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PUTTING IT TOGETHER

Whole Buildings and a Whole Buildings Policy

by Dr. Donald Aitken[1]

Rather than isolated collections of components, buildings are integrated systems that interact with their environments. Through effective energy use, "whole" buildings levy the smallest possible environmental impact, while enhancing their users' comfort and productivity. The federal government can shape consumer demand for whole buildings through coordinating its building-related activities into a "whole building policy."

— Passive Solar Industries Council, 1998

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A Message from the Staff of the Renewable Energy Policy Project

Buildings are important. They matter economically: the building sector represents 13% of America's gross national product. They matter in terms of energy: heating, lighting, cooling and otherwise operating buildings consumes about one third of the nation's energy. And they matter environmentally: the energy consumed by buildings results in 35% of the greenhouse gases released by human activity in this country, as well as voluminous conventional air pollution — not to mention the environmental impact of wasted building material, debris from demolished structures, and profligate water use.

For these reasons, buildings should constitute a critical focus of an integrated economic, energy and environmental strategy. We require *whole buildings*, constructed with an eye to minimizing energy use, environmental impact, initial cost and operating cost, while maximizing their users' comfort. To transform the building market and accelerate demand for whole buildings, we require a *whole building policy*, which integrates all the government activities involving buildings and the building sector.

These are ambitious goals. The sprawling agglomeration of professions and activities that constitute the building sector has great inertia and complexity. Hence the attraction of using federal policy: in fiscal year 1998, the U.S. government will spend $476 million on buildings-related programs. Yet, so far, only a tiny fraction of this money addresses energy issues — for example, $9.2 million on energy efficiency R&D.

The issue is not merely the level of funding or even the goals of individual programs, but rather the lack o f coordination among myriad federal efforts — as the Passive Solar Industries Council (202-628-7400, or psicouncil@aol.com) describes in its 1998 *Overview of Building-Related Programs in the Federal Sector*. American practice and government policy often consider buildings themselves as collections of non-interactive components rather than as systems. In an ironically parallel manner, federal policy scatters accountability for buildings policy among isolated programs, cabinet agencies and committees.

Whole buildings will become the rule in America when consumers demand them. That day is coming: Americans are learning more about the links between energy use and the environment, between energy consumption and the cost of operating buildings, between building comfort and worker productivity, and between their buildings and their own health. Through well designed market-transformation policies and coordinated support for public-interest research and development, the federal government is in a unique position to aid in the transition. To make whole buildings a reality, government policy makers must first institute a whole building policy

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Executive Summary

This Research Report, prepared in conjunction with members of the Passive Solar Industries Council, calls for an enlightened Federal policy about buildings in the United States that recognizes the immense and strategic importance of these structures — both those existing and those yet to be built — and the overarching influence that buildings have on energy use, environmental emissions, and the nation's economy.

The recommended policy is based on five objectives that have been developed by the members of the buildings industries and trades, adhering to a comprehensive "whole buildings approach." This represents a method of siting, design, equipment and material selection, financing, construction, and long-term operation that takes into account the systems nature of buildings and user requirements. It treats the overall building as an integrated system of interacting components. This umbrella concept unites buildings and their individual components with the emerging issues of sustainability. It encompasses all real-world physical and economic elements with which buildings interact or on which they depend.

The same framework can bridge the federal agencies involved in buildings programs — whether they deal with research, development, or market transformation — in a coordinated manner, as well as reach to outside agencies and organizations, pulling all together into one unified package of complementary and supporting activities. The result will be buildings that are more energy-efficient, that use solar and other renewable energy sources, that stimulate occupant productivity, that reduce adverse environmental impacts, and that support greater economic efficiency.

The message is clear: to minimize duplication and fragmentation of effort and to maximize potential returns for both industry and society at large, there is a strong need and a clear obligation for enhanced, long-term, stable federal attention and funding for this issue. Resulting programs must be coordinated within and between agencies, as well as with the buildings trades that are using the whole buildings approach.

We urge widespread adoption of the whole buildings approach by government, industry, and the private sector so that all can capitalize on the great potential benefits of integrated policies and programs that will lead to well-integrated buildings. The market transformation that brings all facets of the whole buildings approach into common practice will occur only as a result of a new appreciation of those benefits, combined with a strong market demand by those who want to share in them. The "market push" can in part be stimulated by a federal policy that helps structure markets for emerging technologies. The "market pull" can stem in part from a better appreciation of the role of buildings not just as economic elements but as factors that shape our economy and the quality of our environment.

In fiscal year 1998, the federal government will spend approximately $476 million on buildings-related R&D and other technology programs. Funding for the few whole buildings programs that exist is insignificant in comparison. With relatively scant funding directed toward specific, well-integrated programs that use a whole buildings approach, it is clear that considerable potential economic and environmental benefits are going unrealized.

A whole buildings approach is a better policy and one that will bring about change. It must be elevated to a high level of administrative responsibility and respect. The concept of whole buildings must secure a mandate simultanously from the federal government, industry, and private-sector research centers to coordinate, enhance, supplement, complement, and fill in the gaps that are still barriers to systems integration in research and practice.

The paper concludes by presenting five objectives for a more coherent, integrated federal buildings policy. It also provides specific recommendations to promote the adoption, successful introduction, and continuing effectiveness of a national whole buildings R&D program.

The five objectives and the strategies for achieving them are:

- *Establish the whole buildings framework as a cornerstone of policy*. In part, this can be achieved through the creation of a coalition of buildings industry participants who will exert pressure on and work with Congress and the administration to implement the policy.
- *Fund collaborative, fundamental, and applied research.* This means that the federal government must increase funding to research basic building physics, materials, components, design tools, and monitoring techniques and should provide more funds to existing programs. Furthermore, a new entity must be created or an existing entity empowered to coordinate federal buildings programs on an on-going basis and within a whole buildings framework. The first task of this group should be to design a comprehensive, multi-year action plan outlining the federal buildings R&D strategy.
- *Support accurate estimation and verification efforts.* To do so, the government must support the accelerated development of prediction and verification tools. This means Congress must provide supplemental funding to existing programs.
- *Embrace training and education.* The Department of Energy and other federal agencies must help transform the marketplace by implementing education, training, and technology transfer programs. These should be based on private-sector models that have been successful but have had limited resources and reach.
- *Stimulate demand through awareness.* Federal agencies must not only reach out to industry through education and training, they must also educate the public in order to stimulate demand. The Department of Energy and other agencies should implement public education campaigns in cooperation with allies in a buildings coalition.

PUTTING IT TOGETHER: Whole Buildings and a Whole Buildings Policy

by Dr. Donald Aitken[2]

This Research Report considers strategies for achieving an integrated approach to federal buildings programs based on a "whole buildings" conceptual framework. In an effort to promote such a framework as the foundation for federal buildings policy, members of the buildings industry and trades, related industries, researchers, and other advocates have identified five specific objectives that can foster an integrated approach. The strategies, objectives, and the federal policy framework have been developed through careful study of current federal policies and programs against the backdrop of the critical role that buildings play in the U.S. economy and the potential contributions that the whole buildings approach can make to the well-being of the nation.

The paper is the product of a series of coordinated efforts by whole buildings advocates. REPP commissioned it in response to a request from the members of the Passive Solar Industries Council (PSIC). PSIC is a consortium of architects, builders, designers, building materials and product manufacturers, consultants, educators, engineers, utility companies and organizations, and individuals with diverse but related interests.

