The Role of Building Life-Cycle Information Systems in the Delivery of Energy Services*

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1 Overview

This paper is concerned with the role of building life-cycle information systems in the delivery of end-use energy services (i.e., heating, ventilating, air conditioning (HVAC), and lighting) to commercial buildings. The paper is comprised of two parts. First are general remarks, motivating the importance of this topic for the proposed NIST Advanced Technology Program on Information and Telecommunications Technology for Utility Applications. The second part of the paper details the research agenda on this topic of the recently initiated Building Performance Assurance Program at Lawrence Berkeley Laboratory and the opportunities we see for cooperative research programs.

Part I
General Remarks

2 Introduction

Traditionally, utilities supply energy inputs (natural gas and electricity) to customers. These customers, residential households and commercial building operators, transform these energy inputs

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Most discussions of the potential impact of the National Information Infrastructure (NII) on utility operations, e.g., (Olken, 1994), have focused primarily on the impact of the NII on traditional utility delivery of energy inputs (especially electricity), e.g., transmission and distribution automation, automatic meter reading, real-time pricing, remote operation of cogeneration plants, and load management. These discussions have been concerned with internal utility operations, and utility-customer interfaces.

In contrast, here we are concerned with the impact of the NII on the conversion of energy inputs into end-use energy services in the commercial building sector. Our discussion mainly concerns customer information systems rather than utility information systems. Furthermore, whereas most other discussions emphasize only the operational phase of the building life cycle, here we wish to consider the impact on the entire building life cycle, i.e., design, construction, commissioning, operations, and maintenance.

3 Energy Services Sector

One of the hallmarks of advanced market economies is the outsourcing of many service functions which were traditionally performed internally by households, landlords, or firms. A commonplace example concerns food preparation, which has seen a dramatic rise in consumption of processed (rather than raw) food and restaurants meals. Among firms, outsourcing of information processing services, distribution services, food preparation (catering), manufacturing, janitorial, security services, and supply (stores) management services is increasingly common. Such large diverse service sectors are characteristic of advanced market economies.

Similar outsourcing of direct services is occurring in the commercial building end-use energy services sector. Instead of building owners operating and maintaining their HVAC systems and building energy management control systems (EMCSs) these functions are being contracted out to other firms.

The economic rationale for this outsourcing of direct end-use energy services varies. There are advantages of specialization and of economies of scale in servicing multiple buildings in a metropolitan region. There may also be financial advantages, in that energy service companies may have better access to capital markets than individual landlords (in part because they can reduce investor risks by aggregating a number of projects together in a manner similar to mortgage securitization). Flat rate maintenance contracts for equipment can also be seen as an type of insurance contract for equipment failures. Other forms of risk transfer, e.g., with respect to price movements of fuels, can also be arranged. The increasing complexity of HVAC systems and EMCSs encourages the contracting out of maintenance to specialized firms.

Indirect services for the commercial building end-use energy sector, such as designing, installing, integrating, commissioning, financing of HVAC, lighting, and EMCS systems are also a growing sector.

The energy services industry is comprised of a number of different types of firms: equipment vendors, contractors, architectural and engineering firms, and energy service companies (ESCOs). Retrofit ESCOs typically market, manage, finance, and (sometimes) operate building energy retrofits. (Often referred to simply as ESCOs). This segment of the industry is estimated at \$500M - \$800M annual revenues. Total annual expenditures for utility demand side management programs are about \$2.4B.

Full-service ESCOs supply end-use energy services (HVAC and lighting) for building operators, i.e., they actually operate and maintain the building HVAC and lighting equipment. Such end-use energy services may be supplied by a number of different types of firms: building management firms, facilities management firms, building maintenance firms, HVAC and control system vendors, retrofit ESCOs, and utilities. Outsourcing of end-use energy services is presently more common in France than in the United States.

Utilities are well positioned to compete in the end-use energy service market by virtue of their extensive telecommunications and service infrastructure, ready access to capital, financial stability, experience with Demand Side Management (DSM) programs, and reputations for reliable service.

Aside from the financial opportunities of supplying end-use energy services, utilities may choose to enter the end-use energy service sector in order to preserve market share for their traditional products (gas and electricity), as end-use energy service firms can increasingly choose among competing energy suppliers.

4 Information Processing Technology

The energy service sector is currently undergoing major changes because of rapid improvements in information processing technology. The cost of electronic sensors, electronic motor and lighting controls, communications, and computers is falling rapidly compared to the cost of labor and energy inputs. Hence, there are large economic incentives to substitute information processing technology - in the form of better building design, variable speed fans, lighting dimmers, and sophisticated building energy management control systems - for manually operated controls and energy inputs.

In particular, declining costs for communications make remote building monitoring and control increasingly attractive for many small and medium-size building owners. Remote building operations affords significant economies of scale in labor costs for staff to monitor the buildings and diagnose problems. Note that remote building operations may be undertaken either directly by large owners of multiple buildings, or by specialized service firms.

Remote building monitoring and control of multiple buildings in a metropolitan region also offers the prospect of creating a database of similar buildings under similar weather loads which can be used to benchmark the performance of individual buildings.

Experience indicates that such sophisticated HVAC and EMCS systems often do not yield the anticipated savings without careful commissioning of the buildings (initial testing and tuning) and close attention to operations and maintenance.

Virtually all buildings have serious problems associated with poor start-up and checking. Close scrutiny of energy monitoring, audits, and operations & maintenance (O&M) surveys reveal opportunities for efficiency improvements that go unnoticed by operators and owners. Several studies from the Pacific Northwest suggest that nearly every building has significant problems when building performance is assessed by a commissioning agent's functional testing (Piette et al., 1994, and Yoder and Kaplan, 1992). One recent LBL study of utility funded commissioning of energy-efficiency measures found that the life-cycle savings from commissioning exceeded the costs of commissioning in 11 of 16 case study buildings (results will soon be published). Commissioning makes sense and saves energy.

It has been well documented (see, for example, the work of Herzog and LaVine, 1992, or Claridge *et al.*, 1994) that 15 percent cost savings on whole building energy are possible with improved operations and maintenance. These savings are due to fixing equipment in need of maintenance, better scheduling, less waste, more optimal operation, better tuning and calibration, and more use of existing equipment such as an EMCS.

