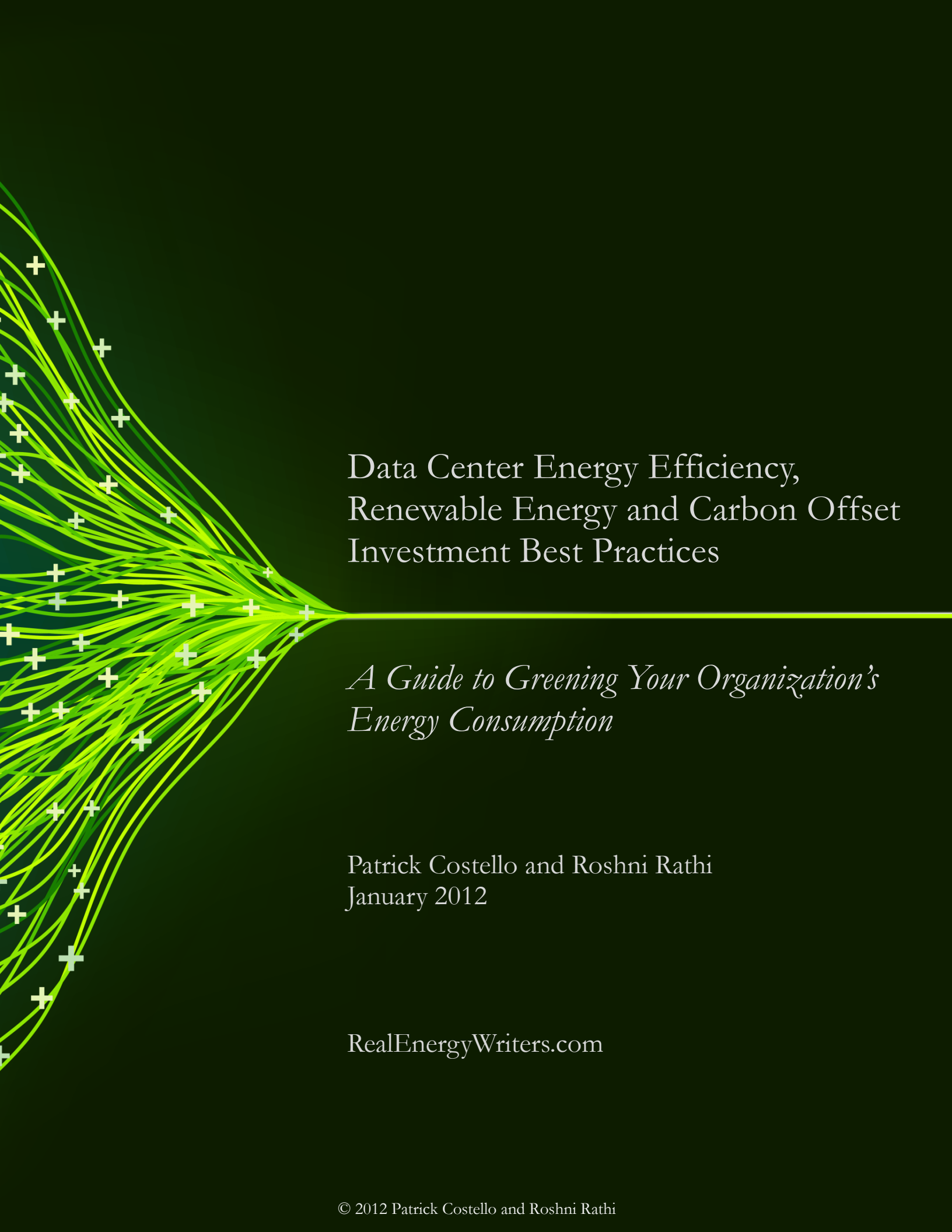

# Data Center Energy Efficiency, Renewable Energy and Carbon Offset Investment Best Practices

*A Guide to Greening Your Organization's Energy Consumption*

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## Executive Summary

Organizations can benefit immensely by lowering their energy use and greenhouse gas emissions through strategic investments in data center energy efficiency, renewable energy, and carbon offsets. A well-executed greening plan can bolster an organization's public image, enhance employee satisfaction, and reduce the cost of operations. This guide aims to help organizations, particularly those with energy-intense data center operations, develop successful greening plans. It explores a wide range of green investment options that can reduce an organization's energy consumption-related environmental impact.

Readers will come to understand:

- Why some companies are criticized while others are commended for their data center efficiency and green energy investment campaigns.
- How investing in data center energy efficiency brings immediate, permanent reductions in greenhouse gas emissions, energy costs, and exposure to power market volatility.
- The significance of the Power Usage Effectiveness (PUE) and Carbon Usage Effectiveness (CUE) metrics and how to calculate them for a data center.
- The pros and cons of pursuing direct carbon emission reductions through efficiency investments versus pursuing indirect carbon emission reductions through purchases of environmental commodities.
- The value of using monitoring equipment, such as data loggers, as well as computer models to assess energy efficiency opportunities in a data center.
- The cascading benefits of investing in demand-side data center efficiency solutions.
- How investing in newer processing technology can offer substantial efficiency improvements.
- How server virtualization minimizes energy losses associated with powering and cooling idling servers.
- What exactly the "cloud" is, and the environmental advantages of outsourcing server operations to a network-based cloud computing service.

 

- The types of cogeneration and fuel cell generation systems, their pros and cons, and how they can advance an organization's energy efficiency and environmental goals.

- The types of data center cooling systems (including free cooling) and methods of airflow management that maximize data center energy efficiency.

- The range of renewable energy investment options (including on-site generation) and the advantages and disadvantages of those options.

- Key cost, performance, and integration concepts involved in assessing the value of investing in on-site generation, particularly on-site solar PV generation.

- How the extent of environmental benefits provided by energy efficiency and green energy investments can vary substantially by region.

- How to distinguish between and benefit from investments in environmental commodities including voluntary renewable energy certificates (RECs), white tags, and carbon offsets

- The difference between, and pros and cons of investing in bundled RECs (through a green power program), unbundled RECs, and offsets sourced from renewable energy projects.

- The relative effective cost of Scope 2 emission reductions sourced from bundled RECs, unbundled RECs, carbon offsets, on-site fuel cell generation, and on-site solar PV generation.

- Best strategies to communicate green investments for maximum credibility.

### Who Will Benefit from This Guide:

If you need to quickly make sense of the many available data center energy efficiency, renewable energy, and carbon offset investment options, then this report is for you. We have aggregated key insights from hundreds of resources and conducted independent analyses to provide a straightforward guide that will help you develop an integrated greening and communications strategy.

 

## About the Authors

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Patrick has authored and coauthored a number of publications that explore policy, technology, and market dynamics related to renewable energy generation, conventional energy generation, and energy efficiency investment strategy. Works that Patrick recently coauthored include the quarterly *Integrated Energy Outlook* (ICF International, 2011-2012), *Firming Renewable Electric Power Generators: Opportunities and Challenges for Natural Gas Pipelines* (Interstate Natural Gas Association of America, 2011), *The Future of Energy Efficiency: Technology and Strategies to Improve Energy Efficiency* (Business Insights, 2010), *Investment Decisions for Baseload Power Plants* (U.S. Department of Energy, 2010). Patrick has also contributed to the *Energy Efficiency Markets Newsletter* on several occasions.

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Roshni has conducted diverse analyses, such as estimating industrial and lifecycle greenhouse gas emissions, evaluating abatement costs for low-carbon technology options, and projecting the impacts of energy-efficiency policies. She has helped develop energy tracking and peer benchmarking tools, and has led corporate initiatives for employee engagement in sustainability. For the past three years, Roshni has assessed quantitative uncertainty in greenhouse gas emissions reported for various source categories in the U.S. Environmental Protection Agency's *U.S. Greenhouse Gas Inventory Report*.

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### Companies and organizations named in this report include:

Facebook, Greenpeace, Uptime Institute, ICF International, The Green Grid, U.S. Environmental Protection Agency, Digital Realty Trust, U.S. Department of Energy, Lawrence Berkeley National Laboratory, Onset Computer, Schneider Electric, Power Assure, Intel, AMD, Oracle, IBM, HP, Cisco, VMWare, CA Technologies, Citrix, Dell, Microsoft, Symantec, IDC, National Institute of Standards and Technology (NIST), Accenture, WSP Environment & Energy, Google, Amazon, SalesForce.com, Sun Microsystems, Syracuse University, Qualcomm, Database of State Incentives for Renewable and Efficiency (DSIRE), OpenEnergyInfo, Neuwing Energy Ventures, Nexant, Sterling Planet, FuelCell Energy, UTC Power, Bloom Energy, Lazard Ltd., Connecticut Department of Public Utility Control, American College Testing, American Council for an Energy Efficient Economy (ACEEE), U.S. Green Building Council, eBay,42U, Cadmus, Raritan, Emerson Network Power, AccelOps, Wright Line, Skanska, Lee Technologies, Cummins, Caterpillar, GE, Ameresco, National Renewable Energy Laboratory (NREL), National Energy Regulatory Commission (NERC), Federal Trade Commission (FTC), Green-e, Center for Resource Solutions, SolarBuzz, SunPower, FirstSolar, Sharp, Kyocera Solar, Suntech Power, Yingli Green Energy, Enphase Energy, SMA America, Fronius USA, Wesco Distribution, California Solar Center, Electricity Storage Association, BendBroadband Vault, Sonoma Mountain Data Center, Federal Energy Regulatory Commission (FERC), Nike, European Union Emissions Trading System (EU ETS), Regional Greenhouse Gas Initiative (RGGI), Yahoo!, World Resources Institute (WRI), Chicago Climate Exchange, Ecosystem Marketplace and Bloomberg New Energy Finance, Stockholm Environment Institute, The World Bank, The Carbon Neutral Company, Carbon Disclosure Project, Haworth

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# Chapter 1 Introduction

Public concern about environmental sustainability and corporate stewardship has grown steadily in recent years. In particular, the impact of greenhouse gas (GHG) emissions on climate change and the role of fossil fuel electricity generation as the largest source of GHG emissions in the U.S. have attracted substantial attention. Emissions associated with electricity consumption are often a significant barrier to improving the environmental profile of many organizations because the average amount of $CO_2$ emitted per unit of electricity consumed is very high.

IT and telecom firms, many known for their progressive, game-changing strategies, have led the charge in reducing energy use and associated emissions. Several of these companies have focused their efforts on data centers, which contribute significantly to the companies' total environmental footprints. Data centers are facilities that house equipment to store, manage, and distribute digital information. They already make up about 1.5%[1] of national electricity use in the U.S. and account for an annual GHG impact of at least 76 million metric tons of $CO_2e$ ($MtCO_2e$).[2,3] The energy and GHG impacts of data centers are expected to more than double by 2020.[4]

Many highly visible IT and telecom companies reap public relations and environmental benefits by following industry best-practices and implementing data center energy efficiency, renewable energy, and carbon offset investment strategies. Organizations across sectors can learn from and adopt these strategies to improve their own environmental sustainability.

This year, seven of the top ten organizations in *Newsweek's* Green Rankings were IT and telecom companies, with IBM, HP and Sprint Nextel in the lead.[5] Not to be outdone, Intel ranked 1st in the U.S. Environmental Protection Agency's list of top green power purchasers.[6] And like many other companies that have invested heavily in data center efficiency, Facebook announced the construction of two of the most energy-efficient data centers in the world in Prineville, Oregon and Forest City, North Carolina.[7]

Investing in green products and solutions, however, does not always translate into positive PR. Organizations should be careful about how they communicate their efforts and be aware of how the investments of other organizations have been praised or criticized by the press. .

[1] U.S. EPA 2007b
[2] Greenhouse gases vary in their contribution to climate change, with small concentrations of some gases being far more potent than others. Global Warming Potential (GWP) is a measure of the global warming impact of a gas as compared to that of carbon dioxide. GHG quantities are converted to carbon dioxide "equivalents" by multiplying the amount of each gas with its Global Warming Potential (GWP). This enables comparisons of the impacts of different types of GHGs.
[3] The Climate Group 2008
[4] The Climate Group 2008
[5] Newsweek 2011
[6] U.S. EPA 2011p
[7] Rusli 2010

For example, Dell, the leader of *Newsweek's* Green Rankings in 2010, was criticized by *The Wall Street Journal* only a few years ago. Responding to the IT company's announcement that it had become 'carbon neutral' in 2008, the newspaper suggested that Dell may have misled the public about the extent of its achievement. The *WSJ* also questioned the incremental environmental benefits of the Renewable Energy Credits (RECs) that Dell purchased to offset its carbon emissions.[8] Earlier that same year, *The Inquirer* criticized Intel's REC purchases on similar grounds.[9] And despite Facebook's development of extremely high-efficiency data centers, Greenpeace launched a campaign to "unfriend" Facebook CEO Mark Zuckerburg as long as Facebook continues to build its data centers in utility regions, like that of Pacific Power in Oregon, that Greenpeace asserts are disproportionally powered by coal generation relative to the national average level.[10]

At a time when the label 'green' can be ambiguous due to misuse and overuse, GHG-reduction and energy-efficiency strategies are sparking debate over, and redefining public expectations about what it means to be 'green'. Increasingly savvy consumers, skeptical industry watchdogs, and agile reporters are quick to distinguish between genuine environmental commitments and so called "greenwashing." For this reason, it's critical that organizations seeking PR benefits from green investments use transparent and accurate communication.

This guide offers an overview of best-practice and innovative energy and emission reduction strategies implemented by IT and telecom companies to reduce emissions associated with energy consumption. It provides information about:

- Available data center energy efficiency, renewable energy, and carbon offset investment options
- The financial and environmental costs and benefits associated with these options
- Potential risks and criticisms associated with green investments
- Suggested ways to communicate green investments to stakeholders

The first step in building an effective greening strategy is to conduct an energy assessment and a greenhouse gas inventory to establish a baseline against which success can be measured. Once the baseline has been established, organizations should set aggressive yet reasonable goals to reduce energy consumption and emissions below the baseline. Organizations can use the information in this guide to assess pros, cons and trade-offs of available options and develop a tailored integrated greening and communications strategy.

[8] Ball 2008
[9] Harding 2008
[10] Greenpeace 2010b

# Chapter 2 Energy Efficiency

## Introduction

An increasing number of commercial, government, and non-profit organizations are cutting their energy use and associated carbon footprints by improving the energy efficiency of their data centers. Organizations that reduce their carbon emissions by improving efficiency, rather than by purchasing RECs or carbon offsets, are often perceived as taking more direct responsibility for their environmental impact. Google and Yahoo!, two leaders in green IT, have both shifted to this efficiency-focused approach, prompting many other organizations to also invest in energy efficiency solutions for their data center operations.

Data center electricity consumption represents about 1.5% of total U.S. electricity load, and this share is growing quickly. The U.S. Environmental Protection Agency (EPA) estimates that U.S. data center energy consumption doubled between 2000 and 2006, and it projects that consumption has since doubled again.[11] Emissions will rise in step with consumption, and one estimate projects that global data center emissions will quadruple from 2007 levels by 2020.[12] Energy-intensive data centers can be a substantial barrier to achieving green operations at many companies. Implementing data center efficiency solutions can protect and sometimes enhance an organization's image. However, improving data center efficiency is now more commonly perceived as a "must-do" rather than as an admirable goal. Greenpeace recently voiced this view in its criticism of Facebook's new ultra-efficient data center in Oregon. The environmental organization wrote a letter to Facebook saying, "Efficiency is certainly important, but is only the beginning of taking responsibility for your rapidly growing energy and environmental footprint."[13]

Decreasing data center energy consumption is not only a PR opportunity, but also a financial opportunity. On average, data centers experience energy costs per square foot that are 10 to 30 times those of office buildings.[14] Data center efficiency solutions yield immediate, permanent reductions in energy costs and decrease exposure to power market volatility. Efficiency solutions also reduce exposure to potential federal greenhouse gas regulations, which are unlikely to be passed in the next few years but could still impact large-scale, long-term data center investments. In many cases the most cost-effective greening approach for organizations with medium to large data center operations is to implement data center efficiency solutions.

Data centers typically fall within one of the following categories: traditional enterprise, on-demand enterprise, telecom, high performance computing (scientific), hosting, internet, and hybrid.[15] The data center classes across these categories range from small server closets with a handful of servers to enterprise-class systems with thousands of servers. The Uptime Institute™ provides data center design standards that are used to assign new or upgraded data centers to tiers

[11] U.S. EPA 2007b
[12] Kamplam et al. 2008
[13] Greenpeace 2010a
[14] LBNL 2006
[15] 7X24 et al. 2010a

or classes based on their availability, downtime and power supply redundancy.[16] Exhibit 1 below provides a basic overview of data center tiers as defined by the Uptime Institute standard.

**Exhibit 1: Data Center Tiers and Associated Characteristics**

| | |
|---|---|
| **Tier I**<br>**Small Organization** | • 99.67% annual site availability<br>• No system redundancy<br>• Can sustain power outage of less than one hour<br>• 20-30 gross watts per square foot |
| **Tier II**<br>**Medium Organization** | • 99.75% annual site availability<br>• Some power and cooling system redundancy<br>• Can sustain 24 hour power outage<br>• 40-50 gross watts per square foot |
| **Tier III**<br>**Large Organization** | • 99.98% annual site availability<br>• Substantial power and cooling system redundancy<br>• Can sustain 72 hour power outage<br>• 100-150 gross watts per square foot |
| **Tier IV**<br>**Very Large Organization** | • 99.99% annual site availability<br>• Full power and cooling system redundancy<br>• Can sustain 96 hour power outage<br>• |

Sources: Turner et al. 2005 and EdgeBCC 2009

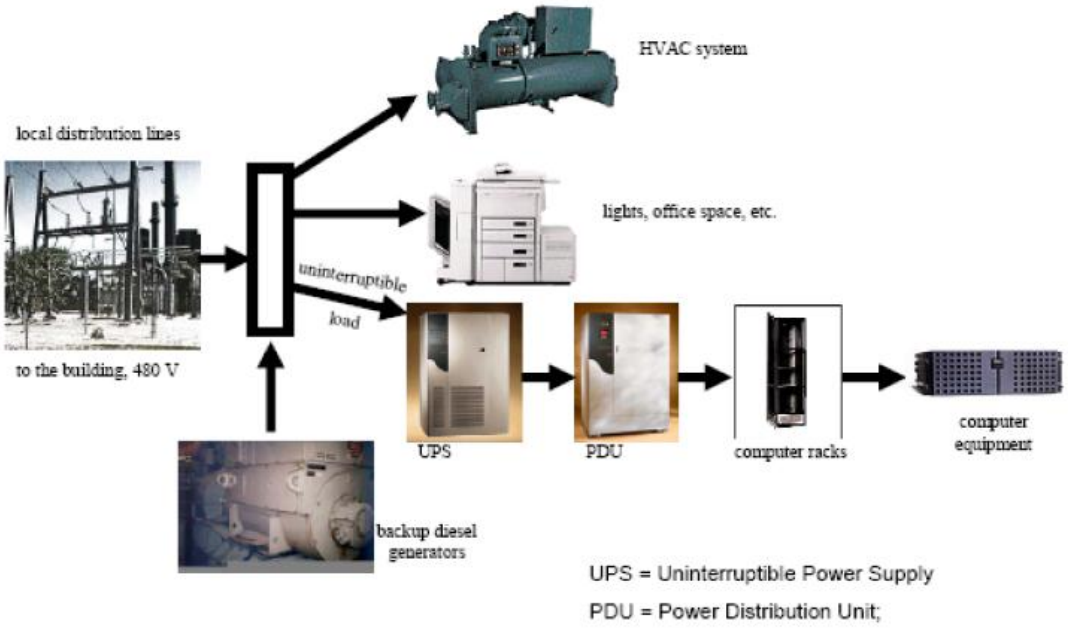
While the majority of U.S. data centers are relatively small and have less than a few dozen servers, mid-tier and enterprise-class data centers collectively consume more energy.[17] This report explores efficiency solutions appropriate for a broad range of data centers.

Opportunities for reductions in electricity consumption are present at many stages of the flow of energy to data center end-use systems. The diagram below provides a high-level view of the flow of electricity in a typical data center.

[16] Neudorfer 2010
[17] U.S. EPA 2007b

**Exhibit 2: Data Center Electricity Flow**




Source: ICF International 2009, Prepared for ORNL

## Efficiency and Sustainability Metrics

Providing reliable power to computing equipment requires a number of energy-intensive support systems. While there are many efficiency metrics, the preferred data center efficiency metric is Power Usage Effectiveness (PUE™).[18] The PUE metric, developed by The Green Grid® (TGG), represents the ratio of the total energy consumed by the facility to that consumed by the facility's IT equipment[19] over the course of one year. Total data center energy is the sum of a data center's energy consumption, including grid electricity, fuel consumed on-site (e.g. natural gas), and district utilities (e.g. chilled water, steam). Different energy types should be weighted based on their source energy factors, and converted to common units (typically kilowatt hours) before summing.[20] IT equipment energy consumption should, at a minimum, be measured at the output of the uninterruptable power supply (UPS) but ideally should be measured directly at the IT load.[21] The basic PUE formula is provided below.

$$\text{PUE} = \frac{\text{Total Data Center Energy (kWh)}}{\text{IT Equipment Energy (kWh)}}$$

[18] 7X24 et al. 2010a
[19] IT Equipment Energy includes "the load associated with all of the IT equipment, including compute, storage, and network equipment, along with supplemental equipment such as KVM switches, monitors, and workstations/laptops used to monitor or otherwise control the data center."
The Green Grid 2010
[20] 7X24 et al. 2010b
[21] 7X24 et al. 2010a

Ideally, a data center would achieve a PUE of 1.0, a level that indicates that every unit of energy is used to power IT equipment. A recent survey conducted by EPA as part of its ENERGY STAR® Data Center Initiative found that its representative sample of data centers had a PUE range of 1.25 to 3.75 and an average PUE of 1.9. This average indicates that the typical data center expends an additional 0.9 W for every 1 W of energy needed to power computer equipment.[22]

While PUE is one of the most commonly used efficiency metrics, it does not reflect all efficiency characteristics of a data center. In particular, PUE may not adequately capture improvements in the energy efficiency of IT equipment, because reductions in energy consumed by IT equipment are reflected both in the numerator and the denominator in the PUE formula. Some metrics that highlight other aspects of data center energy efficiency include Corporate Average Data Center Efficiency (CADE), Data Center Infrastructure Efficiency (DCiE), Data Center energy Productivity (DCeP), and Energy Reuse Effectiveness (ERE).

A new sustainability metric, known as Carbon Usage Effectiveness (CUE™), complements energy efficiency metrics, in particular the PUE metric, to provide insight into another dimension of data center environmental performance. CUE, also developed by TGG, is the ratio of the $CO_2$ emissions associated with total energy consumed by the facility to the total energy consumed by the facility's IT equipment. Below is the CUE calculation for a data center that sources all of its electricity from the grid. The denominator is the same as that used in the PUE calculation.

$$\text{CUE} = \frac{\text{Total } CO_2 \text{ Emissions caused by the Total Data Center Energy } (kgCO2eq)}{\text{IT Equipment Energy (kWh)}}$$

Or

$$\text{CUE} = \text{Carbon Emission Factor} \times \text{PUE}$$

Another sustainability metric, the Carbon Emission Factor (CEF), is determined by the $CO_2$ intensity of grid electricity ($kgCO_2eq/kWh$) in a given region. This information can be found in the EPA's eGRID database.[23] Data centers with on-site energy production use the same formula but the CEF is determined using a combination of $CO_2$ associated with grid-sourced energy and $CO_2$ emissions from on-site generation. The ideal CUE value is 0, a level that indicates that no carbon emissions are associated with a data center's operations.[24]

## Identifying Appropriate Efficiency Solutions

To identify the most appropriate efficiency solutions for a data center operation, an organization must closely evaluate its current operations and planned operations. For example, an organization that plans to build a custom facility will likely have more options than either an organization that leases a data center or an organization that uses a small on-site data center attached to a regular office building. An organization that needs to expand its data center

[22] U.S. EPA 2011j
[23] EPA eGrid: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html (U.S. EPA 2011b)
[24] The Green Grid 2010

operations may choose among options such as a move-in-ready data center, a custom-designed data center, and an expanded on-site data center. Companies like Digital Reality Trust help organizations evaluate these options and the array of applicable efficiency solutions.[25]

The type of efficiency improvements an organization can implement if it has an existing data center facility and wishes to continue using it will depend on whether the organization is repurposing some or all of the facility, expanding the facility, or optimizing the facility. There are a number of key steps that should be undertaken to identify the most appropriate efficiency solutions:

- Develop a component-level and system-level energy baseline (using current and past energy use) against which efficiency efforts can be measured
- Benchmark facility-level energy use and component-level energy use
- Project future energy use and needs
- Evaluate data trends to identify and prioritize opportunities for efficiency improvement

Several publicly available software tools can help organizations complete these steps, including the Department of Energy (DOE) Data Center Profiling Tool, Air Management Tool, and Electrical Systems Tool[26], Lawrence Berkeley National Laboratory (LBNL) Data Center Tools[27], and Schneider Electric's TradeOff Tools™.[28]

In assessing energy efficiency opportunities, it is important to carefully measure component and system power consumption by using monitoring equipment as well as computer models. As the Uptime Institute notes, "You can't manage what you don't measure."[29] Detailed measurements reveal the extent of potential improvements as well as the potential server capacity that could become available.[30]

Such measurement may reveal that system components are:

- Not optimized for their locations
- Unnecessarily wasting energy by working against one another
- Working unnecessarily hard
- Consuming an unexpected amount of energy, even while idle.

Some data centers waste a substantial amount of energy through inefficient airflow and by using more cooling capacity than necessary to achieve optimal equipment performance. An example of system components working against one another is when computer room air conditioner (CRAC) units in the same room may not work in unison, sometimes because they are not centrally

[25] Digital Realty Trust: www.digitalrealtytrust.com (Digital Realty Trust 2010)
[26] U.S. DOE Tools: http://www1.eere.energy.gov/industry/datacenters/software.html (U.S. DOE 2011b)
[27] LBNL Tools: http://hightech.lbl.gov/DCTraining/tools.html (LBNL 2011)
[28] Schneider Electric Tools: http://www.apc.com/prod_docs/results.cfm?DocType=Trade-Off%20Tool&Query_Type=10 (Schneider Electric 2011)
[29] Raritan 2009
[30] Trowbridge 2010

controlled, with one unit humidifying while the other is dehumidifying.[31] Substantial energy waste can also result from inefficient airflow and heat transfer.

Energy waste can be identified at a data center in just two to four weeks using data logging instruments that track critical performance measures such as power use, airflow, temperature, and humidity at key system locations.[32] Data measurements outside a data center facility are useful as well. Organizations have become increasingly interested in obtaining detailed on-site weather measurements to calibrate the performance of data center components such as the HVAC system.[33] Data logging tools, such as Onset® Computer's HOBO® shown in Exhibit 3 below, can be set up quickly for internal and external evaluations and can wirelessly transmit data that is then aggregated and viewed remotely through an online analysis platform.

**Exhibit 3: Onset HOBO Data Logger**


Source: Onset Computer 2011

Software-based measurement tools can also be used to identify energy wastes. As highlighted later in this chapter, servers in idle mode typically use between 70% and 85% of the power consumed when fully operational, and data centers often have numerous idle servers that are unnecessary.[34] The company 1E® sells server performance management and evaluation software that measures physical and virtual server-level energy consumption to support server power management and identify opportunities to decommission unneeded servers.[35] Schneider Electric, an industry leader in energy management services, also provides software monitoring solutions and identifies the following data center junctures as some of the most important to evaluate for efficiency losses:

- Point of connection between utility and facility

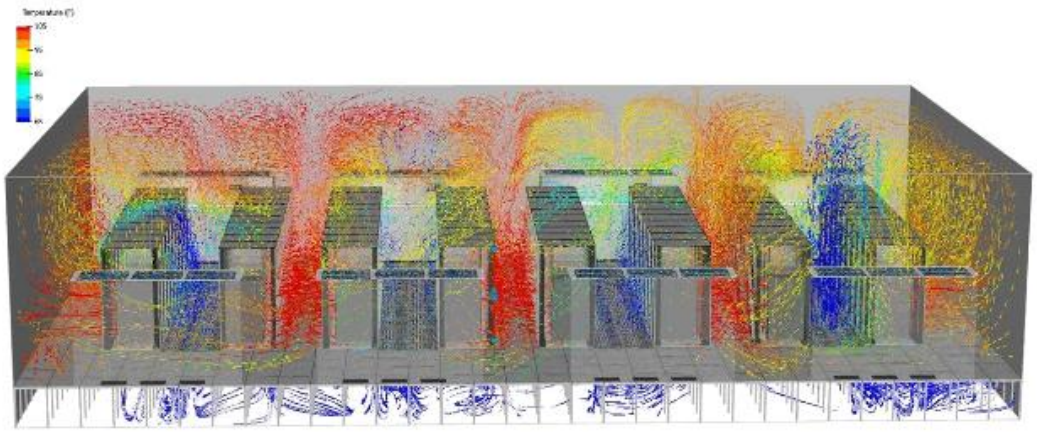
[31] Korn 2010
[32] Evans 2010a
[33] Evans 2010a
[34] Emerson Network Power 2009
[35] Cohn 2009a and Cohn 2009b
1E NightWatchman® Server Edition: http://www.1e.com/softwareproducts/nightwatchmanserver/index.aspx (1E 2011)

- Between power transfer equipment and ancillary system power distribution equipment
- Between on-site generators and power transfer equipment
- Between power transfer equipment and cooling distribution equipment
- Between essential cooling systems and cooling distribution equipment
- Between power transfer equipment and UPS systems/associated switchgear
- Between UPS systems/associated switchgear and power distribution units
- At the branch circuits between the power distribution units and critical loads[36]

Another company that offers data center efficiency assessments is PowerAssure®, which provides Dynamic Power Management (DPM) software that can integrate any device, sensor, and management system to provide a holistic view of data center performance and identify efficiency improvement opportunities.[37]

Computer simulation models can supplement hardware and software-based measurement tools. For example, computational fluid dynamics (CFD) 3-D modeling can provide important information about how to reconfigure and possibly retrofit server rooms to achieve substantial IT equipment and upstream efficiency gains.[38] Exhibit 4 below is the sample output of a CFD model of a server room.

**Exhibit 4: Sample Computer Room CFD Model Output**



Source: Wright Line 2009a[39]

Assessing data center performance using hardware and software measurement tools as well as modeling tools greatly facilitates the process of identifying which system components should be optimized, upgraded, or replaced.

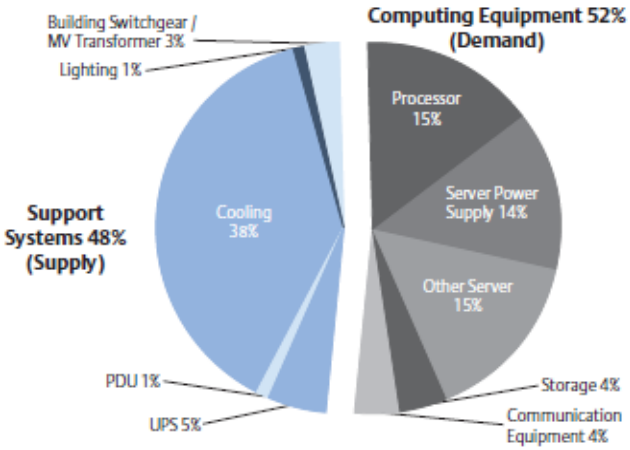
[36] Parker et al. 2007
[37] PowerAssure: http://www.powerassure.com/products/dynamic-power-management-software (PowerAssure 2010a)
[38] Wright Line 2009a
[39] Eaton's Wright Line Business, a leader in airflow management solutions for today's complex data centers.

