capacity rivaling mainframe computers at a fraction of the cost.

Unimedia.

Summing it up at the 1994 World Future Society meeting, the Bell Atlantic CEO Raymond Smith predicted that the world will experience seamless communication within the next 15 years, capable of accessing vast database resource pools (what MIT Media Lab Director Nick Negroponte calls the "unimedia digital pool" of alpha-numerical data, graphics, animation, sound, video, and real-time televideo-conferencing, et cetera) . Essentially we will have a fully integrated service of videophone, computer, TV, radio, and library available on a penpad-size device via cellular-modem connection.

Internet Video.

A summary of a paper circulated on the Internet by Gary Welz, President, Science and Engineering Television Network (a consortium of professional societies affiliated with the Association for Computing Machinery, whose purpose is to develop, produce and distribute scientific knowledge), presented the following chart showing the download time for a 30 minute video program compressed into 300 MB of data transmitted across lines of various bandwidths:

14.4 kb/s	128 kb/s	1.5 Mb/s	45 Mb/s	155 Mb/s	620 Mb/s	1 Gb/s
Dial-up	ISDN	T1	T3	OC3 (2 yrs)	OC12 (4 yrs)	Super Hwy (4yrs?)
46 hrs	5.2 hrs	27 min	53 sec	15 sec	4 sec	2.4 sec

GREEN BUILDING DESIGN OPPORTUNITIES

It is clear that the next five to 15 years are going to be very heady times, taking advantage of hardware advancements to operate sophisticated object-oriented language programs. There should exist the capability to showcase "green" building design, construction, commissioning, operation, and lifetime maintenance through a combination of 3-D graphics, video, virtual environment (VE) simulations, and numerical data sets of energy, pollution and financial throughputs, along with the option for real-time video team conferencing about this multimedia display.

Whole-System Analyses

Each component of the building should be capable of being modified or upgraded through point-and-click and/or voice-activated operations. For example, a user will be able to click on the window glazing and a pull-down menu opens for selection of higher R-value glazings to be selected. Any change of values will then automatically recalculate the data values throughout the program, tabulating and indicating resulting synergistic opportunities like the downsizing of the chiller system, first cost and life-cycle cost savings, and reductions in environmental pollutants

Sophisticated Procurement Databases

Integral to the design tool will be a product procurement option, which showcases the green products and services commercially available. The products will have references in the form of case studies and testimonies from happy customers (and dissatisfied customers?), and detailed cost and performance data. The database would encompass a range of available products/services from entire buildings to discrete components (e.g., certified sustainably harvested timber and wood products, products made of reusable materials, sophisticated software design packages for real-time energy/environmental sensor monitoring for ensuring optimal building performance, low plug-load/high-performance end-use equipment, landscape database of energy- and resource-conserving tree/plant species appropriate for specific microclimates and building types).

Whole building simulation, from conception through lifetime operation (via integrated sensors in the building's digital energy/environmental management and monitoring system), should become routine. The computer simulations on Silicon Graphics workstations by world energy efficiency expert Eng Lock Lee and his firm, SuperSymmetry, provide a glimpse of the extraordinary things to come.

Inter-Institutional Synergisms

Some of the most promising possibilities for the energy design community are the synergisms that are likely to result from the advanced communication tools enabling quick and easy interfacing with very diverse institutions. Today's work environment is notoriously inefficient and rife with lost opportunities because of the inability for key players engaged in the design, construction, financing, outfitting, servicing and operation of buildings to communicate with one another at critical points. This phenomena is amply detailed in recent E-Source publications (Houghton 1992).

Consider just one overarching opportunity: improving the interface between utilities and architects/builders. Globally, utilities are projecting expenditures of roughly $2 trillion per decade to expand capacity to meet growing demand. A range of analyses suggest that energy efficiency investments could deliver a large fraction of these utility services, saving perhaps $1 trillion per decade and accruing enormous cost-free environmental benefits

Value-Added Services

The "greening" of new, as well as existing, buildings constitute a large percentage of this investment opportunity. A number of cutting edge utilities engaged in fourth generation Demand-Side Management (DSM) programs are recognizing the value of providing full-service, full-financing arrangements to help capture these "green investments." This is a dramatic shift of corporate culture, regulatory practice, and public understanding of the traditional role of delivering a resource-intensive commodity, electricity, to the new era of delivering information-rich, value-added services (i.e., electricity, and efficiency, and financing arrangements, and environmental benefits, and enhanced productivity for its customers, as well as other emerging options and benefits).

There is the growing realization, as these cutting edge utilities look at how best to design such value-added services, that advanced communication technologies have a powerful role to play across the spectrum of their operations:

- working with architects and builders to employ better energy design tools;
- employing interactive-multimedia applications for in-house training of staff;
- using hypermedia applications as marketing tools to educate and motivate customers to take advantage of DSM programs;
- exploring the customized use of these communication applications for real-time building monitoring for verifying persistence of savings of DSM investments, and providing feedback for maintaining optimum building performance;
- providing curricula resources to secondary schools and universities, vocational and architect schools , and engineering departments; explaining and justifying program investments to senior management, regulatory agencies, and to customers and media in the service territory;
- as well as potential uses like convincing state and federal officials to enhance building and equipment performance regulations.

New Era of Energy Design Tools

It is frequently noted in the information/communication industry that the value of information can be proportional to the number of people who have access to it, and that when two pieces of information are combined the result is often new information. It would appear that tremendous synergisms could result from utilities, their customers, and the various intermediary suppliers (architects, builders, developers, financial institutions, manufacturers, retailers, ESCOs, etc.) taking advantage of energy design tools in the broadest sense of the term.

This decade offers the opportunity to evolve energy design tools that are both empirical case-study driven (of successes, lost opportunities and failures) and simulation-inspirations of greater opportunities that can be achieved in the pursuit of sustainable development goals. And especially an opportunity to use these tools far beyond their intended uses by architects/builders to educate, market, and motivate the broad range of decisionmakers from utility senior management and their customers in diverse sectors and socio-economic situations, to regulators, financial institutions and public officials.

The trend seems clear, even if the dates remain fuzzy: advanced communication tools will make it easier for team and group shareware activities to occur both in real- and delayed-time and in geographically disparate spaces. Virtual meeting rooms will, in turn, allow exploration of virtual environments like the design of buildings and building equipment. A succinct overview of this appeared in *Technology Review*, June 1992, "Being There: The Promise of Multimedia Communications," discussing efforts-in-progress like AT&T's Rapport system, Japan NTT's TeamWorkStation, Xerox PARC's MediaSpace, and BellCore's Cruiser.

An important step I see needing to occur is far greater interaction between the energy design community and the experts and expertise in the computer/communication industry. Just as lessons learned get disseminated at the proliferating conferences like the ACEEE summer study, there is immense value to be gained by promoting the cross fertilization of lessons learned in applying advanced communication tools in other sectors (notably the defense and health sectors which seem to be gathering the most experience to date).

An excellent advancement in this regard was the announcement in June, 1995, by twelve major corporations to establish an Industry Alliance for Interoperability. The Alliance was organized by Autodesk, which, in less than 15 years has become the world's fifth largest software company, operating in 115 countries. Other companies included Carrier, Honeywell, AT&T, Tishman and eight other building industry companies, as well as the national laboratory, Lawrence Berkeley Lab (LBL).

The Alliance goal is to establish a software standard that would allow all building software (Computer-Aided Design-CAD, energy design software, construction management, cost estimating, et cetera) to share the same description of the building, resulting in huge cost savings compared to the norm. Today, each tool user has to create a separate data base for the tool to use. It can take a week to input a DOE-2 software description for a large building-- one of the reasons people don't use energy software.

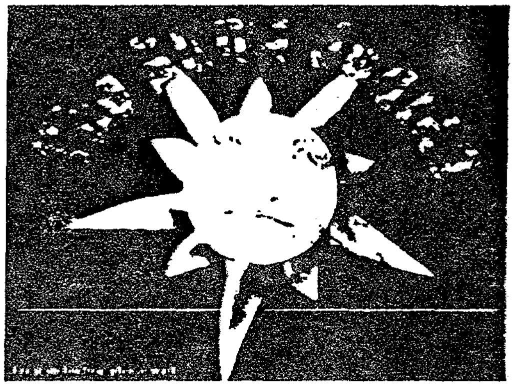
The global market for such a knowledge tool is enormous. It will enable hundreds of billions of dollars per year of energy saving opportunities to be identified and implemented. The annual prevention of tens of millions of tons of environmental pollutants will be a natural outcome of this knowledge-intensive design process.

CREST'S DIGITAL MEDIA ACTIVITIES

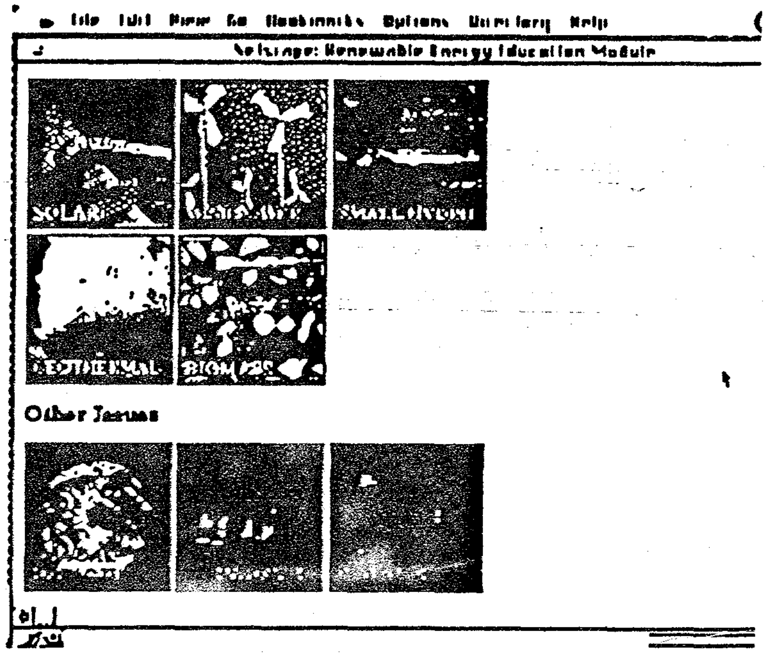
Interactive Multimedia CD-ROM

For the past several years the Center for Renewable Energy and Sustainable Technology (CREST) has been promoting the use of digital media tools for education, training, and enhanced decisionmaking. During this time, three interactive multimedia CD-ROMs have been produced, which are freely available for downloading from CREST's Internet site, Solstice (URL: http://solstice.crest.org). These include:

The Greening of the White House



Renewable Energy Technology Exhibit.



Solstice - CREST's Internet World Wide Web (WWW) site

In addition to producing interactive multimedia CD-ROMs, CREST is immersed in the digital media revolution by gathering and posting some of the best available information on its Internet server, known as Solstice. CREST is the host to the Internet Virtual Library term 'energy.' As host, our responsibility is to maintain a listing of energy-related information available through the Internet. Roughly 140,000 people from 65 countries are now accessing Solstice on a monthly basis, downloading the equivalent of one million pages of text (an increasing fraction of it are digitized slides). Solstice is accessible from 165 countries by email, and most countries should have access to full Internet service by the end of the decade, according to the Internet Society.

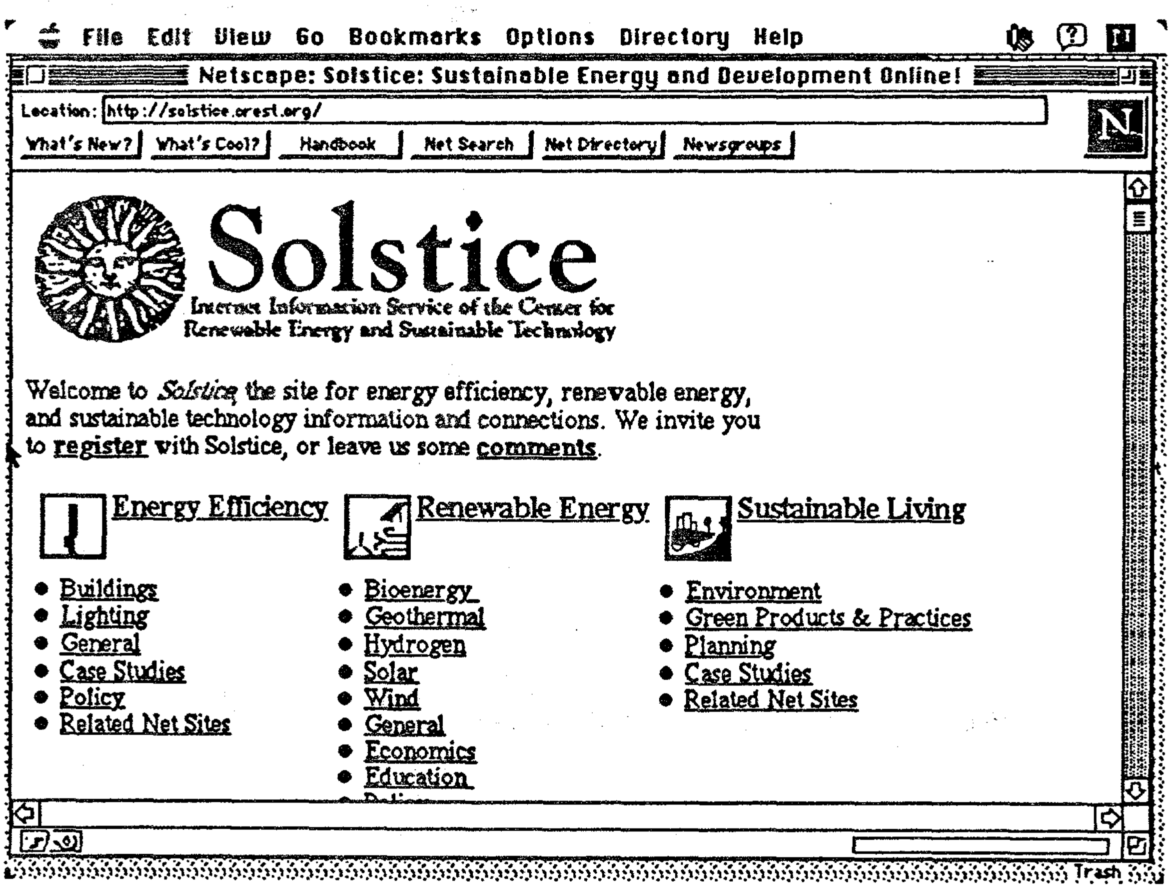
The growth of the World Wide Web (WWW) has been nothing short of astronomical since its origins in 1989 at CERN, the European Particle Physics Institute in Geneva, Switzerland, where it was designed to help physicists share and exchange documents worldwide cross machine boundaries. This is an extremely important point: it does not matter if the user has an IBM-compatible personal computer, a Macintosh, an UNIX computer, or other kinds, they can all access the WWW information.

The Web's two premier features are 1) hypertext, whereby words and phrases can be tagged to serve as links to other relevant documents; and 2) multimedia browsing, whereby the user can access not only text, but photos, graphs, animations, and even audio and video clips . The hypertext tag may appear as an underlined or color highlighted word, phrase or image. By clicking on the link the user may retrieve a document located at another space on the same computer or stored on a computer in any of a hundred different countries worldwide. In just the past three years the number of Web sites has risen from 100 to more than 10,000, and about 40,000 are anticipated be online by the end of 1995.

WWW browsers provide powerful search engines that allow users to perform keyword and Boolean subject searches of the tens of thousands of servers on the Internet. Some browsers, like Netscape, allow you to open multiple windows to perform multiple searches simultaneously. And having found information that one wants to retain -- be it text, images, audio or video clips, et cetera -- that information can be printed out or stored to disc. Software files can also be nested in hyperlinks and downloaded with a click of the mouse. A very useful function offered by some browsers is a mailing function that permits e-mail messages to be sent directly from the document being viewed.

Online Discussion Groups

There are tens of thousands of specialized online discussion groups now operating electronically, and CREST also maintains online discussion groups. Known commonly as mailing lists, topics include bioenergy, strawbale building construction, and sustainable resource development. CREST's home page is pictured below, and the URL address is: <http://solstice.crest.org/>



References and Bibliography

Anonymous, 1994. Special Issue: The Information Revolution, *Business Week.*

Anonymous, June 1992. Being There: The Promise of Multimedia Communications, *Technology Review.*

Fletcher J., July 1990. *Effectiveness and Cost of Interactive Videodisc Instruction in Defense Training and Education*, Washington, DC: Office of Assistant Secretary of Defense, Institute for Defense Analysis, IDA Paper P-2372.

Forge, S. 1995. *Consequences of Current Telecommunications Trends on the Competitiveness of Developing Countries*. Washington, DC: World Bank.

Haynes, P. Sept. 17, 1994. Survey of the Computer Industry, *The Economist..*

Houghton, D., R. Bishop, A. Lovins, B. Stickney, J.Newcomb, M.Shepard, and B. Davids 1992. *The State of the Art: Space Cooling and Air Handling*. Boulder: E-Source.

Leebaert, Derek editor. 1991. *Technology 2001, The Future of Computing and Communications*. Cambridge: MIT Press.

Negroponte, N. 1995. *Being Digital..* New York: Alfred Knopf.

Saunders, R., J. Warford, & B. Wellenius. 1994. *Telecommunications and Economic Development..* Baltimore, MD: Johns Hopkins University Press.

Talero, E. and P. Gaudette. 1995. *Harnessing Information for Development..* Washington, DC: The World Bank, Telecommunications and Informatics Division, Industry and Energy Department.

AID. 1993. *Information Systems Plan*. Washington, DC: U.S. Agency for International Development.

Winslow, C. and W. Bramer. 1995. *FutureWork: Putting Knowledge to Work in the Knowledge Economy* . New York: Free Press.

The Journey from There to Here
The Eco-Odessey of a CEO

Ray C. Anderson*

Good afternoon, ladies and gentlemen. I'm quite mindful that you and I are strangers to each other. I suspect that most of you are strangers to each other, too. So everybody stand! Meet those around you ... Now hug your neighbor .. on both sides of you! . . . I hope the symbolism of that was not lost on you, fellow astronauts on Spaceship Earth: We're in this together and need each other.

This afternoon my assignment is to tell you about the route by which I came to be here. In doing so, perhaps I can provide one example of something that I believe in my heart and mind must happen, one way or another, for millions if not billions of people if mankind is to prevent itself from self-destructing.

Forgive me if I stay on a personal note for a while longer. I am a product of the post-war era which was, of course, one of enormous prosperity and economic opportunity. I graduated from Georgia Tech in 1956, and spent the next 17 years preparing myself (mostly subconsciously) to become an entrepreneur. In 1973, I cut the corporate umbilical cord (I was 38 years old and had a very good job with a major corporation), and I founded a new company to produce, of all things, carpet tiles - just then beginning to be used in American office buildings, where the electrical wiring was in the floor, the furniture was open plan systems furniture, and the office was becoming computerized - known in those days as the "office of the future". The office of the future needed carpet tiles. The new venture was an entrepreneur's dream: beginning with an idea, adding the equity capital including my own life's savings and the investments of friends, arranging the bank debt, acquiring a site, building and equipping a factory, securing raw materials in a time of extreme scarcity, developing and producing those first products, and launching a sales and marketing effort in the teeth of the worst recession since 1929 - and surviving.

And then prospering, beyond anyone's wildest dreams. Perhaps some of you, if you're an architect or interior designer or facilities manager, contributed to that success by specifying or using our products. I take this opportunity to thank you very much. Today that company is global. We produce in 22 manufacturing sites, located in the U.S., Canada, the U.K., Holland, and Australia; are building a factory in Thailand; and sell our products in more than 110 countries. Our sales this year will likely exceed $800 million. We make and sell 40% of all the carpet tiles used on earth, enjoying the largest market share in nearly every one of those 110 countries; plus commercial broadloom carpet, textiles, chemicals, and architectural products (specifically access floors).

---

* CEO and Chairman of the Board, Interface, Inc.

For 21 of our 22 years of existence, I, for one, never gave one thought to what we were taking from the earth, or doing to the earth, except to be sure we were in compliance and keeping ourselves "clean" in a regulatory sense. Until one year ago.

True, before that we had had, developing for fully 10 years, a program called Envirosense®, which had been focused on indoor air quality and alleviating Sick Building Syndrome and Building Related Illness. This effort had been based on some proprietary chemistry we had acquired in the field of anti-microbials, called Intersept® (with an "s"). Intersept is an additive which, if incorporated into plastic materials, will render the surface of those materials self-sanitizing. So materials such as carpets, paints, fabrics, air filters, and HVAC duct liners, cooling coils, and drip pans can be made to be more hygienic and can lead to better quality of air, i.e., reduced bacterial and fungal counts, contributing to healthier indoor environments, tackling the microbial contamination piece of that very complex equation.

More than 30 companies have joined the Envirosense Consortium (itself, a non-profit educational effort), many of those companies incorporating Intersept into their products under license from Interface, all with the profit motive in mind to be sure; that is, making a buck by selling their products or services to solve a problem, a real and important problem. Envirosense had been and still is an external, market-focused program. And it is accomplishing good things in the field of IAQ.

But then, about a year ago, the president of our research arm, Interface Research Corp., organized a task force, with representatives from all of our businesses around the world, to review Interface's companywide, worldwide environmental position. And he asked me to make the keynote remarks, to kick off the meeting and give the group an environmental vision. Well, frankly, I didn't have a vision, but finally I very, very reluctantly accepted his invitation to speak to the new task force. I sweated for three weeks over what I would say to that group. And then, through pure serendipity, somebody sent me a book: Paul Hawken's The Ecology of Commerce (1). I read it and it changed my life. It was an epiphany for me. I wasn't halfway through it before I had the vision I was looking for and a powerful sense of urgency. In making that kick-off speech, I incorporated many of Hawken's examples of what's happening to the eco-system:

1. The reindeer of St. Mathew Island to illustrate carrying capacity, overshoot, and collapse. And as a metaphor for Earth.

2. The depletion of the Ogalala aquifer and the implications of that, namely famine right here in the U.S. of A.

3. The loss of 25 billion tons of topsoil every year, equivalent to all the wheat fields of Australia, and a hungry world population increasing 90 million a year.

4. The usurpation of a disproportionate share of Net Primary Production by the human species, moving toward overshoot and collapse for thousands, maybe millions, of species. "The Death of Birth", as Hawken calls it.

5. The loss of tropical forests to raise soybeans to feed cows in Germany to produce surplus butter and cheese that piles up in warehouses, while a million displaced forest people live in squalor in Rio de Janeiro.

6. The alarming increase in the rate of species extinction, deaths by pesticide poisoning, resource depletion, and so on - much of that happening right here in the Great Lakes region.

I borrowed Hawken's thoughts shamelessly. And I bought in completely to his main theme, that business and industry, the largest, wealthiest, most pervasive institution on earth, must take the lead in saving the earth from man-made collapse. I gave that task force a kick-off speech that, frankly, surprised me and stunned them, and then galvanized them into action, and through them, our whole company, to step up to our responsibility to lead.

I offered the task force a vision: Interface, the first name in industrial ecology (worldwide) through substance, not words. I gave them a mission: to convert Interface into a restorative enterprise; first to reach sustainability, then to become restorative - putting back more than we ourselves take - by helping others reach toward sustainability, <u>even our competitors</u>. The first time I said that I couldn't believe my own words. Since saying it I've been challenged for my "fuzzy thinking" about abandoning the competitive imperative. My answer is that help extended to a competitor need not be free, and ought not to be; and the best help might be the sheer stimulation of <u>get going</u>! And I suggested a strategy (you know this one): Reduce, reuse, reclaim, recycle, (later we added *redesign*), adopt best practices, advance and share them. Develop the sustainable technologies and invest in them when it makes sense. And I challenged them to pick the year by which Interface would achieve sustainability. Two days later they told me their target year, the year 2000. I'll be 66 that year, and hope to live to see it happen. I think they may be a little ambitious and it may take longer, but I still hope to live to see it. We gave this program a name, EcoSense®. We are trying to take it throughout our company of 5000 associates and involve everyone.

We also coined a word, "PLETSUS®", an acronym for Practices LEading Toward SUStainability, and we began to share PLETSUS ideas, internally and externally. You can go into Interface's home page website on the Internet and find EcoSense and PLETSUS ideas, right there for you and the rest of the world to see and use. Feel free, and share yours with us. We'd be very happy if it caught on and became a worldwide clearing house for idea sharing. Jim Hartzfeld in our shop is in charge - (EcoJim

@aol.com).

Though you can share, EcoSense is basically, however, our internally focused effort to do what's right. But, it's not just the right thing to do; it's also the smart thing for a manufacturing company that is 100% dependent on a non-renewable resource, petroleum, for its raw materials and its energy-intensive processes.

I made other speeches in the months that followed, patterned after that kick-off address. One of those was given to a group of Georgia Tech alumni and faculty; afterward, one of the professors in the audience sent me a copy of Daniel Quinn's book, Ishmael (2). I read it, then read it again. I've read it five times, now, and bought and given away over 200 copies. I'm here to tell you that Hawken and Quinn, together, will not only change your life, but make you understand why. If you haven't already, read Ishmael to understand why the world is in a mess. Hawken will tell you what; Quinn, why.

There's so much to learn! I continued to read, going back to Rachel Carson's Silent Spring (3), Vice President Gore's Earth in the Balance (4), Beyond the Limits (5), by Meadows, Meadows, and Randers (that's really scary!), Vital Signs 1994 and 1995 (6), Lester Brown's work, and Joe Romm's Lean and Clean Management, (7), and others: David Brower (8); and most recently the work of Dr. Karl-Henrik Robèrt of Sweden and the account of how he initiated the movement there called "The Natural Step"(9). Watch that! It's very important. At the moment I am reading Daly and Cobb's book, For the Common Good, trying to get a grip on the economics of ecology.