5 Utility Interest

As described above, institutional changes in the commercial end-use energy service sector (i.e., increased outsourcing), changes in utility regulatory environment, and technological changes have combined to encourage utilities to enter the commercial building end-use energy services sector.

As we shall see in the second part of this paper, building life cycle information systems greatly facilitate the efficient delivery of end-use energy services. Hence, this topic is of clear interest to those utilities (and other firms) which offer end-use energy services.

However, building life-cycle information systems are even of interest to utilities which do not plan to provide end-use energy services. Such systems can supply utilities with information for: market research, planning transmission and distribution facilities, evaluation of demand-side management (DSM) programs, and short term load forecasting.

Also, customer interest in more sophisticated electricity price tariffs, such as real-time pricing, clearly hinges on the existence of some control system (manual or automatic) at the customer site which can respond to price changes. By facilitating the adoption of sophisticated building energy management control systems, building life-cycle information systems help create a market for real-time priced electricity.

6 Public Policy Issues

The public policy implications of this topic arise primarily from the prospects of improved energy efficiency in commercial buildings. Studies at LBL and elsewhere have suggested annual savings in energy costs of 25 per cent due to building design improvements, 15 percent savings from improved building commissioning and similar savings from closer attention to building operations and maintenance. These savings are not simply cumulative, since the studies were done on different buildings. Since the commercial building energy sector is about \$85B annually, this suggest a potential annual savings of \$15B to \$30B in energy costs, partially offset by some additional costs of improved design, commissioning and operations and maintenance.

Improved energy efficiency yields a number of public policy benefits: reductions in trade deficits, improvements in energy security, reductions in air pollution, reduction in carbon dioxide production (and global warming), and improved economic competitiveness.

Another public policy issue is the prospect of improved indoor air quality via more effective monitoring and control of ventilation systems.

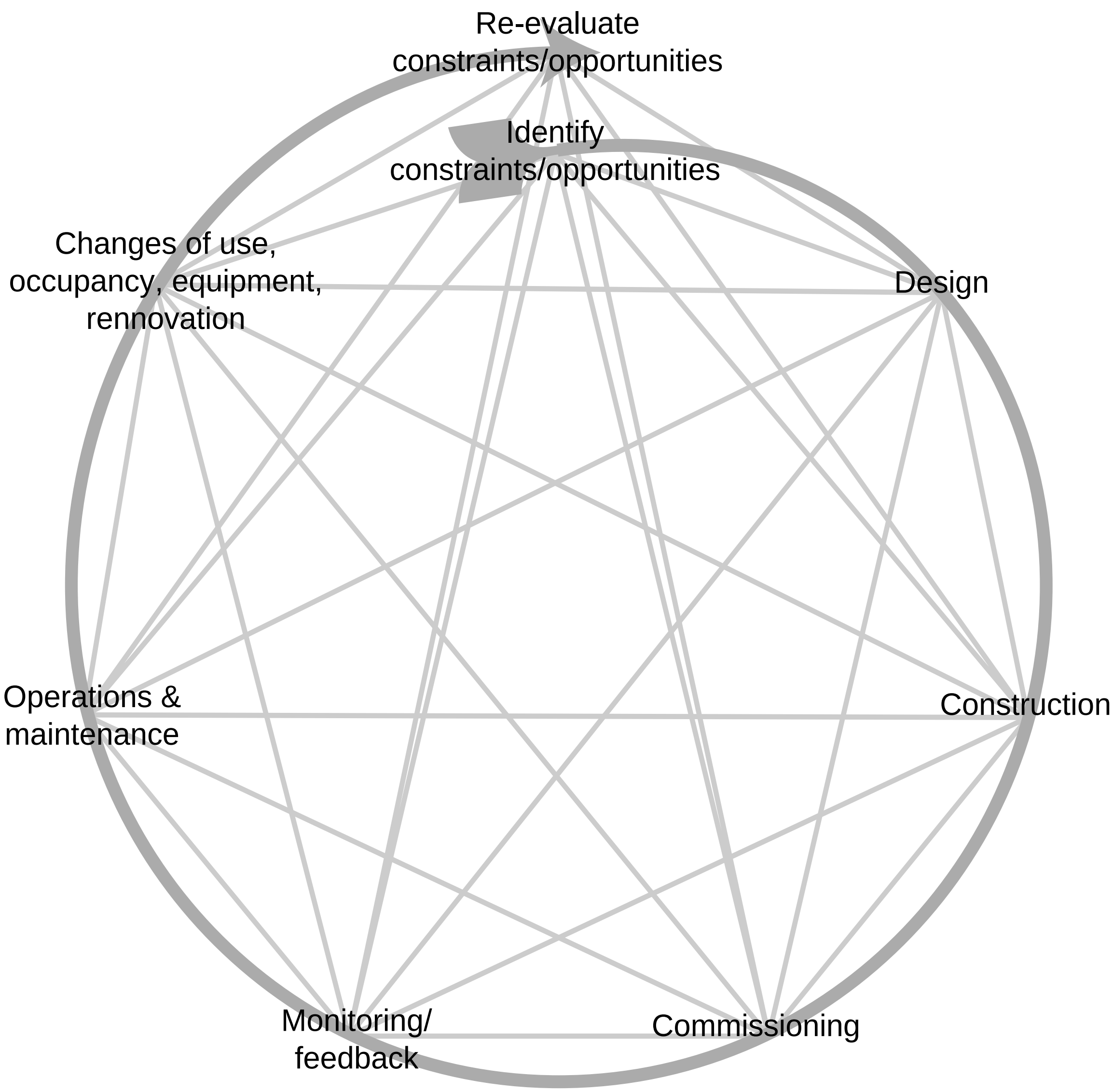

Figure 1: Ideal Building Life-cycle Information Flow Diagram

Part II
Research Agenda

In this part of the paper we discuss a research agenda for building life-cycle information systems in the delivery of end-use energy services in the commercial building sector. The Building Performance Assurance Program has recently commenced at Lawrence Berkeley Laboratory.

