Re-inscribing design work: architects, engineers, and efficiency advocates.

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1 - SYNOPSIS

Professional cultures of architects and engineers can affect energy efficiency adoption. Accounting for these effects may help raise the level of efficiency adoption in practice.

2 - ABSTRACT

The energy efficiency literature often assumes that building designers are intermediaries in the building design process. Using interview data from architects and engineers, I explore the different roles that these professionals play in building design. To learn how professional cultures affect energy efficiency decisions, I interviewed 29 designers a decade after they participated in an energy efficiency project to see whether and how their participation affected their subsequent work. The results show that more engineers than architects designed differently as a result of the project. This paper explores reasons why engineers in the United States may be more likely than architects to be positively influenced by their participation in energy efficiency projects. I introduce a model of profession culture to explain this difference, and I argue that in the engineering profession is better situated—in terms of goals, tasks, values, and abilities—than the architectural profession to fulfill the quantitative goals set by energy efficiency advocates. Finally, I suggest two ways in which efficiency advocates could improve the level of efficiency adoption in practice by responding to the cultural differences of the design professions.

3 - INTRODUCTION

Research regarding the market for efficient technologies and buildings has long been focused on the demand side and, more specifically, on the individual end-user. Building designers have either been ignored by the bulk of energy research (Lutzenhiser 1993; Nader et al. 1979) or considered to be “intermediaries” in the energy efficiency decision-making process (Stern et al. 1984). If designers are not perfectly responsive to client demands, then they play a role of their own in the supply chain that delivers buildings (efficient and otherwise) to buyers and users. This paper describes the roles of designers and addresses how these roles affect the level of energy efficiency adoption. For the purpose of this paper, design is primarily the province of architects and engineers. Design work involves the literal translation of concepts into practice, and architects and engineers do more of it than owners, managers, and users do.[1]

To trace the connections between design work and energy efficiency adoption, I interviewed designers a decade after they participated in an energy efficiency project to see whether and how their participation affected their subsequent work. Based on this information, I advance the notion of professional culture in practice to explain the different effects reported by architects and engineers. I devote the main part of this paper to describing attributes of professional cultures in practice, using interview data to describe the cultures of architects and engineers according to categories developed by Abbott (1988). Next, I overlay the interests of energy efficiency advocates on the usual practice of architects and engineers. By comparing cultural attributes, I argue that the engineering profession is better situated—in terms of goals, values, and abilities—than the architectural profession to fulfill the quantitative goals set by energy efficiency advocates. In conclusion, I propose the notion of “cultural fit” as an explanation for the empirical observation that engineers respond more positively to energy efficiency than architects do.

4 - EFFECTS OF RESEARCH ON PRACTICE

The project I studied was a research and demonstration project called "Energy Edge." It was supported by Bonneville Power Administration, an electric utility in the Pacific Northwest of the United States. The project goal was to achieve 30% cost-effective energy savings over the Model Energy Code (circa 1985) in 28 new commercial buildings. Energy Edge paid for design assistance and incremental technology costs, and it monitored the buildings after they were built. In addition to creating the energy-efficient buildings themselves, Energy Edge hoped to influence the building industry by promoting interest and proficiency in energy-efficient design (Keane & Co. 1986).

In 1996, I interviewed 29 designers from 18 of the Energy Edge buildings to learn how their Energy Edge experience affected their view of energy efficiency. All of the designers were asked whether they designed differently as a result of their participation in the utility project. I found that most of the enduring effects of the Energy Edge project on designers' practice could be characterized in four ways: positive, mixed, free-rider, and negative (Janda 1996). I base this characterization primarily on the designers' own views of changes to their practice before and after participation in the project. Because the interviews were conducted nearly a decade after the utility project was completed, they provide a reasonable indication of the permanent changes to design practice and efficiency choices that the designers themselves attributed to the project.[2]

When aggregated by professional groups, the data show that engineers tended to respond more positively to Energy Edge than architects did. Engineers were almost twice as likely as architects to say that they designed differently as a result of their participation in Energy Edge. The greatest proportion of architects (38%) had a mixed reaction to the project, but the smallest number of engineers (9%) felt this way. Slightly more engineers (36%) than architects (28%) identified themselves as free riders. None of the engineers interviewed felt as negatively about Energy Edge and energy efficiency as one architect did.

What does it mean that, in general, more engineers than architects responded more positively to Energy Edge? One answer is it that it means nothing: it is a fluke produced by a specific, (to some extent) self-selected set of designers who are not representative of the general population of architects and engineers.[3] Another answer is that it is a finding: there is something about the way in which architects and engineers do their work or the work itself that produces this result.[4] My argument follows the latter conclusion. I propose that differences between the professional cultures of architects and engineers influenced their response to Energy Edge.

5 - PROFESSIONAL CULTURES IN PRACTICE

The idea of using culture to explain behavior is not new to the efficiency literature (Blumstein, et al. 1980; NRC 1980). O'Drain et al. (1993) describe efficiency programs as an attempt to overlay efficiency ideas on the pre-existing cultures found among the participants. These authors do not, however, describe either the pre-existing cultures or the set of ideas to be superimposed. I will take up this task in the remainder of this paper, beginning with a description of some general elements of "professional culture."

The concept of "culture" has been used to describe the behavior of many kinds of groups from tribes (Mead 1928) to pinmakers (Lubar 1987). "Professional culture" focuses on the goals, values, beliefs, and practices that affect the behavior of a certain class of occupational groups: the professions. Whereas organizational culture may only span a single organization or company, elements of professional culture are shared across the boundaries of companies and workplaces. Professional cultures are a product of historical context, work practices, and individual experiences.

Many books and articles trace the development of architects and their profession (e.g., Blau 1984; Cuff 1991; Gutman 1988; Kostof 1977; Larson 1977; Levy 1980; Saint 1983); several have been written about engineers and theirs (e.g., Kunda 1992; Layton 1986; Levy 1980). A full discussion of these professions' histories is beyond the scope of this paper.[5] In this paper, I focus on "work practice": the activities, experiences, and beliefs that directly govern everyday work. Central to work practice is what Abbott (1988) calls a "jurisdiction"—a group of tasks over which a profession claims exclusive social and cultural control. For architects and engineers, these jurisdictions often seem separate, but they are overlapping. They are sometimes coordinated, sometimes in conflict. I will begin with a description of the jurisdiction itself, then I will focus on what Abbott calls the "cultural machinery" of jurisdictions: how architects and engineers define, classify, and treat their problems.

