E-Vision 2000
Transcripts

Day Two, Morning Session

October 12, 2000

Dan Reicher: Good morning everyone and welcome back to the second day of E-Vision. We thought we had a very successful first day and we thank you for all that you've contributed. Thank you to our panelists and we're looking forward to a very exciting day today. Before I introduce the chair of our first panel, I want to emphasize that tomorrow is your opportunity, during the morning forum, to present your ideas and your views about not only what you've heard and what you've debated for the past couple of days, but more importantly, the direction that you would encourage those of us in government, others in industries and the labs, to take as we move forward on some of these key issues.

There are research budgets and there are deployments funds. We have been pleased that we've had some modest increases in our budget at the Department of Energy Office of Efficiency and Renewables, so we actually have some ability to make some changes, make some adjustments, make some improvements in what we're looking at and what we're supporting, similarly, I think the labs represented here and some of the industry research going on. So tomorrow is really an opportunity to tell us what you think both on the R&D side, and frankly I'd also like to hear about your views on some of the policy-related aspects of the issues we've been discussing over the past few days.

If the opportunities presented by electronic commerce were to really take hold in our society and bring some of the benefits we were hearing about yesterday, what kind of policy prescriptions we'd want to offer. Similarly, the things you're going to hear today I think will raise some interesting policy ideas as well. There are a variety of spots still available to speak tomorrow. You don't need formal remarks. We expect this to be quite informal and we very much encourage you to sign up and give us your views and opinions tomorrow.

With that, it is my great pleasure to introduce Vivian Loftness who will Chair the Productivity Panel today. Vivian is Professor of Architecture at Carnegie Mellon University and Senior Researcher in the Center for Building Performance and Diagnostics. She is extensively published and has made major contributions to the definition of total building performance and sustainability for a range of building types—museums, research laboratories, courthouses, and offices. In the Center for Building Performance at Carnegie Mellon, Ms. Loftness has been actively researching and designing high-performance office environments with DoE, DoD, Department of State, NSF, and major building industries such as EDS, [?] Steel Case [?], and Johnson Controls.

Supported by a university building industry partnership, the Advanced Building Systems Integration Consortium, she is a key contributor to the development of the Intelligent Workplace, a Living Laboratory of Commercial Building Innovations for Performance, along with authoring a range of publications on international advances in the workplace. She has served on five National Academy of Science panels as well as being a member of the Academy's Board on Infrastructure and the Constructed Environment. Her work has influenced both national policy and building projects, including the recently completed Adaptable Workplace Lab at the U.S. General Services Administration. Vivian received her Bachelor of Science and Master of Architecture from M.I.T. and is a registered architect. It gives me great pleasure to introduce Vivian Loftness. [applause]

Vivian Loftness: Thank you very much. We have a very interesting panel this morning. When I was called to put together a panel in rapid fire to cover the issue of productivity and energy, clearly this was a challenge that was not going to be easily met, especially since no one has clearly defined productivity in the work environment among the white color or high-tech environment, and because the linkages have actually not been heavily researched.

The panel that we have put together, we think, will give a very good and insightful stretch to the definition of productivity and the impact it has on energy and the importance it has to energy research. I'm going to introduce the first half of the panel before the break and then the second half after the break so that the names and c.v.'s are linked with the actual talks.

We have set up this panel similarly to yesterday’s, but with a slight variation. We’ll have two speakers and then two responders who will both address the issues of the papers as well as add new dimensions that they feel are critical to this discussion. Let me say that three major speakers who are going to be offering papers this morning, the papers are in your notebooks so that if you want to annotate directly on the papers, you have those with you. I’m also going to take the prerogative of the panel chair position to round out some of the issues that we think should be looked at as part of this dialogue about productivity and energy.

Let me start by introducing, we’d like to launch right into the papers since there is the real meat of the discussion. Bill Fisk is Acting Department Head for Indoor Environment Research at Lawrence Berkeley National Laboratories. He has been working for a long period of time with substantial success in researching the interrelationship of energy use, ventilation, indoor environmental quality, and health and productivity in commercial buildings. I think you’ll sense both the level of accomplishment and the understanding of the international advances. I think one of the things that Bill will contribute to this discussion is the notion that health is a critical part of productivity, that health and energy are linked, and that there is a future and research in that area.

David Wyon who will speak second is a British-born environmental scientist, but who has been living and working, up until recently, in Scandinavia. In fact, after receiving a very unusual set of degrees in Natural Science, Applied Psychology, and Preventative Medicine, has been working with the National Swedish Institute for Building Research as one of their major researchers. A lot of the accomplishments that have looked at energy and environment, both in health and productivity, have come from Sweden, and David has been central to that. More recently, he has joined at an adjunct faculty member at Danish Technical University in Copenhagen and is a researcher at the Danish Indoor Center for Indoor Energy and Environment, a newly formed research unit that is looking at the linkages of energy and indoor environmental quality, so he brings a very strong international and U.S. perspective. He is also a researcher with Johnson Controls Institute so he has a pretty healthy industrial understanding as well.

The responders will be adding new dimensions. The first one is Richard Wright who most of you know. Dick Wright is the retired Director of the

Building and Fire Research Laboratory at the National Institute of Standards and Technology. He is one of the key leaders of NIST, also a key member of the White House Panel on the Construction and Building, and looking at the future of construction of building in relation to national policy. He is the chair of the National Research Council's Board on Infrastructure and the Construction Environment and clearly brings a very good perspective, both of the federal sector as well national policy issues.

Then Art Rosenfeld who has, I actually thought I could ask the audience to give me his c.v. because I'm sure that most of you can piece together the c.v. through your workings with him. Probably some of the most unusual and exciting list of accomplishments while being a Professor of Physics from the University of California at Berkeley, founded and directed the Center for Building Science at Lawrence Berkeley Laboratories. This is one of the largest, if not the largest assembly of researchers, at least in the U.S., that is looking at buildings and aspects of not just energy, but other issues of building research. He was also the Senior Advisor, until recently, at the U.S. Department of Energy, the Assistant Secretary for Energy Efficiency and Renewable Energy, and just recently accepted a position as a Commissioner in the California Energy Commission. I think Art will provide some perspective to these papers as well. With that, I'm going to pass the baton to Bill Fisk.

William Fisk: Good morning and thank you, Vivian, for the introduction. My presentation today has two major parts. The first section of the presentation is going to address the opportunities for improving health and productivity by providing better environments inside our buildings. I'll include some estimates of the nationwide reductions in illness and economic benefits. I want to say right up front that these estimates have a large uncertainty and I hope you don't focus entirely on the uncertainty but just think about—is there really a large opportunity here.

The second part of my presentation, I'll address what I believe are the changes in building practices that may come about in part because of the evidence that productivity and health can be improved and because of other factors, and then go to discuss the implications for the research and technology transfer programs of DoE.

This diagram shows two pathways to economic benefits that involve health that underlie my thinking for part one of this talk. In both cases, we start with changes to building design operation and maintenance that improve indoor environmental conditions that, in some cases, improve the health, satisfaction, and comfort of the workforce. This can lead to reduced healthcare costs which brings about economic benefits. It can also lead to increases in work performance, for example, because of reductions of absence rates or distractions from work, which also leads to economic benefits. The estimates that I'm going to provide today include both of these types of economic benefits—healthcare cost savings and improved work performance due to reductions in illness.

There's another pathway that I'm not going to discuss, as shown by the red arrows in this figure, where improvements in the indoor environment may directly improve performance without affecting health and David Wyon is going to address this topic to some degree in the subsequent talk.

Traditionally, when people study health effects caused by the environment, we focus on the severe health effects such as shown in the top of this table that are very important, but they influence a very small population generally. In contrast, I am focusing on the set of health effects in red on this table, which I'll define these affects as they go along, but they are experienced by a huge proportion of our population.

In the case of respiratory illnesses, all of us have common respiratory illnesses every year or two. For these other health effects, not quite as large, but still enormous populations and, in many cases, people are affected frequently. So these really have a significant impact on our well-being and large economic consequence as well.

This rather complicated slide shows how I've estimated health and productivity benefits. I'm going to walk you around this figure. In the little green box, on the upper left, I've reviewed health studies that tell me about the strengths of associations between building-related risk factors. For example, low ventilation rates or moisture problems and health outcomes, for example, respiration illness. It tells me how much the building factors can influence the outcomes. Then building science tells us how much we might be able to reduce those risk factors. If I combine that information with professional judgment, I've derived some estimates of the percentage potential reductions in the health outcomes.

In the yellow box, on the bottom, we've taken published estimates of the cost of health outcomes and demographic health and economic statistics together and derived the societal costs of the health outcomes and, by society, in this case, I mean the United States and the size of the population that is affected. When I combine the information in the two red boxes, basically, when I multiply the numbers together I get the outcomes that I'm seeking—the potential nationwide productivity or economic gains for improved health and the potential nationwide reduction in adverse health outcomes. This is a completed process that I can't go through all these details when I provide the examples today. In fact, I've looked at well over 100 papers, used well over 100 papers to derive the numbers I've presented to you today. But for each health category, I'm only going to provide one example of how buildings influence health. So just keep in mind that this is one example of a much broader set of literature.

Let's turn to communicable respiratory diseases. These are these common respiratory illnesses that we all experience, like common colds and influenza. There are three ways, in theory, and to some degree supported by evidence though which buildings could affect transmission. We can change the concentration of aerosols that contain an infectious agent like a virus that we inhale, for example, by changing the amount of dilution and ventilation. We can change the viability of these aerosols—are they infectious when we inhale them—for example, by changing temperature or humidity, and some pollutant exposures may change people's susceptibility to infection.

Now these very common respiratory illnesses that we tend to accept as a matter of life really have a huge economic significance. As shown on the right-hand side of the slide—180 million days of lost work per year; 120 million additional days when we have restricted activity; and healthcare costs of about $36 billion per year; and when I add the value of lost work total—a total annual cost of about $70 billion per year.

Here is my one slide providing evidence that buildings can make a difference in respiratory illness. What I show here are the results from seven studies that have had respiratory illness of unspecified type, or influenza, or short-term absences outcomes. These studies have compared the prevalence of respiratory illness in different populations with different building characteristics, typically different ventilation rates. As you can see in this figure, each of these studies has found statistically significant decreases in respiratory illness associated with factors like higher ventilation rates or lack of space sharing.

How have I gone from here to the national estimates? What I've done, in this case, I've thrown out the absence outcomes because they're not really respiratory illness and I've thrown out the one outlier which is a 40% decrease in schools from a rather old study. I've actually used ten studies. I only could fit seven on here and I come out with a probable range by which these practical changes in buildings, things like increases in ventilation rate or reduced space sharing could reduce respiratory illness a practical range of 9% to 20%. If we could then get to that 9% to 20% reduction in illness, we'd eliminate 16 to 37 illnesses per year, and save $6 billion to $14 billion annually.

My second category—health affects as allergies and asthma, and I've combined these two together because most of asthma has an underlying allergy that contributes very much to asthma. About 20% of our population have allergies. This is an important segment of our population and 6% have asthma. The annual costs are not very certain, but the best estimates are about $15 billion per year. Based on the scientific literature, characteristics of the indoor environment are very important to the exacerbation of asthma and to asthma symptoms and they probably play a significant role in the development of asthma as well. I've listed these factors here. Many of them are allergen exposures that occur indoors. Molds and moisture problems, the molds often resulting from moisture problems; tobacco smoke is important; and infectious disease, which I talked about previously, is a major source of exacerbation of asthma as well.

Here is one slide providing the evidence that buildings are important. On the vertical axis I have a measure of increased risks called odds ratio. I don't know if you are familiar with this parameter but if the odds ratio is unity, it means the study found no increase in risk. If the odds ratio is two, as illustrated by the red line, it suggests approximately 100% increase in risk. If an odds ratio is four, it's about a 300% increase in risk and so on.

If you look at this chart which shows the results of all the major studies, it's clear that with only one exception, these studies have found that moisture problems or visible molds in our buildings are associated with significant increases in asthma health effects. In many of these studies, the magnitude of the increase in risk is at least 100%.

Moisture problems are important for other reasons as well. They cause a tremendous amount of damage to our buildings which requires a cost of [?] remediation and they can degrade the thermal performance of building envelopes which increases energy use. Based on our current knowledge, there are a number of interventions that we can make in our buildings to reduce allergy and asthma symptoms. Some of them involve changes in human behavior like reducing tobacco smoking, and some of them involve changes in the design and operation of our buildings, and some improved maintenance in our buildings.

I don't have time to go through the derivation of the percentage reduction by which I expect we can reduce each of these health effects, but using the method that I described previously, I've estimated that we could reduce allergy and asthma symptoms between approximately 8% and 25% by changes to our buildings. If we did so, we'd save $1 billion to $4 billion. I'm not claiming that it's easy to get people to take these measures. This is going to be a challenge. But what I'm saying from what we know today, we can do this. These are not measures that are beyond our reach. It is practical and possible to get benefits on this order of magnitude.

The third category—health effects of sick building syndrome symptoms. These are acute symptoms that are associated with occupancy in specific buildings. There is a whole constellation of symptoms. The most common ones are irritation symptoms of eye, nose, and throat, and central nervous system symptoms such as headache and fatigue. They have primarily been reported in offices and schools, but there's evidence that even in homes, certain homes cause symptoms in people and they're quite widespread. It's not just the well-publicized sick buildings. In fact, the largest study in the United States suggests that about a quarter of office workers reported two or more symptoms that were frequent and then improved when they went away from their workplace. I've used that as an estimate of the percentage of workers that are significantly affected—that's 15 million workers in the United States.

We have a challenge estimating the cost of these symptoms. Clearly, there are costs for investigations and remediations, but there is not database that we can use to estimate those costs. We believe the largest costs, by far, is their affect on people's performance at work. There are two lines of evidence. There's subjective data, implying about a 4% decrement in performance and there are objective data, but only from three studies suggesting on average of about 2% average decrement of performance for a set of office tasks on average for the population due to these health symptoms. If we accept that estimate, and this is one of the more uncertain numbers in my analysis, the estimated costs of these symptoms is about $60 billion annually.

Do buildings make a difference? There's a wealth of evidence in this case that buildings influence the problems with these symptoms and some of the most consistent or compelling evidence is that increased ventilation rates could reduce symptoms. In a major review, and the results are summarized here, 20 of 27 assessments that met certain quality criteria found lower ventilation rates associated with significant worsening of at least one symptom. When the lower ventilation were below 10 liters per second per person [?], or 20 CFM per person, the minimum rate in the ASHRAE standards, the results were very consistent—18 of 20 assessments found a significant affect.

The magnitude is appreciable as well. Using some of the best data, they suggest that increasing ventilation rates by five liters per second per person, which is half of the minimum recommendation for office buildings, on average would reduce symptoms by about a quarter in the U.S. population.

There is some very interesting work in Denmark, and I believe David Wyon may show much more of this, where in a controlled laboratory setting we've modified air quality by removing and replacing pollutant sources and changing ventilation rates and looked at how people's performance on office-type tasks changed. As shown here, average performance in text-typing edition and proofreading is affected significantly when we do these experiments.

