Chapter 17

Sustainable: Mining the Green Gold

Many new cars in the United States, especially in the state of California, sport a sticker with their Global Warming Score. It's a score that ranks each vehicle's CO_2-equivalent value on a scale of 1–10 (10 being the cleanest) relative to all other vehicles.[1] The score is based on a calculation of various greenhouse gases, including carbon dioxide, methane, and hydrofluorocarbons from the air conditioning system, the car is likely to emit. The thinking is that over time consumers will increasingly factor this score in their buying decisions.

Sites like GoodGuide[2] score a variety of cell phones on a number of factors such as:

- Energy management, as measured by a phone's standby power consumption.
- Materials management, specifically the use of eco-materials in a phone or its packaging.

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- Toxic waste, specifically inclusion of polyvinyl chloride or brominated flame retardants in a phone.
- Product management, as measured by third-party certification standards.
- Environmental disclosure, as measured by the availability of an environmental fact sheet for a product.

A company called TerraPass, which facilitates trading in carbon offsets, has long allowed consumers to calculate on its website the carbon footprint of their car model. It goes further and allows you to calculate the carbon equivalent of air trips you take and your home's carbon footprint.

These scores and ratings highlight that consumers are sensitive to the fact that our modern technologies like automobiles, aviation, and air conditioning all contribute to carbon proliferation. We can argue about whether that leads to global warming, but if we are building next-generation, smart products, should we not also be looking at efficiency when it comes to emissions? Since a dip in 2009 caused by the global financial crisis, the International Energy Agency reports that emissions are estimated to have climbed to a record 30.6 Gigatonnes (Gt), a 5 percent jump from the previous record year in 2008.[3]

Tony Prophet of HP, whom we met in Chapter 2, says it is a source of personal pride for him that the HP supply chain is sustainable. The comment is noteworthy given the dimensions of the HP supply chain are already extremely complex. It goes way beyond tackling carbon and other emissions from its products to those in its supplier operations and product packaging. HP's numbers are impressive—1.4 billion KWH of electricity customers saved from 2008 through 2010 using high-volume HP desktop and notebook PC families; recycled over a billion ink cartridges using HP's "closed-loop" process, which uses plastic from returned cartridges to make new ones; over 2 billion pounds of other electronic parts recycled since 1987.[4]

Prophet also talks about fair labor practices around the world and sourcing of "conflict minerals." He says that at a time when demanding analysts like "The Greenmonk" expand the definition of "sustainable" for the high-tech industry.

"The Greenmonk"

Tom Raftery has been pushing for sustainability for a long time. An Irishman who lives in Spain, Raftery bleeds green. After a stint at the Cork Internet Exchange, a "hyperefficient data center," he is now an analyst at Redmonk and looks for environmental improvements across many industries, but particularly in technology. Typical of his comments is this one:

> Facebook has a very efficient data center in Prineville, Oregon [as we discussed in Chapter 8]. Its PUE is 1.07, which is near the theoretical maximum (of 1.0), but it is powered by Pacific Corp, 63 percent of whose electricity is generated by burning coal—very definitely not Green. Same with Microsoft's Dublin, Ireland, data center—again a very respectable PUE of 1.2, but run on the Irish electricity grid, 87.5 percent of which comes from fossil fuels—again, not Green.

He invokes William Stanley Jevons, who published a book, *The Coal Question,* in 1865. The Jevons paradox says that as we become more efficient in use of materials, we just increase consumption. Raftery agrees: "Amazon Web Services allows anyone with $10 to rent a 10-machine cluster with 1TB of distributed storage for eight hours. Economically efficient, but in the big scheme of things, not very Green."

Surely, there are at least a few technologies he considers Green?