Despite significant advances in building technology and the promulgation of tighter building codes, buildings consume one third of all energy used in the United States at a cost of $200 billion/year, half of which is wasted compared to what is cost-effectively achievable. Assuring total building performance (health and productivity, as well as energy) ought to be a national goal and priority in an increasingly competitive world. Achieving this goal requires a careful reexamination of the process by which buildings are designed, built, and operated. A life-cycle perspective on how information is managed in the building sector provides useful new insights and opportunities for achieving performance potentials. This announcement describes an internally funded, fast-track project to explore these issues, with the goal of then creating public-private partnerships to develop workable, cost-effective solutions to assuring building performance.

7 PURPOSE

Commercial building performance consistently falls short of its potential, with costly results to people and institutions in the US. Energy use in commercial buildings accounts for $85 billion per year, more than half of which could be saved if the experience in a small number of unique, carefully designed and operated buildings could be widely replicated. Occupant health and comfort suffer in poorly conditioned spaces, resulting in lost productivity and a growing incidence of multi-million dollar lawsuits. However the outlook is not entirely bleak. Individual buildings have been designed, built and operated to use less than half the energy of typical design practice today, and with levels of comfort, health and productivity that exceed todays norms.

The technical prescription to assure better building performance is conceptually simple: 1) Using computer-based design tools, develop integrated building systems that meet occupant comfort and performance needs at less than half the energy intensity of today's new buildings; 2) Construct the building as designed; 3) Employ sophisticated, but cost-effective commissioning procedures – a series of controlled subsystem functional tests during the startup of a newly constructed building – to verify that the building initially operates as designed; and 4) Implement appropriate operations and maintenance procedures to ensure that ongoing operation continuously meets occupants needs and building efficiency criteria. In most buildings this consistent attention to assuring proper building performance throughout the life cycle of the building is never achieved, with predictable harsh economic and human impacts – billions of dollars of energy wasted, millions of hours of productivity lost, unnecessary health care costs, and rising insurance premiums to guard against financial risks. If only a small amount of these resources were invested in a different paradigm, much of the potential could be achieved.

Public and private efforts are underway to develop some of the tools needed to design, commission, and operate buildings more efficiently than in the past. But these piecemeal activities exist in a perverse, compartmentalized, cost-conscious, risk averse environment that limits their effectiveness. Anecdotal evidence suggests that 25% of all building professionals time is spent simply managing the cumbersome process of information flow between the various actors involved in each phase of the life cycle, and between stages in the building life cycle. Even with this huge investment, the results are poor – little of the design intent, data, and documentation generated in the design phase (Figure 2) is available months later in suitable form to the commissioning agent, who must then recreate the data needed for proper commissioning. These costs are then built into the fee for commissioning, which becomes an impediment to the widespread use of commissioning procedures. The building operators are unlikely to inherit much of the designers' or commissioners' knowledge base — they are on their own to develop by trial and error the procedures that will result in proper building operations. With unlimited funds, any of these obstacles can be overcome. In the real world, these disconnects and inefficiencies in the information flow throughout the life cycle are a primary cause of the failure to meet performance targets.

While the popular press discusses the Information Superhighway, the building profession is bogged down in the mud of an unpaved, unmapped back road. Traditionally, communications during the building life cycle are transmitted via voice, written documents, and annotated drawings. The development of computer-based analytical tools, such as those used for structural or energy analysis, has generated the need for a variety of distinct representations of the building. The cost and bulk of the building documentation, the difficulty of abstracting information for analyses and the difficulty of understanding engineering specifications have created costly barriers to further automation of the flow of building information throughout the life cycle. Vast amounts of useful information, such as equipment specifications or design objectives, are "lost" in subsequent phases of building operation because there is no effective archiving and transferring critical information. Decision makers in each stage are different and disconnected from each other, allowing information to be lost, with few mechanisms to efficiently retrieve complex historical information. For example, information on as-built (or modified) designs are often inadequately maintained and must be recreated when further building renovations or retrofits are required. Furthermore, research on building technologies and processes to date have attempted to address the needs of isolated stages, missing the synergies of an integrated approach. Figure 2 illustrates the problem this program of research addresses and schematically indicates the proposed solution.