Here it's correlated with dissatisfaction with indoor air quality and the range of the effect is a few percent. In a recent paper that isn't yet published, they said that the decrements in performance have occurred only when the intensity of sick building syndrome symptoms experienced by the workers increases. This is some of the objective evidence that these symptoms affect performance.

These are some of the tactical options that we could use to reduce symptoms based on the scientific literature we have. I'm not going to go through the list but just note that these are measures that we can implement today. In some cases, we need a little research. In many cases, we need to more explicitly quantify the benefits.

Using the method that I described in the diagram, I've estimated that we could reduce symptoms by 20% to 50%. That corresponds to $10 billion to $30 billion in annual savings or $150 to $450 per office worker. A pretty big number but this does not really reflect the full uncertainty in the cost of these symptoms so it's probably a somewhat larger range that I can't quantify.

If we put this all together, it paints a picture of pretty important influence or pretty large potential to improve health and economic performance by improving our environments. We see here the opportunity to reduce respiratory disease in a two to three [?], tens of millions of workers, and reduce allergy and sick building syndrome symptoms in tens of millions of workers, and to save tens of billions of dollars annually.

I just have time for one very quick cost benefit analysis. Here I'm considering increasing the ventilation rate in a large Washington, D.C., office building from 2.5 to 10 liters per second per person. Two-and-a-half is 5 CFM per person, it's the minimum rate in the previous ASHRAE ventilation standard; 10 is the value in the current standard. This would cost about $10 per person each year when considering both the energy cost and the requirement to increase the capacity of some of our ventilation equipment.

If I took the lower range implied by the data I showed previously and I said we'd expect a 10% reduction in respiratory illness, we'd save $43 per person per year. If we increase productivity by a quarter of a percentage point, we'd save $98 per year, and we'd have a benefit cost ratio of 14. Most measures that we can think of are going to have high benefit cost ratios if there is even a small impact on health and productivity and this is simply because salaries and healthcare are so expensive relative to the cost of operating and maintaining our buildings.

Part Two—the implications for DoE. I'm going to talk briefly about some changes in building practice. I believe we are starting to occurring a leadership role for DoE and some specific research needs, I think that are particular to DoE.

As background, I think it's important to compare expenditures or costs and this chart shows total U.S. expenditures for employee compensation, health, a subset of health costs, private sector health insurance, and commercial building energy use. There are a couple points to make from the slide.

First of all, virtually all of our research on commercial buildings today is based on the desire to constrain or reduce commercial building energy use, one of the smaller costs associated with businesses that employers face. I think this is an extremely important goal because of the environmental impacts of energy, but I don't think that businesses see it as always a major driver in their decision making because they have these much higher costs. Fortunately, there are some opportunities, and these are some that I'll focus on later, where we can potentially get benefits and all these outcomes simultaneously and I think these are opportunities that DoE really needs to pay a lot of attention to.

I'm not the only one, but I, and others, are starting to predict that there will be some widespread changes in the design, operation, and maintenance practices in our buildings. A current practice aims typically for adequate indoor environmental quality, maybe you could even say marginally adequate, let's just get by. I think, over a couple of decades, we are going to transition to a practice that aims for indoor environmental quality that maximizes health and productivity.

One of the questions is—what happens to energy use. That depends on how we make this change. There is some evidence this is starting today. The green building movement, indoor environmental quality is becoming a centerpiece of the green building movement. Today, large building projects now often have environmental consultants and they are starting to become interested in indoor environmental quality, not just the outdoor environment. They call me up. I think we heard yesterday that some energy service companies are becoming interested in marketing services to improve the indoor environment. I know that large utility organizations are also getting very interested in this.

The driving forces go beyond the evidence I provided you that we have possible health and productivity benefits, but broader societal changes like increasing affluence, increasing demands for excellent health by individuals, the desire to constrain healthcare costs, and foreign competition at lower salaries. All these factors are going to make us want to get the most out of our workers and improve our indoor environments. The changes in practices are the types of things I've talked about before.

With this as background, I am proposing that DoE take a leadership role in research and technology transfer in this area with two goals—to improve the health and well being of the U.S. population, and to guide this response that I showed in the previous slide so that energy-efficient technologies are used whenever possible.

Such a role, I think, is very consistent with DoE's missions, including it has a general public service mission. It has an energy efficiency mission. In this case we can prevent an energy efficient response to the degree possible and we'll capitalize on opportunities to actually stimulate energy efficiency, and it's very consistent with DoE's mission and its long history of advancing science and technology in the buildings arena. Furthermore, I would argue that a strong DoE role is critical if we are going to have success in this transition because the way we're going to get the benefits is through changes to the design, operation, and maintenance and use of our buildings. It really requires resources and expertise in the buildings arena to get these benefits, and DoE and DoE's contractors really have unmatched capabilities in this area.

Here, I list, in the paper I go into detail for each of these topics. These are research areas that I think should of particular interest to DoE and I picked these for three reasons—they all have health consequences; they all affect the energy use in our buildings; and, in many cases, I believe there are opportunities for potential simultaneous benefits in health and energy use.

What I'm proposing as role for DoE is not to be the leader in all aspects of this subject area, but to focus on the subset of areas that are of greatest interest for DoE and most important for DoE.

In the ventilation area, I've expanded that list a little bit. There are a number of associated research needs. We need to know more about minimum ventilation requirements and various building types. Today ventilation rates that are virtually out of control in our buildings because we don't have practical ways to measure and control ventilation rates. We need to demonstrate heat recovery when it's applicable. We need to conduct research on better means to use ventilation, to get better exposure reduction per amounts of outside air supplied such as through displacement ventilation or task ventilation.

One of the win-win opportunities I think should be of interest to DoE is a technique called “indirect, directed operative [?] cooling” which is a substitute for compressor cooling. The evidence I’ve seen suggests we might reduce energy use by about 50% and have similar, maybe larger reductions, in peak power. These systems provide 100% outside air rather than re-circulated air so they increase the ventilation rate a great deal in our buildings. Because we have these increases in ventilation rates, we’ll have a large reduction in indoor generated pollutants so it looks like we can win in both respects.

But there are research issues as there are in all these topics. We do get some modest increases in indoor humidity. Is that important in the climates where these systems will be used? Is there an increased risk of cooling system microbiological contamination? Both these systems and compressor systems have water in contact with the air, here we have more water, probably depends on how often it’s dried out and the levels of maintenance, but it’s an important question to examine. It’s an unfamiliar technology. We have to help people learn about it and I don’t think we have the tools available for people to do system sizing.

One final example, I think the DoE working with industry should consider reconsider rethinking HVAC architectures from the ground up for two reasons. We have enormous number of performance problems with HVAC systems in our buildings. They just don’t work the way they’re supposed to work. The improvements that we see are incremental and they occur very slowly.

This effort would have two goals—energy savings and improving indoor environmental quality and comfort in our buildings. I didn’t talk much about comfort, but we have an enormous number of thermal comfort complaints in our buildings as well. I’ve listed here just a few possible features of a new HVAC architecture. We might have very few ducts and smaller fans, saving energy. I think we certainly would have more individual controls so that people can tailor the environment to meet individual needs. We’d use better sensors and newer types of sensors. Maintenance is a big problem with these systems. Perhaps we could design these systems so that the maintenance is performed in the shop on modular units rather than in the space where it never gets done.

In conclusion, I think we have a real opportunity to reduce respiratory illness, allergy and asthma symptoms, SBS symptoms, and, in turn, increase worker performance. There are opportunities for very large financial benefits of tens of billions of dollars per year. I go on to say that there are large uncertainties in the quantitative estimates but still we are relatively certain that the opportunities are large and I propose a leadership role in research and technology transfer for DoE. It's consistent with DoE's mission. DoE's capabilities are necessary and there are opportunities for simultaneous energy health and economic benefits. Thank you. [applause]

David Wyon: Good morning, it's going to take you little while to get used to my accent. I usually find I have to repeat what I said first while people adjust to the pronunciation and the choice of words. I do apologize for that. It is my accent that is wrong, not yours.

I'm going to be talking about how we might improve productivity and still reduce energy use in buildings and I'm going to confine my presentation of the evidence to the work I've done and other people have done in offices and schools.

I'm an experimental researcher. I've personally inconvenienced over 5,000 volunteer subjects in experiments on the indoor environmental quality for a total of over 20,000 hours of exposure to more or less uncomfortable conditions. The lucky ones got the control conditions. Some of the experimental conditions were rather unpleasant, but not to the extent that they are in military research because my work has been on the civilian population and it follows directly on from the work that was done following and during the Second World War. I've just simply applied the approach to the civilian population including women, older people, and children.

I'm going to try to do three things in the short time available. I'll present the experimental evidence for the effects of temperature and indoor air quality on productivity. I'm going to sketch DoE research strategy for getting from idea to widespread adoption of that idea. And, I'm going to list a few solutions that would save energy without affecting health or productivity. They all have their attendant problems, which is why they haven't been adopted. They require research, and it's that research that I think DoE should support. There's a caveat here.

Some of the results that I shall be showing you show rather large affects of temperature or indirect quality on the performance of specific tasks such as reading as much as 30%. But, you have to remember, in interpreting that that's not a 30% affect on productivity because you're probably not doing tasks which require reading or in which reading speed is critical for all of your working day.

People nowadays have a varied set of tasks they tackle during the day. Some of them are not critical and that means that even if there is an affect on the performance of that task, it doesn't affect overall productivity. So these results need to be interpreted in terms of exactly what kind of work you're doing during a day.

Performance is what affects productivity which affects profits. These are affected at the next level of the human criteria hierarchy by the comfort, the effort, and the motivation of the people doing the performance. These are, in turn, affected by their health and this is mediated by the physics and chemistry of the indoor environments. So there are a lot of specialties involved here.

In all of the experiments I do, I try to evaluate human response at all three levels. Taking data on their symptoms, their physiological response, how they feel, how they interpret the environment, and how well they perform tasks.

As Bill Fisk said, the ratio of salaries per square foot of office space to rental costs is very high, something like 2 to 15 in an estimate made by James Woods, and the ratio of salaries to construction costs is even higher, again expressed per square foot per year. It can be as high as 40 times—40 to 1. We often say that the cost of creating the indoor environment, that is the HVAC costs for heating and conditioning the air, can be as much as 100 to 1 in terms of salaries per square foot versus the cost of conditioning the air.

The building characteristics at the top and the design and operation of the building affect what happens at the bottom, the health, comfort, and productivity of the occupants of the building. These are what we call the desirable outcome parameters. In between, there's a chain of cause and effect, where the IEQ "indoor environmental quality," variables that are affected by the building characteristics are the independent variables that drive the physiology and the psychology of the occupants and affect their symptoms, perceptions, and actions.

It moves from the top to the bottom. Decisions made in the design and operation of the building turn out to have affects on health, comfort, and productivity. We often do our experiments within those lines because experimental work cannot engage in assigning people at random to uncomfortable conditions for months or years, we have to work in the short term. People are prepared to do a few days or a few hours of work under experimentally determined conditions, but when you move to the long-term affects, you have to use a survey approach. Most of the experimental work is done within these lines—where we alter the IEQ variables in some way for a whole day or a few hours. We examine what happens to the physiology and the psychology and how people feel and how well they perform various tasks.

In measuring productivity, we have a range of approaches. These bullet points list some of them that you'll be seeing in my paper and in this presentation. We can simulate work. We can get people to type onto a computer or to proofread a text that we've prepared with errors of various kinds to see whether they find them. We can use diagnostic tests, which may be tests of skills of various kinds or even tests of creative thinking. I haven't time to go into how we do that, but I assure you that it is possible to measure how creatively people think. It's very difficult to do. How they respond to open ended questions. How many ways they can think of using familiar object other than what it was intended for, for example, and then we characterize those answers in terms of how unique they are.

We can look at some aspect of the tasks, the embedded task, reading and addition tasks are part of schoolwork, they're not all of schoolwork, but they're part of it. They occur naturally in school. We can use existing measures—insurance claim processing or in a call center, we can measure the time it takes to deal with each customer. We can, of course, measure absenteeism, and we can ask people to estimate how well they think they're going their work. They're often the best judge of that themselves. Of course, that has to be validated, but quite a lot of people have worked with self estimates of performance, and, of course, we have to use self estimates of the intensity of symptoms such as headaches. There is, in fact, no other way of determining how severe a person's headache is than by asking them.

The same is true of eye irritation although that does correlate with objective measures such as blink rate and the break up time of the tear [inaudible] both of which have turned out in experiments to correlate very well with perceived irritation of the eyes. So there is very good validation of perceived intensity of sick building syndrome.

Temperature and indoor environmental quality, air quality, may affect productivity by altering how alert people are—what psychologists call their state of arousal. That is, whether they're half asleep or so nervous that they are also dysfunctional. It can affect the effort they put in. It can affect their sick building syndrome symptoms such as headaches, difficulty of concentrating, sore eyes, dry lips or skin, which are a source of distress and distract from work.

There can direct toxicological affects of gaseous or particular pollution. I've worked with toluene for example, and it does smell terrible, it does give you a headache, and it does have a direct toxological affect on the nervous system.

There can be allergic responses, of course not everybody has an allergic response, but an increasing and already significant proportion of the working population may have an allergic response to some aspect of the indoor environment. Most of us have a sense of smell, so if we feel that the indoor air quality is worse than it should be, it can cause us both distress and affect our motivation. I shouldn't have to work in air of this quality.

There is a relationship between the level of arousal and the breadth of attention that you can bring to bear on different tasks. Creativity requires low arousal, you have to be relaxed to be able to think originally and that carries with it a broad range of attention to different aspects of the mental task. Memory is the same.

At the other end of the scale, control tasks and logical thinking require a high level of arousal. Remember your mother always telling you to sit on the edge of the seat and put your feet on the floor if you're trying to do mathematics. She was right. But it brings with it a very narrow range of attention. It enables you to concentrate, to shut out irrelevant aspects of the environment.

Vigilance is a special case. If you are just waiting for a red light to go on and you want to react to it quickly, some people call that vigilance. I call it reaction time. You need to be alert, at a very high peak of alertness. However, if you want to be vigilant for anything that could happen, unspecified targets, and that's what we employ people to do mainly nowadays in industrial production, they are there because we cannot predict what might happen. If we could, we'd build machine to deal with it. Then they need to be relaxed and to have as broad a possible range of attention. Any factor of the environment that affects alertness, and temperature does, so does lighting and noise, can affect the range of attention that you can bring to bear on different tasks.

Let's start with temperature. How does heat stress or cold stress affect performance in offices and schools? Heat affects mental work while cold affects manual work. The warmer your fingers, the more skilled they are. Cold stress has never been shown to have a negative effect on mental work, and heat doesn't affect manual work. So bear in mind that there are usually a manual and a mental aspect to different tasks to people do and that heat is good for one and cold is good for the other. Thermal discomfort of either kind is distracting and raised temperatures increase sick building syndrome, as I'll show you later on.