> I guess Smart Meters would be the first one. While not hugely sustainable in and of themselves, properly rolled out with Smart Grid technologies and demand management, they have the potential to greatly increase the penetration of renewables on the electrical grid and reduce global emissions.
>
> I love LED lights. I have a bunch of them installed around the house and they are fantastic. Great light and huge savings. I'm using Exergi LEDs to replace 50W halogen spots. The Exergis consume a measly 3.6W and give out almost as much light. That's a massive saving. The quality of LED lights is improving daily.
>
> I test-drove the Nissan Leaf (Nissan's all-electric vehicle) last year and I loved it. For many people it won't work as a primary vehicle, but for families who are looking for a second car, it excels. It is a fantastic drive, with range being the only limiting factor. Cost of motoring

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> with a Leaf is greatly reduced and as your utility adds more renewables to their generation set, your car becomes more and more Green!
>
> My iPhone. This is a funny choice, I know, but before the iPhone I used to go through Nokias at a rate of a new phone every six to nine months as new features were launched. However, with the iPhone, new features are rolled out free with the latest download of its operating system—iOS. Less need now to shell out for new hardware; just download the latest free software update. The lifetime of my phones now is on the order of two years.

A Tough Crowd

There is a reason why Raftery calls his iPhone choice "a funny one." In many sustainability forums, Apple is the devil personified. It does not help that the company rejected in 2010 a resolution that would require it to publish a CSR (Corporate Social Responsibility) report centered on its greenhouse gas emissions, toxic waste, and recycling. Apple's "Board of Directors recommended shareholders vote against the resolution because they believe Apple has addressed sustainability reporting and that a formal report would add little value and involve unnecessary time and expense."[5]

Jeff Swartz, CEO of Timberland, the shoe company, has commented on his blog,

> CEOs of publicly traded companies in the fashion industry don't get the "pass" that comes to the supercool Apple leaders and their uber-cool company. Meaning, my shareholders and my consumers insist that we create profit, quarter by quarter, and that we do it . . . in a sustainable fashion, both in terms of environmental practice and in terms of transparency and safe working conditions in the supply chain. Why does a bootmaker get held to a higher standard than an iPad maker?[6]

Apple gets savaged for the workforce performance of Foxconn, its contract manufacturer in China. Multiple employee suicides were followed by an article in the London *Daily Mail* titled "You are NOT allowed to commit suicide: Workers in Chinese iPad factories forced to sign pledges,"[7] which sounded callous and made for very bad press. Soon

after, combustible dust was blamed for a deadly explosion at a Foxconn plant.[8]

It does not matter that Apple points out its Supplier Code of Conduct draws on internationally recognized standards and "outlines expectations covering labor and human rights, health and safety, the environment, ethics, and management commitment. Apple monitors compliance with the Code through a rigorous program of onsite factory audits, followed by corrective action plans and verification measures."[9]

In its 2011 Supplier Responsibility Progress Report, Apple provided details such as:

> We expanded our training initiative beyond our final assembly manufacturers so that more workers in our supply base understand their rights and protections under local law and Apple's Code. Since launching in 2008, Apple's programs have trained more than 300,000 workers.
>
> We dedicated additional resources to protecting the rights of workers who move from their home country to work in factories in another country. Many of these immigrants are charged exorbitant fees that drive them into debt, an industrywide problem that Apple discovered in 2008 and that we classify as involuntary labor. In 2010, we continued our search for these violations, auditing all of our production suppliers in Taiwan and many in Malaysia and Singapore. As a result of Apple's audits and rigorous standards, foreign workers have been reimbursed $3.4 million in recruitment fee overcharges since 2008. We also trained suppliers on how to improve their recruiting practices, as well as on their legal and ethical obligations to foreign workers.
>
> We worked aggressively to prevent the hiring of underage workers. We equipped facilities with stronger age-verification tools, educated them on managing third-party recruiters, and held them accountable for the recruiting practices of affiliated schools and labor agencies. In addition, we are leading the industry by requiring suppliers to return underage workers to school and to finance their education.

It does not matter that Foxconn is also a key supplier for other tech vendors or that its Microsoft XBox 360 team threatened mass suicide in January 2012. It does not matter that Apple's retail stores and the App Store give opportunities to employees and entrepreneurs in many countries. For all the admiration and praise Apple gets in many other areas, it is fighting an uphill battle when it comes to the stainability image.