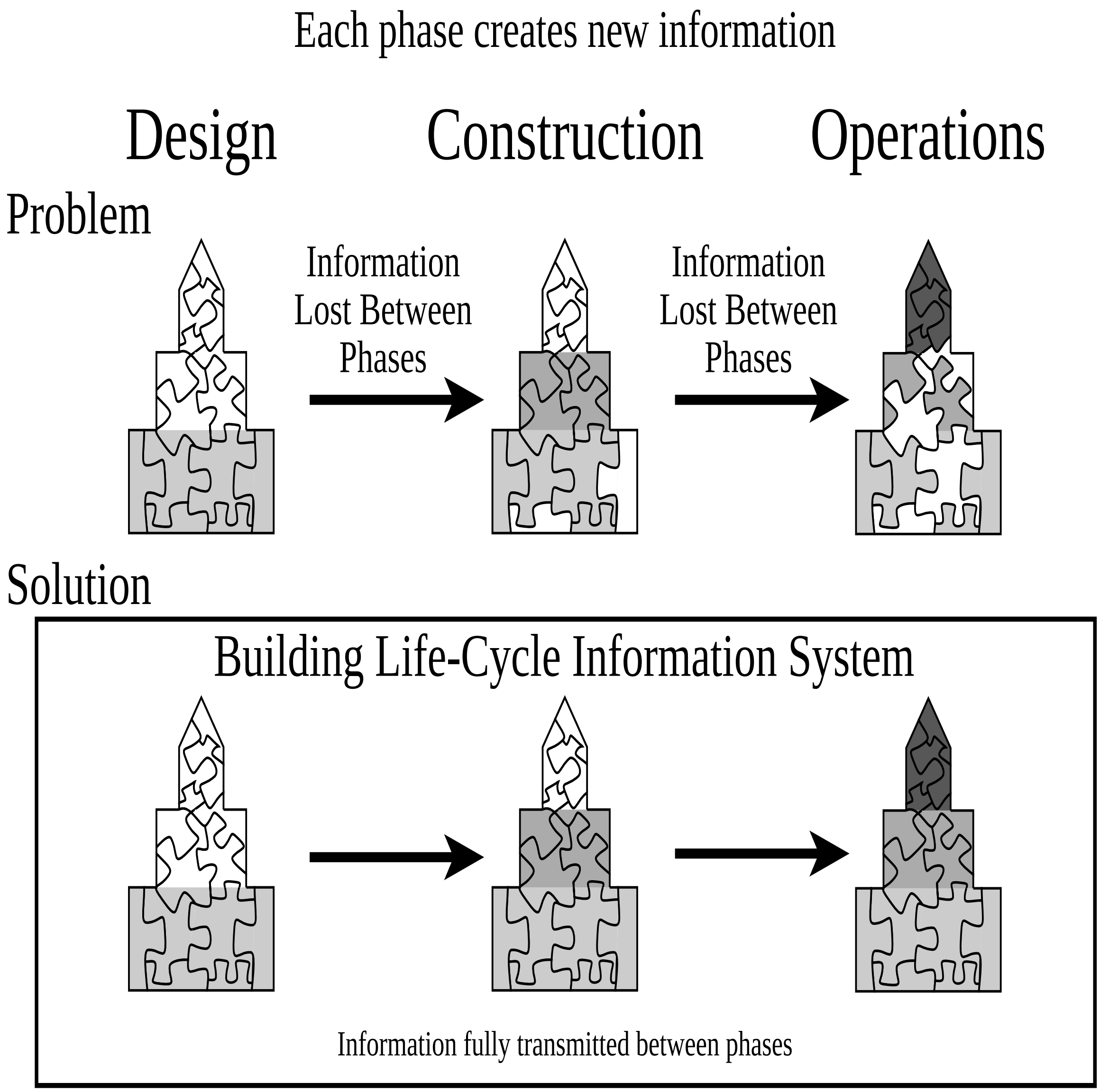

Figure 2: Building Life Cycle

The goal of this program is to address these problems by initiating the development and standardization of a set of integrated building life-cycle information systems. These systems are individually optimized to respond to the specific needs of each phase of the building's life-cycle, but are linked by an informational infrastructure (the Building Life-cycle Information Support System). BLISS serves as the backbone around which a dynamic data archive can be constructed in parallel with the building's construction (Figure 3). Tools for individual phases and sub-phases of the building's life cycle can then be developed to be interoperable with the backbone, while maintaining their own functionality.

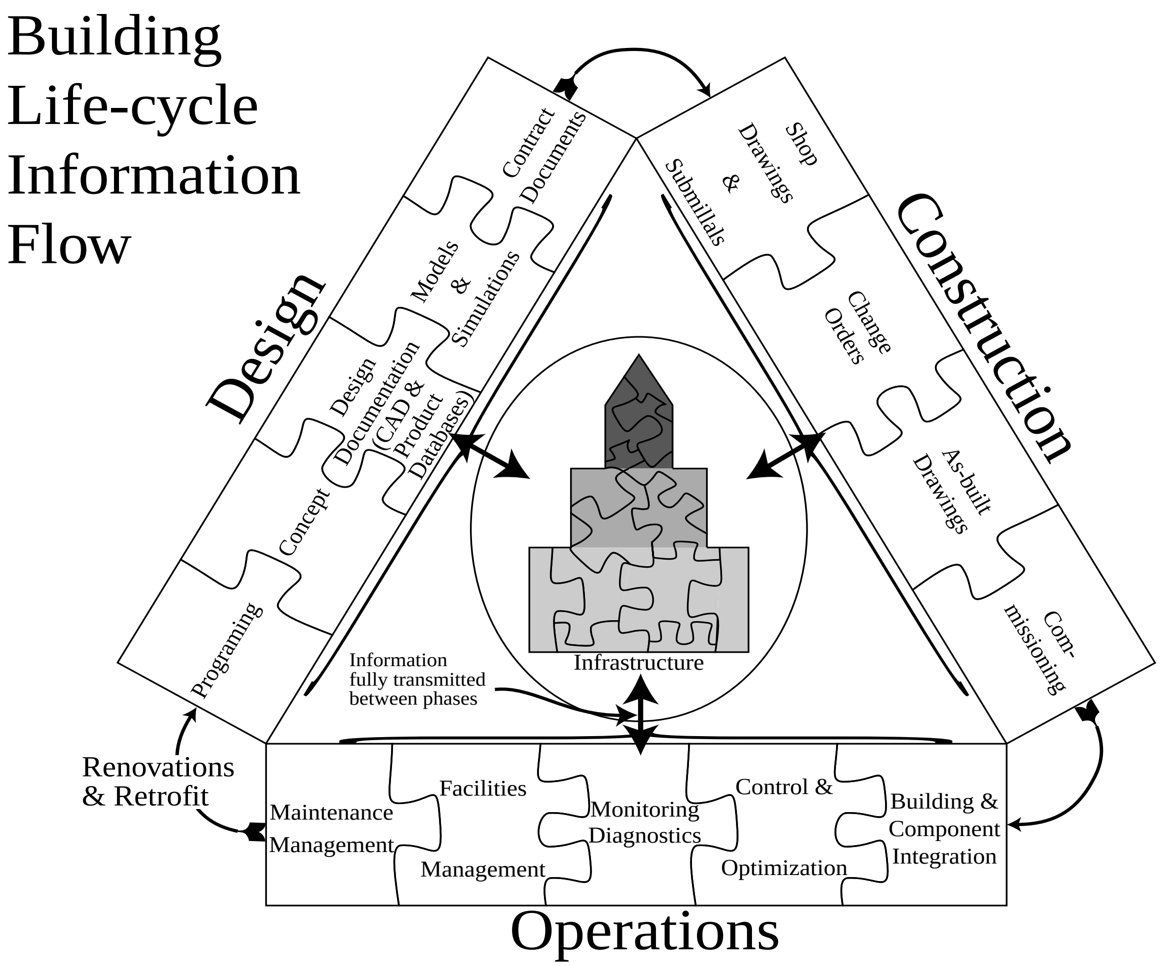

Figure 3: Building Life-cycle Information Flow Diagram

Achieving the program goal in commercial buildings would greatly improve the competitiveness and productivity of American industry by providing significantly enhanced performance; the potential performance benefits need not increase the life-cycle costs and may actually reduce them. Examples of the potential benefits include: more comfortable buildings, increased occupant productivity, increased energy efficiency, lower operating costs, and improved indoor air quality. Currently, much of the potential is not captured because there is insufficient knowledge about either the benefits or the associated cost impacts.