In another life-changing experience, I met and came to know and love a fellow named John Picard. John is an environmental consultant. He's so smart and knowledgeable and enthusiastic, and so practical and aggressive at the same time about what's realistically doable. John is consultant to the Southern California Gas Company's Energy Resource Center building project (the ERC). It's a landmark building (it's 60% recycled and highly energy efficient), and John Picard's influence can be seen all through that building. Tony Occhionero was ERC project manager for the Gas Co. We worked with John and Tony to devise the first-ever in the history of the world (to my knowledge) perpetual lease for carpet. We called it the "Evergreen Lease®". In the Evergreen Lease, Interface, the manufacturer, not only made the carpet with state-of-the-art recycled content, but we also took responsibility for installing the carpet, and maintaining it, and because it is free-lay carpet tiles, selectively replacing worn and damaged areas, one 18" square at a time, and implementing a sort of rolling, progressive, continuous facelift by periodically, over the years, replacing modules; and most importantly recycling the carpet tiles that come up. We continue to own the carpet. Title for the carpet tiles never passes to the user; it stays with us, the manufacturer, along with the ultimate liability for the used up, exhausted carpet tiles. The Gas Company pays by the month for color, texture, warmth, beauty, acoustics, comfort under foot, cleanliness, and healthier indoor air (Intersept is built in), and avoids the landfill liability altogether. We deliver these benefits but continue to own the means of delivery - theoretically for as long as the building stands.

Here's the thing: The economic viability of the Evergreen Lease for us depends on our closing the loop, i.e., being able to recycle used face fiber into new face fiber, and used carpet tile backing into new carpet tile backing; and we have yet to learn to do either economically. So, you might say, we're cantilevered a bit. But we will get there. It's key to achieving sustainability; this, along with thousands of little things and a few other BIG ones, like developing benign energy sources to drive our production processes, and eliminating scrap and emissions throughout our process. If we can get it right, closed loop recycling, benign energy sourcing, and scrap and emissions elimination - converting our linear processes to cyclical processes - we'll be sustainable, and never have to take another drop of oil from the earth. We'll spend the rest of our days harvesting yesteryear's carpets and other petrochemically derived products, and recycling them into new materials; and (hopefully) converting sunlight into energy; with zero scrap going to the landfill and zero emissions into the ecosystem. That's the vision. There's a lot of work ahead if it's to be realized.

The Evergreen Lease is a manifestation of what Paul Hawken and Bill McDonough have called "licensing", or "products of service". It's the future. We're grateful to the ERC and John Picard and Tony Occhionero for driving this concept to a reality, and letting Interface be a participant. I'll add this footnote: For the Evergreen Lease to become broadly successful, not only must we master closed loop recycling, but the financial institutions must get outside their comfort zones, too, and become third party participants in this strange concept they never saw before, a lease without a term.

I also met Bill McDonough, finally, after hearing about him for years. He's a visionary architect. He approaches everything, even the ecological crisis, as a design problem. We're working with him in our textile business, our carpet business, our chemical business, and our Architectural Resources business to execute some of his design solutions in product form. Bill has blazed the trail for 20 years with such concepts as, "Waste equals food", "cradle to cradle", and we're following just as fast and hard as we can.

We're also wrestling with the complex issue of how to measure ecological and environmental impact. We've called it EcoMetrics. For example, how do you evaluate the following hypothetical trade-off? One product consumes 10 lbs. of petrochemically derived material (per unit), a non-renewable resource. Another, functionally identical to the first, consumes only six pounds, substituting four pounds of abundant, benign inorganic material, but through the addition of a chlorinated paraffin. How do you judge the true cost or value (which is it?) of that chlorinated paraffin - in God's currency? That's EcoMetrics, the search for God's currency, a scale that weighs such diverse factors as toxic waste, dioxin potential, aquifer depletion, CO^2 emission, non-renewable resource depletion, and embodied energy. EcoMetrics: helping us measure where we are and which direction we're headed - to tell us when we reach sustainability. Others, I see in my reading, are wrestling with the same issue, especially during the transition phase toward sustainability.

During the year, I've continued to read. A friend took issue with me and disputed Hawken and Lester Brown and others as "alarmists". We have a friendly debate going. He sent me Bast, Hill, and Rue's book, Eco-Sanity (10). It's the other view. It says good science doesn't support the alarmists' views; that the world has 650 years supply of petroleum, not 50; that the concern over the ozone layer is misplaced and unfounded; that acid rain is a disproven theory; that global warming is, too; that problems with automobiles, nuclear power, and oil spills are past problems that are nearly solved; that pesticides and toxic chemicals are manageable problems; and that deforestation and resource depletion are problems limited mainly to third world countries. There's another book out there: The True State of the Planet (11), edited by Ronald Bailey, that conveys a similar, "the sky is not falling" message to "chicken little" environmentalists. It forecasts a coming age of abundance; says we can wait a while on global warming to get the computer models perfected; claims that famine is a thing of the past for most of the world's people; and so forth. These people write persuasively and will test your resolve! They shook mine at first.

Honest people of good will and with good intentions can disagree. They can interpret the same data differently, and even reach opposite conclusions, without having to be branded as footdraggers or alarmists. But, how do we reconcile all of this? Where's the truth?

The title of this talk is, "The Journey from There to Here, the Eco-Odyssey of a CEO". Well, environmentally, "there" is where I was just about a year ago, pushing Intersept through the Envirosense Consortium to make a buck and staying in compliance on all the rest. "Here" is where I am today, with an awakened, sensitized conscience - realizing, for example, that "compliance" can mean "as bad as the law allows" - and an awakened, sensitized company; hoping to do what's right, wrestling with what's the truth in all this, and looking for a reconciling statement. I think I have it, or at least the beginnings of it. Here it is:

Whether the earth will run out of oil in 50 years or 650 years may seem like a big contradiction in conclusions reached; but either, in geologic time, is the blink of an eye. Our life span is so short that it's like being in only two or three frames of a movie that has been running a long time and has a long time yet to run. Our time on earth is just so short that we don't see enough of the movie, can't see the next scene even, much less where it's all headed. But our few frames can have a huge effect on the outcome of the movie. Not to trivialize through analogy, but I remember hearing a NASA scientist say once, talking about Apollo XI, that first man-on-the-moon expedition, that 90% of the time the spacecraft was off-course! It was the critically important mid-course corrections that got it there, that determined the outcome. I stand firmly convinced on this point: earth, no, humanity, is off-course and desperately needs a mid-course correction.

Our planet is billions of years old and has billions of years to go. Creation goes on. Even the 10,000 years since the agricultural revolution began are a blink of God's eye. As David Brower reminds us, if you compress all of geologic time to date into the six days of biblical creation, 10,000 years is barely one second. The industrial revolution, growing out of the agricultural revolution, started just 1/40th of a second ago on the same time scale. A lot of damage has been done in 1/40th of a second. To be sure, a lot of economic growth has occurred, too, but at what price, measured in God's currency? Common sense tells us that neither the damage nor the economic growth can continue indefinitely.

The 10,000 years since the agricultural revolution began is, say, 500 generations. Fifty years of oil is two and a half generations worth; 650 years is 32-1/2 generations worth. Seems like a big difference on our scale of observation, but whether it's the last 1/2% of an epoch or the last 6% of an epoch that we're living in doesn't really much matter; time is short. In a blink of God's eyes the whole epoch will be over.

I know I'm preaching to the choir, but we're part of the continuum of humanity and life in general. We will have lived our brief span and either helped or hurt that continuum and the earth that sustains all life. It's that simple. Which will it be?

Well, how <u>can</u> we help? I believe one person can make a difference, you and I; that people coming together, as in organizations like yours and mine - this one - can make a big difference; that companies coming together, for example customers and suppliers in recycling efforts, can make a huge difference. Harnessing wind and current solar income can make a monumental difference. If five billion people change their minds (that's Daniel Quinn's mission through <u>Ishmael</u>), and do their daily thing, whatever it is, with the earth's welfare in mind, then earth, humanity, and all the continuum of life will gain a new lease on life. That mid-course correction that I think earth and humanity need probably depends on that, more than any other one thing: changed minds - new paradigms.

Another part of the reconciling statement lies in what I'll call "the McDonough Paradox". Bill and I were talking one day about the contradictory position of the two polarized schools that I've called the "alarmists" (most of us) and the "foot draggers" (most of them). Let's express those positions in terms of *perception, action, and outcome.* The alarmist perceives the earth to be in crisis, sees our actions as totally inadequate, and predicts the outcome to be collapse. On the other hand, the foot dragger perceives things as not so bad, even getting better; sees our actions as good enough, maybe too good, meaning expensive and misguided; and sees the outcome as an abundant future for all.

Here's the paradox: the surest way to realize the alarmist's outcome (collapse) is to accept the foot dragger's view of where we are and what we need to do. And the surest way to realize the foot dragger's outcome (abundance) is to believe the alarmist's view: we're in trouble and we've got to change.

Bill, himself, puts it this way: You're the alarmist and you've got a big bet with your foot dragger friend about how it will all turn out; and you're working like hell to lose your bet.

If enough minds change, I think then a new paradigm for business will emerge: "Doing well by doing good". It's not original with me, but I'm with Hawken: this can move the world from the path of exploitation to the path of sustainability.

Finally, as we used to sing in Sunday School when I was a child, "Brighten the corner where you are, brighten the corner where you are". Many years after learning that Sunday School song, I was exposed to the writings of the 18th Century philosopher, Emmanuel Kant, and his somewhat more sophisticated corollary, which he called, "The Categorical Imperative". What a great cause in which to invoke Kant and his 18th Century admonition (to paraphrase): "Before you do something, consider what the consequences would be if everybody did it." If we all succeed, individually, in doing good for Mother Earth in the corner where we live and work, setting the example for others, and govern our actions by the Categorical Imperative (what if everybody did it?), we will be helping Daniel Quinn in his mission to change five billion minds and give earth that mid-course correction. I believe it's not an option; it is humanity's only hope.

For the time we have left here, let us concentrate on the corners where we live and work: maybe architecture, engineering, manufacturing, education, government, construction - I don't know - whatever. Let's reflect on these two days and learn from each other how others brighten their corners. And ask ourselves, "What if everybody did it?" Then resolve ourselves to set an example by brightening our own corner; and (here's the hard part) spread the word, until everybody gets it, and does it, because it's the right thing to do and it's the smart thing to do. Thank you. Good luck!

REFERENCE LIST

1. Hawken, Paul 1993. *The Ecology of Commerce.*
2. Quinn, Daniel 1993. *Ishmael.*
3. Carson, Rachel 1962. *Silent Spring.*
4. Gore, Al 1993. *Earth in the Balance.*
5. Meadows, Meadows, Randers, 1994. *Beyond the Limits.*
6. Brown, Kane, Roodman, 1994, 1995. *Vital Signs 1994, Vital Signs 1995.*
7. Romm, Joseph J. 1994. *Lean and Clean Management.*
8. Brower, David 1995. *Let the Mountains Talk, Let the Rivers Run.*
9. Robèrt, Dr. Karl-Henrik, *"Educating a Nation: The Natural Step"*, In Context/No. 28.
10. Bast, Hill, Rue, 1994. *Eco-Sanity.*
11. Various authors, edited by Ronald Bailey, 1995. *The True State of the Planet.*
12. Daly and Cobb, 1994. *For the Common Good.*

Promoting Sustainable Energy Strategies in Russia

Robert K. Watson[1]

INTRODUCTION

Enormous structural changes are taking place in the economy of Russia. It is important that vital sectors of the economy undergo a smooth transition from a centrally-planned paradigm to a more market-oriented structure. Introducing market-oriented institutional structures and energy planning approaches to Russian utilities can facilitate the transition to the market and allow them to become vehicles for change rather than mere witnesses.

As real electricity prices increase relative to other prices, a significant industrial restructuring can be expected, with an accompanying reduction of energy consumption. By developing programs to help industry become more energy-efficiency, the electricity sector can play a central role in Russia's economic recovery. A robust energy sector will be in a much better position to lead other sectors of the economy toward market-oriented solutions to the present economic crisis.

Because of the magnitude of the task of recreating an economy for one of the world's superpowers, institutional restructuring should take place incrementally. The transition of U.S. utilities from a "build-and-grow" paradigm to one of Integrated Resource Planning (IRP) and subsequently to a hybrid of competition and IRP began and is continuing on the state and regional level. Local success stories on the West Coast and New England persuaded other states to adopt these methods. This strategy could also prove to be very effective in regions of Russia that are served by integrated electricity grids, such as the South Russia Power Pool (Yuzhenergo) that serves the North Caucasus region.

As the Russian energy system currently undergoes dizzying change, simultaneously privatizing and restructuring, these issues will be largely decided within the next two years. One of the greatest challenges involves implementing an environmentally sustainable strategy which ensures that energy efficiency and renewable energy are incorporated into the new structure.

CHARACTERISTICS OF THE RUSSIAN SYSTEM

Russia's power system is still the largest integrated grid in the world with about 216,000 Megawatts (MW)[2] of installed capacity in 1994 and 858 billion kWh of sales, down from a peak of 1,074 billion kilowatthours (BkWh) in 1990. Electricity generation is predominately thermal (69%)--63% of which is natural gas, 26% coal, 11% heavy oil and diesel; 11% of the total comes from nuclear, and the remaining 20% from hydropower. Energy consumption per capita has decreased, though not as rapidly as GDP, which has resulted in a 25% increase in energy intensity (energy/unit GDP) between 1990 and 1993. According to the most recent figures, this trend

---

[1] Director, International Energy Programs, Natural Resources Defense Council

[2] One thousand Megawatts is roughly the amount of energy required to supply the needs of 1 million U.S. households.

appears to have levelled-off dramatically in 1994. It is not clear whether the decrease in energy intensity is a function of increased economic activity or reduction in energy consumption or both.[3]

Approximately 90,000 MW, almost half of Russia's entire generating capacity is in the last third of its design life and is expected to be retired over the next 15 years. This includes nearly 60% of the nation's thermal capacity and over 40% of the nuclear capacity.[4] In addition, a resumption of demand growth under optimistic economic assumptions could result in the need for an additional 200 BkWh and 40,000 MW for a potential need of 130,000 MW over the next 15 years, an astonishing 9,000 MW per year.[5] A conservative estimate of costs to build some of this replacement and new capacity is calculated at: between $60 and $80 billion by the year 2005 under a high demand scenario and $30 to $40 billion under a low demand scenario.[6]

CHANGES IN THE RUSSIAN POWER SECTOR

In 1992, the Russian energy sector was reconfigured from a structure of separate ministries for oil & gas, power and electrification, and coal into a single Ministry of Fuel and Energy. The nuclear power ministry remained independent. As an interim measure, the electric power ministry was nominally privatized as the "All-Russia Joint Stock Company for Electricity" (RAO EES Rossii), with 51% of the assets sold to investors, who are mostly employees of the former ministries, and 49% retained by the government. Assets transferred to RAO EES Rossii included the national transmission network, the dispatching function, and all non-nuclear power plants over 1000 MW.

Restructuring to a Competitive Market for Electricity

Current proposals to restructure the electric utility sector include divesting RAO EES Rossii of its generation capacity, leaving it as the national grid coordinator and system planner. Although, given RAO EES Rossii's dual ownership of generation and dispatch there is, not surprisingly, some resistance in certain quarters to divestiture. Less clear is what to do with the roughly 70 smaller joint stock companies formed out of oblast-level (roughly equivalent to a U.S. state) utility companies. Since many of these companies' most valuable capital stock--the newer, larger generating facilities--was expropriated by RAO EES Rossii, some of them may be too thinly capitalized to

---

3 All energy figures are from the Center for Energy Efficiency (CENEf) in Moscow.

4 *Joint Electric Power Alternatives Study (JEPAS)* Russian Ministry of Fuels and Energy, U.S. Agency for International Development, June 1995, pp 2-7; 2-24, 27, 28.

5 JEPAS at 1-7.

6 JEPAS, Executive Summary at 20.

get funding for their power system needs at economic rates, particularly if they have to give up what remaining generation they have.[7]

Legal and Financial Issues

On the national legislative front, a new law legalizing and professionalizing the Federal Energy Commission (FEC) has just been enacted which also gives the Regional Energy Commissions (REC) new powers. A draft energy efficiency law is undergoing its third review and may be considered by the Parliament this year.

Legislative questions are gradually being resolved and financial difficulties remain as obstacles to improving the environmental performance of the energy sector. Russia is the only country in history which has a developed economy without a developed capital market. This makes it difficult to replace polluting, obsolete power plants with new, efficient ones, which are highly capital-intensive due to pollution control and other modern technologies.

Despite recent improvements in the Moscow region, non-payment of electricity bills can be as high as 40% in some areas. In general, the fuel supplier ultimately is the entity not paid, which has led to disruptions in fuel delivery. Circular non-payment conditions make it very difficult for utility companies reconfigured as distribution companies, or newly-formed generation companies to raise money to upgrade and maintain existing facilities, or build new generating capacity.

Questions and Issues Needing Resolution

There are several issues that must be resolved before the Russian power sector completes its difficult transition to a market-based system. First, privatization should be completed first before attempting restructuring. It is currently not clear (a) whether there is sufficient market economy management experience in Russia to have a fully restructured private system or (b) what the ultimate structure of the system will look like. A private, vertically-integrated utility structure is close enough to the existing situation to allow for a smoother eventual transition to a more market-oriented system.

Second, regulatory compacts and institutions need to be more firmly established. This should be a prerequisite to a system where contracts between buyers and sellers have primacy. Rules of contract law must be first established, then uniformly accepted, before a national market in electricity can emerge. In addition, in order to be effective, there must be acceptance of independent regulation of the remaining monopoly aspects of the system, such as transmission and distribution.

Third, as mentioned above, capital sources outside the government need to be developed before investment at the levels required by the power sector can take place. At the core of this question lies the improving, but still severe non-payment issue. Currently, there is no penalty for not paying utility bills; until energy ceases being a free good, people will continue to under-pay, or not pay their bills, which makes cost

[7] In fact, some of the local utility companies operating these plants flatly refused to turn them over to RAO, which has called into question the status of these plants.

recovery for facility investments highly questionable. If there is no certainty about return on capital, private investors will remain on the sidelines.

Finally, many of the "public goods" provided through a regulated system should be established before leaving them to the "market." These goods include development of energy efficiency markets and expertise, protection for low-income and other "captive" consumers; environmental protections; research and development; and portfolio management in fuel diversity and environmental quality.

PRIVATE EFFORTS TO PROMOTE SUSTAINABLE ENERGY IN RUSSIA

The focus of this section will be the efforts of a U.S.-based, environmental non-governmental organization (NGO) to promote sustainable energy strategies in the North Caucasus region of Russia.

Strategic Approach

This project employs a similar strategic approach used by a national environmental group in the U.S. where the Pacific Northwest region[8] was targeted as a model for the rest of the country. Serious concerns about the regional Power Marketing Agency's ambitious construction scenario involving several large coal and nuclear power plants which threatened serious environmental and economic harm caused this environmental group to adopt a several-pronged strategy to change the projected plans.

National legislation was drafted by prominent Northwestern lawmakers, local experts and environmentalists were organized into a professional opposition, and alternative analytical reports and testimony were produced. The combination of these approaches led to the first officially-adopted program of integrated resource planning (IRP) for the region, the first in the nation.

In the Russian version of this approach, the intent is to make the North Caucasus region serve as a proving ground for integrating IRP with a competitive, restructured power system.

Choice of the North Caucasus Region of Russia

The Southern Russia Power Pool (Yuzhenergo), which serves the North Caucasus region, coordinates 9 local utilities with a total capacity of almost 10,000 MW and annual production of 55 billion kWh; annual consumption is 63 billion kWh. The three principal electric utilities are Kubanenergo, Rostovenergo and Stavropolenergo. Rostovenergo is the largest utility and faces an energy shortage of between 10 and 15%; Kubanenergo is the next largest and only has generating capacity to meet approximately half its needs, most of the rest it imports from Stavropol which is relatively well-endowed with generating capacity. These three main utilities and six much smaller ones are all coordinated as part of a pool by Yuzhenergo.

---

[8] This region comprises the fours states of Idaho, Montana, Oregon and Washington.

Overall, regional energy demand exceeds available generating capacity by 15-20%. This shortfall used to be made up for by imports from other regions of Russia, coming mainly from transmission connections through the Ukraine. With the break-up of the Soviet Union, power transmission through the Ukraine has been unreliable, forcing the region to cope with even greater shortages. A transmission line from the Central Region of Russia will alleviate this shortfall somewhat, but there still is very little flexibility in the event of a major power plant outage in the region.

The North Caucasus is a unique region of Russia comprised of 8 administrative areas covering 431,000 square kilometers, with a population of 17.5 million people. The region is surrounded by the Black, Caspian, and Azov seas, and borders Ukraine, Georgia, and Azerbaijan. This region is one of the principal destinations for Russians seeking recreation and improvement of their health. Thus, maintaining a clean environment is essential for this recuperative area.

Public opposition led to the 1988-1989 cancellation of a 3 1,000 MW units of a nuclear power station in the Rostov Oblast, which has exacerbated the region's energy shortage. The remaining 1000 MW unit, a VVER-1000 model, is on the priority list for completion by the Russian Ministry of Atomic Energy.[9] Before 1991, because of a capacity shortage, the utilities were forced to limit industrial consumers, and in some cases agriculture and residential consumers, during peak hours. Only after a significant decline in industrial production as a result of the crisis that has occurred over the last few years, the capacity shortfall has been reduced. One key to the region's economic recovery is adequate energy resources.

The North Caucasus region is ideal for a comprehensive IRP program for the following additional reasons:

--Yuzhenergo is one of Russia's seven integrated regional electricity grids, which together form the national electricity system.

--Plans are being developed for a large coal-fired power plant, with little pollution control planned, near the city of Rostov (pop. 1 million +). Wind patterns would blow the smoke plume directly into the city 25% of the time.

--There is political and industrial support and to move toward innovative energy planning practices in the region.

--The region has a history of public participation in energy decisions, a result of opposition to the Rostov nuclear plant.

--The region is a major tourist and health recuperation destination and is known for its clean environment and natural beauty.

--Because of the rich agricultural lands, the region has high potential for growth. Now that the Ukraine is not exporting as much produce to Russia, the North Caucasus region likely will be one of the new "bread-baskets" for Russia.

--The region is accessible for visits and communications. Rostov has over 1 million people and is a major Black Sea port. Other major cities include Stavropol and Krasnodar with populations of approximately 500,000 people.

[9] *Joint Electric Power Alternatives Study (JEPAS)*, Russian Ministry of Fuel and Energy, United States Agency for International Development. Moscow, Washington D.C. VIP Summary-5

Program Description

Since more energy decision-making power is being allocated to the regional level in Russia, this presents an ideal opportunity to create a working model of decentralized energy planning. To approach the implementation of IRP in the North Caucasus, work must occur in six substantive areas described more fully below: (1) Institutional Development, (2) Personnel Training, (3) Analytical Tools and Data Collection Improvement, (4) Demonstration Projects, (5) Materials Production Infrastructure. Work is being performed principally by Russian analysts in close conjunction with American assistance.

Institutional Development. Within the framework of existing Russian legal authorities, it is necessary to develop utility regulations and design tariff structures to provide incentives to utilities, business and consumers to conserve energy. The legal and legislative basis for privatized energy companies and their relationship with regulators, government and consumers at the regional level must also be established. Public participation in energy decision-making could be codified into the structure of the institutions created, as would other important means of ensuring comprehensive decision-making. Creating new energy institutions will require effort at both the national and regional level.

Personnel Training. Training programs for staff of newly-created institutions will be necessary to ensure that people in charge of analytical and decision-making tasks understand the principles of IRP. These training programs should be conducted through local universities and utilities for utility planners, regulatory commissioners, local government officials, non-governmental organizations and private business. The training would cover public- and private-sector issues of management decisions related to energy in a market context. Training on how to conduct public participation in the policy process from the perspective of the decision-maker and the affected public should also be provided.

Analytical Tools and Data Collection Improvement. Technical analysis of reliable data is a critical component of IRP decision-making. Adequate data and tools are needed to evaluate energy consumption in various sectors as well as to test the implications of different policy paths on system reliability and cost of service. Types of analysis needed include: energy forecasting, conservation measure screening, cost-effectiveness testing, development of long-run production costs for supply- and demand-side options, and models for environmental and economic dispatch of power plants. It is important to develop mathematical models and other analytical tools for testing conservation programs and integrating demand-side information into supply planning in the context of emerging market-based economics. However, the data underlying these models must be robust, otherwise resulting conclusions will be faulty.

Demonstration Projects. Demonstration projects give experience in designing and carrying out energy efficiency--both on the supply-side and demand-side--and allow first-hand discovery of barriers to implementation that will inevitably confront large-scale implementation of these technologies and practices. Real-world demonstrations of energy-saving technologies and techniques are also critical for the development of measured data, of which there is an almost virtual lack in Russia.

Small, concrete projects in different sectors of the economy, such as industry, agriculture and buildings will be necessary to test hypotheses about the magnitude of conservation resources and the potential for their capture.

Materials Production Infrastructure. As efficiency programs are developed, it is imperative that the material needs to fulfill those programs are available. Joint venture partnerships between American and Russian firms to produce energy efficient materials and technologies in Russia is one way to begin developing the production infrastructure necessary to supply these needs. Financing the development of Russian industries to improve existing products is another possible way to approach this question. It will be necessary to develop innovative financing mechanisms to create a return on investment attractive to western bankers. Important technologies include: metering and control devices for electricity and heat supply, insulation materials for the entire building envelope, lighting equipment, motors and improved industrial production techniques.

Work to Date

Over the last four years, intensive joint efforts have resulted in remarkable progress in the target region. The constant presence of the environmental group has led to a high level of trust and camaraderie between the American and Russian counterparts. The importance of the interpersonal aspect of the should not be diminished. Initially, there was a great deal of reticence and suspicion of motives on the part of the Americans. It could not be understood why the environmental group and its partners were volunteering to help them. It was clear that they understood the American concern with the environment, but the Russians always seemed to be waiting for the real motive to surface. One of the most remarkable events came nearly three years into the process when one of the closest Russian partners remarked to the environmental group's project director, "You really are concerned with helping Russia protect its environment!"

