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Grow a Greener Data Center

Douglas Alger

A guide to building and operating energy-efficient, ecologically sensitive IT and Facilities infrastructure

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Introduction

Interest in green—*demand* for green, really—has come to the Data Center and in many ways its arrival was inevitable.

No social value has gained more momentum among consumers, government officials, and businesses in recent years than that of being green. Evidence of green's popularity can be seen everywhere, be it in the growing consumer purchases of hybrid automobiles (sales are projected to soon top 1 million hybrid vehicles per year), the abundance of green claims featured in product advertising and labeling, and even the recent winners of the Nobel Peace Prize (awarded in 2007 to former U.S. Vice President Al Gore and the Intergovernmental Panel on Climate Change, for disseminating knowledge of man-made climate change).

Data Centers are a prime target for greening due largely to their incessant consumption of energy. At many individual companies, Data Center power bills are now large enough that they have come to the attention of their chief executive officers. As a group, Data Center power consumption has grown so dramatically as to trigger government action. Consider, for instance, efforts by the United States Environmental Protection Agency to create separate Data Center and server energy-efficiency standards and the European Commission's creation of a voluntary Data Center Code of Conduct in which participating companies pledge to minimize Data Center energy usage.

Data Centers are also no longer relegated to being the hidden nexus of a company's technological plumbing but, for many, are showpieces that reflect their business values. The Data Center of a major financial institution has multiple layers of redundant infrastructure consistent with its emphasis upon reliability, for instance, whereas a fast-growing technology company is likely to have a Data Center designed with agility in mind, possessing physical infrastructure that can be deployed quickly and reconfigured as needed.

What, then, could be a better way for a business to exhibit its social responsibility and consideration for the environment than having an intelligently designed, energy-efficient Data Center that provides ample company productivity while using as few natural resources as possible?

Motivation for Writing This Book

Data Centers have historically had a huge, negative impact upon their surrounding environment—consuming massive quantities of electric power and water, emitting pollutants through standby generator systems, and discarding materials detrimental to the environment in the form of UPS batteries and outdated computing hardware. Today, however, it is possible to design Data Centers that are more ecologically sensitive and more cost-effective to operate while providing superior reliability and availability.

This book was written to help show business executives, IT managers, and facilities personnel how to design and operate Data Centers in such a way as to be energy-efficient and less impactful upon the environment, leaving more resources to future generations.

Sources for This Book

This book incorporates varied source material, reflecting the array of technologies used within Data Centers and the broad range of topics that fall under the umbrella categories of green building practices and green technologies.

Content includes multiple case studies and real-world examples of green technologies implemented in operational Data Centers and data culled from dozens of white papers and case studies pertaining to efficiency topics—in both Data Centers and general office commercial buildings—including energy consumption, cooling optimization, environmental impact of cabling media, and more.

Additional material is summarized from several environmental building assessment systems and efficiency metrics prevalent in the Data Center industry.

Who Should Read This Book

Anyone concerned with the physical design, construction, or ongoing management of their company Data Centers; anyone interested in greatly reducing the energy consumption and operational expenses of either Data Centers or lab environments; or people whose business contains a computing environment and who desire to make their company greener can find useful and relevant information within this book.

The job roles involving those areas of responsibility can vary widely, yet commonly include chief financial officers, green czars, construction project managers, IT or Data Center directors, network engineers, system administrators, and facilities managers.

If your job interacts in some way with your company Data Center and includes hardware purchasing decisions for such environments, this book contains information that can help you do your job more effectively, reduce your company's environmental impact, and save your company money.

How This Book Is Organized

This book provides a step-by-step walkthrough of various Data Center-related strategies and technologies that can be implemented to make a Data Center greener.

Chapters 1 and 2 present the benefits of designing and operating a green Data Center and standards used to measure how green a facility is whereas Chapters 3 through 9 include the book's core content of how to make Data Center infrastructure, both physical components and hardware, greener. Chapter 10 addresses green strategies that go beyond the Data Center but are still relevant to companies with a server environment.

- **Chapter 1, "Going Green in the Data Center":** This chapter defines green, discusses the drivers for companies to build greener Data Centers, and presents the benefits a given business can see from environmentally friendlier server environments. The chapter also outlines incentive programs that reward green efforts and recaps environmental activities that several major companies pursue today.
- **Chapter 2, "Measuring Green Data Centers":** This chapter presents assessment systems used around the world to measure how green buildings are, formulas for calculating Data Center energy efficiency, and an overview for industry organizations pursuing the development of each. This chapter also offers guidance for putting Data Center metrics in the appropriate context to understand a facility's performance.
- **Chapter 3, "Green Design and Build Strategies":** This chapter discusses methods for limiting the environmental impact that occurs during the construction of a Data Center through decisions concerning physical location, choice of building materials, landscaping choices, and jobsite construction practices.
- **Chapter 4, "Powering Your Way to a Greener Data Center":** This chapter discusses how energy is used in Data Centers, traces the potential for power savings along the electrical delivery chain, and presents carbon emission factors for different regions of the world. The chapter additionally presents alternative energy options and offers design strategies, technology solutions, and operational methods for reducing Data Center energy usage.
- **Chapter 5, "Cooling Your Way to a Greener Data Center":** This chapter discusses how Data Center temperature settings impact energy usage and offers design strategies, technology solutions, and operational methods for improving cooling efficiency.
- **Chapter 6, "Cabling Your Way to a Greener Data Center":** This chapter compares the environmental impacts of cabling media and illustrates the benefits of streamlining both structured cabling and patch cord installations in a Data Center to improve airflow and reduce energy consumption.
- **Chapter 7, "Refrigerants and Fire Suppressants":** This chapter discusses the fire suppression materials commonly employed in Data Centers, reviews government regulations concerning their usage, and suggests green approaches for deploying them.
- **Chapter 8, "Choosing Greener Gear":** This chapter offers strategies for making a Data Center greener through IT hardware choices, outlines server energy-efficiency standards and metrics, and discusses both hardware utilization and how to reduce hardware power consumption.
- **Chapter 9, "Greening Your Data Center Through Consolidation, Virtualization, and Automation":** This chapter explores the energy-saving opportunities you can realize by transforming the way IT infrastructure provides, allocates, and operates Data Center resources.