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There are others who savage HP. You see that on so many emails these days: "think about the environment before printing." HP, of course, happens to be the largest printer company in the world.[10] Then there are others who would like HP to offer more soy- rather than petroleum-based inks.

Heather Clancy at *ZDNet* picks on another angle:

> HP's emissions related to employee travel were way up: a 49 percent increase related to air travel alone . . . the revelation is disappointing nonetheless, especially since Hewlett-Packard actually sells a line of telepresence technologies.[11]

Raftery comments again:

> Neither of these businesses (printing and devices) is particularly environmentally friendly and yet HP's founders spoke of HP's commitment to the environment as far back as 1957 in HP's first statement of corporate objectives, The HP Way.[12]

Blood Diamonds, Conflict Minerals, and Rare Earths

Hollywood introduced us to the moral issues in *Blood Diamond*, a movie starring Leonardo DiCaprio. That movie was set in Sierra Leone, but the action has since moved east in Africa, particularly to the Democratic Republic of the Congo, around a number of minerals we need in our high-tech devices.

The bland industry term for that is "conflict minerals," but as the *Huffington Post* reported:

> It's a war which most people know nothing about, despite the fact that we're all directly connected to it. Armed groups are fighting over the lucrative minerals that power our cell phones and laptops, leaving a trail of human destruction that has no equal globally since World War II.[13]

The UN General Assembly Mission Council is the mission and ministry agency of the Presbyterian Church, and on its blog it urges:

> The need and momentum is growing for a credible international certification system to ensure that minerals in consumer electronics and other products are not fueling rape and violence in eastern Congo. Ten years ago, a certification system addressing the trade in blood diamonds helped end wars in Sierra Leone and other West African countries. Similar systems have also led to significant progress in guaranteeing social and environmental standards through fair labor, forestry, and oil revenue transparency.[14]

Apple in the same report above highlighted what it is doing regarding "conflict minerals":

> We mapped the use of potential conflict minerals in our supply chain. We identified 142 Apple suppliers that use tantalum, tin, tungsten, or gold to manufacture components for Apple products and the 109 smelters they source from. Apple is also at the forefront of a joint effort with the EICC and the Global e-Sustainability Initiative (GeSI) that will help our suppliers source conflict-free materials.

Then there are rare earths, critical in many of today's technology products. iPods, for instance, contain small quantities of the rare earths dysprosium, neodymium, praseodymium, samarium, and terbium. Fiber-optic cables need erbium, europium, terbium, and yttrium.[15] Today, China is the major supplier of rare earths, but its own internal consumption has forced it to cut back on its exports. There are rumors of total Chinese bans on exports of certain of those minerals.

The U.S. Department of Energy published its Critical Materials Strategy analysis in December 2010. It identified five rare earth elements at "critical" risk of supply disruption within the next five years: europium, neodymium, terbium, yttrium, and dysprosium. [16]

The Mountain Pass Mine in the Mojave Desert in California has plentiful deposits of bastanite, from which several rare earths are extracted. Mining operations ceased at Mountain Pass in 2002 amid environmental concerns, although processing of previously mined ore continued at the site. Mining has since restarted to the consternation of environmentalists. The dilemma is minerals critical for newer cleantech versus environmental risks for which the mine was closed in the first place. And are we replacing one dwindling resource, fossil fuels, with another, rare earths? Is that really sustainability?

Then there is the promise of undersea mining. *New Scientist* editorialized:

> Now is the time to put in place legal frameworks to ensure that any rush for minerals will avoid the destructive effects of California's gold rush in the 19th century. The International Seabed Authority, which regulates mining claims in international waters, must adopt clear guidelines on conserving vent ecosystems.[17]

Packaging and Extended Supply Chains

An area where some tech companies have shown sustainability creativity is product packaging.