5.1. Jurisdiction

Gaining control over work is an important goal of most professional groups. In the building industry, as in medicine, the major groups involved in the process hold different degrees of power.[6] Doctors, for instance, have more authority than nurses but neither group can treat patients without their consent. Similarly, architects, engineers, and clients enter into an interdependent yet structured negotiation with each new building design. Traditionally, architects control the overall design of a building, directly negotiating with the client, the subcontractors (including the engineers), and the builder during construction. Under subcontract to the architect, engineers design the mechanical and electrical components of the building and may contract out the system installation or install it themselves. This section describes some characteristics of the work that architects and engineers do. I concentrate here on the differences between architects' and engineers' levels of authority, their design goals, and their views on heating, ventilation, and air-conditioning (HVAC) systems.

5.1.1. Authority

Although the building design and its mechanical and electrical systems are symbiotic, architects and engineers describe their roles as separate and unequal. Architects see themselves as taking more responsibility than engineers:

> It's been traditionally the architect's role to lead the project. So between that tradition plus the fact that the engineers—generally speaking—prefer to make an exit without any serious investigation of options, the vacuum has been filled by the architects. (Interview 29)

Contractually, engineers work for architects. This means that although engineers may make design recommendations to architects, architects may or may not follow them. An engineer described the work he does with architects in this way:

> We look at their preliminary designs, and then we'll make comments, recommendations, things that will affect the system and comfort of people and the operation of the building. Many times they listen to us, sometimes they don't. So, if they have an area that they are more concerned about—the aesthetics—than they are the function, the aesthetics usually win with the architects. But they do provide things for us that we feel are important. (Interview 33)

If an engineer makes a suggestion that goes against the scope of the design, however, chances are it will not be heeded. For example, one engineer described designing a system for a building that came to a triangular glass point. In the point, the architect had put a conference room. Air conditioning this triangular greenhouse was "an impossible situation." The engineer recalled:

> And I said "it's going to be tough. I hope you're going to darken the glass." [The architect] darkened the glass. [I said] we're going to have to blow air in there, and it's going to blow the flowers off the wallpaper. And we're still going to be defeated. (Interview 20)

Although the architect would darken the glass, he would not change the design concept. The engineer was forced to compensate with a mechanical strategy which he feared would not perform adequately. The power relationship is clear: architects have more design authority than engineers.

5.1.2. Good architecture

When asked to describe his usual design goals, an architect responded:

> Satisfying the client's needs. Whether it be commercial or personal. As long as it's practical and fits the goals of good architecture. (Interview 21)

Architects describe good architecture as something that is not only aesthetically pleasing, but in some way special and extraordinary. Even when architects are constrained by specific design requirements, they may describe their work as distinctive. One architect who does hundreds of McDonald's a year gave the following example of the design authority he exercises in his job:

> ...We took the basic floorplan and everything from the ground up is different. We designed what we call the metal arches, kind of an entrance way into the building, it was kind of a novel approach. We tried to pick up on their golden arches theme. So we painted them a bright yellow and called them golden arches. The building is just totally different. It's got glass block at the entrances, and horizontal window bands, and all kinds of different things. Definitely is not the typical McDonald's. (Interview 25)

The difference between this McDonald's and the one across town might be invisible to a Big Mac buyer, but the subtle design distinctions enable this architect to see his own stamp on a notoriously homogenous building type. Architects also see themselves as social guardians, mediating between the actors in the built environment for the good of society as a whole. One architect described working for a money-grubbing developer with a sense of guilt:

> Architects do what they can, but it's very difficult to circumvent this [bad development] anyway. You hear this all the time. People take on commissions they shouldn't. And they do things they shouldn't. But they say, well, the next guy would do it. And maybe I can influence it a little bit so it will be better. (Interview 19)

This architect wants to be part of the solution even as he contributes to the problem.

5.1.3. Appropriate technology

When asked to describe his usual design goals, an engineer responded:

> We strive to apply appropriate technology to each project to meet the owner's needs. (Interview 5)

Whereas architects have a positive goal of improving people's lives, engineers have accepted the noble charge of guarding against thermal misery. As one engineer summed it up.

> Their [the architects] main concern is to make a building that looks good and feels good to the people. Our main concern is keep the people comfortable. (Interview 33)

To some engineers, good engineering has an array of attributes:

> When the system really goes in as designed without any changes due to cost. When there's high quality products, a good contractor, and energy efficiency. Indoor air quality. Low noise. Good comfort. Maintainability. Buildings that aren't doing well, you get a lot of calls about. (Interview 23)

Their aspirations, however, are somewhat less lofty than architects':

> We're not talking apples falling on Newton's head, but within the context of what things are...it's only air-conditioning. We're not saving people's lives, or anything. (Interview 20)

The engineers I interviewed expressed no concerns about society as a whole and more concerns than architects about the specific occupants in their buildings. Some are even willing to go against the grain of "good engineering" to get the job done. One engineer confessed that there were times he wished he could use a reheat system, an "energy hog" that can no longer be used under current energy standards, because:

> I don't want to have, after the building is built, for them to call me up and tell me they're uncomfortable. So I want to use a reheat just to get people off my neck, not because I think it's good engineering. I'll admit that we're self-serving there. (Interview 20)

Engineers have to worry about callbacks and reliability. Callbacks usually pertain to problems rather than successes. Avoiding callbacks is a significant reason why engineers want a reliable HVAC system that provides enough heat and cooling when and where it is needed. If there's a problem with the HVAC system, an engineer said:

> It just keeps coming back, and haunting and haunting, until you get mad and pay somebody to fix it. (Interview 27)

5.1.4. HVAC systems

In office buildings, a source of tension between architects and engineers is the physical size of the HVAC system and the room to put it in. One engineer said getting adequate space for mechanical equipment "is always a battle" because:

> The architects that we work with want air conditioning systems that you can't see, you can't hear, and don't take up any space. But you can't buy that. But that's the main goal, get 'em to give up the space required to put a decent system in. (Interview 33)

From the architect's point of view, it is probably true that in an ideal world there would be no electrical or mechanical equipment to disturb their designs. Architects do complain about giving up space to mechanical and electrical systems:

> [The] switch gear and electrical room is just huge. It's absolutely stupid how big it is, and the clearances [the engineers] gotta have. I find the engineers half the time are gonna show little boxes [on the plans], and then all of a sudden, they get the catalog pattern for the switch gear, and it's huge. And I say, "Why didn't you tell us?" So I make them tell in the very beginning, how big is it. "How big do you want the room?" And we negotiate that room size—Is it square? Is it long and narrow?—from the very beginning. (Interview 34)

Only part of this architects' difficulty is related to the actual size of the space required. Some of his discomfort comes from not knowing what the size or shape will be. In this regard, it is clear that architects have more control than engineers, but they are not in absolute control:

> I guess after a period of time, you know that's gonna happen. You're fooling yourself if you draw a small [mechanical] room, from the architectural standpoint. You're fooling yourself if you think, "Well, the meters can go down here in the parking structure right next to the cars, and..."—it can't happen. (...) It's just not the way it works. (Interview 34)

This short list of topics shows some ways in which architects and engineers differ. According to Abbott's theory of professions, these differences matter because they are neither haphazard nor objectively rational. In Abbott's view, the differences between professions serve a strategic function, enabling them to retain socially legitimate control over their separate jurisdictions. Professions maintain their hold over their jurisdictions by developing systems of abstract knowledge. A knowledge system formalizes all of the professional knowledge about a jurisdiction. It contains actual texts (e.g., professional handbooks), the academic knowledge they are based on, and the practical knowledge needed to use them. In addition, a knowledge system strikes some balance between order and ambiguity. An absolutely ordered knowledge system runs the risk of deprofessionalizing the professional work. In this event, the work can be parsed into discrete tasks and delegated to relatively unskilled labor. An overly ambiguous knowledge system, on the other hand, is open to competition from other professional groups. If no one can prove what "more aesthetically pleasing" is, for instance, then anyone can be a designer.

For professionals, doing work means bringing information into and out of their particular knowledge system. This process occurs in three stages, which Abbott calls diagnosis, inference and treatment. These stages describe the ways in which professionals absorb information about a problem, classify it, and treat it. I will discuss each stage in turn, showing how architects and engineers construct their coexistence.

5.2. Diagnosis: the problem frame

Although they may be working on the same building, architects and engineers frame the problems they address quite differently. In the previous section, I referred to architects and engineers as having different design goals. The shorthand I used was that architects favor aesthetics while engineers provide comfort. In the paragraphs that follow, I will expand on these ideas, showing how the assumed properties of professional problems influence individual design decisions and, in turn, energy efficiency adoption.

Diagnosis is the process of assigning subjective properties to the objective tasks which the professions perform (Abbott 1988). This process begins by the members of the profession deciding what information is relevant and what is not relevant about a particular client or problem. During this activity, professionals take information into their knowledge system and form a picture of the observed problems. This picture forms the basis for subsequent inference about the "problem" and ultimately leads to a particular treatment of it.

In describing a design problem, architects often refer to abstract, qualitative properties that are not easily quantified. One architect described his focus on providing "aesthetics and openness and connection to the outdoors." (Interview 2) None of these properties can be objectively measured with current tools or instruments. These subjective qualities do, however, have objective components. The architect said he uses lots of windows to achieve the desired effects, and it is easy to imagine that a feeling of openness and connection with the outdoors would be achieved through the use of "lots" of windows. But there is not an absolute connection between the number of windows and the presence of aesthetics. There is no rule that says a building with six windows will be more aesthetically pleasing than a building with five windows.

In contrast, engineers define their problem according to physical properties that are more easily quantified. Although they hold themselves responsible for occupant comfort, their definition of the problem of comfort is often limited to the tangible, measurable aspects (e.g., airflow rates and quantities of heat and cooling). When asked what kind of service he provides to his clients, one engineer responded: "Well, frankly, I try to give 'em as much heat as I can within the code. Typically, as much as I can. At least 150% or better." (Interview 20) In the engineering view, more heat is better, and a steady-state thermal environment is the desired objective. This perspective assumes that there is direct connection between the amount of heat (or cooling) provided and the presence of comfort.[7]

The qualitative properties seen by architects and the quantifiable attributes addressed by engineers manifest themselves in many ways during the diagnostic stage. Compare, for instance, an architect's view of the importance of site and climate with that of an engineer. The architect emphasized the following aspects:

> To me, the most important thing is that the site IS the building. All my buildings have to relate to the site. And then they have to relate to the topography. And then they have got to relate to the elements. I'm talking about the winds, the rains, and all those kinds of things. (...) My orientations are very important. And then light is...to me, that's all architecture is about. Using light. I try to use natural lighting throughout the building, every place I can. It's the main forte, the main thrust of our buildings. (Interview 4)

The engineer, who works in the same town as the architect, had a different picture of the relationship between a building and its environment:

> In Oregon, particularly on the west side where we are now, our climate is pretty mild. We're in the valley here. Our average temperature in the winter is like 45. So it doesn't get really cold. And our design temperature in the summer is 88 degrees. We have two distinct climates in Oregon: the coast and the valley are kind of moderate, and then eastern Oregon which is more severe. You get the snow, and design temp there is in the winter is I think 10 degrees and in summer I think it's 95. But here we're talking about 22 degrees in the winter and 88 in the summer. So a lot of energy strategies are tough to pay for because they don't have the extremes. The humidity is low, so it's a pretty forgiving climate. The strategies used in other parts of the country are good concepts, but they just don't pay for themselves over here. (Interview 5)

The architect wants his building to relate to the topography and the elements, each of which is influential, but unquantified. The climate and the site are subjectively evaluated by the architect, and the building design responds to the architect's evaluation. The engineer, on the other hand, sees the climate in terms of specific summer and winter "design temperatures"—numbers which are based on objective measurements published in the ASHRAE handbook of fundamentals. Here we begin to see the basis of two very different knowledge systems. The architect's knowledge system, which is qualitative, abstract, and subjective, and the engineer's knowledge system, which is quantitative, ordered, and absolute.

5.3. Inference: the design process

After diagnosing a problem by absorbing relevant pieces of information, the next step in Abbott's chain of professional work is "inference." Inference connects the picture generated during diagnosis with a range of possible treatments and probable outcomes contained in the knowledge system. In building design, inference is what architects and engineers do once they have collected the initial data they need and start seeking a solution.