Comfortable conditions with which people are perfectly satisfied, say 80% of the population are satisfied, may still be reducing performance by between 5% and 15%. We can objectively measure performance changes within the comfort zone. It used to be thought there was a range of acceptable performance and that comfort was a luxury at some point within that. It turns out to be the other way around. People are satisfied with a fairly broad range of thermal conditions but it affects their work within that range. What we call rule-based logical thinking and routine work, require cool conditions for efficient performance; whereas creative thinking, memory, and vigilance require work conditions for efficient performance.

This is some early work I did on Swedish school children. They were only ten years old. Their reading speed was greatly decreased by about 30%, in fact, by temperatures below the sweating threshold. In fact, as we got above the sweating threshold, about 27 degrees Celsius they, paradoxically, perhaps, for some people, tended to increase they reading speed because they were better able to deal with the thermal environment. When they were doing sentence comprehension, that is trying to understand what they were reading, again, we found this surprising result that intermediate temperatures, the kind that occur very often in offices and schools were worse for mental performance than more severe temperatures.

The New York Commission on Ventilation, many, many years ago now showed that typewriting performance was reduced by about 30% whether you were a woman and good at typing or a man and very bad at typing, in both cases, working at 24 degrees Celsius, which is generally considered quite comfortable, reduced the speed of work by as much as 30%.

Creative thinking in the quiet. These are 12-year-old English boys in one of my experiments. In the quiet, moderate thermal stress actually increased their score on a test of creative thinking and we have observed that in other experiments too. Whereas noise, of course, knocks it out completely and there is no significant affect of temperature under noisy conditions.

I promised to show you how temperature affects sick building syndrome. This is an intervention experiment done in the offices of the Volvo Truck Corporation in Sweden where they experienced, for a week at a time, temperatures in the range 19 to 24.5 degrees Celsius, all of them reasonably comfortable. But, you can see, that the percentage of office workers reporting problems with the eyes, nose, throat, and facial skin increased from a minimum around 21 degrees Celsius, a minimum of about 15% of the group, to as many as 30% to 40% who had those problems at the upper range of the thermal comfortable zone.

In the same experiment, I've picked out here the symptoms that might be expected to affect mental performance—feeling of fatigue, feeling that you can't think clearly and have difficulty concentrating. This is a literal translation in Swedish *[words spoken in Swedish]*, that is, literally, heavy headed. It doesn't mean sleepy. It means having a thick head, being unable to think clearly.

You can see that again we have a minimum of these symptoms, around 20—about 68, 21 degrees, 70 degrees Fahrenheit, and a staggering 60% report these problems at the upper end of the comfort range. So think about that when deciding whether to provide air conditioning. Office staff are feeling like that as temperatures rise. Only a few degrees Celsius can affect these symptoms very greatly.

People who experience sick building syndrome have been shown, experimentally, by Canadian workers at McGill, to perform diagnostic computerized tasks less well. Those who reported any sick building syndrome symptoms performed 7.2% less fast on one task, and the "P" value is highly significant. "P" is the probability that this result could have been observed by change, and it's vanishing small, and they had a 30% higher error on another computerized task. It's not surprising. If you feel any of these symptoms of headache, fatigue or sore eyes, or irritated skin, it's such as distraction that it does affect your work and here's the evidence for that.

Let's move now to air quality and how that affects performance. The first thing to remember is that thresholds of irritation vary with health and between people. They vary over time for the same person, depending on their state of health. That unwanted odor can be just as distracting as noise; that odor perception varies with temperature and humidity; and that variable dust contamination rates and variable cleaning efficiency may alter required air supply rates.

A supply rate that is adequate in one building may be inadequate in another for that reason. People with allergies may have a threshold of sensitivity that is a million times lower than that of a healthy person. Imagine walking into a room which was a million times smokier than the level that irritates you. That's how it feels for a person with an allergy to tobacco smoke. This is data from the Swedish allergy report dated 1989. Even people who are not clinically allergic may be hypersensitive and their threshold may be 100,000 lower. They respond at levels 100,000 times lower than you or I would respond, if we're lucky enough not to be hypersensitive to the indoor environment.

The first evidence we had that there was any affect of air quality on school performance was provided by a relatively recent study by Mirvald [phonetic] in Norway and across the "X" axis you see that she has classed the different classrooms she studied into lower carbon dioxide concentration, which is an indicator of good ventilation, going to what is much more normal, very high $C0^2$ concentrations which shows very poor ventilation. You can see how their performance index of school work which she applied to all of these classrooms is severely affected by the ventilation rate in these classrooms.

The trouble is that this result could be due to the fact that in middle class areas, their parents make sure they have better ventilation, and their children also perform better. This is not direct evidence that ventilation rates affect performance, but it is indicative that this may be happening. Norway is a pretty egalitarian country and people do go to the public schools there. But since then, we have set up the International Center for Indoor Environment and Energy in Copenhagen at the Technical University of Denmark and we've run a series of experiments that directly links air quality and ventilation rates to performance of various kinds of office work.

This is the experimental set up. We have six people working for a four-and-a-half hour period, a typical half-working day, in a normal office with daylight. Behind the screen, so they can't see what's there, we have both equipment for conditioning the air, directly from the outside, so the building's ventilation system is not involved, and we can place, or remove, various sources of air pollution.

In the experiments I'm going to be talking about, the source of pollution was a piece of carpet taken from an office where it had been for 20 years and it was in sufficient quantity to have floored the whole office. We didn't put it down on the floor because we didn't want them to notice the days when we removed it. Sometimes it was there behind the screen, and sometimes it wasn't. It was either hanging in racks behind the screen or it was absent completely, but the same subjects came day after day and they didn't know when it was there, and they were, of course, in balanced design.

In another experiment, the carpet was always there and we had three different ventilation rates, in liters per second—3, 10, and 30, liters per second per person multiplied by ten roughly, for CFM and this corresponds to….

[End of Tape 7, Side A. Start of Tape 7, Side B]

…which is very home and in older offices, ranging up to six air changes per hour which is almost unheard of, even in modern offices.

During each four-and-a-half hour exposure, the subjects assessed the perceived air quality, the sick building syndrome symptom intensity, and their thermal comfort. They performed simulated office work throughout each exposure and they were told, and reminded, to adjust their clothing so that they were thermally neutral, so this an experiment only looking at the affects of air quality. I can tell you that during the time they were working, they did not notice a change in air quality. This carpet was not moldy or anything like that which would cause you to notice immediately. Their estimates of air quality, between the two conditions, were not different, significantly.

They reported air quality on what we call the acceptability scale where they choose, somewhere on this divided scale between—clearly not acceptable and clearly acceptable, where the breakpoint is at just not acceptable, or just acceptable. This gives us an estimate of how many people would be prepared to work in air of this quality. They report their sick building syndrome symptom intensity on what are called visual analog scales. These are ungraduated scales. The subject puts a mark somewhere on the scale between, for example, no headache or severe headache, and also estimates how well they think they have been working. They also give us some estimates of how hot or cold, or humid or stuffy the air is.

The first experiment showed a significant affect of the carpet behind the screen. The carpet reduced the performance of a text typing task by 6.5%. We repeated that experiment because it was so surprising. We repeated it in another country, in Sweden. The first experiment is on the left, the next experiment is in the middle, and the experiment in which the carpet was always present and we had three different ventilation rates is on the right. You can see a clear and convincing affect of removing the carpet or increasing the ventilation in every single case. We think this is caused by the fact that people felt worse. You can see in each of these experiments that removing the carpet reduced headache, reduced difficulty in thinking clearly, and so did improving the ventilation. We think is probably this is the reason for the observed affect on performance.

The shape of the fact is like this, as you would expect. As we increase the outdoor air supply rate, the performance increases by 1.7% for every two-fold increase in the ventilation rate above three liters per second per person. Working at home does have its disadvantages unless you make sure you’ve got good ventilation.

We can also, as Bill Fisk showed earlier, I think this data show that our data is linearly related to the percentage of people who are dissatisfied with the air quality on that scale of acceptability. So, the more people who are dissatisfied, the bigger the decrease. So text typing performance decreased by 1.5% for every 10% increase in the percentage dissatisfied with the air quality. This makes it possible to quantitatively transfer the data that is more often available, percentage dissatisfied, into an estimated affect on performance.

It wasn't just on text typing. We have the same relationship with a test of addition, mathematical calculation, and on a test of proofreading. As they became more dissatisfied with the air quality, there was an affect on a performance on each of these typical office tasks.

In Helsinki, this summer, I reported an experiment I performed in a London office building recently where we simply changed the filters. Engineers leave filters in place because the older they are, the most dust they contain, the better they are at stopping pollution that comes from outside the building. But, it turns out, a dirty filter is doing something to the air. It not only increases the intensity of sick building symptoms such as eyes, head, difficulty of thinking, and so on, but it also affects how well people think they're working.

For each week, over an 18-week period, we either had a new filter in place or we put an old one back, in a random sequence, and the subjects, of course, had no idea what we were doing. On Thursday of each week they answered questions on their sick building syndrome symptom and on their self-estimated productivity, and there was a significant relationship. Old filters are not as good as new ones. Perhaps we should be changing filters more often instead of leaving them in place until it's too expensive to force air through the dust mat.

Sick leave reduces productivity, of course. In an interesting study in Holland, occupants who reported that they had some means of individual control were absent 34% less often due to sick building syndrome. So, if you give people a chance to do something about the lighting, noise, air quality, or temperature, they not only feel better, they are less often absent. That must be an increase in productivity.

Walter Corona [?] from the Rensaleer Institute carried out a study of a move of an insurance company from an old to a new building. The new building caused a 4.3% increase in the rate at which they processed insurance claims. He simply registered the time it took for a claim to be dealt with once they had settled into the new building, and providing some form of individual control of the temperature gave a further in the performance of this work. This is one of the few studies that have been done in the field with existing measure of productivity. We need to do more of those.

This is bad news, isn't it, from the point of you of a conference that is intended to lead to energy conservation? Conventional solutions to the IEU problems I have described would increase energy use in buildings. Better thermal control, better air quality by means of simply increasing the ventilation rate, would increase energy use in buildings. So we don't want to be pulling in two different directions. We must save energy; we must use more energy, because it pays to use more energy. This is what will happen, unless we take a pro-active approach.

My view is that DoE should focus on developing new energy conserving solutions and, it's not enough to develop them, you have to expedite the process that ensures their widespread adoption. I've seen it happen all too often that promising solutions are developed by academics—they just gather dust on the library shelf and they aren't taken up because the risk of introducing them to the market would be too great.

The idea to widespread adoption process has three essential parts and I think the DoE should work to expedite all three of them. We need scientific experiments of the kind I've been showing you to show causality, to validate the mechanisms, and to quantify the problems. But we also need engineering optimization to develop solutions and bring them to market. Finally, we need field trials to demonstrate the applicability of these solutions and their acceptability. Some of them will involve changes in behavior or even in comfort, but we need to demonstrate that they are acceptable. All of these three are essential if an idea is to become adopted.

It's normally done in the order one, two, three. You do the science, you engineer, the solution, and then you do the field trials. Of course, in practice, the field trials are usually skipped and marketing is substituted instead. It's faster to market. To start with the field trials of an idea, to get an idea of how well it works, you then make it, test it, and then you leave the research to later because that is a multi-year project, whereas you can get to market in less than a year if you—three two three. I don't think we should be locked into the logical way of doing this and assume that the federal laboratories are the source of all possible solutions. I think it's necessary to take an entrepreneurial approach here and to expedite the process—whatever works, to get an idea to widespread adoption.

In my paper, I go into much more detail than I have time to here, for a number of competing solutions. This first list is of technological fix solutions which the occupants may not even notice. Pollution sources can be reduced by simply selecting the materials. You select the building, the furnishing and carpeting materials so that they have low emission rates.

In Scandinavia, we have several voluntary schemes running where manufacturers submit their products and these are assessed in terms of their emission, not just in terms of their chemical emissions, but in terms of how they affect the perceived air quality. This would be well worthwhile doing not only for new buildings, but also for retrofitting old buildings.

One of my favorite solutions is to use point exhaust. It's a standard technique in industry, but it's not used in offices or schools. But the air that goes into a copier or a printer or even a p.c. to cool it is not fit to breathe when it comes out. It, therefore, should not come it. It should go down a pipe and disappear from the building directly and it would achieve three things. This would remove one of the major sources of heat. Nearly all of us have as much heat being generated from the machines we use as we generate ourselves, about 100 watts. It would remove the pollution of the flame retardant chemicals that are on the electronic components and the dust that is being heated and more finely divided and outgust by contact with these hot components, and it would enable us to stop those pesky fans buzzing in the equipment because the fan would be on the roof. We would be drawing air through them without any local fan. Remove heat, pollution, noise, and save energy and improve the environment—that's a pretty good deal.

Heat recovery from exhaust air in hot and cold weather would be perfectly possible. In fact, it's mandatory in Sweden that any dwelling that has more than two families living in it, must have heat recovery from the exhaust air. In Stockholm alone, this recovers enough energy to close two major power stations.

Air cleaners which can remove particulates without reconditioning any supply air. They're simply local air cleaners passing room air through efficient filters, are also a very promising way of improving the air quality without any energy cost to think of.

Then there are the compromise solutions which do have a negative affect on the occupants. Energy storage in the building structure can save enormous amounts of energy, but it does mean that we must let temperatures drift, both upwards and downwards. Use night cooling, for example, to cool a building structure and people will then be cold when the come to work in the morning. We need to find out just how acceptable that solution is.

Individual control of temperature and indoor air quality can mitigate these negative effects if each person has some sort of heating or cooling, those that are present can keep warm even though the building has been cooled pro-actively during the night, for example.

Not everybody is as sensitive to air quality, as I've shown you. If those that need the fresh air can get it, whereas those who are sensitive to drafts can close it off, then we are satisfying more categories of people and saving energy at the same time.

To empower users in this way has to be done in a rational way. We have to give them, what I call the three "I"s. That is, they have to have insight, information, and influence. In order to delegate influence to them, you have to teach them to use the new powers that have been delegated to them. That means understanding how the building works, what their actions will do to energy use in the building, and they have to have on-line information as was mentioned yesterday. If you knew that your dryer was going to cost you $5 per kilowatt hour instead of a few cents, then that might affect your actions. That's what I call the "information" of the three "I"s.

In Europe we believe openable windows are a human right. We almost enshrine it in our constitutions and, indeed, there are many parts of the United States where the air outside is fully of good quality and the right temperature to be used at individual discretion by opening the window. The problem is that we don't want the HVAC system to start heating the county because it thinks the building is getting cold. So we need to make our control systems more intelligent to deal with openable windows so that as soon as you open the window, you stop getting any energy at all from the HVAC system. Very few buildings are capable of doing that, but it would be possible to do it. Very easy to do it, in fact. You need a micro-switch on the window and some local control of the heating and ventilation system.

Natural ventilation is becoming more and more popular in what are called hybrid buildings. In Europe, I think it would pay the DoE to look across the Atlantic to see whether there aren't some regions of the United States that are sufficiently similar to Europe where similar solutions could be applied. California comes to mind.