PSIC was formed in 1980 because no other group was positioned to represent whole buildings in the trades and field. To pave the way for this Research Report, PSIC commissioned an *Overview of the Building-Related Programs in the Federal Sector*, which provided a snapshot of the current federal buildings programs.[3] That report concluded that few federal programs consider buildings as integrated systems, and that those that do are underfunded and generally underpromoted. It also noted that the scattered federal buildings programs are not coordinated through an overall federal buildings policy, let alone one based on the whole buildings approach. The earlier report showed how things are, and this Research Report looks at how things should be.

As an aid to decisionmakers who can help implement the whole buildings approach, the paper starts with a description of the technical nature of buildings and building energy consumption. It goes on to build the case for long-term, stable federal leadership in whole buildings policy. The case for federal leadership emphasizes the important and badly underrated role of buildings in the U.S. economy, the financial impact of buildings on the American people, and the nature of the buildings industry.

PART I: The Technical Nature of Buildings

How Does a Building Use Energy Inputs?

A conventional building constantly interacts through its outer "envelope" (skin), windows, and ventilation system with the ever-changing outside world. The portions of the ambient temperature, fresh air and lighting needs of the occupants that are not provided by the building's natural response are supplied by energy-driven thermal, ventilation and lighting systems. Any other energy needs of its occupants, such as to run computers, must also be met.

A building is therefore by definition a "whole" physical object, and it also behaves as a "whole" dynamic system, both internally and in the larger coordinate system that includes its direct and induced interactions with the natural world. (See Box 1 on Page 3.) Of course, a building does not actually care what temperature it is, or whether it is light or dark inside. The goal is to provide for the comfort and productivity of its occupants.

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[3] PSIC, *Overview — the Building of Related Programs in the Federal Sector* (Washington, D.C., 1998).

The advent of advanced heating, cooling, ventilation and lighting technologies means that a building can now use energy to counteract its own intrinsic response to environmental changes. The internal thermal needs are basically met by heating and cooling systems that mitigate the natural response of the building: as the structure loses heat in winter, heat must be reintroduced to maintain a comfortable temperature for the occupants. And or as the building absorbs excessive heat in summer, heat must be rejected to maintain comfort. The building's internal lighting systems compensate for inadequate natural lighting, while shades and blinds compensate for glare or overheating. And the heat from the bodies of the occupants, from all the lights, and from energy-using devices (computers, copy machines, and so on) can put additional strain on the building's cooling system. All this energy-consuming compensation for the natural state of buildings goes on constantly and simultaneously.

The productivity of occupants, which defines a building's economic value to the building's owners (whether those are developers, store owners, or school districts) is not determined merely by thermal comfort or sufficient lighting. It is increasingly understood that the quality of the space enhances its economic value. And it is becoming clear that the perceived quality of the space derives in part from the user's ability to have control over comfort and lighting conditions. Thus one of the great gifts of passive solar buildings, daylit buildings, and energy-efficient climate-responsive buildings is that the very design practices that deliver energy efficiency improvements also create conditions that improve the quality of the space and the performance or productivity of the occupants.

How Can Inputs Be Reduced from Within a Building?

That all these activities actually interact through physical feedback has led to energy-saving approaches, such as energy management system (EMS) computers that constantly analyze sensor inputs to reveal the state of each energy system, and that seek to optimize that state and minimize adverse interactions. In this sense, an EMS seeks to manage a building's functions as a single "whole" system.

Research over the years has led to innovations that have dramatically reduced both the energy demand of buildings and the magnitude of internal energy-consuming interactions within them. Equally important has been the research and years of experience that now enable designers to select materials and design building envelopes (shells), windows, and interiors that respond naturally to meet the comfort requirements of their occupants. In this case, the building's own mechanical and lighting systems become backups, "touching up" conditions only when necessary, or over a much reduced range of demand, or for less frequent or shorter times.

Box 1: Definitions

Whole Buildings — The whole buildings concept represents a method of siting, design, equipment and material selection, financing, construction, and long-term operation that takes into account the systems nature of buildings and user requirements. It treats the overall building as an integrated system of interacting components. Thus it is more performance-based than prescriptive.

The concept has also been expanded to include the selection, use, and transformation of resources and materials in the manufacturing and building process, and has been extended to the concerns of building occupancy, maintenance, remodeling, and reuse. The impact of materials choices on resource availability, the environmental impact of construction, and the potential for reuse of building materials after demolition takes these concerns even further.

Passive Solar Design — Passive solar design results in a "low-energy" or "climate-responsive building," one that gains and distributes its energy from the sun either as heat or as light or both, without resorting to mechanical means for collection and distribution. In other words, a passive solar building in and of itself serves the three functions of collecting, storing, and distributing solar energy. It is also a structure that stays naturally cooled through proper shading, natural ventilation, and a choice of building materials that stores heat in the winter and allows for its dissipation in the summer. Using passive design, however, does not mean rejecting traditional mechanical heating and cooling or lighting methods. It simply means the building uses what is naturally available first — and at little to no operating cost.

A properly designed passive solar building features careful interior design to provide for physical and visual comfort of the occupants. Passive strategies also reduce building loads and therefore make the use of photovoltaics and solar water heating more feasible.

This has turned out to be a much more certain way to accomplish energy efficiency than by trying to force an efficient result through the mere use of efficient components and "smart" central energy management systems. Too often we put "smart" brains into architecturally "dumb" buildings, leading to far lower energy reductions than could be delivered by buildings designed and assembled to respond in more comfortable ways internally to changing conditions outside.

How Can Inputs Be Reduced from Outside a Building?

Designing buildings to respond compatibly to the natural environment also means providing opportunities to use environmental resources directly. This includes a host of possible design strategies, such as passive solar heating for residences and small commercial office buildings, solar air preheated through ventilated building skins on commercial buildings, solar water heating, daylighting, and even on-site electricity production.

It also includes a portfolio of possible natural cooling and ventilation techniques, including: shade from nearby trees, overhangs, or porches; light-colored or otherwise heat-rejecting exterior surface coatings; natural cooling ventilation (either fan-forced or through operable windows); nighttime flushing of heat accumulated and stored during the day in building interior mass elements; or evaporative cooling assist. New building component technologies are greatly enhancing these results, including window coatings that block unwanted heat gains in hot climates while still letting in natural light, and radiant barriers to reduce heat radiation to the interior from opaque surfaces.

Daylighting (which uses solar energy for its light, rather than heating, value) is a valuable resource both for diminishing the direct (illumination) and indirect (cooling) energy demands of lighting and for enhancing the quality and beauty of any space and improving the productivity of its users. And finally, exciting developments in photovoltaics (PVs) mean building components — which can be "building-integrated" into roofing, glass, or spandrel panels or can be separate PV arrays that can generate electricity, so buildings can now use the significant surface areas available. This, in turn, can contribute to energy-saving goals, while the buildings themselves contribute economic value to the utility grid as "distributed utility" generators and peak-load shaving resources during the daytime.

Larger commercial buildings can use building-integrated PVs as shading devices in synergy with daylighting control requirements. When any electricity generated is delivered to the building's internal distribution panel, owners can reduce and manage peak load demands and charges caused by the other buildings systems. PV skylights, shingles and roofing tiles, and glass curtain wall components are now also on the market. Transparent PV windows are well along in the development stage in the laboratory.