Although the project was designed to have five major components, most of the work has focused in four principal areas: Institutional Development (including the development of Public Involvement programs), Personnel Training, Analytical Tools and Data Collection Improvement.

Developing models for regulatory and legislative approaches to sustainable energy strategies has been given priority status. Work products produced to date include model legislation and detailed reports describing necessary changes to the institutional structure to enable IRP to be conducted at the regional level. To facilitate acceptance of these new models, the education of politicians and decision makers in the power sector about the benefits of integrated energy planning has taken place. Work has been done with regulators on the development of electricity rate setting methods and have the first time-of-use rates in the country in place at Rostovenergo. In addition, the first public involvement department in the country has been created at Yuzhenergo.

Second, several IRP training programs have been conducted and training materials for one-day, two-day and five-day training programs have been developed.

These training programs have resulted in a core of people at each of the four utilities who understand IRP at a fairly sophisticated level and are beginning to implement these ideas in their utility service territory. The public involvement staff at Yuzhenergo have been trained in this program as well. A regional center of expertise has been created at the North Caucasus Scientific Technical Center, which has been undertaking extensive analytical work on IRP for the region's utilities. Finally, this fall, the Novocherkassk Polytechnical Institute will be starting the first IRP degree program in the country.

Third, the project has gathered the first energy production and consumption statistics for the region and placed them in a common format. Fourth, demonstration projects have been undertaken in several sectors. Using borrowed equipment, over 20 industrial audits have been conducted and programs to implement the audit recommendations are currently being developed. Three sets of industrial auditing equipment have been procured for the region through foreign government support and each utility is preparing a priority list of 100 enterprises to be audited over the next 2 years.

The regional-level work is paying off at the national level. Based upon the experience and knowledge developed in the field, results from this project have been increasingly influential in the power sector restructuring debate, especially regarding the inclusion of the public benefits realized under IRP.[10] Encouraged by the positive results realized on the regional level, the Russian Federal Energy Commission (FEC) has asked for recommendations for how to implement the recently-enacted Law on Tariffs and Regulatory Commissions, as well as comments on a draft Federal Law on Energy Efficiency.

U.S. BILATERAL EFFORTS

The United States government has several efforts underway to promote sustainability in the electricity sector in Russia. These efforts are principally under the auspices of the U.S. Agency for International Development (AID) and the U.S. Department of Energy (DOE).

AID's program has focused on structural reform issues in the electric power sector, as well as technology demonstrations, principally in district heating plants. The structural reform has focused on technical assistance for privatization of the national and regional energy companies, as well as developing a proposal for a new market-oriented structure and creating a proposed financing package for the country in energy supply, transmission and distribution and energy efficiency.

DOE's efforts have been focused on building capability in modelling and analytical techniques for energy forecasting, and conducting energy sector trade

---

[10] These benefits include full consideration of energy efficiency as a resource, resource portfolio management to achieve a diversity of fuel sources and generation types, a "safety net" for economically-disadvantaged customers and the inclusion of environmental costs in economic evaluation of resource options.

missions. Another focus of DOE's work includes nuclear safety and the shut-down of unsafe Soviet-era reactors. Both DOE and AID have been active in the support of the Center for Energy Efficiency, which is located in Moscow and does policy work and demonstration programs on sustainable energy.

MULTILATERAL DONOR EFFORTS

In addition to private efforts and bi-lateral aid packages, international financial institutions (IFI), including the International Bank for Reconstruction and Development (World Bank) and the European Bank for Reconstruction and Development (EBRD), and the European Community, (EC) all have programs in or are preparing financial packages for Russia.

World Bank

Three World Bank loans having to do with energy efficiency in the housing, natural gas and electric utility sectors--totalling nearly $1 billion--are currently in development. The Housing Sector Privatization loan will be focused on improving the energy efficiency of publicly operated housing. It was realized early on that fuel costs represented almost 80% of the operating cost of typical apartment buildings. Thus, in order for these buildings to be privatized--the ultimate goal of the loan--energy costs needed to be dramatically reduced.

The natural gas loan includes improvements in natural gas transport, the reduction of pipeline losses and improving the efficiency of large boilers in district heating and electric power plants, as well as the establishment of an "Energy Efficiency Fund" at the Ministry of Fuel and Energy to capitalize economic energy saving projects.

The power sector loan partially supports the completion of a combined-cycle natural gas power plant in Krasnodar Krai (administrative district) of the North Caucasus region. The loan may also include some funds for implementing energy efficiency projects in the region.

European-Led Efforts

The EBRD has focused on promoting nuclear safety through physical upgrades to nuclear facilities and extensive training programs for nuclear operators and the development of emergency plans in the event of an accident. The EC has a similar multi-faceted approach to the United States which involves technical assistance, capacity-building through support for research and advocacy centers, technology demonstration and joint-venture promotion.

CONCLUSIONS

Private groups can play an important, even catalytic, role in promoting environmentally-sustainable energy strategies, even in challenging venues such as the former Soviet Union. This role can involve working through and supporting efforts by bilateral and multilateral donors and programs, or it can involve working principally with local groups to influence both national government and multilateral policy. The intervention tends to be most successful when the private group helps instigate and advocate for certain programs, but the bulk of the on-the-ground work is handled by local experts and groups.

To produce these results, a long-standing presence and consistent message must be presented. A clear commitment to the project and the host country on the part of the project sponsor is also important. If the in-country partners feel that there is an ulterior motive to the participation of the sponsor they will be reluctant to share the appropriate or important information.

It can take a long time to find and develop reliable partnerships in Russia. Patience is an essential ingredient and disappointment quite common. However, working with the right people can be exceedingly rewarding and produce great results and a good deal of satisfaction.

Especially helpful are real-life examples of the system or program that are being proposed. These examples can be a source of comparison for those attempting to transfer the experiment to their own territory. Having professional counterparts available for in-country partners to consult with is also crucial. It is much more convincing for a novice regulator to speak with a counterpart who has gone through similar travails than an expert consultant who may have only an academic understanding of the situation.

Willingness to adapt the IRP and competitive models to the real situation in Russia is also necessary for its success. Rigid adherence to doctrine or theory will inevitably result in failure because of local conditions or attitudes that are hostile to the "ideal" case.

For those willing to deal with the chaos and frustration that inevitably accompanies a shift in economic paradigm and mode of governance, path-breaking results can occur that can shape the future of a country and improve conditions for millions of people.

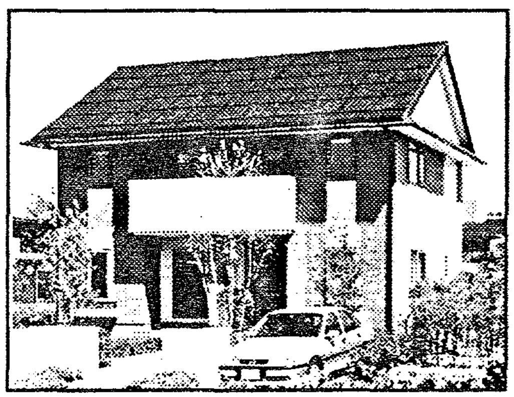
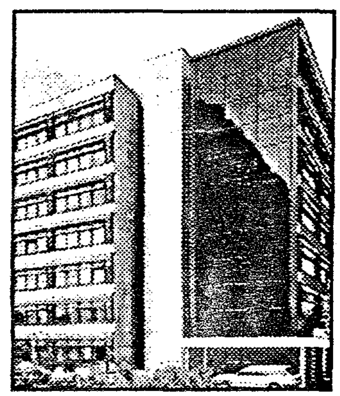
An Overview

of

Worldwide Development Activity

in

Building-integrated Photovoltaics

Presented at

Design for the Global Environment
Georgia Institute of Technology
November 2-3, 1995

Steven J. Strong, President
Solar Design Associates, Inc.
Harvard, MA USA 01451-0242

The Dawning of Solar Electric Architecture

The last two decades have brought significant changes to the design profession. In the wake of traumatic escalations in energy prices, shortages, embargoes and war along with heightened concerns over pollution, environmental degradation and resource depletion, awareness of the environmental impact of our work as design professionals has dramatically increased.

In the process, the shortcomings of yesterday's buildings have also become increasingly clear: Inefficient electrical and climate conditioning systems squander great amounts of energy. Combustion of fossil fuels on-site and at power plants add greenhouse gasses, acid rain and other pollutants to the environment. Inside, many building materials, furnishings and finishes give off toxic by-products contributing to indoor air pollution. Poorly designed lighting and ventilation systems can induce headaches and fatigue.

Architects with vision have come to understand it is no longer the goal of good design to simply create a building that's aesthetically pleasing - buildings of the future must be environmentally responsive as well. They have responded by specifying increased levels of thermal insulation, healthier interiors, higher-efficiency lighting, better glazings and HVAC equipment, air-to-air heat exchangers and heat-recovery ventilation systems. Significant advances have been made and this progress is a very important first step in the right direction.

However it is not enough. For the developed countries to continue to enjoy the comforts of the late twentieth century and for the developing world to ever hope to attain them, sustainability must become the cornerstone of our design philosophy. Rather then merely using less non-renewable fuels and creating less pollution, we must come to design sustainable buildings that rely on renewable resources to produce some or all of their own energy and create no pollution.

One of the most promising renewable energy technologies is photovoltaics. Photovoltaics (PV) is a truly elegant means of producing electricity on site, directly from the sun, without concern for energy supply or environmental harm. These solid-state devices simply make electricity out of sunlight, silently with no maintenance, no pollution and no depletion of materials. Photovoltaics are also exceedingly versatile - the same technology that can pump water, grind grain and provide communications and village electrification in the developing world can produce electricity for the buildings and distribution grids of the industrialized countries.

There is a growing consensus that distributed photovoltaic systems which provide electricity at the point of use will be the first to reach widespread commercialization. Chief among these distributed applications are PV power systems for individual buildings.

Interest in the building integration of photovoltaics, where the PV elements actually become an integral part of the building, often serving as the exterior weathering skin, is growing world-wide. PV specialists from some 15 countries are working within the International Energy Agency's Task 16 on a 5-year effort to optimize these systems and architects in Europe, Japan and the US are now beginning to explore innovative ways of incorporating solar electricity into their building designs.

A world overview of building-integrated PV activity follows with a country-by-country description of component and systems development along with selected examples of Solar Electric Architecture. View these early PV-powered buildings as a first glimpse into the coming new era of energy-producing buildings where this elegant, life-affirming technology will become an integral part of the built environment.

Steven Strong, Solar Design Associates
Harvard, MA, September 1995

Japan

Interest in building-integrated PV has been growing steadily in Japan over the past decade and the government has funded a number of R&D contracts which address this area. For example, Sanyo has developed and prototyped two types of a-Si PV roof modules for residential roof integration. Both are direct-mounted on a sloped roof surface over the roof deck. The first was a curved tile similar to the traditional Japanese ceramic roof tiles. This curved tile measured 305 mm square, was quite elegant and blended well with the traditional Japanese roof tile system but, with an output of only 2.7 Wp per tile, was very expensive to produce and install.

The second Sanyo effort introduced a larger-area, flat-panel shingle measuring approximately 1.1 m by .54 m with an active area of approximately .5 sq. m. It did not integrate as well with the traditional Japanese architectural style but the results were pleasing and it was far more cost effective to produce and install. The concept is very similar to the rectangular roof shingle developed in the US using single-crystal cells in the early 1980's by General Electric.

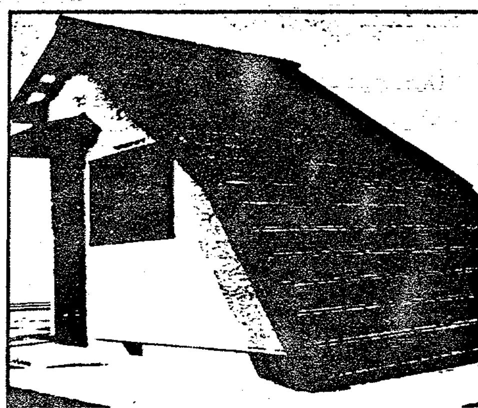
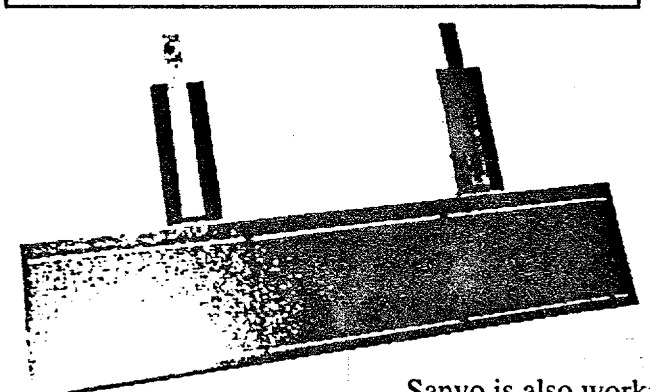


Fig. 1. Sanyo PV shingles under test

A-Si technology appears to be a better choice for direct-mounted roof applications when compared to thick-crystal technologies because it is far less sensitive to the higher operating cell temperatures resulting from reduced module cooling. The first generation of the Sanyo PV roof shingle is shown in Figure 1. The traditional roofing material in Japan has been tile. However, an asphalt-based roof shingle similar to that produced in the US is now being used increasingly on new residences because of cost. Sanyo has recently revised their flat-panel shingle, changing its scale to better integrate with these new conventional roofing materials. The latest version, shown in Figure 2, is approximately 90 cm wide by 35 cm high with an exposed area of about 15 cm high.

Fig. 2. Latest Sanyo glass a-Si PV Shingle



The module is a-Si on a glass superstrate and small plug-in connectors are employed to facilitate module-to-module interconnection. Installation is direct-mount over the structural roof deck. A test house employing this new Sanyo roof shingle has been completed at the Japanese PV test site at Rokko Island operated by Kansai Electric. This house is shown in Figure 3.

Sanyo is also working on a-Si-on-glass modules for commercial curtain wall applications. Their vertical facade PV element is a semi-transparent a-Si glass panel with uniformly-spaced, laser-cut microscopic holes, using a process developed at Sanyo in 1986. This technology, which generates electricity while allowing 30% light transmission, is well suited for auto windows and sunroofs as well as residential windows and commercial curtain wall construction. The integration of the semi-transparent a-Si PV into a conventional building curtain wall reduces glare from direct sun while also reducing the building's cooling demand from unwanted solar gain. Companion opaque (full power) a-Si panels could be installed on the non-view surfaces of the building.

Module construction employs: glass cover, EVA, glass, a-Si thin film with microscopic holes, EVA and a clear plastic back sheet. Prototype modules measure 1.22 m by .370 m by 9 mm thick and weigh 6.4 kg. All modules are custom order. In addition to commercial curtain wall view panels, many other varied applications such as individual skylight units, sloped glazing systems and residential window units are possible with this versatile product.


Fig. 3. Kansai Electric's PV demo house

Following the classic Japanese model for market entry, Sanyo began marketing this transparent a-Si technology to automotive companies first for see-through PV sunroofs which are a high-value-added product, while working to develop a market for building integrated power products which is potentially a very large market when unit costs are lowered. Sanyo is the largest Japanese PV manufacturer, reportedly producing 6.5 MWp in 1992.

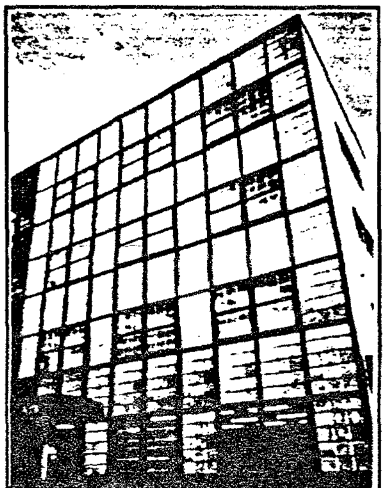


Fig. 4. Sanyo a-Si PV facade

Recently, Sanyo has fielded several prototype installations of its a-Si curtain wall modules in commercial buildings including their own office building and a building for Hokuriku Electric Power Company. A building for the Tsukasa Electric Industry Company, shown in Figure 4, features a full south facade of Sanyo a-Si PV with opaque modules used in the non-view areas and see-through modules used as view glass.

Other Japanese companies are gearing up for the domestic market for distributed PV systems in Japan. Misawa has built a demonstration called the Eco Energy House which is shown in Figure 5. The home features a PV roof employing custom glass-superstrate polycrystalline PV modules from Solarex and an innovative framework of extrusions which provide physical clamping and a weather seal to create an integral PV roof over a sloped residential roof deck.

The Japanese government subsequently sponsored another effort for "The development of a (low-cost) roof-mounted PV array for existing Japanese residences". The prime contractor for this effort is Kandenko Co., Ltd. The program involved an assessment of existing Japanese housing stock and resulted in the development of a new large-area, single- and poly-crystal PV module 1.3 m by .650 m and a stand-off mounting system to install the arrays above the existing roof. The results are quite similar to the 30 residential systems fielded in the US by Solar Design Associates in 1985 for New England Electric in Gardner, Massachusetts..

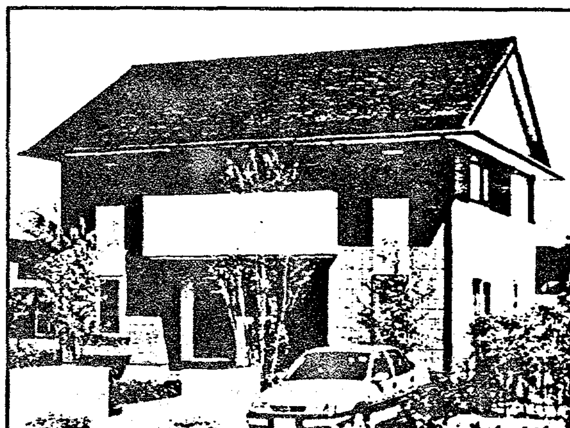


Fig. 5. Misawa PV demonstration house

The Japanese government is also funding participation in the IEA Task 16, Photovoltaics in Buildings. In addition to representatives from the Japanese MITI, the Government Research Institute and Project Sunshine, PV professionals from Sanyo, Kandenko and the

Central Research Institute of Electric Power (Japan's EPRI) are representing Japan in this multi-country development effort.

In 1993, the Japanese government invested 206 million yen in component development, 45 million yen in standards and 1,224 million yen on PV demonstrations. Another area of interest has been the development of combined PV/thermal systems for buildings in Japan. Figure 6 shows a prototype combined PV/T system developed for residential applications. This system employs hybrid collectors using polycrystalline PV cells backed by a thermal absorber to produce 3.2 kWp of electricity and 25 kW of thermal energy.

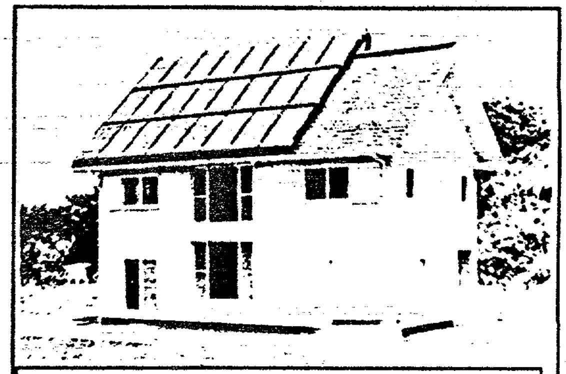


Fig. 6. Japanese PV/T test residence

At their Rokko Island test site, the Japanese have some 500 kWp of small, distributed PV systems under test. Most of these systems are 2 kWp. Some are mounted on test houses as shown in Figure 7, while others are ground-mounted and all are connected to the same distribution feeder through a complex of switchgear that allows simulation of any possible combination of events. When representatives of Solar Design Associates visited Rokko Island, Mr. Kitamura, the Program Manager, stated that:

- Distributed PV systems are safe and reliable and will be encouraged in Japan
- The issues surrounding "islanding" and power quality have all been technically resolved
- All utilities must follow the same national uniform interconnection standards
- All utilities must provide Net Metering, two-way power flow connections to small power producers
- Utilities are 'encouraged' to offer a 10% premium for renewables for the good of the country

These statements were later confirmed and elaborated on in various presentations at the 7th PVSEC held in Nagoya in November, 1993 in a special session entitled: "PV Residences Now Ready". The Japanese have concluded that distributed PV systems on buildings are the most attractive way to field photovoltaics and appear ready to dive into this market and make it happen to the direct benefit of their country and their PV manufacturers and the indirect benefit of the rest of the world.

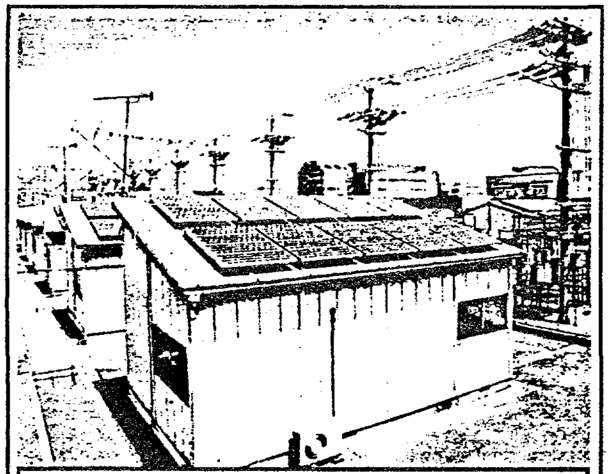


Fig. 7. 2 kW PV test systems at Rokko Island

To get things started, the Japanese Ministry of International Trade and Industry (MITI) announced a domestic program, in January 1994, to subsidize distributed, utility-interactive PV systems for residential roof-top applications. The subsidy, of up to 2.7 million yen (~US$27,000), is meant to cover only up to 1/2 of the price of the PV systems up to 3 kWp per house.

At least 700 residential installations are planned for 1994, the first year of the program; 1,500 in 1995, 2,000 in 1996 and so on, building toward a total of 62,000 and 185 MWp over seven years. The 1/2 subsidy will remain for the first three years of the program and then step down to zero after seven years. The subsidy is proposed to be paid to the PV system supplier, not the homeowner.

Germany

In the aftermath of the disastrous nuclear plant meltdown at Chernobyl, the "Green political revolution" gained a strong following momentum all across Europe as environmental consciousness grew. The German government has lead the way in the acceleration of its renewable programs, allocating about 300 million DM in FY 1993. Out of this, 100 million was set aside for PV.

Fig. 8. PV residence in '1000 Roofs Program'

With the implementation of the "1,000 Roofs" program, the German government assumed a leadership role in supporting distributed PV systems for buildings in Europe. In this program, grid-connected PV systems sized at 1-5 kWp are fielded on residential roof tops with up to 70% cost-sharing from the German government.

Figure 8 shows a typical PV installation under the 1,000 Roofs Program. This residence in Helmstedt received a 4 kWp array of 80 standard (frameless) Siemens M-50 modules integrated into the roof using off-the-shelf aluminum profiles from the German facade company Schüco, replacing the traditional red-clay tile roof. Shortly after the program was started in the fall of 1990, it was expanded to include some 2,500 roof-top installations. By the spring 1994, over 4 MWp of roof-top PV systems had been installed on 1- and 2-family homes across Germany.

In 1993, the headquarters of the Bavarian Environment Ministry received a building-integrated facade of amorphous silicon modules and sun-controlling "eyebrows" over the south-facing windows using mono-crystalline PV modules. This installation, shown in Figure 9, was engineered and supplied by Deutsche Aerospace, (now a partner with RWE in the new German PV joint venture ASE), and provide a total of 53.4 kWp of capacity.

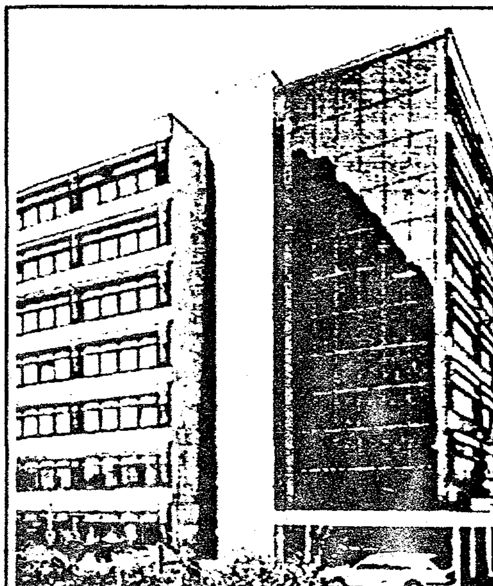


Fig. 9. PV on the Bavarian Ministry

Germany's strong commitment to distributed PV systems for buildings has spurred considerable activity in the development of PV modules specifically for building-integrated applications. Phototronics Solartechnik (PST) of Putzbrunn (near Munich and also now a part of ASE) is developing an a-Si commercial curtainwall module approximately 1 m by .6 m with 6% efficiency. These modules were used on the PV facade at the Bavarian Environment Ministry.

The PST line includes custom-made modules on thin glass superstrates of 1mm to 3mm thick and 1 m by .6m in size. Larger modules can be made up of multiple a-Si panels on a larger sheet of face glass. The maximum output claimed is 60 Watts / sq. m. Both opaque and semi-transparent panels are available. Power reduction for semi-transparent panels is said to be only 15%.

This product is designed for vertical facades of commercial and residential buildings. Four basic product approaches are offered for vertical building facades: opaque PV panels for "cold" facades, opaque PV panels backed by thermal insulation, semi-transparent PV panels for view windows within an insulated glass sandwich and a hybrid combined PV/thermal panel incorporating semi-transparent PV panels for view windows within an insulated glass sandwich with warm-air heat recovery. All orders are custom. A roofing tile is also available which fits into standard tile roof systems with an a-Si glass module top surface measuring .6m by 1.0m.