- **Chapter 10, "Greening Other Business Practices":** This chapter discusses additional green measures that a company with a Data Center can pursue to make their facility and operations greener.
- **Appendix, "Sources of Data Center Green Information":** This appendix lists the entities and organizations that are valuable sources of information on green standards or metrics, green best practices, and case studies that form the basis of effective strategies for green Data Center design.
- **Glossary:** The glossary defines key terms and concepts discussed throughout the book.

Using The Material in This Book

The chapters of this book are written in such a way that each can serve as a standalone reference for a particular Data Center technology or topic—if you are interested in optimizing the cooling infrastructure of a Data Center, you can find all relevant information in Chapter 5, "Cooling Your Way to a Greener Data Center," for example. Keep two overarching principles in mind, however, when reading the many green strategies that are presented. First, because Data Centers are complex, highly integrated environments—hardware technologies, physical infrastructure technologies, and IT services are all intertwined within a company's server environment—the green improvements that you make to these facilities are likely to have benefits that ripple throughout your entire business. Virtualizing a single server, for instance, eliminates the need for the physical server, frees up cabinet space, reduces energy consumption, lowers cooling demand, and lessens the quantity of patch cords that are used. Doing so also reduces provisioning time and creates a resource that can be flexibly allocated as needed to perform a variety of services.

Second, the most-effective method for greening a Data Center (or any building for that matter) is to implement green improvements that are synergistic, combining for greater effect. Using enclosed cabinets to isolate hot and cold airflow and improve cooling efficiency is beneficial on its own, for instance, but using enclosed cabinets *and* choosing hardware with optimal airflow *and* streamlining cable bundles *and* diverting server exhaust to warm other portions of the building can achieve efficiencies beyond the linear accumulation of their individual improvements.

Some of the tips offered in the chapters that follow are more or less suitable to your Data Center depending upon specific conditions such as its business function, geographic location, or whether it is a major hosting space or minor server room. Most, however, are intended to be universal in nature and can be applied at any Data Center that you want to make greener.

Green Design and Build Strategies

This chapter discusses methods for limiting the environmental impact that occurs during the construction of a Data Center through decisions concerning physical location, choice of building materials, landscaping choices, and jobsite construction practices.

Siting the Data Center

The location of your Data Center can have a lot to do with how green it is. If your server environment is built in a region that possesses an abundance of renewable energy, for instance, you have a head start on a facility where such resources are rare.

Some companies, especially smaller ones, don't have the luxury of choosing among multiple potential sites for their Data Center. The hosting environment is, by default, going to be constructed at the same place where the rest of their operations or office space is. If you do have an ability to choose, however, consider the following local conditions when you evaluate potential Data Center sites:

- **Electrical mix:** As discussed in Chapter 2, "Measuring Green Data Centers," some energy sources spawn much more carbon dioxide when used to produce electricity than others. Deciding to locate your Data Center in a region where electricity has a lower carbon emissions factor is an excellent way to make the facility greener before design work begins. (You can find more information about electrical mix in Chapter 4, "Powering Your Way to a Greener Data Center.")
- **Weather:** Some Data Center energy-efficiency measures can be implemented only with the cooperation of Mother Nature. For instance, air side economizers that use outside air to chill a Data Center (discussed in Chapter 5, "Cooling Your Way to a Greener Data Center") are more practical to use in regions where it's cold much of the year rather than in areas where it's usually warm or mild.
- **Building codes:** Are the green measures that you intend to include in your building allowed by the regional building codes? If they aren't, can you either do without that efficiency or else invest the time and effort to negotiate for a variance for your project?

Note The Robert Redford Building in Santa Monica, California, houses offices of the Natural Resource Defense Council and in 2004 became one of the first buildings to achieve a Leadership in Energy and Environmental Design (LEED) platinum rating. Design efforts began in 1999 but the 15,000-square foot (1,393.5-square meter), three-story building was not completed until late 2003. Part of the lengthy time for completion was because of the need to negotiate with the city for the use of green technologies that either conflicted with or else were not addressed by building codes at the time.

Green design elements included rainwater collection, the use of recycled plastic piping (in lieu of copper), and the use of waterless urinals.

- **Work-force proximity:** Although not a Data Center design issue per se, the distance that employees commute to reach your facility affects how much carbon dioxide they generate every day. It's for this reason that some environmental building assessment systems award points for features that promote alternative transportation, such as close proximity to public transit or installing bicycle storage units.

As green as you want your Data Center to be, it's impractical to select a site solely on its environmental merits. Above all else, the server environment needs to be reliable—it does your business no good to have a green Data Center if the facility doesn't adequately safeguard your hardware and mission-critical data. Other factors that you should consider when evaluating potential Data Center sites include the following:

- **Property zoning:** Is construction of a Data Center allowed at the location?
- **Natural disasters:** Is the region prone to earthquakes, ice storms, hurricanes, tornadoes, flooding, landslides, fire, or other severe events?
- **Pollution:** How is the air quality at the location? Is there any risk of IT equipment exposure to dust, industrial byproducts, or other contaminants?
- **Interference:** Are there any nearby sources of electromagnetic interference (also called radio frequency interference) such as telecommunication signal facilities or airports?
- **Vibration:** Are there any nearby sources of vibration such as railroads, major roads, or construction?
- **Political climate:** Is the region politically stable or do conditions exist that might jeopardize the safety of employees or operation of a Data Center?
- **Flight paths:** Is the property within the flight path of an airport, increasing the possibility of a plane crashing onto the site?

Note Site selection considerations, including how to evaluate a property's risk factors and mitigate them, are discussed in greater detail in the book on Data Center physical design, *Build the Best Data Center Facility for Your Business*.

Building Design and Material Selection

Just as important as the decision of where to build your Data Center is choosing what to build it out of. Even if you've been involved in a lot of Data Center projects, this might be a new question (or series of questions) for you. Conventional Data Center Facilities are built with traditional construction materials—concrete, steel, lumber, drywall, glass, and copper, for instance. Employing different materials and streamlining their physical arrangement can result in a greener facility.

Avoiding the Landfill

One of the most straightforward strategies for making the design and build phase of your Data Center project green is to, whenever possible, avoid actions that cause anything to be thrown out.