Closed loop control via users where we actually include the users in the control loop so that they can tell us how we're feeling and we are not trying to heat people who are already too hot or cool people who are too cold, or blow air onto people who are already complaining of drafts. Some way of including the user in the loop would improve the general health and performance of the population in buildings.

In my paper, I propose that there should be some kind of research center. It can be a virtual center, it doesn't have to be a bricks-and-mortar center for indoor environment and energy of the same kind that the Danish government has set up in Copenhagen. Its role would be to optimize energy use for the purpose of improving the indoor environmental quality. It should actively leverage foreign investment in research of the kind I've been describing. It should develop solutions pro-actively and entrepreneurially, and it should expedite the process in any way that works of going from idea to widespread adoption. Instead of just doing the science, it must do the engineering, and it must do the field trials of acceptability and applicability of these solutions. That's an unfamiliar role for a research laboratory but it's a necessary role if we're going to have any impact at all on national energy usage and the national health and the national economy. Thank you. [applause]

Richard Wright: It's a great opportunity to comment on the two very exciting papers that we've had already this session. There will be a couple of points I want to re-emphasize and a couple of points that I want to make in addition. I want to come back to the point that was made about where the real value is in the lifecycle of a building, in the whole lifecycle. These data are based on government office buildings and they're actually something like 30-years old. They had a lot of influence on me, personally, because they tended to move me from working in structural engineering to looking more broadly at the affects that our built environment has on the productivity of the occupants.

Looking typically with a 6% discount rate and a 40-year life to a government office building, not counting the land cost, the initial cost of construction, is about 5%. During the whole life, the operation and maintenance is about 6%, and this leads [?] of the lifecycle cost the owner makes the investment of about 89% into the salaries and supplies for its productive use.

It's been very interesting that prior to the Department of Energy's great attention to operation and maintenance, I could say quite forthrightly that our research investments were absolutely inverse to this performance. We put most of our effort in trying to reduce the costs of initial construction. We put a substantial, but more modest effort into trying to control the costs of operation and maintenance, and we put practically nothing into making the building more useful, more safe, and more economical for the occupants. I think it's extremely important as we take our vision for 2000 of how the Department of Energy should work, that we should be serving the primary purpose of our constructed facilities, and that is to support their occupants or whatever kind of mechanical function is going on in an automated factory.

Taking a few of the points that I want to deal with on the needs for research, I think we have to be impressed by what David Wyon has told us about his studies and others of trying to relate the affects of various pollutants in the indoor air to productivity and to health. I would add another factor that we should look at as we're dealing with the indoor environment as part of E-Vision 2000, and that is safety. The same environmental factors that lead to productivity or health issues, many of these also affect the safety of their occupants and, of course, the consequences on productivity and health [?] of accidents are extremely severe.

There's a lot that we don't know, quantitatively, that would allow us to design and operate our buildings for productivity, health, and safety. Dealing with the specific affects of the components, we don't distinguish very closely between illness, allergy, and SBS. We need to understand the individual affects of each pollutant and then we have a very challenging problem in defining the combined affects of these pollutants.

For instance, at the National Institute of Standards and Technology, where I worked, we were dealing with the problem of smoke toxicity for the safety of occupants in buildings that are subjected to unwanted fires. It was a substantial problem. It took many years of work to understand how to assess the affects of various materials that could be in a fire because of their combinations in affecting health. As we look towards our vision for 2000 I think we can see that we're going to need collaboration between the health scientist researchers, the Department of Energy, and many others in other laboratories and in industry.

This collaboration is not always easy to get because we know how critical the health aspects are, how critical the health sciences are, but there is a very great tendency as you set the budget for agencies such as the Veterans Administration and the National Institutes of Health to be focusing on critical illness factors rather than on the chronic factors which are so extremely important. It's going to take a lot of interest and pressure to get the attention we need to understand quantitatively the affects of our pollutants.

The next point in the logic is that ventilation is a very crude measure of indoor environmental quality, not saying anything, for instance, about what's in that outside air that you're bringing in. Once understanding the affects of our pollutants, we're going to need to have real time measurements available for the pollutants so that we can control directly the quality that we wish to control in the indoor air. This is going to take substantial research.

An easy part of the problem will be to use computational fluid dynamics effectively in designing our ventilation systems to control our pollutants. We have a lot of problems with ventilation systems in existing buildings that the ventilation air can come in and go out, never getting down to the level of the people that are actually supposed to breathe it. We need to model better and control better so that so that we are producing the air quality that we want at the place that we want it. These techniques have become feasible at the p.c. level. So it's not going to be hard to introduce into our systems.

Following up a bit on what Dr. Wyon was just saying about adaptive control systems, we're going to want these at the building, room, and workstation levels. We certainly want to have the occupant in the loop. Those of you who get the chance to read his paper carefully will understand that one person is very different from another person in terms of the productive environment. In fact, for each of us as individuals, the environment that we want may vary from what we want at 9:00 in the morning to what we need at 4:00 in the afternoon to really perform effectively. We're going to have to respond to the individual needs and preferences.

This, indeed, is going to take a central and focused effort. It's going to be extremely complicated because it's going to need that variety of disciplines from the health scientists to the building scientists, to the designers and builders in order to develop solutions and get them implemented. It's going to be very important that this activity be done in partnership with industry because the real excitement and the real effort in getting improved products and getting them into the marketplace will come along best when they are being led by private industry. Those are the points that I thought would be worth emphasizing from the excellent presentations that we had this morning. Thank you.

Art Rosenfeld: Good morning, I'm going to put this up here because, in addition to the simply wonderful papers by Fisk and Wyon, there's one other piece of information you may want to have available to you. I'm going to talk about it in a minute, but there is a website with all of the papers that Bill and David talked about and lots more available to you and you probably want to write that down.

My comments come from two pieces of history. First of all, I want to repeat my comment, Bill, I think you did a fantastic job in convincing us, and David, I think you did an equally fantastic job of showing us that there is a real problem here. Your last line, Bill, said—the costs which we could avoid are in the tens of billions, they're really in the hundreds of billions of dollars a year, and damn it, it's time to do something about this.

Now, some history and an organization, which may be helpful. It's perfectly clear that DoE has to be in this game. Bill Fisk has addressed this issue and David Wyon has addressed this issue, and Dan Reicher is convinced of this and so on. The problem here is that this is a huge issue which already has a big budget already. The problem is not what DoE should do, the problem is how do we get a bunch of agencies to work together to do this. When I say agencies, that's only a little bit of it because my state, for example, California, is ready to put another million dollars a year into the pot. But I want to know what the pot is. Then there is a lot of industry, I'll give you a list in a moment, of people who are concerned with this.

I think really, when we get down to a little bit of discussion, the issue is not going to be what should we be—what should we be doing? But, maybe where we draw the line. I know that Vivian and I are going to get into a little bit of debate because I think it should be buildings, health, and productivity, and Vivian wants to add land use planning, and we'll discuss that.

A little bit of history, first from the point of view of California and a user. Because of all the discussion yesterday, namely we are now moving into the 21st Century. Any building or any appliance built today will see real time electric prices during its lifetime. We have to redo and we will redo building standards and appliance standards to take that into consideration. We are ready to make a major change in our building performance standards. We're ready to do all sorts of things in the sense of requiring better controls, variable ventilation, time of day ventilation. We need to do that and we don't have quite enough information, maybe we'll have built this working 24-hours a day on this for the next two years, but we don't really have quite enough information to put this into code yet. We are eager clients and I think if we do it, ASHRAE will follow, and we'll have to learn what the Europeans are doing about those standards. We're in a big need.

A little bit of history—Dick Wright and I got into this game together because we were co-chairs of an existing subcommittee of the National Science and Technology Council called the Subcommittee on Construction and Buildings. We both got involved in this in 1994. We got great enthusiasm within the committee to increase the research, interagency [inaudible] budgets on workplace health and productivity. We talked to the Vice President's Office. We were all ready with a $10 million initiative. The Gingrich revolution swept into place and we withdrew.

We started one small project which I do want to mention and that's there. The idea is—we've gotten a team of ten qualified reviewers who are interested in indoor productivity, that's the sort of thing that David emphasized, and ten reviewers who are interested in indoor health, the sort of things that Bill emphasized. The idea is to select the five or ten best papers of the year, reprint them once a year, have a meeting like this in which those papers are widely advertised along with a review, but aim not at the group that you are here, but at building owners and operators who need these numbers translated into dollars per square foot, increase in productivity, and so on. However, that's going on.

What we learned in doing that is that there are a large number of people who are interested. Here's a list which is incomplete of people who are already contributing to that process. NIST—that's Dick Wright's old lab, the Department of Energy, EPA has since come in, BISE [?], two West Coast utilities are interested enough to be contributing $50,000 a year; and the others are, so far, receivers of money rather than givers of money. I want actually to read to you, if I can. This blue document is called *Status of Federal Research Activities: A Report by the General Accounting Office.* It gives a huge list at the back of people who are contributing to indoor air quality research today. I make this list because it's only partially complete and yet it's already huge.

Agency—Consumer Product and Safety Commission—1999 budgets—$1 million; Department of Energy—$1.2 million; HUD, that's the residential side of this which we haven't talked about yet, but which deserves equal attention—$8.8 million; EPA—$6.7 million, don't know where the heck it goes. I thought I understood something about this field.

[End of Tape 7, Side B. Start of Tape 8, Side A]

Then we get into huge budgets where we're not going to get all the collaboration because these are medical research but where we need a lot of coordination between the medical researchers and the real building side of the story. Cancer Institute—is small; Heart, Lung and Blood—this is the biggie - $11 million; Allergy and Infectious Diseases, these are all National Institutes of Health - $10 million; National Institute of Environmental Health Sciences - $26 million, and so on.

In addition, the engineering group, under the Office of the Surgeon General, have recently had a large meeting in which they're going to get activity going which is certainly going to be aimed at a few million dollars a year and that is precisely on the interface between all the NIH activity in hospitals and so and buildings. In addition to working already in the construction of buildings, people who should be interested in joining us are General Services Administration, the Department of Education, because of schools, Dan mentioned schools a lot yesterday; Department of Defense, simply because it has such a huge amount of office space and residential space; and OSHA.

In terms of industry, there's obviously the controls industry. There's Johnson & Johnson, for example, which supports David Wyon and the people who make sensors. In addition, there is actually a small operation going already by the unions, particularly the sheet metal unions who have realized that HVAC impacts our health. Then there are the states—California, as I've said, is ready to go, and I believe that New York and other large states are very interested. Then, as I mentioned already, the utilities.

My problem is more sort of for Vivian and Dan to start addressing—how are we going to put all this together into some sort of a steering committee, an evangelical committee? I think, perhaps, I'd like to get Dick's idea about this, that the Subcommittee on Construction and Buildings is probably a good place from which to start beating the drums. With some new money promised, we can probably put it all together.

I've already mentioned that drawing the line with land use planning is something that may want to come up after the next discussion because that deserves it's place in the sun for a minute.

I want to conclude with one remark about one of the reasons that we, in California, have decided that it's time to work here. We have a public interest energy R&D budget in California, which, I am proud to say, is $60 million. It's divided into about six areas which you could figure—buildings, industry, transportation, utility, policy, and so on, so it ends up that buildings get like $10 million a year. So the buildings research team, even before I arrived on the scene last June, sort of looked around and said—what can we do in buildings? Building is a big research issue. California can't do everything. What's in the California context? One thing we decided was that air conditioners on the West Coast are different from air conditioners in the soggy South. They do different things—one dries air, the other cools air; and we should do it differently.

Mainly, we decided that there was a national scandal. In this huge field of indoor air quality, basically, the federal government had let us down and therefore it was necessary for California to go ahead on its own. About that time, this meeting got set up and I think that's wonderful. But it really is time for the federal government to get more actively into this amazingly important field.

A philosophical remark—it's funny, since World War II, if you look at places where risk and health is a little more obvious, take automobiles, we've made really pretty gratifying progress. We had first two-position seat belts, then three-position seat belts, and anti-skid breaks, and windshields have gotten better so they don't break up in your face, and finally airbags, and maybe high-mounted tail lights. All that's happened in 50 years. It's really pretty encouraging. What about buildings? Well, really, without our community, we got rid of smoking. That's pretty good. And, we did figure out about radon, DoE gets a lot of credit for that. We figured out how radon got into buildings. But apart from that, 50 years of basically zilch, so that's a challenge. Thank you very much.

Reicher [?]: I want to be clear, the "it" you're talking about is, and the GAO reports on the status of various agency efforts with regard to building energy, health, and productivity….

Rosenfeld: No, all these numbers I quoted were agencies who talked about indoor air quality.

Comment: I think a little comment on those numbers because I've been on an interagency…. We've looked at these numbers a little more directly in an interagency or multidisciplinary committee called the NORA Committee, the NIOSH Commission and a lot of the money are in very specific areas that you mentioned, Art. They're involved with exposures to lead and a lot of very basic research on asthma and exposures to pesticides. Those are all important topics and they cross the boundaries of what we think about as indoor environment and buildings, but there are not research on indoor environment building science and their relationship to health and productivity where there's really very small amounts of money. Most of those millions of dollars are in related fields, but they are certainly not the topic that we're talking about here today.

Rosenfeld: Thank, I'm sorry. I probably didn't give quite the right remark. I think, Bill, you and I would agree that the amount of money that's really going into indoor health and productivity as we see it is a million or so. The reason I mention these other huge budgets is simply to say that—if we're good at it, we can get the medical community and NIOSH and so forth and so on to collaborate on this on this important aspect of it. Not to say, at all, that the problem is done. Again, I repeat that there are utilities in other states who have public benefits money which, if we're any good, we could get collaboration. Thank you for clearing that up.

Loftness: I think we'll have a chance to re-discuss this also after the second half of this session in terms of looking at what kind of collaborative institute, virtual center for looking at the next generation of buildings and the causal relationship of buildings to health and productivity. I wanted to ask if anyone on the panel wanted to pose a question to the speakers this morning. Otherwise, we'll open up to questions from the audience so that we can have some dialogue about the two papers and the two responses that were presented this morning. Anybody here wants to ask a specific question?

I want to make a personal comment and maybe Kevin does. To use the word "compromise" which I am going to try to convince David Wyon to take out of his paper, the whole notion that there is a design compromise is probably a damper on really what opportunities and innovations are out there. I think if Amory Levins [phonetic] were here, he would talk about tunneling through the cost barriers and looking at a whole new generation of design innovations that not only dramatically reduce energy, but also dramatically improve environments for productivity and health.

I think what we have to do is stop trying to tighten the wrench on existing strategies which will, in fact, have some compromises attached to them, be they either cost or energy use, but to actually leapfrog the solution sets that we have out here and look at whole new innovations. I'm going to talk a teeny bit about that later on, but I think that it's very important not to look at these as design compromises. Certainly TAS Air [?] has the ability to provide energy efficiency and improved indoor environmental quality. It just requires a rethinking of mechanical systems and first, cost savings, but you have to rethink the systems, which I'm sure David would agree with. Kevin, did you have a question you wanted to ask this group or comment?

Kevin Kampschroer: I'll wait until my own session.