To achieve these performance and productivity goals there will have to be a broad transformation in the market that dictates the way that buildings are built and used. There are numerous barriers impeding such a market transformation. These include technical, institutional, and behavioral barriers that will each be evaluated and addressed as the life-cycle information system is developed.

The use of building life-cycle information systems will dramatically improve the design of new buildings by furnishing the ability to compare, contrast, and assess both existing and new proposed designs. Experience and data gained from operating actual equipment could be used to evaluate original design concepts. Figure 3 shows how this information ideally would flow within the building life-cycle. In addition to immediate practical benefits for design, construction and operations, this feedback will provide the foundation of an improved information base for further research in building performance, which in turn should generate new opportunities to develop and apply new integrated building technologies.

Effective information flow should also ensure that important engineering and economic information will be automatically available to the building decision makers in a form that would be easy, or even compelling to use. Development of this information vehicle and the associated process of using the proposed system will require examination of institutional information systems and decision-making processes as well as traditional engineering and economic concepts. One critical success factor will be the careful consideration of the typical needs and problems of building decision makers so that the systems will prove invaluable in performing their jobs. The resulting institutional memory will then be embedding in the life-cycle of the building.

8 GENERAL APPROACH

The initial effort has been to refine the overall conceptual framework for the integrated building performance systems as described above. The majority of the early effort, however, will focus on three projects: Building life-cycle information support system (BLISS); Commissioning information tools (CIT); and Performance evaluation and tracking tools (PETT). These three projects are proceeding simultaneously. The first project is broadly directed at establishing the long-term vision for a dynamic building life-cycle information system. The other two projects, focusing on information systems for commissioning and performance tracking during operations, are designed to generate useful near-term impacts. The projects are described briefly below and in more detail in the following sections:

- **Building Life-cycle Information Support System (BLISS)**

  The focus of this project is to create an information infrastructure for data exchange and archiving. Tailored tools would be connected to this infrastructure. This research is focused on software that may not have a direct impact on the market for several years, but which indirectly affects the development of the tailored tools. The first year's efforts will emphasize the development of a database structure and distributed systems architecture with special emphasis on the needs of CIT and PETT. Key products in the first year will include the creation of a preliminary specifications for the distributed systems architecture and database schema, as well as a computer-based mock-up.

- **Commissioning Information Tools (CIT)**

  The goal of the project is to link the operation of the building to optimal performance. Efforts during the first year will aim at developing a standardized commissioning process and computer-based information tools, starting with selected sub-systems such as chillers or variable-frequency drives. These tools will specify procedures for commissioning, monitoring guidelines, electronic documentation requirements, and methods to continue using this information in the operations phase of the building life-cycle. Key products will include a prototype commissioning tool for a key building subsystem and a mock-up of a commissioning module for integration with BLISS.

- **Performance Evaluation and Tracking Tools (PETT)**

  Documenting and eventually improving ongoing building performance is the central theme of this project. The early focus of this project will be on the fundamentals of defining building performance and the determination of the hardware and analysis techniques necessary to determine performance in operational buildings. As the project progresses, specific PETTs will be developed to allow associated decision makers to cost-effectively use performance data.

  Key products include metrics for the evaluation of building performance including an evaluation of existing systems, and a PETT case-study in a well- instrumented building, demonstrating the potential interaction with BLISS.

9 PARTNERSHIPS & PROJECT ADVISORY GROUP

This program cannot succeed without strong partners. Partners serve several critical needs: as potential financial sponsors for the next phase of work; as potential research collaborators; as sources of valuable information in areas where LBL does not have experience or expertise; most importantly, as potential partners for the tools and processes under development in this program. As key players in our research effort, partner feedback and participation is critical to our success. LBL is actively seeking out interested partners to continue this program.

This program will form an advisory group of stakeholders and others to advise the researchers. Its key role is to assist us in formulating and revising project plans, providing a network of support. Individual projects may rely on informal advisory groups, focus groups or panels as needed.

10 Project A: Building Life-cycle Information Support System

10.1 GENERAL DESCRIPTION

In this activity the first prototype of an integrated building life-cycle information support system (BLISS) will be developed and evaluated. The goal of this effort is to create a software infrastructure that can be used to link interoperable software tools throughout the building life-cycle. This project is an ambitious undertaking that will be successful only if it attracts the interest and participation of major building industry participants. Partnerships with these industry organizations will be developed to evaluate, enhance, and extend the BLISS prototype.

This project has three major elements: 1) to specify the distributed systems architecture, 2) to build life-cycle database, and 3) to develop a mechanism to capture design intent.

The distributed systems architecture will describe how various building software components will communicate with each other. The building database schema will specify the structure and semantics of the database, providing a common vocabulary for the software components. The database schema can also be used as part of the semantic specification of the building automation network application protocols.

The capture and representation of design intent (goals, specifications, decisions), will provide information that is necessary later in the life-cycle for successful building commissioning and operations. Formal mechanisms for this capture currently are not well developed, with a reliance instead on word of mouth, and limited written documentation. Thus, one goal of the project is to pursue formal methods for the representation of design intent, through recording design goals for specific clients and buildings as well as the formal encoding of building codes. This work should facilitate the development of automatic code verification and commissioning software tools.

10.2 BACKGROUND

A standardized building information infrastructure offers many advantages over current practice. For the owner, it should improve communications among design team members and reduce the risks associated with discontinuities as the building moves through key life-cycle stages. Architects, engineers, and contractors might ultimately experience fewer lawsuits and lower insurance premiums with the use of such information systems. Professional liability insurers currently are promoting building commissioning as a loss prevention strategy. For the tool developer, it should reduce the cost of developing new building software tools by reducing the need to develop and test new data structures for describing the building. This integration will help reduce barriers to the entry of new software developers into this underserved market. The size of the market should increase as new tool users experience lower learning costs and less risk because new software offerings will be easier to integrate into existing portfolios of building software tools. The overall result should be accelerated development and use of new and more powerful building software packages in the private sector.

