Waste Reduction Coordination for Headquarters Renovation

Meeting Summary
April 14, 1992

Attendees: Glen Taylor, Joanna Karl, Pat Varley, Michel Gregory, Andy Sloop, Jim Goddard

Steve Kraten

(Additional distribution: Berit Stevenson, Debbie Palmerni, Flor Matias Leigh Zimmerman, Genya Arnold)

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Design & Construction Work: Exterior demolition is 100% complete, interior demolition is between 80% - 90% complete. The remaining interior demolition includes: cutting skylight and parking ramp openings. The space planning is complete and bid documents have been received by Metro. Vendor bids are due by June 1st. The structural permit has been received and sheer wall construction has begun. The City Design Review Committee is requiring that additional retail opportunity be provided with a new structure at the corner of the Plaza. This structure will be approximately 1,600 square feet and is similar in concept to the Pioneer Square shops. The revised completion date for the building is March 15, 1993.

Salvage & Construction Site Recycling: Metro is currently working with Rejuvenation Houseparts to salvage the maple flooring from the building. Approximately 22,000 square feet are available. An equivalent amount has already been removed and sent to a wood processor. The underlayment is cedar planking which has also been salvaged. Quantities for all of these materials need to be accounted for. A slate-like material has been seen at St. John's Landfill and it is not known whether this is from the renovation project. The EPA position has been posted and will close on Friday, May 8. Interviews should take place the following week with the position being filled before the end of May. .

Status of Buy Recycled: Pat and Berit reviewed the construction spec book. Materials included in the specs are: ceiling tiles from Second Look, gypsum wallboard from Domtar, sound control board from Homosote and toilet partitions from Santanna. The price preference for materials will be evaluated once the bids have been received. Bids are due June 1. Recycled paint color is too dark to match the architects design, however use of recycled paint within the building is still considered critical. It could possibly be used in mechanical rooms and as a primer for the final coat. This issue will be forwarded to Bob Martin and Vicki Rocker to determine the level of support and the amount of emphasis that should be placed on using recycled paint in the building.

Public Affairs. The tonnage on the construction sign will be changed to "186 tons reused or recycled". This does not include the wood flooring and planking. Media's reception to news about the project and the EPA Grant position have been luke warm. Public Affairs will continue to make press releases and attempt to get more visibility for the project.

Status of Recycling System: .The recycling chute is included in the bid specs so the final cost will be determined when bids have been received at the beginning of June.

Energy Report:. Joanna,s energy report has been sent to PP&L, Glumac and the Seattle Lighting Lab. A response to the report has not been received, however, Glenn is pushing for an answer by the end of this week. He has asked specifically that they address issues raised in the report such as energy efficient motors and hot water heating. PP&L has been given approval for all items in the Finanswer report except the R-30 roofing installation, the deep water well, and the high-efficiency package. All selected Finanswer items will be modeled together to determine the overall impact of the system. Glenn is having Glumach look at the potential savings for changing lighting in the parking garage. This may also be included in the Finanswer package. The question about inclusion of cooper cricket as a solar assist pre-heat for hot water system shows that the equipment pay-back is 46 years. This does not include the maintenance of the equipment. Conventional solar water pre-heaters have less capital expenditure but have high maintenance requirements. The rule of thumb for the capital cost is that maintenance costs would be equivalent of the initial capital cost after only 3 years.

Water Conservation: Rosemary Furfey should be added to this group to discuss water conservation issues. However, water conservation measures such as plant and irrigation systems are dictated by the City Review board. There may be no recourse now that the Landscape Architects design has been accepted by the City.

Action Items.

Jim Goddard

> Determine quantity of flooring and sub-flooring recovered from the project, date: 5/12/92. Interview EPA position applicants and make selection, date: 5/19/92. Meet with Rosemary Furfey to determine if she could have a role in the water conservation issues, date: 5/19/92.

Andy Sloop

> Review use of recycled paint with the Architect, Bob Martin and Vicki Rocker to determine level of support Metro was willing to place behind the paint program. Determine plan of action and acceptable uses within the building, date: 5/19/92

Michel Gregory

> Continue to publicize the renovation project and the EPA Grant, date: 5/19/92.

Glenn Taylor

Push for a response to the energy issues from Glumach, date: 5/8/92. Investigate possibility of changing lighting for the parking garage, date: 5/19/92.

Next Meeting: May 19, 1992, 3:30 p.m. to 4:30 p.m. in Room 335

JG:clk
facility\hqsal506.sum

METRO - Headquarters Project
Demolition Phase
Recycling Totals AS OF 5/3/92

MATERIAL	QUANTITY	DISPOSAL METHOD	RECYCLING COMPANY/ DISPOSAL SITE
Concrete, Brick, Metal Studs	3,137 tons	Allied Demolition/ Harmon Trucking	St. Johns Landfill
Concrete	74 tons	Allied Demolition	Porter Yet
Clean Wood	9 tons	MDC	Braedl Saw
Metals			
Tin	128 tons	Allied Demolition	ACME
Aluminum	10.5 tons	Allied Demolition	ACME
Brass	780 lbs	Allied Demolition	ACME
Copper	1,691 lbs	Allied Demolition	ACME
Heavy Iron & Pipe	25 tons	Allied Demolition	ACME
Other			
Shrubs	30 yds.	Hoffman	Re-used on residential project
Roofing Asphalt	10 tons	Buckaroo Thermoseal	Metro Transfer
	90 tons	" " "	East Cty Recycling
Mixed Loads	19.93 tons	MDC	Grabhorn
Carpet,trash			
Light Bulbs			

Metro receives EPA grant

The U.S. Environmental Protection Agency has given the Metropolitan Service District a $30,000 grant to document the "Resourceful Renovation" of the Sears building as a demonstration project. Metro is renovating the 73-year-old building into its new headquarters.

In addition to reusing the existing structure rather than building on vacant land, Metro is salvaging, reusing or recycling most of the waste produced in the renovation process. Recycled building materials are being incorporated where possible. To facilitate recycling once the building is operational, recycling chutes for office paper will be installed in existing shafts.

The grant will fund a part-time, on-site project coordinator, a how-to manual for contractors and developers and an educational slide show. Signs posted outside the construction site are being updated regularly to reflect tons of material recycled or reused on the project. Metro plans to conduct workshops and building tours for the construction industry that focus on the resourceful renovation elements.

– DJC. 4/24/92.

Fax 231-4263

METRO

2000 SW First Avenue
Portland, OR 97201-5398
(503) 221-1646
Fax 241-7417

April 28, 1992

Victoria Fung
KATU
PO Box 2
Portland, OR 97207

Dear Victoria:

Attached is a backgrounder on the construction recycling and waste reduction program Metro has implemented on our headquarters construction project. It has a bit more detail than the release we mailed last week. As I mentioned, EPA has given Metro a $30,000 grant to document the effort as a demonstration project.

To date, commercial contractors have made slow progress with construction and demolition recycling. Until recently, it was cheaper to landfill wood waste, drywall and other construction refuse. While higher disposal fees and new markets for recovered construction waste are beginning to make waste recovery and recycling viable, the construction industry is looking for proof that recycling makes financial sense.

We're excited to have the opportunity to use the headquarters building as a role model not only for recovery, but also for use of recycled products and planning for a state-of-the-art recycling system in the finished building. Hoffman Construction, our general contractor, is an enthusiastic and supportive partner in this effort. They expect to come away from this project with a whole new approach to handling waste on all their projects.

With construction and demolition debris comprising 17 percent of the waste stream, projects like this can have a significant impact on what the region sends to Arlington. Please let me know if you'd like to visit the building and talk with the folks making this project tick.

Sincerely,

Michel Gregory
Public Affairs

Executive Officer
Rena Cusma

Metro Council

Jim Gardner
Presiding Officer
District 3

Judy Wyers
Deputy Presiding Officer
District 8

Susan McLain
District 1

Lawrence Bauer
District 2

Richard Devlin
District 4

Tom DeJardin
District 5

George Van Bergen
District 6

Ruth McFarland
District 7

Tanya Collier
District 9

Roger Buchanan
District 10

Ed Washington
District 11

Sandi Hansen
District 12

Recycled paper

April 17, 1992

Doug Moss
E Magazine
PO Box 5098
Westport, CT 06856

Dear Doug:

As the agency responsible for solid waste planning and recycling education in the Portland metropolitan area, the Metropolitan Service District (Metro) is practicing what it preaches. Metro is recycling a 73 year old Sears store into its new headquarters and creating a role model for other commercial building projects in the process. I hope the project piques your interest.

The Environmental Protection Agency was interested enough to award Metro a $30,000 grant to document the "Resourceful Renovation" as a demonstration project. Besides reusing the existing structure rather than building new on vacant land, most of the waste produced in the renovation process is being salvaged, reused or recycled, and recycled building materials are being incorporated where possible. To facilitate recycling once the building is operational, recycling chutes for office paper are being installed in an existing mechanical shaft, and recycling storage space is being designed for easy access to the loading dock. Energy and water efficiency plans are also being developed.

Key to the success of the project is the cooperation of the design/build team. From the beginning, the architect, Thompson Vaivoda/Cole, and the contractor, Hoffman Construction, have been on board with the goals of maximizing waste reduction, reuse and recycling. Preserved for reuse by design are beautiful cast medallions from the original exterior, portions of existing maple and terrazzo flooring, curving oak bannisters, a two-story water tank that will be transformed into a "think tank" meeting room, and two existing shafts that will house recycling chutes.

The contractor and Metro staff developed an overall waste management plan for the project and a waste management form that all subcontractors are asked to complete. Metro provides construction site recycling guides and technical assistance to help subcontractors develop their waste management plans. Waste disposal and recycling reports from all subcontractors allow Metro to track the quantities of materials recycled or disposed of over the life of the project.

Hoffman's project superintendent, Don Nail, is one of our most enthusiastic advocates of reuse and recycling. Before demolition began, he worked with Metro to ensure all salvageable materials were removed from the building for reuse. Non-profit organizations removed 9 tons of carpet, and an architectural salvage company took away 2 tons of doors, fixtures, paneling and hardware.

During the demolition stage, Nail has organized crews to carefully sort waste materials to maximize their recyclability. To date, 165 tons of metal and 9 tons of wood have been recycled. 1,968 tons of damaged bricks, concrete and metal studs were recovered for use in capping the local landfill, now being closed. And when 50 shrubs had to be removed from the existing landscaping, Nail found a home for them in a residential development. As of April 14, only 20 tons of waste were disposed of as garbage. In the actual build-out stage, Hoffman and Metro expect to recover large quantities of wood, drywall, metal, cardboard, cement and asphalt for recycling.

Plans for recycled materials to be used in construction are being finalized. Possible recycled products include dry wall, ceiling tile, ceramic tile, plastic bathroom partitions, counter tops and paint. To be considered, materials must meet quality and performance standards, fall within price guidelines, and be readily available. In some cases, Metro is allowing price preferences for recycled products.

All of us at Metro think this is an exciting opportunity to set a new standard for commercial construction. Please let me know if you're interested in knowing more about this project. I've enclosed a general background piece for your information.

Sincerely,

Michel Gregory
Public Affairs

Patricia Moore
Garbage
2 Main Street
Glocester, MA 01930

Jeff Solomon-Hess
Recycling Today
4012 Bridge Avenue
Cleveland, OH 44113-3320

Edward Rodie
Public Works
200 S. Broad St.
Ridgewood, NJ 07451

Joseph Daniel
Buzzworm
2305 Canyon Blvd. #206
Boulder, CO 80302

Revised versions to:

Construction Trade Magazines

Architecture Trade Magazines

From:

Joanna Karl
Engineer
Solid Waste Department

4/18/92

Glenn-
Here's information on a new solar water heater. This is the first I've heard of it - and don't have any further information.

cc: Jim Goddard

METRO

2000 S.W. First Avenue
Portland, OR 97201-5398
503/221-1646

The Real Goods Rainmaker has struck again. The day after we decided to make water the focus of this special issue, the heavens opened up over California. As is often the case when the subject is water, the situation instantly swung from one extreme to the other. The same state that has been in the throes of a six-year drought was suddenly awash in floods.