That means employing high-quality, durable building materials. The fewer times you have to replace worn or damaged components, the fewer resources that are consumed. Also, choose materials composed of renewable resources, recycled content, or substances that would otherwise end up in a landfill.

Green options among common building materials include the following:

- **Salvaged brick and stone:** Using reclaimed brick and stone has become so popular in construction projects that businesses have emerged that are entirely devoted to collecting and providing such materials.
- **Concrete containing fly ash:** Fly ash is a fine residue created as a waste byproduct when coal is burned in electric power generation plants. Using the glass-like powder as a substitute for cement in concrete keeps it out of landfills and reduces demand for cement, the production of which generates significant carbon dioxide. Concrete containing fly ash is also stronger and easier to pump than that containing only conventional cement.
- **Synthetic gypsum board or drywall:** Like fly ash, synthetic gypsum is a waste byproduct of power plant coal combustion—in this case created when sulfur dioxide is removed from a power plant's exhaust flue gas. Such removal is required by law in many regions because sulfur dioxide contributes to acid rain. As with using fly ash in concrete, employing synthetic gypsum keeps this waste material out of landfills.
- **Green insulation:** All building insulation is inherently green because it improves energy efficiency. Cellulose insulation is considered even greener than conventional fiber glass insulation because it is made primarily from recycled newsprint. Another option is natural fiber insulation made from scrap denim, retrieved from clothing factories and otherwise bound for the trash.
- **Sustainable wood:** Wood is a renewable resource, assuming the forest it comes from is effectively managed to ensure its continued existence and replenishment. Several forest certification programs exist today that verify sustainability; the international Forest Stewardship Council is the best recognized. (FSC-certified wood is specifically referenced in the LEED rating system, for example.)

- **Rubberized asphalt:** Rubberized asphalt is a mix of regular asphalt and crumb rubber—ground up scrap tires. The material reduces tire noise and is less expensive than conventional asphalt; every lane-mile utilizes an estimated 2,000 old tires that would otherwise end up in landfills.
- **Steel:** Modern steel is made in one of two methods and, due to major cost savings of recycling steel over mining iron ore and processing new steel, both involve recycled content. Steel made through the electric arc furnace process in which an electric current is passed through scrap steel to melt and refine it, contains 25 percent to 35 percent recycled content. This type of steel can be flattened relatively easily and is used for items such as automotive body panels, exterior panels for major appliances and containers such as soup cans. Steel made through the basic oxygen furnace process, which combines molten iron from a blast furnace with pure oxygen, contains nearly 100 percent recycled content. Because of its great strength, this type of steel is typically used for items such as structural beams or plating.

What Makes a Green Building Product?

At the beginning of this book, I raised the question of how to define green and, ultimately, how to define a green Data Center.

BuildingGreen, LLC, publisher of the monthly *Environmental Building News*, maintains a database of more than 2,000 "environmentally preferable" building materials. As part of compiling that list, the *Environmental Building News* editorial staff developed standards for designating a building product as green. Their criteria fall into five categories and provide excellent benchmarks for considering when an item to use in your Data Center project is green:

1. Products made with salvaged, recycled, or agricultural waste content:
   - Salvaged products
   - Products with post-consumer recycled content
   - Products with pre-consumer recycled content
   - Products made from agricultural waste material
2. Products that conserve natural resources:
   - Products that reduce material use
   - Products with exceptional durability or low maintenance requirements
   - Certified wood products
   - Rapidly renewable products
3. Products that avoid toxic or other emissions:
   - Naturally or minimally processed products
   - Alternatives to ozone-depleting substances
   - Alternatives to hazardous products

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- Products that reduce or eliminate pesticide treatments
- Products that reduce storm-water pollution
- Products that reduce impact from construction or demolition activities
- Products that reduce pollution or waste from operations

4. Products that save energy or water:
   - Building components that reduce heating and cooling loads
   - Equipment that conserves energy and manages loads
   - Renewable energy and fuel cell equipment
   - Fixtures and equipment that conserve water
5. Products that contribute to a safe, healthy built environment:
   - Products that do not release significant pollutants into the building
   - Products that block the introduction, development, or spread of indoor contaminants
   - Products that remove indoor pollutants
   - Products that warn occupants of health hazards in the building
   - Products that improve light quality
   - Products that help control noise
   - Products that enhance community well-being

More information on the BuildingGreen database is located at http://www.buildinggreen.com.

Beyond employing individual recycled materials for your Data Center project, how about using a recycled building? That is, constructing your server environment within an existing structure rather than constructing entirely new. Even if you have to make major modifications for the pre-existing building to effectively house your servers, the project is still likely to consume fewer materials than a new build. Some of the environmental building assessment systems endorse this by awarding points for building reuse.

Note The building industry generally uses the term *greenfield* to describe pristine or undeveloped land, *brownfield* for abandoned properties (typically industrial or commercial facilities) believed to contain hazardous contaminants, and *grayfield* for properties containing abandoned buildings. I say "generally" because in some regions, *brownfield* merely refers to any land that has been previously developed.

So, perhaps counter intuitively, building on a greenfield site actually makes a Data Center less green.

Embodied Energy and Emissions

You can take an even deeper look at how green your building's construction materials are by considering their embodied energy. That's the total quantity of energy expended in creating and providing a given item, including the following:

- Extracting raw materials
- Processing and manufacturing an item
- Transporting it
- Installing it

Broader definitions of the term *embodied energy* include the energy needed to maintain an item and ultimately recycle or dispose of it. A similar concept, *embodied emissions* or *embodied carbon*, refers to the carbon dioxide produced during those same stages of an item's life.

Accurately gauging the embodied energy and emissions of building materials can be extremely difficult. For one, no single method or formula has been agreed upon for calculating those values. Also, even the same building materials have their own circumstances unique to your specific project. How exactly was a given item manufactured? How far did it have to be transported, first to whatever outlet it was sold from and then to the construction site? For that matter, how was it transported? Different modes of transportation consume energy and produce carbon at different rates.

Despite such variables, several studies have been performed to classify embodied energy and emissions of various materials. Embodied energy is typically measured as a quantity of energy per weighted unit of building material, for example megajoules (MJ) per pound or kilogram. Embodied emissions are expressed as a quantity of carbon dioxide per weighted unit of building material, for example pounds or kilograms of carbon dioxide per pound or kilograms.