Loftness: Let's take questions from the audience. Whoever can grab a microphone.

Aud ience question: I was struck by all four presentations that there was actually one small mention of smoking, particularly related to health affects in buildings. I feel like I'm pretty close to the medical community and I know that respiratory illness, allergies, and sick building syndrome is directly affected by smoking rates. I'm sure you've done it in your research, but there was no mention of it today.

The first presentation, I would like to know if you've distinguished between studies of buildings before and after the no-smoking rule in the United States, and if you distinguished between studies in the United States and studies in Europe where we know everybody smokes.

In the second presentation, I know you had a lot of controlled studies, but your mention that—Europeans think it's their right to have openable windows. I wonder how much that's directly to how smoke-filled their rooms are. As I'm a non-building person, but I was just struck the entire time that there was really no mention of this. Thanks.

Response: Let me say that I think tobacco smoke is one of the most important pollutants. We believe it is causally related with asthma development. It's associated with asthma exacerbation. It's associated with a host of other very important health affects. I had a slide on smoking, I didn't have time to put it in. I think we were focusing here on changes, to the issues that DoE deals with, the design, operation, and maintenance of buildings, and not the changes in human behavior so much, so that's why I didn't emphasize it and by no means does that mean it's not important. I'm not aware of any studies, before and after, of acceptability of air quality or health in the United States before and after smoking ordinances have gone into affect. They'd be rather difficult. In broad surveys in the past, tobacco smoke has sometimes been a parameter in the multi-variant models that we use to look at the relationship of environmental factors to symptoms. Sometimes it shows up as an important determinant of symptoms, but not always.

Wyon: Sure, we use windows to get reduce our secondary exposure to smoke. In many European countries, smoking is forbidden in public places and even in workplaces. In others, such as France, Italy and Denmark, it's not. It's seen as an issue of equity. Nonsmokers are expected to respect smokers need and wish to smoke as much as they're expected to respect our wish to be free from environmental smoke. Yes, smoking does still occur and, yes, opening a window is a very good way to deal with unwanted secondary exposure.

I'm not aware of any studies showing the affects of smoking on performance. I'm not sure that we want to get into that. Many smokers tell me, I'm not a smoke myself, I should say, many people tell me that they can work better when smoke. Who are we to say that that's not true until we've studied it? If we get into that, we may find that people who are dependent on tobacco really do work better when they're able to smoke. Maybe we should design buildings in which it is still possible for them to do so. I haven't done that kind of work myself. But, of course, the focus on the ill effects of smoking is on the long-term effects on health and the kind of experimental work I do doesn't lend itself to that. You can't randomly assign to volunteer subjects to smoke or not to smoke. That would be not only unethical but also not a very effective experiment.

I'm quite certain that the effects of secondary exposure to smoke are all negative. It irritates the eyes, exacerbates SBS symptoms, brings on asthma attacks and so on, there's absolutely no doubt that that is the case. There's plenty of work showing that. There's plenty of work on the subjective dislike of secondary smoke exposure. But the building community has tended to stay away from any direct studies of how smoking enhances performance. I'd be very happy to advise on studies of that kind, but as I say, I'm not sure the DoE wants to get into it.

Aud. question: I notice that all of the comments so far have been on office buildings, especially large office buildings. We're talking about moving a lot of our work to the home and therefore it came very much to my concern as to whether the homes are better or worse than being in the office, and what we can do to do those measurements, and then, of course, there's just the plain outside. Suppose we did our work outside and a lot of people do, there are farmers, and people like that. How is their health affected by air quality outside? Then, of course, to a lesser extent, there are factories and what happens there. It seems to me that the alternatives here are something that we need to know more about than we were able to find out so far. Thank you.

Response: Let me say that we have had a lot of research on some certain types of environmental exposures and health affects in the home. For example, environmental tobacco smoke, moisture problems and molds. There is some research. We have not had a significant body of research on these nonspecific symptoms we call sick building syndrome symptoms in the home, probably because you need to have large populations of people to get statistically significant results, and you don't typically have that in the home.

There is a little research from Norway, I believe a Scandinavian country, suggesting that people in homes do have the same kinds of symptoms, they vary from home to home, and we know from our studies of quality in homes that we have similar types of exposures to pollutants in homes. We just don't have the data and we don't have the opportunity to study these nonspecific symptoms.

I'll comment on outdoor air quality. We need to keep in mind that outdoor air quality can have profound impacts on our exposures to pollutants indoors. In fact, almost all of our exposures to outdoor pollutants occur indoors. In the building, in many cases, modifies those exposures. For example, pollutants like ozone are reactive and concentration indoors tends to be considerably lower than those outdoors. The ratio of indoor to outdoor concentrations depends on ventilation rates and other factors. Also, also we can dramatically reduce our exposures to small particles when we're indoors using effective air cleaning systems. In one of our recent intervention studies, we are able to reduce exposure to submicron [?] particles by 90% by using high quality filters compared to conventional filters. Outdoor pollutants, I think, are very important. Our exposures primarily occur indoors and characteristics of the building affect the magnitude of our exposures for some of those pollutants.

Wyon: The one aspect of working at home that probably overrides all others is that you decide what the conditions are. If you're cold, you can raise the temperature without inconveniencing fellow workers. You can open the window, you can increase the air quality, if that's what you need. You can close it to reduce drafts, if that's what you need. What I'm advocating is that we should make our workplaces more like home so that you can do all of those things in the same way that you can at home.

That said, there are almost certainly many home offices which are having a very negative effect on people's performance. For one thing, ventilation rates in the typical home are way below what they are in offices. It would be at the lower end of that curve that I showed you of ventilation rate against performance. Just as we have ergonomists visit workplace to adjust our sitting posture and the way we use our computer, then I think we'll have them visit the home office too to ensure that negative effects are not occurring there.

Aud. comment: Just a comment from a commercial point of view with regard to putting these things in practice, intrigued by David's comment about—try something and see if it works. I think that raises two additional challenges. One of the things that we've found in the energy service business that was very effective in terms of getting us in the door with regard to negotiating contracts with customers was the fact of deregulation that put energy costs on the agenda at a higher level in the organization than had previously been the case where we could get decisions made to do these sort of things.

Secondly, we need a set of metrics so we can actually put real numbers and real costs on the table that we can propose to reduce and save for customers. Even if you don't think about this from my parochial point of view of energy service company, these would be the same sort of issues that a facility manager or a facility person within a company trying to raise these issue would face as well. Again, I'd emphasize the idea of trying it and seeing if it works. If we had some of these things in place it would be very intriguing.

Wyon: I think it's important too that DoE takes responsibility for having independent assessment of whether it works. A field study done by the company trying to sell you a box that plugs into the outlet is not very convincing, putting it mildly, whereas if it has been shown in a properly conducted study, by a university or a federal laboratory to have the required affect, then you'll find that it sells many more boxes.

Loftness: We're going take a break. I'm sure we could ask another dozen questions and we'll have an opportunity after the break with two presentations and then a question-and-answer discussion. Please get back at 11:00 promptly so we can get started and use our time well.

For those of you who wrote down a website for the productivity and buildings database that has been put together from the broad range of sources, it's been corrected.

Let me start by introducing the speakers for the second half of this session. We're going to actually widen the discussion. The original charge was to look at productivity in buildings, specifically offices and schools. I think the point is well taken that we should be looking at a broader range of work environments, which may not just be offices and schools. We already broadened it beyond productivity in the classic sense to talk about health. Now, what we would like to do is talk about a broader range of environmental objectives that really need to be looked at in relation to energy research and the built environment.

The first speaker in this half of the session is Keith Lawton who is the Director of Travel Forecasting for Metro Transportation and Planning Department in Portland. He brings a very interesting perspective on the importance of land use planning to issues of productivity, health, energy use, and I think that it will really emphasize the need for a federal presence in the land use discussion of which there has been very little, if any, over the past 15 years.

Keith, at Metro Transportation in Portland, has led the development of a comprehensive set of transportation models for use by all jurisdictions in the Portland area. These models have many innovative features including explicit estimation of walking and biking trips, consideration of density, mixed-use instead of single-use zoning, and explicit inclusion of some urban design effects on propensity to own cars and to walk, bike, and to use transit given land use approaches.

He is currently involved in the development of new models to explicitly include trip-chaining and activity-sequencing behaviors, so that once people get in cars what they do in sequence; and is one of the principals in charge of the integrated land use and transportation model for the City of Portland.

He also has served on the Transportation Research Board a number of the committees and chaired them for the National Research Council, and I think that the important thing, in terms of this paper, is to recognize that land use policy in many cases does not exist. Portland is one of the most unusual cities in a constellation of political will at the local, regional, and state levels, to actually establish an urban growth boundary many years ago, and actually has given public forums and votes, has held fast to their urban growth boundary and as a result has become one of the most prosperous and growing economies. And, it’s a very interesting case study that surprisingly has not repeated itself across the country and the question is why, and what role is there in the federal sector and research to dealing with that.

After Keith speaks, Kevin Kampschroer will give a response to that talk and actually also broaden the discussions a little bit in terms of energy research and a broad range of environmental impact issues. Kevin is Director of Research for the Public Building Service in the General Services Administration. The public building service manages about 9,000 buildings, 345 million square feet. And, in fact, Kevin, over his lengthy career, has not only managed a large number of building projects, he was also the project manager for GSA for this facility which, of course, he will take blame, right, Kevin? [laughter] Or, all credit, as the case may be, for things that work well. This is the second largest office building in the U.S. at 3.1 million gross square feet that could be a good or bad. It's going to be an interesting dialogue. I think that between Keith and Kevin, and then I'm actually going to actually wrap up and attempt to broaden the dialogue about productivity, health, and other performance variables related to energy research. With that I'm going pass the baton to Keith.

Keith Lawton: I come to this from a slightly different direction and it's quite a big jump from what we heard earlier this morning. I'm not a university researcher, or anything like that. I'm in the trenches building models and dealing with how do we forecast, how do we develop policy, how do we do strategic planning in a way that makes sense? In Portland, essentially, the drive to look at these issues doesn't come from the technicians, it comes from the politicians and it comes from the people. They're concerned that their future is happening to them and they don't have any say in it. It goes back to Bill McDonough's approach which is—maybe we should think about planning our future and maybe we should think about at least being conscious about what we're doing. My kind of insights really have come from the work that I do in model development, which is mostly statistical, but the way I'm going to present this is primarily as illustrative graphs so that we can see what is happening.

Essentially, my objectives are to take a look at vehicle miles of travel per capita. That directly links to energy use and the emissions. To look at the relationship between the transport infrastructure and land use and by that, really talking about what happens to land use when you change transportation. There is a history in the U.S. of saying—well, here's the land use, let's find the transportation system that fits. The bad part about that is—every time you change the transportation system, the land use turns out to be something entirely different. That's one angle I want to cover.

Another relationship is between land use and travel, which has to do much more with microscale urban design—what's around the house where I live? What's around the place where I work? Are there retail jobs there? Are there places to go shopping? Are there restaurants?

I'm thinking of density, not as a density of how many households near me, but how many things where I can do activities are near me on a really small scale, a walking scale.

Then I want to get into the importance of time use, how much time people use in travel because this turns out to be a big question in terms of productivity and it turns out to be a big question in terms of trying to understand how things actually work.

Then, if I get time, we'll go onto objectives for the transport system and the objectives that we use to warrant new construction are often objectives which are going to lead us into some kind of trouble, so we'll move on.

Vehicle miles of travel have been expanding for a lot of reasons, primarily the baby boomers, more people of working age, more women in the workforce, more two-worker households giving a time crunch, and so people buy more cars so they can do things in parallel, and we've been getting a great growth. In fact, VMT, or vehicle miles of travel, per day, per person, in regions have been expanding at about the twice the rate of population. That is slowing down. We're already seeing that in the Portland area, primarily because this baby boom thing is basically over and we've got as many cars as we can drive. In fact, we have, as you'll see, more cars than we can drive. We've got empty nests and we've got a coming retirement boom which we need to think about because we have cities that aren't going to work that well for retirees.

The other thing that causes vehicle miles of travel to expand is housing changes. The newer housing is lower density, it's on a suburban edge, it's in single-use zoning where you have to travel miles to go and buy a pint of milk. The houses are separated from their services, and their amenities, and their activity space, and there is a lack of road continuity. We've designed roads so that people can't drive on them past your house, but you also can't walk anywhere. You can't get transit there and walk distances to any shops, in fact driving distances, get to be really high. You've got to drive out to the main road, drive down the main road, drive off the main road, etc.

With suburban job location, there's no tidal flow, essentially travel is equal in both directions. This is good. It's very efficient, so we don't have roads that are really busy in one direction and not in the other at different times of the day. Initially, it's faster than travel to the center.

When we first do this, we first go out to the suburbs, the jobs move out. People move pretty quickly, and, as we'll see later, faster means further. In other words, the fast you can go, the more miles you'll go.

Just to give some quick sense of transportation infrastructure in urban form, this really comes from theory by Mills and others, but it's also the core of land use models that have been developed to date. As Vivian said, very little money has been spent on this and land use modeling is not very good at the moment. Essentially, land value is affected by accessibly to activity space. If you can't get to it, you can't get anywhere from there, it has low value. If it has very high accessibility to things, it has high value. You build a road, you open up farmland, the farmer makes some money. His land value goes up.

The other thing that's happening though is when you do that you're making more land available in the urban area, so the cost of land to the buyer goes down. So, it's pretty straightforward. As you get the system speed up, things move out, the farmer makes some money, and these are good things, the prospective house holder gets cheaper land and can buy more of it, so buys a bigger lot. Okay? The winners are the landowners at the edge, and homebuyers. The losers are the taxpayers, in the older urban environment and energy supplies. The fact is, these roads are paid, for in large part, particularly the major ones, with road tax dollars that pays for about 60% to 65% of the cost. But the people who are developing the suburban area and moving there aren't paying all of it. Everybody else is paying gas tax too. So in effect, we're subsidizing that kind of direction.

Looking at national data first, and what I've tried to do here, I came at this from looking at Portland data because I'm building models, I'm trying to figure out what makes things work. But I thought I'd take a look at some national data to see whether the national data gave at least some support to what we're finding locally. We've got some data from the 1998 highway statistics, federal highways. This data is developed from traffic counts, the Highway Performance Management System, it's somewhat variable, it's done state-by-state, so we've got some measurement error problems. And it includes all travel so it isn't just the personal travel in the household which is what I primarily look at, it includes commercial travel, trucks, visitors, etc.

When we look at this, we see we've got a large range of vehicle miles per capita, right? The largest city, 1 million plus and what I've done here is I've taken cities or regions of a million or more than are essentially freestanding—New York includes northern New Jersey. The largest city is 15.8 miles of travel per person per day. Most cities fall between 20 and 22.5, including Los Angeles at 21.7. Portland is 21.5. The three highest are in the lowest four in density—Dallas/Fort Worth—29; Atlanta—36; Houston—39. Those are interesting numbers.