When all the excitement passes and the flood-related disasters subside, the drought conditions had not ended at all. America is the biggest water guzzler in the world. Every day Americans use more than 5 billion gallons of potable water to flush the toilet, and more than 3 billion gallons to shower. This wasted water is enough to supply the annual needs of more than 80 million people.

Water is a complex, universal issue. In the West, there hasn't been enough. In the South, there has been too much. In the East, the water is often laden with acid. [illegible]

[illegible]

The Real Goods [illegible] catalog [illegible] help you manage water [illegible] respect it deserves.

John Schaeffer

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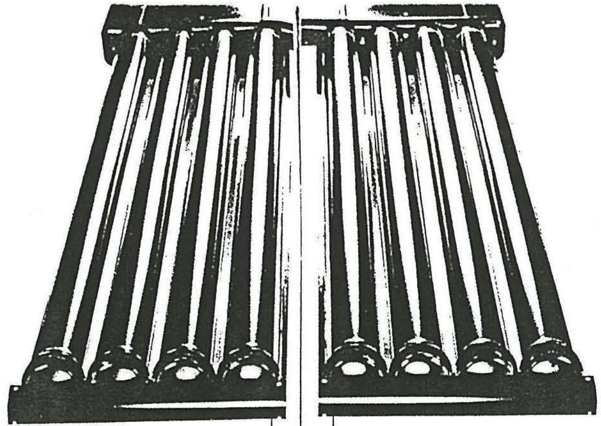
■45-407 PK-20 Solar Water Heater .. $1995 ■45-408 PK-20 Sub-system $165
■05-211 Crating Charge $110



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Aquastars are on page 47.

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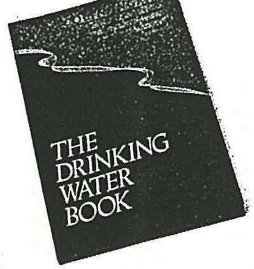

The Drinking Water Book

This book is a summary of author Colin Ingram's five year research project on all aspects of drinking water quality. It is a thorough discussion of water contamination, drinking water safety and filtration/purification. He compares tap water, bottled water, and various filter technologies for their relative safety and effectiveness. The book includes a question and answer chapter, a radon supplement and several appendices: drinking water glossary, further reading, water testing and water standards. This book takes a clear, level-headed look at a very serious situation.

80-173 The Drinking Water Book $12

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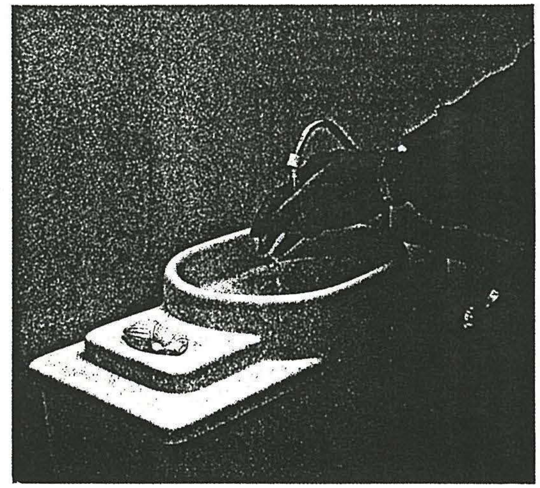
54-172 Aquasave (16 oz.) $9
54-173 Aquasave (64 oz.) $23



Toilet Lid Sink Creates a Dual Role for Water

Wash your hands with clean water that fills the tank for the next flush! This marvelous water saver (and space saver) replaces your present tank lid. We saw these used almost universally in Japan years ago and wondered when America would get smart! Flush the toilet, and clean incoming water is rerouted through the chrome fixture into the basin, then filtered into the tank and bowl. Shuts off automatically. It's a boon to arthritis sufferers - no struggling with faucet handles. And it's so easy that children are more likely to wash their hands. The plastic lid, which has the appearance of porcelain, installs quickly without tools. Fits toilets up to 8" wide. White only.

46-120 Toilet Lid Sink (15"-18") ..... $35 46-121 Toilet Lid Sink (18"-20.5") $35
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"Yippee!" said 5 year old Harrison when he discovered a sink on the toilet lid in his bathroom.

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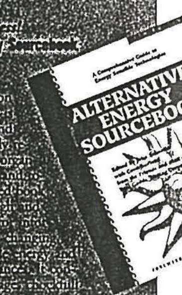

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[illegible] Whether your interest [illegible] you'll find indispensable information in this Sourcebook. [illegible] foreword by Amory B. Lovins of the Rocky Mountain Institute. Also included are many helpful charts, graphs and photographs. The book is neatly organized into [illegible] *Off-The-Grid* [illegible]

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from catalog by:
Real Goods
966 Mazzoni St,
Ukiah, CA 95482-3471

From:

Joanna Karl
Engineer
Solid Waste Department

4/21/92

Glenn-

The following article addresses some specific measures for energy-efficiency, including lighting (and efficient electric motors).

It is by Amory Lovins of Rocky Mountain Institute. I am also getting a videotape of a recent presentation he gave.

cc: Jim Goddard

METRO

2000 S.W. First Avenue
Portland, OR 97201-5398
503/221-1646

The 'Negawatt' Revolution: New Techniques for Electric Efficiency

by Amory B. Lovins

New electricity-saving techniques can reduce corporations' operating costs and improve their profitability, help protect the environment and boost local economic development.

Introduction

In this article, I would like to help you explore how your company can reduce pollution, become more competitive, and make a lot more profit, all at the same time.

Ron Perkins, facility manager at Compaq Computers, found that this was possible. He knew that the modern offices Compaq was building were quite well-designed by competent people, but on learning of further innovations, he said, "I think that on the next office we build, we can use a quarter less electricity per square foot than on our last one."

His fellow engineers said, "Oh, why do you have to make it so hard on yourself? You would be lucky to sweat out another few percent of savings."

Well, he actually saved one-third of total electricity usage in the first year, and he is going to save one-half on next year's new building. His energy-saving techniques are paying back in a few years — even less with credit for the saved cooling capacity. All of those savings for decades to come will go to Compaq's bottom line, while the company reduces pollution because its utility will not need to make as much electricity to provide the same building services.

This is going to be a bottom-line-oriented article, and I emphasize that because sometimes we get in the bad habit of looking at the top line instead. I was recently talking to an officer of a very large corporation. At one facility, the company has an outstanding energy manager who is already saving $3.50 per square foot per year on energy costs, and he has not even done most of the lighting measures yet, which are most of what Ron Perkins used at Compaq. This officer said, "Well, let's see: $3.50 per square foot times a million square feet (92,900 square meters), that's $3.5 million in extra profits a year. That's nice." Yet, in the next breath, he went on to say, "But I can't get very excited about saving energy. It is only a few percent of our cost of doing business." Thus he slipped into the fallacy of thinking about gross instead of net. I pointed out that if, hypothetically, he achieved the same energy savings at all of his facilities worldwide, the corporation's total net earnings would go up by about 56 percent. I think that got his attention.

The Electric Efficiency Revolution

What makes that sort of performance possible is chiefly advanced techniques for very efficient use of electricity. Most of the best of these techniques are less than a year old; that is, the half-life of the technology is only about a year. You can now save twice as much electricity as you could five years ago, but at only a third of the real cost. That is about a six-fold gain in cost-effective potential in five years, and almost a thirty-fold gain in 10 years. I will summarize presently some of the measured cost and performance data for those technologies. But let me first emphasize why I am talking about electricity.

Benefits of Efficient Electricity Usage: Electricity is the costliest form of energy, so it is by far the most lucrative kind to save. Each cent per kilowatt-hour is equivalent in heat content to oil at $17 per barrel, so average commercial-sector electricity is equivalent to oil at $123 a barrel. Electricity costs Americans about $170 billion a year —almost $100 billion of it for business use. Expanding the U.S. electric supply system also devours investments and subsidies totaling about $60 billion per year — the same as total investment in all durable-goods manufacturing industries.

Moreover, each unit of electricity you save, saves three or four units of fuel (chiefly coal) at the power plant. This lets you avoid a lot of pollution, because power plants use one-third of all fuel, and they produce one-third of the resulting carbon dioxide (CO_2), one-third of the nitrogen oxide (NO_x) and two-thirds of the sulfur oxide (SO_x). So saving electricity yields very large environmental benefits as well as economic leverage.

Over the past decade, the United States has gotten over seven times as much new energy from savings as from all net increases of supply. It is curious, though, that of the roughly $150 billion a year already being saved on the national energy bill, only about 1 percent is from saving electricity. The rest is almost entirely direct savings from oil

Amory B. Lovins is an experimental physicist who is active in energy policy in some 30 countries. He is director of research for Rocky Mountain Institute, a nonprofit resource policy center based in Snowmass, Colo. This article is adapted from his presentation to a general session of IDRC's Colorado Springs World Congress.

and gas, because that is what we were worried about.

Saving oil and gas is still worth doing, and many U.S. corporations have done an exemplary job of it — with quite a way still to go. But in the future, I think the biggest opportunity will be in new *electrical* savings. Indeed, even if you have already done a lot to save electricity, you can start all over again, because there is a whole new menu of technologies that were not available even a year or two ago.

Saving Electricity Through State-of-the-Art Lighting Retrofits

New energy-saving devices have a U.S. electricity savings potential equivalent to hundreds of 1,000-megawatt power plants plus more than twice the annual oil output of Alaska. Perhaps the most lucrative savings are in lighting, which directly uses one-fifth of all of the electricity in this country. Adding the space conditioning to take away the heat of the lights, lighting directly and indirectly uses about a quarter of all of the electricity in this country, and costs American business tens of billions of dollars a year.

> *'... even if you have already done a lot to save electricity, you can start all over again, because there is a whole new menu of technologies that were not available even a year or two ago.'*

In a typical big office building, about one-third of the electricity goes directly to lighting. Since lighting represents most of the space-cooling load, lighting directly and indirectly accounts for upwards of two-thirds of a big office's electrical use and a larger share of peak demand.

Most of that lighting is fluorescent, so let me describe some things that you can do by retrofitting existing fluorescent fixtures. It does not much matter what you start with: The savings will vary only a few percent whether you start with an inefficient 20-year-old lighting system or a newly installed, fairly efficient one.

In either case, a thorough, modern retrofit can reduce fluorescent lighting's direct energy use by upwards of 70 percent — in many cases 80 percent to 90-plus percent. That cuts total operating costs for lighting, space cooling and lighting maintenance by upwards of $1 per square foot per year. The cost of the retrofit is less than $2 per square foot up front, but you end up with about half as many lamps and a quarter as many ballasts to maintain as you started with, so the net-present-value cost of the retrofit is only about $1 per square foot — a payback of one or two years. In new construction, the payback is negative: You will actually *reduce* the total costs of new construction, because you save more by downsizing the mechanical systems than you pay extra for better lights.

You will get the same amount of light as before, but it will look better and you will see better. You will also get better aesthetics, thermal comfort and reliability. There is a good chance, too, that you will have more productive workers in the office, and that is probably worth more to the bottom line than getting rid of all of your energy bills. And of course your building will be worth more and you will have a much larger competitive margin to play with than the rent differences you worry about in many leasing markets.

Using Reflectors to Save Electricity: The first part of this integrated package of retrofits is to install imaging specular reflectors, made of very shiny metal bent into a customized, computer-designed shape that reduces the number of bounces per exit ray from almost three to about one. Such reflectors are available both for new and for retrofit use. The shape is very important, and you have to be careful what you buy: Some reflectors make the optics worse.

Good reflectors will typically reduce watts per foot-candle by something like 35 percent to 40 percent. The reflectors enable you to remove half of the lamps and relocate the rest. It will then look as if the original lamps are all still there, but it is done with mirrors — the reflectors make a virtual image of the missing lamp. In a typical Chicago office, for example, each removed lamp represents about $25 per year in avoided operating costs.