Within LBL, new linkages will be established with the current building design and simulation software development efforts. Existing software development projects such as PowerDOE and the Building Design Advisor (Papamichael, 1994, Novitsky, 1993, and Birdsall, et al. 1990) will be examined with an eye toward how they might benefit from a linkage to BLISS. Efforts to partner with other private and public software developers will be expanded, with the objective of promoting the development of interoperable software tools that share common database schema and building descriptions.

10.3 RESEARCH TASKS

Creating an integrated building life-cycle information support system (BLISS) is a major effort that begins with initial programming and design. BLISS would provide a repository for storing information about the building and a distributed computing environment with standardized methods and procedures for connecting the various tools and support system software together. More specifically, it would encompass traditional descriptive information about the building, like product specifications and CAD drawings, and less conventional items, such as performance criteria and design intent, models representing the interaction of complex building systems, results from functional tests during start-up, and distributed intelligence embedded in building systems.

The researchers developing these systems will build on the existing disconnected, and often incomplete building data structures and software tools, adding to, integrating, and restructuring these elements to meet performance objectives such as optimized energy efficiency and environmental quality throughout the building life-cycle. For example, the database schema design will evolve from a careful evaluation of the many existing options and a synthesis of the best features available in existing tools. First year activities would include development of a conceptual framework for the life-cycle information support system, creation of a computer-based mockup of all BLISS elements, initial specification of the distributed systems architecture and development of prototype database schema. An effort will be made to quantify the costs and benefits to users of such a life-cycle information system to ensure that the resultant products are useful in the real world.

Figure 4 is a schematic diagram of all of the components of the life-cycle information support system and their relationship to the core infrastructure software services. The BLISS prototype is intended to provide the services shown in the diagram: database management services, interprocess communications, and directory services.

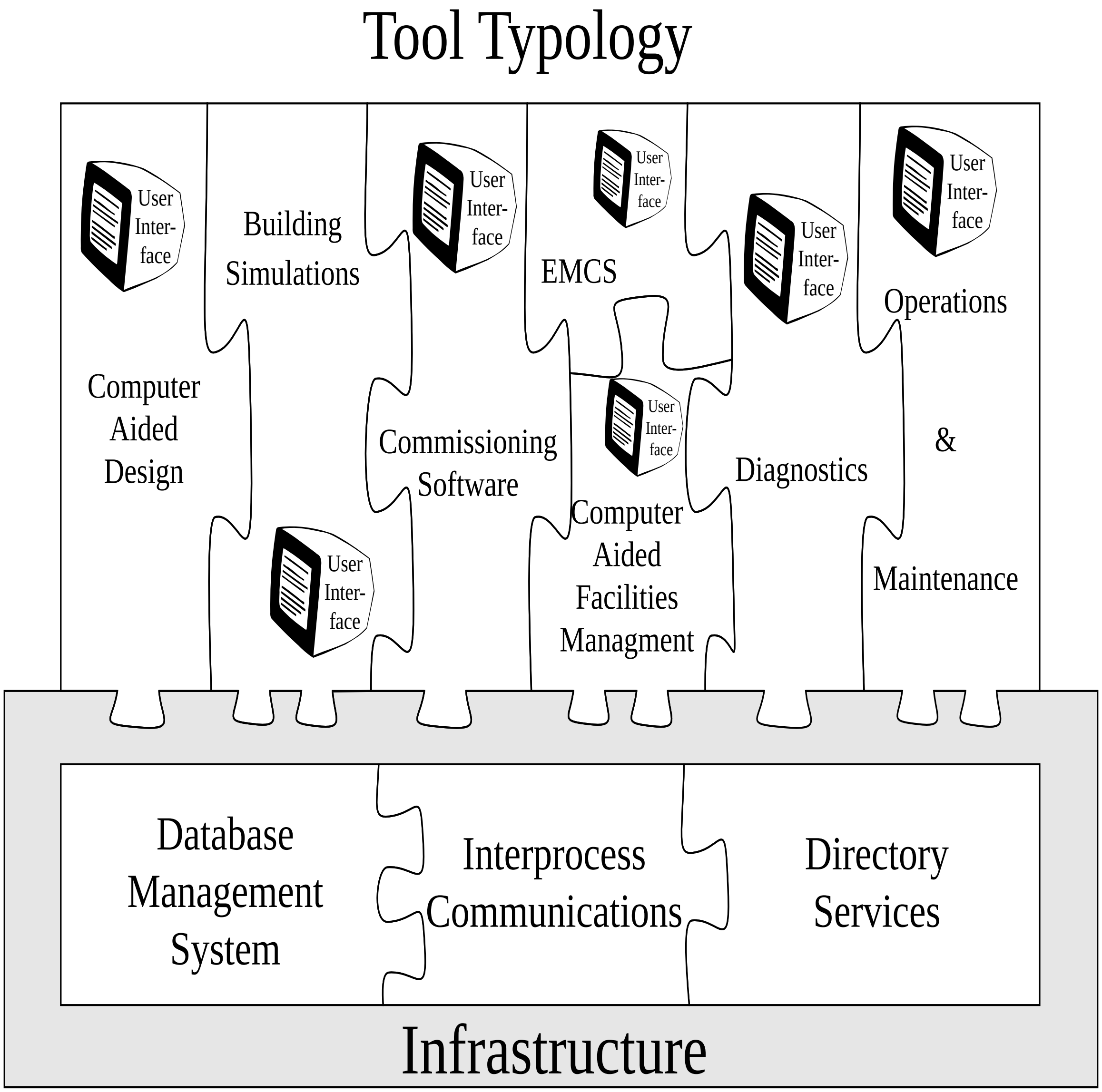

Figure 4: Components of a Building Life-Cycle Information System

11 Project B: Commissioning Information Tools

11.1 GENERAL DESCRIPTION

The general approach of this project is to improve the transition from building design to construction and initial occupancy by creating information links between the design and start-up phases with Commissioning Information Tools (CIT). Commissioning is the process by which a building is inspected and tested to ensure that it has the capability to operate as intended. A non-burdensome commissioning process will produce buildings that have lower operating costs while providing a more healthy indoor environment that will increase productivity and user satisfaction.