## Energy Efficiency Solutions – Best Practices and Innovative Strategies

There are a range of best practice efficiency improvements available for both demand-side and supply-side system components. Demand-side components, which directly support business activities, consist of processors, server power supply, storage equipment, communication equipment, and other server components. Supply-side components, which support demand-side operations, consist of the Uninterruptible Power Supply (UPS), Power Distribution Unit (PDU), cooling systems, lighting, and building switchgear.[40] The exhibit below provides a general breakdown of these components by power consumption at a typical 5,000 sq. ft data center with a PUE of 1.9.

**Exhibit 5: Overview of Data Center Energy Consumption**




Source: Emerson Network Power 2009[41]

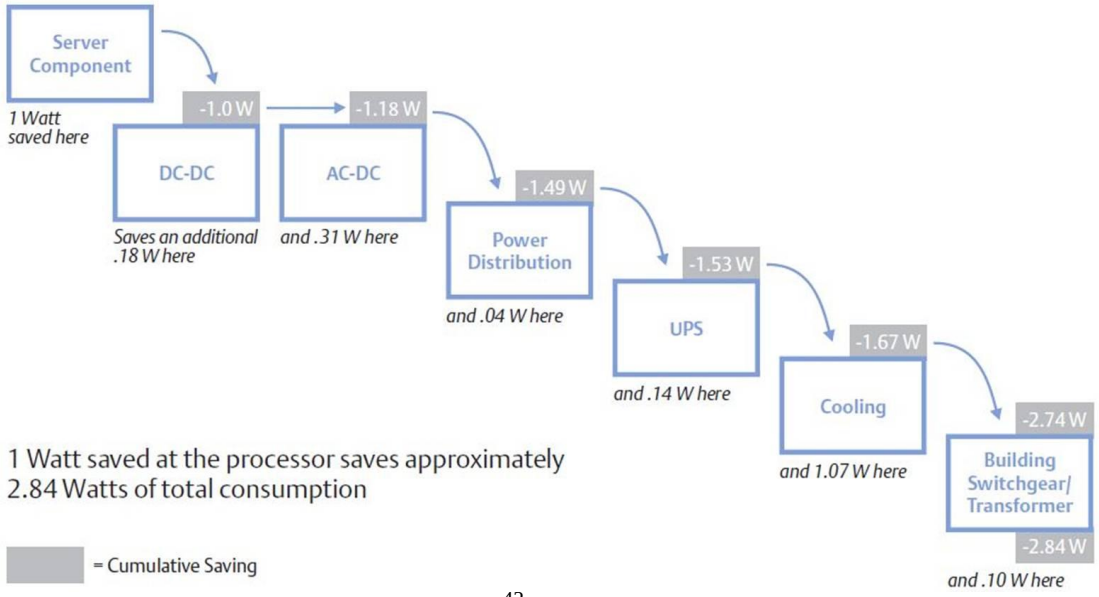
Supply-side and demand-side energy consumption at a typical data center are comparable, highlighting the scope of a data center's support systems as well as the scope of supply-side efficiency improvement opportunities. While cooling systems often consume more energy than any other supply-side or demand-side category, state-of-the art data centers now implement extremely efficient cooling systems that represent a much smaller share of total energy consumed.

Optimization of demand-side systems can yield substantial energy savings compared with optimization of supply-side systems because downstream energy savings at demand-side components yield cascading upstream supply-side savings. The exhibit below illustrates this cascade effect at a sample 5,000 sq ft. data center.

[40] These system components are addressed later in the report.
[41] Emerson Network Power 2009. The Energy Logic approach developed by Emerson Network Power.

**Exhibit 6: The Cascade Effect**




Source: Emerson Network Power 2009[42]

In the following sections we explore demand-side and supply-side efficiency solutions corresponding with the cascading flow highlighted above in Exhibit 6.

## Demand-Side Energy Efficiency Solutions

Improving server-level energy efficiency is one of the most effective ways to improve the overall energy efficiency of a data center. As indicated in the sample case study example above, saving 1W at the server component-level could save a data center over 2.8 W of total energy consumption.[43] Server efficiencies have improved significantly in recent years with better power supply design, power management firmware, DC voltage regulators, and cooling fans.[44] Some of the greatest efficiency gains are the result of improvements in the efficiency of the processor, which consumes more electricity than any other server component.[45]

### Server Processors

For many years data center managers focused strictly on processor performance as the benchmark for purchase decisions, though in recent years this benchmark has received less attention than processor performance per watt consumed. While a large portion of servers still use single-core processors, most servers use multi-core processors, which boast better efficiency and greater performance.[46] Multi-core processors are a single processing component with multiple processing units known as cores. State-of-the-art multi-core processors for data centers

[42] Emerson Network Power 2009. The Energy Logic approach developed by Emerson Network Power.
[43] Emerson Network Power 2009.
[44] U.S. EPA 2010c
[45] Minas and Ellison 2009
[46] Patrizio 2010

include the six core Intel® Xeon® 5600 series processor, the twelve core AMD® Opteron™ 6000 series processor, and Oracle's 16-core SPARC T-Series processors. Many new multi-core processors offer lower energy consumption when idle and can better support server virtualization (discussed later), which can yield additional energy savings.

Investing in newer processing technology even after just a short period of time can offer substantial efficiency improvements. For example, in early 2007, Intel introduced two new 50-watt quad-core server processors to replace an 85-watt and a 120-watt quad core server processor introduced in late 2005, respectively delivering a 41% and 58% decrease in power consumption for comparable performance.[47] When Intel introduced this new processor line in 2007 it estimated that every watt saved in computation would yield one watt of power conversion savings and one watt of cooling savings. Using this estimate, replacing just one of Intel's 85-watt or 120-watt servers with one of Intel's comparable new servers would respectively yield 70 watts and 140 watts of upstream conversion and cooling savings.[48] Significant processor efficiency gains can also be achieved by investing in higher-end processers even from within the same processor technology series. For example, the Intel® Xeon® 5600 series processor requires up to 30% less operating power than does the Intel® Xeon® 5500 series processor.[49]

The processor sector is extremely competitive, with leading manufacturers such as Intel, AMD, and Oracle regularly introducing new processors to meet evolving ICT needs.[50] Likewise, server manufacturers such as IBM, HP, Cisco, and Oracle regularly introduce new server designs that complement and enhance processor performance. Improved server architecture and processor arrangements can also yield substantial efficiency gains. Two common server designs are the rack server, which is the standard design, and the blade server. Blade servers are compact arrays of processors that are stripped of many components used by a standard rack server. Multiple blade servers can share the same power supplies and cooling fans, and current blade servers are more efficient than standard rack servers. Dell, which sells both blade and rack servers, states that blade servers offer the same performance as rack servers but consume 20% less energy.[51]

[47] Intel 2007
[48] Intel 2007
[49] Intel 2011
[50] The relative performance of server processor products is typically compared using standards set by the Standard Performance Evaluation Corporation (SPEC).
[51] Dell 2011

**Exhibit 7: Blade Server**

Source: Synergy Global Technology 2011[52]

However, because they consolidate so much data processing in such a small area, blade servers can lead to hotspots and present cooling challenges that require supplemental cooling.[53] We address the challenges presented by blade servers later in this chapter. Blade servers provide an ideal platform for server virtualization, and pairing the two amplifies the efficiency benefits of server consolidation.[54]

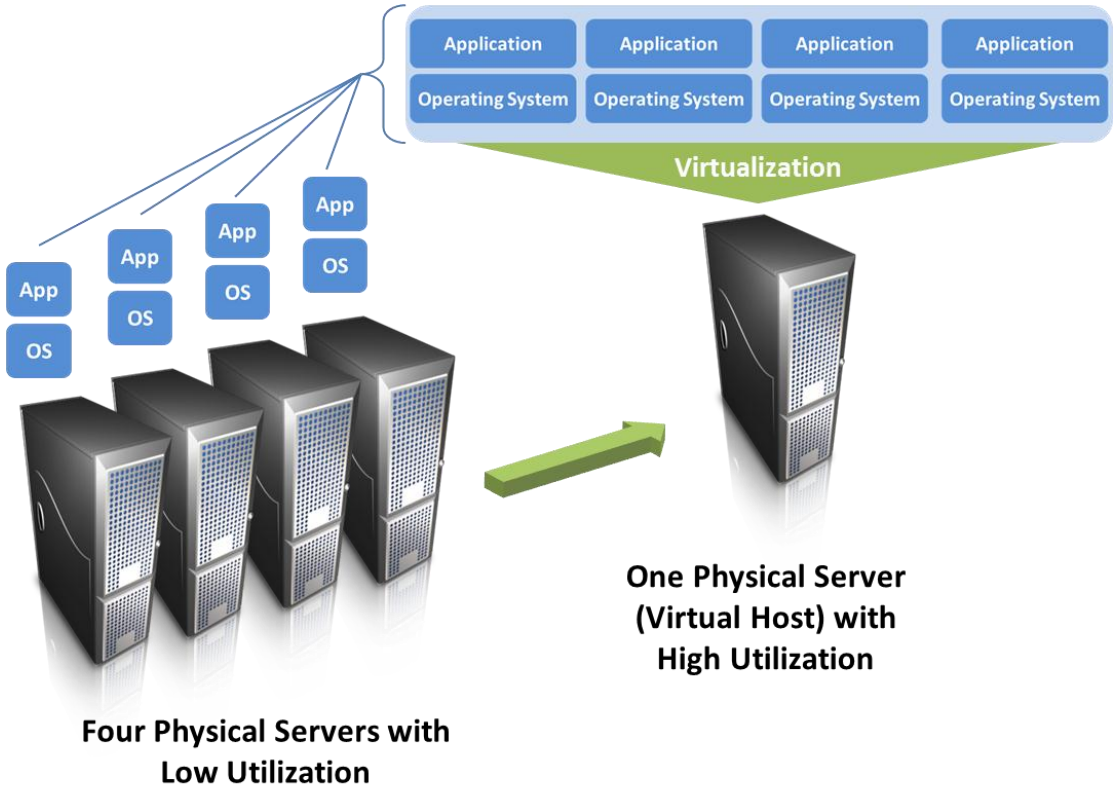
## Server Virtualization

Another best-practice demand-side efficiency solution is server virtualization, which is the division of a single physical server into multiple isolated virtual servers. Server virtualization makes it possible to consolidate dozens of applications and operating systems that exist on multiple servers onto a single server. For example, eight servers with low utilization running email and various MS Office programs could be consolidated to operate on just two servers.[55] In a process known as live migration, virtual servers may also be moved between physical servers while running. Live migration makes it possible to rebalance virtual servers across physical servers depending on real-time demand. This eliminates the need to run excess server capacity by making it possible to quickly turn servers on and off as needed.

[52] Synergy Global Technology 2011. www.RackmountMart.com.
[53] Stack et al. 2010
[54] Stack et al. 2010
[55] Citrix 2008

**Exhibit 8: Illustrative Server Virtualization**




Server virtualization maximizes server utilization, thereby minimizing energy losses associated with powering and cooling idling servers. At many data centers a server manages only a single application and, as a result, may sit idle for as much as 85% to 95% of the time.[56,57] Even while idle, a typical server consumes 70% to 85% of the power it consumes when fully operational.[58] Implementing server virtualization for a typical group of servers can increase remaining server utilization from 8-15% to 70-80% and yield up to an 80% decrease in total server energy consumption because processor efficiency also increases as utilization increases.[59] Virtualization solution provider VMWare® estimates that every server that is virtualized saves 7,000 kWh annually, yielding annual emission savings of approximately 4 $MtCO_2e$.[60] There are many virtualization solutions providers to choose from, including VMWare, CA Technologies®, Citrix®, IBM®, Dell, HP, Microsoft, and Symantec. The use of server virtualization is growing rapidly, and the research firm IDC projects that nearly 70% of data center workloads will be virtualized by 2013.[61] The benefits of server virtualization can be multiplied when paired with cloud storage and data processing solutions.

[56] Assuming the use of typical x86 servers. VMWare 2008
[57] Kevin T. McDonald, Author of "Above the Clouds: Managing Risk in the World of Cloud Computing" and Senior Infrastructure and Cloud Strategist at ICF International notes that server utilization has historically fallen in the low 10 to 20 percent range.
McDonald 2011
[58] Emerson Network Power 2009
[59] Assuming the use of typical x86 servers. VMware 2008.
[60] VMWare 2008.
[61] Turner 2010

## Cloud Computing

Outsourcing server hosting to a network-based cloud computing service is another approach to achieving significant emission footprint reductions. Cloud computing allows an organization to share large-scale IT infrastructure over the Internet with other organizations (public cloud), or over its own network behind a firewall (private cloud).[62] By sharing this infrastructure, an organization can leverage operational efficiencies not possible at most data centers. The primary difference between a private cloud and other cloud models is that a private cloud is contained within an enterprise.[63]

To understand what exactly the 'cloud' means, it is helpful to consider the National Institute of Standards and Technology's concise definition of cloud computing:

> *Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction.*[64]

Cloud computing can offer substantial energy savings because cloud systems closely match server demand and capacity, reducing peak loads, boosting server utilization, and taking advantage of the most efficient state-of-the-art infrastructure designs.[65] As a result, the carbon footprint associated with workloads handled by cloud systems is often significantly smaller than that associated with workloads handled by most locally operated data centers. A recent study conducted by Accenture and WSP Environment & Energy on behalf of Microsoft compared the environmental impacts of providing three of Microsoft's major business applications – Exchange, SharePoint, and Dynamics CRM – through: (1) on-premise-based operations; and (2) Microsoft's cloud-based operations. The Accenture and WSP study found that Microsoft's cloud-based operations offered average carbon emission reductions of

- 90% or more for small operations (per approximately 100 users)
- 60 to 90% for medium operations (per approximately 1,000 users)
- 30 to 60% for large operations (per approximately 10,000 users)[66]

Dozens of organizations provide cloud solutions, and the carbon emission reductions associated with each will vary by the location and design of a given cloud operation. Microsoft, Google, and Amazon are three of the largest cloud computing providers.

The three types of cloud computing services are:

- Software as a service
- Platform as a service

[62] Mell and Grance 2011
[63] Cloud Computing Use Case Discussion Group 2010
[64] Mell and Grance 2011
[65] Microsoft et al. 2010
[66] Microsoft et al. 2010

- Infrastructure as a service

Cloud software as a service (SaaS), or the "application" cloud, enables a consumer to use a provider's specific application through cloud infrastructure (e.g. SalesForce.com). Cloud platform as a service (PaaS), or the "service" cloud, enables a consumer to deploy processor-intense application operations supported by a service provider to the cloud (e.g. Google App Engine[67]). This service model allows consumers to control the deployed applications and sometimes hosting configurations. Cloud infrastructure as service (IaaS), or the "infrastructure" cloud, enables a consumer to deploy nearly any type of software on the cloud and provides a consumer with access to processing, storage, networks and other computing resources (e.g. Amazon Elastic Compute Cloud[68]). The IaaS model allows a consumer to control the deployed software (operating systems, applications) and sometimes networking components such as host firewalls as well.[69] The infrastructure cloud offers the greatest flexibility and access to data center resources without involving the management or control of data center infrastructure.

Security concerns represent one of the largest barriers to more extensive adoption of public cloud solutions by organizations with sensitive information. Public cloud solution providers typically keep the location and security measures of their cloud operations secret, and are still working on technical and contractual solutions to alleviate security concerns without revealing trade secrets or raising the cost of service. Security concerns aside, cloud services offer organizations a cost-effective way to dramatically reduce their data center energy consumption and environmental impact as well as possibly avoid substantial capital investment in infrastructure upgrades or new data center development.

## Supply-Side Energy Efficiency Solutions

### Power Supply

There are a variety of supply-side efficiency solutions. One best practice solution is to improve the efficiency of power delivery components, specifically the uninterruptible power supply (UPS) system. When electricity enters a data center facility, it is routed through the UPS, which serves as a battery backup to protect facility operations from electricity fluctuations and outages, before powering IT equipment.[70] The UPS converts incoming AC electricity to DC to charge batteries (or sometimes a flywheel), after which the DC electricity is converted back to AC before it is delivered to the Power Distribution Unit (PDU). This double conversion results in electricity losses and creates significant waste heat that must be offset by a cooling system. Alternate UPS systems, including line interactive and passive standby systems, operate at higher efficiencies by avoiding this double conversion process. But they do not fully condition the electricity, which leaves IT equipment more exposed.[71]

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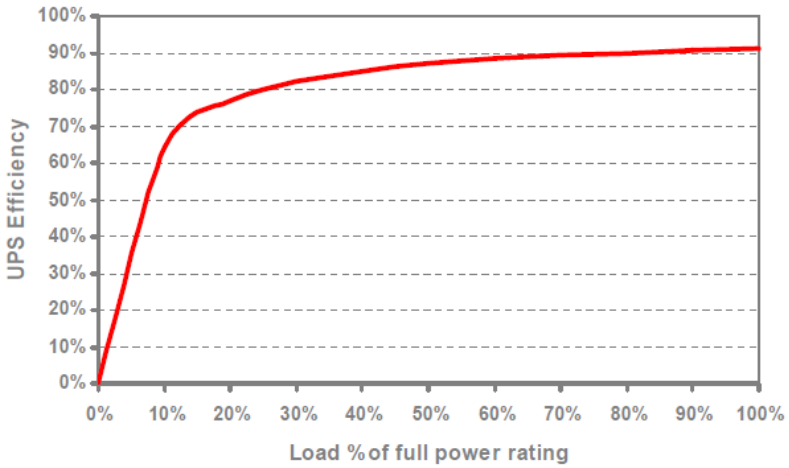
[67] Google App Engine:
http://code.google.com/appengine/docs/whatisgoogleappengine.html (Google 2011a)
http://www.google.com/apps/intl/en/business/index.html (Google 2011b)
[68] Amazon Web Services: http://aws.amazon.com/ec2/ (Amazon Web Services 2011)
[69] Mell and Grance 2011
[70] U.S. EPA 2007b
[71] Emerson Network Power 2009

UPS efficiency primarily varies by UPS design and by UPS utilization. Utilization levels play a key role in determining UPS efficiency, as highlighted in Exhibit 9 below. On average, medium to large data centers have load levels that range from 30% to 70%.[72] At these load levels, standard UPS systems achieve efficiencies between approximately 80% and 90% after accounting for electrical transmission losses.

**Exhibit 9: Effect of Utilization on UPS Efficiency**




Source: Rasmussen 2007, Schneider Electric

UPS efficiency can be improved by increasing the utilization level and raising the voltage of UPS delivery to the PDU.[73] Another way to reduce central UPS energy losses is to replace an old UPS with a new UPS as new systems can achieve efficiencies of 92% to 95%.[74] Some organizations have achieved even higher UPS efficiencies through various strategies. Sun Microsystems (acquired by Oracle) has a data center with three UPS systems that achieve 97% efficiency[75], while Google has decentralized UPS systems that achieve 99.9% efficiency.[76] Google's innovative strategy relies on a customized design that shifts the UPS and battery backup system to the server cabinets. Google supplies AC power directly to server racks and uses a single AC-to-DC conversion.[77] Syracuse University's new Green Data Center (GDC) also uses a single AC-to-DC conversion system to achieve substantial efficiency improvements. The GDC uses gas-fired microturbines to serve as the UPS and high-voltage DC power is delivered directly to servers.[78]

### Cooling and Airflow Management

Data center managers must maintain tight control over temperature and humidity ranges to ensure maximum equipment performance and efficiency. The ASHRAE TC 9.9-recommended

[72] U.S. EPA 2011k
[73] Emerson Network Power 2009
[74] U.S. EPA 2007b
[75] Wirth 2007
[76] Miller 2009c
[77] Miller 2008
[78] Sedore 2010

operating envelope for IT equipment is 64.4°F to 80.6°F, with a humidity range of 41.9°F dew point to 60% RH and 59°F dew point.[79] Climate control systems consume enormous quantities of energy to meet these requirements, and their consumption has only grown with the increasing compaction of IT equipment that has led to higher rack power densities and hotspots. While energy losses associated with cooling vary by data center facility, Amazon estimates that a typical data center with a PUE of 1.7 has cooling losses as high as 33%, suggesting that for every watt used to power a server, 0.56W are used for cooling.[80] The power consumed for cooling is even higher in data centers with a higher PUE.

The basic requirements that must be met to ensure optimum operating conditions for equipment are that (a) appropriately conditioned air should be presented at equipment air intakes, and (b) airflow in and out of the equipment should not be restricted.[81] There are several cooling system configurations that can be used to meet these requirements. This section addresses many of the major strategies used to improve the efficiency of common cooling system configurations through component optimization, free cooling, variable cooling capacity, airflow management best practices, and central control of cooling units.

### *Cooling Systems and Potential Improvements*

All cooling systems are based on the refrigeration cycle, which cools an area by using energy to pump heat away from it. Systems vary based on the cooling medium (refrigerant, water) that is used to transport heat away from the server room, and the condensing medium (air, glycol, water) to which heat is rejected before the cooling medium returns to the room. The systems used in IT environments may be air-cooled, glycol cooled, water-cooled, or chilled water based. Each type of system has its advantages and disadvantages, and it is important to choose the appropriate system and configuration based on data center size, availability requirements, and potential for efficiency improvements.

Air-cooled systems, which use a refrigerant as the cooling medium and air as the condensing medium, are low cost systems with a moderate cooling capacity used mostly in small-to-medium size data centers. These systems can either be split systems or self-contained systems, depending on where the various components of the refrigeration cycle are located. In split systems (also known as direct expansion, DX, systems), the refrigerant carries heat from the evaporator coil and compressor that are in the computer room air conditioning (CRAC) unit, to the condenser coil that is located outside the building. The refrigerant enters the evaporator coil in the server room CRAC unit as a cold low-pressure gas and absorbs heat from the air that is blown over the coil. This decreases the temperature of the air so that it can be used for cooling the equipment. The slightly warmer refrigerant is then compressed in the compressor to further increase its temperature before it is piped to the condenser coil, where it releases heat to the outside air and condenses into a cool liquid. The cooled refrigerant is piped back to the server room and cooled further as it expands as a gas through the expansion valve into the evaporator coil, and the cycle repeats. In self-contained air-cooled systems, all the components of the refrigeration cycle, including the condenser, are inside the CRAC unit, and exhaust air is rejected outdoors or to an

[79] ASHRAE 2008
[80] Hamilton 2009
[81] Rasmussen 2011a

unconditioned space such as above a drop ceiling. Air-cooled split systems are the most commonly used cooling technology in data centers.[82,83]

Glycol-cooled systems use glycol (a mixture of water and ethylene glycol) as the condensing medium and a refrigerant as the cooling medium. All components of the refrigeration cycle are located in the CRAC unit, and the condenser is replaced with a heat exchanger that enables the transfer of heat from the refrigerant to the glycol solution. The glycol is then piped to an outdoor fluid cooler that uses fans to reject heat from the glycol to outside air before the cooled glycol is returned to the heat exchanger. Since glycol collects and transport heat better than air, glycol-cooled systems are smaller than air-cooled systems. These systems are also used in small-to-medium data centers with moderate availability requirements, but are more costly and less common than air-cooled split systems. Also, data center managers are sometimes hesitant to use glycol-cooled systems because they introduce a liquid into the IT environment. [84,85]

Water-cooled systems have the same configuration as glycol-cooled systems, but they use water instead of glycol as the working fluid, and use a cooling tower[86] instead of a fluid cooler to lower the temperature of condenser water. These systems are less common than either air- and glycol-cooled systems, but they have a dual advantage over both systems. The first advantage is that water as a condensing medium absorbs more heat than either air or glycol, and the second is that cooling towers use evaporative cooling to allow the cooling of condenser water to the lower ambient wet-bulb temperature. However, water-cooled systems have high upfront and maintenance costs and, like glycol-cooled systems, introduce a liquid into the data center. They are typically used in conjunction with other systems in data centers of varied sizes with medium to high availability requirements.[87,88]

Chilled water systems use chilled water as the cooling medium and condenser water as the condensing medium. All components of the refrigeration cycle are relocated to chillers that produce chilled water that is pumped to coils in computer room air handlers (CRAHs). CRAHs draw air over the chilled water coils, which absorb heat and cool the air. The water then returns to the chiller, where heat is rejected to a condenser loop that transports heat from the chiller to the atmosphere using the cooling tower. Of all the cooling technologies discussed so far, chilled water systems have the highest capital cost for smaller systems, but have the lowest cost for larger installations. The combination of CRAHs and chillers is more efficient than CRACs, so chilled water systems have the smallest footprint for the same amount of cooling. These systems

[82] PTS Data Center Solutions 2011
[83] Evans 2010b
[84] PTS Data Center Solutions 2011
[85] Evans 2010b
[86] A cooling tower is a device that rejects heat to the atmosphere through the evaporative cooling of water. Water is sprayed onto a spongy material (fill) at the top of the tower and, as it drips down toward the collecting basin, some water evaporates and lowers the temperature of the remaining water. Using a cooling tower, the temperature of water can be lowered to the wet-bulb temperature of ambient air, which is the lowest temperature that can be achieved by cooling a wet surface. This temperature is lower than the dry-bulb temperature, which is the lowest temperature that can be achieved by cooling a dry surface in the same atmospheric conditions.
[87] PTS Data Center Solutions 2011
[88] Evans 2010b

are typically used in medium and large data centers with moderate-to-high availability requirements.[89,90]

One quick way to improve the efficiency of existing cooling systems is to monitor and optimize the operation of their various components. For instance, water chillers should be monitored to ensure that the chilled water that they produce is not below the required temperature of 55°F. This is because chiller efficiency is impacted negatively when the temperature differential between the condenser water and chiller water (the "chiller lift") increases. Also, over-chilled water is often below the dew point that corresponds to the optimum humidity level in data centers and leads to excess condensation and dehumidification in the CRAH units. This decreases their efficiency and cooling capacity.[91] Optimizing the operation of cooling tower fans can also improve chiller efficiency.[92] Cooling tower fans typically circulate to maintain low basin temperature, which is a set temperature at the bottom of the tower, so that the lift is lower and the chiller is more efficient. At some point, however, the energy used by the tower fan is greater than the energy that is saved by further lowering the lift. In such a case, the maximum savings point should be found by installing variable frequency drives and optimizing fan operation based on wet-bulb temperature.[93]

In colder climates, data center managers can take advantage of "free" cooling to decrease the total energy consumed to meet the cooling needs of IT equipment. Free cooling is the use of the outside temperature to directly cool the IT room and supplement or even replace mechanical cooling systems. Building codes in some areas in the Pacific Northwest actually mandate free cooling for all data centers.[94] There are three common strategies for free cooling:

1) In glycol-cooled systems, free cooling can be provided by adding an economizer coil containing cold circulating glycol alongside the evaporator coil in the CRAC unit.[95]
2) Water-side economizers, best suited for regions with wet-bulb temperatures lower than 55°F for 3,000 or more hours a year[96], can be retrofit in chilled-water-cooled data centers to produce chilled water directly from the cooling towers. Water-side economizers can improve efficiency by up to 75% by pre-cooling chilled water before it enters the chiller or even eliminating the need for compressor cooling.[97]
3) Air-side economizers allow cold air from the outside into the data center to directly cool the inside environment.[98] Outside air does not have to be below the data center's cooling set point to improve efficiency; it only needs to be below the exhaust air temperature.[99] Though there is some concern regarding air contamination from the direct use of outside

[89] PTS Data Center Solutions 2011
[90] Evans 2010b
[91] Pacific Gas and Electric Company 2006
[92] Pacific Gas and Electric Company 2006
[93] Parker et al. 2007
[94] Evans 2011
[95] Evans 2010b
[96] LBNL 2006
[97] Water-side economizers can also improve reliability of chillers and decrease maintenance requirements by reducing chiller operation.
LBNL 2006
[98] LBNL 2006
[99] Pacific Gas and Electric Company 2006

air, current research suggests that air filtration may be an adequate measure to mitigate this concern.[100]

Geothermal free cooling, a more expensive and less widely used strategy, can provide efficiency benefits at data centers in areas with low geothermal temperatures. It has been implemented successfully at the American College Testing (ACT) data center in Iowa City, Iowa,[101] and is in planning stages at least two other facilities[102]. A geothermal cooling system consists of a closed loop piping network housed in vertical holes drilled in the earth. The pipes contain either coolant or water as the cooling medium. Heat is carried away from the data center by the cooling medium and rejected to the cool earth that surrounds the piping system before the cooling medium returns to the data center. The ACT data center in Iowa City uses exterior dry coolers as back up for the geothermal system, and switches cooling load to these units if cooler weather makes them more efficient than the primary cooling system.[103]

"Multicool" coils that contain chilled water can also be combined with existing air-, glycol- or water-cooled DX systems to improve their efficiency, especially if the building that houses the data center also produces chilled water for other HVAC purposes. Since such multicool systems provide high redundancy, they can be used even if the building chilled water is not available at all times.[104,105]

Data center managers can also improve efficiency by replacing or supplementing the traditional air cooling systems discussed above with direct liquid cooling systems that pipe chilled water to coils on server racks. The chilled water, which is in very close proximity to equipment exhaust vents, picks up waste heat and transfers it much more efficiently than the room air. Also, heat transfer to a cooling medium on the rack is more efficient than heat transfer in the CRAC or CRAH unit because it takes place at a higher temperature. Direct liquid cooling can also be combined with a water-side economizer to take advantage of free cooling.[106]

### *Improvements in Airflow*

In a conventional legacy data center with chaotic airflow, only 60% of the conditioned air from CRACs and CRAHs actually reaches the IT equipment.[107] Appropriately channeling cool air from AC unit vents to equipment intakes, and hot air from equipment exhausts to AC unit intakes, could significantly reduce the cooling energy footprint. Airflow issues that lower cooling efficiency include:

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[100] LBNL and ASHRAE are examining this issue, but there does not appear to be a consensus on the validity of concerns and potential solutions. See Shehabi et al. 2007, ASHRAE 2009 , and Han et al. 2010
[101] GreenerComputer 2009
[102] Prairie Bunkers, LLC's Data Center Park near Hastings, Nebraska and TierPoint's Liberty Lake Complex near Spokane, Washington
Miller 2009a and Miller 2009b
[103] GreenerComputer 2009
[104] Evans 2010b
[105] Evans 2011
[106] Pacific Gas and Electric Company 2006
[107] Wright Line 2009b

1) Bypass Airflow: Conditioned air that does not reach the cooling of IT equipment, such as when air that is supplied by CRACs and CRAHs is fed back to their intake vents through leakage from areas such as holes under enclosures, misplaced perforated tiles and cable cut-outs. It also includes air that escapes from the room through non-sealed gaps in doors or walls.[108,109]
2) Recirculation: Hot air that is exhausted from IT equipment and drawn back via equipment intakes. Recirculation commonly occurs when there isn't enough supply of conditioned air because the bypass air airflow is large and typically at the highest points of a high density enclosure. Recirculation can raise the temperature of IT equipment up to 15$^{o}$F, which can lead to overheating, damage, and reduced efficiency of IT equipment.[110,111,112]

IT and facilities personnel often attempt to counteract the temperature impacts of these airflow issues by either adding more CRAC/CRAH capacity or decreasing the temperature set point. The attendant changes in cooling system operation can decrease energy efficiency significantly. First, the higher air feed velocities that are required to compensate for bypass air and recirculation require excess fan power. Then, lower return temperatures cause the AC units to operate at reduced efficiency because of the smaller temperature differential between the return air and the refrigerant in the evaporator coil. Cooler return air also loses more water vapor to excess condensation on the cooling coil, leading to a lower cooling capacity and more energy consumption for humidification.[113]