Modern Phosphors: As you move the remaining lamps to new positions, you should consider replacing them with lamps that outwardly look the same, but use a modern phosphor that gives much more accurate and pleasant color. These lamps also give you up to about 18 percent more light per watt.

Tunable High-Frequency Ballasts: Also, as you relocate the ballast (which controls the current to the lamps), you should replace it with a high-frequency electronic ballast. This a kind of electronic Wonder Bread: It saves electricity 15 ways. People normally count just two ways, namely that the ballast wastes less energy and that the lamps run more efficiently at high frequency (which also gets rid of flicker and hum). Those "intrinsic" savings now total upwards of 40 percent extra light per watt with good brands. However, a high-frequency electronic ballast does a lot more than that:

- it avoids duplication of circuitry by serving up to four or even six lamps per ballast instead of just two;
- it is less sensitive to abnormal supply voltage or lamp-wall temperatures, so you need less overdesign;
- it will dim the lamps according to how much daylight is present, and brighten them as they dim with age;
- you can "tune" the ballast to get more light where it is needed; and
- controls can turn off the lamps after you leave the room.

These successive savings multiply so quickly that in a typical setting — where you can put control systems in your whole floorspace, and where you get about a 50 percent savings from daylighting in the perimeter zone (about half of your floorspace) — just the ballasts and controls will save 70 percent to 84 percent of watts per useful foot-candle delivered. Even in unfavorable cases you would save about 50 percent, and excellent daylighting in new buildings can save well over 90 percent.

But those are just ballast and control savings. You are already saving an additional 15 percent on the lamp phosphor, and 35-odd percent on the reflectors, bringing the total to more than 80 percent. There are many other things you could do too, such as:

- not overlighting;
- using task lighting;
- using polarizing lenses, which essentially get rid of glare (so you can see as well with about half as much light because contrast is better);
- bouncing light around better inside the space by using lighter-colored finishings and furnishings;
- using top-silvered blinds and glass-topped partitions to bounce light farther into the core of the building; and
- providing better maintenance to the lighting equipment.

These measures can raise the typical retrofit savings to 90 percent or more.

Furthermore, for each three units of lighting energy you save, you will also typically save a unit of net space-conditioning, and for each two units of peak-lighting energy you save, you will save about one peak unit of cooling energy and thus reduce demand charges. But even without the space-conditioning benefits, the direct electricity savings of the lighting retrofit package add up to about 70 percent to 90-plus percent. Again, you will get the same number of foot-candles that you started with, but of better quality.

Compact Fluorescent Lamps: Exactly the same opportunity applies with incandescent lamps, which are normally replaced with compact fluorescents that miniaturize the kinds of elements just discussed. They save about 75 percent to 80 percent of the electricity used by incandescent lamps. They last about 13 times as long as a regular light bulb, so they will save you a dozen lamps and a dozen trips up the ladder, and that will more than pay for them even though they are fairly expensive up front.

The net cost of compact fluorescents per kilowatt-hour saved is *minus* a few cents. This is not a free lunch; it is a lunch you are paid to eat. That is, compact fluorescent lamps are more than paid for by avoiding maintenance costs, so the electricity savings are better than free. These lamps have the potential to eliminate about 50 Chernobyl-sized power plants in the United States, while improvements in fluorescent lighting could potentially eliminate another 60 such plants.

> ***The net cost of compact fluorescents per kilowatt-hour saved is* minus *a few cents.***

Modular Compact Fluorescents: You can get similar energy savings at even lower costs with modular compact fluorescents assembled from different pieces: a small magnetic or electronic ballast, an adapter (often built into the ballast) to screw into a normal socket, a plug-in lamp, and often an optical component. For example, suppose you want to replace the 75-watt floodlamps in the lobby of your building. By adding a reflector accessory to a 7- or 9-watt lamp plugged into a 1-1/2-watt ballast/adapter, you will get an 8-1/2- to 10-1/2-watt flood lamp that does the same thing and lasts four to five times as long. For restaurants or similar uses, there are lots of decorative accessories — fancy cut-glass chimneys, globes and so on.

Modular compact fluorescents typically cost *minus* 10 or 20 cents per kilowatt-hour saved, because all you have to replace is a little $3-to-$6 tube every 10,000 hours, not the whole assembly. Modular compact fluorescents are available in such a profusion of sizes and shapes that they will fit essentially any application (except, temporarily, with dimmers).

Impact of High-Efficiency Lighting: Measured cost and performance data for all of the best lighting equipment on the market, plus a few minor things like better maintenance practices, reveal a potential to produce the same amount of light as now, with superior quality, using only about 8 percent as much lighting energy as now — and the net cost of that is slightly less than zero. So lighting retrofits offer a potential, including space-conditioning effects, to save the output of about 120 Chernobyl-sized power plants plus about $30 billion worth of power-plant fuel a year.

Other Electricity-Saving Techniques

There is much more you can do to buildings to save electricity, especially with "superwindows" that insulate as well as 8 to 12 sheets of glass and can let in five-eighths of the visible light but only 2 percent of the heat. Such windows more than pay for themselves by avoiding costly space-cooling capacity. Designers are just starting to learn how to "tune" the facades of a building to get different spectral properties on different elevations so that you can equalize the heat and light flux across the shell from all directions and get rid of a lot of mechanical and control capacity and complexity.

Efficient Office Equipment: One of the most important things you can do to save electricity in buildings, which I dare say very few people have paid much attention to so far, is to use efficient office equipment. For example, if you get an AT-class notebook-sized computer that uses one to six watts instead of 150 watts, its present-valued electrical savings will be enough to repay its marginal cost. (Using battery-powered portable computers also means that you do not need uninterruptible power supplies, you do not have any health and safety worries about cathode-ray tubes, and you have all of the productivity and flexibility benefits of complete portability.)

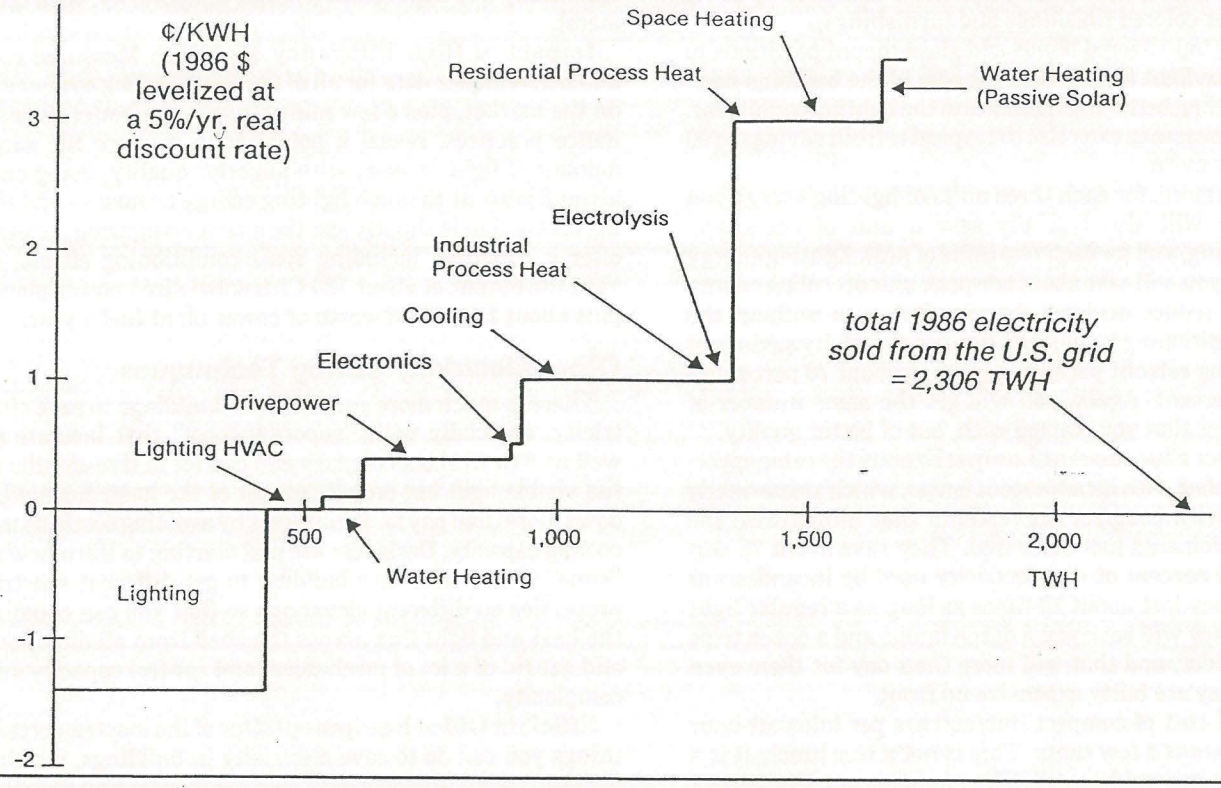
If you are the kind of facility manager who is having to jackhammer in millions of dollars' worth of extra ductwork, chiller capacity and wiring to cope with new plug loads, you can probably solve that problem with better lights and office equipment. In addition to using efficient laptop or notebook-sized computers, you should also consider using things like cold-fuser photocopiers, cold-fuser or inkjet printers, inkjet fax machines, software control for laser printers so they are only on when you are printing, and so on. These are rather simple innovations. The computer makers have not yet paid much attention to them, but they should, and you should demand that they do. In fact, a new Rocky Mountain Institute (RMI) report describes how to save about 90 percent of all office-equipment electricity at roughly zero or negative net cost.

The same goes for more specialized equipment. One of the things I learned from Compaq, for example, is that you can make electronic-assembly cleanrooms that work better than regular ones and use about one-tenth as much electricity.

Efficient Electric Motors: Motor systems can save even more electricity than light. Motors use over half of the electricity in this country. They use more primary energy

CHART A

A PRELIMINARY ESTIMATE OF THE FULL PRACTICAL POTENTIAL FOR RETROFIT SAVINGS OF U.S. ELECTRICITY AT AVERAGE COST — 0.6¢/KWH



than highway vehicles use. Among the menu of improvements to motor systems, most people only look at high-efficiency motors and adjustable-speed drives (ASDs). Those are important, but they are only half of the savings you can get from roughly 35 classes of measures which apply to the choice, sizing and maintenance of motors, four kinds of controls, and improvements to the upstream electric supply and the downstream mechanical drivetrain. Those savings together can save close to half of total U.S. motor energy, with a payback of about 15 months. There go another 150 big power plants, not counting savings you can make in downstream equipment with better pumps and bigger pipes and so on. (The Electric Power Research Institute shared these conclusions about motors in our joint *Scientific American* article in September 1990.)

The key to these kinds of savings, as with lighting and building design, is ***whole-system engineering with meticulous attention to detail.*** Saving energy is like eating a lobster: There are big, obvious chunks like the high-efficiency motors and the ASDs, but if that is all you eat and you throw away the rest, then you are missing out on a roughly equal quantity of tasty little morsels tucked away in crevices. You have to dig for that last half of the energy savings. Corporate real estate professionals who buy and design buildings have to be ready to find, and pay for, the extra work that the design professionals will have to do to dig in all those little crevices. But there is a great reward in doing that. You not only double the savings; you also cut the cost of the savings by severalfold because you can often get many benefits for a single expenditure. For example, the reason that saving half of the motor energy (or one-fourth of the electricity) in this country is so ridiculously cheap — paying back in about a year, in big buildings as well as in factories — is that you are only having to pay for seven of the 35 kinds of motor-system savings. The other 28 are free byproducts of those seven. But you can only do that if you look in great detail.