This description of new technology options for reducing building energy use by capitalizing on available environmental resources at the building site also reinforces the need to take a whole buildings perspective in the application of multiple energy-saving strategies. This is because passive solar heating can deliver up to six times more energy per square foot of area, and solar water heating can deliver up to three times more, than solar electricity. Recent federal and public excitement for "solar roofs" must be tempered by careful analyses to use all building components in combination so that the greatest energy and cost saving potential is realized by the overall, integrated design.

This means that buildings should be designed to be intrinsically low energy users first, to use the thermal energy potential of solar energy second, and then to meet a desired fraction of electricity needs through solar electric devices third. (This is set by a combination of costs and available unshaded surface area.) Experience has shown that a careful integration of passive solar design and daylighting into buildings, however, usually leaves ample space for the production of electricity by solar energy as well. This condition need not cause design incompatibilities, provided that heat, light and electricity from the sun are simultaneous design goals right from the start. And new products just coming on the market today integrate the two functions of electricity production and water or air heating into single devices, which further reduces the building surface area that is required.

The advances in technology described here highlight the complexity of the relationships between building components, energy consumption, and building design. This can lead to inappropriate strategies in final building design due to ignorance of the importance of the interactions. A sure way to guarantee such an unfortunate result is to select components or design elements one by one according to their individual capacity to save energy, rather than to appraise the performance of the combination of all potential measures in their actual interactive roles. This is incredibly difficult and well beyond the capacity of any one designer or even industry group. It requires a large coordinated effort as well as the availability of fast, accurate, user-friendly design tools. Such tools are now beginning to emerge (such as Designing Low-Energy Buildings with *ENERGY-10* software). This need for an integrated approach is behind calls for leadership and the continued involvement of the federal government.

PART II: The Need for Long-Term, Stable Federal Involvement

U.S. energy policy is a consistently underrated element of U.S. economic planning. As a nation, we are more concerned with the short-term or first cost of energy than with understanding the economic implications of energy choices in view of other economic variables (such as environmental impacts and benefits), the employment implications deriving from the resource choice itself, or the implications of these choices on long-term issues of sustainability. And within this neglected area, buildings remain the most underrated aspect of energy economics, and the most unexploited opportunity for improving efficiency.

The Significant Energy Use and Environmental Impacts of Buildings

Table 1 shows primary energy use in the three main energy-using sectors of the U.S. economy from 1973 to 1997. It demonstrates that while energy use in the residential buildings sector increased from 24.1 quads in 1973 to 33.7 quads in 1997, the percentage share of total U.S. primary energy used by buildings also rose, from 32.4% to 36.0%, a figure that includes 66% of total U.S. electricity consumption.[4] The consumption of electricity in the commercial buildings sector doubled in the last 16 years, and is expected to increase by another 150% by 2030.[5] Figure 1 shows how residential, commercial and industrial buildings used energy in 1995. (See Figure 1 on Page 6.)

Table 1: Primary Energy Use, 1973-1997
(In Quads*)

Sector	1973	1986	1990	1995	1997
Buildings	24.1	26.9	29.4	32.1	33.7
Industry	31.5	26.6	32.1	34.5	32.6
Transportation	18.6	20.8	22.6	24.1	25.5
Total	74.2	74.3	84.1	90.7	91.8

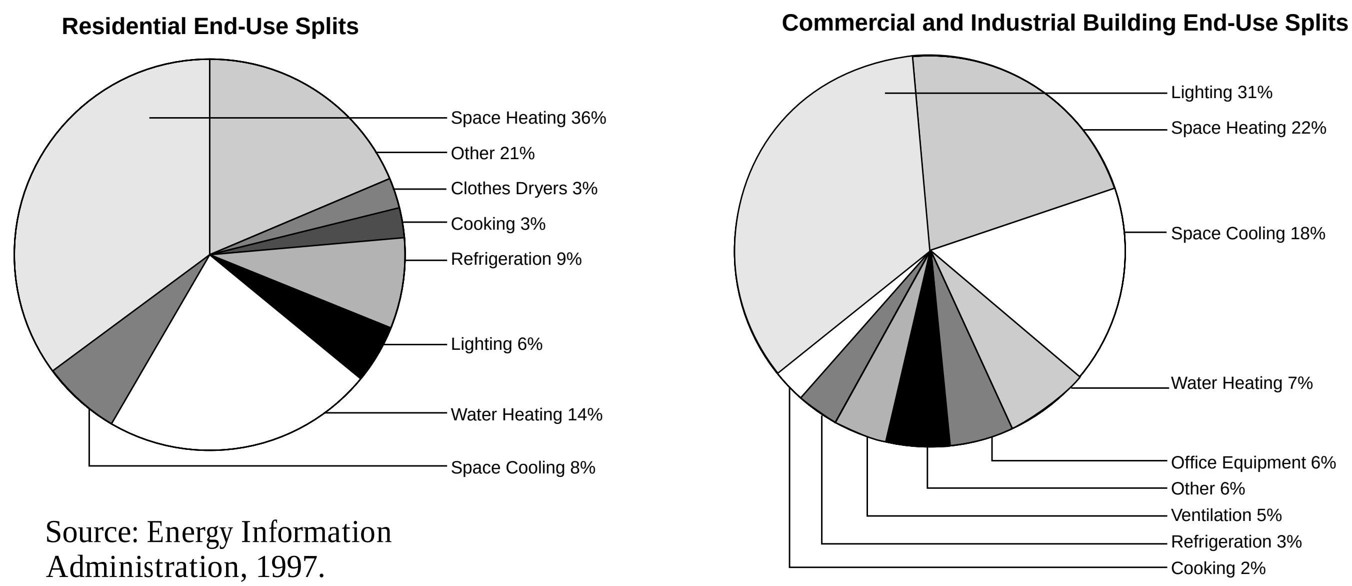
* A quad is one quadrillion British thermal units of energy (a 1 with 15 zeros after it).

Source: Adapted from p. 2.12 of the Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies, “Scenarios of U.S. Carbon Reductions,” U.S.D.O.E., Washington, D.C., 1997. Data are from the 1996 and 1997 energy use estimates of the Energy Information Agency. Rounding of the figures causes a slight discrepancy in totals from listed column values.

[4] The “building sector” is generally narrowly defined to represent only the actual buildings in service in the United States. Energy use of the building sector is either expressed as site energy used or primary energy required to deliver energy services to all buildings presently in service. Table 1 shows the latter. Electricity consumption from U.S. Department of Energy, Office of Building Technology, State and Community Programs, *Core Data Book*, April 30, 1997.

[5] Dr. Ren Anderson, Technology Manager, Building Energy Technology Program, National Renewable Energy Laboratory, private communication.

Figure 1: How Buildings Use Energy
(Percentage of consumption by end-use in buildings, 1995)



Source: Energy Information Administration, 1997.