Optimizing the airflow in a data center can yield significant efficiency gains by minimizing bypass airflow and recirculation air. In general, data center managers should ensure that delivery vents are as close to the equipment intake vents as possible, and that the air return vents are as close to the equipment exhausts as possible.[114] Poorly located vents are not uncommon and could erase the benefits of cooling system improvements and airflow management best practices. IT personnel should also try to distribute the IT load evenly in the room. This prevents the creation of high power loads that create hotspots because high power density server racks can "borrow" cooling capacity from adjacent server racks.[115]

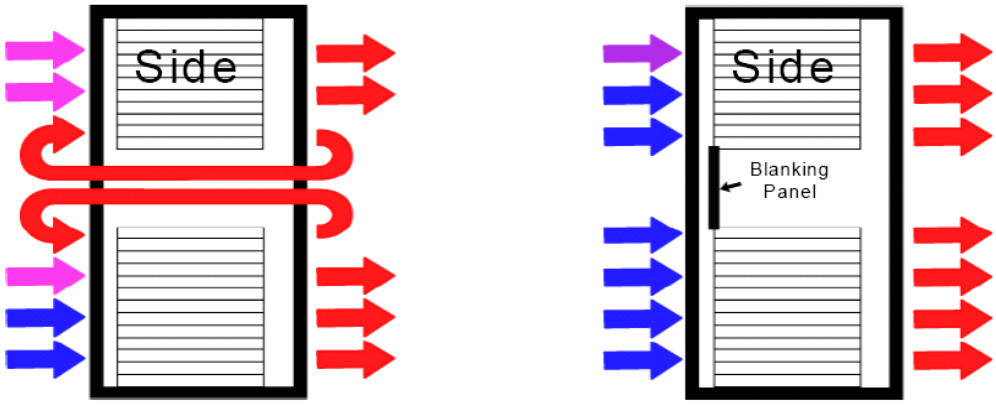
Retrofitting empty rack spaces with blanking panels is an easy, low-cost way to decrease recirculation by increasing the distance between equipment exhausts and intakes (see Exhibit 10).[116] In a data center with short rows and a distributed load, blanking panels can lead to a temperature reduction of 5-15$^{o}$F at the hottest server, which is directly above the empty space in the rack. The temperature reduction in a similar server in a data center with long rows and mostly high-density racks could be up to 20$^{o}$F.[117] Shelves or racks that have open space outside the rails

[108] Sorell 2009.
[109] Wright Line 2009b
[110] Sorell 2009
[111] Wright Line 2009b
[112] Rasmussen 2011a
[113] Rasmussen 2011a
[114] Rasmussen 2011a
[115] Rasmussen 2011a
[116] Rasmussen 2011a
[117] Rasmussen 2011b

should be avoided because they do not present good physical barriers to recirculation and blanking panels cannot fix this issue.[118]

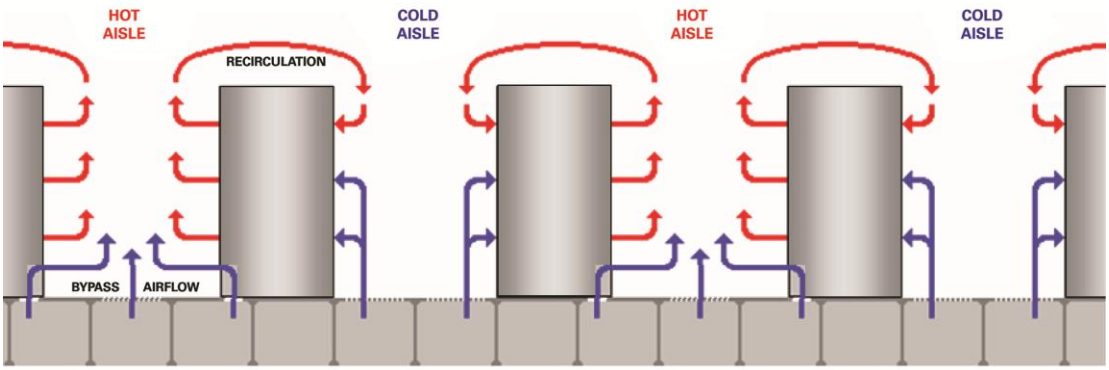
**Exhibit 10: Effect of Blanking Panels on Rack Airflow**




Source: Rasmussen 2011b, Schneider Electric

In new data centers (and, to the extent possible, in existing data centers), racks should be placed in rows such that each row faces the direction opposite to its adjacent rows (see Exhibit 11). This creates hot aisles and cold aisles that physically separate the exhaust air from the intake air. Delivery vents should be placed in aisles where racks face each other (cold aisles) so that conditioned air is delivered to the equipment intakes on either side. Hot air that is exhausted from the backs of the servers into the hot aisle should be evacuated before it mixes with the cold air. This separation between hot and cold air limits bypass air and recirculation.[119,120]

**Exhibit 11: Hot Aisle/Cold Aisle Rack Arrangement**



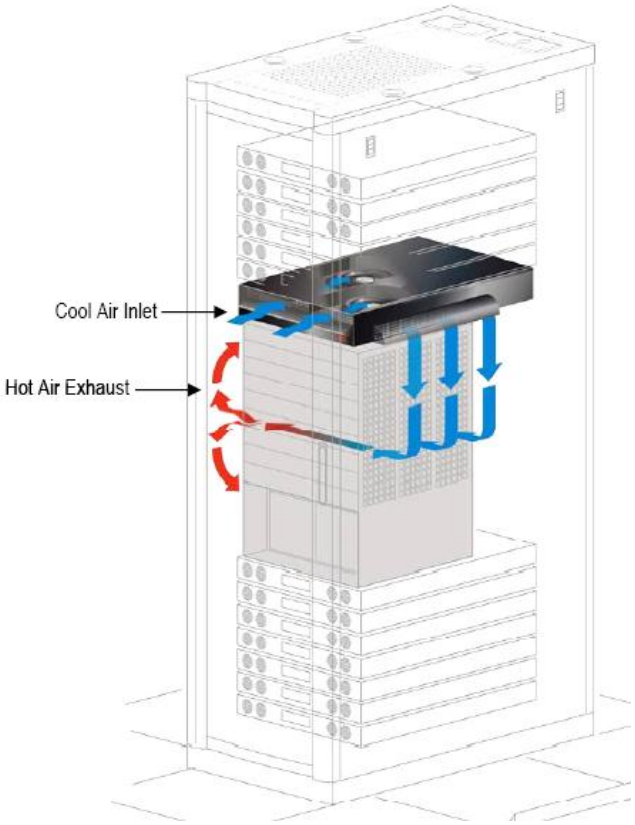

Source: Chatsworth Products 2009, Image courtesy of Chatsworth Products, Inc. (CPI)[121]

[118] Rasmussen 2011a
[119] Michigan Academic Computing Center 2011
[120] Rasmussen 2011a
[121] Chatsworth Products, Inc. (CPI) is a leading manufacturer of systems designed to optimize, store and secure IT infrastructure equipment.

Blanking panels and the hot aisle/cold aisle arrangement are applicable to IT equipment that has a front-to-back cooling airflow and do not work for equipment with side-to-side airflow. Equipment that has side-to-side airflow cannot be placed adjacent to similar equipment because then the intake vent and exhaust vent of the two pieces of equipment will be perfectly aligned leading to high recirculation. This equipment also cannot be mounted easily in an enclosure because the walls of the enclosure would encourage recirculation by presenting high resistance to fresh cold air as well as to exhaust air. Data center managers typically address the cooling needs of equipment with side-to-side airflow by staggering them vertically to prevent the aligning of intake and exhaust vents. However, this leads to some amount of recirculation because there is still dispersion of exhaust air. Supplemental fans could also help with cooling, but they operate by mixing cool and hot air and are not very efficient. The most efficient solution to decrease recirculation in this case is to use in-rack air distribution equipment located right above or right below the side-to-side equipment. The distribution equipment would take in cold air from the front of the rack and redirect it to the side of the equipment that has intake vents, and take hot exhaust air from the equipment and redirect it to the back of the enclosure.[122]

**Exhibit 12: Front-view Perspective of Side-to-side Airflow with In-rack Air Distribution Equipment**




Source: Rasmussen 2010b, Schneider Electric

[122] Rasmussen 2010b

The efficiency benefits of hot aisle/cold aisle arrangements can be further enhanced by retrofitting aisle containment closed loop systems. These systems are designed to maximize the cold conditioned air that is delivered to equipment intakes and the exhaust air that is delivered to the air-conditioning intake by separating hot and cold air using physical barriers that completely enclose at least one type of aisle. Aisle containment can be achieved by physically isolating the entire aisle from the rest of the room, or by using a ducting channel that directs air from the racks to appropriate vents. Compared to legacy data centers where the typical supply and return temperatures are 54$^{o}$F and 70$^{o}$F, data centers with closed-loop aisle containment systems can support temperatures of 68$^{o}$F and 95$^{o}$F.

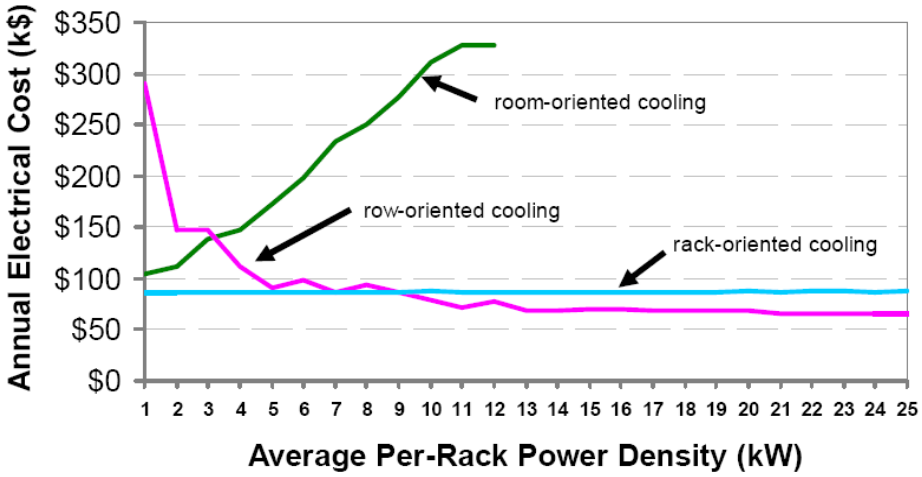
There are two modes for implementing closed-loop systems: cold aisle containment, where cold air is ducted from the precision AC unit to equipment intakes and hot air moves freely through the room, and hot aisle containment where all exhaust from the racks is captured and directed to AC intakes while cold air moves freely through the room.[123] Hot aisle containment is somewhat preferable to cold aisle containment because cold aisle containment is more risky in the case of a power loss and it leads to high ambient temperatures uncomfortable for IT personnel. Hot aisle containment is also more efficient because it presents intake air to the AC units at higher temperatures.[124] Exhaust air can be evacuated from hot aisles either by passive exhaust or assisted exhaust using fans.[125]

Airflow in data centers can also be improved by appropriately designing room-, row- or rack-oriented configurations of CRAC units to match data center requirements. In a room-oriented design, an entire room has one or more CRAC units that operate concurrently. Row-oriented designs assign dedicated CRAC units to each row, and rack-oriented designs place CRAC units in each rack. The placement of room-oriented CRAC units is typically restricted by the physical constraints of the room, and the individual CRAC units are difficult to monitor and coordinate to improve performance unless a central control system is used.[126] Row and rack units are less affected by design constraints or installation variation, and are more efficient because the airflow path length is much shorter and requires less fan power. The short airflow path also leads to lower bypass air and recirculation, and cooling capacity can be varied based on the actual needs of specific rows and racks.[127] Exhibit 13 graphs the annual costs of operation for the three types of designs.

[123] Wright Line 2009b
[124] Niemann et al. 2010
[125] If server exhaust is not strong enough, assisted exhaust risks remixing hot and cold air by drawing in air from the surrounded plenum into the rear rack. To prevent this, only a slightly negative pressure is created at the top of the enclosure and zero static pressure is maintained through the rest of the rack. Wright Line 2009b
[126] Dunlap and Rasmussen 2010
[127] Dunlap and Rasmussen 2010

**Exhibit 13: CRAC Electrical Costs as a Function of Average Rack Power Density**




Source: Dunlap and Rasmussen 2010, Schneider Electric

At low power densities, room-oriented CRAC units actually have an advantage over row-oriented cooling because of the need for CRAC units in each row even though load is light. But the efficiency of room CRAC units suffers at higher densities because CRAC fans have to move air over larger distances and mix more air within the room to prevent hotspots. Efficiency is consistently high and operating costs are consistently low for rack-oriented cooling because the CRAC units are closely sized to the load and unnecessary airflow is avoided. The efficiency of row-dedicated units is poor at low densities because they have significant electrical loss when operated well below their rated capacity. But as density gets higher their performance improves because they are closely coupled to IT loads, have short airflow paths, and have sustained usable capacity at high density.

### *General Improvements*

As noted earlier, lowering the temperature set point in a data room leads to a cascade of effects that decrease efficiency and increase power consumption for cooling. Decreasing bypass air and recirculation effects through careful airflow management enables higher set points, saving four percent of total energy consumption per degree rise in temperature.[128] Data center managers can more confidently increase set points if at-the-rack environmental sensors are used to check that IT equipment inlet temperatures are within specifications.[129] It is also important to ensure that humidity is not too high, because coil condensation in CRAC units lowers their cooling capacity. Humidifiers are also a significant source of heat that has to be offset by the cooling system.[130]

Central control systems that prevent "demand fighting" and vary cooling capacity with load can improve efficiency in server rooms with multiple CRAC units and in data centers with varying demand. Demand fighting occurs when multiple CRAC units in a room have different set points

[128] Miller 2009d
[129] Raritan 2009
[130] Rasmussen 2011a

and operate in opposite modes thereby canceling out each other's effects. Together, non-synchronized units consume more energy than units that operate in unison.[131] For instance, humidifiers in separate CRAC units that aren't set at the same setting or calibrated properly may work to simultaneously humidify and dehumidify a room. This problem can be rectified by setting up both units on a central or coordinated control system.[132,133]

Control systems, such as the Power Assure® Dynamic Power Optimization software, adjust facility resources continuously based on facility utilization so that cooling capacity grows or shrinks based on actual demand. This creates an "energy-proportional" data center where the fixed component of climate control power consumption is as low as possible and the variable component varies with changes in demand.[134]

Since data center cooling systems are sized to handle peak load, which is rarely reached, they are typically not as efficient at partial loads. CRAC fans, which run at a constant peak, can be retrofitted with variable frequency drives (VFDs) to allow speed and power drawn to ramp up and down with load. In chilled water systems, VFDs can provide additional energy savings of about four percent. Technologies such as the Emerson™ Climate Technologies Copeland Digital Scroll™ can also be used to match cooling capacity to load without needing to turn compressors on and off.[135]

Surveys indicate that many cooling and airflow inefficiencies are unintentionally caused by IT and facilities personnel. Educating IT and facilities personnel on the air distribution system and cooling settings is important to avoid compromising improvements in cooling systems. Education sessions are helpful in this regard as are simple measures such as labeling systems. For example, putting labels on hot aisles to identify that they are intended to be hot will ensure IT personnel do not mistakenly believe that the hot aisle is a problem and attempt to decrease its temperature, thus defeating the purpose of the hot aisle/cold aisle system.[136]

### Cogeneration

Data centers are likely candidates for on-site cogeneration – or combined heat and power (CHP) – solutions because of their consistently high electricity and cooling demand. On-site cogeneration has the potential to significantly reduce data center fuel use and GHG emissions by displacing or replacing less efficient grid-electricity or onsite conventional generation used to serve data center demand. Cogeneration systems can achieve relatively high efficiencies of 50% to 80%[137] because they combust a fuel to generate power and simultaneously harness the waste heat from fuel combustion to provide useful heating or cooling. In data centers, the waste heat captured from cogeneration can be used by absorption or adsorption chillers to drive a cooling

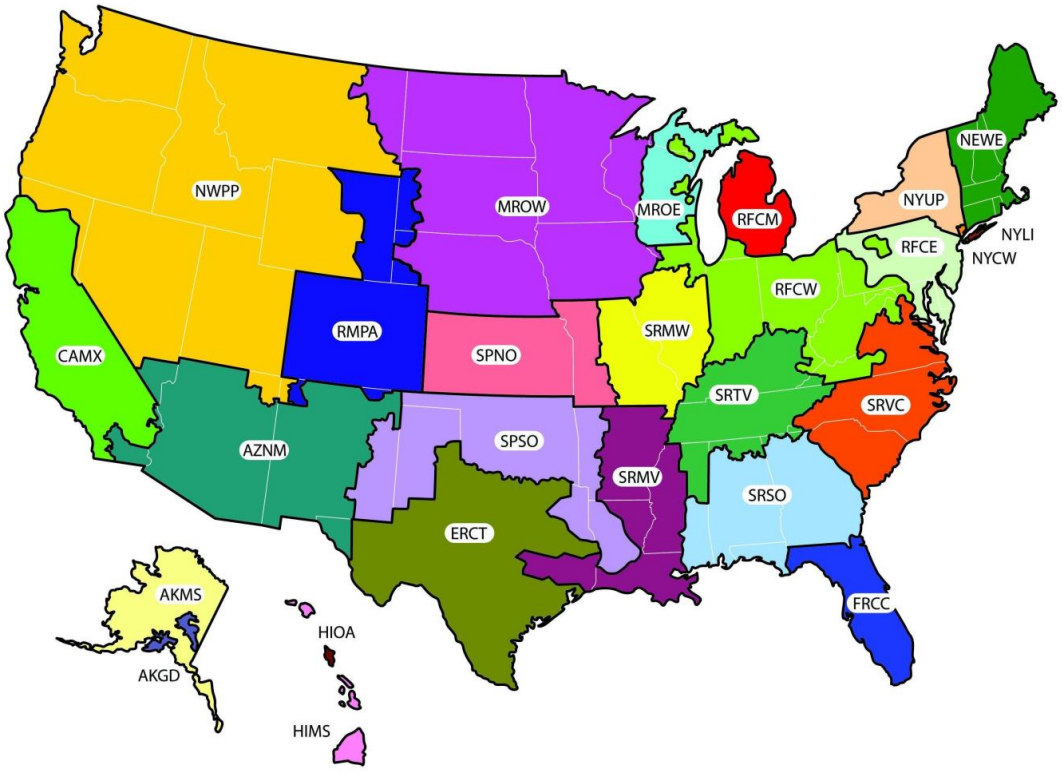
[131] Evans 2010a
[132] Rasmussen 2011a
[133] Alternatively, if a central/coordinated control system cannot be implemented, the problem can be mitigated by setting all units to the same humidity level, calibrating them properly, and increasing the deadband to about +/-5%. Rasmussen 2011a
[134] PowerAssure 2010b
[135] Emerson Network Power 2009
[136] Rasmussen 2011a
[137] U.S. EPA 2011c

system and decrease the electric air conditioning load. Compared to conventional generation, cogeneration uses fuel energy more efficiently because it harnesses energy from waste heat that would have otherwise been exhausted. Producing power at the site of consumption also has the added benefit of avoiding transmission and generation losses associated with grid electricity. As of 2008, 16 megawatts (MW) of cogeneration capacity was installed across 16 U.S. data centers.[138]

On-site cogeneration at efficient data centers can provide primary energy savings of 4% to 16% and GHG emission reductions of 8% to 20%.[139] Data centers that have not yet implemented efficiency best practices will typically see larger savings from on-site cogeneration because they have higher total energy demand than efficient data centers. A key determinant of the emission reductions achieved through cogeneration is the regional emission factor of the grid-sourced electricity being displaced. The grid emission factor represents the average GHG emissions per MWh of generation in the regional grid system in which the renewable project is located, and can be obtained from the U.S. Environmental Protection Agency's eGRID database.[140] A cogeneration system located in a region with a high grid emission factor will yield greater emission reductions than would a system located in a region with a low grid emission factor. The exhibit below indicates the location of each eGrid subregion.

**Exhibit 14: EPA eGrid Subregion Map**




Source: U.S. EPA 2010a[141]

[138] U.S. EPA 2008
[139] ICF International 2009
[140] EPA eGrid Database: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html (U.S. EPA 2011b)
[141] U.S. EPA 2010a

Since cogeneration is an efficiency measure, it tends to lower data center PUE and CUE.[142,143] Qualcomm, a wireless telecommunications R&D company that has installed two cogeneration systems with a combined capacity of 6.9 MW at its facility in San Diego, California, estimates that the systems reduce demand for grid electricity by 14 million kWh per year and decrease the company's overall carbon emissions by 12%.[144]

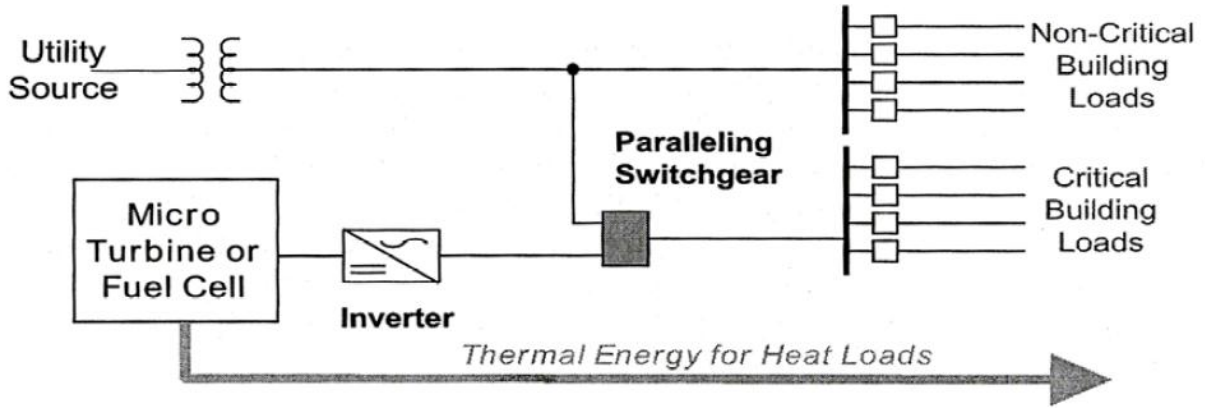
Integrated cogeneration systems include a prime mover (heat engine), generator, heat recovery, and electrical interconnection. The entire system is typically identified by the prime mover, which could be a high-volume technology such as a reciprocating engine, combustion or gas turbine, or a lower-volume technology such as fuel cells or microturbines. Larger-volume prime movers are more economic for cogeneration systems that are over 5 MW. Lower-volume technologies are more appropriate for loads below 5 MW. Various fuels, including natural gas, oil, coal and alternative fuels, can be combusted in the heat engine to drive the electric generator. On-site cogeneration can be classified as a secure source of supply under current data center tier standards if the facility also has on-site fuel storage.[145]

Data centers with on-site cogeneration typically use cogeneration as the primary power source and employ a utility feed through the UPS system as a back-up power source. Standby diesel generators or a second utility feed can provide secondary back-up for critical applications.[146] The figure below provides a schematic representation of the integration of cogeneration into a data center power system. The waste heat from fuel combustion is channeled to absorption or adsorption chillers which convert the thermal energy to provide chilled water to Computer Room Air Handlers (CRAHs) for computer room cooling. These chillers are backed up by electric chillers that are run as part of the critical load.[147,148]

[142] 7X24 et al. 2010b
[143] In PUE accounting, inputs to the CHP system are included in the total energy or power (numerator), but the outputs are not included. A global taskforce that includes the U.S. Department of Energy's Save Energy Now and Federal Energy Management Programs, U.S. Environmental Protection Agency's ENERGY STAR Program, European Commission Joint Research Center Data Centers Code of Conduct, Japan's Ministry of Economy, Trade and Industry, Japan's Green IT Promotion Council, and The Green Grid recommends that, for purposes of PUE calculation, 67% of input energy to the CHP system should be allocated to primary generation, and 33% to secondary generation.
U.S. DOE et al. 2011a
[144] U.S. EPA 2008
[145] ICF International 2009
[146] ICF International 2009
[147] ICF International 2009
[148] U.S. EPA 2008

**Exhibit 15: Schematic of Cogeneration Integrated with Data Center Power System**




Source: ICF International 2009, Prepared for ORNL

Further information on the optimal design and implementation of on-site cogeneration systems is available in the *Opportunities for Combined Heat and Power in Data Centers* report prepared for the Oak Ridge National Laboratory by ICF International, published in March 2009. U.S. EPA's CHP Partnership[149] also provides technical assistance for the development of cogeneration projects.

On-site cogeneration systems can yield several benefits in addition to environmental footprint reduction. On-site cogeneration with absorption cooling can often decrease energy costs by providing power that is cheaper than grid electricity and displacing electric air conditioning load for cooling. Qualcomm's annual energy cost savings from its cogeneration systems have been as high as $775,000.[150] Continuously operating cogeneration systems can also reduce the amount of battery backup that is needed to be built in to premium power systems.

On-site cogeneration can improve data center reliability because it acts as an alternate source of electricity to protect critical functions against longer-term grid outages during which UPS and battery systems cannot provide sufficient power. Compared to emergency backup generators that have to be started up in the case of an outage, cogeneration systems provide additional reliability because they can operate continuously.[151] Cogeneration systems can enable rapid facility upgrades or expansion by supplying higher power demand that cannot be met by local utilities in the near-term. Reducing external power demand by adding on-site cogeneration also decreases the additional utility infrastructure and associated costs that may be needed in new or expanded data centers.[152]

On-site cogeneration installations, especially those powered by cleaner fuels, may benefit from cost reductions or revenue streams from state and federal incentives or through the sale of commoditized environmental benefits.[153] The three key types of programs available for

[149] U.S. EPA Combined Heat and Power Partnership: www.epa.gov/chp (U.S. EPA 2008)
[150] U.S. EPA 2008
[151] U.S. EPA 2008
[152] U.S. EPA 2008
[153] Organizations that sell commoditized environmental benefits cannot claim the green attributes of their CHP systems, but still receive the cost and reliability benefits.

monetization of environmental benefits from cogeneration are (i) cap and trade programs, (ii) offset programs, and (iii) renewable energy certificate (REC) programs (discussed in Chapter 3). The cap and trade programs that can provide revenue to cogeneration installations in the US include the Regional Greenhouse Gas Initiative, the Western Climate Initiative, and the $NO_x$ Budget Trading Program. Offset programs[154] include the New Source Review program that applies in all areas of the country that are not in attainment with the National Ambient Air Quality Standards (NAAQS) and $CO_2$ offset programs in states such as Oregon and Washington. Depending on their location, facilities can also generate white tags or renewable energy certificates (RECs) from cogeneration that can be certified for sale in state renewable portfolio standard (RPS) compliance markets and voluntary renewable energy markets. Compliance markets generally offer substantially higher prices for the environmental attributes of cogeneration systems than do voluntary markets. The exhibit below provides a list of the 14 states with renewable portfolio standards that include cogeneration as an eligible technology.

**Exhibit 16: States that Include Cogeneration as an RPS Eligible Technology**

| | | |
|---|---|---|
| Arizona[a] | Michigan | Pennsylvania |
| Colorado | North Carolina | South Dakota |
| Connecticut | North Dakota[b] | Utah |
| Hawaii | Nevada | Washington |
| Massachusetts | Ohio | |

(a) Only CHP systems that use renewable fuels are eligible in Arizona, fossil-fueled CHP systems are not eligible.
(b) North Dakota's Energy Portfolio Standard is a goal, not a mandatory requirement.
Source: U.S. EPA 2011g

White tags are the energy efficiency equivalent of a REC (also known as a green tag) and represent 1 megawatt hour of conserved energy, whereas a REC represents 1 megawatt hour of renewable energy generation. Whether the registered environmental attributes of a cogeneration system are considered white tags or RECs will depend on the market in which the commodities are traded, the state in which the system is located, and the generation fuel type (e.g. natural gas v. biogas). Data center energy efficiency improvements such as installing more efficient lighting[155], an energy management system, or replacing a chiller may also generate white tags.[156] White tags are currently eligible to be sold to utilities and retail suppliers in Connecticut, Pennsylvania, and Nevada to help them meet the states' energy efficiency resource standards.[157] Compliance and voluntary market demand for white tags is significantly lower than demand for compliance and voluntary RECs. Neuwing Energy Ventures, Nexant and Sterling Planet are among the companies that broker white tags.[158]

[154] Carbon offsets are discussed in further detail in Chapter 4.
[155] IBM, for example, has sold white tags generated by installing more efficient lighting at a data center in Connecticut.
Wood 2008b
[156] Sterling Planet 2009
[157] Wood 2008a
[158] Wood 2008a and Cohn 2008

The various environmental revenue streams for cogeneration vary widely in their structure and amount. EPA's CHP Partnership maintains an up-to-date list[159] of the state and federal incentives and favorable regulatory treatment available to cogeneration installations. The Database of State Incentives for Renewable and Efficiency (www.DSIREUSA.org)[160] and OpenEnergyInfo[161] also provide detailed information on available financial incentives.[162]

Some economic barriers pose challenges to the deployment of cogeneration systems at data centers. Volatility in fuel prices can increase the financial risks associated with on-site cogeneration. Also, larger data centers, which tend to be located in areas that have lowest energy costs or outside states with the most stringent renewable energy standards, often cannot take advantage of robust revenue streams from compliance RECs to improve the financial return from on-site cogeneration.

There are also some unresolved questions about the reliability benefits of on-site cogeneration. Since failure modes of cogeneration systems are not as completely known as those for UPSs, battery storage and standby diesel generators, data center operators are sometimes reluctant to use on-site cogeneration in data centers that require ultra-high reliability. Moreover, gas-fired cogeneration systems are not currently recognized as secure supply sources under the *Tier Classification* because the fuel is not stored on-site.[163]

Organizations that implement highly efficient cogeneration systems at their facilities can receive public recognition for their efforts. EPA's CHP Partnership awards the ENERGY STAR® CHP Award to cogeneration projects that consume at least 5% less fuel than state-of-the-art separate heat and power generation. Partners in the program also receive a CHP Partner Certificate, are allowed to include the EPA's CHP Partnership logo in sales, marketing and advertising materials, and can benefit from various communication opportunities that are available through the program.[164]

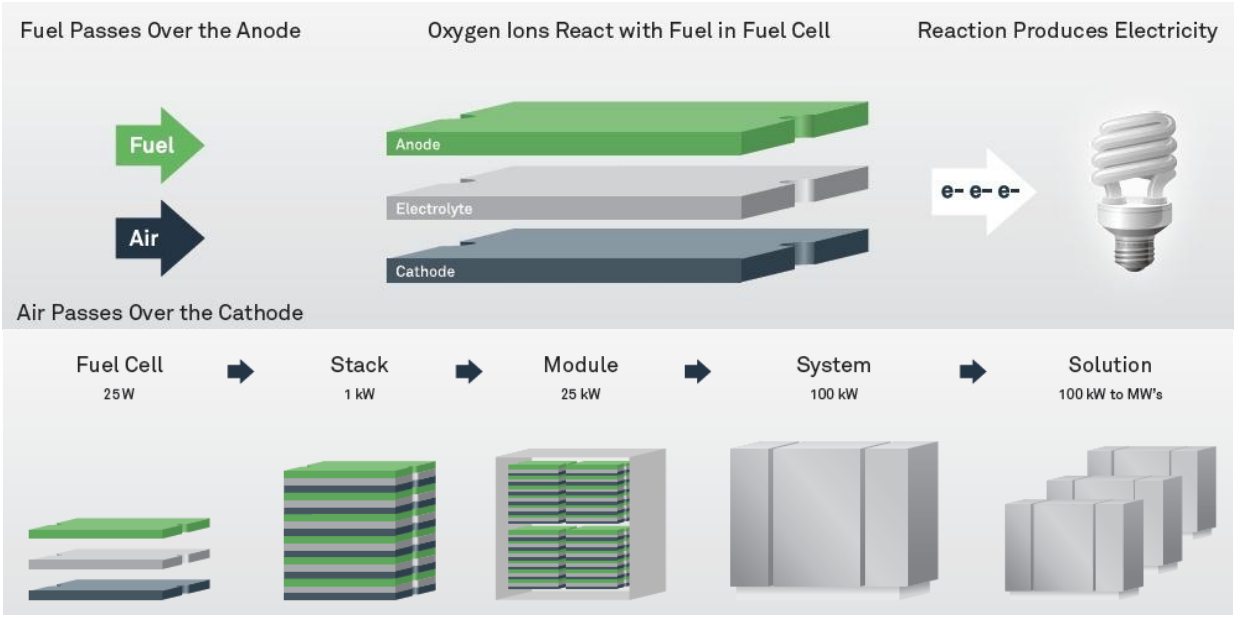
### Hydrogen Fuel Cells

On-site energy generation using hydrogen fuel cells has become increasingly popular in recent years. Fuel cells are electrochemical energy conversion systems that convert hydrogen (typically derived from natural gas) and oxygen into water to produce electricity.[165] The exhibit below provides a simple overview of this process and highlights how fuel cells can collectively provide hundreds of kilowatts of energy.