Total Potential Savings

Chart A shows the total potential savings for U.S. electricity if everyone installed the best commercially available efficiency techniques into present buildings and factories. The vertical axis shows the cost of saving, in cents per kilowatt-hour, and the horizontal axis shows the quantity of electrical savings. The graph summarizes measured cost-and-performance data for about 1,000 technologies. To make the graph simple enough to read, however, I have lumped them together for each application. By the time you get up to the upper right-hand corner, you are saving about 75 percent of U.S. electricity at a marginal cost of a few cents per kilowatt-hour, about half of present rates, but at an *average* cost of about 0.6 cents per kilowatt-hour. That is about one-tenth of the rate most companies are paying, and it is much cheaper than just *fueling* a coal or nuclear station, even if building it cost nothing. That means it is actually worthwhile for a utility to give you such savings, even if it has capacity coming out of its ears, because capacity is a sunk cost, but the utility can save marginal variable cost.

Finding Energy-Saving Assistance

Unfortunately, we are still at an early stage of developing the mature delivery systems for these technologies as integrated packages. If I ran a factory, I would like to be able to call some number and they would say, "Torque Team! Let us come do all 35 things to your motors." Or if I ran an office, I would like to call some number and hear them say, "Light Brigade! Let me charge in and do everything to your lights. We will do it all and do it right."

> ***One of the most important things you can do to save electricity in buildings, which I dare say very few people have paid much attention to so far, is to use efficient office equipment.***

But there are only a handful of companies that perform whole-system lighting retrofits, and no company (as far as I know) that does packaged drive-power retrofits. So it is like the days before packaged holidays: There is just too much hassle in arranging all of the little pieces. This is ultimately about a trillion-dollar-per-year business opportunity worldwide.

The Role of Utilities: But many utilities are in fact getting heavily involved in helping their customers save electricity, not only by financing and marketing saved electricity, but also by telling you exactly how to do it. Many utilities will:

- provide general and specific energy-saving information;
- finance energy efficiency with concessionary loans or even gifts (Southern Cal Edison has given away over 800,000 compact fluorescent lamps because it is cheaper to do that than to run their power plants);
- provide rebates for buying, selling, installing or specifying efficient equipment, or for scrapping the old equipment, or for beating government standards; and
- offer leases, like 20 cents per compact fluorescent lamp per month on your electric bill, so that you can pay for the lamp over time, just as you would otherwise pay for a power plant over time.

These methods, especially the rebates, are very effective. Many companies have already taken advantage of them. If your utility does not offer them, then I think you ought to have a chat with your utility about what business they are in. Are they selling you kilowatt-hours, or are they profitably providing customer satisfaction? If the latter, then it is perfectly all right for the utility to sell you less electricity and have less revenue — as long as the utility's costs go down more than its revenues go down. People in other businesses understand this very well: Anybody who sells shoes knows that you can make money on margin instead of volume.

But that is still heresy in the utility business, especially since in 46 states utilities get more profit when they sell more electricity and less profit when they sell less, and if they do something smart to save you money, they get none of it and you get all of it. That is not a very good way to encourage efficient investment on their part. But in November 1989, the nation's utility regulators agreed in principle to change the rules so as to decouple profits from sales and let utilities, in effect, keep as extra profits part of what they save you: They will get an extra reward for efficient behavior. These reforms are now spreading rapidly, transforming the utility culture and bringing the entrepreneurs out of the woodwork. And you too are much better off with the kind of deal that Pacific Gas & Electric just cut in California, where they get to keep 15 percent of savings that they achieve for their customers: It is better for the customers to get 85 percent of an actual prompt saving than to get all of nothing.

If all Americans saved electricity as quickly and cheaply as 10 million of us did in Southern California in the early 1980s, then we could improve the economy by several percent a year and still *decrease* each year the total amount of electricity that this country uses. The total costs of the utilities to achieve that gain in electric productivity would be about 1 percent of the cost of building and running new power plants. That is pretty good for old, well-established implementation methods.

Electricity as a Commodity

I think we can do even better, though, with new methods that we have been developing at RMI to make a market in "negawatts": that is, to make saved electricity behave like a commodity, just like copper, wheat and sowbellies. All ways to save or make electricity can then compete against each other at open auction, and the utility chooses the lowest bids. (This is now happening in eight states.) Or utilities can sell each other saved electricity. Or customers can get rewarded for going bounty-hunting and saving *other* customers' electricity.

I know of utilities that even want to become "negawatt brokers" and make spot, futures and options markets in saved electricity. Some customers want to sell to utilities reduced demand or reduced uncertainty of demand, which could be traded in secondary markets like reduced air pollution. And we even have about a dozen utilities that are

> ***I know of utilities that even want to become "negawatt brokers" and make spot, futures and options markets in saved electricity.***

selling efficiency in the territories of *other* utilities. (You cannot sell electricity in another utility's territory where it has a monopoly, but efficiency is just a financial and informational product you can sell anywhere, so Puget Power sells electricity in one state and efficiency in nine states.) It

is even possible for *gas* utilities to make a lot of money selling *electric* efficiency: they have all the same ability to deliver it to the customer that electric utilities have, but none of their potential inhibitions.

Another thing that I think you will see coming up more and more in many of the states where you operate is a "feebate" for new buildings. When you hook up a new building to the grid, you will either pay a fee or get a rebate. Which of those it is and how big it is will depend upon how efficient your building is. That will very rapidly change how we design buildings.

How Electric Efficiency Benefits All of Us

Let's look at a few examples of the impact of electric efficiency. The first example involves economic development. A little municipal utility in Osage, Iowa (population 4,000), by using weatherization and load management, saved so much money that it was able to prepay all of its debt, build up a big surplus, and cut electric rates five times in five years, to half of the average level in Iowa. The result was that they were able to attract two big factories to town and, most importantly, they kept more than $1,000 per household per year of new disposable income recirculating in town, supporting local jobs and local multipliers. The Main Street shops in Osage were noticeably more prosperous than in other towns nearby.

> ***. . . Southwire had a couple of smart engineers who, over eight years, cut the firm's electricity use per pound of product by 40 percent and its gas use per pound of product by 60 percent. The result was that the company's energy savings almost exactly equaled its profits during a tough period when many such firms went under.***

Exactly the same principle of plugging unnecessary leaks of dollars out of the economies where you operate applies everywhere, and it is the most powerful form of economic development we know. And the same kind of leak-plugging applies especially to the corporate income statement. When the rod, wire and cable business fell on hard times in the early 1980s, the biggest independent company, Southwire, had a couple of smart engineers who, over eight years, cut the firm's electricity use per pound of product by 40 percent and its gas use per pound of product by 60 percent. (By the way, that energy usage is still going down and they are still on two-year paybacks.) The result was that the company's energy savings almost exactly equaled its profits during a tough period when many such firms went under. Those two smart engineers may have ended up saving 4,000 jobs at 10 plants in six states.

Or consider soft leasing markets. A few years ago, I was talking to leasing brokers in Chicago. They were fighting over rent differences of 5 or 10 cents a square foot. Those brokers could have been saving close to $1.50 a foot just on lighting retrofits, which also make the building look nicer and help make the workers more productive. Also, the money saved on lighting retrofits is fungible, so you can use it for build-out, or for rent concessions or for whatever it takes to get tenants. Whichever developer adopts these measures first is going to grab market share from its competitors.

Environmental Benefits

Finally, there are environmental benefits. A single 18-watt compact fluorescent lamp, producing the same light as a 75-watt incandescent lamp for 13 times as long, directly saves 570 delivered kilowatt-hours over its 10,000-hour lifetime. This savings keeps out of the air more than a ton of CO_2 from coal plants and about 20 pounds of SO_2, plus various other pollutants. (By the way, if the lamp were saving oil, as it might in a developing country, one such lamp will save enough oil to run your family car 1,000 miles.) But far from paying extra for the benefits, such a lamp costs you tens of dollars less than it saves in replacement lamps, their installation labor and utility fuel. In other words, the lamp generates tens of dollars of net wealth, and it defers hundreds of dollars of utility investment for which you can doubtless think of better uses.

> ***We can abate over half of global warming with energy efficiency which costs less than burning fuel . . .***

That is a general illustration — and one of the more expensive ones that I could pick — of the proposition that it is now generally cheaper to save fuel than to burn fuel. Therefore, the pollution you do not put into the air when you do not burn the fuel is achieved *not at a cost but at a profit.*

For example, suppose you are looking at power plants that emit sulfur and help cause acid rain. The standard way to clean that up is to raise everybody's electric bills to clean up the plants. However, you could instead help customers — using the proven implementation methods I have mentioned — to get superefficient lights, motors, appliances, windows, etc., so they do not need so much electricity to do the same job. The utility can then burn a bit less coal, emit less sulfur, and back out the dirtiest plants first. But the important thing is that the utility will save a great deal of money, because efficiency is cheaper than coal. You can then use

me of the money to clean up remaining plants, some to lower the rates to more competitive levels, some perhaps to compensate coal miners, and, I hope, some to reward utility investors for having hired such smart managers.

Cooling the Global Warming Debate: The same argument applies to global warming. Regardless of whether global warming is happening, will happen, or what it will be like, broadly speaking there are three things we should do about it. We can abate over half of global warming with energy efficiency which costs less than burning fuel, so that cost of abatement is strongly negative. Another quarter of global warming can be abated by sustainable farming and forestry practices, which, as the National Academy of Sciences just showed, are actually at least as profitable as present practices and often more so. Let's call that roughly a break-even proposition. Another sixth of global warming can be prevented by displacing chlorofluorocarbons (CFCs) — but we have to do that anyway to protect the stratospheric ozone layer, so it doesn't matter what it costs. If, therefore, the cost of abating global warming ranges, broadly speaking, from strongly negative to roughly zero to irrelevant, why fiddle while coal burns? We ought to be getting on with the job.

In addressing global warming, though, it is essential that we choose the best energy buys first, owing to the concept of "opportunity cost" — the idea that you cannot spend the same dollar on two things at once. If you spend a dollar on an expensive way to displace standard power stations, such as nuclear power or photovoltaics, then you will not displace much coal-burning. But if you spend the same dollar on something cheap, like electric efficiency, then you will displace a lot more coal-burning for that dollar. Whenever you buy something expensive instead of something cheap with a given dollar, you will buy less solution, and you will end up unnecessarily releasing extra carbon into the air that you would have avoided had you chosen the best buys first. That is why the order of *economic* priority is the order of *environmental* priority.

Sweden offers a very encouraging example of what happens when you take economics seriously. The Swedish people have voted to phase out the nuclear half of their power supply over the next 20 years, but Parliament has meanwhile voted not to build more dams on the northern rivers and to reduce the country's CO_2 output; and over the next 20 years, they expect the economy to grow by half. How do you do all of that? The Swedish State Power Board has published a very careful description of how to double Sweden's efficiency of using electricity at a cost of 1.3 cents per kilowatt-hour, do some fuel-switching to gas and wood, and operate most those power plants which emit the least carbon. The board found that by doing those three things together, they could support the projected 54 percent larger gross national product, handle the nuclear phase-out, yet *reduce* the utilities' CO_2 output by one-third, and *reduce* the total cost of electrical services in Sweden by almost one billion dollars per year. That is very encouraging, because Sweden is probably already the most energy-efficient country in the world, and it has a severe climate and a heavily industrialized economy. If they can do that, we can do better.

Conclusion

I hope that this overview of a very rich and complex field will share with you some of my sense of excitement about your new opportunities in the electric efficiency revolution.

The leadership of enlightened companies is going to be vital in controlling pollution and boosting competitiveness through these and other advanced techniques for resource efficiency.

SUGGESTED READING

1 Fickett, A.P., C.W. Gellings and A.B. Lovins. "Efficient Use of Electricity," *Scientific American*, September 1990, vol. 262, no. 9, pp. 64-74.

2 Johansson, T.B. et al., eds. *Electricity*, Lund University Press, Lund, Sweden, April 1989. Available from American Council for an Energy-Efficient Economy (Washington, D.C.).

3 Leggett, J., ed. *Global Warming*, Greenpeace/Oxford University Press, September 1990.

4 Lovins, A.B. and H.R. Heede. *Energy-Efficient Office Equipment*, September 1990; A.B. Lovins et al., *The State of the Art: Lighting*, 1988, and *The State of the Art: Drivepower*, 1989; and other publications of the COMPETITEK technical information service of Rocky Mountain Institute (Snowmass, Colo., 81654-9199).