Dell claims that it slashed over 18 million pounds of packaging from 2008 to 2010 by focusing on a "three C's" packaging strategy: cube, content, and curbside recyclability.[18] The cube involves the reduction of size so that packaging is more efficient, from the size of the boxes that hold a product's components to the number of items that can be moved per shipping pallet. Dell has also boosted the percentage of recycled products that goes into its packaging content. The company increased its usage of recycled foam, and has used more recycled plastic as well. An estimated 9.5 million half-gallon milk jugs went into Dell's packaging—enough to stretch about 1,500 miles. Bamboo, a fast-growing, sustainable plant material, has also made its way into Dell's packing materials. The third is focus on materials customers can easily recycle in their neighborhood garbage collections.

Cisco described to Greenbuzz.com a pilot program that showed $24 million in annual savings.[19] Some of the techniques demonstrated included the reduction in size of antistatic and documentation bags and boxes, cutting plastic needs by 50 percent. Paper-based documentation was digitized and migrated to CDs or "pointer cards," 3 × 5-inch cards with online references. Nine 75-inch telepresence carton units now fit on a single truck, while only two units could be transported prior to re-engineering the packaging. Cisco also used recycled cushioning in one router family. Previously these cushions were largely made from virgin oil.

What gets measured gets managed. Using that thinking, Sprint, the U.S. telecom company, working with Trucost, a firm that helps assess emissions across a company's supply chain, released results of their analysis. It showed that Sprint's supplier emissions totaled 2.08M metric tons of CO_2, slightly more than Sprint's total direct and indirect emissions of 1.95M metric tons in 2009.[20]

IBM has asked its 28,000 suppliers in more than 90 countries to install management systems to gather data on their energy use, greenhouse gas emissions, and waste and recycling.[21]

The Changing Definition of Sustainability

Jeremiah Stone, in the SAP Labs division of the software company, provides a perspective on how the definition of sustainability has evolved in just the last couple of years.

In Stone's words:

> When we launched our program in late 2008, SAP's starting position was a strong solution set in environment, health, and safety management with its long-time partner, Technidata. Otherwise, it was a blank sheet as far as our sustainability portfolio was concerned.
>
> First, we predicted a strong shift from sustainability reporting to performance management solutions, particularly around greenhouse gas (GHG) emissions and reduction in energy consumption. Second, we expected that this increased focus on GHG emissions and corresponding energy costs would drive significant investment in carbon footprint and energy management solutions. Finally, we expected to see an accelerated demand for solutions addressing Design for Environment (DFE), and sourcing driven by stricter procurement policies.
>
> Two major factors have delayed market maturation following our initial investment. The first was the "great recession" of 2009, and second was the failure of COP-15 (the 2009 Copenhagen Climate Convention) to deliver a global carbon reduction framework. These two factors have led to a slowed proliferation of Chief Sustainability Officers (CSO) with significant budgets for IT purchases or projects, and a cautious carbon legislation climate particularly in the United States and Australia.

In contrast, the BP Macondo well blowout, several mining disasters, and multiple food contamination scares from China to Germany have increased short-term awareness of operational risk and product compliance and stewardship. Further, the continued growth of the global consumer, or "middle" class continues its march unimpeded, driving demand for commodities ranging from rare earth minerals required for production of high tech gadgets to increased energy required to feed these gadgets and increasing proliferation of modern housing and facilities.

These high profile events and the energy efficiency megatrend are driving increased demand for:

Predictive risk management—Data drawn from core systems of record like human resources, asset and supplier management are driving predictive analytics to identify emergent risk in advance of traditional expert-based systems. Customers here span high-risk industries such as mining and mills, oil and gas (up- and downstream), chemicals, utilities, transportation and logistics, industrial machinery, and component manufacturing.

Supply chain traceability—This helps track movements of product at a lot or batch level across the extended supply chain to support market withdrawals or recalls on a finely targeted basis. Customers here span manufacturing, with added emphasis from food and industrial machinery and industries with expensive components.

Energy and environmental resource management—Tools for energy efficiency, optimized energy procurement, and emissions management. Industry focus here mirrors that of the predictive risk management opportunity, with the additional presence of banking and retail due to their large real estate portfolios that need building energy management.