[159] U.S. EPA 2011d
[160] DSIRE Home Page: www.dsireusa.org (U.S. DOE et al. 2011c)
[161] OpenEnergyInfo Home Page: www.OpenEI.org (NREL 2011b)
[162] ICF International, on behalf of the U.S. Department of Energy, provides a database of existing CHP systems: http://www.eea-inc.com/chpdata/index.html (ICF International 2011)
[163] U.S. EPA 2008
[164] U.S. EPA 2011f
[165] Hydrogen for the process is extracted from hydrocarbon fuels such as natural gas and biogas through a process called reforming in which high-temperature steam is reacted with the fuel to release hydrogen.

**Exhibit 17: Fuel Cell Electricity Generation Overview**



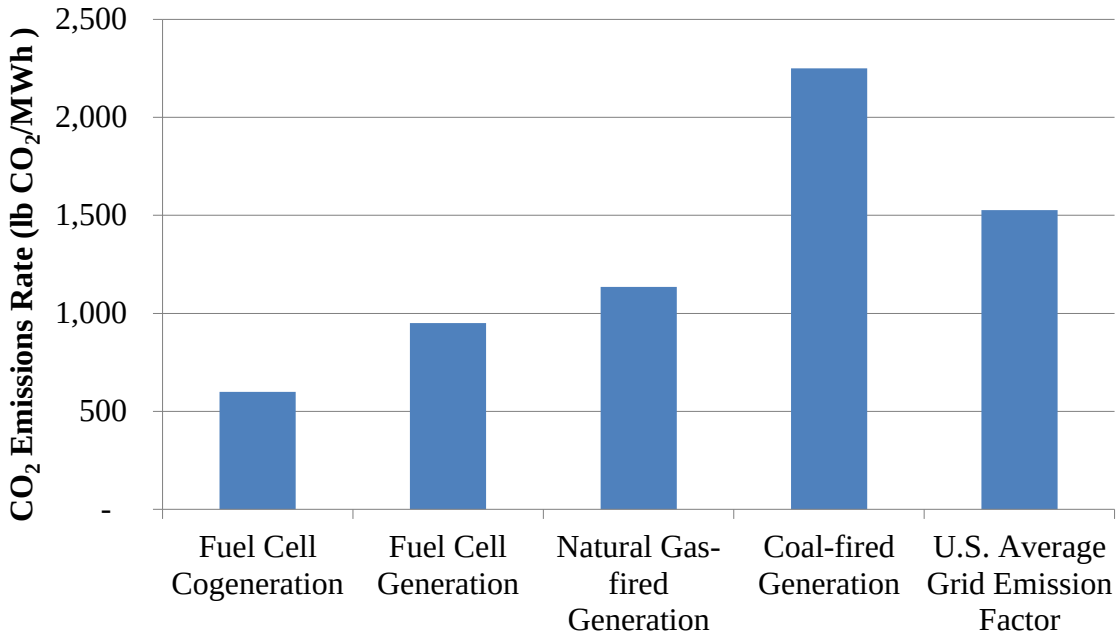

Source: Bloom Energy 2011b

Fuel cell energy generation is very efficient relative to conventional generation systems because fuel cells use the chemical energy of the fuel directly rather than through combustion.[166] Fuel cells that do not take advantage of cogeneration achieve thermal efficiencies of 40% to 50% while fuel cell cogeneration systems achieve thermal efficiencies of 80% to 90%.[167] Because of these higher efficiencies, fuel cell power generation is less emission intense than the electricity provided via the power grid in most states. The exhibit below highlights how the $CO_2$ intensity of fuel cell generation with cogeneration is less than half that of the U.S. average grid emission factor and roughly a quarter of coal-fired generation $CO_2$ intensity. In instances where fuel cells are powered by renewable fuels (such as biogas), $CO_2$ intensity is presumed to be zero.[168]

[166] Fuel Cells 2000 2010
[167] The Connecticut Center for Advanced Technology 2010
[168] Physical delivery of biogas to an on-site generation system (via a dedicated pipeline or by other transport methods) may not be feasible. However, in some instances it may be possible for organizations to still claim green benefits of biogas power generation if they enter into a bilateral contract to procure biogas that is upgraded and transported via the same transmission and distribution network as the natural gas that is consumed on-site for power generation. The additional biogas in the transmission and distribution network may not be used exactly at the site of generation, but it will replace the natural gas consumed at some other facility that draws from the same network. Such a strategy has been implemented in some states to produce RECs eligible to meet renewable portfolio standards.

**Exhibit 18: Illustrative Comparison of Power Generation and Electric Grid $CO_2$ Emission Rates**



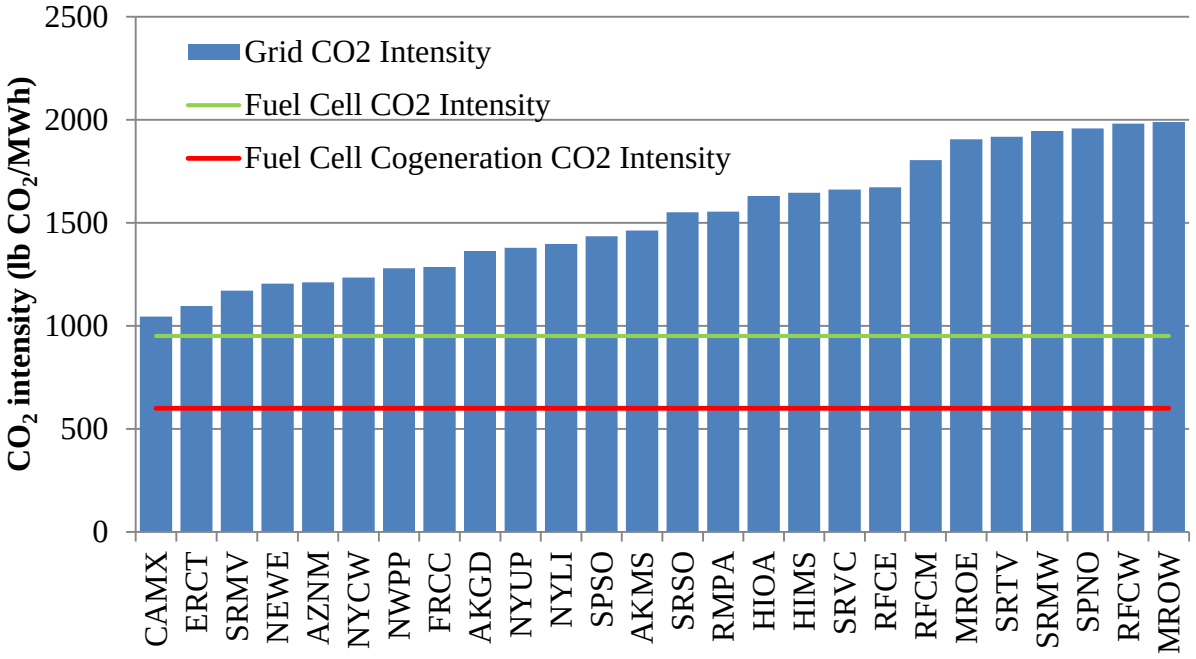

Sources:
(a) Bloom Energy 2011a
(b) FuelCell Energy 2011
(c) UTC Power 2011[169]
(d) U.S. EPA 2007a (Natural gas-fired generation and coal-fired generation emission factors)
(e) U.S. EPA 2010a (National grid emission factor)

The extent to which an organization can reduce its $CO_2$ emissions using a fuel cell cogeneration system varies by the grid emission factor of the region in which it is located. The exhibit below compares the $CO_2$ emissions associated with electricity sourced from fuel cell generation systems (with a natural gas feedstock) with the $CO_2$ emissions associated with the consumption of grid-sourced electricity in different U.S. regions. Fuel cell cogeneration system savings range from 43% to 70%, with an average savings of 60%. Stand-alone fuel cell system savings range from 9% to 52%, with an average savings of 35%.[170] A fuel cell generation system located in the California area would offer the lowest emission reduction benefit while a system in the upper Midwest would offer the highest emission reduction benefit.

[169] The $CO_2$ emission rates provided for standalone fuel cell system reflect an average of the emission rates provided by Bloom Energy (773 lb $CO_2$/MWh), FuelCell Energy (980 lb $CO_2$/MWh), and UTC Power (1100). The $CO_2$ emission rate provided for the illustrative fuel cell cogeneration system is based on FuelCell Energy estimates for its DFC3000 system.
[170] An organization that replaces an existing on-site fossil fuel-fired generation system with a fuel cell cogeneration or standalone fuel cell generation system may realize greater $CO_2$ savings than indicated by the EPA eGrid grid emission factor estimates.

**Exhibit 19: Fuel Cell Generation $CO_2$ Emissions Rate vs. Electric Grid $CO_2$ Intensity by EPA eGrid Subregion**




Sources:
(a) Bloom Energy 2011a
(b) FuelCell Energy 2011
(c) UTC Power 2011[171]
(d) U.S. EPA 2010a (National grid emission factor)
Note: Natural gas feedstock assumed for illustrative fuel cell systems[172]

Fuel cell systems are expensive relative to conventional on-site generation systems. Illustrative unsubsidized upfront costs include $7,000-$8,000/kW for the Bloom ES 5000 Energy Server[173] and approximately $5,500/kW for the FuelCell Energy DFC3000.[174] In 2010 the investment bank Lazard Ltd. estimated that after accounting for federal tax incentives, the levelized cost of

[171] The $CO_2$ emission rates provided for standalone fuel cell system reflect an average of the emission rates provided by Bloom Energy (773 lb $CO_2$/MWh), FuelCell Energy (980 lb $CO_2$/MWh), and UTC Power (1100). The $CO_2$ emission rate provided for the illustrative fuel cell cogeneration system is based on FuelCell Energy estimates.
[172] Some organizations power their on-site generation system(s) with biogas (from sources such as landfills or manure digesters) in which case the generation is assumed to have no $CO_2$ emissions.
[173] Bloom ES 5000 Cost: Jenkins 2010
[174] FuelCell Energy DFC3000 Cost: Lazard 2009.
To correctly compare the DFC3000 and the Bloom ES 5000 capital costs, the DFC3000 cost estimate (provided by Lazard) has been adjusted to reflect the system cost prior to accounting for the 30% federal investment tax credit (ITC). In addition, the DFC3000 2009 cost estimate is converted to 2010 nominal dollars since the Bloom ES5000 capital cost estimate is provided 2010 nominal dollars. Lazard does not specify that the fuel cell capital cost estimate it provides is for a FuelCell Energy DFC3000 system; however, it is highly likely that the cost estimate is that of the FuelCell Energy DFC3000 system because Lazard's assumed fuel cell performance factors (including capacity factors and heat rate) are effectively identical to those advertised for the FuelCell Energy DFC3000. These performance factors are typically unique to a particular system design, so it is unlikely that Lazard paired cost assumptions from a different manufacturer with the performance attributes of the DFC3000.

generation from fuel cells ranged from 11¢/kWh to 24¢/kWh.[175] Available market information suggests that the low end of Lazard's estimate may still be out of reach.

In 2008 and 2009 the Connecticut Department of Public Utility Control approved several contracts with proposed fuel cell projects (without cogeneration). These projects ranged in size from a few megawatts to over a dozen megawatts, and all used the FuelCell Energy DFC 3000 model with natural gas feedstock.[176] Only one of these approved projects has been developed to date, suggesting that the original contract prices are insufficient to attract affordable financing and advance development.

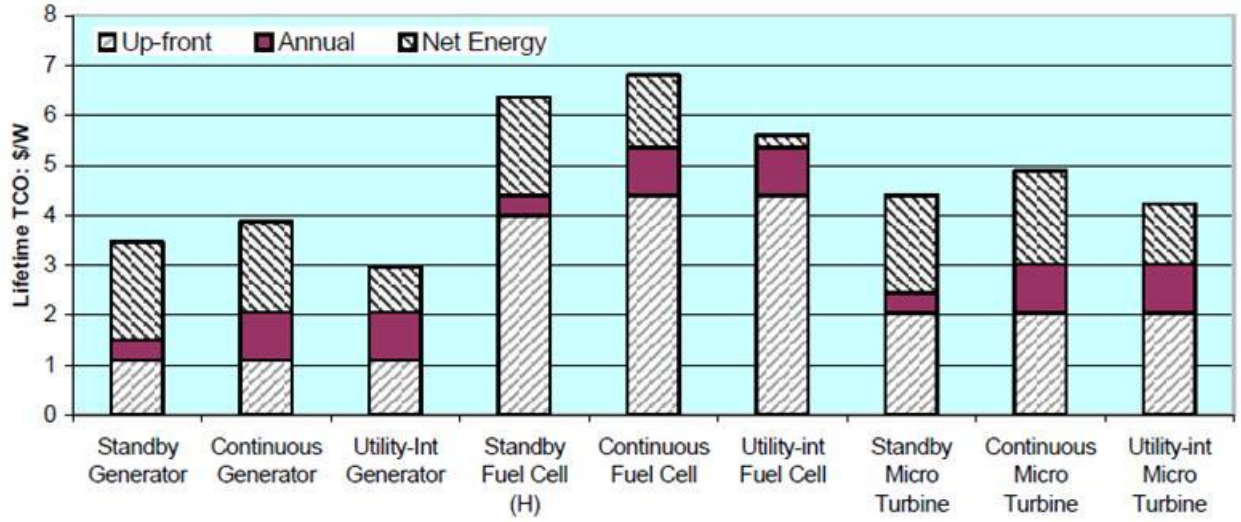
The primary barriers facing fuel cell development are fuel price fluctuations, potential GHG regulation, and high upfront costs. Take, for example, the proposed 3.2 MW Cube Fuel Cell project in Danbury, Connecticut. Raising the assumed cost of natural gas for the project from $5/MMBtu to $10/MMbtu would raise the implied levelized cost of the system by over 4¢/kWh.[177] And if federal GHG regulation that included a $20/Mt tax on $CO_2$ emissions were passed, the cost of the same project in a given year would rise by an estimated 1¢/kWh, an amount that seems insignificant but would actually raise annual operating costs by over $260,000.[178] At present, however, neither natural gas price fluctuation nor $CO_2$ policy risks are major concerns. Natural gas prices are currently very low (around $4/MMBtu) and are expected to remain reasonably low due to unprecedented growth in shale gas drilling that is dramatically expanding market supply. In addition, it appears unlikely that Congress will pass federal GHG policy to tax $CO_2$ emissions in the near to mid-term.

Currently, the greatest discrepancy between fuel cell generation systems and conventional on-site generation systems is the upfront cost. As shown in Exhibit 20 below, fuel cell systems remain substantially more expensive than conventional on-site generation technologies.

[175] Lazard 2010; for older but more detailed cost estimates see Lazard 2009
[176] Projects selected through Connecticut's Project 150: CT Energy Info 2011
[177] Author analysis. Assuming an average heat rate of 8241 Btu/KWh (Connecticut DPUC 2011b)
[178] Assuming an annual average capacity factor of 95% (Lazard 2009) and an average heat rate of 8241 Btu/KWh (Connecticut DPUC 2011b)

**Exhibit 20: Total Cost of Ownership Comparison between On-site Generation Systems**




Source: Rasmussen 2010a, Schneider Electric
Note: State incentives not included

Fuel cell projects are eligible to receive a 30% federal investment tax credit (ITC) that is applied against the upfront project capital cost. In addition, many states offer incentives that could substantially improve the economic viability of some fuel cell projects. For example, California has a rebate program that offers fuel cell projects between $2.50/watt and $4.50/watt depending on the fuel used.[179] Also, the Delaware Senate passed a bill this June to reclassify fuel cell systems that use natural gas feedstock as eligible to meet the state RPS, and specifically the RPS solar carve-out.[180] The measure would allow fuel cell producer Bloom Energy, which proposed[181] a 30 MW fuel cell installation in Delaware, to contribute 1 REC or 1/6 of a solar REC (SREC) for every 1 MWh of generation to the state RPS. Delaware Tier 1 RECs, like most other Tier 1 compliance RECs in the Mid-Atlantic region, trade at around $1/MWh[182], while Delaware SRECs currently trade at approximately $100/MWh.[183,184]

[179] U.S. DOE et al. 2011d
[180] Nathans and Livengood 2011
[181] State of Delaware 2011a
[182] The PJM marketplace is currently experiencing a substantial supply overhang which has driven down Tier 1 REC prices to unprecedented lows. REC prices will very likely rebound as regional Tier 1 renewable energy generation requirements ramp up in the next few years and the market comes into balance. Current market prices are sometimes available in the PJM GATS REC tracking system's "Bulletin Board Purchase Request" webpage: https://gats.pjm-eis.com/myModule/rpt/myrpt.asp?r=204&TabName=Bulletin+Board+Purchase+Requests (PJM Environmental Information Services 2011)
For an overview of historical Tier 1 REC prices in numerous REC markets, see Bloomberg New Energy Finance 2010
[183] SREC Trade 2011
[184] Using the proposed fuel cell SREC contribution ratio, it appears the Bloom fuel cell project could produce the same quantity of SRECs as would approximately 32 MW of solar PV capacity (assuming a 95% fuel cell capacity factor and a 15% solar PV capacity factor). The bill would set a cap (with some exceptions) on the quantity of fuel cell-sourced SRECs that a utility can apply towards its SREC compliance requirement to 30% of a utility's annual requirement. For more information about Delaware proposal (SB 124) bill, see State of Delaware 2011b

In the past, fuel cell installations have been relatively limited due to high upfront costs, but the average cost of fuel cell systems dropped nearly 40% between 2002 and 2010.[185] Assuming costs continue to decline, the U.S. could see substantial new fuel cell development. Currently there are nearly 500 existing and planned U.S. fuel cell installations, roughly two dozen of which are fuel cell cogeneration systems. Existing fuel cell cogeneration systems are located at sites such as residential, hospitality, fitness, educational, water treatment, government, and communications facilities and predominantly found in California and the Northeastern U.S.[186]

## Communicating Energy Efficiency Improvements

Investing in energy efficiency is increasingly seen as the minimum effort that companies with large energy and carbon footprints should make to decrease their environmental impact. This perception, combined with concerns regarding the authenticity and public acceptance of many other greening solutions, has made energy efficiency the logical first step in any organization's greening strategy.

Organizations can pursue several certifications and awards to gain recognition for existing data centers that have made significant efficiency improvements and new data centers that have been built to high efficiency standards. These awards are typically be announced in highly publicized press releases, and several recognition programs also provide marketing and branding materials. Members of The Green Grid (TGG) that that register their PUE results with TGG can gain visibility through listings on the website, and those that provide third-party validation of their PUE are eligible to certify their performance and be considered for future TGG recognition programs.[187] The American Council for an Energy Efficient Economy (ACEEE) awards the Champion of Energy Efficiency Awards annually to industry leaders for their contributions to the field of energy efficiency.[188]

Organizations could also consider becoming ENERGY STAR partners and applying for the ENERGY STAR label. This label is awarded to standalone data centers or to buildings with large data centers that perform in the top quartile of their peers.[189] Facilities could also take the ENERGY STAR Challenge to decrease their energy use by 10%.[190] The ENERGY STAR label has been awarded to eight data centers so far. A list of these data centers along with descriptions of their efficiency strategies is available online at the ENERGY STAR Labeled Building and Plants Database.[191]

Several data centers have also applied for and received the U.S. Green Building Council's prestigious LEED certification. The American College Testing (ACT) data center in Iowa City, Iowa, was the first U.S. data center to be awarded the LEED-Platinum rating, in recognition of its highly efficient HVAC system with geothermal free cooling and the recycled content that was

[185] The Connecticut Center for Advanced Technology 2010
[186] Fuel Cells 2000 and U.S. DOE Hydrogen Program 2011
There are nearly 1100 total fuel cell installations worldwide (Fuel Cells 2000 2011)
[187] The Green Grid 2011
[188] ACEEE 2011
[189] U.S. EPA 2011h
[190] U.S. EPA 2011l
[191] U.S. EPA 2011i

used in its construction. IBM's Leadership Data Center in RTP, North Carolina, and eBay's Topaz facility in South Jordan, Utah, have been awarded the LEED-Gold certification. Companies that demonstrate their environmental commitment through innovative efficiency improvements and LEED certification of their data centers have enjoyed very positive press coverage.[192]

**Exhibit 21: Sample Energy Efficiency Solution Providers**

| | |
|---|---|
| **Efficiency Strategy** | ICF International, 42U, Cadmus |
| **Monitoring Solutions** | Raritan, Emerson Network Power, AccelOps, 42U, Onset |
| **Equipment & Installation** | Schneider Electric, Wright Line, Liebert (Emerson), Raritan |
| **Design, Construction, Equipment Integration** | Emerson Network Power, Skanska, Lee Technologies |
| **Virtualization and Cloud Solutions** | VMWare, CA, Citrix, IBM, Microsoft, Google, Amazon, HP |
| **CHP Design and Equipment** | Cummins, Caterpillar, GE, Ameresco |
| **Fuel Cells** | Bloom Energy, Fuelcell Energy, UTC Power |

[192] Some examples of positive press coverage: http://www.zdnet.com/blog/datacenter/ebay-datacenter-gets-leed-gold-certification/568 (Chernicoff 2010), http://www.greenbiz.com/news/2009/08/12/act-lands-first-leed-platinum-rating-data-center-us (GreenerComputer 2009), http://www.ibm.com/ibm/environment/news/rtp_ldc_leed_2010.shtml (IBM 2010), http://blog.gsmiweb.com/2010/11/top-10-leed-certified-data-centers-part-1/ (Skraby 2010a), http://blog.gsmiweb.com/2010/12/top-ten-tueday-leed-data-centers-part-ii/ (Skraby 2010b), http://www.fanniemae.com/newsreleases/2010/5002.jhtml (Fannie May 2010)

# Chapter 3 Renewable Energy

## Introduction

Investing in renewable energy has become an increasingly popular way for organizations to meet sustainability goals. Images of wind turbines, solar panels, and other renewable generators are now closely associated with environmental stewardship. Choosing among the array of renewable energy investment options, however, can be complicated. Recent criticism of the value and benefits of renewable energy certificates, the most popular form of investment in renewable energy, further complicates the selection process. The following sections outline common renewable energy investment options and explore the advantages and disadvantages of each.

Prospective renewable energy investors should understand the benefits of renewable energy and how those benefits are quantified. One of the key environmental benefits of renewable energy is that it decreases the demand for current or new conventional generation and prevents associated greenhouse gas (GHG) emissions from existing or planned fossil fuel-fired power plants. Emission reductions, expressed in terms of metric tons of $CO_2$ equivalent ($MtCO_2e$), are a function of the reduction in output from fossil fuel generators due to an increase in generation from a renewable energy project connected to the same grid system. Hence, the emission reduction benefits of renewable energy are "indirect," because renewable generation occurs at one place on the grid and emission reductions occur at another.

Renewable energy projects are described as "additional" if they have been determined to be beyond business-as-usual (BAU), i.e. if the projects are not already planned or in development, and if they would not have been built if not for expected investment or revenue from the sale of their green attributes.[193] On-site renewable energy installations are regularly accepted to be additional, but other renewable energy investment options do not always offer clear additionality.

Exhibit 22 provides an overview of the types of renewable energy investment options. The options vary in cost, complexity, directness of support, clarity of additionality, and PR value.

[193] Additionality is also discussed in Chapter 4 as a key criterion for the evaluation of carbon offset projects.

**Exhibit 22: Range of Renewable Energy Investment Options[194]**


Developing on-site projects (Option 1) demonstrates strong support for renewable energy, as does providing direct financial support to specific off-site renewable energy projects through an arrangement with a project developer (Option 2). Off-site projects are typically much larger than on-site projects. Purchasing high quality carbon offsets sourced from renewable energy projects (Option 3) is more scalable and less expensive than the first two options and, in some instances, may offer more support to renewable energy development than purchasing voluntary renewable energy certificates (RECs) (Option 4). Buying RECs is the most common approach taken by organizations to indicate support for renewable energy. RECs and offsets are both tradable commodities that represent environmental benefits. RECs represent the environmental benefits of renewable energy, and offsets represent the benefits associated with GHG emission reductions from a variety of projects that include both renewable energy and other low-carbon technologies. Carbon offsets are addressed briefly in this chapter and are the focus of the next chapter.

Below we discuss some key concepts that relate to all renewable energy investment options and then explore the advantages and disadvantages of each.

## Key Background Information

### Influence of Renewable Energy on PUE and CUE

Data centers cannot improve their PUE through the use of renewable energy because electricity from renewable sources is treated at par with grid electricity in PUE calculations – it is included in total energy or power (the numerator in PUE calculations) and is assigned the same source weighting factor as grid electricity.[195] CUE, however, is improved by the use of renewable

[194] Please note, a renewable energy project that an organization supports through a contract or partnership with a developer will not necessarily be considered additional. To be considered additional, such a project would likely need to undergo an additionality test comparable to that applied to renewable energy projects that provide high quality offsets. Nonetheless contracting/partnering is more expensive, is more complex, offers more direct support, and generally appears to yield noticeably greater PR value. Due to the scale of such contracts/partnerships their PR value can be comparable to, if not greater than, that provided by an on-site renewable energy investment.

[195] 7X24 et al. 2010b

energy. This is because the lower GHG emission factors that are associated with renewable energy decrease the numerator in the CUE calculations.

### Overview of Renewable Energy Certificates (RECs)

RECs, also known as green tags, are financial instruments that represent the environmental and renewable attributes of a specific quantity (typically one MWh) of renewable energy. Like other financial instruments, RECs can be bought and sold in specialized markets. The types of energy generation generally considered to accrue RECs include solar photovoltaic (PV), concentrating solar power, wind, geothermal, landfill gas, tidal/wave, certain types of hydroelectric and certain types of biomass power generation. Organizations procure RECs to support renewable energy development and, in most cases, to reduce the emissions associated with their electricity consumption.

RECs are treated as a distinct commodity from the energy with which they are produced. RECs can be traded either paired with (bundled) or separate from (unbundled) the associated electricity. REC transactions occur in two broadly-defined types of markets: compliance markets and voluntary markets. Compliance markets exist in states with mandatory renewable energy requirements, commonly known as renewable portfolio standards (RPS).[196] These standards generally require that a certain portion of electricity sold to customers be sourced from renewable energy generation, so RECs in compliance markets are bought by entities with RPS compliance obligations. Voluntary markets exist at a national level and provide an opportunity for individuals and organizations to support renewable energy developed independent of RPS compliance requirements.

RECs can be transferred numerous times but the green benefits associated with them can only be claimed by their final owner, a rule designed to protect against double-counting the benefits of the same unit of renewable energy. The final owner of a REC is not automatically allowed to claim the associated environmental benefits: to claim any benefits, the buyer must permanently remove the REC from the market and prevent its resale by "retiring" it. RECs can be tracked and formally retired through any of nearly a dozen regional tracking systems such as PJM GATS, NEPOOL GIS, M-RETS, ERCOT and WREGIS.[197] Once an organization retires RECs it owns, it can publicly claim that it is supporting renewable energy, and in some cases, claim that it is decreasing or "offsetting" [198] greenhouse gas emissions.

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[196] 29 States and the District of Columbia have a mandatory RPS while eight states have a renewable energy goal.

[197] These REC tracking systems typically align with regional transmission organizations such as PJM, ISO-NE/NEPOOL, MISO, ERCOT and WECC. Green-e, the leading certifier of voluntary REC products, provides the following list of renewable energy generation systems, by regional tracking system, that have been deemed eligible to meet Green-e's voluntary REC certification requirements:
http://www.green-e.org/tracking_attests_recd.html (Green-e 2011c)
Although these facilities meet Green-e's eligibility criteria, they are not all necessarily used by Green-e Energy participants.
Green-e 2011c

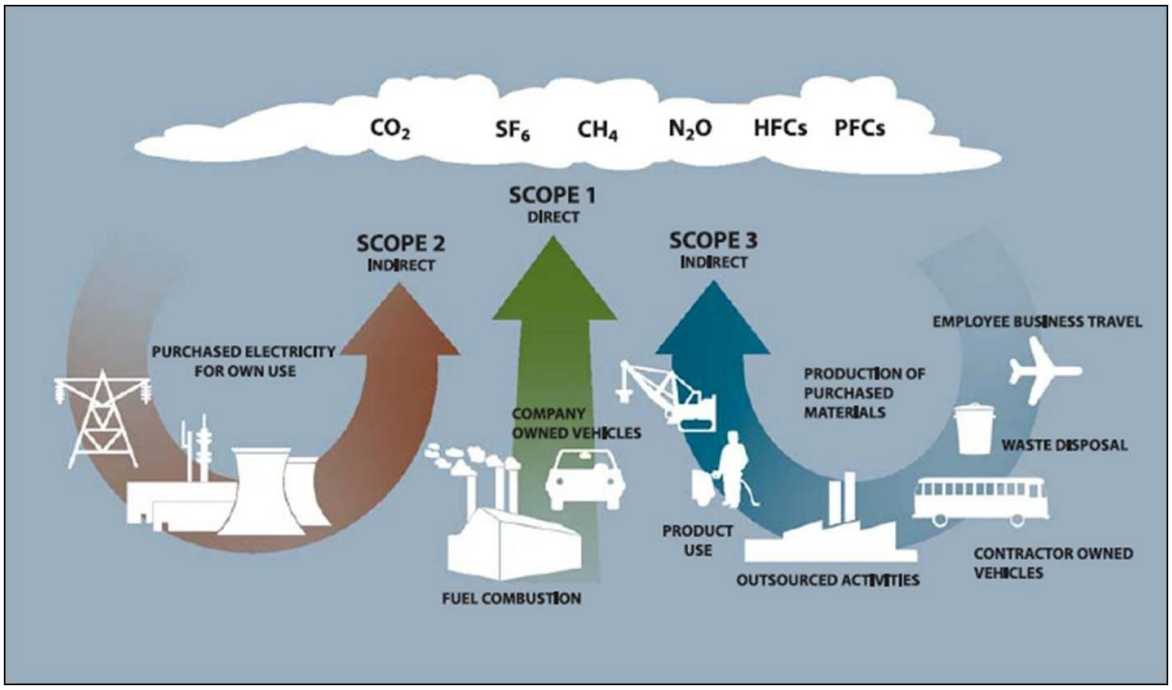
[198] Carbon offsets are different from RECs. Offsets are discussed in Chapter 4.