5.3.1. Finding a solution

For engineers, the solution set for design problems is limited. One engineer told me that designing the right system for a building is like "fitting a pair of shoes."(Interview 16) Another engineer said:

> You design equipment based on the geometry of the structure. So you match stuff to it. (...) If you say the structure's different, I say the chiller size is different. (Interview 5)

Engineers get a certain sized space from the architects, and they specify equipment to condition it appropriately. Theirs is a matching and fitting game, with specific boundaries and unambiguous endpoints. There is some flexibility within these boundaries, but the overall picture is defined by the technologies on the market, the shape of space, and the location of the building that they have to condition. A typical statement from one engineer was: "It just depends on what's available, and then you try to use that as creatively as you can." (Interview 11)

Architects, on the other hand, describe the process of their work as boundless. Given the ambiguity of the design problems they have claimed, solving the problem is more difficult for architects than for engineers. Instead of there being one solution to a design problem, there are many. The “solutions are limitless,” said one architect (Interview 19). Another architect commented:

> There are a thousand solutions to any design problem. Knowing when to turn your computer off, lay the pencil down, and move on is something most architects that are still in business realize. That you have to get to a point of closure. (Interview 14)

In response to what they see as infinite possibilities, architects frame the problem of design differently than engineers do. They seek not only what to design but when to stop.

5.3.2. Origin of solutions

Another element of the inference process involves the origins of the solutions themselves. Do designers create solutions or merely apply them? Architects claim that solutions arise from inspiration:

> For me, the only way it can happen is when I go out, look at the site, and I think about what the client’s trying to do, and it tells you something. All of a sudden, the building has to happen, and it happens. It has no relationship with anything other than itself. If you think it does, you’re fooling yourself. You have to go out there, and you have to let the site speak to you. It sounds goofy, but it really does. So you have to get in there, and you have to say, “OK this will happen here.” And the building creates itself from that. (Interview 19)

An engineer’s solution does not come from “out there” or “inside one’s head.” Instead, it comes from research and discussion. As one engineer put it:

> We look at what they want, and we go to our library, to systems that they’ve used, systems they know will work. Or maybe we’ll sit down and brainstorm with the project managers and engineering manager on the system and come up with a different mousetrap. (Interview 16)

Engineers get ideas for current systems from past experience. Even coming up with “a different mousetrap” is not a singular creative act: it is a logical process performed by a group.

Like the process of diagnosis, the inferential activity of engineers is more ordered than that of architects. Based on the quantitative information they gather during diagnosis, engineers select a system from a limited set of pre-existing solutions. Their inference period has a clear endpoint. Architects, on the other hand, engage in a creative process which would be open-ended if it were not bounded by time and money.

5.4. Treatment: justifiable solutions

Treatment is the final step in Abbott’s sequence of professional work. In this phase, the professional brings results back to the client. In building design, this step is composed of two components: the design itself, and justifying the design to the client.

5.4.1. Justification

Engineers must quantify their work in specific ways (e.g., load balances) to justify their chosen solution. When asked why engineers have to quantify their work, one engineer’s first response was: “It’s a standard of ethics; a normal operating procedure.” Then he continued:

> It’s what you end up in court for. “You’re an engineer. Why isn’t this working?” The first thing they asked was: “Did you do a heat loss/heat gain on this building?” I said “Yes.” “Why didn’t you realize it was oversized or undersized?” (Interview 11)

Due to the absolute connection between the size of a system and the load it is supposed to handle, engineers must be able to prove they made the “right” choice. Architects *can* quantify their decisions, but they need not do so. Architects are held to a creative standard rather than a working one. In one engineer’s eyes, this difference allows them enviable flexibility:

> [Interviewee #8] is an architect. He’s called me and said “God, I’m getting ready to put this insulation in this crawlspace and I’m going to heat it up with rocks and how many BTUs do I have?” He never has to answer that question. He’s not held to a standard that says if he doesn’t put the right amount of rocks under there, it’s not right. (...) We have to quantify. And that’s something that [Interviewee #8] doesn’t have to do. That doesn’t mean he doesn’t, but he’s not held to the same standard. He’s held to a creative standard; that’s how he does things. We’re held to a working standard: what does it take to heat and cool? (Interview 11)

When it comes to quantifying, several architects were quick to say that it was not their forte. "I hate doing calculations," said one architect (Interview 1). "Let me make sure I get the math right," another muttered when doing a simple calculation (Interview 29). A third architect admitted:

> I've got lousy math skills. Lousy. But I'm good spatially. That's what I concentrate on: envisioning. I'm always compensating technically. But that's something you *can* do. You can always compensate technically. You have the right people that are there, doing engineering for you, things like that. And you buy the right computer programs that give you the information you need. You can pick up that gap accurately. But it's the other end that I concentrate on. (Interview 19)

If architects do not have to justify their treatments quantitatively, what is it that they must excel in? When asked what it takes to be a good architect, one architect responded:

> It's both communication and education. After all, you're trained; the client isn't. (Interview 29)

To have designs accepted by their clients, architects must be able communicate their choices in terms their clients will understand. This process may require "educating" them as to their benefits. An architect explained:

> If it's about giving up a detail, sometimes you have to say its worth $1000 to attract someone, like a customer, into the building. Then there are maintenance issues: often better materials last longer and take less care. There are a thousand different things associated with one design decision, and that's our obligation to the client. To tell him what it will cost him if he loses quality. You can always take it back to monetary assertions. But you have to look at their goal and weigh it differently than the dollar amount. In a church, for instance, spirituality becomes paramount. What does it cost to provide a spiritual space? (Interview 19)

Whether or not it is actually worth $1000 to attract a customer cannot be easily assessed. Like the cost of providing a spiritual space, the worth of attracting a customer is valued subjectively. Even if an architect attaches a dollar figure to the value of a solution, the solution's success is not easily proved or refuted. Cuff (1991, p. 35-6) believes that this "high indeterminacy" of architectural work is a central factor in maintaining the architect's autonomy. If their power lies in ambiguity, some architects may prefer to use strategies that have unquantifiable benefits.