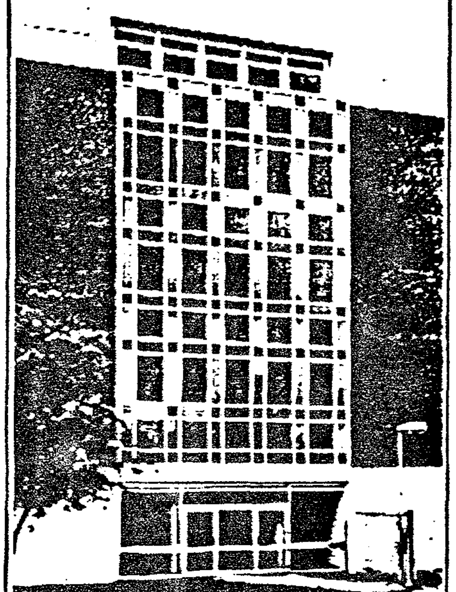


Fig. 10. STAWAG PV Facade

Telefunken System Technik (TST) and Nukem (both now part of ASE) have each developed large-area, glass-on-glass, frameless modules using thick-crystal cells for vertical wall and sloped roof integrated applications. Nukem, which is wholly-owned by the German electric utility RWE, offers a full line of PV modules including special custom large-area frameless modules.

Modules are available with either CZ or polycrystalline cells in sizes up to 1.5 m by 2.5 m at up to 360 Wp. Module construction is glass-on-glass lamination with a poured and cast methyl methacrylate resin as the cell encapsulation and lamination adhesive. Large-area module voltage and current parameters can be configured to suit project requirements. ASE also recently acquired the assets of Mobil Solar Energy Corporation in the US and will be marketing an unframed version of Mobil's large-area 300 Wp module to the building-integrated market.

Flachglas Solartechnik (Flagsol) in Köln, a subsidiary of Flachglas, a major producer of architectural glass in Europe, has embarked on an ambitious development program for both thick-crystal and thin-film commercial curtain wall applications and is looking at semi-transparent thin-film curtain wall modules similar to those produced by Sanyo in Japan. Flachglas sees PV as a means to add additional value to their glass products.

In May 1991, Flachglas installed a prototype 4.2 kWp, 50m^2 array in the south facade of the administration building of the Stadtwerke Aachen AG (STAWAG), a local municipal utility in Aachen, Germany. The facade, shown in Figure 10, employs 10 x 10 cm polycrystalline cells laminated between two sheets of 4mm glass backed by an air space and two more panes of glass (3mm and 4mm).

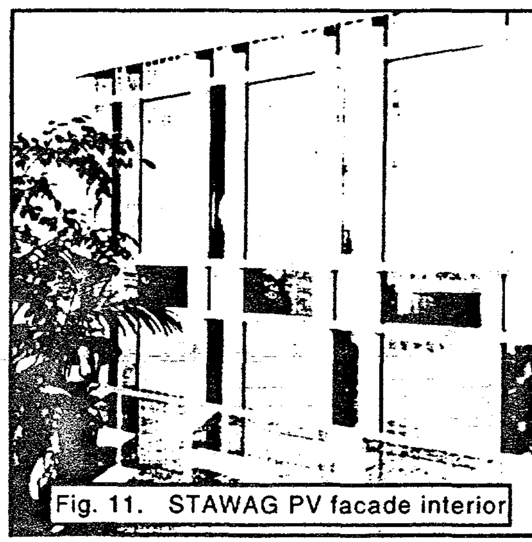


Fig. 11. STAWAG PV facade interior

Four different size panels were specified by the architect to provide balanced daylighting for the stair hall while creating a pleasing design pattern. The interior of the STAWAG PV facade is shown in Figure 11. The system is utility-interactive. Flachglas provides complete system design and integration as desired by the client and recently received a contract for design and construction of a 300 kWp utility-interactive PV roof to be installed at the Science Park Gelsenkirchen near the Essen, Germany. This system will cover some $2{,}130m^2$ making it the largest building-integrated PV system in Europe.

Other German companies have also developed innovative approaches to building integration. The commercial building shown in Figure 12 features a facade of "structural glazing" elements which incorporate PV modules and operable view glass in a prefabricated assembly. Close design collaboration between the architect, (Planerwerkstatt Hölken and Berghoff of Vörstetten), the PV system engineers, (Solare Systemtechnik of Freiburg) and the construction contractor, (Greschbach of Karlsruhe), allowed the entire building facade to be installed in half a day. The combined capacity of the PV facade and the roof-top array is 18.5 kWp. The building was completed in 1993.

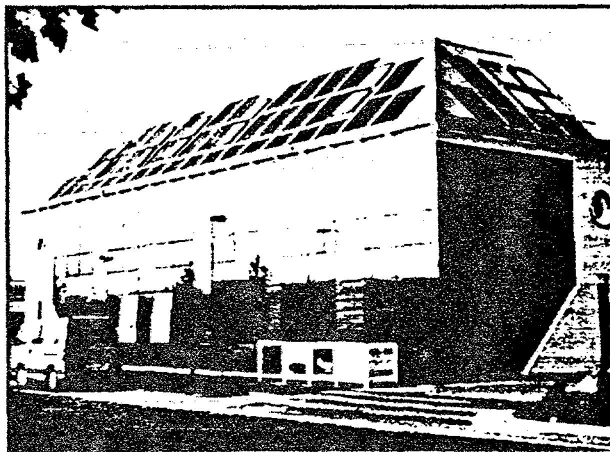


Fig. 12. Structural PV Glazing in Freiburg

The Institut für Solare Energieversorgungstechnik (ISET) in Kassel is also developing and refining methods of mechanical and electrical integration of PV elements into commercial building facades as well as working on other 'balance-of-system' issues for building-integrated PV including small, modular, DC-to-DC maximum-power-point tracking devices and DC-to-AC power converters.

The Fraunhofer Institute for Solar Energy Systems in Freiburg has active research efforts underway in a number of areas related to PV-in-buildings and has recently completed the design and construction of an energy autonomous house in Freiburg which incorporates PV, active solar thermal, passive solar gain, super insulation and a hydrogen system consisting of an electrolyzer, storage and a fuel cell. This house is shown in Figure 13.

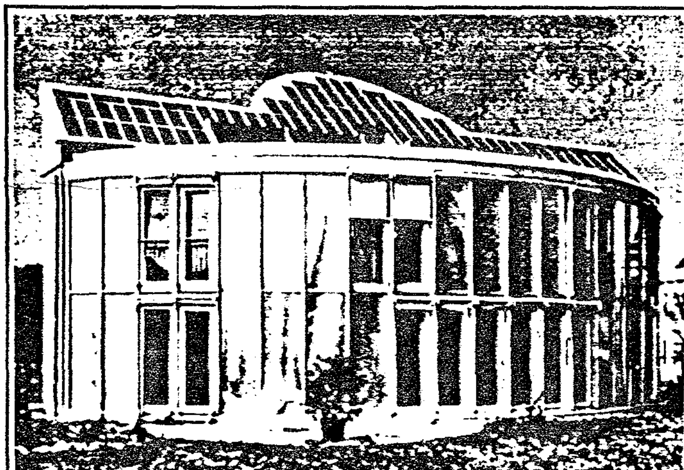


Fig. 13. The Fraunhofer Energy-autonomous House

Under the leadership of Dr. Jürgen Schmid, who realized very early on the many benefits of PV-in-Buildings, Germany took the lead in establishing the IEA Task 16, Photovoltaics in Buildings and is the operating agent. In addition to representatives from the Government's Federal Energy Office, PV professionals from several government-funded research institutes, universities and PV companies are representing Germany in this multi-country development effort.

The immediate future for building-integrated PV in Germany will certainly be affected by the current budget strain on all branches of government due to the enormous costs of the re-unification of east and west Germany. PV is said to still be an important priority but things like housing, schools, etc. are first in line. Program managers say the best they are hoping for is level funding but some budget reductions seem certain in the near term as the country struggles to accommodate the fiscal burden of re-unification.

Switzerland

Political fallout from the nuclear disaster at Chernobyl has also had a very significant impact on Swiss policy making. The Swiss declared a 10-year moratorium on new nuclear plant construction in mid-1990 and, shortly thereafter, announced a dramatic increase in support for photovoltaics and other renewable energy sources with the pledge to field 50 MWp of PV by the year 2000.

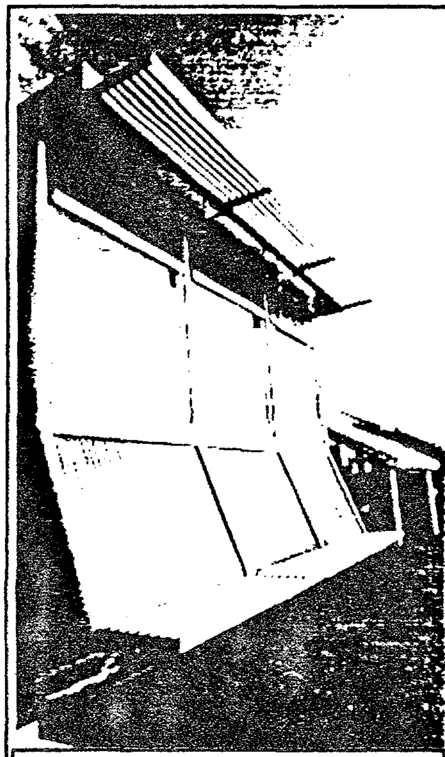


Fig. 14. Integrated PV facade by Schweizer at the Swiss Demo Site

Large areas of flat, open land are not common in Switzerland and, accordingly, activity in photovoltaics for buildings has increased significantly. A substantial amount of funding (6,100,000 SF) has been allocated by the Swiss Federal Energy Office to support the development of building-integrated PV, including component and systems development, systems integration issues, utility interface, demonstration projects, and education / information dissemination.

As a part of the Swiss Federal PV in buildings program, the Solar Energy Laboratory at the Swiss Federal Institute of Technology (EPFL) in Lausanne has recently dedicated a demonstration site for the testing and evaluation of building-integrated PV systems. At present, some twelve demonstration pavilions are complete, presenting different approaches to roof and facade construction.

Figure 14 shows an innovative integration of PV into a commercial building facade on display at the 'Demo Site'. The system, developed by the Swiss firm of Ernst Schweizer in Hedingen, places the PV elements at 20^o to the vertical, creating a sun-controlling overhang for the floor below.

Sponsors of the Demo Site envision it as an "international center for the architectural integration of PV" in support of the IEA Task 16. A sort of 'shopping market' where architects, engineers and building owners can go to see a variety of working building-integrated PV systems on display. Sites for additional systems are still available and manufacturers the world over are invited to participate.

In addition to the Demo Site, the EPFL has a number of innovative installations of PV on their campus. Figure 15 shows the integration of PV elements into daylighting roof monitors on the EPFL Administration Building. The PV modules are fabricated with a clear back skin and a slight spacing between the cells to allow in a gentle pattern of direct sunlight while the primary daylighting comes from the north-facing clerestories.

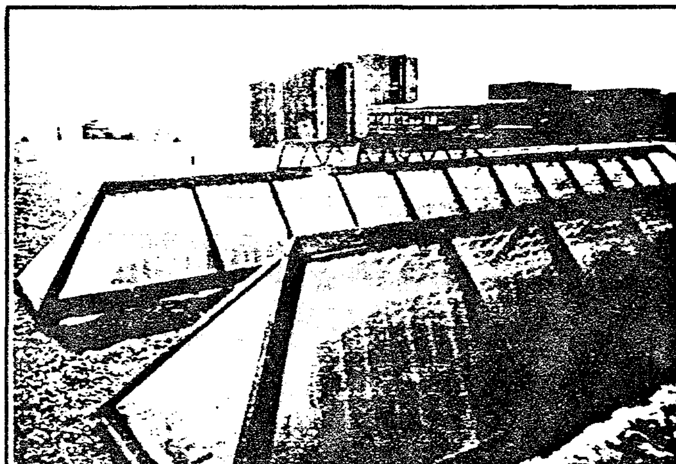


Fig. 15. Integral PV / Daylighting monitors at EPFL

Engineers at the EPFL's Laboratoire d' Energie Solaire (LESO) have designed other PV systems for new and existing buildings on the campus including PV elements used as sun shades, retrofits of existing roof monitors, a novel flat roof system and a facade retrofit.

A privately funded program started before the German "1,000 roofs" program was instituted to install a megawatt of capacity in distributed roof-top PV systems. Using specially-arranged private, long-term financing with low interest rates and volume purchases, 333 grid-connected PV systems, each rated at 3kWp, have been constructed by the Zurich company Alpha Real.

Alpha Real is also developing a novel PV roof tile system in collaboration with Plaston LTD. (Widnau) with funding from the Swiss Federal government. These tiles have an active area of about .25 sq. m and employ 24 10 x 10 cm silicon cells to produce approximately 30 Wp each.

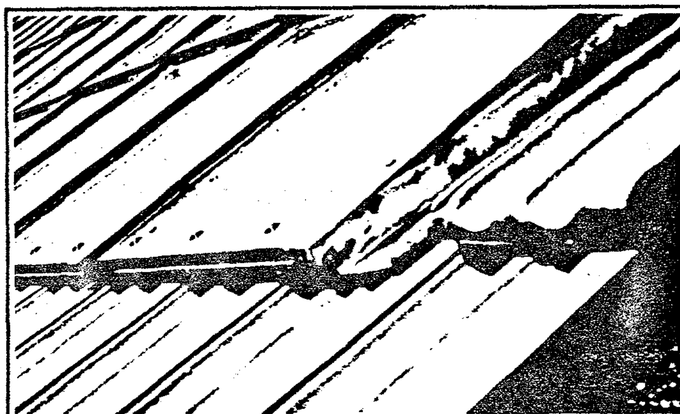


Fig. 16. Plaston's PV roof tile replaces clay tiles

Quick-connect, plug-in connectors are employed. The tile design is very clever in that they integrate directly into the system of conventional tiles as shown in Figure 16 and are thus appropriate for both retrofit as well as new construction. Several prototype residential installations have been fielded.

With well over 90% of the sloped roofs in Switzerland and most of the rest of central Europe constructed with clay tile, the potential market for new and retrofit installations of PV roof tiles is very large across Europe and in other countries such as Japan where clay tiles are also the traditional roofing.

The Swiss government has embarked upon an ambitious nation-wide educational program on photovoltaics. The program goal is to inform the Swiss people of the virtues and benefits of solar electricity. The program includes public information (including the Swiss DemoSite) and technical seminars and workshops for electricians, roofing craftsman, architects and building engineers. In an effort to reach all segments of the population, PV systems have been fielded on Swiss school buildings as a way to acquaint the next generation with photovoltaics.

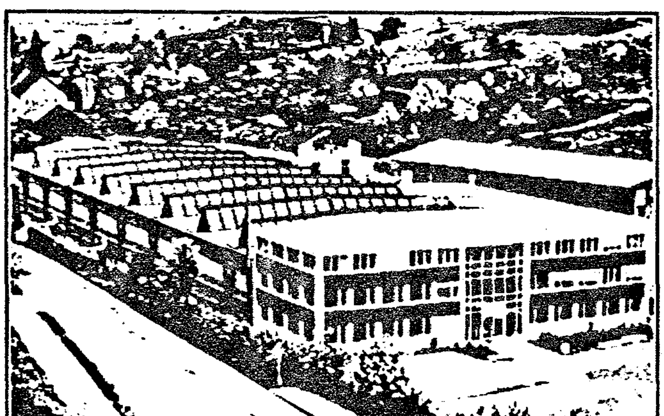


Fig. 17. PV roof and facade integration at Fenster AG

Solution AG fur Solartechnik (Härkingen) has developed a line of large-area, glass-superstrate PV modules custom made to project specifications which employ either single-crystal or polycrystal silicon cells. Modules can be made up to 1.7 m long by 1.3 m wide. Combined PV / thermal hybrid designs have also been produced using air to scavenge heat from the back of the modules and deliver it to storage or a load.

Working in collaboration with Atlantis-Energie AG (Berne), Solution has fielded several demonstration projects with building-integrated PV arrays. Figure 17 shows a new industrial plant and office building in Arisdorf (CH) completed in 1991 for window

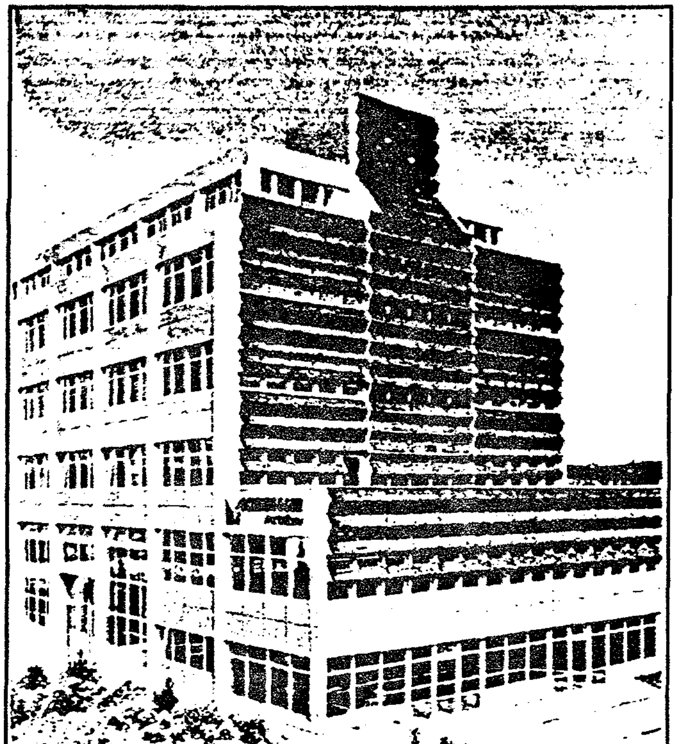


Fig. 18. Swiss PV facade at Scheidegger Metallbau

manufacturer Aerni Fenster, AG where Solution installed a 62 kWp grid-tied system. 9 kWp of modules were integrated into the office building's facade and 53 kWp of modules were integrated into the roof of the production facility on the south side of north-facing daylighting clerestories.

Another significant project realized by Solution and Atlantis is the new office and manufacturing building for Scheidegger Metallbau in Kirchberg, shown in Figure 18. Completed in 1992, the south-facing facade of the building incorporates a multifunctional PV system employing PV elements for sun shading and facade cladding with reflector augmentation in the spandrel areas, while scavenging thermal energy from the center section to temper the stairhall. The system peak output is 18 kWp.

The Swiss government is also heavily involved in the IEA Task 16, Photovoltaics in Buildings. In addition to representatives from the Government's Federal Energy Office, PV professionals from several government funded research institutes, universities and PV companies are representing Switzerland in this multi-country development effort.

The immediate future for building-integrated PV in Switzerland looks very promising. With generous government incentives to underwrite the cost of introducing a new technology, Swiss architects and engineers have responded with very innovative concepts in the design of building-integrated PV.

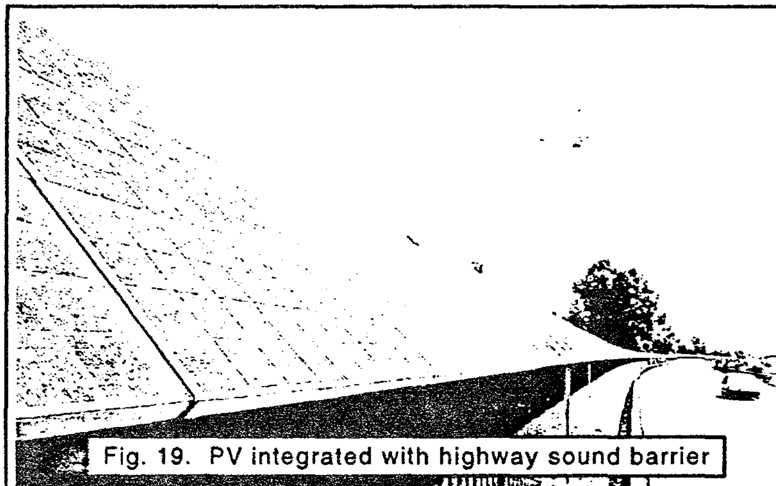


Fig. 19. PV integrated with highway sound barrier

They have also fielded some innovative systems integrated with other "built forms" such as the system shown in Figure 19 which is integrated with the sound barrier along highway N13 south of Chur. Other PV systems have been fielded along rights of way of the Swiss railroads which are, of course, electric.

A number of Swiss companies have begun to produce custom PV modules to meet special design requirements with some even producing custom triangular modules to architect's specifications. In addition, the country has instituted net metering and uniform interconnection policies on a national basis which, in itself, represents a major national commitment to PV since Switzerland has over one thousand individual electric utility companies.

The Netherlands

Interest in PV and distributed systems for buildings has also grown in the Netherlands just as it has across the rest of Europe. Recent R&D activities have concentrated on improvements in the development of PV building elements and improved power conditioning. Government funds have been appropriated for a pilot program of grid-connected, distributed PV systems with building-integrated PV arrays. In the next 4 years, some 1,000 homes will be built with roof-integrated PV systems. In this effort, the Dutch will study the influences of PV on architecture, town planning, home financing and ownership.

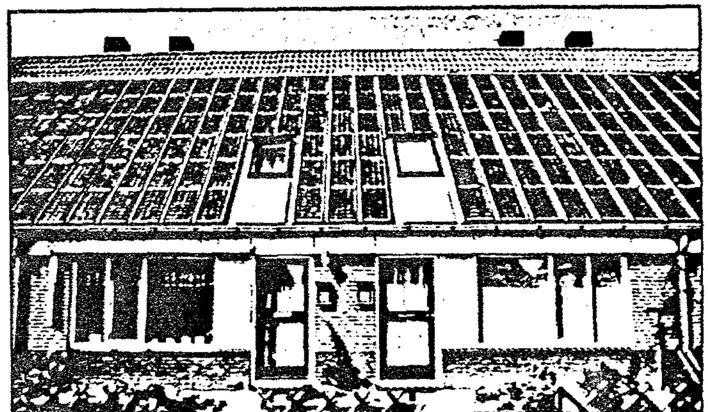


Fig. 20. PV-powered Dutch multi-family housing

Figure 20 shows a 10-unit multi-family housing development in Heerhugowaard, a town 50 km north of Amsterdam, where a roof-integrated 25 kWp utility-interactive PV system was installed as a demonstration of building-integrated PV applications.

Financed largely by the Dutch regional utility PEN with additional support from the Netherlands Office of Energy and Environment, (NOVEM), the PV system uses standard polycrystalline PV modules from R&S (Netherlands), integrally mounted with off-the-shelf aluminum profiles adapted from a greenhouse glazing system. Each individual unit has its own 3 kW power inverter.

The Dutch PV program has provided funding for the development of building integration techniques for both residential and commercial buildings. In addition to the multi-family housing demonstrations, a number of detached, single-family homes have received roof-integrated PV systems such as the home shown in Figure 21 in Lekkerkerk which features an integral 3kWp array of glass-superstrate crystalline silicon PV roof tiles from Switzerland.

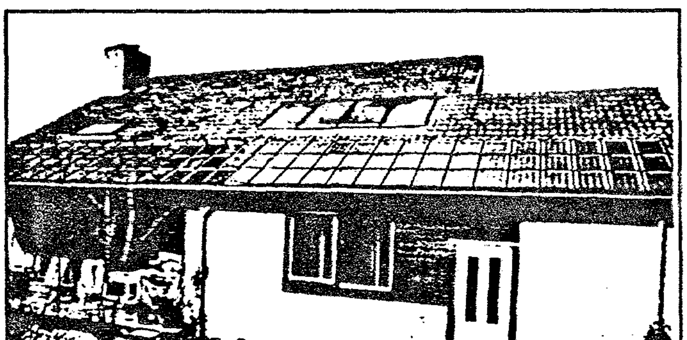


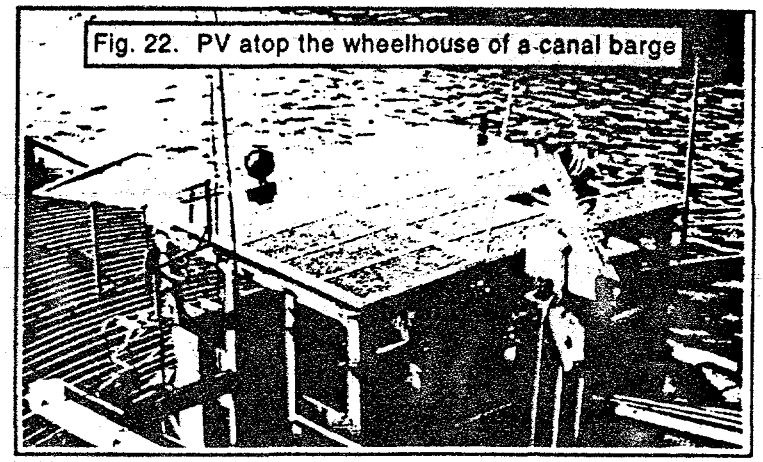
Fig. 21. Residence in Holland with PV roof tiles

A PV-powered, energy autonomous demonstration house was constructed in Woubrugge, a small village between Amsterdam and Rotterdam. The PV array incorporates standard (unframed) polycrystalline modules in a roof-integrated mount using aluminum profiles similar to those employed in the Heerhugowaard project. Space and domestic water heating are provided by solar thermal collectors. As would be expected, the house is heavily insulated and employs high-efficiency glazings and appliances.

The Dutch have also explored other methods of integrating PV into their lives, including the use of PV on-board the hundreds of house boats that line the canals in and around Amsterdam as well as on cargo barges so important for the shipment of goods. Figure 22 shows a "roof-top" PV system atop the wheelhouse of a Dutch canal barge. The PV system provides power for lights and communications equipment allowing the Captain to shut down the ship's diesel when the vessel is not underway.