Commissioning software and information tools create a pathway to carry the design information into commissioning. Looking upstream, it can be seen as one of the first modules, or software tools, that is designed from the start to be compatible with the overall building life-cycle software and data structures (Bliss). Commissioning information is also important for downstream phases of the life-cycle. It is therefore a starting point for the Performance Evaluation and Tracking Tools project (PETT), which focuses on tracking buildings performance during ongoing operations. While mostly concerned with new construction, commissioning of existing buildings (often referred to as recommissioning) or retrofits will be considered for future phases of the project beyond the first year.

The specific objective of this project is to develop the initial conceptual design for an information system in a standardized commissioning process, and to develop prototype software modules related to specific building subcomponents. This software will be available for application in field demonstrations by the end of first year of the Building Performance Assurance program. The commissioning procedures defined in the software could be incorporated, perhaps by reference, into building design and construction specifications.

11.2 BACKGROUND

Building systems and energy-efficiency measures often do not perform as well in practice as intended at the design stage. The difference between design and actual performance is related to the differences between engineering theory, real world practice, and Murphy's Law. For example, on paper, a cooling tower design may appear to be properly integrated with the complete cooling system, while in practice, problems might appear. These problems can be traced to some phase of the building life-cycle. Incorrect assumptions about cooling loads at the design stage often result in incorrect sizing. Improper control sequences during installation and start-up can defeat optimal performance. Lack of proper maintenance and water treatment can cause reductions in operating efficiency over the life of the system.

Recent research at LBL and elsewhere has shown that there are construction and start-up problems that reduce building performance in virtually all buildings. Building commissioning procedures and functional tests are designed to identify such problems. Commissioning currently means many things to different people, and it is not done in a consistent manner, if done at all. Commissioning software tools will help standardize the process, and create a set of electronic documents that set the stage for ongoing performance analysis as the building enters full-scale operation. The primary benefit is to get design intent translated into initial operation. By creating a standardized commissioning software tool we will help address the lack of knowledge about how to do commissioning. There are several libraries of functional test procedures in the United States. This project will seek to compile the universal features of these tests, and make them available in a consistent format so results can be tracked for a single building. The results will also be useful to owners or managers responsible for multiple buildings to compare commissioning experiences among buildings. Another benefit will be to allow commissioning to incrementally improve operating performance above design expectations.

11.3 RESEARCH TASKS

The first year activities will be conducted in cooperation with interested building owners and other partners (such as utilities and government organizations) that promote commissioning. Partners will also be used to understand the needs of the real-world users and to collect suggestions for improvements to the proposed approach. Several candidate buildings have been discussed for case study sites to develop the commissioning process. Results from demonstrations will be combined with existing case study data to determine the potential costs and benefits of widespread commissioning. The commissioning specification and associated software will serve as a voluntary standard that can be refined based on feedback from a constituency of users whose support will be critical for growth in this area. The research tasks will start with an evaluation of best practices and definitions of key requirements for practical commissioning procedures and related specifications. The nature of information and data in current design tools will be assessed as they pertain to information needs for developing commissioning procedures.

The goal of the first year is to develop the conceptual design for a software information tool for use within the commissioning process, and specific modules ready for field testing. Commissioning standards and specifications vary significantly by building and system type. Therefore, this project will tackle a subset of the commercial building systems in the first year. The first year tasks will include an examination of the potential costs, energy savings, and non-energy benefits of commissioning, focusing on the benefits of using the proposed information tools. Explicit links between data in the commissioning software tool and the building operations software tool will be developed. A continuation of this process will be necessary to support the full-scale development of commissioning software tools. The tool will be expanded to cover a greater number of commercial building systems. Demonstrations will be necessary to show the value of applying the software. The software itself will continue to evolve as other elements of the building performance assurance systems are developed.

12 Project C: Performance Evaluation and Tracking Tools

12.1 GENERAL DESCRIPTION

The basic approach of this project is to develop information systems that allow the performance of the building to be continuously evaluated and tracked as part of its normal operation. The initial focus will be on defining many of the major and relevant indices for evaluating the various aspects of buildings performance and the information tools necessary to use them in the operating phase of a building's life. These systems will evolve into data specifications for advanced monitoring, and software for collecting the data and performing evaluations, which ultimately could be linked to optimization and diagnostic functions. Initial activities will center on software design suitable for an on-site or remote user. Another area of research may be higher-level performance analysis software, for more sophisticated engineering analysis.

The information tools developed in this project should ultimately be used by all the decision makers in (at least) the operational phase of the building, but the shock troops during operation are the occupants and operators who interact with the building on a daily basis. Accordingly, this project will emphasize operator needs and interfaces to assure that the tools developed will be useful to them. Many of the other decision makers in this phase will be dependent on the building operators to supply them with information. Eventually, a suitable information repository could allow some of these functions, such as major retrofit decisions, to be decoupled from daily operation.

It is likely that if building performance information systems were used, the ability to compare, contrast, and assess existing designs would dramatically improve the design of new buildings. This feedback could provide the foundation for further research in building performance, with improved information on which to develop advanced building technologies. Another outcome will be spin-off opportunities to assist in the development of advanced, integrated building technologies.

There are two deployment options for these tools of evaluation and tracking (especially the latter): provide them to the building operator, or develop remote monitoring and diagnostic capabilities for an off-site user. The former may be appropriate for large buildings, while the latter environment is important for small and medium-sized buildings that do not have their own engineering staff. Both options can use the same software and building operations performance data structures under development in the Building Life-cycle Information Support System (BLISS) project. Also, the data structures and analysis in this project will build on monitoring and diagnostics established in commissioning tests defined in the Commissioning Information Tools (CIT) project. The commissioning tests will be one-time or short-term intensive performance tests, while this project will focus on continuous operations.

12.2 BACKGROUND

A key barrier to assuring that building performance meets the highest standards is the lack of both real-time performance indicators and baseline performance indicators with which to compare real buildings. While much of the technology to collect the appropriate raw data currently exists (e.g., EMCS and DDC), the tools do not exist to profitably use information or to justify the cost of collecting it. If such information existed, both building owners and occupants would be able to use it to better estimate the value of the building services provided, while building operators would better be able to optimize performance. Increased demand could bring down the unit cost of data collection. Ultimately such information could feed back to forecasters, building designers and policy makers for use in future buildings.