To go even further, an analysis performed for the American Institute of Architects (AIA) determined that including the energy used to construct the infrastructure needed to operate, service, and maintain buildings brings the share of primary energy consumed directly or indirectly to serve all buildings in the United States to more than 50%.[6]

In addition to being significant users of the nation's primary energy resources, buildings are responsible in a major way for the nation's atmospheric emissions. Table 2 provides the carbon emissions from buildings in 1990 and 1997, showing that buildings are responsible for a considerable share of U.S. carbon emissions. Carbon dioxide is the major greenhouse gas resulting from fossil fuel burning, and is implicated in human contributions to global climate change. In 1995, buildings accounted for 35% of U.S. carbon emissions (11.3% directly from on-site use of fossil fuels, and 23.7% indirectly from building use of electricity), for 47% of the nation's emissions of sulfur dioxide, and for 22% of nitrogen oxides, along with contributing to emissions of carbon monoxide, volatile organic compounds, and other sources of pollution.[7] In addition, on the global scale about 40% of the flow of raw materials into economies each year goes into the construction of buildings.[8] In 1995, between 32 million and 42 million tons of those resources were converted in the United States to construction and demolition waste, an amount roughly equivalent to the total U.S. burden of municipal garbage.[9]

In 1995, 64% of the energy used in buildings was for space heating and cooling, water heating, and lighting — all of which can be reduced in major ways by whole buildings design that reduces each of these in part through the selection of advanced efficiency technologies and in part by optimizing their interactions through design and building material selection.[10]

The flow of resources from construction to demolition adds yet another dimension to the necessity for whole buildings design. This same flow of resources and production of waste consumes large quantities of energy and contributes to the degradation of resources and the environment. Therefore, an appropriate whole buildings policy must minimize these other impacts through careful selection of building materials and

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[6] Randolph Croxton, FAIA, Croxton Collaborative Architects PC, New York, N.Y., private communication.

[7] *Core Data Book*, op. Cit., note 4.

[8] David Malin Roodman and Nicholas Lenssen, *A Building Revolution: How Ecology and Health Concerns Are Transforming Construction*, Worldwatch Paper 124 (Washington, DC: Worldwatch Institute, March 1995), pp. 2

[9] Ibid.

[10] *Core Data Book*, op. cit. note 4.

their interactions, more efficient and less wasteful construction methods, and complete "cradle to grave" (or the newer "cradle to cradle") life-cycle analysis of the building.

Historically, the macro-economics of energy use in buildings has not stimulated much political interest. However, the larger economic arguments become more powerful when they are coupled with the individual financial interests of U.S. citizens. For example, the 1995 energy bill of $531.6 billion spread over 99.1 million households translates into more than $5,300 per household, or on the order of $2,100 for every citizen.[11] And it is the citizens who pay for this, both directly to the utility company and at the gas pump, and indirectly in the embodied energy costs of all goods and services consumed.

An additional reason for the federal government to stand up and take notice of the economic value of the building sector is that the 1995 value of new construction was $396.5 billion, representing 5.5% of U.S. gross domestic product (GDP).[12] Including the $250 billion spent on building renovation brings the total to $646 billion, more than 8% of 1995 GDP. And taking into account the value of material and equipment suppliers, the buildings sector probably accounts directly for 10% of GDP.[13] This is a hugely important industry.

The Significance of "External" Building Energy Economics

Energy economics generally involves comparing costs of British thermal units at the wellhead or by the barrel, or the costs of kilowatt-hours at the electric utility busbar. It completely ignores the efficiency of the dollars spent to deliver the desired energy services. Analysis has shown repeatedly that U.S. GDP receives a considerably greater boost through expenditures on energy efficiency and domestic supplies, for example, than on imported supplies. Investments in energy efficiency and for renewable energy resources also yield a greater return to the U.S. economy from enhanced employment opportunities than investments in domestic fossil fuel resources or nuclear generation do.[14]

Furthermore, expenditures on energy efficiency and renewable energy resources also provide the greatest reduction in costs to mitigate energy-related environmental destruction and to reduce medical costs accruing from human health problems related to energy production and use. But these are all externalities, and hence not figured into the normal equation of energy economics. And yet U.S. citizens and businesses actually pay for these costs, so they are certainly not "external" to U.S. economics.

Table 2: Carbon Emissions in the Building Sector, 1990 and 1997

(In Million Metric Tonnes)

End Use/Fuel	1990	1997
Residential		
Electricity	162	183
Fossil	91	102
Subtotal	253	285
Commercial		
Electricity	150	163
Fossil	59	62
Subtotal	209	225
Sector Total		
Electricity	312	346
Fossil	150	164
Total	462	510

Adapted from p. 2.12 of the Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies, "Scenarios of U.S. Carbon Reductions," U.S. DOE, Washington, D.C., 1997. Data are from the 1996 and 1997 energy use estimates of the Energy Information Agency. Rounding of the figures causes a slight discrepancy in totals from listed column values.

[11] Ibid.

[12] Ibid.

[13] U.S. Department of Energy, "A Strategic Plan for the Office of Building Technology, State and Community Programs," Draft Plan, December 9, 1997.

[14] Many publications document this. See, for example, "Solar, Jobs and California's Economic Recovery," A Report of the Solarcal Council," January 1983; *Solar Industry Journal*, Vol. 3, No. 4, 1992, p. 17; Ed Wood and Jack Whittier, "Biofuels and Job Creation: Keeping Energy Expenditures Local Can Have Very Positive Economic Impacts," *Biologue*, September/December 1992, p. 6. A comprehensive argument is presented in E.B. Goodstein, "Jobs and the Environment — The Myth of a National Trade-Off," a report to the Economic Policy Institute, Washington, DC, 1994.

Equally significant is the failure to recognize the relative inequity of building energy economics in comparison with the economic value of those who work, buy, or learn in buildings. For example, an employer or building owner spends anywhere from 72 to 100 times as much per square foot of conditioned space on an employee as on the energy to condition and light the space for that individual.[15] Any action that improves the quality of that space, such as natural daylight illumination or natural ventilation, and that yields even a 1% improvement in employee productivity or reduction in absenteeism provides benefits equal to saving 70–100% of the cost of energy. That, in turn, can often yield a payback of well under one year for expenditures to reduce building energy use, but with the payback resulting from factors other than energy savings.

We are now learning that low energy and daylit building designs reduce employee absenteeism, increase retail sales, and improve the performance of students in schools, and that these improvements tend to be more on the order of 5–15% rather than just 1%. (See Box 2.) Over the 10-year life of a building, a 10% improvement in employee productivity can be equal in value to the building owner as the entire first cost of the building.[16] These kinds of paybacks are of great importance to employers and store owners, and must be taken into account in the evaluation of whole buildings benefits to society.

Box 2: The Bottom Line of the Whole Buildings Approach[17]

The quantifiable evidence of the economic impact of energy savings and productivity gains of passive solar or low-energy buildings and the whole buildings approach is impressive:

The West Bend Mutual Insurance Company built a 150,000 square-foot facility integrating the shell, interior design, and heating and cooling systems and "environmentally responsive" workstations. The result was a 40% reduction in energy consumption and a measured increase of 16% in claim-processing productivity as a result of employee appreciation of the building design and systems.

Lockheed Missiles and Space Company moved 2,700 employees to a new 600,000 square-foot facility that had been designed for energy efficiency, daylighting, and acoustic and visual comfort. The $2 million extra first cost was recouped in just four years from energy savings of $500,000 per year — but beyond that, a measured reduction in absenteeism of 15% is reported to have actually paid all costs back to Lockheed in the first year.

The Bullocks department store chain purchased a building in San Jose, California, and replaced one-quarter of the roof with translucent tensile fabric to use natural daylighting. The store found that sales in that section of the store increased by 15% regardless of what merchandise was put in that area.