The University of Bath has compiled an Inventory of Carbon and Energy that includes embodied energy and carbon ratings for approximately 170 construction materials. Researchers drew information from a variety of published sources and, where regional elements needed to be incorporated, generally based them on factors relevant to the United Kingdom. (For instance, using the typical mix for electricity produced in the UK to help calculate embodied emissions values.)

Table 3-1 lists values for several common building materials, based on the University of Bath's Inventory of Carbon and Energy.

Table 3.1 *Embodied Energy and Carbon of Common Building Materials*

Material	Embodied Energy		Embodied Carbon	
	MJ/lb	*MJ/kg*	*Lb CO_2/lb*	*Kg CO_2/kg*
Aggregate	0.045	0.10	0.002	0.005
Aluminum (virgin)	98.88	218.00	5.20	11.46
Aluminum (recycled)	13.06	28.80	0.77	1.69
Asphalt (road and pavement)	1.09	2.41	0.06	0.14
Brick	1.36	3.00	0.10	0.22
Cement	2.09	4.60	0.38	0.83
Cement (25 percent fly ash)	1.60	3.52	0.28	0.62
Cement (50 percent fly ash)	1.10	2.43	0.19	0.42
Glass	6.80	15.00	0.39	0.85
Insulation	20.41	45.00	0.84	1.86
Insulation (fiberglass)	12.70	28.00	0.61	1.35
Insulation (cellulose)	0.43 to 1.5	0.94 to 3.3	—	—
Paint	30.84	68.00	1.61	3.56
Plaster (gypsum)	0.82	1.80	0.05	0.12
Polyvinylchloride (PVC) pipe	30.62	67.50	1.13	2.50
Steel (virgin)	16.01	35.30	1.25	2.75
Steel (recycled)	4.31	9.50	0.20	0.43
Stone	0.45	1.00	0.025	0.056
Timber	3.86	8.50	0.21	0.46
Wallpaper	16.51	36.40	0.88	1.93

A handful of lessons can be taken away regarding embodied energy and emissions:

- **Buy local materials:** The shorter distance that an item has to be transported, the lower its embodied energy and emissions.
- **Buy materials with recycled content:** Reusing an item or material invariably consumes fewer resources than using something new.
- **Get back to nature:** Goods made from natural components rather than man-made ones typically consume less energy and resources.

- **Less is more:** The fewer materials you use in construction, the less energy and carbon emissions that are involved.

Finally, as you consider embodied energy and emissions when choosing among various building materials, don't forget to compare items based on how they are actually used in the construction of a building. For instance, although steel has higher embodied energy and emissions than brick or stone, it also has greater strength relative to its mass. If you were to build a wall out of the three materials, you can obtain the same structural strength by using a smaller amount of steel—perhaps enough less to involve less embodied energy and emissions.

Maintaining Air Quality

The building materials and fixtures you choose for your facility additionally impact air quality, both outdoor and indoor, which in turn affects the health and productivity of employees. Because green considerations often focus upon the external environment, you might not automatically think of indoor air as a consideration for how green your facility is. Nearly all environmental building assessment systems include indoor air quality as a rating criterion, though.

Numerous building-related components—from paints and adhesives to flooring and carpeting to furniture and office equipment—contain contaminants. Some, such as ceiling tiles, produce particulate matter that can cause eye, nose, and throat irritation. Others include organic chemical compounds that evaporate into the air. Known as volatile organic compounds (VOC), these substances can emit smog-forming particles and make building occupants ill. VOCs typically include carbon-based molecules, although specific regulatory definitions about what substances are VOCs and what aren't differ by region.

According to the U.S. Environmental Protection Agency, health impacts from VOCs can include the following:

- Eye, nose, and throat irritation
- Headaches, loss of coordination, dizziness, and nausea
- Nosebleeds (epistaxis)
- Shortness of breath (dyspnea)
- Vomiting (emesis)
- Memory impairment
- Damage to liver, kidney, and central nervous system functions
- Cancer in humans and animals

As when dealing with any irritating or harmful substances, the severity of symptoms can vary based on concentration and length of exposure.

To maintain good air quality at your facility, choose paints, adhesives, sealants, wood products, carpeting, and other materials that are classified as low- or no-VOCs. Several countries mandate relevant products be labeled with their VOC content, and many manufacturers provide the information even in regions where they are not required to do so. If such information is not readily available for a product you are considering purchasing, inquire with the manufacturer.

During construction, provide ample ventilation when the materials are installed. Set up fans to expel polluted air outside during construction, not to bring outside air in. When possible, air out items before they are installed.

Note A handy construction tip is to provide extra ventilation whenever building materials are used that are either wet or emit an odor. Odors are a sign that an item is releasing chemicals into the air, so don't remove fans until well after the smell is gone.

How many fans do you need to deploy to air out a building space? That depends upon three factors:

- The size of the area you're ventilating
- How frequently you want to fully replenish the area with fresh air, known as air changes per hour
- The air moving capability of your fans, which is typically listed in cubic feet per minute (cfm).

Various environmental and construction agencies recommend performing anywhere from 5 to 12 air changes per hour to maintain good air quality. To calculate the cumulative cfm fan rating you need to fully refresh the air in an area, take the size of the space in cubic feet, multiply it by the number of air changes per hour that you want, and then divide by 60.

For instance, if you have a room that is 15 feet by 15 feet wide, with a 10-foot ceiling, and you want to perform 5 air changes per hour, you need a fan rated at 187.5 cfm:

15 feet × 15 feet × 10 feet = 2250 cubic feet.

2,250 cubic feet × 5 air exchanges = 11,250 cubic feet per hour.

11,250 / 60 minutes = 187.5 cubic feet per minute.

(Using metric equivalents, that's a 63.7 cubic meter room; 63.7 cubic meters × 5 air exchanges = 318.5 cubic meters per hour. 382 / 60 minutes = 5.3 cubic meters per minute.)

As a more extreme example, say you want to air out your huge Data Center—a 100,000-square foot room with a 12-foot ceiling—at a rate of 12 air changes per hour. That room requires multiple fans with a cumulative rating of 240,000 cfm:

100,000 feet × 12 feet = 1,200,000 cubic feet.