### Basics of REC Accounting

The environmental benefits of a REC are generally expressed in terms of indirect $CO_2$ emissions avoided by the displacement of fossil fuel-fired generation.[199] Avoided emissions are estimated by multiplying the electricity associated with RECs with an average emission factor for the regional electricity grid within which the electricity is displaced. The grid emission factor represents the average GHG emissions per MWh of generation in the regional grid system in which the renewable project is located. Regional grid emission factors can be obtained from the U.S. Environmental Protection Agency's eGRID database.[200]

Emission inventory systems that help participants measure and track their carbon footprints segregate emissions into three categories: Scope 1, Scope 2, and Scope 3.[201] Scope 1 emissions are those that have been directly emitted by and are under the direct control of a reporting entity. Scope 2 emissions are indirectly emitted by the reporting entity mostly via purchased electricity,[202] and Scope 3 emissions are indirect emissions from a reporting entity's upstream and downstream operations.[203] The exhibit below provides a visual overview of these three categories.

**Exhibit 23: Categories of Emissions**




Source: WRI/WBCSD GHG Protocol Corporate Accounting and Reporting Standard 2004

[199] Because it displaces the combustion of fossil fuel at conventional generation facilities, renewable energy generation may also entail environmental benefits such as reductions in sulfur oxides ($SO_x$) and mercury (Hg) as well as reducing demand for environmentally unfriendly fossil fuel extraction. However, these additional potential benefits are difficult to assess and typically are not quantified or reported by organizations.
[200] EPA eGrid Database: http://www.epa.gov/cleanenergy/energy-resources/egrid/index.html (U.S. EPA 2011b)
[201] WRI/WBCSD 2004
[202] May also include purchased heat and steam.
[203] Bird 2010b

Most renewable energy investment strategies involve counting emission reductions associated with renewable energy generation against Scope 2 emissions; however, some renewable energy investments involve counting emission reductions against Scope 1 emissions, while other investments may not provide a system host, owner or investor the right to claim any emission reductions.[204,205] Organizations can count retired RECs against their carbon footprint by either (a) deducting the associated renewable energy generation (MWh) from total consumed electricity used to estimate Scope 2 emissions, or by (b) deducting estimated avoided $CO_2$ emissions from total Scope 2 emissions. Indirect emission reductions associated with bundled or unbundled RECs should not be applied against Scope 1 or Scope 3 emissions.[206,207]

However, as discussed in Chapter 4, it is possible to purchase carbon offsets derived from renewable energy projects that may be applied against Scope 1, 2, and 3 emissions. To qualify as offsets, emission reductions from offset projects must be certified by a third-party organization to pass stringent tests of additionality.

## Develop On-site Renewable Energy

On-site renewable energy systems are located on or adjacent to a facility where the energy is consumed. This section focuses on solar photovoltaic (PV) generation, the most flexible and fastest growing form of commercial on-site renewable energy. Mid-scale (10 kW to 5000 kW) on-site wind generation installations are viable in select areas of the country but are far less common than on-site solar PV generation installations often due to logistical challenges.[208] Other

[204] A renewable energy investment that could yield Scope 1 emission reductions is an on-site generation project that meets both of the following criteria; (a) the owner permanently retains the environmental attributes of the project; and (b) the project decreases the use of existing, on-site conventional power generation (e.g. diesel power generation).

[205] Renewable energy investments that would not provide emission reductions include any project where the investor does not have the right to claim the environmental attributes of the renewable energy project because the attributes were either not conferred due to contract structure (e.g. direct equity investment without rights to project output) or were not retained by the project owner (e.g. owner sells all offsets or RECs associated with a project).

[206] Bird 2010b

[207] This report does not cover many of the intricacies of carbon accounting but does highlight some carbon accounting guidelines.

[208] Total installed on-site wind capacity in the U.S. is very limited compared to on-site solar PV capacity. The growth rate of on-site wind development is also much lower than that of on-site solar PV capacity. While detailed cost, performance, and feasibility data is widely available for utility-scale wind generation projects, much less is available for mid-scale projects (10 kW to 5000 kW). The most detailed publicly available report on the cost, performance, and feasibility of mid-scale wind projects in the U.S. was published by NREL in 2008: http://www.nrel.gov/wind/pdfs/midscale_analysis.pdf (Kwartin et al. 2008)
This report highlights a number of issues facing mid-scale distributed wind generation, the most significant of which are the scarcity of wind turbine options and high turbine costs: "Most turbine manufacturers have scaled back their involvement in the mid-scale market segments in favor of larger turbines suitable for large, central-station wind farms. Those distributed-scale turbines that are available are often relatively expensive (on a $/kW basis), hard to order in single units or small lots, and suffer from long delivery delays." The report highlights that mid-scale wind generation is viable in several regions in the U.S. such as Northeastern states, California, and along the border of North Carolina and Tennessee. A map is provided in Figure 12. Commercial, industrial, and public facility winners. NREL's System Advisor Model (SAM) is a useful tool to use when conducting a preliminary evaluation of the viability of on-site wind generation:
https://www.nrel.gov/analysis/sam/ (NREL 2011g)

forms of renewable generation, such as geothermal, hydropower, and biomass, are typically impractical on-site generation options. Although the focus of this section is on-site solar PV generation, much of the information presented in this chapter is relevant to all forms of on-site renewable generation.

### Benefits

Investing in on-site renewable energy projects is one of the most meaningful and direct ways to support renewable energy development. On-site renewable energy development is widely recognized to be beyond business-as-usual because (a) on-site projects are directly enabled by the host organization, and (b) on-site renewable energy is almost always more expensive than grid-sourced electricity.

An organization can claim environmental benefits associated with on-site renewable generation as long as it does not sell those benefits (in the form of RECs) to another party. Assuming the environmental benefits of the renewable energy are not sold, they will reduce an organization's Scope 1 emissions if the renewable generation reduces the fuel used for on-site conventional generation (e.g. gas-fired generation) and Scope 2 emissions if the renewable generation displaces the consumption of grid electricity.[209]

Due to the high cost of developing on-site renewable energy systems, some organizations host a renewable generation system but sell the associated renewable attributes (RECs) as part of a third-party ownership financing model (e.g. power purchase agreement or lease structure). Organizations that sell all RECs produced by an on-site system can no longer claim any of the associated environmental benefits. After the REC component of on-site renewable generation has been sold, the remaining power component is known as "null power." Null power should be assigned an average grid emissions factor, and thus is neither renewable nor emission-free.[210] An organization that uses this null power cannot make the claim that a facility is powered by renewable energy or that the on-site renewable system decreases its carbon footprint.

Even though the environmental attributes of an on-site project cannot be claimed after ownership of associated RECs is transferred to another entity, many organizations try to capture public relations benefits by claiming to "host" renewable energy systems.[211] However, in October 2010 the Federal Trade Commission (FTC) proposed new guidelines that would prohibit this practice of claiming to "host" a renewable energy facility after selling the associated RECs. The FTC is expected to issue final guidance later in 2011.[212] An organization may avoid this issue by either (a) ensuring that its marketing claims highlight that that the RECs have been sold and that

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Information on some of the U.S. businesses and organizations that have installed on-site wind generation systems, specifically systems that use the popular Northwind turbines manufactured by Northern Power Systems: http://northernpower.com/pdf/northwind100-install-base.pdf (Northern Power 2011)

[209] Later this chapter we address how some organizations sell the environmental benefits of their systems at a high value in the form of RECs but then purchase a matching amount of low cost replacement RECs so that they can still achieve Scope 2 emission reductions.

[210] CRS 2010c

[211] Cory 2011

[212] Overview of FTC Proposal: FTC 2010b
Full Text of FTC Proposal: FTC 2010b

renewable energy is not used; or (b) buying new RECs from the market to replace RECs sold.[213] This latter, "replacement REC", strategy would work well for an organization with an on-site solar PV system. The organization could sell its solar RECs (SRECs), which may be worth several hundred dollars per MWh in some compliance markets, and then purchase a matching amount of voluntary RECs (e.g. Green-e National Any Technology RECs) for just a few dollars per MWh.[214] Because the replacement REC strategy could potentially be perceived as misleading, organizations should carefully review the strategy and any potential implications before implementing this strategy.

On-site renewable energy can also provide power price stability in addition to the public relations benefits associated with supporting renewable energy development and reducing emissions. Volatility in fuel prices has no effect on on-site solar and wind generation systems. Power prices could rise substantially in the coming years due to the implementation of pending environmental regulations and the possible passage of federal GHG emission reduction legislation. The all-in, or "levelized," cost of electricity from on-site renewables may be higher than the cost of power procured from the local utility, but renewable generation continues to become more competitive as costs rapidly fall, and some systems are very close to achieving "grid parity" in certain locations (e.g. solar PV in Hawaii).[215]

### Cost and Performance Considerations

While solar PV generation is typically more expensive than other forms of renewable generation, costs are declining rapidly and local, state, and federal incentives can further reduce the net cost to a system owner. The cost of solar PV systems has declined markedly in the past few years due to cost reductions in photovoltaic (PV) modules[216], the most expensive component of a PV system.[217] Exhibit 24 below highlights how system costs have declined in recent years.[218]

[213] These two strategies were proposed by in a recent telecast by Robin Quarrier, Green-e Analyst and Counsel with the Center for Resource Solutions and described in Cory 2011

[214] The highest SREC prices in the country are currently in the New Jersey and Massachusetts SREC markets.

[215] Grid parity describes a situation where a generation system can produce electricity at or below the cost of electricity produced by conventional generation resources. Solar PV generation in a region with high power prices and strong solar PV subsidies would be closer to achieving grid parity than solar generation in a region with low power prices and weak solar PV subsidies. The following article provides additional color to the concept of grid parity: http://www.renewableenergyworld.com/rea/blog/post/2011/04/distributed-solar-nears-grid-parity-for-some-values-of-parity (Farrell 2011)

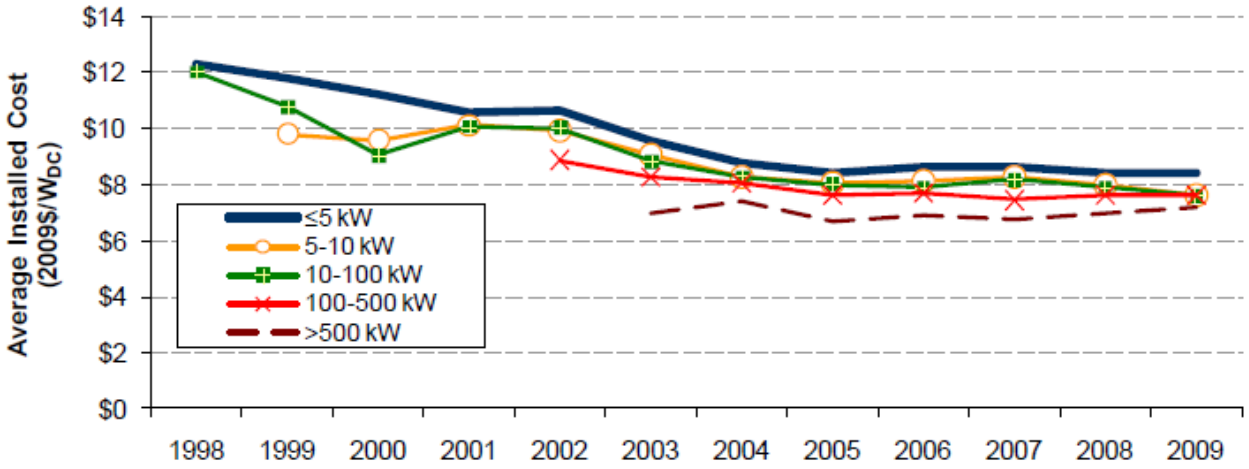
[216] A PV module is an array of connected solar cells that convert light energy into electricity.

[217] A recent report produced by the Rocky Mountain Institute estimates that in 2010 module costs represent roughly half of the total cost of rooftop solar PV systems and more than half the cost for ground-mounted systems. Rocky Mountain Institute 2010

[218] Costs are typically described in terms of direct current kilowatts, or $kW_{DC}$.

**Exhibit 24: Installed Cost Trends over Time by PV System Size**




Source: Barbose et al. 2010, NREL

Prices have since fallen substantially from levels highlighted in the exhibit above. For example, as of December 2011, the all-in up front cost of a 500 $kW_{DC}$ rooftop solar PV system may range from approximately \$3550/$kW_{DC}$ to \$3750/$kW_{DC}$ before federal and state incentives.[219]

System costs today vary less by module technology and more by module manufacturer. The two most common module technologies are crystalline silicon modules (80-90% U.S. market share) and thin film solar modules (10-20% U.S. market share).[220] Solarbuzz.com, a resource for residential and commercial solar cost trends, provides a concise overview of these technologies. Costs can typically vary greatly by manufacturer, particularly. In California, home to more solar PV installations and capacity than any other state, the most popular brand of crystalline module is manufactured by SunPower and the most popular brand of thin film module is manufactured by FirstSolar.[221,222] There are dozens of other high quality PV module manufactures such as Sharp, Kyocera Solar, Suntech Power, and Yingli Green Energy among others. The most popular manufacturers of solar power inverters, another key system component, include Enphase Energy, SMA America, SunPower, and Fronius USA.[223]

[219] Wesco Distribution 2011. Illustrative system costs were provided by Chris Crump, Southwest Region Solar Manager. Assumed system specifications: 500 $kW_{DC}$ fixed plate monocrystalline or thin film rooftop system. The low cost estimate assumes the use of Chinese Tier 1 modules, while the high cost estimate assumes the use of American modules. The estimates reflect system costs using either crystalline or thin film modules. Thin film modules may still be less expensive than monocrystalline modules, but additional system components used by a thin film system (combiners, DC optimizers, etc.) can raise the total up front cost to about equal that of a system using monocrystalline modules. Illustrative costs do not account for federal or state incentives.

[220] Solarbuzz 2011

[221] According to NREL's Open PV Project, California's solar PV installations represent the majority of total U.S. PV installations.
NREL 2011a

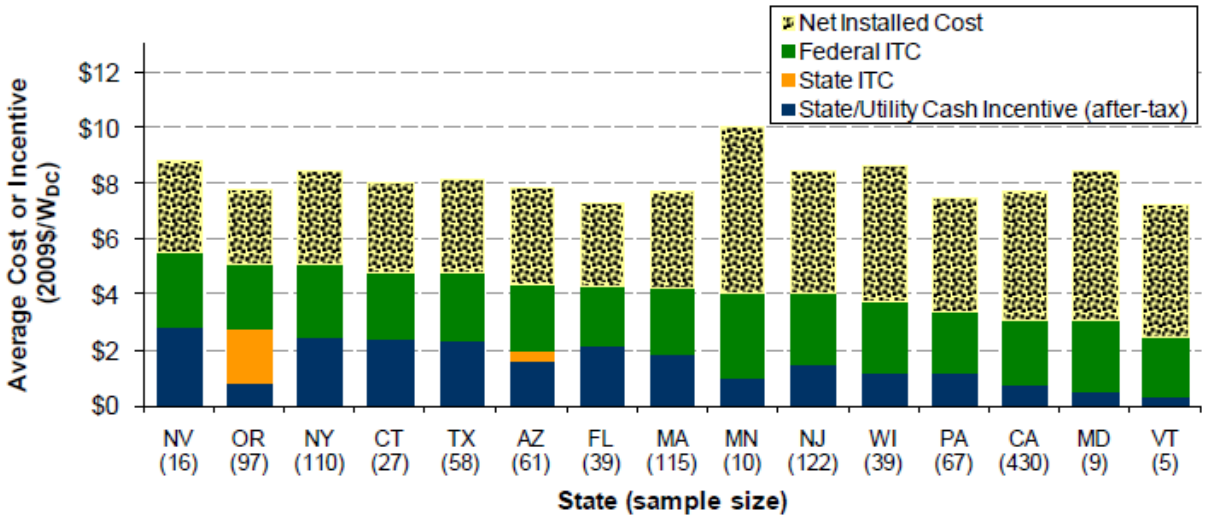
[222] Most popular crystalline module for PV systems less than 1000 kW: SunPower: SPR-225-BLK-U
Most popular thin film module for PV systems less than 1000 kW: First Solar: FS-275
California Energy Commission and California Public Utilities Commission 2010

[223] California Energy Commission and California Public Utilities Commission 2010

Local, state, and federal incentives play a key role in enabling on-site solar energy development. Exhibit 25 below highlights how these incentives can reduce the net cost to a system owner by over 50% in some states.

**Exhibit 25: Incentive Levels and Net Installed Costs across States for Commercial PV Systems Installed in 2009**




Source: Barbose et al. 2010, NREL

The Federal Investment Tax Credit (ITC), equivalent to 30% of installed system costs, is available to all solar PV project owners.[224] Some states, such as Oregon and Arizona, also offer a sizable ITC that can be used along with the Federal ITC. Many states and utilities offer additional financial incentives as well. The Database of State Incentives for Renewable Energy (www.DSIREUSA.org) is an excellent resource for learning about financial incentives available in each state. An additional federal incentive available to renewable generation systems is the Modified Accelerated Cost-Recovery System (MACRS) which allows for full depreciation of solar generation facilities over five years.

The cost of developing a solar generation facility may also vary depending on the project financing structure. Not all organizations have a sufficient tax liability to take advantage of the ITC, without which the upfront costs of a PV system could be prohibitively expensive. In such cases, an organization may opt for alternate financing structures such as third-party financing. Under such an arrangement, an organization would host a solar generation project and purchase the output for a contracted period of time through a Solar Service Agreement (SSA, also known more generally as a solar power purchase agreement, or SPPA). The owner of the PV system, not the host, would cover the upfront system costs as well as systems operations and maintenance. The on-site system output purchased by the host typically includes electricity but not necessarily the associated environmental benefits. In instances where the third-party owner of a solar PV system keeps those benefits (in the form of SRECs), the electricity purchased by the host is considered null power, a concept addressed earlier in this chapter. Host organizations often have

[224] The federal ITC is currently available to all solar generation facilities that come online prior to 2017.

the option to purchase the system after several years or at the end of the contract term.[225] "The Customer's Guide to Solar Power Purchase Agreements," available at the California Solar Center website, explains how the SPPA works. The range of financing options available is explored in detail in the National Renewable Energy Laboratory's (NREL) 2009 report, *Financing Non-Residential Photovoltaic Projects: Options and Implications.*[226]

It is very important to consider a potential PV system's expected levelized cost of electricity (LCOE) to appropriately evaluate a planned energy generation investment. LCOE is calculated as a generation system's total lifecycle costs divided by its total lifetime energy production. It is typically expressed in cents per kilowatt hour (cents/kWh) or dollars per megawatt hour ($/MWh). This metric is used to compare the expected cost of electricity generated by a planned generation system with the cost of alternate system options and with the current and projected cost of grid-sourced electricity. Calculating a system's LCOE requires a number of complex data assumptions, though NREL provides a simple LCOE calculator along with input guidelines.[227]

System performance, described in terms of a capacity factor, is a key input to an LCOE calculation and, all else being equal, can substantially raise or lower a generation system's LCOE. Capacity factor represents the ratio of net electricity produced in a given time frame to the energy that could have been generated if a system were to theoretically operate at continuous full-power operation during the same time frame. For example, the capacity factor (CF) of a solar PV system over the course of 1 year would be calculated as follows: [228]

$$CF = \frac{kWh_{AC}\ (net\ system\ output\ in\ a\ given\ year)}{kWh_{DC}\ (system\ capacity) \times 8760\ (hours\ in\ a\ year)}$$

Solar PV capacity factors in the U.S. range from 10% to 26%, a performance range that yields significantly different LCOE estimates.[229] Exhibit 26 examines the cost and performance of a sample 100 $kW_{DC}$ crystalline solar PV system under varying capacity factor estimates.

[225] Minnesota Department of Commerce, Office of Energy Security 2010
[226] Bollinger 2009
[227] NREL's simple LCOE calculator: http://www.nrel.gov/analysis/tech_lcoe.html (NREL 2011f)
[228] Solar PV generation systems generate electricity in direct current (DC), while the transmission system transmits electricity in alternating current (AC). Solar PV systems use a power inverter to convert system output to $kW_{AC}$. The net output of a solar system is commonly determined by applying a DC to AC derate factor to the rated DC capacity. A generic DC to AC derate factor is .80; that is, a 1 $kW_{DC}$ system would provide .80 kW of AC capacity. NREL's PV Watts v1 tool provides a breakdown component derate factors:
http://www.nrel.gov/rredc/pvwatts/site_specific.html (NREL 2011e)
[229] Generic crystalline solar PV system type assumed.
NREL 2010

**Exhibit 26: Illustrative Capacity Factor-Driven Variation in LCOE[230]**

| Parameter | Units | Very Low Capacity Factor | Common Capacity Factor | Very High Capacity Factor |
|---|---|---|---|---|
| Capacity | kW[a] | 500 $kW_{DC}$ \| 400 $kW_{AC}$ | | |
| Capital Cost[231] | $/$kW_{DC}$ | $3,550 (no incentives) \| $2,485 (with federal ITC) | | |
| Capital Cost | $/$kW_{AC}$ | $4,438 (no incentives) \| $3,106 (with federal ITC) | | |
| Effective Total Cost | $ million | $1.78 (no incentives) \| $1.24 (with federal ITC) | | |
| Capacity Factor | % | 10 | 15 | 26 |
| Net Annual Generation | $kWh_{AC}$ | 350,400 | 525,600 | 911,040 |
| LCOE Before Subsidies | ¢/$kWh_{AC}$ | 70.6 | 48.1 | 27.8 |
| LCOE After ITC[b] | ¢/$kWh_{AC}$ | 51.2 | 34.1 | 19.7 |

Source: Author Analysis Using NREL's Simple LCOE Calculator[232]

Notes:

(a) Conversion from $kW_{DC}$ to $kW_{AC}$ assumes a DC-to-AC derate factor of 80%.

(b) This illustrative LCOE does not account for accelerated depreciation (5 year depreciation under MACRS) or the subsidies offered by many states and utilities such as sales tax reductions, rebates, and SREC revenues; these and other subsidies may dramatically reduce the LCOE of a solar PV system.

The capacity factor of a solar PV system is essentially a function of the quality of available solar resources, typically determined by solar irradiance and weather conditions and the technology used, such as crystalline/thin film solar modules and fixed tilt/single-axis tracking. It is important to consult one or more professional developers or consultants to determine the most appropriate system design. Two useful publicly available tools to assess local solar resources and potential system performance are NREL's PV Watts and NREL's System Advisor Model.[233]

[230] LCOE calculated using NREL's LCOE calculator (NREL 2011f). Financial assumptions assume include a 20 year financial period, 12.5 percent discount rate, $20/kW-yr Fixed Operations and Maintenance (Fixed O&M) and no fuel cost.
Fixed O&M cost assumption: NREL 2010
Annual system output calculated as follows = 400 $kW_{AC}$ ( system capacity) * 0.80 (assumed DC to AC derate factor) * 8760 (hours in a year)

[231] Wesco Distribution 2011. Assuming the use of a Chinese Tier 1 solar PV module on a fixed plate rooftop system.

[232] NREL 2011f

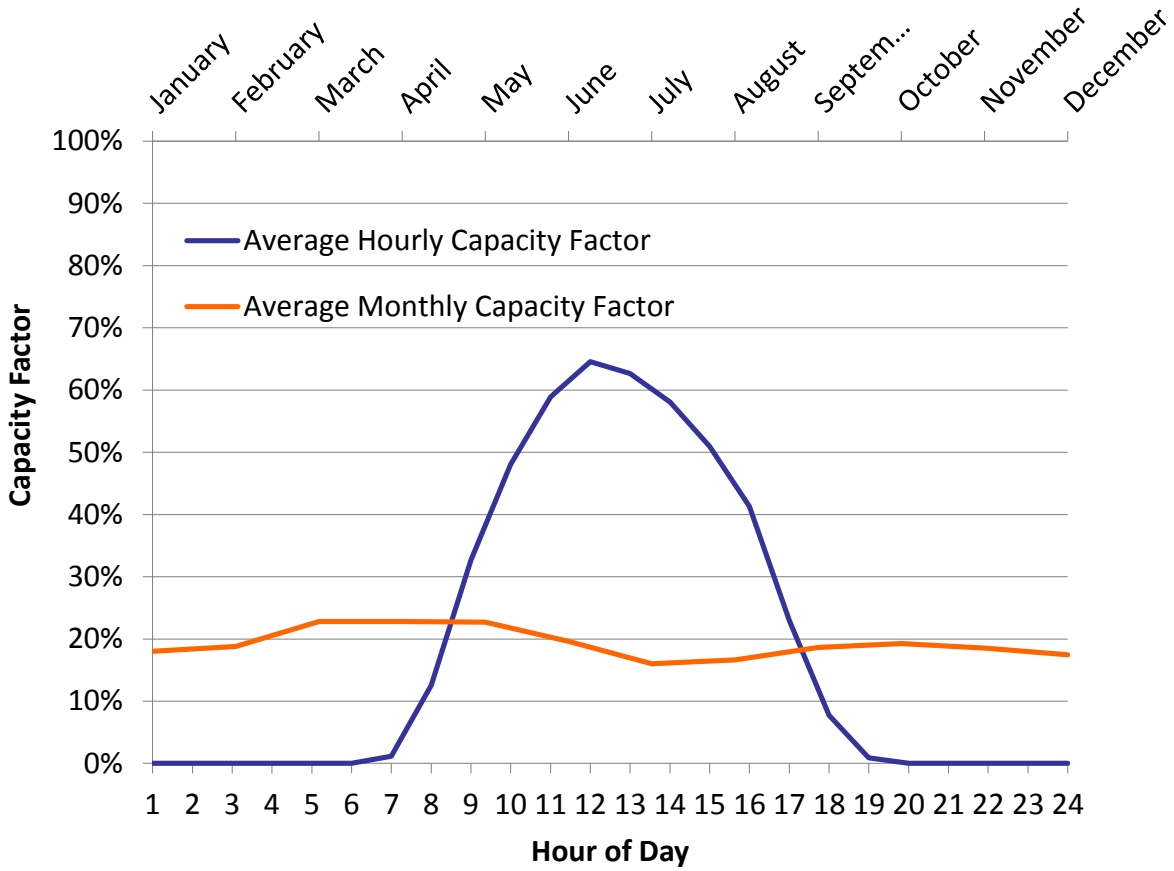
[233] NREL's PV Watts tools are useful when looking for a quick overview of resource potential. NREL's System Advisor Model (SAM) is substantially more sophisticated than PV Watts and allows for the user to project cost and performance of solar PV systems as well as other renewable generation systems. Users can modify nearly every detail of system design, performance, and environment.
PVWatts™ Site Specific Data Calculator (Version 1): http://www.nrel.gov/rredc/pvwatts/site_specific.html (NREL 2011e)
PVWatts™ Grid Data Calculator (Version 2): http://www.nrel.gov/rredc/pvwatts/grid.html (NREL 2011d)
System Advisor Model: https://www.nrel.gov/analysis/sam/ (NREL 2011g)

### Integration Considerations

The performance characteristics of a solar PV system are important to consider when assessing the viability of on-site solar PV generation. Solar PV generation is driven by the intensity of solar irradiance and affected by other factors such as cloud cover, precipitation and temperature. Solar PV performance varies daily and seasonally. Generation rises quickly in the morning, peaks in the afternoon, and then falls quickly late in the afternoon. Exhibit 27 below shows the average hourly and monthly capacity factor of a sample 100 $kW_{DC}$ fixed-tilt crystalline PV system in Arizona modeled using NREL's System Advisor Model (SAM). Within a single day the capacity factor may reach a very high level, but the annual average net capacity factor over the course of the year is much lower. The sample system has an annual average net capacity factor of 19%, roughly on the higher end of what distributed PV systems achieve in the U.S.

**Exhibit 27: Sample Solar PV Generation Profile by Hour of Day and Month of Year**




Source: Author Analysis Using NREL's System Advisor Model[234]

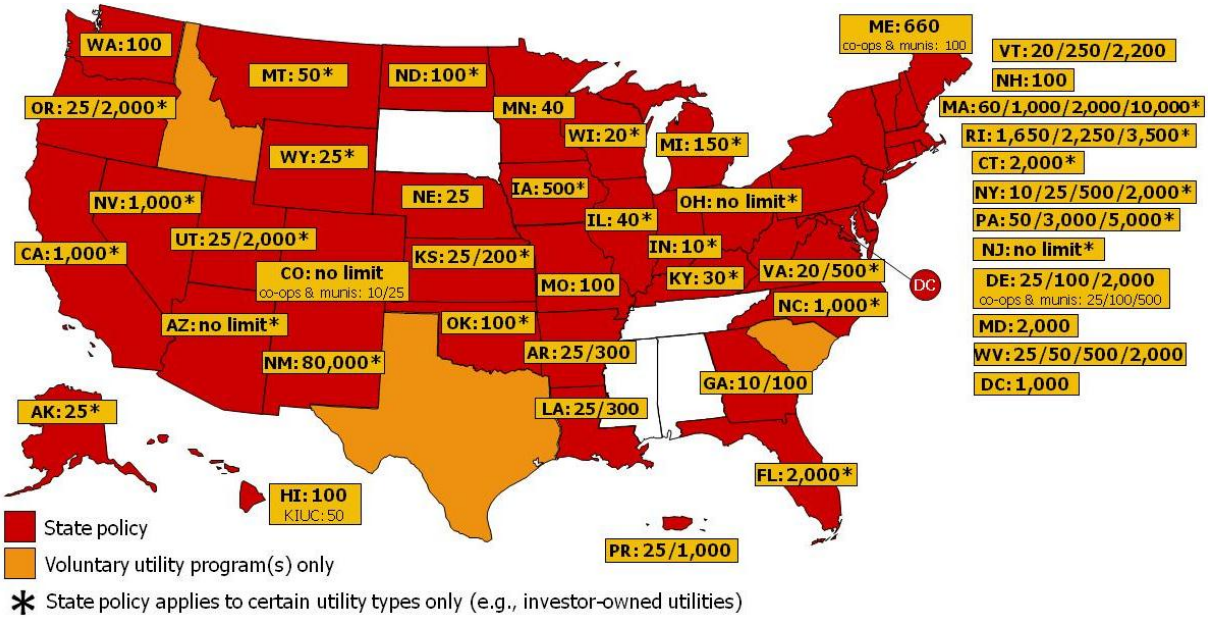
The load profile, or variation in electrical demand over time, of a facility may not synchronize with the availability of electricity generated by an on-site PV system. For this reason, facilities hosting a PV system typically sell excess generation during periods of low demand back to the grid through a net metering program. Net metering programs allow distributed generation owners

[234] NREL 2011g

to sell excess power to the grid at retail electricity rates, which are much higher than the wholesale electricity rates. State or utility net metering programs are available in 43 states and the District of Columbia. Exhibit 28 provides an overview of net metering program availability and capacity (kW) participation limits. Some states have multiple limits that vary by customer type, technology, and application.