ID INDEX
CORPORATE MANAGEMENT
LOVINS, AMORY B.
"The 'Negawatt' Revolution: New Techniques for Electric Efficiency," November/December 1990, vol. 159, no. 6, pp. 5-11.
1 Electricity-saving techniques
2 New energy-saving devices
3 Trends in energy saving
4 Global warming

Contents

Site Selection

TWO SECTIONS VOL. 35, NO. 6 DECEMBER 1990 COPYRIGHT© CONWAY DATA, INC. GEO-SITES ISSUE

INDUSTRIAL DEVELOPMENT SECTION

A GEO-ECONOMIC REVIEW

Waste Reduction Coordination for Headquarters Renovation

Meeting Summary
April 14, 1992

Attendees: Glen Taylor, Barrett Stephenson, Steve Kraten, Genya Arnold, Joanna Karl, Pat Varley, Michel Gregory, Andy Sloop, Jim Goddard,

(Additional distribution: Berit Stevenson, Debbie Palmerni, Flor Matias Leigh Zimmerman, Steve Kraten, Don Roupe)

****

Design & Construction Work: Demolition on the project is approximately sixty-five percent complete. Roofing is currently being removed from the building. The design review held on April 9, 1992 focused primarily on the open plaza area. The reviewers feel that the designs did not meet Grand Avenue design requirements, which state that 75% of Grand Avenue frontage must provide retail opportunities. This issue has not been completely resolved.

Salvage & Construction Site Recycling: The current totals for recycling of demolition material are attached. It is not known where the roofing material is being disposed.

Status of Buy Recycled: The attached matrix of recycled content materials was reviewed. Items 1, 2, and 4 are considered to be standard building materials that are being specified by Hoffman. It is not expected that there will be a price preference required for incorporation of these items in the project. Item 5, the Santanna Toilet and Shower Partitions, will require a cost preference of approximately $5,000. The group felt that this would be one material that should be used and that Metro would be willing to support the cost preference. More information about its recycled content is required. Tiles and countertops will be reviewed with Hoffman to determine which are acceptable to match the style of the building. Most of the other items are included in Tenant Improvements, which will not be specified for approximately one month. Work will continue to fill in the blanks on the matrix. The recycled paint color is lighter than expected. Samples will be available in the next two weeks. About 400 gallons would be available for the project; lab testing will begin shortly.

Public Affairs. The recycling signs have been installed at the site. Michel Gregory is attempting to use her contacts in the media to place stories about the EPA Grant and the Resourceful Renovation Project. This will hopefully lead to a more favorable representation of the project than has been received with previous news releases.

Status of Recycling System: Steve Giusto has been working with Metro on the chute design. He submitted the attached letter, detailing potential problems with the chute placement. Hoffman is including the chutes per the functional requirements, however the exact support, spacing and location decisions need to be made by Hoffman as a part of the overall building design. It is most likely that Hoffman will be designing, building and installing the chutes, so there should not be a coordination problem.

Energy Report: The review of the financier report is complete. The comments and issues are being compiled. The designers have been given a preliminary go-ahead on which items to include. Glumac, the electrical designer, will be working with the Seattle Lighting Lab in an attempt to keep the lighting design at one-watt per square foot. More information is being gathered on hot water and on-demand systems. Rosemary Furfey, in Planning, could be a resource for more water conservation measures.

Action Items.

Debbie Palmerni

Find out what disposal method is being used for the roofing materials: 4/30/92

Pat Varley

Determine recycled content of Santanna Partitions by 4/21/92; fill in blanks on recycled products matrix: 4/28/92

Review materials required for the construction specs with Hoffman: 4/21/92

Barrett Stephenson

Work with Pat Varley and Hoffman to determine which recycled content materials are acceptable for use on the project: 4/21/92

Michel Gregory

Release story of EPA Grant and resourceful rejuvenation to media contacts: 4/21/92 (see attached, 4/17)

Joanna Karl

Compile all questions and issues from the financier report: 4/17/92 research on demand hot water systems by 4/28/92. (see attached, 4/17)

Next Meeting: April 28, 3:30 p.m. to 4:30 p.m. in Room 145.

JG:clk,gbc
facility\hqsal420.sum

METRO - Headquarters Project
Demolition Phase
Recycling Totals AS OF 4/13/92

MATERIAL	QUANTITY	DISPOSAL METHOD	RECYCLING COMPANY/ DISPOSAL SITE
Concrete, Brick, Metal Studs	1,968 tons	Allied Demolition/ Harmon Trucking	St. Johns Landfill
Concrete	74 tons	Allied Demolition	Porter Yet
~~Clean Wood~~	~~9 tons~~	~~MDC~~	~~Braedt Saw~~
Metals			
Tin	128 tons	Allied Demolition	ACME
Aluminum	10.5 tons	Allied Demolition	ACME
Brass	780 lbs	Allied Demolition	ACME
Copper	1,691 lbs	Allied Demolition	ACME
Heavy Iron & Pipe	25 tons	Allied Demolition	ACME
Other			
Shrubs	30 yds.	Hoffman	Re-used on residential project
Mixed Loads	19.93 tons	MDC	Grabhorn
Carpet,trash			
Light Bulbs			

LIST OF POTENTIAL PRODUCTS MADE WITH RECYCLED MATERIALS

item #	PRODUCT	COMPANY	USES	ESTIMATED QUANITIES	ESTIMATED COST	COMAPARABLE COST FOR NON-RECYCLED	DIFFERENCE IN COST	COMMENTS
1	"SECOND LOOK" CEILING TILES	ARMSTRONG	CEILING TILES	57,443 SQ FT	N/A	N/A	SAME	requested specifically by TVA
2	DOMTAR GYPSUM PANELS	KNEZ BUILDING MATERIALS	WALLS	?	N/A	N/A	SAME	contains recycled NP
3	FIBERBOND GYPSUM PANELS	LOUISANA-PACIFIC	WALLS	?	?	?	20% higher than ordinary	up to 12% scrap wallboard paper facing 100% OCC & NP
4	SOUND-A-SOTE BOARD	HOMASOTE	NOISE-CONTROL WALL& FLOORS	?	?	?	?	about 27% recycled NP & tele bks 3 layers, water & fire resistant
5	PARTITIONS	SANTANA	TOILET/SHOWER	?	$632-7 colors $447-black&white	metal-$300	$333 per comor $147 " "	priinting and kids rooms life cycle costs is less than metal low maintenence
6	INTERIOR & EXTERIOR TILES	STONEWARE	BATHROOM ,ETC FLOORS & WALLS	?	$6.75-10.00 S/F negotiatable	comparable negotiatable	varies	25% post &47% pre-consumer custom colors & sizes welcome
7	INTERIOR & EXTERIOR TILES	SUMMITVILLE	BATHROOM, ETC FLOORS & WALLS	?	$1.67-2.49 S/F negotiatable	comparable negotiatable	varies	feldspar tailings once sent to landfill from production of tiles
8	SYNDRETE-CEMENT COMPOSITION	SYNDESIS	TABLE TOPS,ETC.. INTER/EXTERIOR	?	$75-$100 S/F needs drawings	?	?	made for scrap/recycled stone, wood& plastic shavings
9	STONELIKE BUILDING MATERIAL	AVONITE	COUNTER, WALLS, FLOORS, ETC...	?	$40-$125 linear ft design specific	?	?	60% pre-consumer recycled scrap plastic-range of colors
10	SAFETY SURFACES	CARLISLE	GYM & KIDS-INTERIOR & EXTERIOR		$4.80-$13.70 S/F thickness/style	?	?	100% recycled tires Red, Black, Green, Grey, Flecked
11	SAF DEK RUBBER SURFACE	NO FAULT	GYM & KIDS-INTERIOR & EXTERIOR (MATS)	?	$15.00 S/F for installed 1000 S/F	?	?	100% granutized tire rubber 7 colors+ custom colors
12	SAFETY SURFACES	RB RUBBER PRODUCTS	GYM, KIDS & RAMPS ROOF DECKING	?	at least 1/2 cost of other rec areas	?	?	100% recycled tire buffings not permeable/anti fatique mats
13	WONDER MAT	MAT FACTORY	GYM, KIDS, ETC INTERIOR MATS	?	$6.10 S/F	?	?	100% recycled from tires
14	REMILLED WOOD FROM OREGON	STORIE WOOD PRODUCTS	VARIES	?	2/3 cost of virgin but better quality	?	?	resawn wood from Oregon's bridges,building & docks
15	CARPET	IMAGE CARPETS	VARIES	?	$17.50 S/YD	?	5% less than nylon	100% PET plastic fibers 24 colors, looped not available
16	PAINT	RASMUSSEN	VARIES	?	appr $6/gal	?	?	100% recycled latex paint may have limited applications

OREGON PAPER FIBERS
4970 N. BASIN AVENUE
PORTLAND, OREGON 97217

April 9, 1992

Hoffman Construction

Attention: Mr. Cade Lawrence

Re: Recycling Shute for The Metro Building

It appears Metro desires to install the (3) three recycling shutes in the shaft area next to the elevator. After looking at this option, I feel it will not be at the best interest for Metro on a long term recycling of multi grades of paper.
The problems are as follows:

1. There is not enough room for (3) three shutes side by side on any one wall.
2. False floors for support will need to be built on the 2nd and 3rd level.
3. At least one wall of the shaft would need to be completely removed for proper mounting and positioning of feed doors.
4. The 1st floor where the recyclables will empty will have excessive wasted space to properly position bins due to the fact that the chutes will have to exit the ceiling at an angle to exit from the shaft area.

It is my firm belief that relocating the recycling chutes outside the shaft area will have many advantages.

Sincerely,

Steve Giusto

cc: Genya Arnold
Metro

Jim Goddard, SW

METRO

2000 SW First Ave.
Portland, OR 97201-5398
(503) 221-1646

News release

April 17, 1992
For immediate release
For more information, contact Vickie Rocker, 220-1163, or Michel Gregory, 221-1646

Metro receives EPA grant for headquarters renovation project

In constructing its new headquarters, the Metropolitan Service District is practicing what it preaches. The agency is recycling the 73-year-old Sears store in inner northeast Portland into its new headquarters, creating a role model for other commercial building projects in the process. The U.S. Environmental Protection Agency (EPA) wants it to be an example for the nation.

EPA has given Metro a $30,000 grant to document the "Resourceful Renovation" as a demonstration project. In addition to reusing the existing structure rather than building on vacant land, Metro is salvaging, reusing or recycling most of the waste produced in the renovation process. Recycled building materials are being incorporated where possible. To facilitate recycling once the building is operational, recycling chutes for office paper will be installed in existing shafts.

"We're very proud of the EPA grant and the fact that we're making reuse and recycling work on this public project," said Rena Cusma, Metro executive officer. "Metro's goal is to help contractors deal with construction and demolition waste in a new way."

The grant will fund a part-time, on-site project coordinator, a how-to manual for contractors and developers and an educational slide show. Signs posted outside the construction site are being updated regularly to reflect tons of material recycled or reused on the project. Metro plans to conduct workshops and building tours for the construction industry that focus on the resourceful renovation elements.

- more -

Before demolition work began, Metro arranged for The Salvation Army and The Warehouse Project to remove nine tons of carpet, and Hippo Hardware paid to take away two tons of doors, fixtures, paneling and hardware. Preserved for reuse in the renovated building are cast medallions from the original exterior, portions of existing maple and terrazzo flooring, curving oak bannisters, a two-story water tank that will be transformed into a "think tank" meeting room, and existing shafts that will house recycling chutes.