If we take a look here, there we have Houston and we look at the density—real low; Atlanta, Dallas, Seattle is here. I can't get them all in because it would be hard to read, Minneapolis, St. Paul, here, are just under 25. Portland is in here somewhere. New York and L.A. New York is really different. These are average densities that we're looking at here in terms of person per square mile. New York really has a binomial distribution, it has some really dense places and some really non-dense places. This is nonlinear. There is a lot transit use, a lot of pedestrian usage in the very dense areas, so it doesn't surprise me. What is really interesting, to most people, when they first see this graph, is L.A. It happens to be the densest region in the United States, taken as an urban region, and, it isn't out there in terms of vehicle use.

Looking at it another way, we took a look at road supply from the same report. This is miles of roadway per thousand people. So we've got miles of roadway down here, and we've got daily VMT on this side here. Again, note that L.A. is low on road supply compared to everywhere else. These are things we've known about for some time, but it doesn't deserve its reputation.

Phoenix is interesting. It's one of the few modern cities that initially went purely with an arterial development. It didn't build any freeways for a long time, and so it's down here, and we look here and we see these cities here that developed since World War II. They've been developed in the auto age, they've been developed with a policy in each of those regions of solving the problem of congestion by building more highways and building faster highways. They are also cities that do not have a lot of land use control and so the natural response is—spread out, more density, and more travel. It's an interesting piece.

Looking at Portland data, we did a 1994 household activity and travel survey. We looked at activities both for which you traveled and activities for which you didn't travel. You could do two activities, one after the other in one place, and that's perfectly okay, including home. We did a two-day diary of activities and travel for every member of some 7,000 households. That's an expensive process and difficult to do, but it gave us a lot of data. The nice thing about this data to look at is that it's consistent and comparable across various parts of our region. It's done in the same way. All of the activities, the households and activities weren't just put in census tracks [?], they were directly geo-coded to approximate coordinates, within a few feet, so that we know exactly where these people are, where the houses are, and where the places are they visited. We were able to measure land use density and mix, at all of those locations, because we have a geographic information system, and because we had a geographic information system, we weren't stuck with looking at density measures that are tied to things like census tracks, polygons, or traffic zones, or block groups. These are all different things that are constructs of different size so that the census tracks near the center of the city are very small and in the suburbs they are very large because they have the same number of people in them. When you start to look at land use affects, walking for example, you could be in a central city location and you've actually got access to all of surrounding census tracks to the one you live in so that you're accessibility is far higher than you would think of just in your census tracks, this is a measurement problem.

We went differently. We simply drew a whole series of circles around each of these points, a quarter mile, half mile, three-quarter mile, mile, mile-and-a-half, because we were testing, and started to look at—how do we get a measure, and it's really a density measure—it's the number of people that can get to someplace or that you can get to within say half-a-mile, that's ten minutes walking, or a mile, that's 20 minutes walking.

The other thing that we've done is the travel times and distances I'll be reporting are not taken from the report back of the folks that are being surveyed but are taken from a computer-based network where we can simulate travel. You find when people report time, they're pretty vague about it.

The measures we used that became useful to us were jobs within a mile of the household, retail jobs within a mile, local intersections within a half mile of the household, and that really talks to being able to walk. There are a lot of local intersections. There are a lot of sidewalks.

There's a lot is a lot of ease of movement between places and we look to the mixed variable which really dealt with both the jobs and housing balance plus how big is that mix, how many are there there?

The way I'm going to display the data is simply to put it into deciles—one tenth of each measure range, with Decile 1 being the least dense, and Decile 10 being the most. Just as a quick example, we can map it. We can map retail employment within a mile of central Portland so that, for example, everybody in this red line here that has more than 6,000 retail employees within 20 minutes walk. Between the red line and the blue line, between 4,500 and 6,000 and, as you'll see this is something we'll use in our modeling system.

We're going to talk about car ownership, trip making, mode of travel, and daily vehicle miles. Just quickly, typically we look at cars as being driven by household, size, and income. But here, we start looking at—this is cars per adult, right? Cars per driver, essentially—1.4, 1.6. At this point we don't care anymore. Once we get above one, you can't drive two cars at once, so we've got saturation.

When we look at the urban index, and remember that this is essentially ex-urban, semi-rural. This is near the downtown, very dense, very mixed, and this end of it is suburbs, and this end of it is city, as it gets more dense. We see that there is definitely a trend in terms of car ownership coming down as you…. And our car ownership models show that, they also include other things like number of workers, income, and household size, etc.

A very interesting piece that we started to get into is activities or trips, things that people do. It doesn't seem to make any difference, right? Those are all statistically all the same number, a little under four.

Aud. question: Keith, is it per trips? What's the data there?

Lawton: It's actually trips per adult, and it's trips per day, the "day" got cut off. I've been fighting with Microsoft for several days. So essentially, that's trips per day.

It's important to notice that lots of surveys that have been done have not looked at pedestrian travel. Once you start to include pedestrian travel, and it was always a picture, trips go down because the car trips go down.

Now we're beginning to see that people have the same activities, pretty much no matter whom they are, no matter where they are.

When we look at the urban index here and we look at the modes, and I've got three of them here. That's car—the white one up there. That's walk and transit. Guess what? It turns out that pedestrian use is really important. The average in Portland is about 9% of all trips are pedestrian. The suburbs it's typically about 4% or 5%. When you get to the most urban area, it gets to be 30% of the trips are by walking. Data from the Bay area shows even higher numbers. But not many places look at it this way. There is definitely some substitution. As you get to be denser and get a better walking environment, and you also obviously have more transit, you get better transit use as well. It goes to about 12% to 16% in the Portland area, at the highest. There's more detail in the paper in terms of the numbers, you can actually look it up there.

Then we start to look at daily vehicle miles per adult. I, by the way, live 30 miles outside the city on a vineyard so I'm one of these guys out here, right? But the average for people who live in really suburban, ex-urban is about 20, and the average for people who live in the most urban area is about 6 or 7, but typically, this little group down here….

[End of side Tape 8, Side A. Start of Tape 8, Side B]

…that's 100% difference in vehicle miles of travel, upwards or 50% down. That comes directly to energy use. It comes somewhat indirectly, but quite closely to pollution emissions, and it's a very big sector of energy use in the country. This is a thing we can look at and if you remember, when we looked at the data from the comparable cities, the range there was almost two times. So Houston and Atlanta were almost twice the average and certainly are more than twice the lowest and were about 80% than Los Angeles. So the two numbers are sort of the same, they're done differently, they come from different places, but it definitely suggests that density has some affect, and what we were trying to do in Portland is to find out what is density? It is really mix. It's what are the things you can get to?

Now the piece that links all of this together, I think, anyway, this is controversial, is time use. You've got 24 hours a day, that's pretty inelastic. In fact, it's very inelastic. We have to sleep, we have to eat, we have to work, we have to play, we have to recreate, and it doesn't leave a whole hell of a lot of time for traveling and there's a perception that as things gets worse and slower, people take more time traveling and therefore they lose productivity. It looks to me as though vehicle miles of travel seem related to density, which we saw in the two previous slides. Car ownership, in fact, varies little by density. And as we get more shifts [?] to transit as our density goes up, etc., so let's move on.

First of all, this is an old study by Yacob Zahavy [?] and others. It was done in 1979, 1980, and unfortunately he died of a heart attack shortly after and nobody carried on the work, plus his data correlated so well, there was a certain amount of doubt about its accuracy. I'm beginning to think that he made a lot of sense.

This is essentially Minneapolis, St. Paul, in 1958; Minneapolis, St. Paul, in 1970; Munich in 1976; Toronto in 1964, and what we're looking at here is the time people spent traveling all day for travelers. For people who traveled, how much time did they consumer all day and it's usually between 60 and 80 minutes, most of the time. Toronto—64; Calgary—71; Montreal—71; Baltimore—77; out here we've got London—77; Redding – 77; Portland—94; and in the Zahavy [?] stuff, he also includes a lot of stuff in South America and elsewhere which were a little more difficult to show on the same graph. But, the same time, very, very similar.

Portland—we've looked at it by income, we've looked at it by a whole lot of things, believe you me, but here's the urban index again. Look at this—60 minutes, a little more, just these guys out here, living in the sticks, are doing a little more.

What's really happening is people are using slower modes and if we take a look at this, this is the same time graph divided into three, but it's pretty straight forward. As we saw that time is constant, therefore less time by car, time by walking goes up, time by transit goes up, and transit, of course, is more effective in places where you can't walk, which is this kind of intermediate density, but we don't need to stay there very long.

The other thing I looked at here was—of the people who traveled, did they use more time by the mode they mostly traveled? If you look at over a whole day, which is what I do in activity pattern analysis, almost nobody uses one mode, they use all kinds of modes, right? About 50% of their journeys from home include a work stop. About 25% of their journeys are between home and work. Everything is mixed up. People change modes as they travel even within one trip from home and back. But for people who use transit and pedestrian only, they didn't use cars at all, a little over 60 minutes. The people who use mostly car, a little over 60 minutes. And for people who mix it up, like more than 75% car, people who mix it up, who had less than 75% car, they had about 80 minutes. Again, roughly constant.

Now we know that activities seem to be fairly constant. We all do the same things. It shouldn't be a surprise. Time use per travel is often constant. That is surprise. Modes used vary with density. Vehicle miles of travel vary significantly with the urban design, the density, and the mix.

What we've really got is—we're choosing to make some choices between,… Because we're fixed for time and we're doing the same number of things, it affects how much we travel and this is really the driver in land use models and transportation models. There is also the driver in the interaction between the two. Travelers in the slow modes don't seem to use excessive time. Cities which have grown in the past 50 years with little forethought for land use and provision of fast roads have low density and high VMT per capita. The parts of the cities, like in Portland, that have developed in the past 50 years, have low density and high vehicle miles of travel per capita.

The reason I'm getting into this is my policy makers are saying—what do we have to do to make things change? And we're looking at—how do you change densities? You can't do it by fiat, you've got to figure out how the market works, you've got to figure out what's causing the problem, and figure out how to get there. How strategically can the policymakers get to what they want their city to be?

As an aside, Portland, and Oregon, in particular, started this whole game up to try to save farmland of all things, which is a good thing actually. We've got about 90,000 square miles in Oregon. Of that, we have the [Walamada?] Valley which produces almost the farm goods. We have a culture which also includes our cities, is about 100 miles long and about 50 miles wide. It's like the size of Los Angeles, a little bigger maybe. It's very valuable farmland, 7 foot, 8 foot deep soils, very productive, and a group of farmers want to keep it that way and a group of the urban elite who want to keep farmland near them, so there's definitely a political objective to do that. There's also an objective to save energy, to have better air quality, and to have a more livable space, so there's a lot of policy drive behind all of this analysis.

What don't we know? We don't know what defines quality of life. What do people want in housing location? Right now, they've got suburbs or they've got city, but they don't have something in between. They don't have suburbs that have been differently designed that have mixed use, etc. These are not options that they had in the marketplace. We are beginning to provide this kind of option in Portland and the people who are developing it are reporting that people are buying it. That, at least, seems to be reasonable. But people might need accessibility to places of business, shopping, work, and play, like—how much can I get to in 10 minutes? Does it matter if I'm going 60 miles an hour and getting there in ten minutes, does it matter if I'm going ten miles an hour and getting to it in 60 minutes? The issue is time because that's really what people care about.

We need some surveys there, or some experimental work which deal with market research, stated preference tradeoff, experimental designs. How much land, how much house, versus how much land, versus urban character, accessibility, walkability, pedestrian paths, bike paths, etc.

The other biggie that we need to work on is the quantifiable relationship between urban form and transport supply. Typically, land use models have been in one box, transportation models [inaudible] are in another box. They haven't been interacting the two models. We need to do more integration and there's been a real lack of research funds for this at the university level.

Just as an aside, the Transportation Model Improvement Program, being run by U.S. DoT, they put about $35 million into it, so far, over the past five or six years. They're doing it part for EPA. EPA put in $100,000, which wasn't a whole lot. Of that, $25 million has been spent at Los Alamos National Laboratories, so I guess we're supporting the Energy Department, but we've got some good work from them. In fact, they're working on a prototype in the Portland area right now, and I'm very much involved in that, but they were asked to do transport and land use and they said—well, you want us to do land use as well as transport? We'd like another $25 million. And, U.S. DoT said, I'm not sure about this.

But the real issue is Housing and Urban Development looks at housing and has forgotten about urban development. There's an energy piece to all of this. There's a transportation piece to all of this. There's an air quality piece to all of this. What we've really got is a problem where we've got a bunch of federal agencies that really need to be working together much more in terms of looking at what is their part of the pie? What is their saving? What is good for them? Can we get to some coordination in terms of funding?

I think I'll just dash into this because it's important. Traditional measures of performance—essentially, minimize congestion. Congestion is the big bugbear. That means, let people travel quickly.

Maximize mobility. The Texas Transportation Institute has just released a major study on mobility. Let's really define the speed. They assumed the lack of mobility, [inaudible], has a value. In other words, they compare the time traveling congested versus uncongested and saying—the time you lose on those travel links is worth $10 an hour, $15 an hour. It depends on which economist you talk to. That becomes lack of productivity. That becomes a reason to build more roads. We've just seen that the lack of mobility imposes increased time on a particular original and destination, but people don't seem to take any more time.

A better approach might be to look at accessibility. How many activity opportunities can be reached in a given time, at whatever speed? That brings density and urban design into the mix with your transportation solution. I would suggest that trying to avoid congestion is a fool's errand—it guarantees more roads, it guarantees more sprawl; more energy use; and congestion will return.

It doesn't matter where you enter this thing. Demand to build more and faster roads, you build more, more lower density at the fringe, more VMT, more travel, and lo and behold, more congestion, lower speeds, demand to build more and faster road. All you get is what you see in Atlanta, just explosure outwards. We've got to start thinking about how do these things tie together. How do we get the message out because we're really dealing with things that have a long time before which they can take an affect. We build those roads; we make those decisions. The bad part happens 20, 30, years ago. We end up with something that we can't foresee unless we model it.

We also are building cities, to use Bill McDonough's words, or nearly, that we can't retrofit. We've built them this way. What happens later if we're short of energy? We might not be, we might. What happens when you're old and you can't get transit to these places and they're not close to neighborhood anythings? These are cities that we're building that are going to be very difficult to reverse when we're done and we need to have a lot of forethought, and we need to think about and be conscious about the decisions we make as we get involved in urban planning. I'll close there. [applause]

Kampschroer: I come from a perspective of the business management of buildings, not from the research perspective, not from the scientific perspective. It's interesting to come with that focus and listen to these presentations and think about how we could use this kind of information in our work for the million federal tenants that we serve.

What does transportation have to do with productivity? I come from a focus on buildings. Trying to understand what people do within the building systems, how they relate to each other, how they interact with the human systems and the human procedures and protocols that exist within the space, the way people operate their businesses and so on, and try to link those back to how we operate and maintain and build buildings is a complex enough task as it is for us. I think what this paper provokes us to look at is where the beginning and end of systems really are and to think differently about the interrelationship of systems and where interrelationships actually should and could have an affect on how we design buildings, from my perspective, or how we design transportation systems and so on.