If architects and engineers have different ways of justifying their solutions to their clients, how does this affect the strategies they choose to recommend? When interviewed about their technology choices, engineers often complained about passive strategies, and architects often expressed objections to active measures.[8]

5.4.2. Arguments against passivity

Engineers are used to rectifying the "problems" created by architects' design goals. They know that architects can design spaces that are difficult to condition. As one engineer described:

> Usually you laugh. The architects are aware of all this stuff, too. They put 8 foot high and wide windows on a south wall with no overhang, they know what they're doing. ... Their neck goes back into their chest and they tell you slowly that they know what they're doing. That architecturally, that's what they want. So you just deal with it. (Interview 20)

When an architect uses techniques that are meant to conserve energy or improve building performance, engineers may be somewhat suspicious. This may not reflect a distrust of the architect himself, as much as a reluctance to rely on the kinds of passive measures an architect is likely to propose. One engineer described working with passive systems with misgiving:

> When it comes to passive, most of the things you're talking about are initiated by the architect. Almost all of those are architectural type things. We will incorporate heavy walls, for instance, the water tubes, that sort of thing. Those are all good ideas. Along with those ideas, comes the owner's belief it's going to save money. Along with the owner's belief that he's going to save money, is his belief that he's going to have a system that works the way he wants it to work. And his engineers can make sure that happens. I think that's where the resistance comes. The engineer can spec a chiller that controls it, but you get into a radiant exchanges with the water and everything, and suddenly that's a whole new ball game. We have worked with ponded roofs and that sort of thing, but we sure like to have something to sign off on. (Interview 11)

Although the architect may try to take responsibility for a passive system, the engineer still feels accountable for the occupant's comfort and unsure of measures that cannot be turned off, on, or up. Engineers value systems that are reliable, responsive, and controllable. Passive systems do not offer these qualities, and as a result, seem dull or problematic. As one engineer said:

> Our systems are dynamic. Architect's energy efficiency measures are static. They don't do much. (Interview 18)

The belief that materials and passive systems don't do much is reinforced in a variety of ways. Engineers are responsible for quantifying the system, and there are few reliable numbers or methods available to predict the performance of passive measures. The usual way of doing it is through computer simulations, which the practically-oriented building engineers distrust.

Their suspicions are not unfounded. For example, one of the Energy Edge buildings had a high thermal mass content which was supposed to act as a heat source and sink for the building. The efficiency design advisors hired by Energy Edge said there would be no need for a cooling tower. Although the mechanical engineer for the building could see that proposed design "penciled out on paper," he explained:

> From our experience from previous projects of this type, we knew that it wouldn't work. The difficulty in extracting and the time consumed in extracting the energy from the structure wouldn't be available to the space to keep the comfort level proper. So there were disagreements on the need for cooling towers and that. I told them they needed two cooling towers of a certain size. Energy Edge said they didn't need a cooling tower at all. [The owner] agreed to put one in, and then he put the provisions for the second one. He was either going to name it after me or after the other engineer. When we ended up putting the second one in, the other engineer got his name on that. [laughter] (Interview 33)

In this case, practical experience proved more reliable than computer printouts. Even though coming up with numbers is important to engineers, they have to be the *right* numbers. Engineers trust numbers they generate themselves about machines and systems that they have practical experience with; they are suspicious of numbers that come from someone else's computer. Particularly if the numbers are about materials and designs rather than machines.

5.4.3. Against mechanical activity

For their part, architects are not suspicious of active measures, but they do not always see a role for themselves in the design process if the focus is on machines, or what one architect called "metal boxes:"

> That's what discouraged me about Energy Edge. Virtually all of it was the latest, most efficient machines. As exciting as that is, it isn't the whole story. Because a smaller efficient machine is even more attractive than a larger efficient machine. (Interview 8)

Another architect decided to get involved with Energy Edge precisely because of the usual focus on machines:

> I wanted to prove something. What was happening in those particular days is that there were a whole lot of articles about extraordinary measures that one could take to save energy. And it seemed to me that that was kind of missing the point. I just wanted to prove that if you built a building using reasonable standards and not go way out on the edge that you could build a cost-effective energy-efficient building. I guess I must have been right. We won. I think it was a little frustrating for the people who were putting on the competition. I think it frustrated them that I wasn't interested…well, it wasn't that I wasn't interested, but I wasn't *willing* to press the out of bounds markers relative to the heating plant. That you could do it with efficient lighting and these other sort of incremental measures, and it would end up being a successful project. (Interview 38)

Getting to a smaller metal box means employing passive strategies; creating a space that needs less mechanical conditioning and electric lighting. These strategies create a space is more energy efficient, naturally. To some architects, these qualities are very appealing. One architect described his own house as:

> A big giant treehouse. Where I open up doors at the bottom and I open up windows on the upper level, it just sucks the air through there. And we've got a lot of big giant fir trees that act like a big giant umbrella. (Interview 4)

If designed properly, there is no need for fans because convection will naturally ventilate his shaded space. The same architect had a very different feeling about a heat pump he bought for the space, thinking he would make an investment that would save energy:

> I think its a rap. It's not natural. It makes noise and there's all kinds of just, I don't know. Just the noise pollution. I don't know if the performance, it does save you maybe a third of your energy costs as far as heating. But I just don't think you ever recapture your investment in it. I just need to tell you that I found out the hard way. If I could do it again, I wouldn't do it again.

Although the heat pump is efficient, to this architect it is a noisy, mechanical device that detracts more from the quality of his environment than the savings on his utility bill are worth. In keeping with the desire of architects to improve the quality of the built environment and aesthetics, they are more excited about non-energy benefits than energy savings. Passive measures often also provide benefits that are difficult to measure, thus falling more within the architect's range of justifiable treatments than the engineer's. As one architect described:

> One of the more subtle aspects of daylighting as an energy savings strategy is the fact that human beings don't do well when they're deprived of daylight. I mean their emotional side suffers. Therefore, they aren't as productive. While it's hard to measure those things, I think architects understand their benefits. (Interview 29)

6 - BALANCING POWER AND RESPONSIBILITY

The previous examples show that architects and engineers are not simple intermediaries in the design process. Both professions have their own interests, and these interests influence both work practice and design decisions. The interests of architects and engineers do not mirror those of energy efficiency advocates, and they do not mimic each other. When seen from a systems of professions standpoint, there is no reason why they *should*. Architects and engineers have different cultures and different goals not in spite of each other, but to some degree because of each other. Having two professional groups involved in building design, each group must differentiate itself in order to defend its jurisdiction and protect its claim. Table 1 summarizes the cultural attributes discussed over the course of this paper.

The fact that architects and engineers often define their work as separate rather than symbiotic is not an accident. It is strategic. In the current balance of power and responsibility, neither architects nor engineers have an incentive to adopt the tenets of energy efficiency as an integral part of their work practice.