1,200,000 × 12 air exchanges = 14,400,000 cubic feet per hour.

14,400,000 / 60 = 240,000 cubic feet per minute.

(Using metric equivalents, that's a 33,960-cubic meter room; 33,960 cubic meters × 12 air exchanges = 407,520 cubic meters per hour, and 407,520 / 60 = 6792 cubic meters per minute.)

Caution Zinc filaments have been known to grow from the underside of Data Center floor panels, a phenomenon known as *zinc whiskers*. Typically just a couple of microns wide and a few hundred microns long, the filaments are considered innocuous unless they are dislodged, at which point they can be propelled by the Data Center's cooling system and enter sensitive hardware, potentially causing an electrical short.

Because zinc filaments can become airborne, are they a threat to the health of Data Center users in addition to Data Center hardware? No studies have been conducted on the issue, so for now there is no clear answer. Even just considering the nonzinc particles that can be stirred up by a Data Center's air conditioning system, I would err on the side of caution and minimize the time that employees spend working in the Data Center. Avoid setting up desks or other items inside the Data Center that facilitate employees using the space as a long-term work area.

Choosing Efficient Fixtures and Appliances

Although the vast majority of your building's resource consumption occurs in the Data Center, don't overlook other fixtures and appliances. Every watt of electricity you save, gallon (liter) of water you conserve, or pound (kilogram) of carbon dioxide that you avoid generating, the greener your facility is. It doesn't matter where in the building the savings occur.

This is especially true for mixed-use facilities, in which a notable portion of the building footprint is occupied by non-Data Center space. As mentioned in Chapter 2, it's often much easier to implement certain green practices in office spaces than hosting areas.

Efficiency opportunities can include the following:

- **Lighting:** Design office areas to maximize daylight, reducing the use of powered lights (and typically increasing the comfort and productivity of building occupants). Install timers and motion sensors so lights automatically shut off during times when employees are not present. Fluorescent T12 bulbs are the ubiquitous choice for ceiling lights, but thinner T8 and T5 bulbs use less energy—25 percent to 50 percent less by various estimates. (T indicates the tubular shape of the bulb; the number represents the diameter of the bulb in eighths of an inch.) Light emitting diode (LED) lights are used rarely in office buildings but can provide even greater energy savings.

Note Some lighting must remain on in your building, including the Data Center, at all times due to safety reasons. You don't want employees to suddenly find themselves in complete darkness.

Requirements for emergency lighting are typically spelled out in regional building codes. If they are not specified for your Data Center project for some reason, be sure to at least illuminate major walkways in your Data Center and the entire building so that a person can easily locate and walk to an exit.

- **Office electronics:** Choose energy-efficient office equipment. The U.S. Environmental Protection Agency's Energy Star program addresses computers, copiers, digital duplicators, fax machines, printers, and even water coolers. An excellent source of information about computers and monitors is the online Electronic Product Environmental Assessment Tool (EPEAT), which evaluates those devices according to 51 environmental criteria including material selection, packaging, energy efficiency, and to what degree a product's component parts can be reused or recycled at the end of its useful life. The tool is available at http://www.epeat.net.
- **Power strips:** In many workplaces, computer peripherals such as monitors, printers, and speakers are left on perpetually, even during nonbusiness hours. Several electrical power strips are on the market nowadays that detect when a primary device (that is, your computer) is either not present or not drawing power and then cut power to the other sockets that peripheral devices are plugged in to. This avoids desktop items drawing power when not needed, without having to rely on people to manually unplug them at the end of each workday.
- **Kitchen appliances:** Ideally your Data Center isn't located in a building that also contains a cafeteria or break room, due to the increased potential for a fire or water leak to occur. If it is, however, you can at least choose energy-efficient appliances.
- **Plumbing fixtures:** Even if your Data Center is located within a dedicated building that contains no office space or other regularly occupied areas, it will likely include one or more restrooms. Waterless urinals forgo the 1.5 gallons to 3.5 gallons (5.7 liters to 13.2 liters) of water per use of conventional toilets, typically saving tens of thousands of gallons (liters) per year. Auto-sensing sink fixtures can also reduce water, as do low flow shower heads if the building happens to include employee shower facilities.

Even fixtures that don't consume power or water can indirectly impact the building's energy efficiency. Designing work areas to be open or use low-height cubicle walls, for instance, improves illumination and can potentially reduce lighting needs.

Note Cisco installed more than 400 waterless urinals at its San Jose, California, campus in 2007 and 2008. Switching to these from conventional toilets saves an estimated 8.5 million gallons (32.2 million liters) of water per year.

Data Center Configuration

The physical configuration of your Data Center—where you place it in a building and how you arrange its physical infrastructure components—provides another opportunity to make the facility more efficient. Strategies to consider include the following:

- Situating your hosting space at the center of a building rather than right against an external building wall provides some isolation from outside temperatures, for instance, so your cooling system won't have to work as hard on hot days.
- Placing cooling infrastructure near heat-producing hardware, a practice known as *close-coupled cooling*. Compared to traditional Data Center designs, where large air handlers attempt to cool large sections of the hosting space, close-coupled cooling requires less fan energy to project cooling where it's needed and reduces unwanted opportunities for chilled air and server exhaust to mix. This approach and the inefficiency that comes with mixing Data Center airflows are covered in Chapter 5.
- Streamlining your structured cabling design by adopting a distributed physical hierarchy. A distributed design uses significantly fewer cabling materials and improves the cooling airflow. This design and a detailed look at the reduced length of cable runs it offers are presented in Chapter 6, "Cabling Your Way to a Greener Data Center."

Building Exterior

The outside of your Data Center building will be subjected to a variety of weather and temperatures during its lifespan. So, in addition to the green characteristics you want for other building elements—durable and preferably made from renewable or recycled content—look for external building components that can mitigate those outdoor conditions.

For instance, you can lower the temperature of your building and reduce how hard your internal cooling system must work by using surfaces that have high solar reflectance and thermal emittance. That is, they efficiently reflect sunlight and shed absorbed heat.