Enterprise environmental accounting—Ability to account at a very fine level of detail the environmental "cost" of product based upon pathway analysis and emission data in stark contrast to standard Lifecycle Cost Assessment methodologies. Demand is primarily coming from consumer products customers who are seeking to drive accountability and performance against environmental goals. The core driver here is brand differentiation in segments where energy, water, carbon, etc., costs are meaningful for end-consumers.

So, we are seeing more and more examples of customers embedding SAP Sustainability solutions into their businesses and means of

production. This bodes well for a continued transition of Sustainability from an aspiration to a core requirement of business success.

Ray Lane, lead cleantech partner at Kleiner Perkins, the venture capital firm, provides his perspective on the changing definition:

> You can see the evolution in the decade Kleiner Perkins has been investing in cleantech. We started out with biofuels, solar and wind. We next invested in conversion tech, coal to gas, thermal electrics, and waste heat to energy. Now we're investing in storage, fuel cells, etc., and in water. Two years ago we hadn't done anything in water, and now we've done three investments in clean water. We are also focused on agriculture from productivity of seeds to producing sugars.

The changing expectations of the elite around sustainability are a good segue to Part III (after the Google case study) where we cover changing regulatory and societal expectations of technology.

Conclusion

To be considered a technology elite, it is increasingly expected that you put sustainability high on your self-evaluation scorecard. The definition of sustainability, however, gets more ambitious by the day. Let's next look at Google's wide array of Green initiatives.

Case Study: Google's Green Initiatives

Jim Miller has an impressive resume. His career includes stints at:

> Intel, at the birth of the Pentium; Amazon.com, in the early stages of e-commerce; Cisco, when broadband exploded; First Solar, as part of the green/solar resurgence; and now Google, where as Vice President for Worldwide Operations he is in the engine room for the emergence of cloud computing.[22]

Most of his employers prior to Google had hardware/logistics elements. So as he was being recruited by Google, he wondered how different it would be to work for a software company for a change. Even after months of due diligence on both sides, "My job offer letter had so few details about the operations I would be running, that I had to take a leap of faith in joining Google," says Miller. That is no surprise, since Google is extremely secretive about its global operations.

Of course, this "software" company has lots of physical assets in its data centers, self-driving cars, and leased satellites that Miller is admirably qualified to optimize. And they are at a scale that challenges even a rocket scientist like Miller.

On any given day approximately 10 percent of the world's Internet traffic traverses the Google infrastructure. That comes from more than 1 billion query searches per day, over 500,000 Android activations a day, 2 billion YouTube videos watched each day and 120 million Chrome browser users. That does not even begin to account for demands from applications like Google Maps, Earth, Voice, Translate, Mail, Docs, Google+, and countless others. Add to that the logistical and energy needs of a global employee base. As Miller says, "My operations team is small (175 out of total employee count of 25,000) but it is intense and we spend a substantial portion of Google dollars (2010 revenues of $29 billion)."

Just don't ask him to publicly discuss how much he spends.

The operations focus is on cost, systems availability, efficiency, and being "green." Google has a stated goal of being carbon neutral as a

company. Its accomplishments to date are impressive. Its data centers claim to use about half the energy of a typical data center.

Let's explore a few dimensions of the "green focus" at Google.

Google Energy LLC

Google has a subsidiary certified by the Federal Energy Regulatory Commission (FERC) to purchase power and resell it to wholesale customers. While the initial market reaction was Enron-esque and that it was designed to speculate around energy markets, Google presents it as facilitating purchases of renewable energy.

Google explains:

> The plain truth is that the electric grid, with its mix of renewable and fossil generation, is an extremely useful and important tool for a data center operator, and with current technologies, renewable energy alone is not sufficiently reliable to power a data center.[23]

So, Google buys electricity directly from a renewable project developer in the form of a power purchase agreement, or PPA. Their first PPA was with NextEra Energy Resources. Google agreed to buy 114 MW of wind power for 20 years from a project in Ames, Iowa, directed to a data center in Council Bluffs, Iowa. In Oklahoma, they added just over 100 MW of wind power for the data center in Mayes County. Since then, Google has announced another commitment of $38.8 million with NextEra in North Dakota.