Will we end up following Brad Allenby's example from yesterday and put 75% of our employees into virtual offices, and what does that do then to the whole concept of transit? When people begin to think of their office as their portable telephone which is used in the car because that's how you can squeeze in a little bit of extra productivity then all of a sudden congestion becomes desirable because you don't want to be driving too fast while you're distracted by talking on the telephone or sending off your fax and so on.

I suspect that we won't end up with that 75% of people in virtual offices because at the same time there seems to be a push there, there's also a push for an increase in collaborative work and an interaction between people and trying to foster that interaction which is never as qualitatively as good as when you are face-to-face with another human being.

It's interesting to note that some of us are already reacting to the failure of suburban office parks to provide a qualitatively good environment by changing the kind of environment that the suburban office park really is. Liberty Trust, for example, in the Philadelphia suburbs, and soon to be in other suburbs, is now incorporating the organization and maintenance and support of things like volleyball leagues as a part of the building amenity. We're talking about not leagues within the individual corporation, but things that occur within this office park to supplement the austerity and dryness of going to these places.

Parking garages that also perform automobile repair and vehicle inspection. These kinds of things change the very concept of what happens at home and what happens at work. If we take this example alone, do we conclude then that what we are really providing is not buildings, but actually substitute societies? Of course, there are places that had traditionally provided that kind of service. We used to call them cities.

It's interesting, I think Vivian pointed out that we don't really understand a lot of the things that we do. The federal government has had a policy, very long standing, and I think a good policy, to locate in the downtown core areas of cities. Do we know what the affects of that policy are? I don't think we do. Do we know what the affects of the interrelationship between our desire to maintain the downtown core of the cities and the support of the suburban office park? I don't think we know that either.

One of the points of expanding the understanding of the interrelatedness of systems is that the people who operate these systems, getting into the buildings management, really don't understand even the very basics about the interrelatedness of systems. In a couple of the papers we read that the relationships between cleaning and ventilation exist. They do, but I can assure you that the people who clean this building do not understand the affect of the way they clean this building on the ventilation system nor do the people who operate the ventilating system have that equal affect on the cleaning.

Here, I think we need to take a broader view of what technology transfer actually means. It's not just the high-tech end of things, it's also the transfer of knowledge of how these things can work in a modern environment and again, here, performed by people who do not have the understanding of the interrelatedness of systems. So, the technology transfer has to occur not only in bringing a new thing to market, but also in making it effective in the use of it. Of course, we've certainly all experienced the affects of when air conditioning systems do not work well for a variety of reasons.

I think one of the things that Keith's paper makes one realize is that we should not accept the state of this system as beyond influence. If a complex set of governments, as the Portland area, can band together and decide that they're going to keep farmland and this is going to have a whole ripple affect on transportation policy and growth, I think we also ought not to accept that the way we build buildings today is the only way we are capable of building buildings. In fact, we should push in our research for the variety of ideas that will get us into different modes of building buildings so that, in fact, we do have better light and better air in the buildings to use.

I would also like to point out that for the people who work in this building, there is light and air and natural sources of daylight whereas we who just visit it are down here in the basement where it's much harder to get light.

On the other hand, I would also suggest that very large buildings are probably a dinosaur that we should be willing to let go, even though they are still recently built because certainly there are data that show that smaller buildings are not only better places to work, with the consequential affects on productivity, but more efficient to operate and more cost effective to operate, and so the demand for increasingly larger size, I think, should change. It doesn't seem to be changing in practice yet, which is something I don't quite understand.

It's also interesting to note that we find building technology process in the 20th Century may not be progress at all when it comes to energy consumption. We measure the energy consumption and energy costs in all of our buildings and although we're relatively pleased with the results that we've had from a variety of energy conservation and investment issues, we operate buildings at 13% lower than private sector comparables, but at the same time we've just recently discovered that it's an anomaly that our new buildings are actually more expensive to operate in the energy arena than our old buildings. In fact, the buildings that are surrounding this one built in the 1920s and 1930s are considerably cheaper to operate in the energy component than the 1960s and 1970s and sealed up.

The Department of Energy question is—why is that so? Once we find out whether it's building mass or the fact that we have a different ratio of the gross building area to the usable building area, or we have a different kind of roofing system or a lower profiles, or whatever the factors are, then, the challenge again becomes how do you change the way we're building buildings and how do you do that? We're very lucky in a city like Washington with a very low physical profile in the building, how do you do that in other cities? It's been demonstrated that it's successful in places, but how do you get that throughout the whole industry so that we actually change the paradigm of the building construction?

There has also been some discussion today and yesterday about what can influence behavior and the difficulty of influencing behavior. I think I have a little ray of hope here. Our experience, at least, in some of the places that we've measured is that group norms are actually fairly effective in changing behavior and can be effective in changing the behavior that affects the cost of operating buildings and energy consumption.

Let me give you a specific recent example since we have mostly anecdotal evidence about the energy consumption, but measured evidence about acoustical behavior in the laboratory that we built in our building recently. The acoustical environment was extremely bright. It was the largest component of complaint. As we come back, six or seven months after people moved in, having made no physical changes to the space whatsoever, it is near the bottom of list and it was all changed by people's collective willingness to change behavior.

I suggest from this that you can, in fact, with effort, which this clearly took, influence all of the kinds of behaviors of people operating in the office, whether it is the way people wear [?] buildings, close the buildings, whether they smoke or don't smoke in buildings, or so on. And, I think David Wyon pointed out that it is very important to make sure that all of the three "I"s are there.

We started out again, in this laboratory, with people with the ability to have individual control over the space, but without the intelligence to know what the affects of their control were on their neighbors and so on. Six months later, again, we have a set of understandings and norms where people do understand that, if you are on the South side of the building in the morning, you do want to lower your shades because it does have an affect on everybody in the space, even if you may happen to personally like the light in there. People changed those as well.

We've heard excellent questions and solutions for answering these questions in the past couple of days. One thing I would like to emphasize is that we need careful consideration of the strategies for how, once we've figured out the answers, how we can actually affect the built environment. How do you get the building design industries to change and adopt different technologies? They are traditionally extremely slow to implement new ideas and new technologies and I think, again, here is a case where a concerted leadership by the federal government, of which, of course, we're a minor part, is clearly in the best interests of the country as a whole.

We've discussed that there's a potential that we'll be put, as businesspeople, in the position of a tradeoff. That is to say that we want to increase indoor air quality which will therefore increase productivity and it will cost more in terms of energy consumption but it will be a net good deal. It's certainly true and an area for study. I would suggest though that, as been suggested before, that there is fairly clear evidence that we probably shouldn't accept that we have to be in that position of a tradeoff, but rather that we can actually devise solutions that satisfy both goals at once.

Again, I give you a parallel example that relates to customer satisfaction and cost. We measure customer satisfaction over a wide variety of factors including the thermal comfort in the building and the perceived indoor air quality and so on and so forth. For many years, the typical reaction to this measurement system was from building managers that we employ, either by contractor or in-house that—yes, I can influence customer satisfaction, just give me more money. It turns out that after seven years of looking at these data that money has nothing to do with it. The building managers who are successful at influencing…. The surveys that come back from the tenants, year after year, get better survey results, and in fact, they're more efficient because they've learned how to operate buildings in a way that responds to people's individual needs rather than, I think, going after that mythical average that satisfies everybody but seems to actually very few people at all. It's also the human factors that are involved and the interrelationships that have a greater affect on perceived quality of the building than, in fact, the building itself.

One last point, there has been some discussion about lifecycle cost versus first cost. I think this is very problematic especially in the renovation area. We have huge numbers of old buildings that we're concerned about renovating and that tradeoff becomes very acute because you can usually attract investors much more readily to a brand new project. This is certainly true in the private sector as well as in the government.

Business schools have been teaching for years that net present value is the only acceptable method for making business decisions about investment and yet we see in the building industry that people are not willing to look at net present value. They're even using more crude tools like return on investment and not even looking over a reasonable period of time.

I think what is often lacking in the data is the ability to show what the longer term affects of the decision, even with the relatively simplistic factors of maintenance operating cost and longevity of the asset. Even if you take those, you can usually make much better decisions, and yet we don't seem to have the tools yet where we can put that in front of the building industry so that those are routinely made in the production of bid packages and specifications and deign ideas and so on.

There is a ray in hope of all of this, though. I think that the market factors are beginning to recognize change, at least in the San Francisco market and I suspect there's no coincidence that it's California where this is occurring. We are seeing in our market surveys and our rental activities there that buildings designed with greater flexibility and ventilation, under floor systems and control systems that allow user control, are actually experiencing a market differential in rents received by the building owner. That is to say, if you build a building and have these characteristics that the market is now willing to pay about $2 a square foot more for that space relative to other kinds of more traditional space. As soon as you get this kind of market differentiation in rent, of course, you have an immediate ability to borrow greater amounts of money in the construction of your next building because you can project a very different income stream over the life of the asset.

With those comments, I would also suggest that the whole area for research here is as broad as everybody has suggested and it also needs to be transformed in a way that is intelligible to the financial community because it's the financial community that in many cases makes a lot of the decisions that we're actually hoping to influence. Thank you. [applause]

Loftness: I'm going to take probably ten minutes of question-and-answer time to try to give an overview and wrap up and discussion. If we can still squeeze some questions in before lunch, we'll do that.

Let me just go quickly through a number of issues. We've been talking specifically about health and productivity and more recently Kevin introduced the notion of the commerce value of buildings. It's extremely important to realize that about 20% of the workforce is directly involved in the construction or operation and management and marketing of buildings and yet we have about .003% of federal funds and research going into buildings. This is a very important statistic. This, by comparison to 15% of profit in the IT industry going back into research, so there are some really critical issues of recognizing that buildings are critically related to both jobs and I'd like to mention, this seems to have a strange timing thing to it, trade.

A study that I'd hoped that Lisa Heshong would present herself here at this meeting, Heshong and the Hone [?] study found that there was 40% increased sales in big box retail that had daylight. That included a 65% reduction in energy use. All of a sudden we're looking at a linkage between the trade value of buildings and the energy use in buildings and so I'd like to present the notion that we can take a very optimistic approach, which is the ability to use energy as a litmus test for very productive, very high profile buildings.

The human potential of buildings and communities, David Wyon mentioned quite clearly in terms of individual productivity, and Keith Lawton brought up in terms of quality of life issues.

Clearly, land use patterns are not just a way to save energy, they are a way in which to change the quality of life, certainly for those who are too young to drive, and those who are too old to want to drive, and not to mention those who cannot afford a car of which there are still a substantial number in this country. We've got the ability to look at buildings and communities as catalysts for improving individual productivity and overall quality of life.

Another issue which is extremely important to the IT world, and for most of the public and private sector, is organizational effectiveness. Everyone is re-engineering their organization. In fact, they seem to be doing it on a six-month basis. The result is that the buildings are being asked to change from open planned high density to low density, closed office, to collaboration spaces to individual spaces, and guess what? The buildings can't do it.

A tremendous amount of waste goes out the window and there's a whole question of what we call "imbedded infrastructures" that is making it extremely difficult for buildings to be flexible to match the organization which is why a lot of things are being dumped on the market and people are, in fact, are paying more for rent for flexible buildings.

There is also an environmental potential that clearly is a DoE mandate, but I think all these others will prove themselves to be key to the energy and environmental question. Obviously, energy reduction is a natural. There is a whole host. The building is using over a third, if not more of the total U.S. energy use. It's using 10% of all electricity use. It's a big chunk and it's in heating, cooling, lighting, and powering buildings. So, we obviously should be playing a much more significant role in the Kyoto Agreement and other agreements.

It also turns out that Worldwatch has pulled up the way in which buildings use other resources. We're pretty serious culprits in water use, in wood harvest, and raw material use. We're pretty much out there cleaning up in terms of what we're consuming and this is not just in new buildings, this is in renovations and existing buildings as well. We have a major role to play in terms of the whole material conservation and with that comes energy and pollution as well.

Something that Kevin just raised, and I think is extremely important, certainly in the U.S. context. We're driving to the bottom line. How cheaply can I put that shopping mall? How cheaply can I put up that office building? We're really pushing. It's because we don't think there's any blue book value. This is just a depreciation. When it's dead, it's dead and actually we can sell it to government and they'll move people into it so once it's dead it can live again. There's an obsolescence cost that nobody is really putting on the table.

Better yet, really, is the tourism cost. Nobody comes to Washington to visit a spec office. Right? They come here for its land use planning. They come here for its historic buildings. It's not the least-cost structures that are going to draw people here and that's a really important question in terms of the finances of the country.

Bill Fisk mentioned and gave very clear arguments for why buildings are clearly related to health. I think we need to first get over the sick building cost and then we need to start looking at the healthy building gains. What can we actually do to do a flip over? Then safety and security, that Dick Wright had mentioned, was important.

Educational potential of buildings. Again, Lisa would have made a very strong case for learning and why kind of environments are necessary for learning. They found in a study in Northern California of a whole host of schools, actually it was multiple states, datasets with an innumerable number of classrooms and students. They found 20% to 26% higher test scores in the day lit classrooms. If we'd known that 15 or 25 years ago, maybe we wouldn't have done all of those windowless classrooms.

Now the question is, as we take historic buildings, which was mentioned earlier today, take historic old school buildings, do we really want to narrow down the size of the window and seal them up and turn them into little modern offices when, in fact, the more productive work is occurring in the more traditional classroom. I think the question of historic buildings and where is the threshold of natural technologies and high technologies is really an advanced area of research.

Finally, the science and technology potential of buildings and communities. Obviously technological adaptability of the IT generation is key. But at the same time, that Kevin had mentioned, we've got the whole face-to-face and digital question. How much face-to-face communication is going to be replaced by digital? There is no indication that the face-to-face is going to diminish. In fact, there's every indication that face-to-face is going up because of the digital. Just like paper has gone up because of the digital age. And, what does that do to organizations and building space?

Then there is the potential of buildings to become an advanced technology that we export. I think David or someone has research data shows how much of advanced building technology is exported from small countries like Sweden and Denmark around the world compared to how much is exported from the U.S. We export very little and we export very little because we don't invest in research to advance new building components. Certainly some stuff we ship off and it's usually our yesterday's generation solution sets. So there's a whole science and technology area in the building construction area of things we should be exporting to China and India and other developing nations. Are you going to interrupt me, Art?

Rosenfeld: This may be wrong, it's 15-year-old data, but Sweden scaled to our economy exports $60 billion. Twenty years ago, when I followed this, Sweden exported $60 billion a year, that's scaled up a fact of 50, and imported maybe 10. The United States imported in the building field about $40 billion worth of mainly tiles, ceramics, and glass.

Loftness: You've heard a number of people argue that there needs to be some sense of a virtual research institute. The building sector has been hardly on the radar screen. Consequently, we are not hitting any of these. We've got a whole list of things and we've got a very small percentage of the DoE budget that's focused on buildings, and an even smaller percentage of the National Science Foundation budgets if focused on buildings, and EPA has even a smaller percentage. NIH seems to have a big percentage, but it's related to environmental health. Guess what? How much of that is buildings? Almost nothing. We're looking at an extremely small percentage of the federal investment and we're saying—wait a minute, somebody has to turn around before we've built up the next 50 years of infrastructures and buildings.