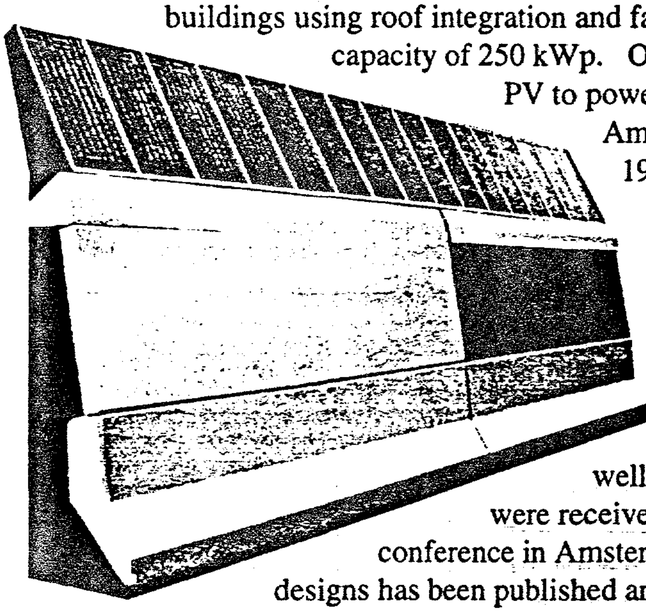
Similar PV systems on the roofs of Dutch houseboats allow boat owners to live independent of the utility mains without operating an on-board generator. Nearly all PV systems on watercraft are installed flat because of variable orientation. The first of these systems were fielded by ECOFYS (Utrecht) as demonstrations. Now that they have been shown to be reliable and cost-effective, boat owners are installing these systems themselves. As might be expected, the Dutch government has long ago instituted a program to power the thousands of aids to water navigation with PV.

Fig. 22. PV atop the wheelhouse of a canal barge



In the interest to further integrated PV solutions that utilize existing aperture area and available structural elements, the Dutch have also developed PV for highway soundbarriers. Figure 23 (below left) shows a prototype section of a pre-cast concrete soundbarrier element with integrated PV. The Dutch government will complete the first 80 kWp demonstration in 1994. Also being considered are the rights-of-ways along the Dutch railroads, where a recent assessment has shown that PV placed in the available area would provide enough capacity to completely power the rail system.

The Dutch government has announced plans for a large-scale PV-in-buildings project on 100 units of new housing to be constructed in Nieuw Sloten, a new city district of Amsterdam. The project is being funded by the Energy Company of Amsterdam (the electric utility), as part of its Environmental Action Plan, in cooperation with NOVEM and EU-Thermie. Plans call for PV to be installed on some 70 buildings using roof integration and facade integration techniques, resulting in a total capacity of 250 kWp. Other future plans call for up to 600 kWp of roof-top PV to power a new, large-scale housing development in Amersfoort with construction scheduled to start in 1995.



The Netherlands is actively involved in the IEA Task 16 program with participation by NOVEM and ECOFYS. The Dutch coordinated the first world-wide design competition on PV-in-buildings sponsored by IEA Task 16 and Novem. The competition was open to A&E professionals as well as students. 100 entries from all around the world were received and awards were presented at the 12th EC PV conference in Amsterdam in April, 1994. A book of the most creative designs has been published and is available from NOVEM.

The prospects for advancement of building-integrated PV in the Netherlands look very promising. Budgets and research activity are increasing and significant demonstrations are planned over the next few years. The Dutch see PV as a significant part of their 20-year National Environmental Policy Plan and, if the Dutch program goal of fielding 250 MWp of PV by the year 2010 is to be achieved, there will surely be thousands of PV-powered buildings.

Austria

Interest in distributed PV applications has increased in recent years in Austria along with the rest of Europe. The Austrian government has announced a comprehensive plan to reduce CO_2 emissions and PV is seen as an important part of this effort. Over the past ten years, Austria has fielded a number of stand-alone and grid-connected PV systems totaling some 800 kWp including a 30kWp utility-interactive system at Mount Loser, high in the Alps and a 40 kWp U.I. system along the A1 motorway.

In May 1992, the Austrian government announced a distributed roof-top PV demonstration program modeled after the German "1,000 roofs" effort. This program will initially include some 200 kWp of PV systems financed with support from the government and the electric utilities. In addition, several local district authorities have offered additional funding of up to 50% of the systems cost.

A good example of the Austrian roof-top PV program can be seen in the energy-efficient, private, single-family residence constructed in 1992 in Gleisdorf, a small town in southern Austria. The house was designed as a 'low-energy' house and, as such, incorporates solar thermal collectors for domestic water heating, extra-heavy insulation, high-quality glazings, passive solar gain and state-of-the-art high-efficiency appliances. The home's detached garage, shown in Figure 24, incorporates a 2 kWp roof-integrated PV array employing frameless Siemens laminates. The array has provisions for free air flow behind the modules to provide back-surface cooling.

In 1993 another 'low-energy' house was completed near Vienna. With support from the local electric utility, Wiener Stadtwerke Wienstrom, and the Austrian Roof-top PV Program, a 3 kWp PV system was installed with approximately one half the capacity mounted on the roof and the remainder integrated into the south facing facade. The house also incorporates solar thermal collectors for domestic water heating. The utility is monitoring the output of the energy systems to determine the amount of possible reduction in CO_2 from large-scale use of PV and solar thermal systems.

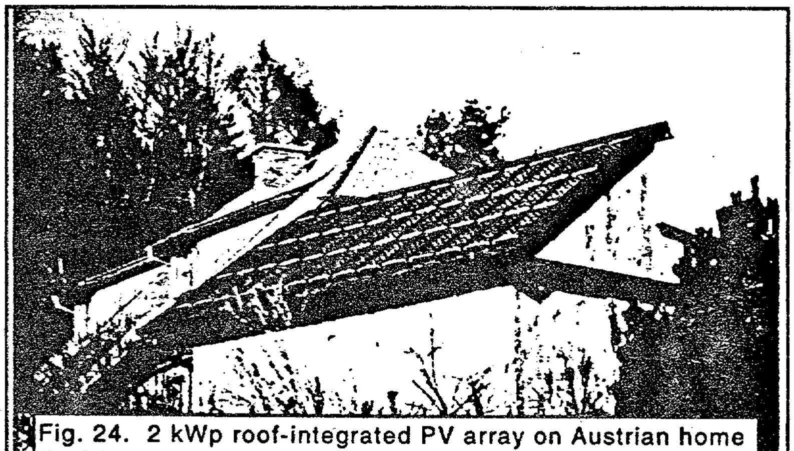


Fig. 24. 2 kWp roof-integrated PV array on Austrian home

Within the first five months of the Austrian roof-top PV program, over 160 kWp of systems were committed with significant cost-sharing from the homeowners. Many of these systems are building integrated. Nearly all of the systems under the first 200 kWp roof-top program are presently complete and in operation, and discussions are now underway to expand the program by another 100 kWp.

As in most of Europe, tile is the traditional material for sloped roofing in Austria. In an effort to make residential PV arrays compatible with the majority of existing roofs, a flat-glass roof tile using single-crystal technology has been prototyped in Villach, Austria by a private group headed by a Dr. Kroner. The tiles are a glass-on-glass laminate with silicon gel used as the encapsulant. Each tile measures approximately 12" wide by 9" high in active area and incorporates twelve 3 inch square cells to deliver about 12 Wp. A prototype residential roof system, shown as Figure 25, was successfully fielded in Gleisdorf and the group is now looking for development capital.

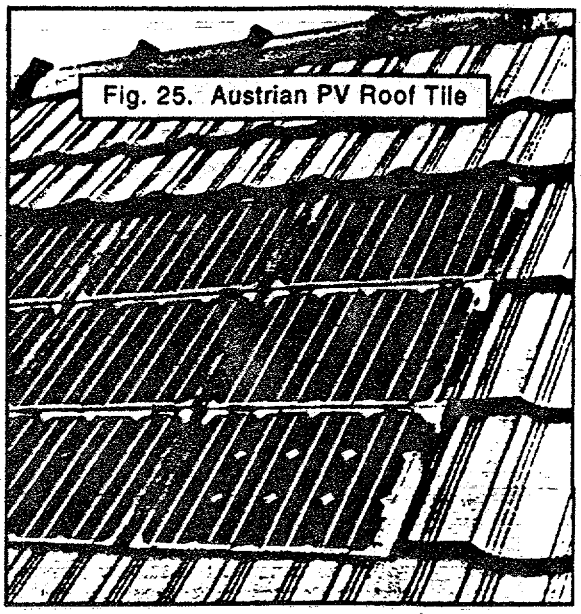


Fig. 25. Austrian PV Roof Tile

With much of Austria alpine, efforts have been made to utilize other available sites for PV in addition to buildings. In 1992, the Austrian electric utility Oberösterreichische Kraftwerke AG, (OKA) completed a 40 kWp PV system atop the existing soundbarriers along the southern motorway A1 near Salzburg.

The system, shown in Figure 26, incorporates standard Siemens modules preassembled into subarrays and lifted into place with a light crane reducing field labor. An advanced IGBT pulse-width-modulated inverter feeds system output directly into the OKA distribution feeder.

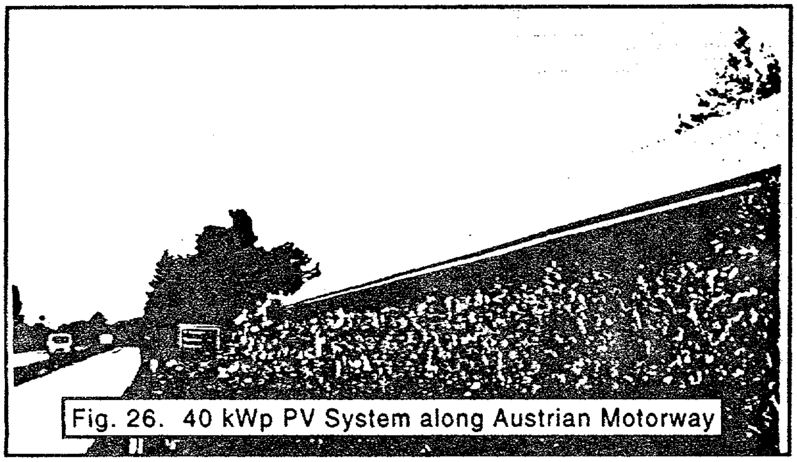


Fig. 26. 40 kWp PV System along Austrian Motorway

OKA fielded the first utility-interactive PV system in Austria in 1988 and has since taken a lead role in the promotion of PV in Austria for both stand-alone and grid-tied applications. The utility is studying the potential benefits provided by the PV system they installed along the motorway for line support as it is located near the end of their distribution line.

Austria has also initiated work in PV facade integration in commercial buildings with the recent construction of the 13 kWp system on an office building in Innsbruck shown in Figure 27. The building was an existing structure which was scheduled for extensive renovation. During the reconstruction process, the idea was proposed to incorporate a PV array on the south facade as a sun screen to limit unwanted sun-driven summer cooling loads from direct solar gain through the glazing.

The grid-connected system employs large-area single-crystal PV modules manufactured by DASA in Germany (now ASE). The system's output is estimated at 10,370 kWh per year and will be monitored as part of the programme of the Austrian Utilities Association (TIWAG).

Austria supports IEA Task 16 effort with representation from the Technical University at Wien and OKA participating.

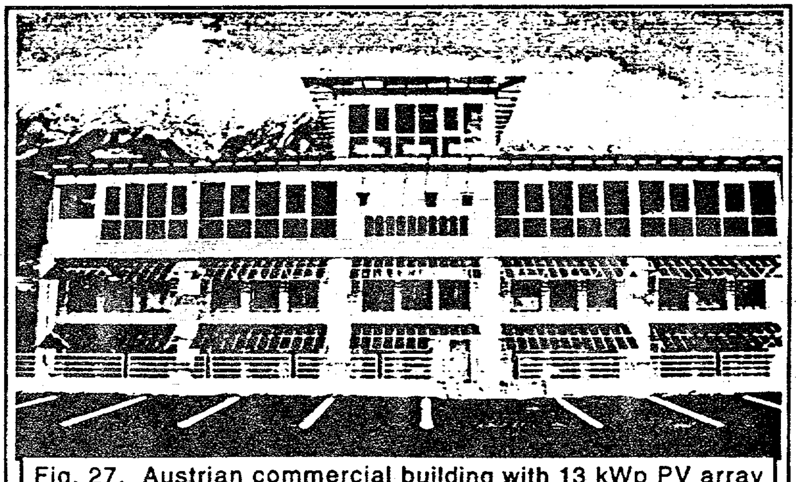


Fig. 27. Austrian commercial building with 13 kWp PV array

United States

Photovoltaics was born in the US with the invention of the silicon solar cell at Bell Labs in the early 1950's. With the first world oil shock in 1973, interest blossomed in terrestrial applications of PV and, a conference was held at Cherry Hill, NJ where experts in all aspects of PV convened to plan the best strategy for the development of the PV industry. As a result of the Cherry Hill meeting, the United States embarked on a comprehensive, multi-level program of research, development and demonstration of PV for large-scale terrestrial power use.

Many major corporations including US industrial giants such as Atlantic Richfield, Exxon, Texaco, Shell, General Electric, Westinghouse, Boeing, and Martin Marietta, jumped in, investing hundreds of millions of dollars in PV research and development and the race was on! With its considerable resources, focused program and federal government leadership, the US quickly became the acknowledged world leader in the development of PV. After just five years, costs had been reduced dramatically and efficiencies had improved significantly.

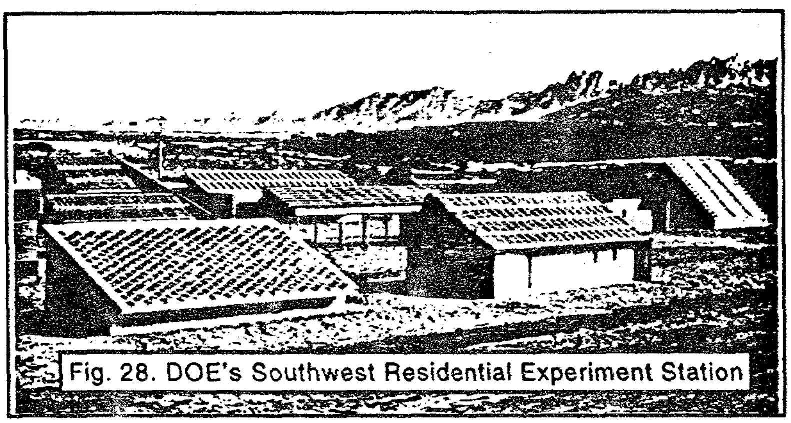


Fig. 28. DOE's Southwest Residential Experiment Station

In the late 1970s, a well-planned program of development of distributed PV was established by the US Department of Energy (DOE) at MIT which included the design and demonstration of many different approaches to building integration. A number of hardware and building designs were commissioned and three demonstration sites were established across the country where prototype building-integrated PV systems were fielded for evaluation under different climate conditions. The DOE's Southwest Residential Experiment Station (SWRES) constructed at New Mexico State University in Las Cruces, NM to test PV systems in the hot, dry, desert climate is shown in Figure 28.

Working under contract to the US DOE, Solar Design Associates developed the first building-integrated PV system employing large-area .9m x 1.8m PV modules and, in 1979, constructed prototype residential roofs for testing and evaluation at the DOE-sponsored residential experiment stations. Based on the results at the residential experiment stations, the US DOE and MIT commissioned Solar Design Associates to design the energy-efficient, passive solar residence powered by photovoltaics, shown in Figure 29.

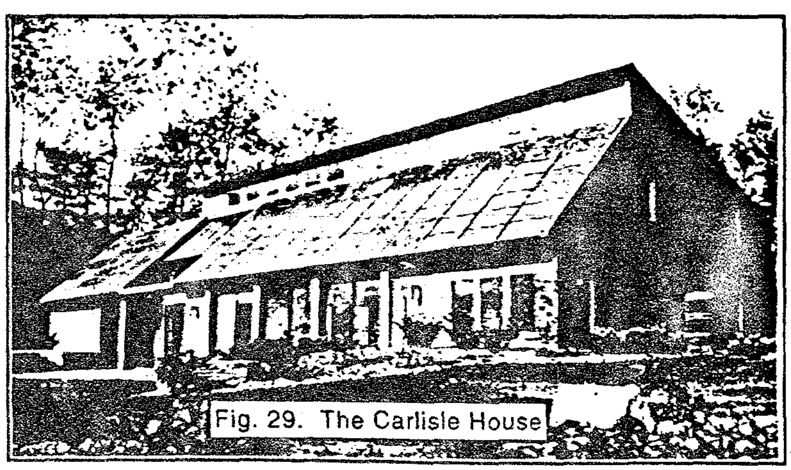


Fig. 29. The Carlisle House

The 'Carlisle House', as it became known, was constructed in 1980 in Carlisle, MA with participation from MIT and the US DOE. The residence features passive solar heating and cooling, super-insulation, internal thermal mass, earth-sheltering, daylighting, a roof-integrated solar thermal system and a 7.5 kWp PV array of polycrystalline modules from Solarex. The home is heated and cooled by a high-efficiency, dual-compressor heat pump system, needs no fossil fuel and shares its surplus power with the utility via a net metering connection. This first residence ever to be powered by a utility-interactive PV system received world-wide attention.

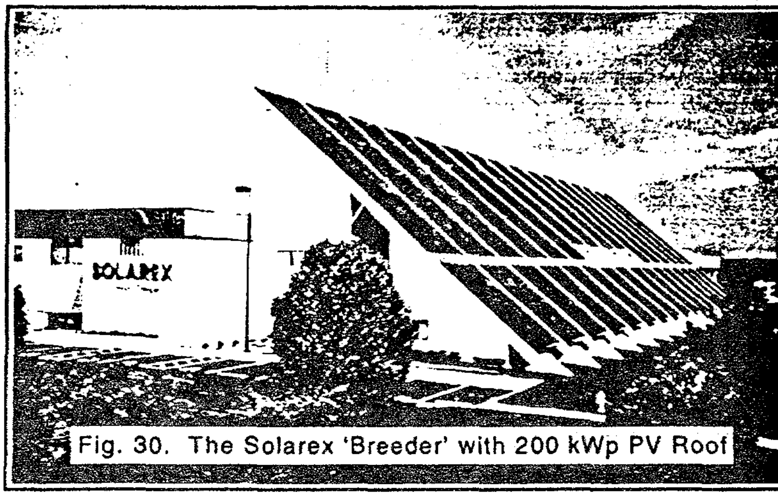


Fig. 30. The Solarex 'Breeder' with 200 kWp PV Roof

In 1982, Solarex Corporation made a most significant commitment to PV-in-Buildings by powering their new manufacturing plant with their own solar modules. The facility, located in Frederick, MD, was designed specifically to receive a 200 kWp array as the entire south roof. A large bank of storage batteries provides a UPS capability for critical plant systems. The 'Solarex Breeder', as the plant became known, was the vision of Solarex founder Joseph Lindemeyer and is shown in Figure 30.

In 1983, the Boston Edison Company commissioned Solar Design Associates to design the Impact 2000 residence as a demonstration of future trends in energy technology and design that would be commonplace early in the next century. The house, shown in Figure 31, features passive solar heating and cooling, super-insulation, internal thermal mass, earth-sheltering, daylighting, a roof-integrated solar thermal system and a 4.5 kWp PV array of large-area modules, each $2.5m^2$, integrated as the finished weathering skin of the roof. Heating and cooling are supplied by a high-efficiency, ground-coupled heat pump system and no fossil fuel is required on site. Like the Carlisle house before it, this house shares its surplus electricity with the Boston Edison grid via a net metering connection. The building of the house was the subject of a national TV series on energy-efficient construction.

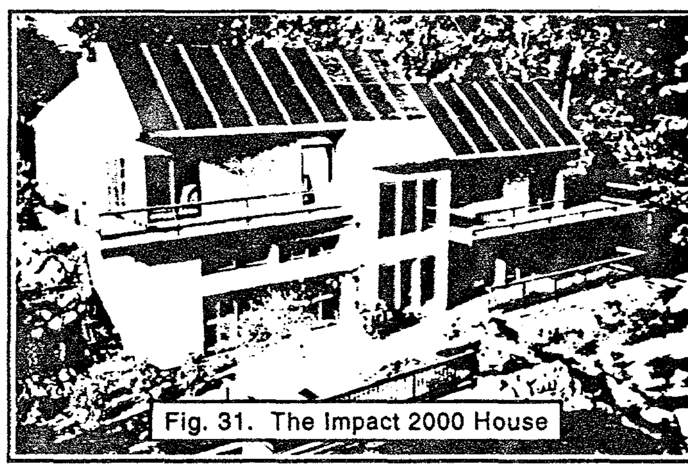


Fig. 31. The Impact 2000 House

In 1984, a significant commercial-scale building-integrated PV system was completed at Georgetown University in Washington D.C. The project, sponsored by the US DOE, integrated a 300 kWp PV array of Solarex polycrystalline modules into the stepped south roof of the new Intercultural Center. The project architect worked closely with the PV system engineers to design the building specifically to receive the PV array. The electricity generated serves the building's loads and the surplus is used to support the campus utility grid. The Georgetown Intercultural Center is shown in Figure 32.

In 1985, Solar Design Associates fielded 100 kWp of distributed, roof-top PV systems in a demonstration sponsored by the New England Electric System which includes the world's first PV-powered neighborhood, in the central Massachusetts town of Gardner. Following the NEES pioneering example, far-sighted utilities, such as the Sacramento Municipal Utility District (SMUD) in California, are now beginning to install distributed PV systems on buildings to support their grid, helping to meet their peak demand while reducing dependence on traditional sources of power and improving the environment.

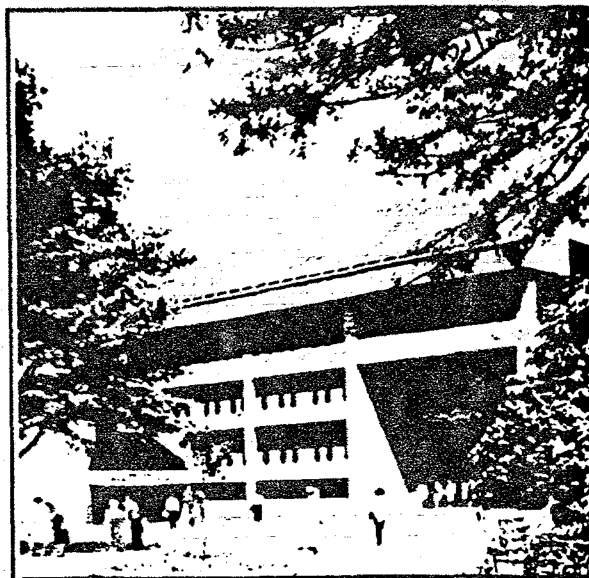


Fig. 32. Georgetown University 300 kWp Roof

According to SMUD board Chairman Edward Smeloff, their multi-year program will field some 850 kWp of distributed PV systems in 1993 with 1 MWp in 1994 and another 1 MWp in 1995. Southern California Edison has also recently announced plans for a distributed, roof-top PV program and other utilities such as Niagara Mohawk (NY), Delmarva Power and Light (DE), the New York Power Authority and the City of Austin (TX) Electric are also fielding PV-powered buildings.

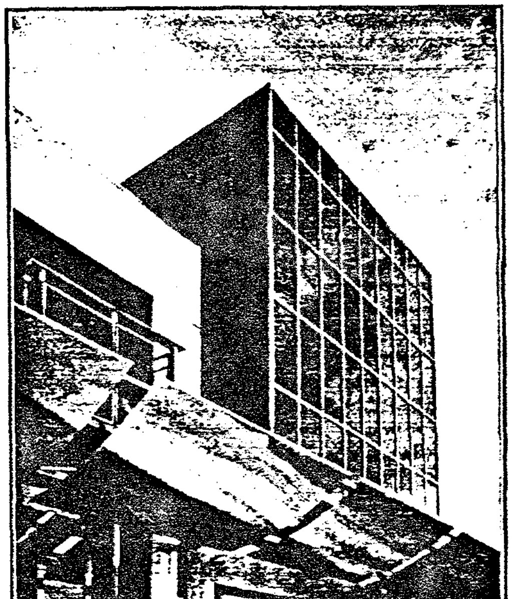


Fig. 33. APS PV cube and entry canopy

In 1992, Advanced Photovoltaics Systems (APS) completed its new manufacturing plans in Fairfield, CA. APS produces a-Si glass modules measuring .75m by 1.5m in size and asked New York architect Gregory Kiss to integrate these modules into their new building. His design incorporates a cubic control room for the production facility clad with APS modules. The cube, shown in Figure 33, also has a skylight fitted with both clear glass and PV modules. The building's front entry canopy also incorporates PV modules above the curved metal elements.

In June of 1993, the US DOE and the National Renewable Energy Laboratory (NREL) awarded 5 contracts for a 5-year, $25M program called: "Building Opportunities in the U.S. for Photovoltaics" ("PV:BONUS") to encourage development of building-integrated PV systems. Specific products include a PV element for architectural curtain walls by Solarex and large-area integral roofing modules from Energy Conversion Devices.

The US PV program was invited to join the IEA Task 16 development effort in PV systems for buildings and, in January 1994, the US DOE's Office of Building Technology accepted this invitation. The potential market for building-integrated PV systems in the US is enormous and many companies are beginning to work at the development and commercialization of building-integrated PV components and systems. If consistent government support can be assured, this potential will be realized.

Fig. 34. The US National Renewable Energy Laboratory's new SERF building features a 15 kWp PV system

United Kingdom

Until recently, the UK PV industry has concentrated on traditional export markets for remote PV power systems. In 1990, a review for the UK Department of Energy (now part of the Department of Trade and Industry or DTI) indicated that the status of PV had moved from a 'long-shot' to a 'medium term' solution as an energy resource for the UK. This conclusion was based on the decreasing costs of PV devices and perceived advantages of applying this technology to commercial buildings.

The report concluded that daytime loads of commercial buildings are a good match for PV power systems and commercial building facades are often clad with expensive materials - such as marble or stone - which can be replaced by the PV panels in an integrated structure. These factors together with avoided costs of land and array support structure could make building-integrated PV systems cost effective in the UK within 10 years for optimum designs.