During the demolition stage, waste materials have been carefully sorted to maximize their recyclability. To date, 165 tons of metal and 9 tons of wood have been recycled; 1,968 tons of damaged bricks, concrete and metal studs were recovered for use in capping the St. Johns landfill. And 50 shrubs from the existing landscaping were transplanted to a residential development in Vancouver. As of April 14, only 20 tons of waste were disposed of as garbage. In the actual build-out stage, Metro expects to recover large quantities of wood, dry wall, metal, cardboard, cement and asphalt for recycling.

All subcontractors on the project are asked to complete a waste management form. Metro provides construction site recycling guides and technical assistance to help subcontractors develop waste management plans. Waste disposal and recycling reports from all subcontractors allow Metro to track the quantities of materials recycled or disposed of over the life of the project.

Construction/demolition debris, much of which is recyclable, makes up approximately 17 percent of the metro area waste stream. The Metro project will provide a real-life example of how those materials can be recovered and how much can be saved through avoided landfill disposal fees.

DATE: April 17, 1992

TO: Glenn Taylor, Construction Project Manager

FROM: Joanna Karl, Senior Engineer

RE: Energy Conservation

The following are my recommendations, questions, and concerns, based on all the input which I have received regarding our proposed energy conservation measures (ECMs). The memo is organized as follows: (1) Energy conservation measures (ECMs) considered in PP&L's Financer program; (2) Additional ECMs requiring consideration; and (3) Other.

Although this memo is intended to aid in the selction of measures to be included in the Financer program, its overall purpose is to ensure a cost-effective energy-efficient design of the building, whether or not PP&L will finance such measures (due to: possibly being too late in this process, the use of gas rather than electricity, or other reasons). Note that design-related comments are organized under the ECMs, interspersed with comments regarding the Financer study.

It is important to recognize that energy conservation involves a system, which includes the building, the mechanical/electrical equipment designed into the building, the office equipment used in the building, the operation and maintenance of the mechanical/electrical equipment, and the comfort level of the people working in the building with the overall building and its energy-efficient features. The mechanical/electrical equipment used to achieve energy savings is typically combinations of off-the-shelf technology.

As a result of dealing with a building system, the marginal cost of a more energy efficient building may lead to down sizing of the mechanical/electrical equipment, which in turn can lead to a low or non-existent marginal cost. Further, in evaluating the cost-effectiveness of a building design, it is necessary to consider its lifecycle cost.

I. Energy Conservation Measures considered by Glumac for PP&L's Financer program:

(1) R-12.5 Wall Insulation.

-Is the brick veneer (which appears as if it is being removed from the building) included in the R-value for the walls in the modeling? (Mike Porter, City of Portland)

-Compare the material cost of R-19 with 6" framing (such as used in Super Good Cents) to the dollars saved in energy (Mike Porter, City of Portland and Curt Nichols, ODOE).

-Confirm that the comfort level was considered for all 12 months of the year in the modeling[1] (John Perry, ODOE)

-Should have specs on how its installed - and assurance its installed correctly (Steve Scott, PECI)

(2) R-30 Roof Insulation.

-The cost-effectiveness of this measure should take into consideration: the increase of rates over time, and the use of a smaller heating system due to the increased insulation (suggested by Curt Nichols, ODOE).

- Should have specs on how its installed - and assurace its installed correctly. (Steve Scott, PECI)

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[1]DOE's modeling did not show the cost-benefit of a certain insulation level, which resulted in 1 month/year that people are uncomfortable. (John Perry, ODOE)

(3a) High Efficiency Glass.

-"Tune" the glass by incorporating different emissivities at different exposures, i.e., trap the heat from the north side, and let some go on the south side (Paul David, Microgrid)

-Evaluate "superglass" or other high performance glazing systems which are tuned to the elevations on which they will be installed (Chris Robertson)

-Should "tune" the glazing with appropriate spectral characteristics for the orientation of each of the walls, using a glazing with a high R-value with argon (which will increase the R-value by R-1 to R-1.5). This will also make the building much quieter (Bill Browning, Rocky Mountain Institute)

-Should have operatable windows for cross ventilation, air movement, less energy use for heating/cooling (in this climate). [2] (Bill Browning, Rocky Mountain Institute)

(3b) High Efficency Glass w/ Sunscreen - DELETE

-Compared to the high efficiency glass without the sunscreen , this measure saves both less electricity and less fossil fuels, and costs more (with maintenance not even included).

-Maintenance could increase their cost. (Mira Vowles, Portland Public Schools)

-Consider a manually operated screen.

(4) High Efficiency Skylight

-Mechanical shades may be applicable for the skylights. (Mira Vowles, Portland Public Schools)

(5) T-8 Electronic Fixtures

-Should consider 3-lamp T-8 parabolics (instead of diffusers) (Steve Scott, PECI)

-Reduces glare on computer screens

-Although parabolics have the same power consumption as the diffusers, the overall energy usage may be less because in some instances it may be possible to use fewer of them.

-Single electronic ballasts with dimmer preferable to 3-lamp fixtures wired in tandem for 1/3-2/3 switching - See discussion under "Indoor Lighting" below.

(6) Occupancy Sensors

-Consider integrated infra red ultrasonic devices (Steve Scott, PECI)

-Minimizes false kick-offs
-Can just install in place of a switch (making the incremental cost = $0)
-Location of monitoring is important, such that it will be triggered

(7) Daylight Controls

-Need to be installed properly and calibrated once they are in (Chris Robertson)

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[2]With a building less than 6-7 stories tall, there is no pressure difference to create any problems. An example of such a building is the NMB bank headquarters in the Netherlands.

(8) Sweep Lighting Control

(9) High Efficiency Exit Signs - RE-MODEL[3]

- Consider 5W/sign LED-emitting diodes[4] , as opposed to the 13 W PLs modeled (Curt Nichols, ODOE; Steve Scott, PECI)

(10) 80C Temp Rise Transformers

(11) EMS System

-Attributes of the DDC should be the ease of global variables, allowing information to be shared between different panels (i.e., information such as "outside air temperature" at Panel 12 in the roof can be picked up and transferred to another panel elsewhere).[5] (Steve Scott, PECI)

-An effective EMS system can be very responsive, i.e., within 10 minutes of a worker's complaint the temperature should be corrected (Steve Scott, PECI)

- The range of temperature can be increased during the weekend and evenings (i.e., 71-74 degrees during the normal work day, and 65-80 during the weekends/evenings) (Steve Scott, PECI)

-The EMS should include the ability to monitor the building's performance (i.e., the amount of lighting, heating, and fans), perhaps on a floor-by-floor basis.[6] (Steve Scott, PECI)

(12) Variable Speed Fans

(13) High Efficiency Package Rooftop - DELETE if energy use is greater for the evaporative condenser over the air cooled condenser.

-On p.34 of the report, the "energy savings" for the evaporative condenser over the air cooled condenser is 27,862 kWh. However, when the numbers for "Electrical Energy Use" are compared, there is an increase of 10,213 kWhs. (The increased energy use for the evaporative condenser, rather than an air cooled condenser, is expected in this climate due to the water pump and the fan in the cooling tower.) (Mike Porter, City of Portland)

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[3]Two options exist in addition to the LED-emitting diodes are: (1) the electro luminescent exit sign (0.5W/sign) and (2) the self-luminous exit sign (no energy). Although each of these has the ability to save even more energy than the LED-emitting diodes, they contain low-level radioactivity, and require registration with the federal government and special disposal. Therefore, they are not being recommended.

[4]LED-emitting diode exit signs can be viewed at the remodeled Lloyd's building or some older ones can be seen at the building across Salmon from the One World Trade building). Although they look different, most people will not even notice. Also, a battery back-up system can be installed. (Steve Scott, PECI)

[5]Barbara Coleman does not have elegant global sharing (Steve Scott, PECI)

[6]This information should be made available to everyone to encourage conservation by the users (i.e., lighting, appliances, plug loads, etc.). This information could also be displayed in the lobby - "Yesterday, this building was 98% (or 60% or whatever) efficient (compared to predicted energy use)". Year-to-year comparisons might be valuable in assuring that operation and maintenance are appropriate. The following book is recommended: "O&M Guidebook for Energy Conservation" (74pp), Phone: (464) 656-5176, Governor's office for.. (Georgia). (Steve Scott, PECI)

(14) Well Water Cooling - DELETE

-This measure does not appear cost-effective.

(15) Computer Room Air Conditioning

(16) Solar Domestic Hot Water.

-See comments under "Hot Water" below

-Solar back-up system should be gas, not electric (other than possibly in bathrooms - see comments under "Hot Water" below) (Curt Nichols, ODOE)

II. Additional Energy Conservation Measures Requiring Consideration:

(1) Security Lighting. - ADD to modeling

-Compact fluorescent lighting should be considered (Mike Porter, City of Portland).

-For both indoors and outdoor security lighting, consider low-pressure sodium (100W incandenscent = ~28 W low pressure sodium, which consists of 18 W plus the ballast). (Curt Nichols, ODOE)

-All lamps burn out at the same time

-Indoor - The low pressure sodium is kind of yellow-orange in color. Therefore, security can identify anyone who is not supposed to be there by the yellow-orange lights (assuming they don't turn on the regular white lights).

(2) Elevators. - ADD to modeling

-Energy efficient motors should be considered for the elevators (Mike Porter, City of Portland)

-Should select elevator by genergy use (i.e., in older elevators the generators run all the time, even when there is no activity). (Steve Scott, PECI)

-Should avoid incandescent lights in the elevator, and incorporate occupancy sensors as well. (Steve Scott, PECI)

-Stairs should be central and more visible than the elevators (Steve Scott, PECI)

(3) Indoor Lighting - ADD to modeling

-Most retrofits are able to achieve .5-.7 W/SF today, while the state-of-the-art is .3 W/SF (Bill Browning, Rocky Mountain Institute). It is possible to routinely achieve .8 W/SF, and .6 W/SF is also attainable (Chris Robertson)[7]

- The design should have no incandescents, even including desk lamps (Steve Scott, PECI)

-Include task lighting with dimmer background (i.e., 10-20 footcandles) - which should result in well below 1 W/SF[8] (George Tsongas, PSU Mechanical Engineering professor; Mira Vowles, Portland Public Schools)

-Daylighting

-Consider using lighting shelves;
- The west wall can be difficult to control (John Perry, ODOE)
-Important that the direct light is blocked, and people get reflected light (John Perry, ODOE)

- Single elctronic ballasts with dimmer preferable to 3-lamp fixtures wired in tandem for 1/3-2/3 switching recommended by Carson, Bekooy, Gulick, and Kohn (Steve Scott, PECI)

-Switching system undesireable because: (1) People don't readily use switches; (2) Switches are abrupt and cause clicking back and forth; (3) Large trucks or bank of clouds can cause lights to go on and off; and (4) New lights are too bright, and older lights are not bright enough (this is because new lights dim over time, and the design is for the average brightness.

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[7]The new State office building's 1.1 W/SF could have been cut down even more. (John Perry, ODOE); The NRDC's .57 W/SF building (New York) could have been even lower except the designer erroneously put in a bank of incandenscents. (Chris Robertson)

[8]The Lockheed building is an example of .3 W/SF - it uses light shelves, daylighting, and task lighting. (George Tsongas, PSU Mechanical Engineering professor)

-Dimming system desireable because: (1) Energy-efficient; (2) Cost-effective because it eliminates switches, ballasts, and wiring; (3) Automatically dims lights to correct for brightness when new, and increases brightness when lamp is dirty or old; (4) lamp life is extended; (5) no hum: (6) no purple vision stroboscopic effect (1/3 of people are effected by this; there's no strobe because its at 20,000 hz rather than 120 hz)

(4) Hot Water - ADD to Modeling

- Water saving devices that would save water and energy should be included (As of November 1, 1992, plumbing fixtures in Oregon will not be allowed to exceed the following requirements: shower heads-2.5 gpm; lavatory sink faucets-2.0 gpm; urinals-1.0 gpm; and water closets-1.6 gpm.) (Mike Porter, CIty of Portland)

-Instantaneous On-Demand System and Small Storage Water Heating (i.e., 2 gallon tanks in restrooms) (Steve Scott, PECI; Paul David, Microgrid; Dave Brook, OSU Extension)

-The incremental cost of piping is $0;

-Hot water piping losses are reduced;

-Standby losses (from tanks and circulating pipes) - which can be more than the hot water energy use - can be minimized or eliminated; and

-Showers would probably require gas powered on-demand system; and bathroom sinks could be electric (either on-demand or 2 gallon tanks).