I think a number of us have suggested that there really is a need for some sort of a research institute. I think a virtual institute is important. A few of us have argued that it should be more NIH-like. In other words, it should not displace all of the university and national laboratory research, it should consolidate. It should provide clarity and voice to a broad range of research.

Now how much should that have in terms of resources? I would argue that we should have one hour of downtime for Sun Microsystems because of unreliable power. That, by the way, is $60 million. Right? Give us one hour of their downtime in the first year and then we can talk. There are maybe 200 Ph.D. students in the building research area in this country of which have might be federally supported, the other have are supported by their home countries, other places.

We have almost nobody out there. We scrape the resources together to support Ph.D. students. There are two NSF research laboratories. One at Berkeley and one at Carnegie Mellon and that's it. So, I think it's really important to realize that we've been starving this industry for a long time on the assumption that it doesn't matter. I think all of us argue that it matters a lot. I'm going to jump to the end because I have a whole series of research agendas that we'll never get through.

I want to talk about one thing which I do thing is really important. There's lots of research we can do. We'll produce papers on these too. I want to talk about one thing—living laboratories. I would like to echo something that David Wyon said—sometimes we have to do it all backwards. Right? Build it. Find out it's all wrong. Re-engineer it, build it again, find out it's all wrong and ultimately you can start doing some science.

There are three levels of research we're talking about. We're talking about design science research; we're talking about design engineering research; and we're talking about design economics. How do you make it happen? All three of those are critical.

We have a laboratory at CMU that is a delight to work in. It is 95% daylit. Of course, we make students and faculty work around the clock so there is nighttime energy use. We're at about .2 watts per square foot whereas the average U.S. building is about 2 watts per square foot and it has a very high quality of light. We're almost a completely naturally ventilated facility. We run about 10% of the year on forced ventilation and that's because in Pittsburgh there's 10% of the year that's really just too hot and you have to shift over, but the rest of the year you can use natural ventilation effectively. We run hot water through the façade. It's the most benign. You can use waste heat off of power generation. We can manage to not add to the peak in order to provide heating at certain times of the day. It's a real pleasure.

It's fraught with mistakes too. It's got control systems that go haywire. We can't figure out how to manage our own temperatures without having a software engineer onsite. It's really an interesting environment in which to learn. There is no excuse for there not to be dozens of these laboratories. For LBL to have to do research in a spec office building, which is what they're contemplating when they should be researching in a lab where everything is up for grabs—innovation and enclosures, innovation and mechanical, innovations in lighting, innovations in networking strategies, innovations in space definition, so that they can really look at the interrelationships.

The same is true for Oak Ridge. The same is true certainly for DoE's headquarters and they're in an abysmal highest-energy use federal building possible, and with a lot of basement workspaces, all sorts of things that are really not the future. I would agree with Bill McDonough—design is an optimist activity. There is no excuse for us to not leapfrog, not just sort of crank down on what we're doing, and VAB [?] systems are a thing of the past. Separate out ventilation from thermal conditioning. We can save energy.

By the way, we can also cut off the heating and cooling systems when the windows open. There are 12,000 employees in Paris. Every time they open the window the local heating goes off, no problem. Simple technology but it requires a different mindset about the whole notion of mechanical systems and enclosures.

I think that it's time for us not only sweep up the investments with collaboration with other federal agencies and with industry, but also to really engineer solution sets, test them out, see if we can break the sound barrier or the cost barrier. With that, I'm going to close. We gave five or ten questions, if we eat into lunch, for questions and answers. To the audience.

Aud. question: Relative to your slide on schools and test scores. Is there coordination or what's being done in the Department of Education that's relative to the need for new school facilities and that sort of thing? Is there any coordination there, or opportunities?

Loftness: I'm sorry to say if Lisa were here, she might be able to answer that question. I do know that there have been a number of school studies that have been done, not funded by the Department of Education, to look at physical environments and test scores. Almost all of them are showing similar conditions. Higher test scores. Some of them are showing better health statistics, better growth, less dental decay. There's an amazing set of statistics out there that are just beginning to emerge but I don't know if it's education.

Aud. question: Vivian, what role ought to be played or might be played by the commercial sector as opposed to academia and government? I'm talking about Herman Miller, Tishmats Spire [?], organizations like that that are responsible for building much of our commercial infrastructure and then figuring out what goes in them.

Loftness: As a recipient of probably a dozen major building component manufacturer's research funding, they have often research groups that are five or six people total in organizations that may house 60,000 employees.

Although there is a lot of product research, the whole idea of looking at fundamental research questions is still a very small slice of those organizations. Johnson Controls is probably one of the most, and maybe David Wyon should come up and answer this, is one of the most consistent investors, not only in in-house research but in university-based research. I think, unless there is a real federal commitment, I think you're going to find industries saying—look, we already have a market. We do enough research to make sure our market is solid or is growing. But for us to look at some of these open-ended questions is a burden. I may be misquoting the industry, so let me pass to David.

[End of Tape 8, Side B. Start of Tape 9, Side A]

Wyon: Vivian is right. Most of what is clastic *[? phonetic]* research and declared [inaudible] research is product development in big companies. Actual support for research is very difficult to get from big companies.

We had a period five years ago at Johnson Controls when the senior vice president was interested in quality-built environments and he gave us a terrific boost in that direction. I'm afraid to say that the present management has taken a different approach and we have a tenth of the people that we had five years ago in that area. So it comes and goes. It is a question of management attitude. At places like Steel Case [?], Herman Miller, they have periods when they put a lot of money into this. We still support the Center for the Built Environment along with 14 other industrial sponsors at the University of California Berkeley. That's an example of very good value for money. The same is true of the Intelligent Workplace at CMU where Johnson Controls was one of the original sponsors.

It isn't very difficult to get together 10, 15, 20 industrial sponsors who will each put up 20-30K per year which is, of course, peanuts in their product development budget, but it turns into a lot of university research and I would encourage anybody here who represents heavy industry with products in this area to examine the possibility of sponsoring university research of that kind.

Aud. question: The question was sort of leading up to whether a PNGO-type program, Partnership for New Generation of Offices, is not possible and plausible. After all, the beneficiaries on the economic end of it are not necessarily going to be the federal government but these private sector investors.

Loftness: Is Jim Fry [phonetic] still out there? Jim, do you want to answer this? We've got a United Technologies Carrier research chief here who might be able to answer whether that kind of partnership would make sense.

Jim Fry [phonetic]: The simple answer is yes. We've been doing research and development, building energy systems, and indoor air quality for aircraft and buildings actually, both, for about ten years, at a pretty substantial level. We do invest in some university research. I do agree with the panel that the amount of effort going into this relative from the federal government funding is miniscule and actually ridiculous when you look at the opportunities for the U.S. economy and private industry here as well as just the overall American public.

We are going forward with what we call integrated building systems, at United Technology where we do an onsite power generation like other companies are with fuel cells, micro-turbines, integrating that into combined heat and power with active air quality treatment systems and we are going to partner with a wide range of universities and hopefully other industries and perhaps with the government, we're not sure yet. We'd like to see a little more commitment from the government in these integrated building systems-type efforts.

The panel remarked earlier how difficult it was to get different federal government agencies to work together in these interdisciplinary type efforts. A personal area of interest to us is indoor air quality that can lead to allergies and respiratory distress and asthma. We've been working on that for a number of years. It's an extremely difficult question to answer. It does require a very interdisciplinary approach of health specialists, air quality specialists, environmental specialists, statistical analysts, etc. We do feel this is a very important area but we can't do it alone. I think, Vivian, you quoted .003% of profits spent on building. Carrier spends anywhere from 2% to 5% depending on how you count the numbers.

Hamilton Sander [?] did an aircraft cabin quality control system about the same amount, but it really isn't enough. And, we don't have all the internal expertise we need to really address these interdisciplinary, multi-industrial, questions and we are looking to partner. We're going to put a lot more effort into this in the next few years. I'm not sure we see the level of effort and integration from the federal government to really even bother with approaching them. I don't want to sound too negative there, but that's our lay of the land in terms of how we see the situation.

Loftness: Let me add something else. I think there are a lot of innovations that are not going to fall cleanly in a particular industry's production area. Natural ventilation is no one's real interest, and yet on the one hand, there are some very interesting interfaces of natural ventilation and mechanical systems, it's really pushing out of the edge of a manufacturer's ability to fund substantial research to enter into open-ended questions.

Land use is in no one's particular interest. In fact, one of the points, Henry Lee might kill me, but one of the points that I was trying to make yesterday, is—do we need to subsidize power-reliability research when the industry is definitely come to the fore and help solve that problem? Do we need to subside IT research, unless we're subsidizing the aspect of power reliability that looks at the next generation of building solutions, and land use is an interesting one.

If you start to put together mixed use planning, you all of a sudden have some justification for distributing energy loads because you've got mixed uses under a particular generator. It seems to me if we're going to do research in the IT area, it really should be focused on the next generation of built environments. Of course, you're listening to an architect and building researchers, what are we going to say, right?

Comment [Fry?]: I'd like to make another comment in terms of the practicality of getting some of this R&D done. We have a grant carrier in UTRC with the State of New York to put in active filter system in buildings, change the ventilation rate pattern and actually prove that we can improve the air quality by actual measurable numbers, not just by some indirect CO^2 or ventilation, but actually measuring the indoor contaminants before and after with dummy systems, very similar to what we saw from the man from Johnson Controls and guarantee results, basically. Do you know we cannot get a building in the State of New York? You get all kinds of legal issues, all kinds of liability issues, so what we're going to do is basically donate a Carrier building.

Comment: I'd like to add to that. This is a huge issue for our research. We try to do these field studies and it's an enormous effort to get access to buildings and I'm calling on GSA and people in the private sector to realize how important this is to us.

We have a study underway with the Center at UC Berkeley in a call center looking at the impacts of ventilation and temperature on performance. It took us two years to get access to that building. We had a prior intervention study we performed together with NIOSH looking at how improved cleaning and also improved filtration affected health outcomes in a building. It took us, again, almost two years to get access to a building. There are so many people involved in the decision process that you could spend months with a building and then in the end, somebody turns you down. It's a major barrier to the kinds of research we need to do in this area. I'd like you to all recognize that and do whatever you can to help improve that situation.

Wyon: I'd like to say that I've just recently been struggling with the problem of access. The Harvard University School of Public Health asked me to provide access to some of the buildings managed by Johnson Controls. When it went to the legal department, it came back thumbs down. There's too much liability involved. They don't see any commercial advantage in making the buildings we manage available to Harvard School of Public Health and yet Don Milton [?[is producing some wonderful results showing how ventilation affects health, particularly upper respiratory tract infection.

How is he going to continue that work unless we give him access to buildings? I'm afraid to say that my recommendation to him is going to be that we can provide that in Denmark. I can get him access to buildings in Denmark, Sweden, Norway, and Finland. Everybody we approach there is positive to taking part in that kind of study. The unions are positive. Each individual occupant is positive. We have no difficulty and that's really why I've spent 30 years of my life in Scandinavia. It's a good place to do this kind of research. America is a really bad place to do this kind of research.

Aud. comment: My name is Louise Dunlap [phonetic] and I just wanted to call to people's attention an amazing opportunity that may have been mentioned earlier this morning on the panel, but Congress is going to leave probably within a week to eight or nine days. The new year begins ten weeks from Sunday. As of January 1, 2001, we have an opportunity for an extraordinary piece of legislation to take affect which gives tax incentives in the form of deductions for commercial buildings, including schools and rental properties, to the tune of $2.25 a square foot. It includes heating, water, ventilation, and daylighting. It's a total package requiring a 50% reduction, it's performance based. This is a collaborative effort with the Department of Energy, California Energy Commission, Natural Resources Defense Council, members of the Real Estate Roundtable, and major developers in California, Chicago, and New York.

This legislation is actually in the Community Renewal and New Markets Bill that Chairman Roth has reported from Senate Finance. It's going to conference in the next few days. It's structured as a deduction which is what Chairman Archer of Ways and Means said he had to have. It does not yet include the residential and the air conditioning provisions which were in the original bill offered by Senator Smith, but I just want you to realize that we are literally within a week of getting something that could radically advance all the things we've been discussing this morning. It would run from January 1, 2001, to December 31, 2006, allowing construction until December 31, 2008.

The simple title is Community Renewal and New Markets Act. It's one of the "hot" bills agreed to by Speaker Hastert and President Clinton as one of the bills they want to pass this year. It is officially lodged within the Senate Finance version which is S. 3152, but if you just call it the Community Renewal and New Markets Act, everybody will know what you're talking about. It also has very active support of the Governor of California.

Reicher: I want to thank every one and Vivian and your panel in particular for a fantastic session. One of the most overused phrases in Washington is "opportunities and challenges" but really think that characterizes what we had this morning. Opportunities that extended well beyond what I had imagined, and, in a way, challenges that may loom larger than I realized. As a recovering lawyer, I'm not going to get into some of the legal challenges, but there are many challenges out there.

I go back to my plea this morning. I'd love to use tomorrow morning as a time to flesh out from those of you on the panels and in the audience what some of the realistic actions might be coming out of these panels that would inform not just the DoE, not just the overall government research agenda, but the role of the labs, the role of the private sector.

We've heard discussions about virtual centers, we've heard discussions about a Partnership for a New Generation of Offices. I will remind you there is a Partnership for Advancing Technology and Housing which has not, frankly, been one of the great success stories of the past couple of years in terms of government industry partnerships.

We've heard talk about the role that the federal government could pursue with its own 500,000 buildings in moving things along. We've talked about better integration of the research budget, increasing the research budgets. We just heard a minute ago about the opportunity on the policy side for tax incentives.

There is a whole array of ways that we could become better organized, that resources could be increased, that we could bring a much greater laser focus to what is obviously an area of huge opportunity—and—relating that back to the panel yesterday on information technology. There is obviously a huge set of connections that we need to discuss. So I'm, in a sense, elated and overwhelmed by what I heard from this panel.

I would make one final point. We do live in Washington, D.C. We do have to justify what we do to the Congress. The more that we can make these research connections between workers in buildings or students in classrooms and the investments we make in the buildings in which they perform, the more we can make those direct tangible, supportable, the better we're going to do to get the kind of increases in funding that I think is clearly a unanimous view here that we need to achieve.

I hope many of you can stay around for tomorrow. We, as the organizers, need to talk quickly about how to best organize tomorrow morning so it can be as interactive as possible, but if the panels could deputize a couple of people to talk tomorrow, we obviously have some more spots for people from the audience. I think I want to make that as structured and action oriented as we can and come out of this with good ideas of how to move forward. With that, we invite you to lunch. We have two very exciting speakers. The former CEO of Bethlehem Steel, Hank Barnette, and the current Vice President for Research of General Motors, Larry Burns. I think you'll have not only have a wonderful meal but be stimulated as well. I look forward to seeing you in a few minutes. Thanks for a great session.

[Lunch]