Table 1. Professional Cultures of Architects and Engineers

	ARCHITECTS	ENGINEERS
Jurisdiction	Building design	HVAC, lighting systems
Design Goals	Aesthetics, good of the community, timeless design	Occupant comfort, system responsiveness and reliability
Concerns	Bad clients, cost, stress failure of materials	Callbacks, cost
Goal Orientation	for many	for few
Problem Definition	Qualitative	Quantitative
Solution Set	Infinite	Limited
Solution Sources	Internal (inspiration)	External (libraries, manufacturers)
Justification	Qualitative	Quantitative
Favored Technologies	Passive	Active

If architects dislike machines, why don't they capitalize on their ability to make buildings perform better without them? In theory, adept use of architectural efficiency measures can significantly alter the need for mechanical systems and the men who design and install them. In some climates and building types, daylighting, thermal mass, and natural ventilation can reduce or even eliminate the need for big metal boxes and rooms to keep them in. If architects wanted more power over the design process, designing climate-responsive buildings would be one way of gaining it. But architects don't want more power. They want more freedom. Working with engineers and mechanical systems is a small price to pay for artistic license. And as an added benefit, architects get to delegate the notoriously difficult responsibility for comfort to engineers.

Why don't engineers insist that architects design better buildings? As the industry is currently configured, architects give engineers jobs. If architects suddenly started designing buildings that did not rely on building engineers as much, the importance of the role for building engineers would diminish. Architects who design bad buildings provide engineers the perfect framework to be socially responsible.

Why don't engineers design systems that are as efficient as possible? They have few incentives to do so. The disincentives are particularly clear in the area of reducing the size of the HVAC equipment to match the projected load more closely. Engineers' fees are often based on the size of the equipment, so if the equipment was smaller they would get less money. If the fee structure was changed, however, other reasons to avoid downsizing would remain. An engineer gave three reasons why it makes sense to use "safety factors" when sizing equipment:

> As the equipment gets older, then it can't produce as efficiently. So the question is, do you want to put something in there so that, when you do get some degradation of the equipment, can you still hold the building temperature? The other thing is you don't know what that building is going to do. We designed a building 15 years ago. Now they've got hundreds of computers in them. If you designed for that [many computers] at that time, somebody could say "well, you oversized." Now we look pretty good. We look like we saw ahead. There's issues of warm-up or cool-down. On the weekends around here we let our buildings cool down or warm up. So you have to think about how soon it will take to pick up that building or cool it down. So we prefer to use strategies to limit the performance of equipment and not worry too much about oversizing eventually. So the owner doesn't pay a penalty in operation. (Interview 5)

While these practical considerations are influential, the fact remains that real increases in building efficiency would diminish the engineer's grasp on his jurisdiction.

Why don't engineers use building performance characteristics to make a bid for power? They could design buildings from the inside out and proclaim themselves new kinds of architects. In Abbott's framework, such a revolt is unlikely because aesthetically pleasing buildings are a socially legitimate goal which engineers are not prepared to claim. Many buildings, either separately or together, are valued for their beauty. The New York City skyline and the Parthenon are two examples. Engineers have few illusions about their ability to provide fine aesthetics. As one engineer put it:

> I've designed buildings. That is, I've engineered them. They're just boxes. School gyms and factories and warehouses. They're not beautiful or anything, but they work. (Interview 17)

Because neither architects nor engineers have adopted energy efficiency ideals as their own, a third group has entered the scene: energy efficiency advocates. Their ideas, as described below, have been overlaid on the pre-existing cultures of architects and engineers, with different effects.

7 - OVERLAYING EFFICIENCY

"Energy efficiency" does not have the standard structural components of a profession. There are no degrees granted in this field, no licensing exams, and no official code of ethics. Although energy efficiency does not have all of the earmarks of a full-blown profession, many people who work in this area share a system of beliefs. These beliefs, coupled with the objective tasks to which they lay claim, constitute enough cultural attributes to compare them with architects and engineers. In Table 1, I presented a summary of some strategic differences between the cultures of architects and engineers. In Table 2, I have added a third column that describes some of the attributes of an efficiency advocacy "culture."

Unlike architecture and engineering, energy efficiency is a relatively new area of interest created by changes in knowledge outside the building industry. Growth in knowledge is one of the ways that social forces external to the professions can create a "new" legitimate set of problems and with it an opportunity for a new professional jurisdiction (Abbott 1988, pp. 177-211). The "problem" of energy efficiency in buildings is based on the twentieth century realization that the world and its resources are finite. It is supported by research from the environmental sciences showing that the burning of fossil fuels contributes to environmental degradation. As I will discuss below, the ways in which the problem of efficiency is addressed has developed a characteristic shape of its own. The shaded areas in Table 2 show that the usual shape of efficiency advocacy has more in common with engineering than with architecture.

Table 2. Cultures of Architects, Engineers, and Efficiency Advocates

	ARCHITECTS	**ENGINEERS**	**ENERGY EFFICIENCY ADVOCATES**
Jurisdiction	Building design	HVAC, lighting systems	Energy efficiency in buildings
Design Goals	Aesthetics, good of the community, timeless design	Occupant comfort, system responsiveness and reliability	Energy efficiency, life-cycle cost
Concerns	Bad clients, cost, stress failure of materials	Callbacks, cost	Energy squandering
Goal Orientation	for many	for few	for many
Problem Definition	Qualitative	Quantitative	Quantitative
Solution Set	Infinite	Limited	Finite
Solution Sources	Internal (inspiration)	External (libraries, manufacturers)	External (Research labs)
Justification	Qualitative	Quantitative	Quantitative
Favored Technologies	Passive	Active	Cost-effective

Efficiency advocates differ in many ways from both architects and engineers. Efficiency advocates claim the abstract problem of increasing energy efficiency in buildings, but they are rarely responsible for the design of actual buildings. Much of their work involves analyzing the technical potential of energy efficiency measures on paper. These analyses look at buildings systematically, identifying cost-effective design strategies without regard for which measures fall into what existing professional jurisdiction. By choosing the whole building as their level of analysis, efficiency advocates have selected a jurisdiction which, on some level, puts them in competition with both architects and engineers. This competition does not occur directly: clients do not choose between hiring a design team of architects and engineers or a team of efficiency advocates. Instead, the competition for control manifests itself indirectly, at the conceptual and legal level. The development of a system of energy codes and standards shows the most obvious way in which efficiency advocates affect the work of architects and engineers. The primary goals for all these groups differ, as efficiency advocates are really the only ones for whom energy efficiency is the primary goal.