Both solar reflectance and thermal emittance are typically expressed as either a percentage or as a value between 0 and 1. The higher the number, the less a material absorbs and retains heat. To qualify for an Energy Star label, for example, low-slope roofs must have an initial solar reflectance of at least 0.65 and after 3 years at least 0.50. Steep slope roofs must have an initial solar reflectance of at least 0.25 and after 3 years at least 0.15.

Roofs with high-radiative properties, often called *cool roofs*, make your building greener not only because they conserve energy, but also because they decrease heat islands. *Heat islands*, where urban areas have higher temperatures than nearby rural ones, can increase peak energy demand on an electrical grid, possibly leading to brownouts or blackouts, and contribute to the creation of smog.

Heat islands are caused by the reduced quantity of trees and foliage in developed areas, airflow restrictions created by tall buildings, and exhaust heat from motor vehicles and buildings. Many cities can see a temperature difference of as much as 10 degrees

Fahrenheit (5.6 degrees Celsius) above adjoining rural areas, according to the U.S. Environmental Protection Agency.

Tip Several government agencies have programs to reduce heat islands. Some are financial incentive programs—offering partial rebates on the installation of cool roofs, for example—whereas others are in the form of building code requirements.

Check with the regional planning department where your Data Center is to be constructed to see what programs might exist. Information regarding heat island initiatives in the United States is maintained by the Environmental Protection Agency at http://tinyurl.com/rabyat.

A subset of cool roofs, also known as green roofs or living roofs, employs live vegetation atop conventional roofing. In addition to the temperature-reducing benefits of other cool roofs, green roofs reduce storm-water runoff, act as additional building insulation, and are credited with nearly doubling a roofing system's lifespan by shielding the surface from sun and rain. Green walls or living walls, which apply the same mechanism to a building's vertical surfaces, can also be employed, although are much less common.

Whether applied to a roof or wall, a living surface requires careful engineering. Simply allowing ivy to grow up the side of your building does not equate to a green wall. A proper installation involves a protective membrane to prevent either moisture or plant roots from penetrating to the building, a drainage system to keep foliage from being flooded by pooled water, a soil layer to anchor plants and absorb nutrients and, of course, the vegetation itself—typically plants that are fast growing, drought tolerant, and low maintenance. The entire system needs to be lightweight so as to not pose structural problems for the roof.

Tip Are you interested to know how efficiently a particular brand of roofing system reflects sunlight and sheds heat? Would you like to know how much of a difference that a more efficient roof can make upon your building's cooling (and therefore energy) usage?

The Cool Roof Rating Council maintains a listing of the solar reflectance and thermal emittance of more than 1,200 roofing materials at http://www.coolroofs.org/index.html.

The U.S. Department of Energy and U.S. EPA's Energy Star program each provide roofing comparison calculators. They estimate a roof's cooling costs based upon factors such as regional electrical prices, local weather conditions, air-conditioning efficiency, roof insulation, solar reflectance, and thermal emittance. By entering different data into the tools, you can see the potential savings associated with roofs possessing more radiative properties.

The calculators are located at (DOE) http://www.ornl.gov/sci/roofs+walls/facts/CoolCalcEnergy.htm and (Energy Star) http://www.roofcalc.com/RoofCalcBuildingInput.aspx.

External building surfaces are also, obviously, prime locations to install photovoltaic cells—devices that convert solar energy into electricity. These can include solar panels mounted on rooftops or walls or even building integrated photovoltaics, in which components are embedded within the envelope of the building. Building integrated photovoltaic systems can take the form of roofing tiles, spandrel panels (opaque glass used between floors in commercial building facades), awnings, skylights, sunshades, walls, and more.

Photovoltaics today typically generate 5 watts to 15 watts per square foot (50 watts to 150 watts per square meter) when in full sunlight. You, therefore, need from 65 square feet to 200 square feet (6 square meters to 18.6 square meters) of photovoltaics to produce one kilowatt of power.

Exactly how much energy can be harvested by a solar array varies by product, because some are more efficient than others, and by environmental conditions, including the following:

- **Latitude:** Various parts of the world receive more or less sun exposure than others, which affects how much solar energy can be collected.
- **Climate:** Overcast or stormy weather reduces the amount of sun that a photovoltaic system is exposed to. Nearby snowy surfaces can actually boost performance by reflecting more light onto a solar array, but only if the array itself isn't covered with snow.
- **Orientation:** Photovoltaic components should be installed to receive maximum exposure to the sun. Avoid obstructions to the system such as trees or other structures especially during peak collection hours, when the sun appears highest in the sky.
- **External air quality:** The more contaminants in the air, the less solar energy that reaches a solar array.

Note RoofRay, a solar array modeling service based in Walnut Creek, California, offers an online tool that calculates the solar potential of specific buildings. Along with entering your building address and key information such as the tilt angle of the roof, you trace a solar array onto an actual satellite image of the roof of the building.

The tool then calculates the size of the solar array and, by incorporating regional factors such as typical weather conditions, projects how much energy it can capture and the impact upon your electrical bill. The tool is available at http://www.roofray.com.

If you install a photovoltaic system and employ a cool roof on your building, clean their surfaces frequently. Any dirt or debris that covers them reduces their efficiency, reducing how much energy you collect.

Landscaping

Although not frequently given much consideration when planning a Data Center project, landscaping—encompassing not only lawns and vegetation but also the artificial surfaces on a property—has a significant effect on how green your facility is, influencing building heat loads, water usage, air quality, and other conditions.

Be strategic about what you plant on your land and where. That means not only using drought tolerant and low maintenance plants, but also placing trees in key locations to shade buildings and areas that can otherwise absorb and store unwanted heat, such as parking lots.

If your Data Center project involves building new structures, or expanding existing ones, don't indiscriminately move earth and demolish trees and other vegetation. The goal is to minimize disruption to the land and, where possible, reintegrate natural components. For instance, if you need to remove trees during construction, try to replant them elsewhere on the site.

Figure 3.1 shows workers relocating a tree to make way for Data Center construction. The tree was moved to a makeshift tree farm on the building site, shown in Figure 3.2.

Image provided by courtesy of Scott Smith.

Figure 3.1 *Relocating a Tree*

Image provided by courtesy of Scott Smith.

Figure 3.2 *Temporary Tree Farm*

In Figure 3.3, a few feet (one meter) of dirt is excavated from the ground floor of a building to make room for a sunken Data Center raised floor. Figure 3.4 shows the amount of soil removed from the building in a period of 24 hours.