An initial two years of studies have looked at the potential resource; feasibility of building integration; grid interconnection guidelines and practical roof integration. A recent white paper (R62) has formalized PV as a technology requiring R & D support within the Government Renewable Energy Research, Development, Demonstration and Dissemination Programme. This strategy for PV started in 1994 and builds on the previous studies to assist industry to develop a capability in building-integrated PV systems and then field demonstration systems. This segment of the PV programme will look at technical and non-technical barriers to market development in the following areas:

- Resource studies
- Cladding and roof integration methodologies
- Technical issues for grid interconnection
- Examples of building integrated PV system types

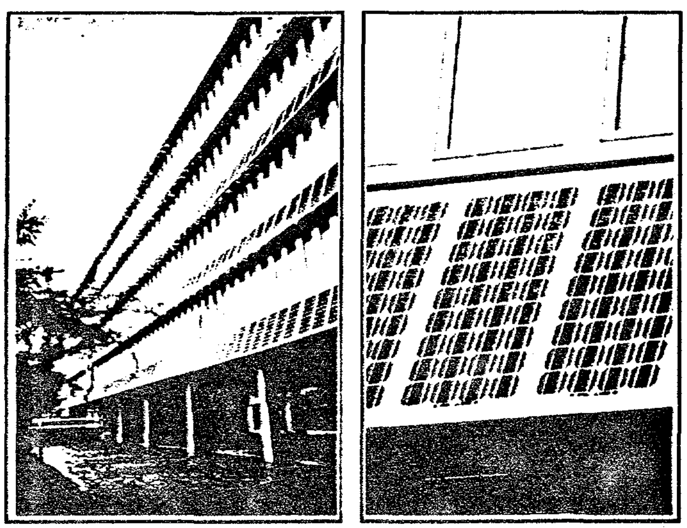


Fig. 35. PV 'Recladding' of UK Building Facade

Many of these topics were examined during the realization of the UK's first commercial PV curtain wall facade at the University of Northumbria at Newcastle. This project, shown in Figure 35, is a refurbishment of an existing university building and incorporates 40 kWp of high-efficiency BP Solar PV laminates into a new rainscreen overcladding spandrel system which also provides integrated sun shading on the south face of the building. The project was realized under the direction of Professor Robert Hill and received support from the local regional electricity company (REC) and other members of the electricity supply industry in addition to DTI and EU THERMIE demonstration programmes.

Although residences are not expected to be the first cost-effective application for building-integrated PV systems in the UK, there is a growing interest from domestic consumers and there are some projects completed or under construction which use PV in grid-connected application. Another demonstration project will incorporate a 10 kWp array into the roof of a visitor center at the Center for Alternative

Technology in Wales. Significant attention is being paid to the combination of PV with passive design principles to optimize daylighting, heating and PV power use.

The UK PV community is discussing options for market stimulation with the UK Government. One strategy would be to include PV in the legal requirement for RECs to buy Renewable Energy at a premium rate (the Non-Fossil Fuels Obligation - NFFO). The 1989 UK Electricity Act created a special "non-fossil fuel obligation" (NFFO) requiring the 12 English and Wales regional electric utilities to produce or purchase a specified portion of their capacity from renewable sources. This has created the vitally-important "market pull" needed to introduce renewables to the utility community. The initial goal of 102 MWp was easily reached and the government has set a target of 1,000 MWp by the year 2000. This initiative has helped to increase interest and activity in photovoltaics in the UK.

On the technology side, BP Solar International LTD. now has working prototype modules using cadmium telluride technology with efficiencies approaching the 10% range. BP also has single crystal modules in the 17% range using high-efficiency, laser-grooved cell processes developed by Martin Green at the University of New South Wales in Australia. BP has established a manufacturing plant in Spain (BP Solar Espana) and plans to look at large area module fabrication of the CZ modules and the use of its CdTe thin film materials in modules developed specifically for building facades. Initially, modules of .5 m by 1.0 m are planned with CdTe technology and CdTe module selling prices in the area of US$1.00 - 2.00 /Wp are forecast by the end of the decade.

The British government has funded a comprehensive evaluation of the potential of building-integrated PV systems in the UK. The study, conducted by Professor Robert Hill and his colleagues at the Newcastle PV Applications Centre, was initially only to include the south-facing facades but was expanded to include all building surfaces regardless of orientation and concluded there were 111 Gigawatts of potential generating capacity available from distributed PV systems on buildings. Another related study now underway is investigating the various types of curtain wall systems for commercial buildings. It is expected that a follow-on study will pursue the development of specific PV products designed for building integration.

The British government is also funding participation in the IEA Task 16, Photovoltaics in Buildings. In additional to UKDOE personnel, PV professionals from BP Solar and IT Power are representing the UK in this multi-country development effort.

Finland

Activity in Finland relative to distributed PV applications has also increased in recent years along with the rest of Europe. Finland has recently embarked on a three-year plan which includes the development of improved load management systems, demonstration of PV / hydrogen systems with hydrogen storage and the fielding of distributed, grid-connected PV demonstration systems on buildings.

There are over 400,000 vacation cottages in Finland and about half of them are located off the grid where PV systems are an ideal source of power. Today there are some 20,000 summer houses around Finland powered by small PV systems. A typical system is designed to meet lighting, home electronics, water pumping and refrigeration needs from April to September.

Figure 36 shows a Finnish summer cottage with a 2.4 kWp roof-top array of a-Si modules from NAPS France. This system was installed in 1992 and includes a battery bank and stand-alone 2.5 kW DC/AC inverter to power lighting, refrigeration, home electronics and small appliances, vacuum cleaner, washing machine and dishwasher. The house is located some 260 km north of Helsinki at 62°N and 26°E.

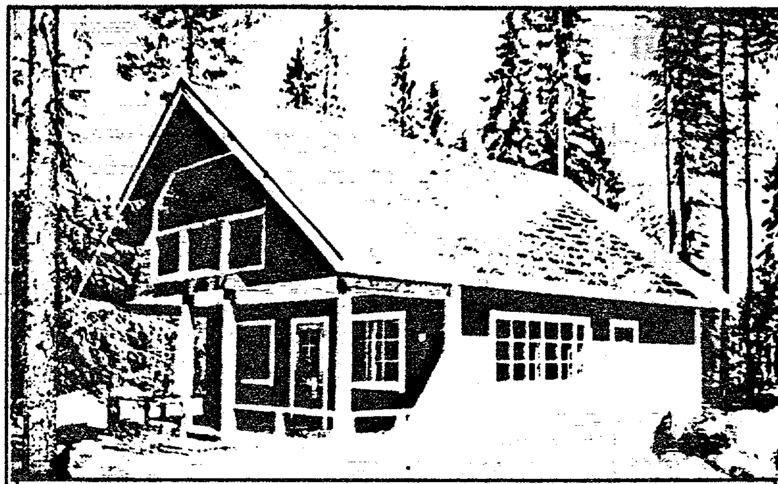


Fig. 36. Finnish summer cottage with 2.4 kW PV array

Since 1991, the Fins have retrofitted 10 residences with PV power systems. Five are stand-alone and five are grid-connected. R&D programs underway are presently investigating the development of building-integrated PV systems and engineers from NESTE have fielded two demonstration projects.

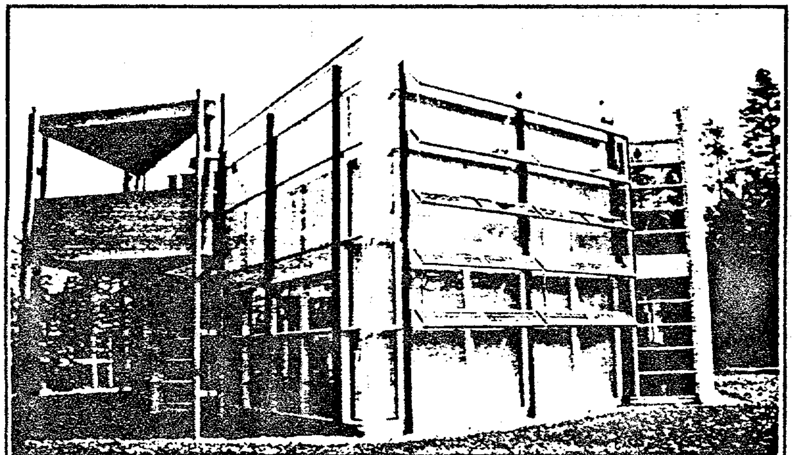


Fig. 37. Southwest facade of NESTEhaus with PV sunshades

The first, shown in Figure 37, is a demonstration house designed and constructed by NESTE as an experimental house incorporating many building components and materials made of plastic. The house features see-through a-Si modules as window glass and crystal-Si sun shades on the south facade to reduce summer cooling loads. The house is located 35 km east of Helsinki in Porvoo, 60°N and 25°E.

The second, shown in Figure 38, is a private house located in Pietarsaari, Finland 63.5°N and known as the Pietarsaari low energy house. This residence features a roof-integrated 2.4 kWp PV array of a-Si modules along with a 10m² array of solar thermal collectors. The PV array is mounted using novel custom designed profiles of glass fibre which have nearly the same expansion coefficient as glass. The house is a demonstration of energy-efficiency and solar design and serves as the Finnish IEA demonstration house. It was completed in 1994.

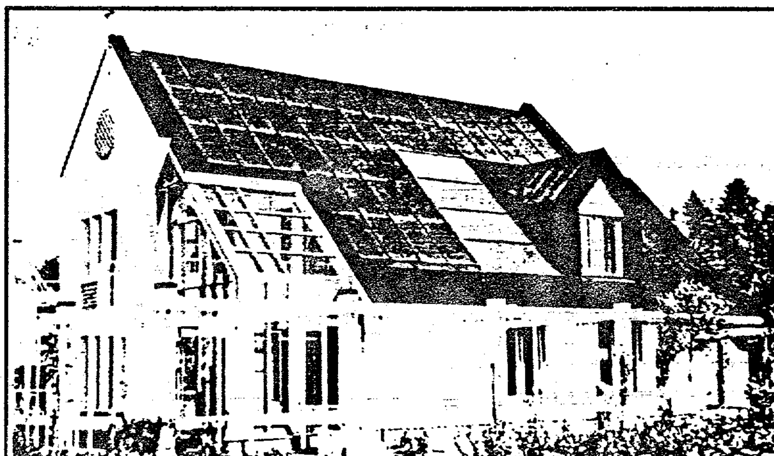


Fig. 38. Finnish PV-powered low-energy demonstration house.

Finland has also joined the IEA Task 16 effort with representatives from Helsinki University and the engineering firm NESTE OY participating.

Spain

Spain's interest in distributed PV applications has also increased in recent years along with the rest of Europe. The potential market for remote PV applications in isolated areas of Spain is considered the most significant in the European Community.

Spain has already fielded hundreds of stand-alone and grid-connected PV systems totalling well over 5 Megawatts in capacity including a 1 Megawatt central plant under construction at Toledo.

Spain has a number of PV R&D and manufacturing activities underway including the production facility of BP Solar and ISOFOTON. Spain's recent activity has focused on systems design, utility interface, demonstration monitoring and testing. The area of building integration of PV is beginning to receive research and development attention.

Fig. 39. PV-powered 4-unit housing cluster in Spain

Spain has joined the IEA Task 16 PV-in-Buildings development effort and was the host of the second meeting of the Experts' working group held in Madrid at CIEMAT in February 1992.

Figure 39 shows the Spanish Task 16 demonstration house which is a four-plex incorporating 4 roof-integrated PV arrays of 2.2 kWp each. The systems are utility interactive. There are thousands of PV-powered off-grid residences in remote areas of Spain and utility-interactive PV systems are now starting to be installed on residences with the cooperation and support of Spanish utilities. Additional building-integrated PV projects are now in the planning stages.

Sweden

In Sweden, as well as in Norway and Finland, PV is often employed to power remote vacation cottages. There are now over 20,000 such PV powered cottages in Sweden and the market is increasing rapidly with over 5,000 new installations every year. In addition, several hundred lighthouses along remote stretches of the Swedish coast are now powered with PV.

Sweden's activity in distributed PV has increased along with that of other European countries. Present program activities include both stand-alone and grid-connected distributed PV systems. Development and testing of DC-AC inverters and battery charge control regulators is being undertaken. PV research and development activities in Sweden are concentrated at the Royal Institute of Technology and the University of Uppsala for cell research and, Catella Generics AB and Vattenfall Utveckling AB (the largest utility in Sweden) for systems.

In 1990, a 3.5 kWp grid-connected demonstration was completed on a single residence in Linköping

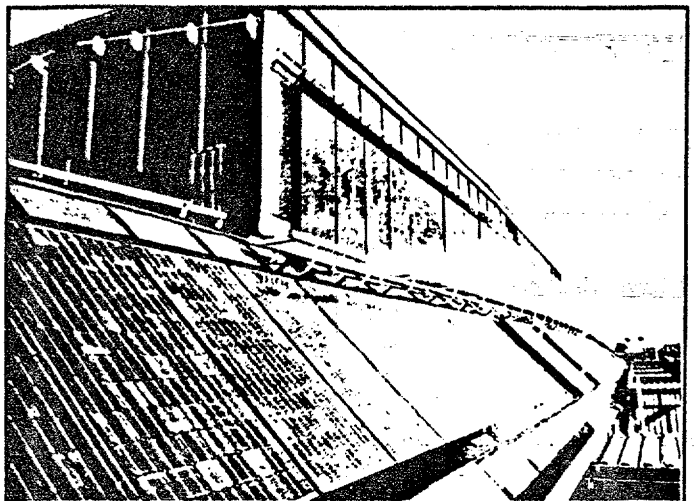


Fig. 40. 10 kWp PV system in Stockholm

approximately 200 km south of Stockholm.

A Swedish company called GPV has recently started manufacturing PV modules. The modules are of standard construction with a glass top skin and tedlar back and come in sizes up to 100Wp. The company has expressed an interest in participating in the development of PV modules for direct building integration.

In 1993, the Swedish utility, Stockholm Energi AB, installed a 10 kWp utility-interactive PV system on an existing apartment building in downtown Stockholm. The system, shown in Figure 40, serves as the IEA Task 16 demonstration building and features three parallel arrays of 3.3kWp each with its own inverter. Sweden has also joined the IEA Task 16 effort with representatives from the Swedish National Testing Institute and Catella Generics representing the county's effort.

Italy

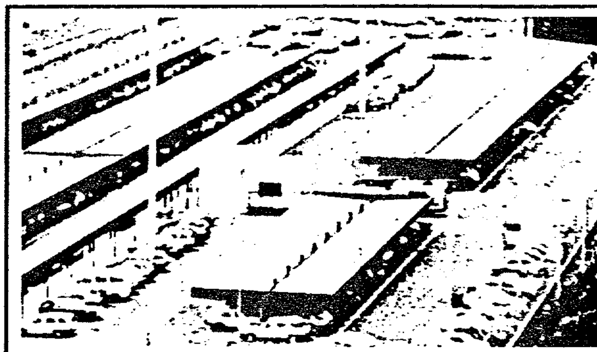


Fig. 41. PV Parking Structure near Rome

Italy's federal funding has increased significantly for PV in recent years and interest in building-integrated PV applications is growing in Italy along with the rest of Europe. As a result of growing environmental concerns and the dependence of Italy on foreign oil, the government has launched a program to field some 25 Megawatts of PV by 1996. Italy's National Agency for New Technology Energy and the Environment (ENEA) will be responsible for research and development and the National Electrical Board, ENEL will be responsible for implementation of the demonstration program and construction of the plants.

The Italian PV program includes plans for a number of building-integrated PV demonstrations. One of the first is a PV parking structure in Rome shown in Figure 41. Others include an innovative 30 kW integrated PV roof for the Eurosolare factory of Nettuno near Rome shown in Figure 42 which combines PV with daylighting, a 20 kW terrace at the German School of Rome and a 4 kW shading structure at ENEL headquarters in Rome. A second series of 10 systems is planned for 1995 with cost-sharing from the Thermie Project. These will include ENEL offices, training and information centers and parking structures.

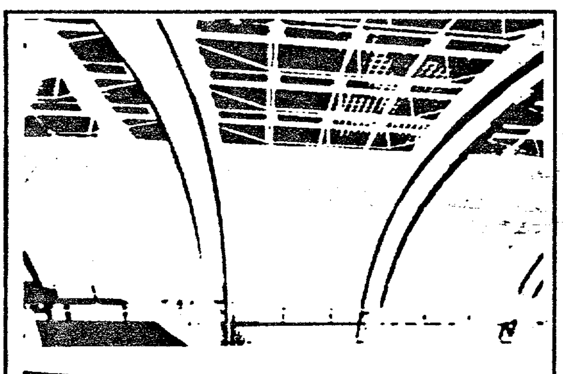


Fig. 42. Integrated PV factory roof

Mr. Robert Vigotti of ENEL is a very strong proponent of

PV and its use in buildings and has considerable influence on the development of the government's policy to promote the technology. Italy has recently joined IEA Task 16 and appointed an architect from Rome to represent the country. Italy has also sent a representative from ENEL to participate in IEA Task 16 meetings as well as in the new IEA PV Task 5.

Canada

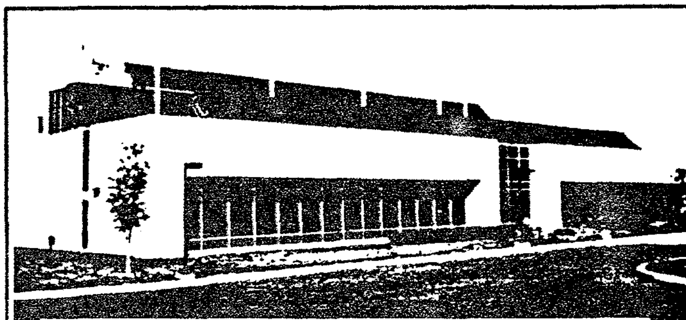


Fig. 43. 30 kWp roof-top PV system at CANMET

Interest in PV has increased in Canada in recent years even though conventional energy resources are plentiful and inexpensive. Present activities within the Canadian R&D program center on improved system design and performance modeling. Projects underway include further software development for system optimization and simulation including modeling of battery storage characteristics. Over a dozen PV systems are being monitored, and codes and standards for PV systems are being developed.

Fig. 44 Stand-alone PV house in Saskatchewan

PV powered buildings are also beginning to be fielded such as the stand-alone residence in Saskatchewan shown in Figure 44. The Canadian Department of Energy, Mines and Resources (CANMET) has installed a 30 kWp array atop their research laboratory near Montreal. The system, shown in Figure 43, works as a building peak shaver while providing PV power to support research efforts in power conditioning development and system simulation modeling.

In Toronto, the Canadian utility Ontario Hydro, in collaboration with the Canadian Energy Diversification Research Laboratory (EDRL), has fielded a 75 kWp roof-top PV system at the McMillian Rehabilitation Center as a demand-side management measure to help shave the hospital's summer air conditioning peak.

Canada has also joined the IEA Task 16 effort. Representatives from the University of Ottawa, PV systems companies and the government (EDRL-CANMET) are representing Canada in Task 16.

Ontario Hydro was influential in the installation of PV on the "Innova House", a low-energy demonstration home in Ottawa which is shown in Figure 45. This system, which features a 2.7 kWp array, is the first grid-connected PV residence in Canada and has been selected as an IEA Task 16 demonstration house.

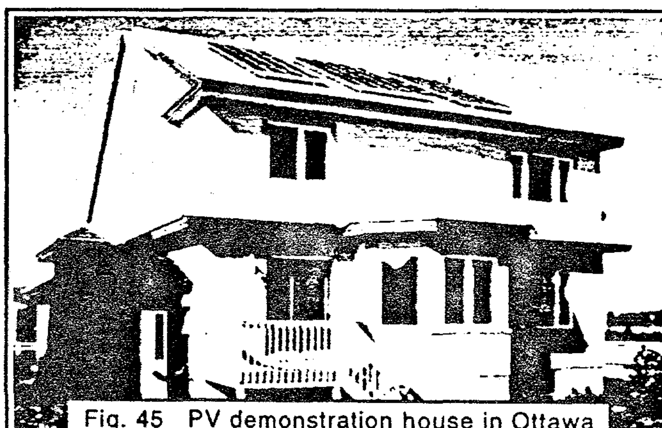


Fig. 45 PV demonstration house in Ottawa

Norway

Norway has long had a strong market for small distributed residential PV systems with the large number of vacation cottages located off the power grid. There are presently over 50,000 PV-powered vacation homes in Norway with over 8,000 new installations completed every year.

A substantial part of the energy R&D activities in Norway has been allocated to medium-scale hybrid power generation plants for isolated communities along the coast. Wind/diesel systems of 50 kW installed power have been developed and are being commercialized. The integration of PV in such stand-alone systems is being investigated and development of supervisory control systems for short-term scheduling of diesel start/stops has received much of the R & D attention in the last 5 years.

A demonstration low energy row-house with 3 apartments has been constructed in Hamar to provide housing for foreign journalists at the 1994 Winter Olympics. The project, shown in Figure 46, established a new level of integrated design incorporating passive solar, super insulation, air-tight construction with controlled ventilation, active solar water heating, high-efficiency heat pumps for backup space and water heating as well as non-toxic building materials.

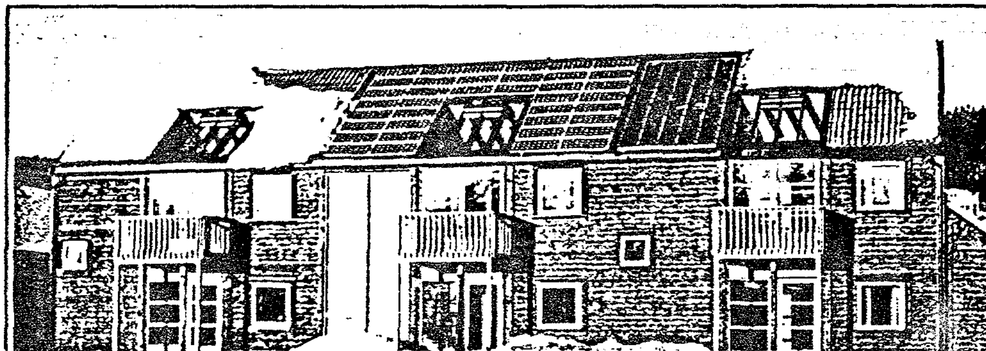
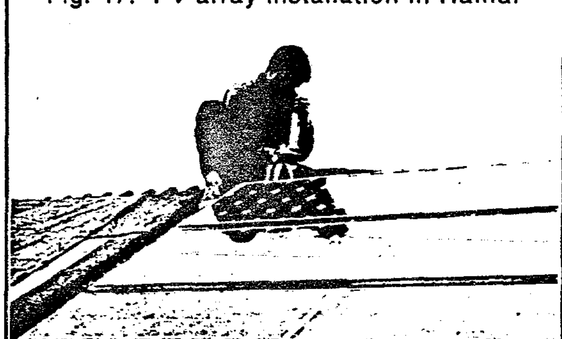


Fig. 46. Low-energy Row House with PV in Hamar

The center apartment gets its electricity from a 2.2 kWp / 27m² roof-integrated, utility-interactive PV system. The array incorporates standard Siemens modules mounted over a watertight membrane. A detail of the PV array installation is shown as Figure 47. The project supports Norway's work in IEA Tasks 13 (Low-energy Buildings) and Task 16 (PV-in-Buildings) and will serve as a model for new building codes to be introduced in 1995 incorporating very high energy efficiency standards.

Fig. 47. PV array installation in Hamar



As Norway has introduced a deregulated electricity market with spot-pricing, utilities are interested in testing electronic meters with 2-way communication for remote metering of small and medium size customers. The impact on this market regime from all kinds of local generation by new renewable energy sources, along with equipment reliability and power quality issues are subject to increasing interest by the distribution utilities in Norway.

Interest in distributed, grid-connected applications has increased along with that of other countries in Europe. As a result, Norway has increased its program involvement in this area and participates in the IEA Task 16 effort. Representatives from the Norwegian Institute of Technology and SINTEF are representing Norway in Task 16.

Factory-Built Integrated Solar Homes - A Progress Report

Lyle K. Rawlings, P.E.[1]

BACKGROUND/PROJECT DESCRIPTION

Over the past fifteen years, hundreds of people across the U.S. have built for themselves highly advanced residences which integrated passive solar architecture; photovoltaic power systems; high-efficiency lights, appliances, and HVAC (heating, ventilating, and cooling) equipment; high-level insulation and airtight construction; and other renewable energy and energy-efficient technologies. Such a home can be referred to as an *"integrated solar home"*. As the essential technologies have improved in performance, price, and availability, the performance of such homes has steadily advanced to the point where they could provide amenities at more-or-less normal U.S. standards of luxury, yet require as little as 5% to 10% of the level of fossil fuel or biomass use that are required in an average U.S. home. However, the resources required to build such a home, both in terms of the time and dedication needed for research, design, and construction of the homes, and in terms of the additional cost of the renewable energy/energy efficient features, have prevented such construction from moving beyond a tiny handful of highly motivated homeowners and into the mainstream of residential construction.

In 1991, a demonstration home was completed in Hopewell, NJ to show that a home integrating advanced passive solar design, photovoltaic power, solar hot water, highly efficient construction, and highly efficient loads could be built economically in the Northeast.[2] Based on lessons learned in the construction of that home, a project was undertaken in 1993 to develop and commercialize a series of integrated solar homes that would be factory-built based on carefully optimized designs.[3]

During the design/development phase of this program, core participants were identified, including a factory-built home manufacturer and builders.[4] It is intended that additional manufacturers and builders will be added as the market for such homes expands. The design/development process primarily involved the development of a series of home designs in traditional styles, including colonials, cape cods, and ranch homes. The various design features and technologies were integrated and optimized carefully, and

---

[1]President, Fully Independent Residential Solar Technology, Inc. (FIRST, Inc.), Hopewell, NJ

[2]Executed by FIRST, Inc. under contract to the New Jersey Division of Energy

[3]Executed by FIRST, Inc. under contract to U.S.D.O.E. Golden Field Office

[4]The manufacturer is AvisAmerica of Avis, PA; the builders are Bradley Builders of Philadelphia, PA and Enerpro Builders of Woburn, MA

compatibility with the manufactured home process was maintained. In the second half of 1994, the participants began building pilot homes for private owners. Homes were built in Pennsylvania, New York, New Jersey, Massachusetts, and Vermont. The residences have been completed at prices which compare favorably with comparable homes in their respective areas, and they have turned out to be beautiful, dramatic homes.