7.1. Apples and oranges[9]: efficiency and engineering

While the differences between efficiency advocates and engineers are significant, there are ways in which their work overlaps. Both engineers and efficiency advocates define their problems in quantifiable physical, technical, and economic terms. Both groups also believe there is a “best” way to design. For efficiency advocates, the best way is implementing the most cost-effective technologies and strategies without regard for aesthetics and with the belief that things work as well in practice as they do in theory. Efficiency advocates have a wider array of potential strategies than engineers have, given their intellectual appropriation of areas commonly controlled by architects (e.g., building shape and orientation). Not having to suffer the consequences of providing comfort in real buildings, efficiency advocates can recommend strategies like natural ventilation and downsizing (or even elimination) of equipment. Building engineers do not have the flexibility to assume the role of the architect in practice, and they do not usually want to design themselves out of a job, so they see a more limited set of solutions than efficiency advocates.

Both these groups depend on solutions that can be ordered from a catalog rather than those that are created from scratch. While an architect can “solve” a design problem by coming up with a shape or detail from his imagination, engineers and efficiency advocates classify problems according to different existing technologies.[10] Efficiency advocates tend to be drawn to the experimental and innovative side of the technology spectrum, but they usually assess “commercially available” and “off-the-shelf” technologies in their analyses. Even architectural strategies such as daylighting and lightshelves are turned into conceptual commodities with average costs and energy savings. While many engineers are technically capable of building up a system from scratch, they usually mix and match components that are offered by manufacturers and equipment suppliers. Efficiency advocates rely more on new technologies developed in research labs to increase energy efficiency (e.g., compact fluorescent lights); engineers rely more heavily on new generations of technologies developed by familiar manufacturers. For both groups, however, the sources of possible solutions are external to the individual designer.

Whatever the source of the technologies and strategies, both engineers and efficiency advocates rely on numbers to help them convince clients (and in the case of efficiency advocates, policy makers) that their designs are “good.” Again, they use different kinds of numbers. For efficiency advocates, a cost of conserved energy that is lower than the average cost of energy usually proves their point. Quantities of carbon avoided has also become part of the efficiency benefits package (e.g., Interlaboratory Working Group 1997). Some efficiency researchers have recognized that non-energy benefits may be more important in “selling” efficiency than energy costs and savings (e.g., Mills et al. 1994). This approach, which would align efficiency advocates more closely with architects, still remains a fringe element in the literature.

In terms of the technologies themselves, efficiency advocates favor technologies for which they can offer proof of cost-effectiveness. This often means, as discussed in the previous section, that they favor active mechanical solutions commonly located in the jurisdiction of engineers. Passive strategies such as daylighting and thermal mass pose more difficult analytical problems than substituting a higher-efficiency chiller for a lower-efficiency chiller. Other passive strategies, such as better insulation and windows, are easier to model, and these strategies are staples in efficiency analyses and energy codes.[11]

7.2. Apples and orangutans: efficiency and architecture

Engineers and efficiency advocates are different, but architects and efficiency advocates are more so. Whereas efficiency advocates and engineers overlap in several areas, the cultural machinery of architecture and efficiency advocacy coincide only in one substantive area. Both cultures assume that their work will have an impact on people other those directly involved in the building project. For architects, this is expressed in their realization that buildings have both individual and social effects. Architects are often concerned about the opinions of building users, clients, *and* public perceptions. Efficiency advocates, like architects, claim that efficiency measures provide benefits on the individual and social levels: to building owners and users, and to society by avoiding the costs and problems associated with energy intensive activities and environmental degradation. Engineers are less concerned than the other two groups about effect of their work on the general public.

8 - CONCLUSIONS

This side by side comparison shows that, generally speaking, the views and methods of efficiency advocates have more in common with engineers than architects. I submit that it is this “cultural fit” that makes engineers more likely than architects to adopt lessons from an energy efficiency project like Energy Edge.[12] Assuming that a better cultural fit will result in higher levels of efficiency, how might this fit be achieved?

Future research could consider two approaches to this question. The first approach holds designer cultures constant and alters the usual path of efficiency advocates. In this scenario, efficiency advocates might react to the different concerns of architects and engineers by providing them with different kinds of information about different energy efficiency measures. This endeavor would explicitly recognize distinctions between market actors and the attributes of energy efficiency measures, and it would focus on matching actors and measures. The second approach is a more radical, long-term strategy: it holds efficiency culture constant and looks at the opportunities for changing the more deeply entrenched cultures of design professionals. In this scenario, energy efficiency becomes an intrinsic value throughout the design industry. The emphasis on efficiency rather than aesthetics or control could foster the development of a third group—architectural engineers. This single field might seize the task of providing aesthetically pleasing (if not wildly innovative) and highly efficient buildings. Whether or not it is desirable to improve the cultural fit between energy efficiency and building design to this extent, the second scenario suggests that increasing levels of efficiency may do more than save kilowatts: it may also create social and cultural change.

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10 - ENDNOTES

(1) I do not mean to imply that substantive changes never occur at the behest of others involved in the building process, only that it is not the most common occurrence. For example, Bijker (1992) has shown that fluorescent lamps have been "invented" in their diffusion stage; Thomas (1994) has shown that process innovation can occur on the shop floor as well as in design labs. Despite these caveats about where the innovative ideas come from, it remains the responsibility of the architects and engineers in buildings (and the design engineers in Bijker and Thomas) to incorporate ideas into the design, thus placing "the design" in their hands.

(2) Although I associate the interview responses with different levels of efficiency in practice, it is unknown, and maybe even unknowable, whether the architects and engineers in the "positive" group actually produced buildings that were more energy-efficient after Energy Edge than they would have done otherwise.

(3) Differences between these designers and the general population of designers are discussed in Janda (1998a; 1998b)

(4) Yet another answer is that designers' views are moot because they are merely client-driven intermediaries. For a discussion of ways in which designers drive clients, see Janda (1998b).

(5) For more historical context and a discussion of the role of individual experiences, see Janda (1998b).

(6) I focus here on the dynamics between architects and engineers, although struggles between architects and contractors also came up during the course of the interviews.

(7) This goal has been questioned by Heschong (1979), who argues that such uniformity is unnatural and undesirable, like a monochromatic world coated in the "most restful" shade of blue.

(8) An active measure is a mechanical or electrical widget (e.g., a fans, motor, or lights) that actively consumes energy and is, in principle, easy to quantify and control. A passive measure relies on physics rather than technology (e.g., convection, thermal mass, daylighting).