Image provided by courtesy of Andy Broer.

Figure 3.3 *Backhoe in the Data Center*

Image provided by courtesy of Andy Broer.

Figure 3.4 *Reusable Soil*

Note Figures 3.1 through 3.4 are from a Cisco Data Center project in Richardson, Texas, completed in 2007.

We built the Data Center in a pre-existing cold shell building, which is an empty building with an unfinished interior. We opted to forgo entrance ramps and sink the Data Center's raised floor so that its top surface would be level with the corridors leading to it, which required excavating the ground floor. The extracted dirt was reused on the property as land berms.

Installation of a security fence around the perimeter of the building necessitated the removal of about 45 trees, including bald cypress, crepe myrtle, live oak, magnolia, and red oak trees. Half of them were replanted in the immediate vicinity of the Data Center building; others were placed in key locations on the campus or donated for use on other (non-Cisco) properties.

To reduce water usage, avoid pollution, and reduce your maintenance costs, you need to implement good landscape management practices, including the following:

- **Irrigate efficiently:** Don't overwater, which not only consumes more water, but can also cause vegetation to grow faster and, therefore, require additional maintenance.
- **Use mulch:** Place mulch in planting areas to insulate foliage, reduce water usage, and limit erosion. Where possible, reuse plant clippings or wood waste from your own property as mulch.
- **Leave grass clippings on lawns:** Grass clippings decompose over time. This is good for the lawn, providing nutrients from the clippings, avoiding the need to dispose of the green waste, and reducing water and fertilizer usage.
- **Limit pesticide usage:** Consider solutions for controlling unwanted weeds and insects that don't involve chemicals so as to maintain good air quality.
- **Avoid excessive pruning:** Pruning can trigger faster growth, requiring additional maintenance activity.

Be aware that many green elements that are effective for the exterior of your building can also be incorporated onto your overall property. For instance, the same advantages of implementing a cool roof—lowering energy consumption to cool a building and reducing heat islands—can be gained by implementing cool pavement, consisting of materials with high solar reflectance and thermal emittance.

Likewise, photovoltaic components can be installed on your property to harvest solar energy. Solar canopies for parking lots can perform double duty at a building site, both generating electricity and providing shade for employee vehicles. Street lamps are also available that can be powered by solar energy alone or by a combination of wind and solar energy.

Consider using pervious concrete or porous asphalt for paved locations on your property such as sidewalks, parking areas, and curb and gutter systems. Unlike conventional paving, pervious materials enable water to seep through. This reduces storm-water runoff, helps recharge groundwater, and better transfers cooler temperatures from the earth below to the pavement, reducing heat island effects. Rubberized asphalt, mentioned at the beginning of this chapter as a green material because it uses ground up scrap tires that would otherwise end up in landfills, is available in pervious form.

You can reduce water usage at your site by collecting and storing rainwater, using it for nondrinking activities such as watering vegetation and (after treating the water) flushing toilets. Rainwater harvesting equipment consists of a catchment (typically atop a building roof) to collect the water, a distribution system (angled roof features, gutters, downspouts), and a container to store it (a cistern).

How much water can you expect to collect? That depends upon the size of the catchment and how much rain falls in the region. To make an estimate, multiply the size of the collection area by the average amount of rainfall for a given period.

For instance, if your catchment area is 20 feet long by 50 feet wide and the area receives 24 inches of rain per year, that's 20 feet × 50 feet × (24 inches / 12) = 2000 cubic feet of water. Multiply by 7.48 to convert to gallons; 2000 cubic feet × 7.48 = 14,960 gallons.

Using metric figures, that's a 6.1 meters × 15.2 meters × (61 centimeters / 100) = 56.6 cubic meters of water. Multiply by 1,000 to convert to liters; 56.6 cubic meters × 1000 = 56,600 liters. (Note: The end calculations of 14,960 gallons and 56,600 liters don't convert exactly due to rounding of metric measurements.)

This is an idealized number because it does not account for water spillage or evaporation, both of which reduce the total water yield.

Note Before installing a rainwater harvesting system on your site, make sure it's legal to do so. Due to water rights regulations and laws that prohibit standing water because it's a breeding ground for disease-carrying mosquitoes, some government agencies either outright prohibit rainwater collection or at least require a permit to do so.

In the United States, Colorado and Utah prohibit the practice whereas—as of this writing—Arizona, Hawaii, Kentucky, Ohio, Texas, Washington, and West Virginia either have or are considering regulations concerning rainwater harvesting.

Strategies for a Greener Construction Site

Construction sites have an inherent messiness to them. Dirt is kicked up as heavy machinery rumbles across the property. Mountains of packaging material form as building fixtures are unwrapped. Scrap building materials accumulate as items are cut to specific sizes. Even the minor leavings of lunches, multiplied by hundreds of people working on site for months, can have a significant impact upon the surrounding environment if not managed in some way.

It's therefore important that just as you design your Data Center to have less environmental impact, so too plan your construction site. Designate separate areas to store building materials, unpackage and assemble building fixtures and appliances, deposit recyclable items (packaging, bottles, and the like), deposit salvageable items (such as leftover building materials), and dispose of construction waste. If the property is undeveloped, carefully choose the makeshift roads that construction vehicles carve in to the property to limit disruption of the soil. Define vulnerable areas on the job site where construction activity is not allowed.

Other approaches to make the construction phase of your Data Center project greener include the following:

- **Mitigating dust, smoke, and odors:** Effective dust control measures include limiting site traffic, reducing vehicle speeds, installing wind fencing, covering dirt piles, and watering regularly at the site.

- **Controlling erosion and waste-water runoff:** Prevent sediment, debris, or other pollutants from entering nearby streams or storm drains by employing diversion ditches, silt fencing, and other retention structures. Minimize soil disturbance, limit grading to small areas, and place ground coverings over exposed areas.
- **Minimizing noise and vibrations:** Newer construction equipment bearing muffling devices can be notably quieter and generate less-powerful vibrations than older systems. Install barriers, such as chain-link fencing mounted with plywood and sound-absorbing mats, at the start of the project. Set up temporary barriers around stationary construction activities known to generate noise (for example, a worker cutting notches in panels for a Data Center raised floor). Include noise-related financial incentives and penalties in your construction contracts so that on-site workers are accountable for noise mitigation. Measure on-site noise periodically.
- **Managing construction waste:** Save money and make your Data Center project greener by reducing how much construction waste is produced and then reusing or recycling what is created. To reduce waste, standardize on building material sizes to make leftover stock less likely. Ask suppliers to consolidate packaging and take back transport materials such as pallets. Separate construction debris into recyclable and nonrecyclable materials; then seek out a local company that buys and resells second-hand construction materials to reuse your leftover materials.