**Exhibit 28: Overview of Available Net Metering Policies and Capacity Limits (kW) by State**




Source: U.S. DOE et al. 2011b, DSIRE

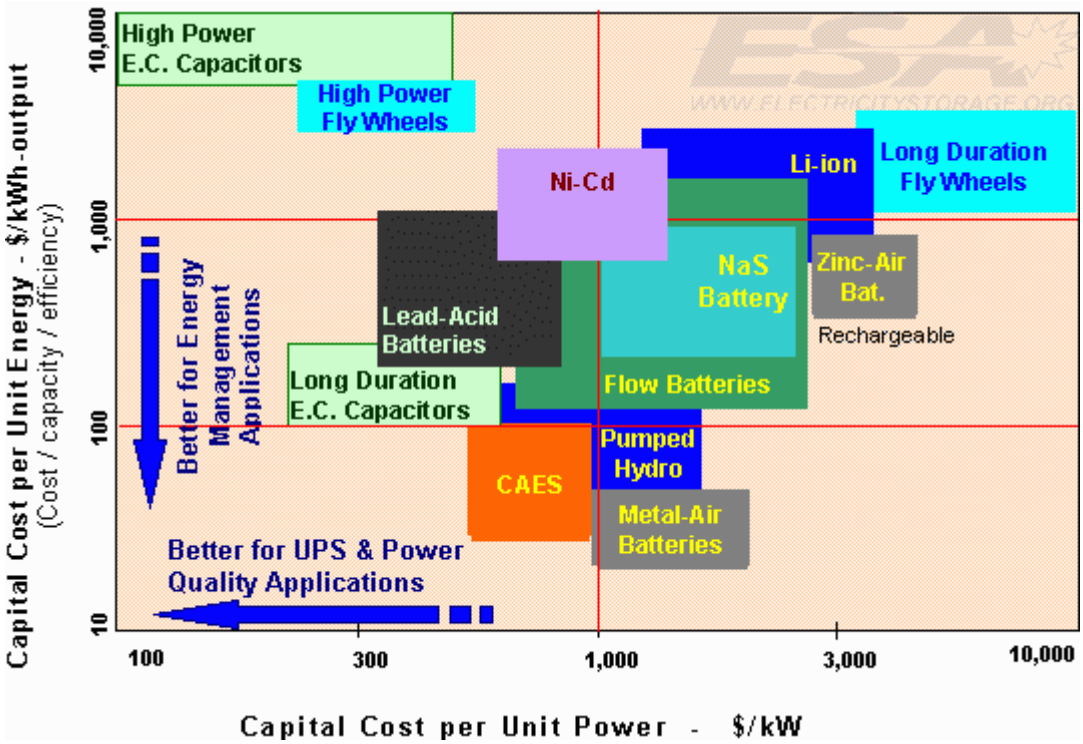
Most state net metering programs limit participation to small- and mid-scale PV systems. States without a specific capacity limit, such as New Jersey and Arizona, typically cap eligible capacity to an amount that is roughly equivalent to on-site load. The Database of State Incentives for Renewable Energy (www.DSIREUSA.org) provides links to the net metering programs available in each state.[235]

Some facility owners may consider integrating an energy storage system with on-site solar PV generation to protect operations from electricity fluctuations and outages. However, such solutions are not necessary in instances where a facility can participate in a net metering program. While data center facilities already have built-in storage capabilities in the form of rechargeable battery- or flywheel-based Uninterruptible Power Supply (UPS) systems, these systems are not typically designed to store and later distribute surplus PV system power. Price discovery for energy storage systems is limited and generic cost estimates highlight that in most instances such solutions are prohibitively expensive. Exhibit 29 below provides rough cost estimates for energy storage systems. In the event that a facility is unable to participate in a net metering program, the most appropriate backup options at this time still include electricity from the power grid and on-site fossil fuel fired generation.

[235] U.S. DOE et al. 2011e

**Exhibit 29: Capital Cost Estimates for Energy Storage Technologies**




Source: Electricity Storage Association 2009
Image used with permission.

## Scope of On-site Solar PV System Development

Thousands of distributed solar PV systems have been installed across the U.S. and the rate of distributed development is growing rapidly.[236] California is home to more solar PV installations than any other state, and currently has over 2,100 systems installed by commercial, government, and non-profit organizations (see Exhibit 30 below).

[236] The U.S. National Renewable Energy Laboratory provides a stunning visualization of solar PV installations in the U.S. since 2000: http://openpv.nrel.gov/time-mapper (NREL 2011c)

**Exhibit 30: Overview of Commercial, Government, and Non-Profit On-Site Solar PV Installations in California**

| | Installed Systems | | | Pending Systems* | | |
|---|---|---|---|---|---|---|
| **Host Type** | **Number of Systems** | **Average System Capacity ($kW_{DC}$)** | **Aggregate Capacity ($kW_{DC}$)** | **Number of Systems** | **Average System Capacity ($kW_{DC}$)** | **Aggregate Capacity ($kW_{DC}$)** |
| Commercial | 1,453 | 148 | 214,784 | 759 | 198 | 150,609 |
| Government | 422 | 190 | 80,096 | 912 | 316 | 288,105 |
| Non-Profit | 292 | 53 | 15,470 | 171 | 170 | 29,088 |
| **Total** | **2,167** | **143** | **310,350** | **1,842** | **254** | **467,803** |

Source: Author Analysis Using the California Solar Statistics Database[237]
*Pending systems are those not yet installed with pending incentive applications with the California Solar Initiative (CSI).

On-site commercial PV systems range from less than 2 $kW_{DC}$ to over 3,400 $kW_{DC}$, though the average installation size is closer to 150 $kW_{DC}$. While government installations are slightly larger on average than commercial installations, commercial installations are more than three times as numerous. There are noticeably fewer installed and pending non-profit systems, which also tend to be somewhat smaller than commercial and government systems. New and planned systems tend to be larger than older systems likely due to improved economics for new projects following recent, unprecedented module cost reductions.

According to the National Renewable Energy Laboratory's (NREL) Open PV Project, a database of PV installations across the U.S. that provides user-friendly information on national, state, and county level solar PV cost and size trends, California's installed PV systems total 1150 MW and constitute roughly two-thirds of all solar PV capacity in the U.S.[238] Organizations that install a solar PV system often register with the Open PV Project and, as a result, the Project is a very useful point of reference when assessing the viability and popularity of on-site solar PV development in a specific area.[239]

Installing on-site solar PV systems at data centers is becoming increasingly popular, with four new data centers coming online in April 2011 that have over 550 kW of solar PV capacity.[240] The exhibit below provides a sample of data-center facilities with on-site solar PV generation. In addition to these, Google and Intel have also installed solar PV generation systems at their data centers.

[237] California Energy Commission and California Public Utilities Commission 2010
[238] NREL 2011h
[239] Even though much of the Open PV Project data is filtered, much of the data is self-reported, and in some instances may not be accurate.
[240] Miller 2011

**Exhibit 31: Sample List of Data Centers with On-Site Solar PV Systems**[241]

| Company | State | Installation Size (kW) | Percent of Facility Load |
|---|---|---|---|
| *Cisco Systems | Texas | 100 | |
| *BendBroadband Vault | Oregon | 152 | 18% |
| *Facebook | Oregon | 100 | |
| *DataScan Technologies | Georgia | 202 | 30% to 50% |
| Emerson Network Power | Missouri | 100 | |
| AISO.net | California | | 100% |
| Sonoma Mountain Data Center | California | 1,000 | |
| **i/o Data Centers<br>**McGraw-Hill Company | Arizona<br>New Jersey | 4,500<br>14,100 | |

Sources: DataCenterKnowledge.com[242], The McGraw-Hill Companies 2011
*New as of April 2011
**Planned
Notes:
(a) The AISO.net solar PV installation size is not publicly available
(b) McGraw-Hill has announced it will participate in a net-metering program

A drawback of on-site solar PV facilities is the large amount of space required to develop sufficient capacity to match a substantial portion of on-site load. For example, the approximately 1MW Sonoma Mountain Data Center solar PV installation occupies an estimated 83,000 square feet (12 watt/sqft), the proposed 4.5MW i/o Data Centers solar PV installation will require an estimated 480,000 square feet (9.4 watt/ sqft), and the proposed 14.1 MW McGraw Hill solar PV installation will require an estimated 2.2 million square feet (6.5 watt/ sqft).[243] Solar PV cell technologies can vary substantially by efficiency, with more efficient cells requiring less space but typically selling for a premium price. Despite the large amount of space required, on-site solar PV generation remains popular and data centers can typically still offset a large portion of grid power consumption.

Overall, on-site renewable energy systems represent the most direct way for organizations to support renewable energy development and procure high quality carbon offsets. However, on-site systems may not be appropriate in certain instances due to economic and logistical hurdles. In these instances, contracting or partnering with specific renewable energy project developers can be a more cost-effective and scalable way to support renewable energy.

## Contract or Partner with a Project Developer

Another way for an organization to support renewable energy and reduce Scope 2 emissions is to procure bundled or unbundled RECs from a specific renewable energy project through a bilateral

[241] The first and possibly only data center in the U.S. to be powered by an on-site wind generation system is the Illonois-based Other World Computing (OWC) data center, which uses a single turbine installed in 2009. Miller 2010
[242] Colleen Miller 2010 and Rich Miller 2011
[243] SolarByTheWatt.com 2009

contract, known as a power purchase agreement (PPA), with a renewable energy developer. Entering into a PPA with a renewable energy project developer is uncommon and primarily used by large organizations as part of sophisticated carbon reduction and power hedging strategies. PPA contracts typically extend for a few years, but may be up to 20 years or longer.[244] Organizations can also purchase RECs from specific renewable energy projects through a REC broker, an option that may be more appropriate for smaller organizations.[245]

Procuring RECs through a PPA demonstrates direct support for a specific renewable energy project and can help strengthen claims of additionality. Investing in renewable energy through a PPA can allow an organization to choose a renewable energy project that is clearly enabled by its financial support.

Long-term contracts involving unbundled RECs (just RECs) are more common than those involving bundled RECs (electricity + RECs) because most commercial entities outside of the utility sector lack the infrastructure and financial means to consume all of the electricity associated with RECs or to resell the energy in power markets. The Federal Energy Regulatory Commission (FERC) traditionally restricted participation in power markets to power marketers and load serving entities, but organizations such as Google and Wal-Mart have recently been granted authorization to participate as well. Overall, entering into a PPA for bundled RECs is only appropriate for organizations with sizeable energy demand and a sophisticated understanding of wholesale power markets.

U.S. renewable energy markets have recently become a buyer's market largely due to low natural gas prices, uncertain demand growth, and the reduced likelihood of Congress passing a GHG emission reduction policy, or a stringent federal renewable energy or clean energy standard. Low natural gas prices have reduced the cost of electricity across the U.S., eroding the economic viability of many renewable energy projects. Most renewable energy project developers prefer long-term PPAs, but current weakness in renewable energy demand in some markets (most notably in the Mid-Atlantic and Midwest) has positioned some buyers to shop around and negotiate more flexible and affordable PPAs.

Direct equity investment in a specific project is another option for supporting renewable energy, though such an investment may or may not provide ownership of the electricity or environmental attributes produced, unless the investment explicitly includes rights to the output of the facility. The PR benefits of making a direct equity investment are high even if rights to the output are not included. Google, for example, has received praise for investing in a renewable energy facility despite not having ownership of the environmental attributes of the project.[246] Large organizations, typically wholesale market participants, often issue requests for proposals to identify PPA and direct equity investment opportunities.

[244] Generally speaking, longer contract periods are less common as they entail greater risk. Most organizations on the buy-side prefer short-term contracts (several months to several years). In some instances, organizations will engage in long-term bundled PPA contracts for power price hedging purposes.
[245] The REC broker 3Degrees, for example, offers this service: http://www.3degreesinc.com/node/17 (3Degrees 2011)
[246] Miller 2010a

While contracting or partnering with a renewable energy project developer is generally more flexible and scalable than developing on-site renewable energy generation, doing so is generally less flexible and scalable as well as more expensive than purchasing voluntary REC products.

## Purchase Voluntary Renewable Energy Market Products

Purchasing renewable energy certificates (RECs) in the voluntary market is currently the most popular way for organizations to support renewable energy. Voluntary REC markets provide renewable generation facilities with the opportunity to sell green attributes to customers irrespective of transmission barriers that would be prohibitive to the physical delivery of renewable energy. Typically, renewable energy projects located in states without a renewable portfolio standard (RPS) sell RECs in voluntary markets. It is usually not possible for projects participating in a voluntary market to meet the requirements of state compliance markets due to geographic, economic, or transmission constraints.[247] For example, a biomass facility developed in Florida would likely sell RECs into the voluntary market because neither Florida nor any of its neighboring states currently have an RPS.

Voluntary renewable energy market products include (a) unbundled RECs sold by brokers and marketers, and (b) bundled RECs sold through utility green pricing and competitive market electricity programs (green power purchase programs).[248] Green power purchase programs are available in many, but not all, U.S. states. The map below indicates the states where bundled products certified by Green-e, the leading certifier of voluntary RECs in the U.S., are available.[249] EPA's Green Power Partnership Program also provides information identifying where green power purchase programs are available and the costs of participating in those programs.[250]

[247] Technically speaking, all renewable energy projects in the U.S. are potentially eligible to sell their unbundled RECs into Colorado or North Carolina, both of which have renewable energy mandates with very relaxed geographic sourcing requirements. However, the going price for unbundled RECs in these states closely tracks the price of Green-e National Any Technology class of voluntary RECs, effectively removing any incentive to export RECs to these two state markets.

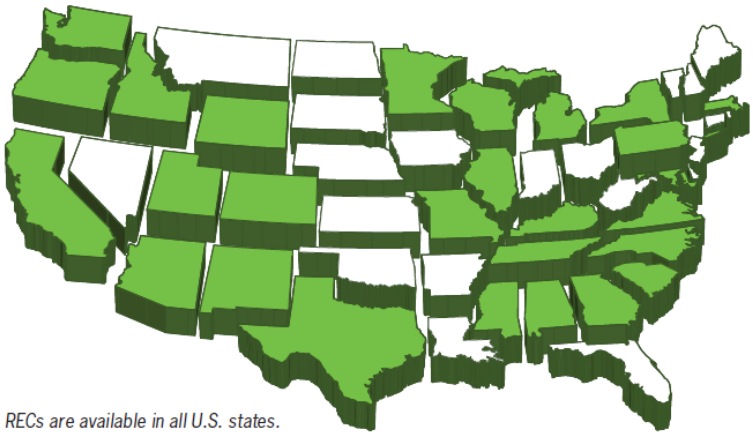
[248] Utility green pricing programs are available in regulated markets and through competitive renewable electricity programs in deregulated markets.

[249] In 2009 Green-e certified an estimated 75% of unbundled voluntary REC sold and roughly 40% of bundled RECs sold through green power purchase programs. These estimates were determined using data presented in Bird and Sumner 2010

[250] U.S. EPA 2011o

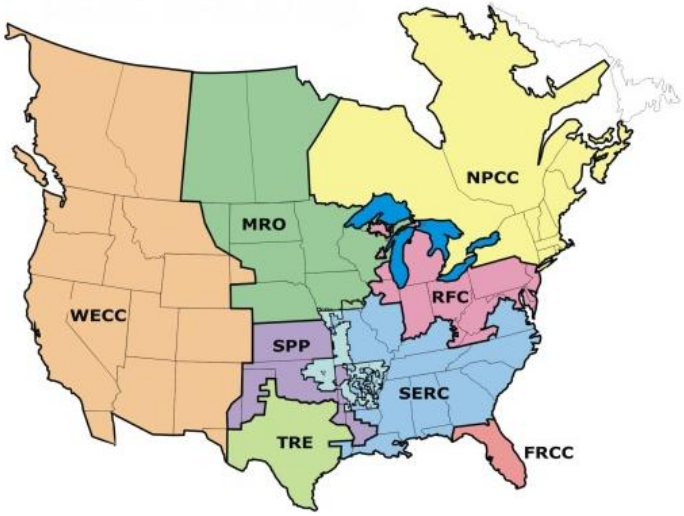
**Exhibit 32: States with Green-e Certified Green Power Purchase Program Products**




Source: Center for Resource Solutions (CRS) 2010a[251]

The two primary differences between unbundled RECS and bundled RECs are that the latter are often costlier and are typically sourced from projects located within the same region as the customer. Bundled REC program organizers typically ensure that RECs sold to participants are sourced from within a participant's North American Electric Reliability Corporation (NERC) region (Exhibit 33). Though bundled REC program participants often believe that purchasing bundled RECs is a way to support regional renewable energy development, they may not realize how large the geographic bounds of their "region" may be. For instance, Dominion Virginia Power's green power purchase program sources bundled RECs from projects anywhere in the South Eastern Reliability Council (SERC) and Reliability First Corporation (RFC) NERC regions, which together cover over 15 states.[252]

**Exhibit 33: NERC Regions**




Source: U.S. Energy Information Administration (EIA) 2011

[251] CRS 2010a. www.resource-solutions.org/publications
[252] Dominion Virginia Power 2011

Unbundled voluntary RECs are sourced from across the U.S. The emission reduction benefits provided by bundled RECs are more likely to be realized locally whereas those associated with unbundled RECS will not necessarily be realized locally. However, because of variations in regional grid emission factors, RECs generated in areas of the country with a high grid emission factor will deliver more emission reductions per purchased REC than in areas with a low grid emission factor and, in turn, may deliver a greater overall impact on global emissions of greenhouse gases and other pollutants. For example, 1 MWh of wind generation sourced from Virginia, a state located in a region with an average grid emission factor of 1661 lb $CO_2$/MWh, would yield an 381 lb/MWh greater $CO_2$ emission reduction than 1 MWh of wind generation sourced from Oregon, which is located in a region with an average grid emission factor of 1280 lb $CO_2$/MWh.[253]

Organizations should only purchase RECs that have been certified by leading third-party agencies and sold through reputable REC brokers or marketers to ensure that purchased RECs have not been double-counted or produced by renewable energy facilities that fail to meet generally accepted standards.[254] Investing in RECs is seen as a way to support renewable energy development by providing developers an additional revenue stream that accelerates cost recovery and debt repayment, thereby reducing project risk.[255] Green-e, the leading certifier of voluntary RECs, certifies RECs generated by projects that meet the criteria below. The criteria are designed to identify projects that most likely need REC funding.

> **Technology Test:** Eligible facility types include wind, solar PV, solar thermal, some new and incremental low impact hydropower, geothermal, ocean thermal, wave, tidal power, gaseous biomass from landfill gas methane, wastewater methane, and digester methane derived from waste biomass fuels used to generate electricity, some liquid/solid state biomass, some co-firing[256] of (a) landfill gas methane (b) wastewater methane and (c) digester methane derived from waste biomass fuels
>
> **Timing Test:** Facility must have become operational or repowered on or after January 1, 1997 (for sales in 2011).

[253] U.S. EPA 2011b

[254] REC Marketers and REC Brokers are not the same but play similar roles. Green-e provides the following distinction on its website: "A REC marketer (seller) purchases renewable energy from a generator or a wholesale renewable energy provider, and then "markets" (sells) that energy to retail or wholesale customers who wish to buy a renewable energy product. A marketer takes title to the renewable energy and resells it, but at no time claims the environmental benefits of that renewable energy—only the final buyer can make those claims. A broker connects a buyer and seller of renewable energy, but does not purchase or take title to the renewable energy being traded." Green-e 2011b
There are dozens of REC marketers and brokers. A full list can be found at the following U.S. Department of Energy website: http://apps3.eere.energy.gov/greenpower/markets/certificates.shtml?page=2 (U.S. DOE 2011a)

[255] U.S. EPA 2010b

[256] Co-firing refers to the combustion of mixed fuels, such as woody biomass and coal.

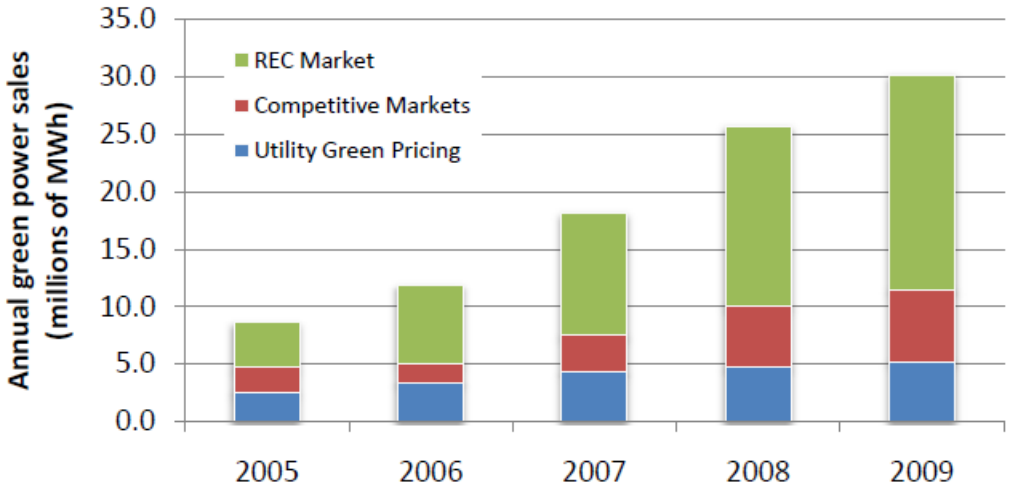
 

> **Legal and regulatory test:** Facility must not be mandated, built as a least-cost facility under a regulatory or legal process, located in an area with a binding GHG cap, or be owned by an entity reporting GHG emissions under such a program.[257]

Unbundled RECs are typically pooled from multiple projects and sold in groups identified by generation source (e.g. wind, solar etc.), region (e.g. Southeastern US, Western US), as well as term (e.g. 1 year to 3 years). Bundled RECs sold through green power purchase programs are often provided in block quantities or quantities equivalent to a specific portion of an end-user's monthly energy consumption.

As shown in Exhibit 34 below, voluntary REC sales have increased dramatically in recent years. This increase in popularity is largely due to a rise in the PR benefits of supporting renewable energy and to declining voluntary market REC prices.

**Exhibit 34: Estimated Annual Green Power Sales by Market Sector, 2005-2009**




Source: Bird and Sumner 2010, NREL

The table below shows that residential customers prefer green power purchase programs while non-residential customers overwhelmingly prefer unbundled RECs. "Nonresidential" sales include both commercial and wholesale sales, though commercial sales represent the majority of the nonresidential sales in 2009.[258]

[257] Green-e 2011a
[258] CRS 2010a

**Exhibit 35: Estimated Annual Green Power Sales by Customer Segment and Market Sector, 2009 (Millions of MWh)**

| Customer Segment | Green Pricing | Competitive Markets | REC Markets | Total |
|---|---|---|---|---|
| Residential | 2.8 | 4.3 | 0.04 | 7.2 |
| Nonresidential | 2.3 | 1.9 | 18.6 | 22.8 |
| **Total** | **5.2** | **6.2** | **18.7** | **30.0** |

Source: Bird and Sumner 2010, NREL

Commercial customers generally prefer unbundled RECs because they are less expensive than bundled RECs and are available in all states. Purchasing voluntary unbundled RECs is typically the least expensive of all the renewable energy support options addressed in this chapter. Purchasing RECs through green pricing programs can be more expensive than purchasing comparable unbundled RECs due to sometimes substantial program marketing and administrative costs. The National Renewable Energy Laboratory (NREL) estimated that green pricing programs spent a median of nearly 19% of program revenues on marketing while the smallest programs spent nearly 50% of program revenues on marketing.[259,260]

Generally, unbundled RECs are preferable to bundled RECs purchased through green power purchase programs because unbundled RECS are often less expensive and more flexible while also offering comparable PR value. Organizations should consider issues associated with both tpes of voluntary RECs before investing in either..

## Issues Associated with RECs

To address the issues associated with the purchase and retirement of voluntary REC products it is necessary to revisit the commonly accepted benefit of these products. Investing in RECs is seen as a way to support renewable energy development by providing developers an additional revenue stream that accelerates cost recovery and debt repayment, thereby reducing project risk.[261] Renewable energy projects are not necessarily riskier than conventional energy projects but they do have different risk profiles.[262] Generally speaking, renewable energy projects still rely on both government subsidies and REC payments to overcome current economic barriers to development. The purchase of voluntary RECs indicates public interest in developing additional renewable energy as part of a larger effort to reduce the emission intensity of America's energy mix. An organization that invests in RECs may count them against their Scope 2 emissions to claim the environmental attributes of those RECs. The use of voluntary RECs to reduce Scope 2

[259] Bird et al. 2009
[260] Dominion Energy's Green Pricing Program allocates half of program revenue to marketing and administration. Dominion Virginia Power 2011
[261] U.S. EPA 2010b
[262] Conventional generation projects are exposed to fuel cost fluctuations and environmental policies which can require extremely expensive emission control technologies or impose substantial emission taxes. Renewable generation projects are exposed to unforeseen changes in government subsidies. Both conventional and renewable generation projects are exposed to cost fluctuations stemming from the changes in the cost of raw materials, labor, or component supply/demand balances

emissions is potentially the largest driver of voluntary REC purchases.[263] Greenpeace, which has stated "the only truly green data centers are the ones running on renewable energy," is one example of an organization that hosts data center operations at a facility where the carbon emissions associated with the electricity consumed are offset by the purchase of voluntary RECs.[264]

### Risk of Double-Counting RECs and Associated Environmental Benefits

One of the major criticisms of RECs is that because they are intangible commodities they can be double-counted if more than one party claims ownership of the same RECs. This issue has largely been addressed by REC certification through organizations such as Green-e that conduct rigorous independent audits[265] and through the assignment of unique IDs to individual RECs in regional tracking systems. However, even after ensuring that a REC *certificate* has not been double-counted, the risk still exists that *emission reductions* associated with a given REC may be double-counted if those reductions are both (1) claimed by the purchasing entity, and (2) included in the grid emissions factor.

Renewable energy is pooled into the power grid along with all other types of grid-connected generation. If a certain renewable energy project is counted in calculating the average emission factor for the electricity in a given region, then its low carbon benefits are distributed among all electricity customers in the region. In such a situation, anyone in that region can claim that they consume energy with a lower emission rate, and the benefits will be double-counted if the entity that purchases RECs from the renewable project also claims the same carbon reduction benefits.[266] Many domestic voluntary GHG programs and market stakeholders largely overlook this issue while others, such as the Carbon Disclosure Project (CDP), have issued clear guidance that protects against this form of double counting. CDP, the world's largest voluntary corporate GHG reporting database, specifies that the lower emission factor of renewable generation can only be used for calculating an organization's emissions if the REC project has not already been counted in the grid average emissions factor.[267] An organization can determine if specific RECs have been counted in the grid average emissions factor by asking the supplier of the RECs. Another program, The Climate Registry, has proposed that it will develop an adjusted emission factor for organizations to use if the total RECs claimed by all participants in the registry amount to a change in the regional grid emission factor greater than five percent.[268] The CDP and The

[263] This driver is built into the National Renewable Energy Laboratory's (NREL) recent projections of voluntary REC market demand growth. NREL projects that voluntary REC market demand, which was approximately 30 million MWh in 2009, could reach 63 to 157 million MWh by 2015 and 94 to 327 million MWh by 2020. However, NREL estimates that demand could be as low as 24 Million MWh in 2015 and 33 Million MWh in 2020 if federal $CO_2$ cap and trade policy is passed that does not support the ability of RECs to reduce GHG emissions. We explore this potential issue for voluntary RECs later this chapter.
Bird et al. 2010
[264] Miller 2010b
[265] Green-e provides a list of ways RECs may be double counting in its definition for "Double Counting" here: http://www.green-e.org/learn_dictionary.shtml (Green-e 2011d)
One example of attempted double counting: http://www.resource-solutions.org/pressreleases/2010/072810.htm (CRS 2010b)
[266] CDP 2011
[267] CDP 2011
[268] The Climate Registry 2010

Climate Registry efforts both work to avoid double counting emission benefits associated with REC purchases though they highlight that a standard margin of error has yet to be defined.

### Limits of Voluntary REC Investments

An organization can use voluntary RECs to reduce its Scope 2 emissions and state that some or all of its operations are powered by electricity from renewable sources. However, an organization should not use voluntary RECs to reduce Scope 1 or Scope 3 emissions. Additionally, an organization that purchases RECs should be careful to communicate REC purchases transparently and avoid overstating the benefits of the investment. Unless the organization has strong evidence that its REC purchases have been sourced from projects that are deemed as "additional," it should pursue a communication strategy that emphasizes its *support* of renewable energy but refrains from indicating that it has *catalyzed* or *enabled* renewable energy development. Additional projects are those that would not have been economically viable without the revenue stream provided by RECs.

RECs are meant to commoditize the environmental benefits of renewable energy, and are not necessarily sourced from truly additional projects. A rigorous additionality test is generally not required in the voluntary REC marketplace, and as a result some non-additional projects can sell RECs in voluntary markets.[269,270] For this reason, an organization that purchases voluntary RECs should be careful to only claim that it has enabled renewable energy development if the projects from which it has purchased RECs have been certified as additional by a third-party.[271]

A number of new wind energy projects that have come online in recent years are economically viable without REC revenue but are certified to participate in the voluntary REC marketplace anyway.[272] Such projects, many of which are located in Texas[273], have flooded the voluntary

[269] The regulatory and timing criteria applied by Green-e, provided earlier in this chapter, are intended to identify projects that are beyond business-as-usual. Though these criteria overlap significantly with those commonly included in additionality tests used to certify carbon offset projects, they do not collectively represent a substitute for a thorough additionality test. As a result, there is no guarantee that projects selling Green-e certified RECs are additional. Green-e does not require projects selling Green-e certified RECs to prove that the projects need revenue from the sale of RECs to be financially viable. Evaluating this need for additional revenue is known as assessing financial additionality. A financial additionality test is a commonly accepted component of most rigorous additionality tests, particularly those used in compliance carbon offset markets. Note, however, that even projects that prove financial additionality may not truly be additional. In Chapter 4 we discuss how many 'business-as-usual' projects have found ways to 'beat' the financial additionality test in carbon offset markets.

[270] The Voluntary Carbon Standard, a leading international offset quality standard, recognizes that some renewable energy projects ("wind power projects in specific parts of the country") are competitive with conventional power generation. As a result, the VCS requires that renewable energy projects pass a financial additionality test (investment analysis) as well as other additionality tests to be VCS eligible.
VCS 2011

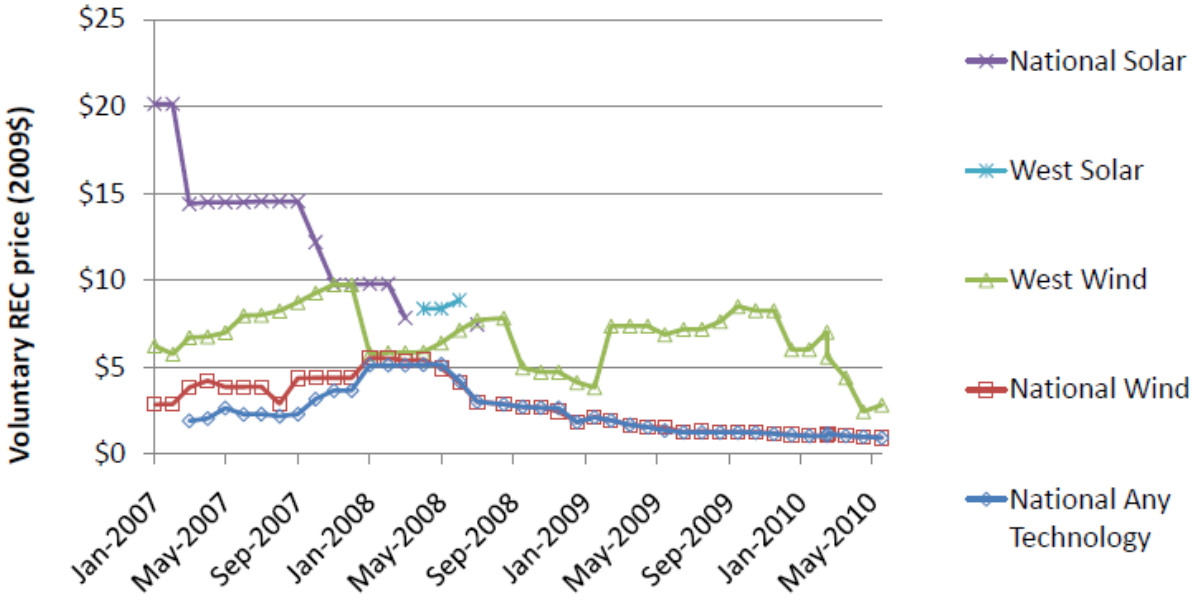
[271] RECs sourced from projects certified to be additional are generally more expensive than those that are not additional. Projects certified to be additional often sell offsets into voluntary carbon markets rather than sell RECs into voluntary REC markets. A project may be certified to sell RECs and offsets, though it can only sell one type of product at a time – a wind generator cannot sell the same renewable attribute from 1 MWh of generation in both the offset market and REC market as doing so would double count the attribute.