Twenty-three $70,000 rowhouses were constructed in North Philadelphia combining energy efficiency with passive solar design. The reduction in energy use was 63% at no added construction costs.

A 2,530 square-foot, two-story, five-bedroom, factory-built colonial house was built in Falmouth, Maine, featuring energy efficiency, passive solar design, and a rooftop solar electric system. The house was built for $35,000 less than comparable custom homes in the area without these features, while reducing energy use by 82%.

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[15] Building energy use costs roughly $1–1.50 per square foot per year, while employee salaries are in the range of $100–150 per square foot of commercial space. A more precise national average for various building energy, repair and maintenance, and employee costs can be found in Joseph J. Romm, U.S. Department of Energy, and William D. Browning, Rocky Mountain Institute, *Greening the Building and the Bottom Line: Increasing Productivity Through Energy-Efficient Design* (RMI Publications, Rocky Mountain Institute, Drawer 248, Old Snowmass, CO 81654).

[16] These figures are from the early studies by the General Services Administration and IBM. They are reported with further discussion in Lee S. Windheim et al., "Case Study: Lockheed Building 157 — An Innovative Deep Daylighting Design for Reducing Energy Consumption," Leo Daly Associates, San Francisco.

[17] The sources for these examples are notes 15 and 16, along with "Building For a Sustainable America, Case Studies," Burke Miller, American Solar Energy Society, Boulder, CO, 1997.

The Nature of the Buildings Industry

The buildings industry is both structurally incapable and economically unmotivated to take responsibility for the required level of research and strategic coordination that can yield the major societal economic and environmental benefits just described.

In 1995, 163,000 architects in the United States contributed to the work of almost 4 million construction workers in 130,600 commercial building companies, with perhaps close to 300,000 additional individual contractors (without payrolls).[18] And about 90% of the homes constructed were not custom-designed but rather designed in-house by development companies.

Decisions were made by hundreds of thousands of architects, hundreds of thousands of builders, and an even greater number of engineers, plumbers, electricians, and purchasers. They were largely individual decisions, made in an entirely decentralized framework. There is no natural coordination of this kind of activity. The fragmentation is intrinsic to the business, resulting in part from the mostly local nature of the building activity. So how can the buildings industry be expected to pull itself together within a coordinated whole buildings policy framework that produces low energy use and healthy buildings? And why would it even want to, unless it can be shown that there is something in it for the individual players?

The amount that the U.S. construction industry is able to spend on its own R&D also provides evidence of the need for federally supported R&D in the buildings industry. It has been estimated that the U.S. construction industry spends between 0.2% and 0.39% of its sales on R&D, while U.S. homebuilding spends 0.25% of sales on research.[19] U.S. contractors spend 0.00125% of sales on research, while Japanese contractors spend more than 300 times as much (although still only 0.4% of sales).[20] This is to be contrasted with a U.S. industry average R&D investment of 3.5% of sales, and international industry average expenditure on R&D at a rate of 4.3% of sales. So U.S. buildings research is seriously underfunded by the buildings industry.

For these reasons, the federal government will have to play the dominant role in defining whole buildings policy and in supporting whole buildings research. There is simply no other entity that could support the multi-faceted requirements.

The type of support suggested here is being called for by numerous parties. The report from the President's Committee of Advisors on Science and Technology (PCAST) on "Federal Energy Research and Development for the Challenges of the 21st Century" noted that "Public sector R&D funding has the responsibility for addressing needs and opportunities where the potential benefits to society warrant a greater investment than the prospective returns to the private sector can elicit."[21] And a strong case can be made for the constitutional obligation of the federal government to support research that affects the health, welfare, and safety of citizens, which buildings most certainly do.

PART III: The Evolution of the Whole Buildings Policy Framework

The whole buildings policy framework is not new. It has been evolving over a number of years. In 1989, in a report prepared for the AIA/ASCA Research Council, Donald Watson identified the need for a whole systems innovation in buildings as a longer-term initiative to improve the climate for innovation (in the U.S. building industry).[22] That report went on to identify an "applied R&D" need that cut cross the public and private sectors, arising from a "lack of … whole-systems integration and innovation in building."[23] In 1992, Watson stressed an expanded concept of "total buildings performance" to include the building within the context of its larger societal demands and impacts.[24]

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[18] *Core Data Book*, Op. Cit., Note 4.

[19] Figure of 0.2% from Council on Competitiveness, 1992 estimate, noted in Interlaboratory Working Group on Energy-Efficient and Low-Carbon Technologies, "Scenarios of U.S. Carbon Reductions," U.S. DOE, Washington, D.C. 1997, p. 2.11; 0.39% from "R&D Scoreboard," *Business Week* , June 28, 1993; 0.25% from *Asian Wall Street Weekly Journal*, August 12, 1991, p. 10.

[20] *Asian Wall Street Journal Weekly Journal*, op. cit. note 19.

[21] President's Committee of Advisors on Science and Technology, Energy Research and Development Panel, "Federal Energy Research and Development for the Challenges of the 21st Century," September 30, 1997, p. 13.

[22] Donald Watson, "Opportunities to Improve the Process of Innovation in the United States Building Industry," a Report for the AIA/ACSA Research Council, prepared under subcontract supported by the U.S. Department of Energy's Grant "Energy Research Program for the Profession of Architecture" 1988–1989, p. 8.

[23] Ibid., p. 9.

[24] Donald Watson, ed., "Architectural and Building Research Needs and Opportunities in the 1990's," AIA/ACSA Council on Architectural Research, 1735 New York Avenue, NW, Washington, DC, 20006 (published in 1993), p. i.

Federal policy encompassing the integrated systems approach was established in the Energy Policy Act of 1992 (EPAct), when "standards" referred to in the Act were required to "contain energy saving and renewable energy specifications."[25] EPAct was also the origin of the Home Energy Rating System (HERS), which included explicit instructions to "provide that rating systems take into account local climate conditions and … solar energy collected on-site."[26]

This policy was echoed two years later when President Clinton issued Executive Order 12902 on March 8, 1994. In his instructions to federal agencies to achieve a 30% reduction in energy use in federal facilities by 2005 (relative to a 1985 baseline), the President noted that "each agency involved in the construction of a new facility that is to be either owned or leased to the Federal Government shall: (1) design and construct such facility to minimize the life cycle cost of the facility by utilizing energy efficiency … or solar or other renewable energy technologies; … and (4) utilize passive solar design and adopt active solar technologies where they are cost-effective."[27]

Listing passive solar and energy efficiency in the same pronouncement does not necessarily imply a whole buildings integration of the two into federal R&D programs, however. The PSIC report referred to earlier concluded that "the vast majority of programs address buildings as components rather than as integrated systems. Funding for the few whole buildings programs that exist is insignificant in comparison to the breadth of building-related programs in general."[28]

The PSIC report described a few federal programs that use the whole buildings framework. Among these are "Building America" and "Exemplary Buildings" in the Department of Energy (DOE) and the "Energy Star Buildings" program in the Environmental Protection Agency (EPA). Whole buildings research has also emerged internationally in several of the tasks of the International Energy Agency. Probably the closest one for promoting R&D with a whole buildings perspective is Task 23 (1997–2002), "Optimization of Solar Energy Use in Large Buildings."[29]

DOE has also been developing a Buildings for the 21st Century "umbrella" strategy to integrate design, advanced materials and equipment, and construction strategies within a single whole buildings framework. The objective of that strategy is "to instill a whole new way of thinking about buildings … from a 'whole building' or systems engineering perspective."[30] The priority of the program's action plan, developed with private industry, nonprofit groups, and the National Laboratories, was to "help accelerate the adoption of the whole buildings or systems integration approach … and create an over arching whole building energy R&D plan for the U.S."[31] Unfortunately, the Buildings for the 21st Century framework has been an unfunded idea since 1996. The program still does not identify or direct any specific funding toward accomplishing the whole buildings coordination that it proposes. That experience demonstrates that whole buildings is still seen only as an abstract concept rather than a concrete program element.