This is where the energy reselling is involved. Google sells the power acquired under the PPAs back to the grid at the local, wholesale price. Today, because generic "grid" power is cheaper than renewable power, this may result in a slight net loss for Google, but longer-term, Google is betting the economics will reverse. In the process of selling, Google strips the renewable energy credits (RECs) to apply in the next step.

The data centers at Iowa and Oklahoma will be largely powered by conventional power from the local grid. Since the RECs were produced on the same grid, one REC represents one MWh of renewable power "used" at their data centers, displacing one MWh of local conventional power, and the data centers are considered carbon free.

While the accounting makes your head spin, the important nugget is that Google has given NextEra a firm, long-term commitment to build wind farms. Mike O'Sullivan, senior vice president of development for NextEra, was quoted as saying, "With the support of customers like Google Energy, we've built our wind fleet from fewer than 500 megawatts a decade ago to nearly 8,300 megawatts—the largest fleet in North America today."[24]

It also allows Google to decouple the data center location decision from the renewable energy source. Data center location decisions are driven by many factors including latency, taxation, talent, and real estate. As Google says, "Building a data center in an optimal area for renewable development would result in increased latency for our users and the inefficient use of land better used for renewable energy."

Investment in Other Renewables

Google has been investing in various start-ups to gain access to other forms of renewable energy. BrightSource and eSolar focus on concentrated solar energy and use swiveling mirrors to reflect sunlight to heat towers of water. The resulting steam is used to generate electricity.

The investments in AltaRock Energy and Potter Drilling were to get access to enhanced geothermal energy. The principle is to drill deep enough to get to the hot core of the earth, then pump water into it and use the resulting steam to create energy. Think of them as manmade geysers.

Google also invested in a company called Makani Power, which is leveraging high-altitude wind. One of their concepts is to fly kites with propellers. As the propellers spin they act like turbines, and the power is circled down a cable back to the ground.

In 2011, Google allocated $160 million of funds for the Alta Wind Energy Center (AWEC) in Tehachapi, California. It also allocated $280 million toward residential solar power; $100 million of that went toward a majority stake in the 845-megawatt Shepherds Flat wind power project in Oregon. Another $168 million investment went into BrightSource Energy's 2,600 megawatts Ivanpah Solar Electric Generating System in California's Mojave Desert.[25]

Google has also invested in the development stage of the "Atlantic Wind Connection"—an underwater transmission network that can harvest electricity from wind farms off the Mid-Atlantic coast and could, when finished by 2020, power 1.9 million homes across a 350-mile network across Virginia, New York, and New Jersey.

All told, Google's investment in such renewable projects now exceeds over $1 billion.

In addition to renewables, Google has made investments (though relatively small ones) in cleantech startups, including battery maker Acta-Cell, electric vehicle maker Aptera, efficient car maker Next Autoworks, neighbor-to-neighbor car sharing company RelayRides, weather insurance company WeatherBill, smart grid company Silver Spring Networks, biofuel maker Cool Planet Biofuels, and efficient power gear conversion startup Transphorm.[26]

Ray Lane, a lead cleantech partner at the venture capital firm Kleiner Perkins, says: "We think the world of Google Ventures. In the hyper-competitive world of venture investing, we share intelligence, co-invest, and do a number of collaborative activities. Google, as a customer, has also been an early adopter of products like fuel cell technology of our portfolio company, Bloom Energy. No question, Google bleeds green."

Data Center Efficiency

In 2010, Google took over a former paper mill in Hamina, Finland, and retrofitted it into a data center. It continues to use a seawater tunnel that was built for the paper mill in the 1950s. The seawater passes through four different straining systems. This reduces corrosion from the salt and other minerals in the seawater before it reaches the heat exchanger and is used to cool the data center. On the way out, water then moves to a tempering building, where it mixes with a separate source of the seawater, so it is cooled before returning to the Gulf of Finland. The goal is to "return to a temperature that is much more similar to the inlet temperature, so as to minimize environmental impact in this area."[27]

Google's experience at Hamina and with every new data center it opens around the world adds to a sizable bag of tricks from a decade of

running data centers. It increasingly shares with the world some of the best practices it has accumulated.