[272] A recent review of the U.S. energy market conducted by Bloomberg New Energy Finance confirmed that wind generation is competitive with coal-fired generation in some U.S. regions.
Bloomberg New Energy Finance 2011

[273] Due to the abundance of economically viable wind generation projects in Texas, the state exceeded its 10 GW by 2025 renewable energy goal in 2010 (nearly all 10 GW is wind capacity). Texas RECs trade at approximately

market with inexpensive RECs. Market participation by non-additional projects drives down REC prices, which are now so low that it is extremely difficult, if not impossible, for 'additional' projects to compete.[274] Current voluntary REC price levels for wind generators, which provide the majority of the voluntary market REC supply, are commonly accepted to be insufficient to catalyze the development of new wind generation projects.

**Exhibit 36: Historical Wholesale U.S. Voluntary REC Prices**




Source: Bird 2010a, NREL
Note: National Solar and West Solar prices truncated by NREL

Current prices of approximately $0.75/MWh to $1.00/MWh (varies by vintage) for National Wind and National Any Technology RECs (shown above) represent an extremely small fraction of the levelized cost of a wind project, particularly projects that might be considered 'additional.' The voluntary REC revenue stream provided at such low prices provides a marginal level of support that industry insiders commonly describe as an afterthought for project developers. What this means is that in some instances, the purchase of voluntary RECs may slightly subsidize renewable energy development, but because the subsidy provided could effectively be inconsequential, public claims of support could be criticized as greenwashing if those claims are not described conservatively.

Many organizations purchase voluntary RECs to support renewable energy development; Cisco and Intel are two of the largest purchasers. Representatives of both companies recently defended the benefits of investing in voluntary RECs. Andy Smith, Cisco's global sustainability manager, stated that "[purchasing voluntary RECs] sends a clear signal to the market that we want cleaner energy," and Marty Sedler, Intel's director of global utilities and infrastructure, stated, "Any

$1/MWh. Many Texas wind projects participate in voluntary REC markets and many participate in voluntary carbon offset markets.
[274] Kollmuss et al. 2010

RECs you buy absolutely help get more generation built. How much? It's very hard to determine."[275]

It is extremely difficult to quantify the extent to which voluntary REC sales spur renewable energy development largely because projects supplying RECs typically do not undergo a robust additionality test.[276] As of this writing, publicly available information that shows the extent to which voluntary REC markets have enabled renewable energy development was not available. Some market participants have questioned the value of investments in voluntary RECs because of this uncertainty. For example, Sarah Severn, Nike's director of corporate sustainability, recently commented that "there is a lot of scrutiny about RECs and whether they're helping to launch projects…It might not be something we'd want to be associated with."[277] Because voluntary market stakeholders have yet to agree upon and implement a test of additionality that will mitigate such uncertainty, some organizations seeking to more confidently state that they have enabled renewable energy development have considered investing in high quality offsets sourced from renewable energy projects rather than investing in voluntary RECs.[278,279] High quality offsets undergo rigorous additionality tests, and evidence supporting project financial additionality is readily available. We explore offsets and offset additionality tests in the following chapter.

One final challenge facing voluntary RECs is that the passage of regional and federal greenhouse gas (GHG) cap-and-trade policy could preclude REC purchasers from claiming emission reductions associated with their RECs.[280] Generally, buyers of voluntary RECs sourced from projects located in a region with a legally binding electricity sector GHG caps cannot claim these emission reductions unless a mechanism, typically called a voluntary renewable energy allowance set-aside, exists to credit GHG reduction benefits to the source projects. However, a voluntary REC set-aside could very well be included in any future regional or federal GHG policy given that such a provision has been included in the Regional Greenhouse Gas Initiative (RGGI) as well as in the California Air Resources Board's (CARB) draft emission trading program regulation (Assembly Bill 32).[281] Nonetheless, this is an issue that should be closely

[275] Elgin 2010
[276] Critics of more stringent additionality tests, specifically tests that involve a financial additionality test, sometimes argue that project developers can pass such a test using manipulated, but seemingly reasonable, financial assumptions.
[277] Elgin 2010
[278] *Native*Energy, a provider of Green-e certified RECs as well as a provider of carbon offsets, is an example of a company that advocates the purchase of offsets sourced from renewable energy projects rather than RECs in instances where an organization wishes to state it has enabled renewable energy rather than just supported renewable energy due to uncertain additionality. Purchasing a voluntary REC sourced from a wind project would allow an organization to say that it is "wind powered", while purchasing a high quality offset sourced from a renewable energy project would allow the organization to advertise that it has *enabled* wind development in addition to saying that it is wind powered.
*Native*Energy 2011
[279] In the next chapter we provide an example of an organization that purchased offsets sourced from renewable energy rather than voluntary RECs due to the organization's greater confidence in the additionality of the project selling the offsets.
[280] Bird et al. 2010
[281] California Air Resources Board (CARB) 2010

followed by any organization that wishes to purchase voluntary RECs to reduce its Scope 2 emissions as part of a long-term carbon mitigation strategy.

Purchasing voluntary RECs is a relatively inexpensive and flexible way to indicate support for renewable energy development. However, the direct impact of that support is difficult to demonstrate due to the lack of clarity regarding which renewable energy projects have actually been enabled by the sale of voluntary RECs. This uncertainty limits the claims a voluntary REC purchaser may confidently make about the benefits associated with its purchase. Despite the concerns highlighted in this section, however, purchasing voluntary RECs can still be used to reduce Scope 2 emissions and can play an important role in a balanced portfolio of emission reduction investments.

## Communicating Renewable Energy Investments

Renewable energy is typically highly regarded because it reduces carbon emissions through the displacement of "dirty" fossil fuels and is often portrayed as improving local economies through job creation. Organizations that demonstrate a commitment to renewable energy enjoy substantial positive press coverage. For example, Google's numerous renewable energy project investments have been widely discussed and have enhanced the authenticity of the company's 'change the world' attitude.[282] Proactive companies can also apply for and receive recognition for their achievements through awards such as the U.S. EPA's Green Power Leadership Awards.[283] Intel Corp, which currently powers more than 50% of its U.S. operations with renewable power, was presented the 2010 Green Power Leadership Award for its commitment to renewable energy through green power purchases, on-site solar systems, and educational "solar kiosks" at facilities.[284] The EPA's Green Power Partnership program also provides a Top Partner Rankings database that highlights companies that have demonstrated the greatest support for renewable energy through unbundled REC purchases, utility green power purchases, and on-site renewable generation use.[285]

An organization can also communicate its renewable energy investments by participating in a voluntary corporate GHG reporting database, such as the Carbon Disclosure Project, and

[282] Some examples of positive press coverage:
"Google makes $38m move into wind energy"
http://www.windpowermonthly.com/news/1000689/Google-makes-38m-move-wind-energ (Quiler 2010)
"Google Invests in 6 GW Offshore Wind Farm"
http://www.renewableenergyworld.com/rea/news/article/2010/10/google-invests-in-6-gw-offshore-wind-farm (Renewable Energy World Magazine 2010)
"Google Invests $168 Million in 392MW Mojave Desert Solar Thermal Plant"
http://www.treehugger.com/files/2011/04/google-invests-168m-mojave-desert-solar-thermal-power-plant.php (Richard 2011)
"Google to buy 100.8 megawatts of Oklahoma wind energy"
http://www.grist.org/wind-power/2011-04-22-google-to-buy-100.8-megawatts-of-oklahoma-wind-energy (Woody 2011)
"Google Invests $280 Million in SolarCity Project Finance Fund"
http://www.bloomberg.com/news/2011-06-14/google-invests-280-million-in-solarcity-project-finance-fund.html (Herndon 2011)
[283] U.S. EPA 2011n
[284] U.S. EPA 2011n
[285] U.S. EPA 2011q

applying the emission reductions associated with its renewable investments toward its reported emissions. In addition, organizations can gain recognition for investing in renewable energy through the U.S. Green Building Council's LEED certification system.[286] Organizations can retire RECs to earn Green Power Points in conjunction with implementing other sustainable practices to earn LEED certification for existing buildings, new construction, and major renovations.

To avert potential criticism of their actions, organizations should carefully choose their renewable energy investments and communicate the benefits accurately. As per the *Environmental Marketing Guidelines for Electricity* issued by the National Association of Attorneys General, any claims about renewables should be clear and should not be presented in a manner that implies more than the actual benefit.[287] The Center for Resource Solutions (CRS), the organization that administers the Green-e Energy and Green-e Climate programs, provides specific guidance on the share of renewable energy that can be claimed based on green power purchases. It recommends that customers who buy power under green pricing programs claim they use renewable energy only up to the sum of (a) the share of their electricity that comes from renewables under the green pricing program, and (b) the product of the share of their purchased electricity that comes from the grid and the renewable component of grid electricity.[288] For instance, an organization that purchases energy under a green pricing program with 50% renewables and is located in a region where the grid electricity has a renewable component of 10% can only claim that it uses [50% + (50% x 10%)] = 55% renewable energy. Organizations should be careful to clarify whether the emission reductions from their renewable energy investments are applicable to their Scope 1 or Scope 2 emissions.

The FTC has proposed a limited set of guidelines for how to describe claims of renewable energy support. These guidelines, provided below, require marketers to clearly describe in customer communications the type of renewable energy used and the share of total energy consumption that is renewable.

> *• Marketers should not make unqualified renewable energy claims if the power used to manufacture any part of the product was derived from fossil fuels.*
> *• Marketers should qualify claims by specifying the source of renewable energy (e.g., wind or solar). Additionally, marketers should qualify claims if less than all, or virtually all, of the significant manufacturing processes involved in making the product/package were powered with renewable energy or conventional energy offset by renewable energy certificates ("RECs")*
> *• Marketers that generate renewable energy (e.g., by using solar panels), but sell RECs for all of the renewable energy they generate, should not represent that they use renewable energy*.[289]

[286] USGBC 2011a and USGBC 2011b
[287] National Association of Attorneys General 1999
[288] CRS 2010c
[289] FTC 2010b

These guidelines, which are expected to be finalized by 2012, do not require disclosure of whether renewable energy claims are based on the purchase of RECs, but do require companies to ensure that they do not mislead customers into thinking that renewable energy provides local benefits.[290]

[290] FTC 2010a

# Chapter 4 Carbon Offsets

## Introduction

Carbon offsets are a crucial component of corporate greenhouse gas mitigation strategies. Offsets are based on the idea that an organization can compensate for some or all of its GHG emissions by paying other entities to reduce, remove or avoid equivalent emissions through specific projects. For instance Organization X can pay organization Y to develop a landfill methane destruction project, which decreases global emissions by Z $MtCO_2e$ every year. Organization X then counts the $MtCO_2e$ reductions against its own emissions, balancing the impact of emissions from its footprint. Purchasing offsets is a cost-effective means of reducing emissions beyond what is possible through energy efficiency-related and renewable energy-related footprint reduction efforts. It is presently almost impossible for an organization to achieve carbon neutrality (zero Scope 1, 2, and 3 emissions) without including carbon offsets in its GHG reduction strategy.

Offset are transacted in the form of offset credits, tradable units that each correspond to a reduction of 1 $MtCO_2e$ from a project. Organizations can purchase and retire[291] these offset credits (also known as carbon credits) to balance some or all of their emissions with an equal number of offsets. Exhibit 37 provides a visual representation of a hypothetical offset transaction in three time periods, T1, T2 and T3. Here, T1 represents the initial business-as-usual scenario. Each block corresponds to 1 $MtCO_2e$, so in T1 the potential offset buyer has baseline and actual emissions of 10 $MtCO_2e$ while the potential project developer has baseline and actual emissions of 8 $MtCO_2e$. In T2, the offset project developer decreases GHG emissions by 2 $MtCO_2e$ against the project baseline and obtains certified offset credits. In T3, the developer sells the credits to the buyer. If the buyer retires all the offsets, the buyer can claim that the credits have reduced their carbon footprint by 2 $MtCO_2e$ against their baseline. The commoditization of emission reductions in this manner has created fairly liquid offset markets in which multiple sellers and buyers can participate. However, the volatility of offset prices and controversy regarding the legitimacy of some GHG offset projects have rendered offset investments increasingly risky, prompting many organizations to rethink the role of carbon offset investments in their long-term sustainability strategies.

[291] To claim the emission reductions associated with an offset an organization must retire offsets it purchases (if they are not automatically retired on its behalf by the offset provider). Retiring offsets ensures that they are used only once.

**Exhibit 37: GHG Offset Transaction**

There are two types of buyers in offset markets. Most buyers purchase credits to comply with government-mandated cap-and-trade systems such as the European Union Emissions Trading System (EU-ETS) and the Regional Greenhouse Gas Initiative (RGGI). Others buy offsets of their own accord to achieve self-determined emission goals. Organizations that voluntarily purchase offsets have the option of buying carbon credits generated for compliance systems as well as those that are specifically intended for voluntary markets. Globally, in 2009, voluntary buyers funded emission reductions of over 93.7 million $MtCO_2e$ through offset purchases worth $387.4 million, at an average price of just over $4.1/$tCO_2e$. Though the number of offsets transacted declined by 26% against volumes in 2008, 2009 sales still represented a 39% increase above 2007 sales.[292]

In general, offsets can help organizations reduce overall costs of achieving emission goals by shifting emission reductions to projects that have lower costs. Offsets can also stimulate technology development and transfer, offer sustainability co-benefits such as reforestation and the creation of jobs, and help develop institutional capacity for emission reductions in sectors and locations that do not have mandatory GHG caps.[293]

To provide actual environmental benefits, offsets must be real, additional, permanent, and verifiable; we explain these terms later in the chapter. Low quality offsets that do not meet these criteria pose a fundamental risk to the environmental integrity of their purchaser's climate actions. In addition, there is also the risk that investing in offsets will divert investment away from efficiency improvements and low emission infrastructure, and potentially lead to higher long-term costs for emission reductions.[294] Citing the risks associated with offsets, organizations such as Yahoo![295] and Nike[296] are moving away from purchasing offsets as part of their GHG strategy and focusing investments on footprint reduction. Others, such as Google[297] recognize these risks but attempt to address them and continue to combine offsets with footprint reduction efforts to reach their goals of carbon neutrality.

Organizations that decide to include offsets in their sustainability efforts should treat offsets as one component of a larger strategy that involves reducing an organization's carbon footprint before or along with offset purchases. Organizations should fully exhaust feasible, cost-effective energy efficiency improvements before investing in emission offsets since efficiency improvements tend to be low risk and offer permanent footprint reductions whereas offsets must be repeatedly purchased to reduce the emissions associated with recurring energy consumption. Organizations should be extremely careful to source high quality offsets and to communicate their offset strategy transparently to stakeholders – firms that purchase low quality offsets or make unclear or overstated claims are often accused of "buying" their way out of emissions and "greenwashing".[298]

[292] Ecosystem Marketplace and Bloomberg New Energy Finance 2010
[293] Kollmuss et al. 2010
[294] Kollmuss et al. 2010
[295] Filo 2009
[296] Nike 2010
[297] Ryan 2009
[298] Kollmuss et al. 2010

## Overview of Offset Markets

Like other commodities traded in markets, carbon credits are subject to the economics of supply and demand. Demand-driven variations in carbon prices arise from specific characteristics of the offsets, including the type and location of the offset project, the project's co-benefits, the standard used for offset quantification and verification, the offset provider, the vintage year of the credit, and pending government regulation. Supply-side factors that determine offset prices include transaction size and the costs of project development and implementation, validation processes, verification and certification, monitoring, legal fees, risk management, training, and overheads.[299] The recent economic downturn coupled with uncertainty regarding the future of some voluntary and compliance markets has yielded a surplus of offsets, presenting an opportunity for consumers to purchase offsets at historically low prices.[300]

## Purchasing Offsets

It is often difficult to choose among the many products and vendors in the voluntary carbon offset marketplace. Before evaluating these options, an organization should first set clear sustainability goals, then evaluate if and what types of offsets can best contribute. Offset buyers should determine if they prefer offsets from particular sources (e.g. afforestation), projects in certain economic sectors (e.g. agriculture and logging), projects in specific geographic locations (e.g. Brazil), or projects that provide particular co-benefits (e.g. conserving biodiversity and promoting sustainable development).[301] It is important to note that the quality of an emission reduction associated with an offset is independent of factors such as project type, location and co-benefits; that is, the benefit of a metric ton of $CO_2e$ reduced is the same irrespective of how and where it was reduced, provided the offset meets the key criteria that maintain its environmental integrity.

Offsets are sold by project developers, retailers/wholesalers, brokers, aggregators, and utilities. When picking an offset provider, an organization should evaluate the provider's credibility (transparency, standards, and registry), ability to meet specific offset requirements, and offset communication support. Organizations that intend to buy large quantity of offsets typically issue a request for proposal (RFP), an approach that provides more options and negotiating power than possible when contacting providers individually.[302] Offset purchasers that require a smaller quantity of offsets typically contact offset marketers directly to request quotes.[303]

The following sections provide an overview of the characteristics of high quality offsets, the differences between offset projects, market participant preferences, and recent market trends.

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[299] Carbonfund.org and RPN 2009
[300] Ecosystem Marketplace and Bloomberg New Energy Finance 2010
[301] Carbonfund.org and RPN 2009
[302] Sample RFP for carbon offsets: http://www.responsiblepurchasing.org/purchasing_guides/carbon_offsets/specs/ICFCarbonTender07-02.doc (ICF International 2007)
[303] Carbonfund.org and RPN 2009

There are numerous carbon offset guides available online that discuss these and other topics in much greater detail - this section strives to be a concise introductory guide.[304]

### Key Criteria to Ensure the Environmental Integrity of Offsets

Evaluating an offset provider's credibility involves ensuring that the offsets being sold meet certain key criteria that establish the integrity of the associated emission reductions. Offsets are viewed as credible emission reductions if they meet the following criteria:

1. Offsets should be **real**. Each offset credit should correspond to an actual emission reduction against a realistic emissions baseline. The baseline refers to the emissions that are projected to occur in the absence of the offset project. After the project is implemented, the difference between the actual emissions and the baseline represents the project-driven reductions achieved and credited as offsets. Since offsets are calculated directly against their baselines, they are only as credible as their baselines.[305]

2. Offsets should be **additional**. Offsets can only count towards balancing their purchaser's emissions if the projects from which they accrue were catalyzed by the revenue from credits. This means that the reductions represented by offsets cannot have been required by regulation and must be "in addition to" those that would have been economical without the sale of credits.[306,307]

3. Offsets should be **permanent**. Some offset projects face the risk of being reversed in the future. For instance, carbon sequestered through a forest sector project could be released to the atmosphere in the case of a forest fire. Offsets should represent permanent emission reductions, or should use mechanisms such as insurance, reserve pools and buffer accounts to minimize the losses in case of project reversal.[308]

4. Offsets should be **verifiable**. Offsets should represent emission reductions that are accurately quantified, monitored and verified. Offset projects should have detailed monitoring plans for data collection and emissions quantification, that are developed by experts using recognized standards such as the International Standards Organization 14064-Part 2 and the World Resources Institute's GHG Protocol for Project Accounting. Before offset credits are issued, quantified GHG reductions must also be verified by an independent, qualified, third-party verifier whose compensation is not outcome-dependent.[309]

5. Offsets should address **leakage**. Monitoring and verification plans for offset projects should provide mechanisms that properly account for potential leakage during the

[304] The Carbon Offset Research & Education website is one such useful guide: http://co2offsetresearch.org/index.html (Carbon Offset Research and Education (CORE) 2011) We also recommend reading the guides and reports referenced throughout this chapter.
[305] Offset Quality Initiative 2008
[306] Offset Quality Initiative 2008
[307] Carbonfund.org and RPN 2009
[308] Offset Quality Initiative 2008
[309] Offset Quality Initiative 2008

lifetime of a project. Leakage refers to a situation in which the implementation of an offset project leads to higher emissions outside the project's emissions boundary.[310] For instance, a project that replaces coal with alternative fuels in one factory may lead to increased availability and combustion of coal at another factory.

6. Offsets should be **unambiguously owned**. Since offsets are intangible, not physical, commodities, it is extremely important for ownership of each credit to be established clearly and documented accurately. Also, when each credit is sold, the transfer of ownership should be recorded unambiguously and the seller of the offset must surrender all rights to claim future credits for the same reduction. The ownership and transfer of each offset is typically tracked by assigning it a unique serial number and accounting for it in an approved tracking system such as a registry.[311]

It is typically difficult for organizations to independently assess whether offsets sold by a provider meet these six criteria. Third-party standards for offsets (discussed in the next section) help simplify this evaluation. Potential buyers should ask offset providers about the third-party standard used to certify their offsets.

### Third-Party Standards

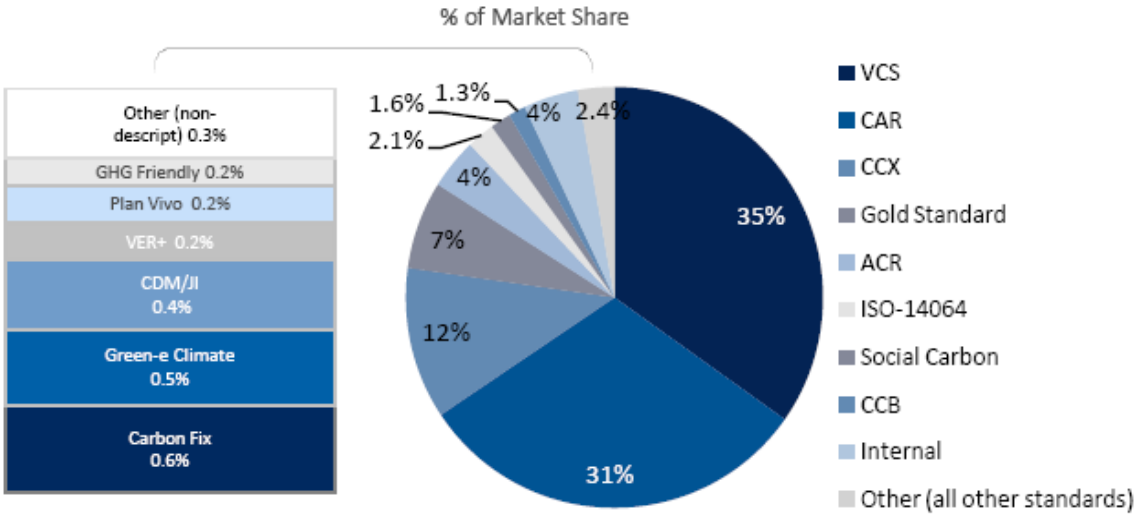
Third-party standards, which vary in stringency and credibility, have been developed by governments, non-profits, and private sector companies to help consumers evaluate offsets. Third-party standards are designed to address the criteria described above as well as issues such as offset accounting, quantification, monitoring, verification, certification, registration, and retirement.[312] Offsets face some of the same issues as RECs in that they may be double counted, so offsets also have registries that track sales and retirements. Standards typically ensure the quality of offsets through one of two mechanisms – some standards provide a set of criteria against which projects are assessed before certification by an independent third-party organization (e.g. Gold Standard, Voluntary Carbon Standard), while other standards act as registries that only accept offsets from projects that adhere to certain conditions (e.g. Climate Action Reserve, American Carbon Registry).[313]

In 2009, 93% of all voluntary offsets sold were certified to meet third-party standards, with the top three standards being the Voluntary Carbon Standard (VCS - 35%), Climate Action Reserve (CAR - 31%), and the Chicago Climate Exchange (CCX - 12%). Exhibit 38 below provides an overview of the market share of third-party standards based on voluntary market transaction volume. The CCX ceased trading of new emission allowances at the end of 2010.[314]

[310] Offset Quality Initiative 2008
[311] Offset Quality Initiative 2008
[312] Kollmuss et al. 2010
[313] Carbonfund.org and RPN 2009
[314] In October, 2010 the Chicago Climate Exchange announced that it would cease all trading of new emission allowances at the end of 2010.
Chicago Climate Exchange 2010

**Exhibit 38: Carbon Offset Transaction Volume by Standard, OTC 2009**




Source: Ecosystem Marketplace and Bloomberg New Energy Finance 2010

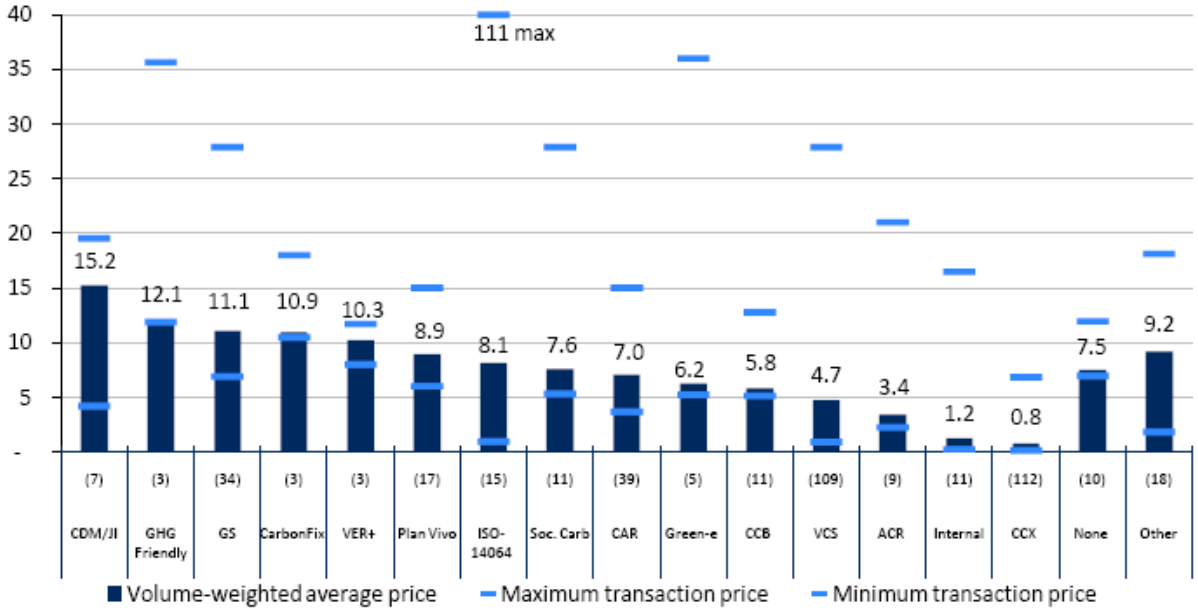
Offset buyer preferences in third-party standards vary by buyer type. Pre-compliance buyers, those expecting to have compliance obligations under future carbon emission regulation, look for standards that will likely be eligible in future compliance markets (e.g. CAR certified offsets were likely to be eligible under anticipated U.S. federal regulation while CCX certified offsets were likely to be ineligible). Other voluntary buyers typically prefer higher quality standards with co-benefits, such as the Gold Standard (offsets certified by this standard are eligible for both current Kyoto Protocol obligations and voluntary purchases), Plan Vivo, as well as Climate Community and Biodiversity Standard (CCB). Many voluntary buyers prefer standards with easy-to-understand requirements. CAR, for example, uses performance-based additionality standards rather than financial-based standards, which can be more complicated. Also, standards that offer offsets from the most diverse projects are often more popular given that many buyers have specific offset preferences.[315]

The cost of offsets certified under different standards can vary greatly. 2009 volume weighted average over-the-counter (OTC) offset prices shown in Exhibit 39 ranged from \$15.2/t$CO_2$e (for CDM/JI credits) to \$0.8/t$CO_2$e (for CCX credits). [316]

[315] Ecosystem Marketplace and Bloomberg New Energy Finance 2010
[316] Ecosystem Marketplace and Bloomberg New Energy Finance 2010

**Exhibit 39: Average Carbon Offset Price by Standard, OTC 2009 ($/tCO$_2$e)**




Source: Ecosystem Marketplace and Bloomberg New Energy Finance 2010
Note: Based on 417 observations

Standards that command higher prices are more stringent, certify higher cost offset projects (such as solar generation rather than avoided deforestation), and tend to be in greater demand.

### Types of Offset Projects

Besides evaluating the credibility of an offset provider, offset purchasers should consider whether the provider can supply the desired volume and type of offsets. Offset purchases procuring a large quantity of credits have more flexibility to request very specific offsets.

There are several broad categories of offsets, the first of which is derived from direct emission reductions. This offset type involves emission reductions that occur at the site of a project. Direct emission reductions may occur, for example, when a natural-gas fired power generator switches to using methane supplied by a landfill, when operational improvements/upgrades decrease on-site fuel consumption, and when methane is destroyed through flaring at a landfill. Direct emission reductions are the least risky reduction type due to their simplicity and easy verification because they occur on-site, have a clear boundary, are easily quantified, and have clear ownership (thus reducing the likelihood of double counting).[317]

The second category of offsets is derived from indirect emission reductions which occur at a location other than a given project site. Renewable energy and energy efficiency projects both yield indirect emission reductions by decreasing generation at emission-intense power plants or reducing demand for new fossil fuel generation capacity. As with RECs, which are often used to offset Scope 2 emissions, indirect offsets should be used carefully because they have a relatively

[317] Offset Quality Initiative 2008

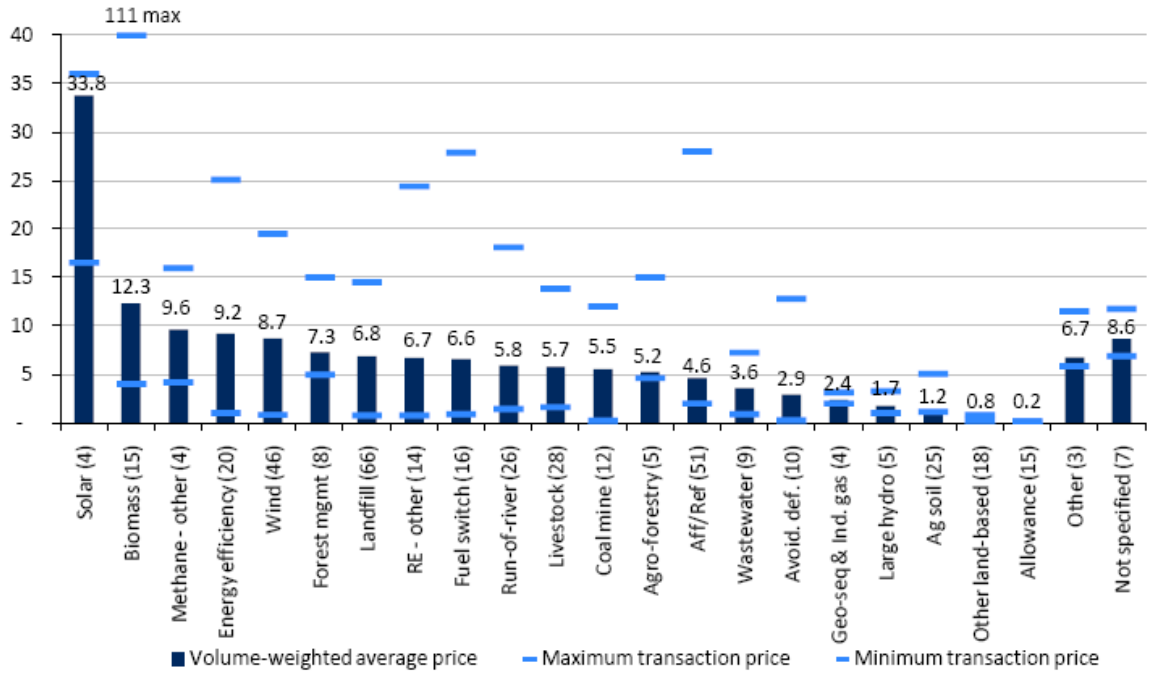
 

higher risk of being double counted if other entities reporting emissions assume a grid emission factor that is lowered because it accounts for the GHG impact of those offsets.