-Recirculation pump (for the hot water) can be turned off when the building is not being used.

(5) Night-time Pre-cooler - ADD to modeling

-Should cool with night-time air (i.e., switch on at 4am to blow in outside air for an hour or two), and may not have to run the air conditioner until the afternoon. Can build this into the energy management system.

(6) HVAC. - ADD to modeling

- Considering the lifecycle rather than focusing only on the capital costs may result in a very different more cost-effective system. For example, an 8" diameter piping system might be selected based on pressure drop specifications. In fact, when analyzed from a lifecycle point-of-view, it may be more cost-effective to use 12" piping (rather than the 8" because it would lead to a reduced pressure drop, and therefore result in reduced pumping costs.[9] (Steve Scott, PECI)

-Confirm that we are getting all the advantages of the Terminal Regulated Air Volume (TRAV) system

- TRAV operates the supply fan at the lowest possible speed adequate to provide the required airflow to each terminal box, resulting in 30-50% greater fan energy savings than Variable Air Volume (VAV) system. (See attached article)

-TRAV is very quiet, due to the lack of the white noise of the mechanical systems. In contrast to VAV, which will control for maximum air pressure independent of the duct pressure, the TRAV decides even what the duct pressure will be. (Steve Scott, PECI)

(7) Maintenance Costs. Incremental maintenance costs should be included in modeling (Carson, Bekooy, Gulick, and Kohn).

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[9]When our system is being designed, Steve estimates it would take around 15 minutes to look at this type of possibility.

III. Other

(1) Monitoring after Construction. The building must be carefully monitored after construction to assure everything is performing as designed. (Paul David, Microgrid)

(2) Energy-efficient office equipment. (Chris Robertson; Paul David, Microgrid; Steve Scott, PECI)

-It is not alwasy possible to get manufacturer's information on the energy efficiency, and it can be difficult to measure. Competek (a copywritten subscription service of Rocky Mountain Institute, which we may have access to through PP&L) has done some measurements. (All power supplies use switching power supplies (like electronic ballasts) which lead to problems with harmonic distortion. Clones often have dismally inefficient power supplies. Power supplies are even more difficult to measure. (Steve Scott, PECI)

-This significant end use may be as much as 20% of the building energy use. It can be cut by 50%, resulting in the option to reduce the cooling capacity of the HVAC system and save both energy and capital costt

(3) Energy Accounting System. An energy accounting system for Metro buildings and vehicle fleets should track the dollars spent on energy, and assure a proper energy return for the dollars spent. (Steve Scott, PECI)

(4) HVAC. Evauate axial fans, evaporative precoooling and evaporative condenser (Chris Robertson)

(5) Lighting Quality . Is the lighting system design in compliance with the new IES/ANSI standard for spaces which will be dominated by VDTs? This standard can be incorporated into low W/SF designs. (Chris Robertson)

(6) O&M Plan. This is quite important to preserving the building's energy conservation features being purchased. (Chris Robertson)

(7) Detailed Commissioning Documentation - This is also quite important to attain the energy conservation being purchased. (Chris Robertson)

cc: Jim Goddard

TRAV – A New HVAC Concept

This first in a series of articles on new approaches to develop future buildings deals with using terminal regulated air volume

To be successful, buildings designed today will have to accommodate the needs of those who occupy them in the next century. Many believe that the communications revolution will soon ignite the world of business with dramatic changes when the right catalyst appears. That catalyst could be as simple as the turn of the century itself.

Today, despite the enormous recent strides in computer and communications technologies, businesses and institutions that populate commercial buildings have not significantly changed their organization of the work place in more than a generation. Commuters continue to fight their way through rush hour traffic to get to their offices for work that could be done as effectively from their homes through expanded communications networks!

The last great change that swept through the work place was a shift in emphasis from management by authority to management by cooperation. The next focus for change will be the work place itself. New communications capabilities will change the structured work place to a more flexible and efficient environment. Successful buildings will be those that can accommodate the change.

This series of articles will focus on new approaches our industry should consider to develop buildings able to meet the challenges of occupant expectations that are likely to occur in the next century. This first article considers a new HVAC concept called terminal regulated air volume (TRAV). Later articles will discuss concepts in: total involvement engineering, new thoughts about humidity control, advances in technology and the intelligent building, and potential effects of a standardized or open EMS protocol.

Why a new HVAC concept?

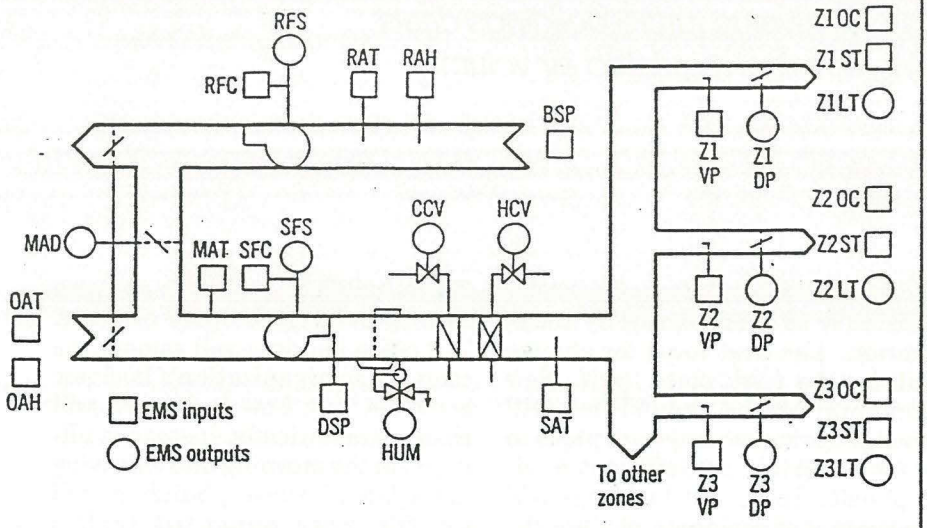
The changes that occur from a wider use of new communications technologies will have an enormous impact on the buildings a new generation of workers will populate. Office buildings will not, as some have speculated, become obsolete. The office building will remain the center of an organization's business activities, but how it is used will change dramatically. Instead of filling up in the morning and emptying in the late afternoon, buildings will see far more constant traffic through their doors from early morning to very late evening hours. These and other changing demands on the building environment represent a major challenge to the HVAC industry, which must devise means to accommodate them effectively and efficiently.

The most popular HVAC system today for commercial buildings is variable air volume (VAV). Variable air volume systems were developed when fully integrated control systems were not available. In VAV, regulation of the fan is accomplished independently of the terminal units. The fan is controlled to maintain a constant duct static pressure, and the terminal units provide air flow depending on the zone space temperatures and thermostat settings within field adjusted limits.

A simple TRAV system outline

By THOMAS HARTMAN, PE,
The Hartman Co.,
Seattle, Wash.

and EMS points interface are shown in Fig. 1. Note that the static pressure sensor is placed on the fan discharge. This sensor is employed only as a high pressure limit and to make certain efficiency calculations. Terminal regulated air volume (TRAV) is possible today because of the emerging developments in full-functioning DDC energy management systems. TRAV is similar to VAV systems in that the volume of air flow is regulated to provide comfort. But TRAV is new because the static pressure regulation characteristics of VAV are replaced with regulation of the central fan directly by the terminal units. Simply stated, TRAV uses advanced applications control software to control the central supply fan based on real-time terminal box air flow requirements rather than to meet a duct static pressure set point. This and other system features involving advanced control technologies combine to make TRAV a much more effective and efficient air supply system. A comparison of the features of TRAV and traditional VAV systems is shown in Table 1.



POINT NAME	DESCRIPTION	COMMENTS
CENTRAL SYSTEM POINTS:		
OAT	Outside Air Temperature	One or more sensors located in ventilated shaded area.
OAH	Outside Air Humidity	Sensor located with outside air sensor.
SFS	Supply Fan Speed	Output to variable speed drive to regulate fan speed.
SFC	Supply Fan Current	Yoke on one leg of fan power. Status indication.
RFS	Return Fan Speed	Output to variable speed drive to regulate fan speed.
RFC	Return Fan Current	Yoke on one leg of fan power. Status indication.
SAT	Supply Air Temperature	
RAT	Return Air Temperature	
RAH	Return Air Humidity	
MAT	Mixed Air Temperature	
MAD	Mixed Air Dampers	Intake/Return/Exhaust sequenced to operate together.
DSP	Discharge Static Pressure	Analog pressure sensor in supply fan discharge as limit.
HUM	Humidifier System	
CCV	Cooling Coil Valve	
HCV	Heating Coil Valve	
BSP	Building Static Pressure	Used as a factor in return fan control.
ZONE POINTS:		
ZnVP	Zone n Velocity Pressure	Pitot tube sensor or heated wire airflow indicator.
ZnDP	Zone n Damper Drive	Electric or Pneumatic damper actuator.
ZnOC	Zone n Occupancy Sensor	Infrared or ultrasonic occupancy sensor digital input.
ZnST	Zone n Space Temperature	One or more space temperature sensors located in zone.
ZnLT	Zone n Lights	Digital or analog output to control lights in zone.

1 TRAV schematic.

Fan regulation

The primary benefit of the TRAV system is its reduced fan horsepower requirements when the system is operating at less than full flow conditions. Fig. 2 shows a comparison of the air flow versus fan power for three different system types. The first two are traditional VAV systems, showing flow versus power for VAV with inlet vane control and with variable frequency drive fan speed control. The third curve shows power versus fan flow for a variable frequency drive on a fan operating a TRAV control scheme. Note that in a TRAV system, as air flow falls to about 50 percent of maximum, the fan power required falls to less than 15 percent of maximum. The reason for this is that at a uniform 50 percent air flow condition, the duct static pressure in a TRAV system falls while the zone control dampers remain open. In traditional VAV, the duct static pressure remains constant while the zone control dampers close to throttle the air flow. The result is the same air flow, but the TRAV control strategy requires far less fan power.

When considering a TRAV system, the designer should carefully investigate the variations in loads for all zones and design the air duct system accordingly. The cost effectiveness of a TRAV system will be substantially reduced if ductwork is installed such that at low load conditions a high duct static is required to provide air to an area such as a computer room, whose load may be relatively constant.

Zone box control

One significant operating problem of VAV systems is the fact that each terminal box is controlled by a single thermostat, entirely independently of any other box. When a

Table 1—Comparison of VAV and TRAV system features.