Building Commissioning

Modern buildings are complex entities—those housing Data Centers are especially so. An effective way to ensure that a facility's various infrastructure systems are all working well is to have the building commissioned.

Commissioning involves a systematic review of equipment to make sure all components work according to their specifications and that interactions between equipment happens properly. The scope of commissioning can vary, both in terms of what phases of a project that a commissioning authority is involved in and what equipment is reviewed. Commissioning can be done on either new or existing buildings (sometimes called *retrocommissioning*).

For a new building, the process ideally begins with the initial planning of the project and continues through design, construction, and then post-construction stages, typically continuing for about a year after a building comes online so that potential warranty issues are identified and addressed. Simply commissioning at the end of a project is less effective because it does not allow potential shortcomings to be addressed in the planning or design stage.

Systems that are commonly commissioned include the following:

- **Heating, ventilation, and air conditioning (HVAC) systems:** Air conditioning and distribution, central heating and cooling, water-cooling delivery elements, pressure management systems, and variable frequency drives

- **Building management systems:** Controls interfacing with HVAC, electrical, fire alarm, and security systems
- **Primary and standby electrical systems:** Power distribution systems, lighting controls, automatic transfer switches, uninterruptible power supply systems, and generators
- **Fire detection and suppression systems:** Fire detection equipment and alarms, notification systems, wet or dry sprinkler systems, gaseous fire suppression system, and the interface between detection and suppression components
- **Plumbing systems:** Hot and cold water, sanitary waste, and storm drainage systems
- **Specialty systems:** Elevators and escalators
- **Building elements:** Building envelope, exterior curtain walls, and roofing structure
- **Voice and data distribution systems:** Cabling, telephony systems, and networking equipment

How valuable is commissioning? An analysis of building commissioning projects sponsored by the U.S. Department of Energy determined that commissioning uncovers an average of 28 deficiencies per new building and 11 per existing building. HVAC systems accounted for the most problems.

The 2004 study, *The Cost-Effectiveness of Commercial-Buildings Commissioning*, reviewed 175 commissioning projects conducted across the United States between 1984 and 2003 involving 224 buildings. It was conducted by Lawrence Berkeley National Laboratory, Portland Energy Conservation, Inc., and Texas A&M University's Energy Systems Laboratory. Its authors concluded that "commissioning is one of the most cost-effective means of improving energy efficiency in commercial buildings" and estimated that buildings in the United States alone could realize $18 billion per year in energy savings.

Retrofitting an Existing Data Center

Although this chapter is written predominantly from the perspective of constructing an all-new Data Center, don't overlook green design and build possibilities for projects that involve upgrading your existing server environments. Although you won't be making a site selection decision, green strategies around building materials, building exteriors, and landscaping are still valid, and it's even more important to maintain good air quality around an already populated building than at a construction site.

Existing roofing systems can certainly be retrofitted with cool roofs, living roofs, or photovoltaic systems, and building commissioning can be done as easily on existing structures as on new ones.

Remember that if you retrofit a pre-existing server environment, you have already implemented one green element. You're reusing a structure rather than constructing something new and have, therefore, avoided consuming even more resources.

Summary

When evaluating a potential Data Center site, consider local factors including electrical mix, weather conditions, building codes, and work-force proximity because each of these influence how green your facility can be.

Durable building materials need replacement less often and, therefore, consume fewer resources. Pick materials composed of renewable resources, recycled content, or substances that would otherwise end up in a landfill. Also choose items with less-embodied energy and embodied emissions.

Maintain good air quality by using building components such as paints, carpeting, and office equipment that have little or no volatile organic compounds, and be sure to thoroughly ventilate the building during construction.

Choose energy-efficient building fixtures and appliances such as lighting components, office electronics, power strips, kitchen appliances, and plumbing fixtures.

Insulate the Data Center from external temperatures by placing it at the center of the building. Employing a distributed design for the Data Center's structured cabling requires less cabling, thereby reducing the amount of materials that are consumed, than a direct-connect design.

Several green features can be incorporated into the exterior of your building including highly reflective cool roofs or vegetation-bearing living roofs, each of which reduce heat island effects. A photovoltaic system can also be installed—either on a rooftop or integrated into building surfaces—with its efficiency influenced by location, climate, sun exposure, and air quality.

Landscaping affects the thermal load, water usage, air quality, and other green elements of your building. Choose drought tolerant and low maintenance plants and strategically place trees to shade buildings and parking lots. Irrigate efficiently, use mulch to save water and reduce erosion, allow grass clippings to decompose on lawn areas, limit the use of pesticides, and avoid excess pruning.

Consider photovoltaic installations on the grounds of your site as well. Pervious concrete and porous asphalt allow water to pass through, reducing storm-water runoff and heat islands. You can use a rainwater collection system to gather an alternate source of water for nonpotable uses such as landscaping.

Reduce the environmental impact of your building construction site by establishing separate areas to store materials, unpackage fixtures, sort recyclables, collect salvageable items, and dispose of construction waste. Prohibit construction activity in sensitive portions of the site. Mitigate dust, smoke, and odors; control erosion and wastewater runoff; minimize noise and vibrations; and manage construction waste.

Have your building commissioned to ensure that its infrastructure systems work correctly in conjunction with one another. The scope of commissioning can vary, but systems that are commonly reviewed include HVAC, building management, primary and standby electrical, fire detection and suppression, plumbing, elevators, building envelope, roofing, and voice and data distribution.

You can implement several green design and build approaches just as effectively during the retrofit of an existing Data Center as during construction of a new facility.

Index

NUMBERS

A

C

D

E

F

G

H

I

J - K

L

M

N

O

P

Q - R

S

V

W

X - Y - Z