The programs mentioned here are good starts. But they do not constitute an integrated federal whole buildings program. They are at best very modestly funded and are not viewed as a cornerstone of coherent federal policy. Given these small first steps, where do we need to go?

Certainly a major role of a whole buildings approach will be to serve as a coordinating framework for integrating the multitude of federal buildings programs and building a bridge to cooperative and complementary R&D programs by industry and the private sector. But if whole buildings is to bring about change, it must be elevated to a high level of administrative responsibility and respect. Whole buildings must secure a mandate simultaneously from the federal government, industry, and private sector research centers to coordinate, enhance, supplement, complement, and fill in gaps that are still barriers to systems integration in research and practice.

No substantive advances will be made in any of these directions without the emergence of whole buildings by common consent as a program that is essential to all others. Although this might appear to be an almost insurmountable task, there are several concrete steps that can be taken to implement a federal policy based on a whole buildings approach.

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[25] The Energy Policy Act of 1991, Public Law 102-486, Sec. 305(a)(2).

[26] Ibid., Part 6, Sec. 271(b)(4).

[27] The Presidential Executive Order 12902, "Energy Efficiency and Water Conservation at Federal Facilities," Part 3, Sec. 306, March 8, 1994, Federal Register 59, No. 47, March 10, 1994, pp. 11463–71.

[28] PSIC, op. cit. note 3.

[29] Description extracted from the IEA Tasks Web page, www.arch.vuw.a.c.nz/iea/research_tasks.html

[30] Description extracted from the Buildings for the 21st Century Web page, <www.eren.doe.gov/buildings/bldg21c.html>.

[31] Ibid.

PART IV: Recommendations for an Integrated Federal Whole Buildings Policy

Describing an important need and obvious benefits does not produce change, unfortunately. The federal bureaucracy's resistance to change is legendary. But it is also important to note that the buildings industry resists change too, simply because it has little economic incentive to make changes that do not relate directly to increased sales. Of course, the most promising way around these barriers is to generate demand for better buildings.

It is also important to underscore here that in a whole buildings perspective the definition of R&D itself extends well beyond the laboratory to encompass the ancillary activities, such as training, education, and market transformation, that transform R&D into productive contributions to society. In this way, the whole buildings approach not only integrates the building components and materials with design and operation, it also unites the present with the future and combines the myriad R&D and market conditioning programs of the federal government.

Where could the central direction — "the nerve center" — of this grand whole buildings synthesis activity even be housed? Can one government entity coordinate the work of others? Certainly there are a number of committees and panels already charged with this responsibility. But the PSIC report questioned the "degree to which the efforts of groups such as the National Science and Technology Council … can be translated to concrete program direction for the numerous disaggregated federal buildings programs."[32]

Should coordination, then, be the work of an industrial coalition, since industry will reap the rewards of the programs? But how could such an entity coordinate federal programs? And judging from the little R&D funding by the buildings industry to date, the federal government would still need to be the primary source of support for this new activity. Whatever the answers to these questions are, it is obvious that some entity must take charge of coordinating and integrating federal buildings programs.

The five objectives and strategies in this section can represent a beginning to the adoption, successful introduction, and continuing effectiveness of a national whole buildings policy. They should serve as the foundation for a coherent national strategy that is based on the whole buildings concept, that integrates R&D with market conditioning, and that coordinates the various federal buildings programs.

Establish the Whole Buildings Framework as a Cornerstone of Policy

A whole buildings approach needs to be explicitly articulated and acknowledged as the cornerstone of any national buildings energy or sustainable design policy. This articulation needs to come from the highest possible levels of government, and should include an acknowledgment of the importance of buildings R&D to furthering all aspects of U.S. economy, education, environment, and quality of life. And since buildings constructed today have lives of 50–100 years, a national whole buildings strategy must also recognize that new buildings should provide the conditions for future sustainability in their design, operation, energy requirements, maintenance, and potential reuse of their construction materials. This would represent a new mode of thinking about buildings.

This is perhaps the most difficult objective because it requires a fundamental change in the current mind-set on federal buildings policy and R&D management. Furthermore, the change must be made from the top down. Currently, the scant programmatic focus given to addressing buildings as whole integrated systems is an after-thought or add-on. From the Cabinet level on down, this orientation must be changed so that the whole buildings perspective is the locus from which all federal buildings policy and program direction emanates. Several precedents at the federal level indicate that such a fundamental shift is possible.

Federal policymakers should be commended for recently establishing a programmatic model of the type of program and orientation that is needed. The newly created Partnership for Advancing Technology in Housing (PATH) program, administered by the Department of Housing and Urban Development (HUD), is an interagency collaborative with the private sector. PATH aims to improve the cost, quality, comfort, and environmental impacts of all new housing by the year 2010 by getting improved technologies into the marketplace.[33] The program is now in the process of formalizing its plan of action for achieving that goal. What is already apparent, however, is that PATH will be the most holistic buildings program available — both in terms of addressing buildings as whole, integrated systems and for its interagency/private-sector strategy for achieving its goals. The program's one limitation is that it addresses only housing. It does not address commercial or institutional buildings.

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[32] Joel R. Hochanadel, *Overview of the Building Technologies Programs in the Federal Sector*, Analytical Summary Edition, prepared for the Passive Solar Industries Council, Washington, DC, February 20, 1998.

[33] Ibid., Compendium Edition, pp. 45-46.

Hints of the necessary change in focus are also found at DOE. As already noted, DOE's Office of Building Technology, State and Community Programs recently adopted the Buildings for the 21st Century umbrella philosophy to guide its building programs. While it is still too early to evaluate the impact this presently unfunded program will have in stimulating fundamental changes in actual R&D program perspectives and public policy, it potentially provides a foundation for taking the whole buildings case to higher levels of the federal government.

Beyond these initial steps, an informal or ad hoc coalition of buildings industry interests (such as builders, architects, designers, engineers, financiers, and realtors) and renewable energy and efficiency industry representatives should be established on the model of the Sustainable Energy Coalition. The coalition could be spearheaded by the Passive Solar Industries Council, which is already a coalition of diverse building interests with a whole buildings mission. The first priority of the coalition should be to implement a communications and advocacy campaign aimed at the administration and Congress. The campaign should target these audiences from the top down. That is to say, the focus should begin at the Office of the President (and relevant bodies such as PCAST, the National Science and Technology Council's Committee on Construction and Buildings, and so on).

In terms of Congress, the coalition should work with the House Renewable Energy Caucus and others in order to use existing relationships between advocates and law makers. And it should target the leaders and members of the Interior and the Energy and Water Appropriations Subcommittees in the House and Senate to make sure that these policy recommendations are implemented. In addition, the coalition should work with the Military Construction and Treasury, General Government, and Civil Service Appropriations Subcommittees in order to affect policy over spending on military and government construction projects and building operations. Likewise, the coalition and other advocates should focus on federal policy through the Senate Energy and Natural Resources Committee and the House Commerce and Science Committees.