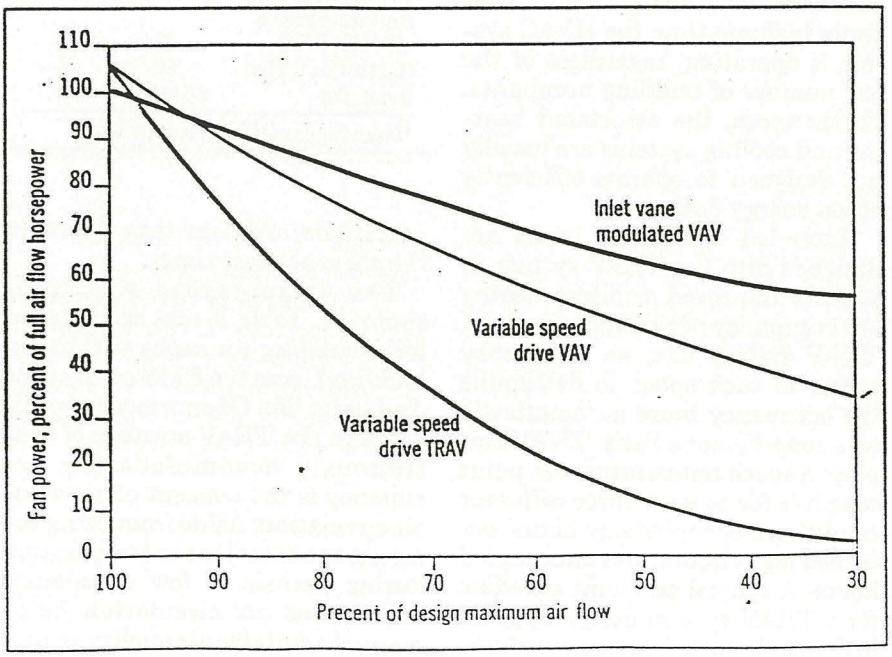
	VAV	TRAV
Fan regulation	Modulate inlet vanes or fan speed to maintain a constant static pressure in supply duct.	Fan control by custom logic controller so every zone meets its present air flow set point.
Zone box control	Local thermostat or sensor controls, each box independent of other adjacent zones.	In open office areas, adjacent zones cooperate to share the area's heating or cooling load.
Air starvation	No coordination if total zone air flow demand exceeds fan capacity. Zones farthest away from fan are starved for air.	Automatic coordination to share capacity limitation among all zones equally.
Occupancy control	Operator entered time schedule or multiple schedules.	Automatic occupancy detection for each zone with occupancy sensors.
Low occupancy operating costs	Relatively high operating costs at low occupancy. Fan hp is proportional to air flow and minimum fan hp is about 40 to 50 percent of full flow hp.	Relative low operating costs at low occupancy. Fan hp falls by third power of fan flow, and there is no practical low limit to fan hp.
Fan volume controller	Loop control maintains static pressure set point. Instability can result by control overlap from separate mixed air damper and zone damper control loops.	Fan control by logic controller, not PID loop. Instability from control overlap is reduced.
Terminal box balancing	Terminal boxes are balanced with mechanical stops that set minimum and maximum flows. Rebalancing is cumbersome.	Terminal boxes are balanced by software applications program. Flow limits can be changed from EMS console easily when distribution of loads change.
Building warmup and low limit heating	VAV systems are usually configured as cooling-only systems. Low limit and warmup are usually possible at perimeter only—with reheat, resulting in long, inefficient warmup cycles.	TRAV systems switch from central cooling to heating modes easily. Terminal boxes adapt via integrated controls, providing faster and more efficient warmup cycles.

single box supplies air to several small offices, the thermostat in one office controls the flow for all. Or when an open office area is supplied by a number of terminal boxes, calibration differences between the thermostats, or small variations in space temperature, often cause adjacent boxes to "fight" one another. Both of these situations often lead to comfort and air quality problems. Because TRAV is a fully integrated control approach, the individual boxes act as just another part of the system rather than isolated devices. In TRAV systems, terminal box damper or reheat control decisions make use of data from adjacent boxes or other temperature sensors. In an open office area, the boxes can be configured to work together to "share" the total load. This ensures that small differences in temperature sensor values caused by calibration or other disturbances will not cause the boxes to fight one another. In multiple offices supplied by a single box, a temperature sensor can be placed in each office and the box controlled to meet the combined needs of the spaces. Such an approach is now cost effective because the EMS total hardware cost to add space sensors is usually below $50 per point.

Air starvation

Another nuisance with typical VAV systems is the problem that occurs whenever the zone boxes are calling for more air flow than the central fan can provide. Most VAV systems are designed with a diversity factor because the designer assumes the sun will not shine on all sides of the building at once. However, when such a system starts in hot weather, all boxes may call for full cooling, creating an air starvation problem. During such a condition, the terminal boxes farthest from the central fan usually suffer drastic reductions in air flow, leading to comfort and air quality problems in the zones they serve.

The integration aspect of TRAV avoids this starvation problem in two ways. First, anytime the central fan is running at 100 percent capacity and a call is made for more air flow, a signal is sent to each terminal box's calculating routine that reduces each box's air flow set point to distribute the air flow deficit uniformly. Such a mechanism leads to more satisfactory precool mode



2 Static pressure vs. flow fan control for typical centrifugal fan.

operation because all areas of the building share the cooling capacity available. The building is therefore at a more uniform temperature at the conclusion of the cycle.

Second, during occupied hours, the potential problems of air starvation are reduced because of the unique means employed to establish occupancy in each space of a TRAV system. Occupancy sensors shut down air flow to any unoccupied space in the building during high demand periods, often eliminating the possibility of air deficits entirely.

Occupancy control

Traditional VAV systems are designed based on an 8 to 12 hr occupancy each day and are controlled by an EMS time schedule that usually incorporates some form of optimum start. Once the building is turned over, there is enormous pressure to extend the time schedule hours because employers don't want to discourage their employees from working late and because the cleaning staff finds conditions unsuitable unless some air circulation is provided during its work hours. The reason VAV system operators try to reduce the occupancy schedule duration is because the VAV energy use is relatively high anytime the HVAC system is operating, regardless of the low number of building occupants. Furthermore, the associated heating and cooling systems are usually not designed to operate efficiently at low energy flows.

Extended occupancy hours are designed into the TRAV system to provide improved comfort during low occupancy periods efficiently. A TRAV system uses an occupancy sensor in each space to determine the occupancy more automatically on a zone-by-zone basis. TRAV employs a space temperature set point schedule for at least three different conditions: occupied day hours, occupied night hours, and unoccupied hours. A typical set point schedule for a TRAV system design appears in Table 2. It is important to understand that the range between the heating set point and cooling set point for each category of occupancy is not a dead band. It is the range in which dynamic control strategies employ free sources of heating or cooling to maintain space conditions most efficiently based on projected conditions (for more information on dynamic control, refer to the series on dynamic control in the April through December 1988 issues of *HPAC*).

The set point schedule shown in Table 2 usually provides good comfort for occupants and permits efficient operation of the building systems during low occupancy periods. Our experience has shown that a slightly higher cooling set point is perceived by widely scattered occupants to offer about the same comfort level as a lower set point in a fully occupied office. Generally, we find occupants are satisfied with wider temperature limits during night and weekend mode hours. We speculate the reasons are lower expectations and less time spent in the office at these times.

Table 2—Typical space temperature limits for TRAV occupancy modes.

Occupancy	Space temperature limits, F	
	Heating	Cooling
Day mode occupied (8 AM to 5 PM)	72	75
Night mode occupied	69	78
Unoccupied	60 to 69*	80

*Depending on outside air temperature.

The temperature schedules shown in Table 2 can be adjusted for a building (or zones within the building) from the EMS at any time during its life. Of enormous significance in the TRAV strategy of continuously accommodating occupancy is the concept of constant air circulation. Aside from being the means to control space temperature during periods of low occupancy, continuous air circulation helps maintain suitable air quality so that occupants are never subjected to a build-up of indoor contaminants. The basic idea of TRAV is to provide at least 20 to 25 percent of the maximum design air flow through the building at all times (requiring about 2 percent of maximum design fan energy) and to introduce amounts of outside air based on outside and space conditions to keep air quality up to suitable levels at all times. Because of the low fan power costs associated with low air flow operation, continuous air flow can be maintained in the building with far lower costs than with traditional VAV systems, even though the VAV system would be shut down at night and weekends.

Fan volume controller

Another concern with VAV static pressure regulation is that the control loops designed to maintain the duct static pressure set point do not usually work very well. HVAC designers are so conditioned to working within the limitations of linear control loops that they tend to approach all control problems from the linear loop perspective.

Unfortunately, many HVAC control requirements like static pressure regulation are not linear. Forcing static pressure regulation into PID loop control is like forcing a square peg into a round hole. The software technician usually finds a way to shave the corners to make it fit, but the result is often unstable in certain situations. VAV fan control problems are exacerbated because the central fan control loop is sandwiched between the mixed air damper and terminal box control loops, each of which has the capacity to change the air delivery characteristics of the central fan.

Current design practice is to isolate related HVAC system components so that they can be controlled by entirely independent control loops. This usually results in more complicated mechanical systems that have higher first and operating costs. TRAV represents a major technological advance because it employs the integrated capacity of

modern EMS such that the mechanical system is kept simple. Rather than attempting to isolate related mechanical components, TRAV designs recognize and accommodate the integrated nature of mechanical systems by configuring the EMS to share information between controllers. This approach results in simpler and less costly mechanical systems and smooth, stable operation at all times.

An example of the benefits of integrated control is a supply air system with no return fan. In such a system, the fan inlet static pressure usually increases as the percentage of outside air increases. These variations of inlet static pressure due to mixing damper position will affect fan flow. But rather than enduring higher first and operating costs of a constant pressure mixing plenum, a TRAV design employs controls that share information from the mixed air damper controller to the TRAV fan control module so that fan speed is automatically adjusted to compensate for inlet pressure changes as the mixing damper position changes.

In this way, TRAV designs acknowledge that some HVAC control applications are not well served by independent PID loop controllers. TRAV relies upon the growing trend in high performance EMS applications toward custom integrated, logic-based controllers for certain control applications. Such controllers can provide much improved control characteristics for many of the nonlinear components in HVAC systems.

Terminal box balancing

In TRAV systems, the maximum and minimum air flow limits for each terminal unit are established as a part of the applications software, not as physically installed terminal box limits, which is typical of VAV systems. This TRAV approach permits a more effective building startup and balancing program and enables the building to be rebalanced with relative ease whenever changes in internal loads require such a measure. The unrestrained operation of the box dampers is necessary to provide steady air flow over a wide range of duct static pressures.

TRAV systems usually employ the software-based air flow limits during daytime occupied hours only. At these times, the limits ensure adequate air circulation and outside air ventilation. During unoccupied or low occupied periods, a TRAV system determines air flow set points such that air quality and space temperature are maintained at suitable levels with the greatest operating efficiencies.

Building warmup cycles

Though the TRAV system concept does not employ a substantial night setback, low limit and warmup cycles are still employed with TRAV designs. Many VAV systems are difficult to bring up to temperature in cold climates because the interior zones are configured without any capacity for heating. When the space temperatures in the core of the building fall below occupied limits at night or on weekends, the only way they can be raised is with heat from the perimeter, which is neither very rapid nor efficient.

A TRAV system utilizes a central heating coil for warmup and low limit heating during cold weather under low occupancy conditions. When heating is required, the integrated nature of the controls provides automatic adaptation of each terminal box so that air flow is regulated based on the need for heating in each zone. Because of the continuous air flow characteristic of TRAV, the design temperature rise is small, so the heating coil can be designed without a significant pressure differential.

It's easy to see why TRAV designs may be well suited for buildings that require efficient occupancy flexibility. The heart of a TRAV system is an integrated, advanced technology control system, not the mechanical system (which is actually very simple). A wide range of adjustments in TRAV operation can be made easily through the control system console. Because of the dependence on a full function control system, developing a TRAV system requires a good understanding of DDC controls capabilities. The control system and how it is configured will ultimately determine whether or not the TRAV system operates successfully.

While TRAV is an exciting HVAC system concept, it is today relatively untested. TRAV applications to date have been limited as refit strategies for existing VAV systems. In these applications, it has been shown that the control of the central fan by a logic controller from terminal box data can result in a stable system that operates more efficiently than the VAV system it replaces.

TRAV is ready for application in new building designs, but to be successful, the control system to be employed must be chosen with care. Most DDC systems cannot provide the full functioning control required for TRAV. As we shall discuss later in this series, a number of features that EMS manufacturers have adopted ostensibly to make their equipment easier to program and use actually have the effect of increasing difficulty and complexity of applying them to integrated controls environments such as a TRAV system.

Conclusion

For commercial buildings that need to provide extended, flexible hours of occupancy, TRAV may be an efficient solution to those needs. However, TRAV is an emerging HVAC concept, and it puts enormous reliance on the integrated controls system that is the heart of its operation. The work that has been done with TRAV to date has shown that the TRAV system concept does work. TRAV is ready for applications in new building designs where its features can be further refined to meet the needs of the next century. Ω