Decision makers currently do not usually consider using building performance indicators because they only poorly understand how building performance relates to their own needs and then cannot justify the costs associated with determining that performance. The rationale of the Building Performance Assurance project is to cost-effectively improve the delivered performance of buildings through information tools during the operational phases of the building's life. A fundamental part of this project must then be to define a metric with which to measure building performance. Because of the many different actors and aspects involved with buildings, no single metric can suffice. A set of them are necessary and can only be compared to each other by the decision makers involved with each building.

12.3 RESEARCH TASKS

As the key barrier is the lack of performance information available to key decision makers including occupants, operators, and owners, the tasks will focus on demonstrating how to specify, collect, interpret, and communicate the necessary information. Properly communicated performance information will encourage building operation consistent with original design intent (continuous commissioning), and will provide operators with tools to make optimum decisions on multiple facets of building performance.

12.3.1 Defining Building Performance

The first task in the project is to define the metrics used in measuring building performance and then to determine what is necessary to monitor in order to quantify them. Each of the potential actors have different criteria that need to be considered in defining building performance:

- Occupants care about the indoor environmental conditions including safety, access, health, comfort and aesthetics. HVAC systems and architectural design contribute in quantifiable ways to some of these criteria, but not to others. Evaluating and tracking these conditions is a quality assurance metric for the occupants.
- Employers of building occupants care about worker productivity (which is linked to the issues above) and rental costs including any O&M. Operations costs include both energy and non-energy components, costs they may be responsible for. Different types of building performance may have different value to employers depending on their impacts on employee productivity, morale, etc.
- Building owners also care about rental and O&M costs that affect their profitability when compared to first costs of the building and its depreciation. Documenting building performance may lower O&M costs and permit rent differentials between more and less efficient units.
- As agents of the owners, building operators care about O&M issues, but their interests require the ability to access and interpret the information easily. They need practical tools which allow them to understand and modify building operation.
- As energy providers, the utilities are interesting in tracking energy (and power) consumption so as to minimize total delivery costs and to provide valuable customer services. Such tracking also allows robust evaluation of utility programs.
- Society cares about various aspects of buildings that affect public good. Such criteria include environmental impacts of buildings and the energy consumption, health and safety of building occupants, and the competitiveness of the businesses within buildings.

12.3.2 Analysis of Existing Tools

This task would begin by reviewing the capabilities of existing performance evaluation and monitoring tools, with near-term emphasis on Class A buildings. The principal hardware issues revolve around EMCS and associated sensors to acquire the data; consideration of data management hardware is also needed. Software issues focus on data analysis and database management.

With the criteria and associated needs defined, the next step would be to evaluate the ability of current hardware and software tools to deliver the necessary information. After determining the capacity of the existing tools, there would be a summary of the steps necessary to develop the needed hardware and software.

12.3.3 Operations Case Study

This task will be to provide a working, but not necessarily complete, tool for use by the building operators of a specific building. Working in partnership with an interested owner of a leading-edge building, a working mock-up of a tool for building operators would be constructed. This operations tools would take detailed data using the building's EMCS and analyze it to provide tracking and near real-time evaluation of certain aspects of building performance to the building's operations staff.

12.3.4 Information Repositories

One important integrating factor is the need for the archiving of building performance information. For example, remote monitoring and diagnostic centers could be used to aggregate data, to provide analysis, including compilation of comparative data, and in some cases to provide remote control. Two-way communication with a repository would support real-time pricing and information exchange. Further, a remote monitoring and diagnostic center might provide an alternative service delivery mechanism, particularly important to small and medium-sized buildings without their own engineering staff. The center may also provide needed credibility (impartiality) and research support to the emerging energy service industry. This task would review the issues and needs associated with information repositories.

13 Conclusions

In this paper, we have described the pivotal role of building life-cycle information systems in the efficient delivery of end-use energy services (heating, ventilating, air conditioning and lighting) for commercial buildings.

We have briefly discussed the institutional and technological evolution of the commercial building end-use energy services sector, the rationale for utility participation and interest, and the public policy implications.

Finally, we have set out the research agenda for a project on this topic now commencing at Lawrence Berkeley Laboratory. We solicit support and participation in this effort from government, utilities, industry, and academia.

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15 References

Birdsall, B., Buhl, W.F., Ellington, K.L., Erdem, A.E. and Winkelmann, F.C., "Overview of the DOE-2 Building Energy Analysis Program, Version 2.1D", LBL Tech. Report LBL-19735, Rev. 1, February 1990.

Claridge, D., Haberl, J., Liu, M., Houcek, J., and Athar, A., "Can You Achieve 150% of Predicted Retrofit Savings? Is it Time for Recommissioning," *Proceedings from the ACEEE 1994 Summer Study on Energy Efficiency in Buildings*, Vol. 5, ACEEE, Washington D.C., August 1994.

Herzog, P. and LaVine, L. "Identification and Quantifica- tion of the Impact of Improper Operation of Midsize Minnesota Office Buildings on Energy Use: A Seven Building Case Study," *Proceedings from the ACEEE 1992 Summer Study on Energy Efficiency in Buildings*, Vol. 3. ACEEE, Washington D.C., August 1992.

Novitski, B.J., "Energy Design Software", *Architecture*, Vol. 83, No. 6 (125-127) June 1993.

Olken, F., et al., “Supply and Demand of Electric Power and the NII”, in *The Information Infrastructure, Reaching Society's Goals, Report of the Information Infrastructure Task Force Committee on Applications and Technology*, National Institute of Standards and Technology, NIST Special Publication 868, September 1994

Papamichael, K., “Computer-Based Design Tools”, *Lawrence Berkeley Laboratory Center for Building Science News*, Summer 1994.

Piette, M.A., Diamond, R., Nordman B., de Buen O., Harris J.P., Heinemeier, K., and Janda, K. *Final Report on the Energy Edge Impact Evaluation of 28 New, Low-Energy Commercial Buildings*, Prepared for the Bonneville Power Administration LBL-33708, February 1994.

Yoder R. and Kaplan M. “Building Commissioning for Demand-Side Resource Acquisition Programs,” *Proceedings of the ACEEE 1992 Summer Study on Energy Efficiency in Buildings,* Vol. 5, ACEEE, Washington D.C., August 1992.