PILOT HOME SUMMARY

An outline and summary of the six pilot homes follows:

1. Kurt Smith Home

Location:	McElhattan, PA (approx 20 mi. west of Williamsport)
PV System Design:	Grid-tied PV system 18 x Solarex MSX120, 2,160 Wp, 3 in series (48V @ max power point) Pacific Inverter PI-3000 (grid-tie only)
Other Solar/ Renewables:	Passive solar, South window opening = approx. 15% of floor area Geothermal heat pump (horizontal)
Home Design:	28'x46' two-story, 4 BR colonial, 12/12 pitch roof Third story (attic) to be finished in the future, including two dormers on south side (restricts roof space for PV system, necessitates "tall, thin" array) Basement moisture-proof & insulated, to be finished in the future. 2,530 sq.ft. on two stories 3,350 sq.ft w. third story finished 4,300 sq.ft. w. basement finished
About the owner:	Kurt Smith is Business Development Manager with AvisAmerica. He is also Avis's point person on the development of the PV-integrated homes.

2. Richard Gidlewski Home

Location:	Ottsville, PA (approx. 30 mi. north of Philadelphia)
PV System Design:	Grid-tied/stand-alone PV system 16 x Solarex MSX120, 1,920 Wp, 4 in series (48V nominal) TRACE Engineering 4048 SW (4 KW grid-tie/stand-alone inverter) Ananda Powercenter 3-200 integrated controller/power center 8 x GNB Evolyte EVB-1180 12-volt, sealed batteries
Other Solar/	Sun-tempered, South window opening = approx. 9% of floor area.

Renewables	Radiant floor heating Solar hot water heating system with PV-powered pump
Home Design:	28'x46', 3 BR cape cod, 12/12 pitch roof Dormers are on north side (no space restriction on roof for PV system, allows "wide, short" array) Basement moisture-proof & insulated, to be finished in the future 2,150 sq.ft. on two stories 2,900 sq.ft. w. basement finished
About the owner:	Rick Gidlewski is employed as an emergency center dispatcher in Bucks County, PA.

3. Richard Perez home

Location:	Albany, NY
PV System Design:	Grid-tied/stand-alone PV system 16 x Solarex MSX120, 1,920 Wp, 4 in series (48V nominal) TRACE Engineering 4048 SW (4 KW grid-tie/stand-alone inverter) Photron SolarUPS 4.0E integrated controller/power center 8 x GNB Sunlyte 12-5000 12-volt, sealed batteries
Other Solar/ Renewables:	Passive solar, South window opening = approx. 17% of floor area Earth tubes for summer cooling and tempered fresh air in winter.
Home Design:	28'x46' two-story, 4 BR colonial, 12/12 pitch roof The "standard" solar colonial design will be used with slight modifications Third story (attic) to be finished Basement moisture-proof & insulated, to be finished 2,750 sq.ft. on two stories 3,575 sq.ft w. third story finished 4,525 sq.ft. w. basement finished
About the owner:	Richard Perez is a researcher for the Atmospheric Sciences Research Center at the State University of New York at Albany.

4. Jim Cahill Home

Location:	Falmouth, Massachusetts (Cape Cod)
PV System Design:	Grid-tied/stand-alone PV system 16 x Solarex MSX120, 1,920 Wp, 4 in series (48V nominal) TRACE Engineering 4048 SW (4 KW grid-tie/stand-alone inverter) Ananda Powercenter 3-200 integrated controller/power center

	8 x GNB Sunlyte 12-5000 12-volt, sealed batteries
Other Solar/ Renewables	Passive solar, South window opening = approx. 16% of floor area. Hot water baseboard heating Earth tubes for summer cooling and tempered fresh air in winter.1
Home Design:	28'x44', 4 BR colonial, 12/12 pitch roof The "standard" solar colonial design was used with slight modifications. A room above the garage was added along with a room connecting the garage with the main house. The added rooms houses the Cahill's "in-laws". 3,250 sq.ft. on two stories 4,040 sq.ft w. third story finished 4,950 sq.ft. w. basement finished
About the owner:	Jim Cahill has been active in the eastern Mass. area in energy conservation and solar energy. Jim is currently establishing a solar home building division of Enerpro Engineering, his energy conservation company, and will market the factory-built PV-integrated homes, and has been established as the first AvisAmerica dealer exclusively for solar homes.

5. Peter Clark Home

Location:	Middlesex, Vermont
PV System Design:	Off-grid PV/wind hybrid system 12 x Solarex MSX120, 1,440 Wp, 4 in series (48V nominal) 2 x Southwest Windpower Air300, 600Wp, 48V TRACE Engineering 4048 SW (4 KW grid-tie/stand-alone inverter) Photron SolarUPS 4.0E integrated controller/power center 16 x GNB Sunlyte 12-5000 12-volt, sealed batteries
Other Solar/ Renewables	Passive solar, South window opening = approx. 15% of floor area. Radiant floor heating Earth tubes for cooling and tempered fresh air
Home Design:	28'x42', 4 BR colonial, 12/12 pitch roof The "standard" solar colonial design was used with slight modifications 2,430 sq.ft. on two stories 3,180 sq.ft w. third story finished 4,050 sq.ft. w. basement finished
About the owner:	Peter Clark is computer programmer and software author. Gloria

DeSousa, his wife, is an environmental scientist. They have been planning for living with renewable energy for over three years with assistance from FIRST.

6. Lou D'Arminio Home

Location:	Ramsey, NJ (about 20 mi. west of New York City)
PV System Design:	Grid-tied/stand-alone PV system 16 x Solarex MSX120, 1,920 Wp, 4 in series (48V nominal) TRACE Engineering 4048 SW (4 KW grid-tie/stand-alone inverter) Photron SolarUPS 4.0E integrated controller/power center 8 x GNB Sunlyte 12-5000 12-volt, sealed batteries
Other Solar/ Renewables:	Passive solar, South window opening = approx. 17% of floor area Earth tubes (provide cool air in summer and tempered fresh air in winter using minimal power, at low cost).
Home Design:	28'x52' two-story, 4 BR colonial, 12/12 pitch roof Third story (attic) to be finished in the future, including two dormers on south side (restricts roof space for PV system, necessitates "tall, thin" array) Basement moisture-proof & insulated, to be finished in the future. Also, living space above garage to be finished in the future. 2,850 sq.ft. on two stories 3,800 sq.ft w. third story finished 4,800 sq.ft. w. basement finished 4,950 sq.ft. w. room above garage
About the owner:	Lou D'Arminio is an attorney with Shanley & Fisher in Morristown, NJ.

CURRENT STATUS AND PLANS

The six pilot homes are complete and occupied except for the D'Arminio home, which will be complete by the end of December. The solar systems in the homes are operating satisfactorily so far, although there has not yet been enough data collection to establish whether their actual performance meets or exceeds their predicted performance. The same can be said for the thermal and passive solar performance of the homes.

Current plans include the construction of a sustainable community featuring integrated solar homes in Falmouth, MA, and the construction of a low-income townhome project featuring integrated solar homes in Philadelphia, PA.

The emphasis for further development of the PV systems will be on reducing the labor and material cost of installing the systems. Installing the PV systems in the factory which manufactures the homes could help to meet this goal and to reduce the inconsistencies encountered from site to site, but many technical and architectural considerations must be addressed before this can be done.

As part of the effort to reduce the material and labor to install Pv systems, a project will be undertaken in the next phase of the program to develop a large area, roof-integrated PV module using polymer materials. The goal is a lightweight, rugged, simple-to-install module that is capable of replacing roof shingles.

Other efforts underway include the development of a reasonable-cost, super-efficient refrigerator and a contract to develop a 48V DC ballast for compact fluorescent lamps for off-grid homes.

Overall, the entities participating in this program hope to make integrated solar homes an alternative that mainstream real estate developers will choose for large and small residential developments as well as for contract homes. Initially, these goals will be pursued almost entirely in the Northeast, but eventually participants will be sought nationwide.

Innovative Strategies for Environmental Sustainability

Shahrokh Rouhani, Ph.D., P.E.[1]

INTRODUCTION

Since early 1980's, our perception of sustainability has fundamentally changed. Historically, the concept of sustainability was primarily concerned with the scarcity of natural resources in the face of a growing world population. Ecological and environmental degradation was merely viewed as an inevitable and acceptable consequence of development. However, after World War II, this view was challenged which led to a growing awareness about the deteriorating state of our global environment.

As Yergin (1992) states the environmental awareness came in three waves. The first wave in the late 1960s and early 1970s was mainly focusing on clean air and water. By the mid 1970s the second environmental wave concentrated its force against any further development of nuclear power. The third environmental wave in 1980s addressed much wider issues, such as global warming, ozone layer depletion, and the mounting problem of hazardous waste.

At first, the solution to the above environmental problems appeared to require a halt in the world economic growth. However, human history repeated itself and creative minds provided solutions that not only addressed the environmental concerns, but also produced economic growth. This paper focuses on one of the main environmental challenges of our decade, i.e. the clean-up of contaminated sites.

REMEDIATION OF CONTAMINATED SITES

In early 1980's U.S. Environmental Protection Agency initiated a massive effort to identify contaminated sites around the country and to establish a priority procedure for their environmental clean-up. These efforts were coined as the Superfund program. Unfortunately, the liability issues dominated the process to the point that of the 1,309 identified Superfund sites, only 67 of them have been cleaned.

Furthermore, technical issues raised additional unexpected hurdles for the clean-up efforts. Environmental projects proved to be susceptible to cost over-runs, seemingly endless investigations, an inability to anticipate change, and counter-productive negotiations conducted in a reactive manner. This has led to a situation that the average clean-up cost of a single Superfund site is in excess of $25 million.

---

[1] Associate Professor, School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, Georgia, 30332 and President, NewFields, Inc., 1201 West Peachtree St., Atlanta, Georgia, 30309.

Bredehoeft (1994) cites that the United States currently spends $10 billion annually on environmental clean-up. If the current strategies are pursued the total cost of the clean up will be approximately $750 billion (1990 dollars) and will take 75 years. This poses a significant financial burden for thousands of potential responsible parties, including federal and state governments, small and large businesses, hospitals, cities, and towns.

The above environmental challenge questions the appropriateness of the current economic growth patterns. At first glance, many types of business activities may be deemed as environmentally unsustainable. However, the cumulative know-how and information pools developed over the last fifteen years, offer great opportunities for significant reductions in compliance-costs. These opportunities can only be realized through a consistent and coherent strategy. Different aspects of such a strategy is presented through the following case studies.

CASE STUDIES

A number of case studies are presented herein to offer examples of innovative procedures used to attain clean-up in a timely and economic manner. The paper cites four specific examples:

1. At a naval air station in Florida extensive soil sampling was conducted. The available data included more than 140 soil borings and cone penetrometer tests (CPT). Despite the abundance of available data, the decision makers lacked a quantitative measure to determine the adequacy of existing data. As a results additional measurements were planned at a cost of $6 million. Upon a request by the U.S. Navy, a geostatistical assessment of the existing data was performed. The analysis provided quantitative measures of data adequacy in the form of estimation standard deviations. Based on the results of the geostatistical analysis, the cost of additional sampling was reduced to a fraction of the proposed amount. The elimination of the redundant measurements also expedited the entire clean-up process by more than one year.

2. Soil sampling at a naval site was completed. Of the collected samples only one showed concentrations above levels considered safe. Due to this one sample a soil remediation scheme at a cost of $4 million was considered. However, upon a statistical analysis using U.S. EPA's own guidance documents, the upper confidence level of mean soil concentration over the delineated area proved to be significantly lower than the targeted clean-up level. This conclusion led to a significant cost reduction.

3. Data from field screening surveys are rarely used in the actual delineation of media contamination. This usually leads to extensive costly laboratory analyses. A large industrial/commercial site was extensively characterized with over 80 soil borings, extensive in-field screening of volatile organic compounds and limited laboratory analysis of selected boring samples (Wild and Rouhani 1996). Rather than pursuing

additional costly laboratory analyses, existing field and laboratory data were combined and co-estimated. In this co-estimation process, laboratory data were considered as primary source of high-quality information. The transformed field measurements, on the other hand, were viewed as auxiliary information that provided the required spatial coverage. The combination of these two types of data yielded a cost-effective characterization of site contamination.

4. Initially, investigators at a Superfund site had determined that the best remedial solution to be soil excavation, followed by its thermal treatment. Pre-design sampling revealed a much larger impacted soil, leading to an estimated cost in excess of $200 million. The remedy was changed to a lesser $100 million solution consisting of excavation and landfill. This solution involved removal of a million cubic yard of impacted soil that was supposed to remain exposed for two years during the construction of the proposed landfill. The potential responsible parties offered an innovative solution based on partial in-situ containment at a fraction of the proposed remedy. The containment alternative was not only more economic, but also offered superior protection of human health and the environment.

The above case studies clearly indicate that innovative strategies can yield cost-effective solution for the protection of human health and the environment. Such approaches will provide a responsible base for an environmentally-sustainable growth.

REFERENCES

Bredehoeft, J.D. 1994. Hazardous waste remediation: A 21st Century problem. *GWMR*, Winter, 95-100.

Wild, M., and S. Rouhani. 1995. Taking a statistical approach. *Pollution Engineering*, February, 44-45.

Wild, M., and S. Rouhani. 1996. Effective use of field screening techniques in environmental investigations: A multivariate geostatistical approach. *Geostatistics for Environmental and Geotechnical Applications*. ASTM STP 1283, R. M. Srivastava *et al.*, Eds. American Society for Testing and Materials, Philadelphia.

Yergin, D. 1992. *The Prize: The Epic Quest for Oil, Money, and Power.* Touchstone, New York.

Sustainable Technologies for the Building Construction Industry

Jorge A. Vanegas[†], Jennifer R. DuBose[††], and Annie R. Pearce[†††]

INTRODUCTION

As the dawn of the twenty-first century approaches, the current pattern of unsustainable, inequitable and unstable asymmetric demographic and economic growth has forced many segments of society to come together in facing a critical challenge: how can societies across the world meet their current basic human needs, aspirations and desires, without compromising the ability of future generations to meet their own needs? At the core of this challenge is the question: how can the human race maintain in perpetuity a healthy, physically attractive and biologically productive environment (Malone 1994).

The development path that we have been taking, in the past few centuries, has been ultimately detrimental to the health of our surrounding ecological context. We are consuming an increasing share of the natural resources available to us on this planet, and we are creating sufficiently large amounts of waste and pollution such that the earth can no longer assimilate our wastes and recover from the negative impacts. This is a result of a growing population as well as new technologies which make it easier for us to access natural resources and also require the consumption of more resources. Unsustainable technology has been the result of linear rather than cyclic thinking. The paradigm shift from linear to cyclic thinking in technological design is the crux of the shift from unsustainability to sustainability.

Recent global attention to the issues and challenges of sustainable development is forcing industries to conduct self-assessments to identify where they stand within the framework for sustainability, and more importantly, to identify drivers, opportunities, strategies and technologies that support achieving this goal. The principal objectives of this paper are to present a brief overview of an overall framework for sustainability and then to discuss the implications for the building design and construction industries. Strategies, technologies, and opportunities are presented to improve the sustainability of the built environment. This summary has been compiled as part of an on-going research, education and curriculum development effort lead by the Center for Sustainable Technology (CST) at the Georgia Institute of Technology. Achieving true sustainability

[†] Associate Professor, School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0355 USA email: jvanegas@ce.gatech.edu
[††] Research Associate, Center for Sustainable Technology, Georgia Institute of Technology, Atlanta, GA 30332-0355 USA email: jdubose@ce.gatech.edu
[†††] Ph.D. Candidate, School of Civil and Environmental Engineering, Georgia Institute of Technology, Atlanta, GA 30332-0355 USA email: gt0338d@prism.gatech.edu

will require a paradigm shift that brings together sustainable technologies for built facilities as total systems.

THE NEW PARADIGM: CYCLIC SUSTAINABLE DEVELOPMENT

Sustainable development offers a new way of thinking which reconciles the ubiquitous human drive to improve our quality of life with the limitations imposed on us by our global context. It requires unique solutions for improving our welfare that do not come at the cost of degrading the environment or impinging on the well-being of other people. Although there is no general agreement regarding the precise meaning of sustainability, beyond respect for the quality of life for future generations, most interpretations and definitions of the term "sustainable" refer to the viability of natural resources and ecosystems over time, and to the maintenance of human living standards and economic development (National Science and Technology Council 1994).

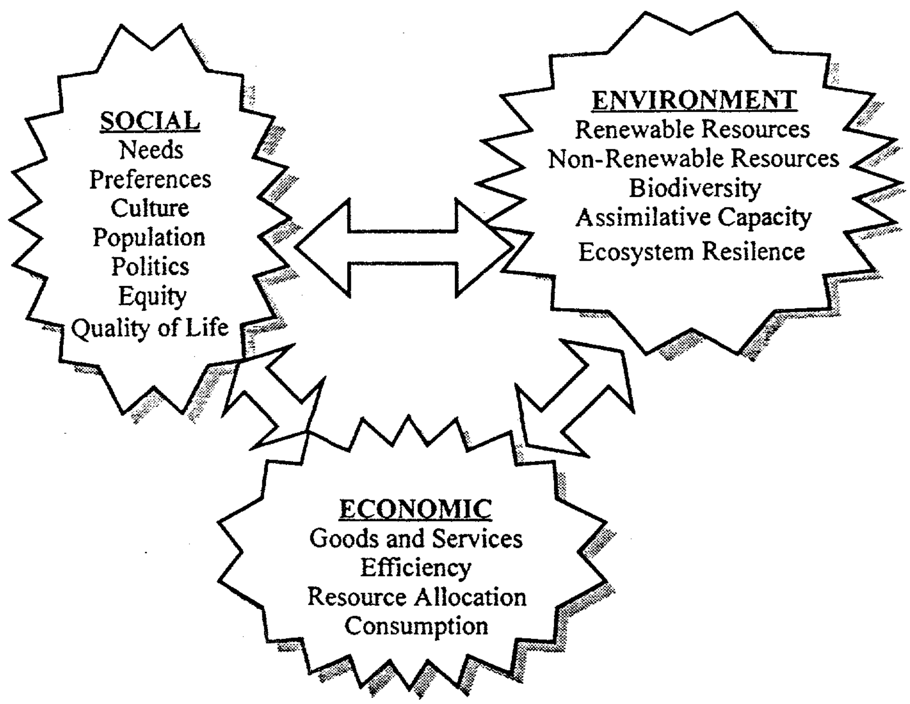


Figure 1: The Context of Sustainability. This figure is one representation of the issues which comprise sustainability. Sustainability is at the nexus of sociocultural, environmental, and economic factors. Although useful, this representation is deceptively uncomplicated in its portrayal of the relationships between sustainability issues, because in fact the relationships between these issues are quite complex.

Sustainability is a relationship, or balancing act, between many factors (social, environmental and economic realities and constraints) which are constantly changing (see Figure 1). As one expert has defined it "Sustainable development is a process of change in organizing and regulating human endeavors so that humans can meet their needs and exact their aspirations for current generations without foreclosing the possibilities for future generations to meet their own needs and exact their own aspirations" (Weston 1995).

Because sustainability is a dynamic concept rather than a static state, it requires decision makers to be flexible and willing to modify their approaches according to changes in the environment, human needs and desires, or technological advances. This means that actions that contribute to sustainability today, either in perception or in reality, may be deemed detrimental tomorrow if the *context* has changed:

> Ensuring sustainability over time means maintaining a dynamic balance among a growing human population and its demands, the changing capabilities of the physical environment to absorb the wastes of human activity, the changing possibilities opened up by new knowledge and technological changes and the values, aspirations and institutions that channel human behaviour. Thus, visions of a sustainable world must naturally change in response to shifts in any part of this dynamic relationship (Pirages 1994, p. 200).

The next three sections discuss the social, environmental and economic issues which are essential to sustainability. These concerns will be applied to the construction and building industry in the latter part of the paper.

Social Sustainability

Sustainability is inherently anthropocentric, since it is the welfare of humans with which we are concerned. More than a concern for mere survival, sustainability is a desire to thrive, to have the best life possible. There are many sociocultural issues which influence sustainability. The most prominent issue is inter-generational equity, in which we must insure that we leave our progeny with the tools and resources they need to survive and enjoy life. As an African proverb says, "We do not own the earth, we are just taking care of our grandchildren's inheritance." In so doing, we should not forsake the quality of life that people today are experiencing. Instead, we must strive to raise the standard of living of those people who *today* lack the most basic requirements such as clean water and adequate food. Other issues in this realm are: environmental justice, population growth, human health, cultural needs, and personal preferences. These elements have a great deal to do with our quality of life and should not be ignored in favor of the more easily measurable economic elements discussed below.

Environmental Sustainability

Environmental concerns are also very important for sustainability. The natural environment is the physical context within which we live. Sustainability requires that we recognize the limits of our environment. There are limits to the quantities of natural resources that exist on the planet. Some of these resources, such as trees and wildlife, are renewable so long as we leave enough intact to regenerate. Other resources, such as minerals, are renewed at such slow rates that any use whatsoever depletes the total stock. We need to minimize our consumption of all resources, renewable and depletable.

Another key environmental issue is to minimize our impact on global ecosystems: the earth is like an organism and we must maintain it in a healthy state. Natural ecosystems can survive some impacts, but these must be small enough so that the earth can recover. In some cases there are particular resources or elements of an ecosystem which are essential to its health. For example, we might appear to provide enough timber for future generations, but if it is all contained in managed monoculture forests (which fail to duplicate the complexities of ecosystems), our efforts may not be adequate (Norton 1992). Protecting ecosystem health may involve the protection of an endangered species, the preservation of a wetland, or protection of biodiversity in general.

Economic Sustainability

Economics, as it pertains to sustainability, does not simply refer to Gross National Product, exchange rates, inflation, profit, etc. Economics is important to sustainability because of its broader meaning as a social science that explains the production, distribution, and consumption of goods and services. The exchange of goods and services has a significant impact on the environment, since the environment serves as the ultimate source of raw material inputs and the repository for discarded goods.

Economic gain has been the driver for much of the unsustainable development that has occurred in the past. A shift to sustainability will only occur if it is shown not to be excessively costly and disadvantageous. Part of sustainability is changing the way things are valued to take into consideration the economic losses due to lost or degraded natural resources, and expand our scope of concern from short term to long term impacts. Once this is done sustainable development will be revealed to be a more economically beneficial option than current development patterns.

ROLE OF TECHNOLOGY

Technology plays a very important role in sustainable development because it is one of the most significant ways in which we interact with our environment; we use technologies to extract natural resources, to modify them for human purposes, and to adapt our man-made living space. It is through use of technology that we have seen drastic improvements in the quality of life of many people. Unfortunately, many of these short term improvements in the immediate quality of life have also exacted a great toll on the environment. In order to proceed toward sustainability, we will have to be more deliberate and thoughtful in our employment of technology. We need to develop and use technologies with sustainability in mind. We need "sustainable technologies."

To avoid confusion and ambiguity it is necessary to establish a working definition of "technology." In this paper the term "technology" is taken to mean "the *application* of knowledge to the achievement of particular goals or to the solution of particular problems" (Moore 1972, p. 5). Thus, technologies include not only the physical tools we use to interact with our environment, but also symbols, processes, and other non-tangible effectors such as language and economic transactions which serve as interfaces between humans and enable actions to occur toward the solution of problems.

Sustainable Technology Characteristics

A sustainable technology is one that promotes a societal move toward sustainability, a technology that fits well with the goals of sustainable development. Sustainable technologies are practical solutions to achieve economic development and human satisfaction in harmony with the environment. These technologies serve to contribute, support or advance sustainable development by reducing risk, enhancing cost effectiveness, improving process efficiency, and creating processes, products or services that are environmentally beneficial or benign, while benefiting humans (National Science and Technology Council 1994, p. 4). To qualify as sustainable technologies, these solutions must have the following characteristics, in addition to meeting pre-existing requirements and constraints (e.g. economic viability):

- Minimize use of nonrenewable energy and natural resources
- Satisfying human needs and aspirations with sensitivity to cultural context
- Minimal negative impact on the earth's ecosystems

Minimizing Consumption. The use of nonrenewable energy and natural resources should be minimized because consumption of resources inherently involves increasing the disorder of materials and energy, rendering them of lower utility for future use (Roberts 1994, Rees 1990). By subjecting materials and energy to consumption processes we decrease their potential utility to current and future generations. Therefore, consuming as little matter and energy as possible, or "doing more with less," is a fundamental objective of sustainability.

Maintaining Human Satisfaction. A sustainable technology must fulfill the needs of the population it is intended to serve. In fulfilling those needs the technology must account for human preferences and cultural differences. In some cases these preferences may conflict with environmental and economic criteria and a compromise will have to be worked out. This is does not mean that human preferences should be ignored; fulfillment of our desires means the difference between surviving and living.

Minimizing Negative Environmental Impacts. Finally, causing minimal negative environmental impacts (as well as maximizing positive impacts) is an important objective of sustainability since the environment consists of ecosystems whose ongoing health is essential for human survival on earth (Goodland 1994). Sustainability of the human race requires that ecosystems be protected and preserved in a reasonable state of health through maintaining biodiversity, adequate habitat, and ecosystem resilience.