(9) I borrowed subheading titles from Holdren (1982) for my discussion of how some cultures are more different than others.

(10) Architects are also limited by physics, budgets, and the properties of materials. The point is not that architects are actually as free as artists as much as it is that they are somewhat freer in this respect than engineers. They can choose, for instance, whether their building is to be a rectangle or a square. There is also a tradition of architects designing buildings that are unbuildable (Harbison 1991), which is not a tradition for HVAC or lighting design.

(11) These strategies are accepted by all three groups, up to a point. Some architects think more insulation is better; some engineers feel it is possible to "go overboard" with insulation. In the eyes of these engineers, some internal load dominated buildings are "more efficient" without high levels of insulation (Interview 33) or that the savings do not justify the extra cost (Interview 18).

(12) While cultural fit explains the general phenomenon that engineers responded more positively to Energy Edge than architects, it cannot easily account for the variation within professional groups. Some architects felt more positively about Energy Edge than other architects; some engineers learned more than other engineers. As Abbott notes, professions are not internally homogenous. Janda (1998b) discusses two ways in which variation within professional groups can affect energy efficiency adoption.

11 - REFERENCES

ABBOTT, A. 1988. *The System of Professions*. University of Chicago Press, Chicago.

BIJKER, W. E. 1992. "The Social Construction of Fluorescent Lighting, Or How an Artifact Was Invented in Its Diffusion Stage." W. E. Bijker & J. Law eds., *Shaping Technology/Building Society*, pp. 75-102. MIT Press, Cambridge, MA.

BLAU, J. R. 1984. *Architects and Firms*. MIT Press, Cambridge, MA.

BLUMSTEIN, C., B. KRIEG, L. SCHIPPER, AND C. YORK. 1980. "Overcoming Social and Institutional Barriers to Energy Conservation." *Energy*, 5(4): 355-371.

CUFF, D. 1991. *Architecture: The Story of Practice*. The MIT Press, Cambridge.

GUTMAN, R. 1988. *Architectural Practice: A Critical View*. Princeton Architectural Press, New York.

HARBISON, R. 1991. *The Built, the Unbuilt, and the Unbuildable : in Pursuit of Architectural Meaning*. MIT Press, Cambridge, MA.

HESCHONG, L. 1979. *Thermal Delight in Architecture*. MIT Press, Cambridge, MA.

HOLDREN, J. P. 1982. "Energy Hazards: What to Measure, What to Compare." *Technology Review*, (April): 33-38, 74-75.

INTERLABORATORY WORKING GROUP. 1997. *Scenarios of U.S. Carbon Reductions: Potential Impacts of Energy Technologies by 2010 and Beyond*. LBNL-40533 and ORNL-444, Lawrence Berkeley National Laboratory and Oak Ridge National Laboratory, Berkeley, CA and Oak Ridge, TN.

JANDA, K. B. 1996. "Designing from Experience: The Effects of Research on Practice." Commercial Buildings: Program Evaluation - *Proceedings from 1996 ACEEE Summer Study on Energy Efficiency in Buildings*, Volume 6, pp. 6.89-6.96. American Council for an Energy-Efficient Economy, Asilomar, CA.

JANDA, K. B. 1998a. "Building Change: Characteristics of Design Firms and Their Effect on Energy Efficiency Adoption." Information Technologies, Consumer Behavior, and Non-Energy Benefits - *Proceedings from 1998 ACEEE Summer Study on Energy Efficiency in Buildings*, Volume 8, pp. 8.193-8.202. American Council for an Energy-Efficient Economy, Washington DC.

JANDA, K. B. 1998b. *Building Change: Effects of Professional Culture and Organizational Context on Energy Efficiency Adoption in Buildings*. Dissertation, University of California at Berkeley.

KEANE & CO. 1986. *Energy Edge: Round I Progress Evaluation*. BPA 169, Bonneville Power Administration, West Hartford, CT.

KOSTOF, S. ed., 1977. *The Architect*. Oxford University Press, New York.

KUNDA, G. 1992. *Engineering Culture*. Temple Press, Philadelphia.

LARSON, M. S. 1977. *The Rise of Professionalism: A Sociological Analysis*. University of California Press, Berkeley, CA.

LAYTON, E. T. 1986. *The Revolt of the Engineers*. Johns Hopkins University Press, Baltimore, MD.

LEVY, R. M. 1980. *The Professionalization of American Architects and Civil Engineers, 1865-1917*. Dissertation, University of California at Berkeley.

LUBAR, S. 1987. "Culture and Technological Design in the 19th-Century Pin Industry: John Howe and Howe Manufacturing Company." *Technology and Culture*, 28: 473-502.

LUTZENHISER, L. 1993. "Social and Behavioral Aspects of Energy Use." *Annual Review of Energy and the Environment*, 18: 247-89.

MEAD, M. 1928. *Coming of Age in Samoa*. W. Morrow & Company, New York.

MILLS, E. AND A. ROSENFELD. 1994. "Consumer Non-Energy Benefits as a Motivation for Making Energy-Efficiency Improvements." Global and Environmental Issues - *Proceedings from ACEEE 1994 Summer Study on Energy Efficiency in Buildings*, Volume 4, pp. 4.201-4.213. American Council for an Energy-Efficient Economy, Asilomar, CA.

NADER, L. AND N. MILLERON. 1979. "Dimensions of the 'People Problem' in Energy Research and 'the' Factual Basis of Dispersed Energy Futures." *Energy*, 4: 953-67.

NRC. 1980. *Energy Choices in a Democratic Society - The Report of the Consumption, Location, and Occupational Patterns Resource Group Synthesis Panel of the Committee on Nuclear and Alternative Energy Systems (CONAES) for the National Research Council (NRC)*. Supporting Paper 7, National Academy of Sciences, Washington, D.C.

O'DRAIN, M., J. PETERS, C. MELENDY, AND B. KRIEG. 1993. "The Process of Evaluation: Insights from Anthropology." Energy Program Evaluation: Uses, Methods, and Results - *Proceedings from 1993 National Energy Program Evaluation Conference*, pp. 330-335. Argonne National Laboratory, Argonne, IL.

SAINT, A. 1983. *The Image of the Architect*. Yale University Press, New Haven.

STERN, P. C. AND E. ARONSON eds. 1984. *Energy Use: The Human Dimension*. W.H. Freeman and Company, New York, NY.

THOMAS, R. J. 1994. *What Machines Can't Do*. University of California Press, Berkeley, CA.