Its practices include:

- Measure PUE: "We use a ratio called PUE—Power Usage Effectiveness—to help us reduce energy used for noncomputing, like cooling and power distribution. To effectively use PUE, it's important to measure often—we sample at least once per second. It's even more important to capture energy data over the entire year—seasonal weather variations have a notable effect on PUE."
- Manage air flow: "Thermal modeling using computational fluid dynamics (CFD) can help you quickly characterize and optimize air flow for your facility without many disruptive reorganizations of your computing room."
- Adjust the thermostat: Raising the cold aisle temperature will reduce facility energy use. Don't try to run your cold aisle at 70°F; set the temperature at 80°F or higher—virtually all equipment manufacturers allow this.
- Use "free cooling": Since chillers are the dominant energy-using component of the cooling infrastructure, minimizing their use is typically the largest opportunity for savings. There is no one "right" way to free cool—but water or air-side economizers are proven and readily available.
- Optimize power distribution: Minimize power distribution losses by eliminating as many power conversion steps as possible. One of the largest losses in data center power distribution is from the uninterruptible power supply (UPS); so be sure to specify a high-efficiency model. Also keep as high a voltage as close to the load as feasible to reduce line losses. We also recommend using energy efficient IT equipment, especially those with high efficiency power supplies. Look for the EnergyStar label for future server purchases.[28]

All these lead to an impressive Google statement: "In the time it takes to do a Google search, your own personal computer will likely use more energy than we will use to answer your query."

RE<C

Through November 2011, Google.Org, one of Google's philanthropic initiatives, funded a project called RE<C—to develop one gigawatt of renewable energy capacity (enough to power a city the size of San Francisco) at a price cheaper than coal, in years, not decades.

Google's former "green energy czar" Bill Weihl explained:

> We've learned that a small team of smart people with basic technical expertise and the freedom to really innovate can do something quite remarkable, and we wanted to see if that really could be true for alternative energies. One of the keys there is the freedom to go after a really aggressive goal, and so we set a goal of making renewable energy cheaper than coal—it's a very simple, kind of audacious and crazy goal.[29]

Some of the R&D projects included an effort to design and build low-cost heliostats, mirrors that track the sun, and reflect sunlight to concentrate solar energy. Another worked on a solar Brayton engine (a gas turbine engine like those currently used in jet aircraft, but powered by sunlight) that would heat air to drive a turbine and generate electricity.

Consumer and Other Applications

Google has created a $280 million fund with home solar installer SolarCity. This is Google's largest investment in clean power to date, and its first in-home rooftop solar.

For several years Google offered an app called PowerMeter, a free energy monitoring tool that helped consumers save energy and money. Using energy information provided by utility smart meters and energy monitoring devices, Google PowerMeter enabled you to view your home's energy consumption from anywhere online.

Google has also built the largest corporate installation of solar panels at headquarters campus in Mountain View, CA. Over 9,000 solar panels means that the "installed capacity of this solar grid is 1.6MW. . . . In one day the system generated 9,468 kilowatt-hours of electricity. This is enough electricity to power 83,000 hours of flat-screen TV viewing

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each day."[30] Google was an early adopter of Bloom Energy's boxes on its campus. "Over the first 18 months the project has had 98 percent availability and delivered 3.8 million kWh of electricity."[31]

Then there are the other less prominent sustainability moves on its main campus. Robyn Beavers of Google provides some examples:

> When we're done with (our carpet), we can send it back to the manufacturer and they grind it up into little pellets and use it again in the supply stream so it never ends up in a landfill. In some of our window shades and the textiles we use in our cubicles, we focus on eliminating toxins. We have filtered water everywhere, we have 90 percent fresh air coming into the building throughout the day—a lot of stuff you can't really see.[32]

Summarizes Weihl:

> I believe that the problems we're facing are solvable, but they're not going to solve themselves. And solving them is either going to require spending a lot more money on energy than we're spending today, which I think is probably a non-starter, or it's going to require major technological innovation. That's where I think Google can help.