The aim of the coalition campaign should be the incorporation of the whole buildings focus in the mission statements, policies, and programmatic strategies of all federal buildings–related bodies, committees, and programs. This should be the first step of on-going relationship-building activities. The coalition should then work with the administration and Congress to ensure that this philosophy is followed up with concrete program direction. Finally, the coalition should ensure that while federal programs recognize buildings as integrated systems, federal policy should also view R&D programs as integrated systems.

Fund Collaborative, Fundamental, and Applied Research

The United States should support a coordinated, coherent program of fundamental and applied research in materials, components, design tools, and monitoring techniques in the context of whole buildings performance. Research today is product-specific and does not adequately address whole buildings performance and demonstration. New programs need to be defined and implemented that in particular consider the interactive effects of all technologies within the building and with the physical and economic environments that support them. New and emerging buildings technologies that facilitate better interactive performance are to be especially encouraged. And, as argued earlier, a coordinating agency or entity needs to be defined and empowered that will facilitate both the conception and synthesis of whole buildings R&D across all public and private sectors, supported by new analytical tools that embrace the interactive roles of buildings as elements in the U.S. economy, environment, and sustainable future. Although this could be a new agency, it might be better to empower an existing agency, given greater authority through the President's leadership, to provide more concrete program direction and review and to handle the coordination between agencies.

Meeting this objective requires a two-pronged strategy that addresses two major flaws in current federal buildings policy. The first is the minute level of funding for buildings systems integration R&D programs. The federal government at the moment underfunds both basic R&D (such as basic building physics studies) and applied research (such as development of analytical tools to facilitate better interactive performance) in the area of whole buildings.[34] The second flaw in federal policy to be addressed is the lack of coordination of R&D activities and program direction among the myriad buildings-related programs.

As indicated earlier, the whole buildings approach is a powerful tool in the policy arsenal for achieving economic, environmental, and national security goals. To achieve this return on investment, the federal government has to take the leadership role and make the investment. The few federal programs that develop systems integration technologies (such as DOE's Best Practices program) or that aim to create high-performance buildings using a whole buildings perspective (such as DOE's Exemplary Buildings program or EPA/DOE's

34 Ibid., Analytical Summary Edition, pp. 17-18.

Energy Star Buildings program) receive scant funding. The term scant is used here in comparison to four benchmarks: the potential of these programs to reduce building energy costs and environmental degradation, the appropriateness of the federal role in this area, the comparison with other federal building component programs that take more of a “shotgun” approach, and the contribution of buildings and construction to annual GDP.

As a start, the federal government should increase funding to research basic building physics, particularly the areas of thermal storage, perimeter daylighting, performance values of “green” materials, and convective airflow. Furthermore, it should fund research that supports existing voluntary, market-driven, industry-based programs (such as the Home Energy Rating Systems Council’s “Guidelines for Uniformity,” the U.S. Green Buildings Council’s LEED Rating System, and Edison Electric Institute’s E-Seal program) that incorporate whole buildings interaction, indoor air quality, water quality, consumer waste, passive solar design, and so on. However, this support should be cooperative and supportive rather than being set up as competing programs.

The federal government must also provide adequate funding to programs that implement the whole buildings concept (such as EPA/DOE’s Energy StarBuildings) while ensuring that other new buildings-related initiatives (such as the Million Solar Roofs program) that receive funding adequately address the whole buildings perspective. Probably most important is the need for funding to be stable (multi-year) and less subject to the changing winds of partisan politics. Large fluctuations in the past have not only sent mixed messages to industry and markets, they have also disrupted on-going R&D activities. The “buildings coalition” should conduct the advocacy activities to support funding for these programs.

Some entity must be given responsibility for ensuring that a coordinated federal buildings R&D policy is implemented at the programmatic level. The federal government administers buildings R&D and related programs at numerous federal agencies — ranging from DOE, the National Institute of Standards and Technology (NIST), HUD, the General Services Administration, and EPA to the Department of Defense and even Health and Human Services. Research is conducted by private companies on their products and materials, at national laboratories, at universities, and by state energy offices across the country. These activities must be coordinated to avoid duplication and to ensure the cross-pollination of research efforts. More important, the research must be coordinated to ensure that individual programs are organized by a whole buildings philosophy.

The federal entity chosen to coordinate federal buildings activities should have as its first task the responsibility for designing an overall, multi-year specific action plan that outlines federal buildings R&D strategy. This would be a comprehensive blueprint for a coordinated, whole-buildings-based R&D agenda. The second task would then be to assign the various parts of the overall agenda to the federal agencies (or in some cases to private researchers) that will be responsible for conducting them. While at first glance it appears that these assignments have already been made, they have not been done through a coordinated federal strategy, nor framed within this integrated concept.

The federal agency given responsibility for coordination will have to have authority commensurate with its responsibility. In other words, federal programs must be accountable to the entity for carrying out the coordinated policy. This will necessitate a level of administration and oversight that cannot be achieved by a committee that meets only once a year and has no institutional resources of its own.

At the same time, this responsible agency must incorporate input and representation of the various federal programs as well as the private sector. Existing bodies already incorporate such input while operating at a high level in the administration. Therefore, it should not be necessary to create a new institutional entity; rather, it will require empowering a standing entity so that federal programs are accountable to it.

For example, the Energy Research and Development Panel of PCAST recently released a report with recommendations of general policy and funding for a host of energy R&D programs. This type of activity could serve as the foundation for coordination of federal buildings policy and program direction. In this example, the President’s Office of Science and Technology Policy could be charged with assessing the degree to which agencies meet the policy recommendations and program direction of PCAST. The new coalition described earlier and its individual members should be charged with working with the administration to implement the integrating activities of the entity and secure congressional acceptance of the concept.

Achieving these goals might at first glance appear to be impossible. Just coordinating the large number of federal buildings programs would be no small task. Yet the human genome project provides a model for such a daunting undertaking. Research on how to map the genetic make-up of the human body is being conducted by organizations worldwide for a period of 10 years or so. The World Health Organization is coordinating that research and collecting the fruits of individual research efforts. This monumental task shows that coordination of massive research undertakings is possible.

Support Accurate Estimation and Verification Efforts

For optimally efficient buildings to become the norm, consumers, designers, builders, and manufacturers must be able to estimate whole buildings performance confidently and within acceptable real-world deviation limits. In the energy context, designers must have continued verification and demonstration that buildings designed and constructed according to whole buildings system conceptions are cost-effective across a variety of climates and building types in both new construction and retrofits. Consumers require this information before making their choices.

Software for this purpose must be developed that is fast, inexpensive to use, and accurate and that permits easy analysis of building envelope and component alternatives, including the effects of their interactions. Such software must also serve as design guidance tools, setting priorities on strategies that, in interaction with other approaches, deliver the highest or most cost-effective return for the package. And these must be supplemented by objective, well-documented case studies and demonstrations to validate computer models, to provide monitored data on actual building cost and performance, and to give confidence to both consumers and lending institutions. The software might also be licensed by the federal government to private software companies to market and sell, in order to help build the public/private bridge and to bring to bear the great skills of private software developers.