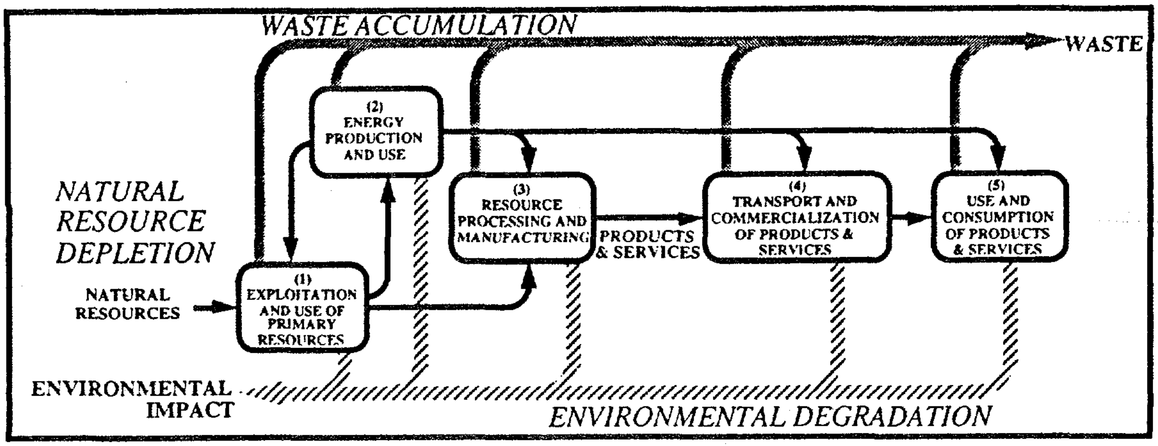


Figure 2: Unsustainable Linear Development
(adapted from Roberts 1994)

THE CURRENT PARADIGM: UNSUSTAINABLE LINEAR SYSTEM

In order to understand the changes that need to be made to develop sustainable technologies it is useful to look at the paradigm which is currently being employed. Despite a wide range of positions and opinions on the subject of sustainability, there is general agreement that the current paradigm of linear development, which disregards constraints to material or energy consumption, is unsustainable. In Figure 2, a model of the unsustainable linear development approach is shown which has prevailed over the last few centuries. In this model, several systems are linked in a linear process that begins with both renewable and non-renewable natural resources such as air, water, soil, mineral or biological resources. In this model, *exploitation and use of primary natural resources* occurs to provide inputs for industrial processes (Subsystem 1). The outputs of this system become the principal inputs for two other systems: the *production and use of energy* (Subsystem 2), whose output is a critical input to all the systems in the linear process; and *resource processing and manufacturing* (Subsystem 3), whose output is a set of industry-specific products or services that are *transported and commercialized* within Subsystem 4.

The linear process ends with the *use and consumption* (Subsystem 5) of the products or services generated by the industrial system across all segments of society. This process has two additional outputs from each of its systems, which are at the core of many problems facing the world today: increasing amounts of hazardous and non-hazardous waste, and increasing levels of environmental impact.

The process is linear because inputs enter at Subsystem 1 and move in one direction through the system to Subsystem 5 and then are disposed, going through the system only once with no cycling of materials. To aggravate the situation even more, this linear process is fueled by continuous increases in the demand for, use, and consumption of products and services, creating pressures for further exploitation of natural resources, and for continued expansion of energy production, resource processing, and manufacturing capabilities. This unrelenting growth has created three serious problems: natural resource depletion, accumulation of waste, and environmental degradation. It is these challenges which must be addressed in achieving sustainability.

A FRAMEWORK FOR A SUSTAINABLE INDUSTRY

A new way of thinking must be adopted to redirect our development toward sustainability. This cyclic sustainable process is a direct response to the challenges and problems posed by the unsustainable linear process described above in Figure 2, and offers a mechanism to gradually overcome the problems of unsustainability.

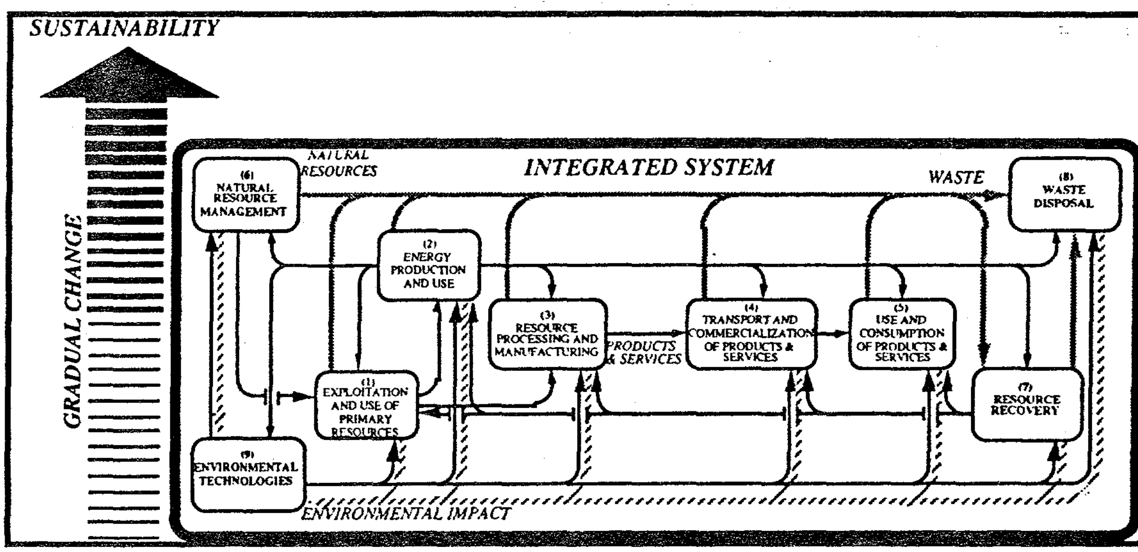


Figure 3: Cyclic Sustainable Development Process
(adapted from Roberts 1994)

The framework for a sustainable system presented in Figure 3 highlights one way of looking at this new approach. Developed from original ideas by D. V. Roberts, current President of the World Engineering Partnership for Sustainable Development (WEPSD), this framework is the basis of several initiatives of the Center for Sustainable Technology (CST) at the Georgia Institute of Technology in the areas of engineering education and construction engineering research. This system shows how to implement two of the three criteria for sustainable technology: frugal in use of nonrenewable energy and natural resources; and minimal negative impact on the earth's ecosystems. The criteria regarding the satisfaction of human needs and aspirations is not represented explicitly in this figure but nonetheless remains important.

First, instead of a linear process, the framework represents a closed cyclical system. The total integrated system includes the same five systems described earlier as a part of the linear system, and in addition, it incorporates four new subsystems, each a response to a specific sustainability challenge:

- *Natural resource management (Subsystem 6)* addresses the need to manage the exploitation of renewable natural resources in a way that ensures that the supply will always exceed the demand. At the same time, this management system monitors and controls the use of non-renewable natural resources to prevent their total depletion.

- *Resource recovery (Subsystem 7)* addresses the need to recover and recycle selected resources and products from waste. These recovered resources would then become inputs to the five basic subsystems in the linear framework. They also would contribute to reducing the amount of waste that requires disposal.

- *Waste disposal (Subsystem 8)* recognizes that a certain amount of waste is inevitable, and thus will require disposal in ways that are not detrimental to the environment.

- *Environmental technologies (Subsystem 9)* addresses the need to incorporate proactively, in every subsystem within the framework, strategies and mechanisms that mitigate environmental impacts at the root – before the impact happens, through the application of preservation, pollution prevention, avoidance, monitoring, assessment and control strategies and mechanisms. This subsystem also takes into account that some damage already has been done to the environment, and that corrective actions such as remediation or restoration are necessary.

Sustainable technologies should adopt this cyclic closed loop system, which mimics natural systems. In this system the generation of waste is avoided; instead, all by-products are used as inputs back into production or as inputs into some other process. By minimizing waste environmental impact is lessened. Because the scale of impact is kept low in this system, change to the environment will be gradual and the surrounding environment will be able to adapt and remain healthy.

SUSTAINABILITY AND THE BUILDING CONSTRUCTION INDUSTRY

While traditional design and construction focuses on cost, performance and quality objectives, sustainable design and construction adds to these criteria minimization of resource depletion and environmental degradation, and creating a healthy built environment (Kibert 1994). Figure 4 illustrates the primary paradigm shift to sustainability within the building design and construction industry. This model of the new sustainability paradigm shows issues which must be considered for design making at all stages of the life cycle of the facility.

Sustainable designers and constructors will approach each project with the entire life cycle of the facility in mind, not just the initial capital investment. Instead of thinking of the built environment as an object separate from the natural environment, it should be viewed as part of the flow and exchange of matter and energy which occurs naturally within the biosphere. In addition to the nonliving components which make up the built environment, sustainable designers and constructors must also consider the living components of the built environment (flora, fauna, and people) which operate together as a whole system in the context of other ecosystems in the biosphere (Yeang 1995).

Life cycle considerations are particularly important with respect to the design and construction of built facilities because the life cycle of a facility involves more than just constructing the facility itself. Operation, maintenance, and decommissioning or disposal of the facility also consume matter and energy, and are largely constrained by the design and construction decisions made in the early phases of the facility's life. Not only are changes easier to make during the design of the facility, but also the costs of the changes are lower, since the facility exists only "on paper" as opposed to being a physical artifact which exists in reality after construction begins and ends. Additionally, choices of more costly design features made during facility and design construction may be offset by cost, resource, and energy savings realized over the life cycle of the facility. Thus, the primary responsibility for creating sustainable built facilities falls to the designers and constructors of such facilities.

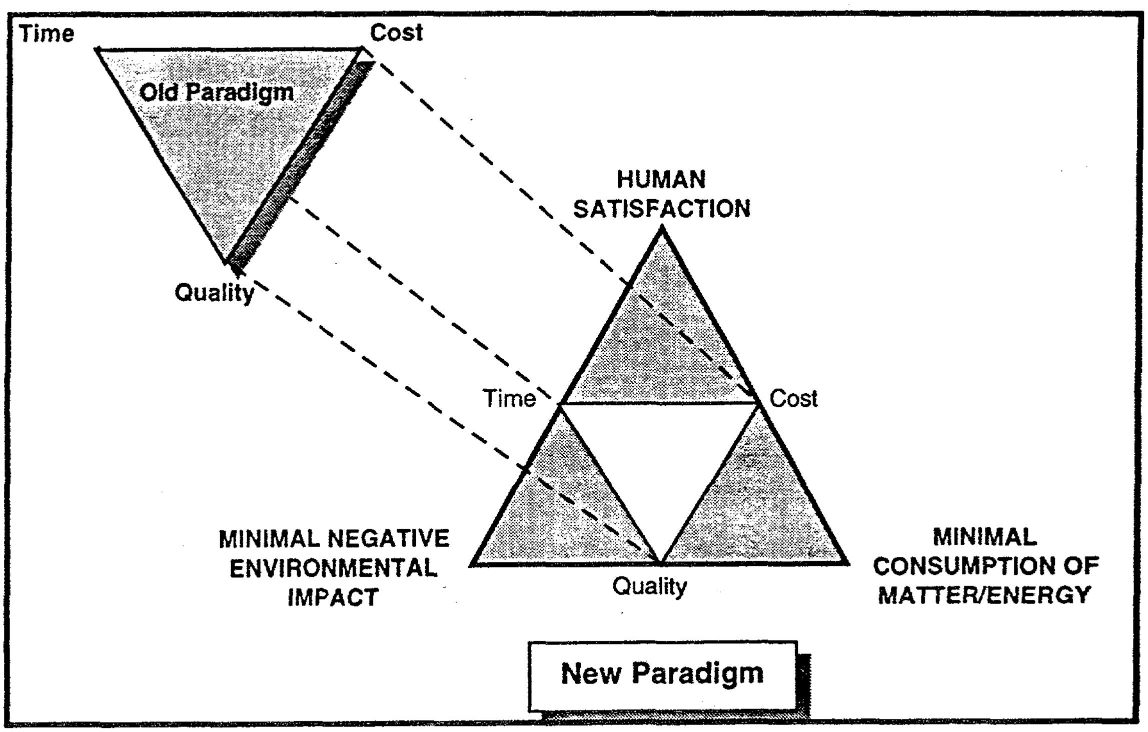


Figure 4: Paradigm Shift from Traditional to Sustainable Design and Construction

People who make project decisions with sustainability as an objective will need to evaluate the long-term as well as short-term impacts of those decisions to the local and global environments. And those who take a sustainability approach to design and construction will be rewarded with reduced liability, new markets, and an earth-friendlier construction process, which will help future and current generations to achieve a better quality of life (Kinlaw 1992, Liddle 1994).

STRATEGIES, TECHNOLOGIES, AND OPPORTUNITIES FOR IMPLEMENTING SUSTAINABLE DESIGN AND CONSTRUCTION

In the creation of built facilities, there are many opportunities to improve how design and construction are currently done to make them more sustainable. Three general objectives should shape the implementation of sustainable design and construction, while keeping in mind the three categories of sustainability issues discussed above (social, environmental, and economics). These objectives are:

- Minimizing consumption of matter and energy over the whole life cycle of consumption, while
- Satisfying human needs and aspirations with sensitivity to cultural context, and
- Avoiding negative environmental impact.

In the following subsections, we present specific strategies for approaching each of the three objectives, along with examples of technologies and opportunities related to each of the strategies.

Minimizing Consumption

Consumption of natural resources is at the heart of sustainability. With its large scale use of material and energy and displacement of natural ecosystems, the built environment greatly influences the sustainability of human systems as well as the natural ecosystems of which we are a part. Minimizing consumption of matter and energy is essential to achieve sustainability in creating, operating, and decommissioning built facilities. The following sections highlight several strategies for minimizing consumption of natural resources over the life of built facilities.

Improving Technological Efficiency: Doing more with less. One strategy for minimizing consumption in creating the built environment is improving the technological efficiency of our materials and processes. For materials, we need to improve the efficiency with which they meet the needs for which they are used. An example of this is improving the technology of windows to reduce unwanted thermal losses and air leakage in climate-controlled applications. With respect to processes, technological efficiency means reducing the amounts of input matter and energy required to generate the desired outcome of the process. In construction, improving site layout to reduce the travel distance of excavating equipment is an example of improving process efficiency, resulting in fewer equipment hours, less fuel used, and lower maintenance costs.

Reuse, Rehabilitation, and Retrofitting. Reusing buildings, materials and equipment is a second strategy for making design and construction more sustainable. By reusing what already exists we save the cost, material, and energy input which would be required to create new facilities "from scratch." The primary reason for disposal of facilities and materials is that those artifacts do not meet the present needs of humans. By using techniques such as adaptive reuse, rehabilitation, or retrofitting, old facilities can be modified or improved to meet new use criteria, at a much lower consumptive cost than building a new facility. An example of adaptively reusing existing facilities are loft apartments developed in the structures formerly used for factories. Materials and equipment can also be reused or rehabilitated to varying degrees. The biggest impediments to this strategy are artifacts which are designed for obsolescence, with short life cycles, or where economic constraints have forced subquality construction or manufacturing.

Creating New Technologies. Many opportunities exist to increase the sustainability of human activity by creating new technologies. Consumption of matter and energy can be reduced by developing new technologies which do not rely on traditional types or amounts of materials and energy to meet human needs. Photovoltaic panels, which generate electricity from solar radiation, are one example of such a technology. Instead of using finite reserves of coal or oil to make the electricity used by humans, PV panels use the essentially infinite resource of solar energy. Opportunities for new technologies can be found by observing natural ecosystems: what sources of energy and matter are used by these systems? Particularly promising opportunities exist in the area of waste recovery and reuse. Using waste masonry and concrete from demolished structures as aggregate in new concrete is one example of taking artificially-generated waste which would otherwise have been disposed in the natural environment, and using it as input back into the building process.

Modifying Historical Technologies. Technologies have been used over the course of human history to meet the needs of people. Many of these technologies have been forgotten or abandoned as new technologies were developed to replace them. While most of these technologies may appear to be obsolete, some may prove to be useful in and of themselves, or to suggest ideas for new technologies. Traditional construction techniques such as rammed earth have found new applications in structures constructed from waste automobile tires, filled with compacted earth. By combining a knowledge of historical building techniques with consideration of the insidious problem of waste tire disposal, builders have developed a low-cost system which helps to deal with waste disposal while creating a useful and durable structure.

Reshaping Human Desires. A more fundamental strategy for minimizing consumption is to attempt to change human desires and tastes. While fundamental human needs such as food, shelter, and water are not greatly adaptable, other human wants are often significantly responsive to external influences. The obvious architectural trends in built facilities from decade to decade are an example of how designers can influence consumer demand and thus the consumption of matter and energy. Other mechanisms for changing human consumptive patterns are education and awareness. If people are aware of the impacts of their choices on the ecosystems of which they are a part, they may make more enlightened choices.

Satisfying Human Needs and Aspirations

The quality of the facility as a man-made environment for people is determined by how well it meets human needs and aspirations for such things as security, non-toxicity, shelter, aesthetics, and other functional requirements. Other human needs which are indirectly met by built facilities include economic profitability for those who participate in the design and construction of the facility. Since sustainability is meaningless without reference to humans and their continued survival, the second objective of applied sustainability is satisfaction of human needs and aspirations.

Improving Economic Viability. In today's world, economic viability is an important consideration for any building project. Indeed, a facility design which is sustainable but too expensive to construct has little value in and of itself. Thus, increasing cost effectiveness of facilities is a critical strategy for creating sustainable built facilities. Economic viability often follows from achieving the objectives of minimizing cost and negative environmental impacts, since less consumption means less cost, and reduced environmental impact means lower liability and remediation costs. However, tradeoffs usually exist with respect to economic viability. While sustainable choices save money in the long term, they are often more expensive initially, making these choices seem unattractive from a short term perspective. To accurately identify the economic viability of sustainability choices, we need technologies which assist in cost-benefit analysis, financial forecasting, and long term predictions. In addition, revised economic valuation schemes which assign meaningful values to reserves of natural resources and ecological habitats are essential in assessing the economic viability of construction projects.

Matching User Needs with Facility Design. In creating a facility which is sustainable based on the human satisfaction criteria, the first step must be to identify the needs of the people who will use the facility. These needs shape the basic functional requirements of the facility, and must be met in order for the facility to be considered sustainable. The facility design process has been described by one architect as "establish[ing] a 'fit' between the pattern of needs and use: the patterns of built form, servicing systems, technological factors, and environmental factors" (Yeang 1995). Opportunities exist in the area of systematic human needs assessment, and adapting those needs as input to the design process. Additionally, technologies such as decision support systems can help designers and project decision makers to match user needs with appropriate building functionalities within the design.

Creating a Healthy Built Environment. In addition to the basic functional requirements of users which must be met by the facility, designers and constructors must also strive to include factors which create a healthy environment both inside and outside the facility. Non-toxic materials are an essential component of a healthy built environment, as well as design features which convey aesthetic or spiritual values conducive to the tasks and activities which occur within the facility. Besides the requirements for creating a healthy indoor environment, sustainable design also requires consideration of the interfaces between the built environment and the natural environment (see Figure 3). Non-toxic materials and processes are essential technologies for achieving sustainability throughout the facility life cycle.

Empowering People to Meet their Own Needs. A final strategy for satisfying human needs in the built environment is empowerment. By including users in decision making for the planning and design of facilities, the final facility will be more likely to meet the needs of those users. Allowing user participation at all phases of the facility life cycle creates an awareness among the users of the interfaces of the facility with its environmental context, and a respect for the flows of energy and material through the built system over time. Strategies such as owner/builder programs, where people are taught techniques for constructing their own homes, invite a respect for the final outcome which might not exist for manufactured or contractor-built houses. This respect and understanding can only lead to more sustainable design and construction.

Avoiding Negative Environmental Impacts

Built facilities impact the natural environment in many ways over their entire life cycles. Yeang (1995) lists four categories of impacts which built facilities have on the earth's ecological systems and resources:

- Spatial displacement of natural ecosystems, and modification of surrounding ecosystems as a result
- Impacts resulting by human use of the built environment, and the tendency for that use to spur further human development of the surrounding ecosystems
- Depletion of matter and energy resources from natural ecosystems during the construction and use of the facility
- Generation of large amounts of waste output over the whole life cycle of the facility, which is deposited in and must be absorbed by natural ecosystems.

Given their large scale and long life cycles, built facilities have particularly large and long-lasting effects on the environment as a whole. The following strategies are examples of approaches which can be taken to improve the sustainability of built facilities by avoiding negative environmental impacts over their life cycle.

Recovering Waste: Reduce, Reuse, Recycle. Various approaches exist to help recover waste from building construction and operation processes. Pollution prevention, for example, is a strategy which advocates anticipating and eliminating pollution before it is produced, and has been used very successfully in factory fabrication applications. Material recycling is also commonly used in prefabrication processes, where careful planning can eliminate waste or enable it to be directly recycled back into the manufacturing process or to other complimentary processes. Construction and demolition (C&D) waste recycling is also becoming increasingly popular, as disposal options become more expensive. Promising applications include recycling C&D waste into new composite materials for construction, such as the concrete aggregate mentioned earlier.

Reusing Existing Development. Another way of minimizing impacts on the natural environment is by making better use of sites and facilities which have already been used. Rehabilitation of existing structures for similar or adaptive uses, as well as using retrofitted existing sites rather than greenfield sites for new development, are examples of strategies which reduce negative impacts on the natural environment. By reusing existing sites and/or facilities, we save costs and avoid negative impacts by avoiding the need to "start from scratch". Additionally, peripheral costs such as extending utility and transportation systems to greenfield facilities, as well as travel savings for users are reduced or eliminated. Thus, not only is reuse of existing development more sustainable because of its reduced environmental impact, it can also be economically beneficial. Finally, redeveloping unsavory components of built systems can lead to improvements in the human system as well, by providing better environments for living and encouraging further development.

Integrating the Built Environment into Ecological Systems. Sustainability must occur within the context of natural ecological systems, since it is these systems which provide the resources for all human activity. The built environment can be integrated into the natural environmental context of its site and bioregion by designing material and energy flows into and out of the built system to fit within the yield and assimilative capacities of that context. Greywater systems are an example of a technology which has been successfully used to facilitate the processing and absorption of human waste water back into the natural environment. Rather than collecting the wastewater and using artificial chemical treatment processes to eliminate contaminants, greywater systems take advantage of the naturally purifying processes of ecosystems in their operation. As an added bonus, the greywater relationship is symbiotic, since the plants which purify the wastewater use the contaminants as a nutrient. Thus, integration of built systems into the surrounding ecological context can be mutually beneficial to humans and nature, provided that humans do not exceed the assimilative capacity of natural systems.

CONCLUSIONS

In striving to achieve sustainability in the built environment, three themes emerge. First, awareness of the impacts that built facilities have on both human and natural systems is essential, and should be considered as early as possible in the planning and design of any built facility. Second, the ecological, social, and economic contexts of the facility must be taken into account for all project decision making. Finally, sustainable designers and constructors must be aware of the connectivity of human systems to the natural environment. No human action can take place without affecting the ecological context in which it occurs. All human activity must be undertaken with an awareness of the potential consequences to other humans and nature, especially the construction of built facilities because of its large scale.

The principal conclusion of this paper is that the area of sustainable technologies is one of increasing interest which has many levels and complex dimensions. In this paper we have tried to provide a brief overview of the wide range of technological issues at an industry level, while emphasizing the need for an integrated approach and understanding of the different components of a sustainable system. We have stressed the importance of adopting a new paradigm which considers industry as a total system, rather than focusing on individual components of processes and operations. In order to achieve sustainability for society as a whole and for construction in particular, intelligent decision making is required which includes full consideration and knowledge of the many trade-offs and impacts associated with each alternative available to be chosen. Sustainability is a desirable state towards which to strive, but the journey is not easy.

REFERENCES

Goodland, R. 1992. *The Case that the World has Reached Limits.* in Population, Technology, and Lifestyle - The Transition to Sustainability, ed. R. Goodland, et al. Washington, DC: Island Press pp. 3-22.

Hill, R.C, Bergman, J.G., and Bowen, P.A. 1994. *A Framework for the Attainment of Sustainable Construction.* in Proceedings of the First International Conference on Sustainable Construction, ed. C.J. Kibert. Tampa, FL, November 6-9. CIB TG 16.

Kibert, C. 1994. *Establishing Principles and a Model for Sustainable Construction.* in Proceedings of the First International Conference on Sustainable Construction, ed. C.J. Kibert. Tampa, FL, November 6-9. CIB TG 16.

Kinlaw, D. 1992. *Competitive and Green: Sustainable Performance in the Environmental Age.* San Diego, CA: Pfeiffer & Co.

Liddle, B.T. 1994. *Construction for Sustainability and the Sustainability of the Construction Industry.* in Proceedings of the First International Conference on Sustainable Construction, ed. C.J. Kibert. Tampa, FL, November 6-9. CIB TG 16.

Malone, T.F. 1994. *Sustainable Human Development: A Paradigm for the 21st Century.* White Paper for the National Association of State Universities and Land-Grant Colleges, The Sigma Xi Center, Research Triangle Park, NC, November 6.

Moore, W.E. 1972. *Introduction.* in Technology and Social Change, ed. W.E. Moore. Chicago: Quadrangle Books, pp. 3-25.

Munasinghe, M. and J. McNeely 1995. *Key Concepts and Terminology of Sustainable Development.* in Defining and Measuring Sustainability: The Biogeophysical Foundations, eds. M. Munasinghe and W. Shearer. Washington, DC: World Bank.

National Science and Technology Council. 1994. *Technology for a Sustainable Future: Framework for Action.* Washington, D.C.: Office of Science and Technology Policy.

Norton, B. G. 1992. *A New Paradigm for Environmental Management.* in Ecosystem Health: New Goals for Environmental Management, ed. R. Costanza, B. G. Norton and B. D. Haskell. Washington, DC: Island Press, pp. 23-41.

Pirages, D. 1994. Sustainability as an Evolving Process. *Futures,* 26(2), 197-205.

Rees, W.E. 1990. The Ecology of Sustainable Development. *The Ecologist,* (20)1, 18-23.

Roberts, D.V. 1994. *Sustainable Development – A Challenge for the Engineering Profession.* in The Role of Engineering in Sustainable Development, ed. M. Ellis. Washington, DC: American Association of Engineering Societies, pp. 44-61.

Weston, R. 1995. *Sustainable Development: Integration of Free Market and Natural Economic Systems*, Presented at the AAES/Engineering Foundation conference "Sustainable Development: Creating Agents of Change" Snowbird, Utah. August 4-8.

Yeang, K. 1995. *Designing with Nature*. New York: McGraw Hill.