The type of information needs described here are crucial to winning acceptance for whole buildings technologies and practices by consumers and lending institutions that are being asked to invest in efficiency and renewable energy. Therefore it is critical that the federal government continue to support existing programs that are developing and demonstrating prediction and verification tools and supplement them in areas that are currently not addressed. Many agencies, national labs, and private-sector groups are developing their own tools to solve individual problems.

DOE could continue to be the lead agency and help coordinate all these entities and provide supplemental support for the programs, which would require separate funding. In September 1995, the Office of Technology Assessment (OTA) noted in a report that building on the field performance data collected over a decade ago would have considerable value. OTA also recommended commercial demonstrations for builders and users and increased support to enable the rapid development of design tools.[35]

This could be achieved by accelerated DOE support for continued development of "Designing Low Energy Buildings/*Energy-10*" software to make it more robust and to include additional technologies. This software allows building designers to measure the interactive and complex effects of energy-consuming and -saving measures and to design options. A number of well-known technologies (including PVs, natural ventilation, exhaust air heat recovery, evaporative cooling, and solar hot water heating) have yet to be incorporated into the software because of a lack of funding. DOE should also continue the Exemplary Buildings program, which is one of the few design-oriented demonstration programs currently in existence. Another area for continued federal programming is the development of short-term energy measurement tools. Additionally, the Home Energy Ratings Systems Council Guidelines, developed in a strong industry-government partnership, should be considered a key measurement and verification tool.

Apart from the individual contributions to improving the nation's building stock, prediction and verification programs provide a foundation for other policy tools. For example, the guidelines developed by the HERS Council are now languishing "on the shelf." They should be the measurement and verification basis for any proposed federal tax cuts for building energy efficiency. The new coalition should work with DOE and the HERS Council, the Treasury Department and Internal Revenue Service, the Senate Finance Committee, and the House Ways and Means Committee to make this a reality.

Embrace Training and Education

Individual, community, state, and federal building decisionmakers must be introduced to the concepts and benefits of whole buildings policy, while architects, engineers, and building operators must be explicitly trained to understand how to pursue their trades in the context of whole buildings performance. At the very least this will require the introduction and widespread dissemination of user-friendly whole buildings design tools that can lead decisionmakers and designers through optimal design selection on the basis of immediately available estimates of buildings performance that embrace all natural and mechanical system interactions. But the aim of this should be higher, with the goal of accomplishing a real market transformation by changing the very basis on which buildings are evaluated and decisions made.

[35] U.S. Congress, Office of Technology Assessment, *Renewing Our Energy Future*, OTA-ETI-614 (Washington, DC: U.S. Government Printing Office, September 1995).

Hand-in-hand with efforts to integrate programs, fund activities, and develop the appropriate design, measurement, and verification tools goes the need to train the building trades on the concept of whole buildings and the accurate, fast tools available to put the concept into practice. These training needs directly address the market transformation issue described earlier. At present, typical U.S. architectural and engineering education programs do not stress building technologies, materials, or components, let alone whole buildings energy performance, and therefore cannot be considered to have a holistic perspective.

To address this need, DOE and other federal agencies must implement education, training, and technology transfer programs that will help stimulate a transformation of the marketplace. In effect, these activities will move the technologies and practices developed through federally supported programs into the marketplace where people can reap the environmental, economic, and national security benefits.

DOE, EPA, and other agencies must look to industry and private models in continued support of combined national technical conferences. Organizations such as the Energy Efficient Buildings Association now open their conferences to similar organizations, such as the HERS Council and PSIC, in order to provide a broader picture for attendees. Similarly, the American Solar Energy Society's annual national conference, the annual Passive Solar Conference, the American Institute of Architect's Committee on the Environment, the American Society of Mechanical Engineers, and the Solar Energy Industries Association's Soltech conference now have a combined, coordinated national conference every four years that provides a forum for engineers, architects, industry members, and federal R&D professionals to share information and move the fruits of federal R&D into the consciousness of private practitioners.

In addition, the federal government must practice what it preaches by providing a more robust program of design assistance, peer reviews, and training for the design and operation of federal buildings. Furthermore, DOE's national laboratories, along with the laboratories at NIST and the U.S. Army Corps of Engineers, must be required to identify "users" or audiences for their research before beginning any project, and then be encouraged to continue and enhance technology transfer programs and partnerships with private industry. The high-level federal entity charged with coordinating federal buildings R&D should also be charged with evaluating the progress of agencies in fostering this cooperation. For example, federal agencies and laboratories could be evaluated based on the number of CRADAs (Cooperative Research And Development Agreements) and licensing agreements they transact.

Stimulate Demand Through Awareness

Since the supply of nonrenewable fuels is subsidized by the federal government, for whole buildings designs that integrate efficiency and renewable energy sources to compete fairly in the marketplace, consumer demand for these applications must be stimulated. Consumers (broadly defined as builders, building owners, homebuyers, lending institutions, and state and federal building managers) must be made aware of the documented and measurable benefits of energy and cost savings, quality of living and workplace, and resultant quality of life and productivity of employees when buildings are designed according to whole buildings principles. Such a campaign must include sophisticated and pervasive marketing programs, imbedded into the very methods by which the building industry reaches its customers and delivers its services. These programs, too, must be assembled as a "system" of related market-development activities, rather than random "shotgun" programs that stand alone, and that may not be able to produce results by themselves.

As does the last recommendation, this addresses the need for federal policy to incorporate market transformation as an inherent accompaniment to R&D activities. It is safe to say that consumers, lenders, realtors, and in many cases builders are unaware of the cost-effective buildings technologies that are currently available. The federal government has historically emphasized strategies that attempt to "push" technologies out of the laboratories into the hands of industry who will commercialize and "sell" the new technologies. In the case of buildings technologies, the federal government must also adopt a "pull strategy," whereby consumers are educated on the availability and desirability of these technologies so that they begin to demand them in the marketplace.

EPA/DOE appears to have the mandate and the funding to implement large-scale public awareness campaigns for Energy Star Buildings, but these may still need to be addressed as just one part of the overall program. Consumers should be reached through targeted public service announcements and local events and demonstration programs (like the American Solar Energy Society's National Tour of Solar Homes). In addition, EPA should continue its efforts to gain the support of builders, realtors, appraisers, and financiers for its program.

While the federal government is somewhat limited in its ability to advertise and promote its own programs, nonprofit organizations and trade groups are not so constrained (except by lack of resources). The new coalition described earlier should implement a public information campaign (in tandem with its campaign targeting the administration and Congress) to make the case to consumers and to those with a role in building construction, finance, and operations. Funding for these activities could be obtained from government agencies, from contributions from the coalition members, and from the foundation community. As is often the case, these activities are not without precedent. Groups such as the Sustainable Energy Coalition, the Safe Energy Communication Council, and the Communications Consortium have implemented similar campaigns covering other technologies.

PART V: Conclusion

Any attempt to reduce the flow of resources, waste, energy use (including dependence on foreign sources of energy), and environmental pollution must look hard at the accessible and economic opportunities afforded by buildings. Similarly, no conversion of U.S. practices and economy to a path leading to long-range sustainability can be accomplished with new buildings carrying a burden of excessive and inappropriate energy and resource use for the next 50–100 years. Only a concerted effort to put in place a long-term, coordinated federal commitment can pull together the many individuals, organizations, and agencies that need to make a whole buildings approach the central focus of planning.

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