The third type of offset is derived from the sequestration of emissions, typically through biological sequestration. Examples of biological sequestration through land use/land-use change/forestry (LULUCF)[318] include afforestation, reforestation projects, and changes in agricultural practices. Sequestration emission reductions face challenges including baseline establishment (more complex than direct projects), higher risk of reversal/lack of permanence through events such as fires or illegal logging, and higher risk of leakage.[319,320] These risks can be decreased through insurance and buffer pools that provide additional offset funding or backup offsets in case of reversal or underperformance.[321]

Of all the OTC transactions that took place in 2009, the highest earning project types were predominantly renewable energy projects (solar, biomass and wind). Methane and energy efficiency projects were also among the top five. Offset prices are, to a large extent, influenced by underlying project costs.

**Exhibit 40: Average Carbon Offset Price and Price Range by Project Type, OTC 2009 ($/tCO$_2$e)**



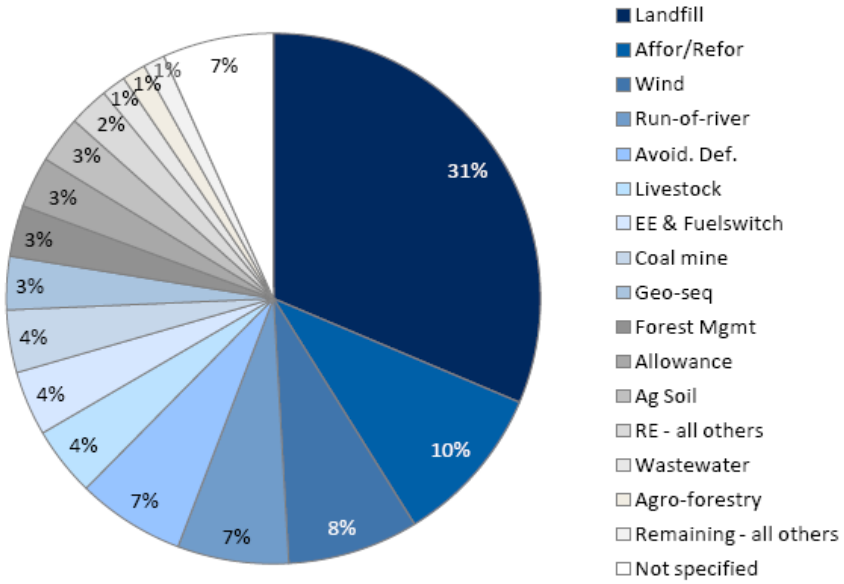

Source: Ecosystem Marketplace and Bloomberg New Energy Finance 2010
Note: Based on 326 observations

[318] Carbonfund.org and RPN 2009
[319] Offset Quality Initiative 2008
[320] Carbonfund.org and RPN 2009
[321] Offset Quality Initiative 2008

In 2009 methane destruction projects represented 41% of market volume, with forestry projects at 24% and renewable energy at 17%.[322]

**Exhibit 41: Carbon Offset Transaction Volume by Project Type, OTC 2009**




Source: Ecosystem Marketplace and Bloomberg New Energy Finance 2010

Methane destruction and Improved Forestry Management (IFM) have been popular among pre-compliance buyers as both project types are likely to be eligible to produce offsets in future compliance regimes. Pure voluntary buyers typically prefer credits from projects with community co-benefits[323] because they have a higher sustainability impact and are more marketable.[324]

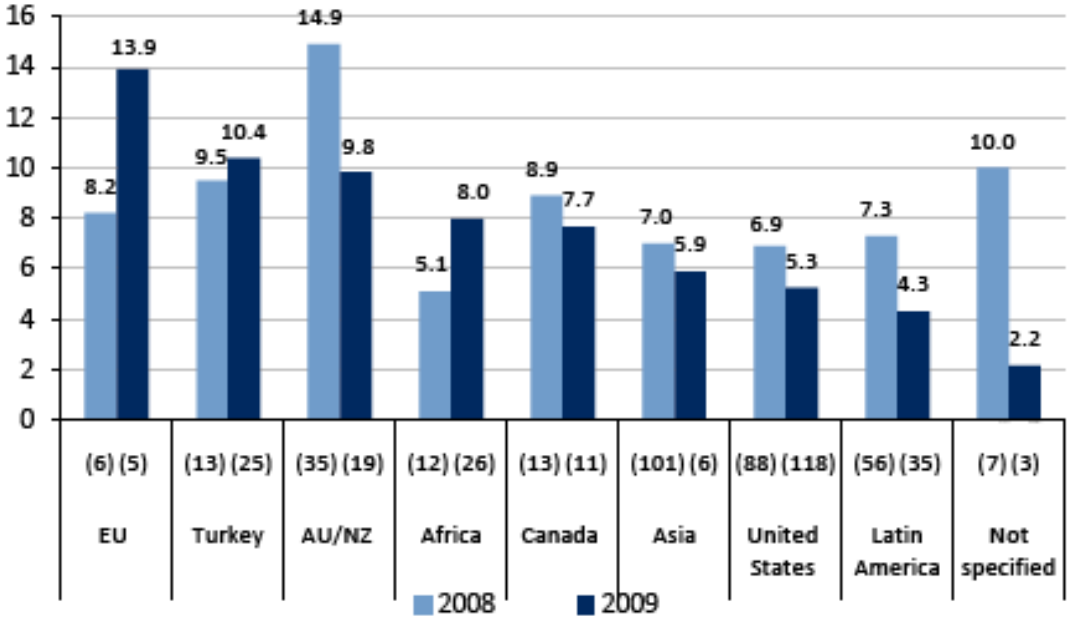
## Location and Vintage

While the geographical distribution of offset projects depends partly on project costs, policies, project opportunities and policies in each country, it is also partly driven by buyer preferences. In 2009, offsets projects in the U.S. supplied about 56% of voluntary offsets[325], with projects in Latin America contributing 16% and those in Asia supplying 12%.[326] Credits from the EU fetched the highest prices ($13.9/tCO$_2$e), followed by Turkey ($10.4/tCO$_2$e), and AU/NZ ($9.8/tCO$_2$e), and credits from Latin America were priced lowest, at $4.3/tCO$_2$e on average.

[322] Ecosystem Marketplace and Bloomberg New Energy Finance 2010
[323] Ecosystem Marketplace and Bloomberg New Energy Finance 2010
[324] Carbonfund.org and RPN 2009
[325] This percentage only includes over-the-counter (OTC) transactions.
[326] Ecosystem Marketplace and Bloomberg New Energy Finance 2010

**Exhibit 42: Average Carbon Offset by Region, OTC 2008 vs. 2009 ($/tCO$_2$e)**




Source: Ecosystem Marketplace and Bloomberg New Energy Finance 2010

While pre-compliance buyers focus on offsets likely to qualify under anticipated carbon regulation, pure voluntary buyers typically support local projects that are more marketable to stakeholders and customers. Some buyers also cite lower risk and the desire to support carbon reductions in specific regions of the world as reasons for preferring offsets from a specific location. For example, several European market participants have noted that they buy credits sourced from the U.S. because they want to support U.S. abatement commitments.[327]

Offset purchasers often prefer offsets with vintages of the current year, recent years, or in the near future, because there is a higher risk associated with deliveries in the distant future.[328] The vintage of an offset refers to the year in which the associated emission reduction occurred or is expected to occur. Pure voluntary buyers tend to prefer more recent or near future vintages so that the purchased offsets can be retired as soon as possible. Pre-compliance buyers place a higher value on future vintages because of the higher likelihood of their eligibility in future carbon regulation.[329]

## Risks and Controversies

Investing in carbon offsets is a valuable way for an organization to decrease its carbon impact cost-effectively and even become carbon neutral. However, an organization that currently integrates or plans to integrate carbon offset investments in its sustainability efforts should be aware of important carbon offset market issues and controversies. The legitimacy of offsets in general and of some project categories in particular has recently been called into question by stakeholders and experts. Concerns regarding the inefficiency of offset markets, future changes in eligibility requirements, discrepancies between certification standards, and the likelihood of

[327] Ecosystem Marketplace and Bloomberg New Energy Finance 2010
[328] Carbonfund.org and RPN 2009
[329] Ecosystem Marketplace and Bloomberg New Energy Finance 2010

project developers "gaming the system" have all weakened the credibility of offset markets and increased the risks of market participation.

Offset markets as a whole have been criticized by some as an inefficient, overly complex way of reducing GHG emissions compared to more straightforward mechanisms such as a carbon tax or donations to climate change projects. This argument stems from the fact that a large portion of the price paid for offsets is diverted to costs for activities such as research and administration that do not directly reduce GHG emissions.[330]

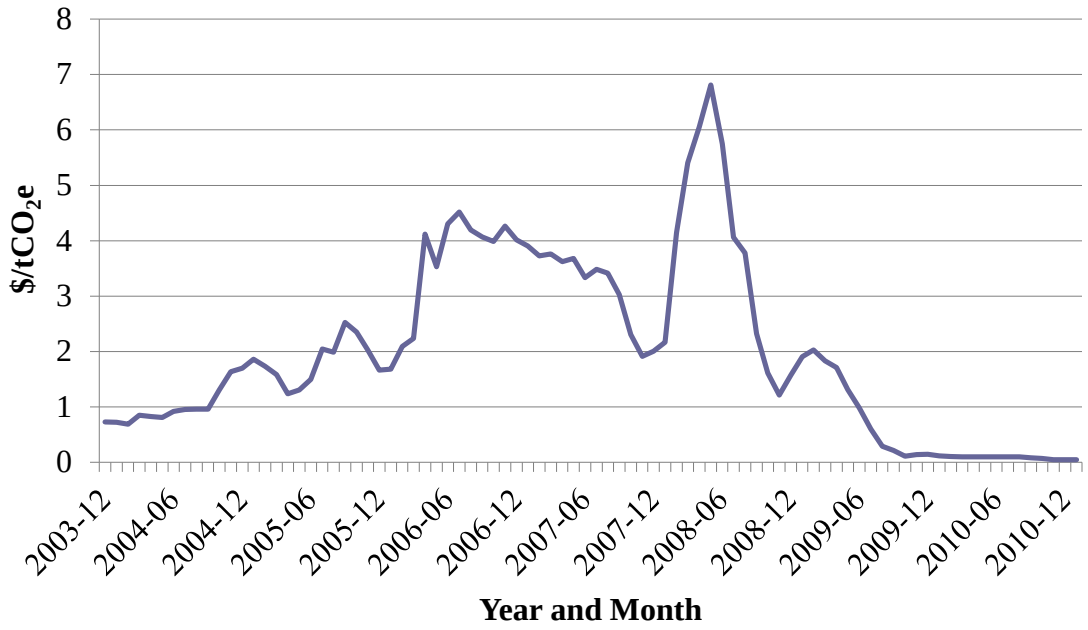
While buyers in voluntary offset markets are motivated by different considerations than buyers in compliance markets, the basic intent of both markets is the same – to reduce total greenhouse gas emissions using a market-based competitive mechanism. Also, offsets sold in mandatory markets can be purchased voluntarily and set the highest bar of offset quality for voluntary markets. Because of these links between the two types of markets, issues and concerns in compliance offset markets can strongly impact trends in voluntary offset markets. A large share of voluntary offset purchases are made by pre-compliance buyers anticipating future carbon regulation. These buyers purchase offsets that they believe are likely to be eligible in future compliance markets. Ecosystem Marketplace and Bloomberg New Energy Finance estimate that in 2009, businesses buying offsets with a pre-compliance motive represented 23% of global voluntary offset transactions.[331] Due to uncertainty regarding the eligibility of specific offsets in future compliance markets, offsets are extremely vulnerable to a significant drop in value if there is a threat of ineligibility. For example, Chicago Climate Exchange (CCX) offset prices fell dramatically in late 2008 due to expectations that the offsets might not be eligible under proposed U.S. cap-and-trade policy.[332]

[330] BBC News 2007

[331] This figure represents only OTC credit transactions.
Ecosystem Marketplace and Bloomberg New Energy Finance 2010

[332] Carbon Finance 2008

**Exhibit 43: Chicago Climate Exchange Certified Emission Reduction Average Historical Closing Price**




Source: Chicago Climate Exchange 2011
Note: Exhibit provides average price across vintages (2003-2010). Prices are nearly identical across vintages.

Additional price swings in voluntary markets can be attributed to concerns regarding the future of international carbon reduction agreements. If international climate negotiations are abandoned there could be a substantial oversupply of offsets that would pour into voluntary markets and drive down prices. While this would reduce the cost of offsets, it would also likely reduce the appeal of offsets to the public (lower PR value) as purchasing the offsets would be unlikely to yield incremental reductions in global emissions. That is, oversupply could be so great that the market would have limited or no demand for new offset projects for many years.

Uncertainty about the eligibility of some project types in different markets has made it difficult for market participants to ensure they are purchasing high quality offsets. Peter Meier, an independent energy economist and World Bank consultant, recently noted that there are "1001 ways to game the [certification] system."[333] Many critics note that project financial additionality tests, commonly accepted as among the most rigorous additionality tests, can be met regardless of how stringent they may appear. Project developers often find ways to use seemingly reasonable financial assumptions to indicate that their projects will fall below the internal rate of return (IRR) threshold specified by a given standard even if the project will actually surpass the benchmark without offset revenues. A recent study conducted by Stanford University researchers demonstrated that up to two-thirds of all CDM credits issued thus far are sourced from business-

[333] Meier 2011

as-usual projects that would have been implemented without the additional support from offset sales.[334]

One example of projects that have been accused of taking advantage of offset markets are projects that destroy hydrofluorocarbons (HFC), greenhouse gases with a substantially higher global warming effect than $CO_2$. HFC destruction projects have largely been rejected as credible offset projects in the past year despite the fact that they represent nearly 50% [335] of global Clean Development Mechanism (CDM) Certified Emissions Reductions (CERs). Many HFC-23 destruction projects, primarily located in China and India, have been accused of gaming the Clean Development Mechanism (CDM) by purposely emitting more HFCs to maximize the number of HFCs destroyed and credits claimed. In late 2010, more than 90 countries supported a declaration to phase out HFC offsets entirely.[336] Some companies offer offset insurance to protect consumers against changes in offset project eligibility. Experts and market participants have also raised concerns about $N_2O$ projects, which represent nearly 25% of issued CERs, potentially gaming the system.[337]

There is, however, reason for companies to remain optimistic about voluntary offset markets and to continue to explore the purchase of offsets as a viable investment option. The CDM Executive Board has proposed changes to hold the Designated Operational Entities (DOEs) that verify CDM projects liable for wrongly issued carbon credits, or certified credits sourced from projects that do not truly meet accepted standards. If passed, this change would raise the risk of offset certification and, in turn, likely raise offset prices; however, this would also increase confidence in the offset products that come to market.[338] Also, despite the uncertainty in the outcome of international climate negotiations and the role of CDM in a post-2012 climate regime, some registries have started offering futures contracts for 2013 in response to interest from potential buyers. The World Bank, too, has a vision for international offset markets after the current Kyoto Protocol trading period ends in 2012. The Bank has set aside funds for the purchases of CERs of vintages from 2013 to 2018 and plans to carry the offsets market forward in the event that international negotiations fall through.[339]

## Communicating Carbon Offset Purchases

Organizations that buy offsets as part of their greening strategy should be extremely careful to communicate their purchase transparently and accurately. Organizations are at risk of being accused of "greenwashing" or "buying their way out of environmental obligations" if they make vague claims about their purchases and do not situate offsets in the context of a larger greening strategy.[340] At a minimum, organizations should follow the FTC's proposed claim guidance[341] when marketing their environmental efforts:

[334] Burston 2011.
[335] UNEP Risoe 2011
[336] Carbon Finance 2010
[337] UNEP Risoe 2011
[338] ICIS Heren 2010
[339] Gronewold 2011
[340] Carbonfund.org and RPN 2009
[341] FTC 2010b

> *• Marketers should have competent and reliable scientific evidence to support their carbon offset claims, including using appropriate accounting methods to ensure they are properly quantifying emissions reductions and are not selling those reductions more than once.*
> *• Marketers should disclose if the offset purchase funds emissions reductions that will not occur for two years or longer.*
> *• Marketers should not advertise a carbon offset if the activity that forms the basis of the offset is already required by law.*

The FTC guidelines are intended to protect offset buyers and consumers from misleading statements about the reality, additionality and timing of emission reductions associated with offsets. In addition to following these basic rules, organizations should provide unambiguous information about their offset purchases and overall greening strategy to maintain the credibility of their environmental efforts. This information should describe whether all of the organization's emissions were offset and whether the offsets are applicable to Scopes 1, 2 or 3. Organizations should clearly communicate that they are not reducing their carbon footprint by buying offsets, but that they are balancing their emissions with equal offsets. Providing information on the third-party standard to which the offsets were certified, the project type, the project location, and the vintage would also help establish credibility.[342]

Offset providers sometimes offer outreach support to facilitate the process of presenting accurate, effective communication materials such as labels and certificates as well as pictures and descriptions of projects supported. For example, The Carbon Neutral Company, which coined the term "carbon neutral" and was recently named Best Offset Retailer by Environmental Finance, offers marketing and PR services as well as tailored stakeholder engagement plans.[343]

While organizations typically communicate their offset purchases though press releases and organizations like the Carbon Disclosure Project, they can now also communicate those purchases by counting them towards LEED certification. In 2010, furniture company Haworth became the first organization to use carbon offsets, rather than renewable energy certificates, to earn green power credits for LEED certification of a new facility.[344] Citing concerns about the additionality of renewable energy projects participating in voluntary REC markets, Haworth opted to use carbon offsets sourced from a renewable energy project certified to pass a more stringent additionality test set by the Voluntary Carbon Standard. The motivation underlying Haworth's well received, innovative strategy highlights how offsets may be viewed as providing greater support to renewable energy, and thus may carry greater PR value than some voluntary REC investments.

[342] Carbonfund.org and RPN 2009.
[343] Carbon Neutral Company 2011
[344] Environmental Protection 2010

## Chapter 5 Report Conclusion

This report discusses many data center energy efficiency, renewable energy and carbon offset investment options that an organization can pursue to improve its environmental profile. The options discussed vary in their costs and benefits, and some options may be better aligned with organizational goals than others. Organizations can maximize the cost-effectiveness and PR value as well as minimize the risk of its energy and emissions sustainability efforts by investing in strategic combinations of sustainability solutions.

The exhibit below describes the range of investment categories addressed in this report. The options are arranged a manner that reflects the relative advantages and disadvantages of each, with the first investment option an organization explores being improvements in data center efficiency and the last investment option an organization explores being the purchase of voluntary renewable energy market products. Again, each of these investment options may not be appropriate for every organization though every organization should strongly consider investing in more than one option.

**Exhibit 44: Range of Energy-Related Sustainability Improvement Options – Recommended Order of Investment**


Generally speaking, data center efficiency improvements offer some of the greatest value propositions of the investment options evaluated in this report. Many data center efficiency improvements have short payback periods, and all efficiency improvements permanently reduce energy-related operating expenses, market exposure to fluctuating electricity prices, and Scope 2 (or possibly Scope 1) emissions. However, it is nearly impossible to fully offset the emissions footprint of a data center through efficiency improvements alone. Additionally, efficiency investments have become just one of the default investments expected of an organization with a sizable environmental footprint.

An organization can further improve its energy-related environmental profile by investing in clean and renewable energy investment options. These options include investing in on-site generation systems such as fuel cell and solar PV generation, off-site renewable energy through a contract or partnership, and renewable energy certificates. While investing in on-site and specific off-site energy projects yields the greatest PR benefits, investing in renewable energy certificates through green power purchase programs or third-party providers is less expensive and far more scalable but carries a much greater risk of criticism. Renewable energy certificates are typically counted against Scope 2 emissions (possibly Scope 1 in the case of clean on-site generation that

displaces conventional on-site conventional). Organizations often invest in offsets sourced from renewable energy projects if they like the cost and flexibility advantages of voluntary RECs but wish to have greater assurance that their investments enable renewable energy development.

Emission offsets are the most flexible category of green investments covered in this report. In contrast to energy efficiency and renewable energy investments, which count against Scope 2 emissions, emission offsets can count against Scope 1, Scope 2, and Scope 3 emissions. Also, more stringent additionality tests are applied to projects providing offsets than are applied to projects providing RECs. However, like REC markets, offset markets have also experienced criticism regarding the prevalence of non-additional projects and projects that may have actually increased emissions. Offset price volatility and uncertainty regarding the presence and shape of future markets also add another level of risk to offset purchases. Overall though, some offset products are more attractive than REC products sourced from green power purchase programs or third-party providers.

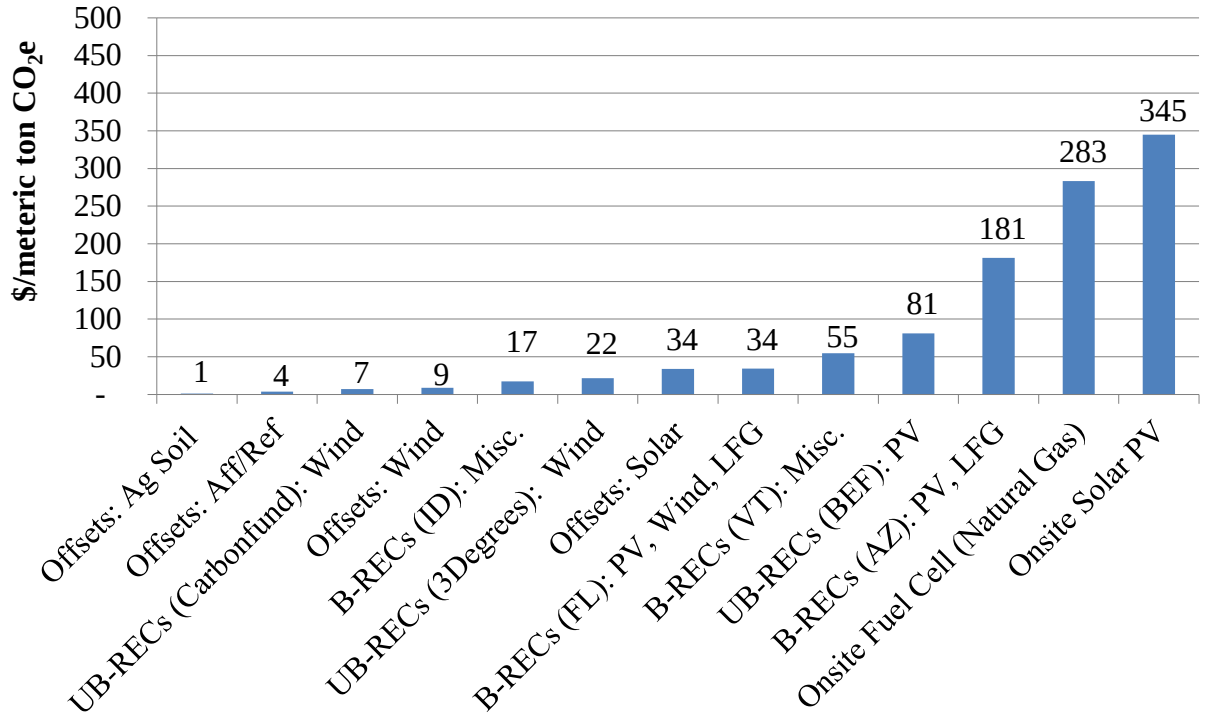
While fundamentally different products, RECs and offsets can potentially be used interchangeably by an organization that wishes to reduce its Scope 2 emissions. RECs may be counted against Scope 2 emissions, and offsets may be applied against Scope 1, Scope 2, and Scope 3 emissions; thus offsets may be used in lieu of RECs to reduce Scope 2 emissions though RECs may not be used in place of offsets to reduce Scope 1 or 3 emissions. Exhibit 45 below compares the effective cost of $CO_2$ emission reductions provided by a sample of REC and offset products as well as illustrative on-site generation systems.

The bundled and unbundled REC products listed vary by location (Idaho, Florida, Vermont, Arizona, and the Bonneville Power Administration, or BPA Territory) and by project type (wind, solar, landfill gas, and not specified). The exhibit also includes national-level carbon offset and REC products without a specified geographic origin. Average 2010 prices are provided for several carbon offset project types. On-site fuel cell and solar PV sourced emission reduction cost estimates are illustrative averages that take into account the 30 percent federal investment tax credit (ITC) but no other subsidies or incentives.[345]

[345] Many subsidies and incentives are available that could substantially reduce the cost of both solar PV and fuel cell systems, and in turn the effective cost of $CO_2$ emission reductions sourced from them. Accelerated depreciation, rebates, and sales tax reductions are just some examples of support mechanisms not captured in this analysis. Selling all RECs or SRECs associated with a solar PV or fuel cell systems would preclude a system owner from achieving emission reductions from those systems.

**Exhibit 45: Comparison of Effective Cost of $CO_2$ Emission reductions Sourced from Carbon Offsets, Unbundled RECs, Bundled RECs, and Illustrative On-site Solar PV and Fuel Cell Generation**




Abbreviations:
(a) UB-RECs: Unbundled RECs
(b) B-RECs: Bundled RECs
(c) Ag Soil: Agricultural Soil Management
(d) Aff/Ref: Afforestation/Reforestation
(e) PV: Solar Photovoltaic
(f) LFG: Landfill Gas
(g) BEF: Bonneville Environmental Foundation

Sources (Detailed List of Assumptions Provided in Appendix):
(a) Average Commercial Electricity Price: U.S. EIA 2010b
(b) Offset Prices: Ecosystem Marketplace and Bloomberg New Energy Finance 2010
(c) Bundled and Unbundled REC Prices: U.S. DOE 2010a and U.S. DOE 2010b
(d) Solar PV LCOE Calculation: NREL 2011f
(e) Solar PV Capital Cost: Wesco Distribution 2011
(f) Fuel Cell LCOE: Lazard 2010
(g) Fuel Cell Emission Rate: Bloom Energy 2011a, FuelCell Energy 2011, UTC Power 2011a
(h) Grid Emission Factors: U.S. EPA 2011b

Notes:
(a) Natural gas feedstock assumed for illustrative fuel cell generation system.
(b) Appendix contains a detailed list of assumptions used to create this exhibit.

This comparison highlights that the landscape of REC, offset, and generation investments varies greatly in effective cost of $CO_2$ emission reductions, with the most expensive emission reduction sources being on-site solar PV generation and fuel cell generation using natural gas feedstock.

The relative cost of Scope 2 emission reductions sourced from on-site solar and fuel cell generation varies by state due to differences in cost, incentives (e.g. tax incentives, REC/SREC revenues, rebates, etc.), performance, electricity prices, and grid emissions factors. For example, in a region with a very high solar PV capacity factor and/or a very low grid emission factor, on-site solar PV could offer substantially less expensive emission reductions than could a fuel cell system in the same location. A high capacity factor would drive down the levelized cost of electricity for a solar PV system, and in turn the cost of each metric ton of $CO_2$ emission reduction provided by each MWh of electricity produced. A lower grid emission factor would result in a higher effective cost of emission reductions as less $CO_2$ would be reduced by each MWh of generation. Because a fuel cell generation system that uses natural gas feedstock emits $CO_2$, the emission reductions provided with each MWh of generation are fewer than those provided by each MWh of solar PV generation. As a result, regional variations in grid emission factors can have a greater impact on the cost of emission reductions from fuel cell generation.

The following calculations provide a basic example of a strategic pairing of green investments, specifically the combination of an energy efficiency and carbon offset investment. Every 1% reduction in the energy consumption at a 1 MW data center could yield $4,472 in annual electricity savings.[346] If these savings are annually reinvested in offsets, they could be used to retire around 815 $MtCO_2e$ each year[347] – as much $CO_2$ as released by the consumption of over 1,895 barrels of oil[348]. All else constant, the environmental benefits could be much greater if the assumed load factor is higher, electricity prices are higher, the grid emission factor is higher, or offset prices are lower. This simple estimate n highlights the potentially substantial environmental value of even relatively small efficiency improvements.

An example of a basic efficiency improvement that can greatly reduce the environmental impact of facility is server virtualization. VMware estimates that each server virtualized at a typical data center will save 7,000 kWh annually[349], or annually reduce emissions by nearly 5 $MtCO_2e$ – as much $CO_2$ as released by the consumption of over 11 barrels of oil. Using the same assumptions from the previous calculation, every server virtualized would yield around $715 of annual energy

[346] Assuming a 50% annual load factor and an average commercial U.S. electricity price (commercial rate) of $0.1021/kWh.
U.S. EIA 2010b
[347] Assuming an average U.S. grid emission factor of 1526 $lbCO_2e/MWh$ and an average U.S. offset price of $5.3/tCO2e.
(a) Grid Emission Factor: U.S. EPA 2011b
(b) Offset cost: Ecosystem Marketplace and Bloomberg New Energy Finance 2010
[348] This greenhouse gas equivalency calculation was completed using the U.S. EPA's *Greenhouse Gas Equivalencies Calculator*, which, like the EPA's *Green Power Equivalency Calculator* is very useful tool when working to effectively communicate the environmental value of sustainability efforts.
*Greenhouse Gas Equivalencies Calculator*: http://www.epa.gov/cleanenergy/energy-resources/calculator.html (U.S. EPA 2011a)
*Green Power Equivalency Calculator*: http://www.epa.gov/greenpower/pubs/calculator.htm (U.S. EPA 2011m)
[349] VMWare 2008

savings. If 20 servers were virtualized and their energy savings reinvested in carbon offsets, they would neutralize the annual carbon impact of a 0.9 MW data center.[350,351] Server virtualization investments often have a very short payback period due to the large associated energy savings.[352] This and other energy savings options with short payback periods can provide an organization with easy emission reductions as well as energy cost savings that can fund additional efficiency, renewable energy, and offset investments.

This report is designed to enable readers to engage in more detailed discussions of how to improve the environmental profiles of organizations in a way that maximizes environmental benefits and PR value while minimizing costs and risks. What it means to be "green" continues to evolve, and even the most innovative strategies implemented by organizations today may become standard practice in just a few years. For this reason, an organization should invest in a balanced portfolio of green solutions and view the improvement of its environmental profile as a continual goal rather than a one-time achievement.

[350]This does not factor in the upfront cost of server virtualization. Net savings of $700 annually would be realized after virtualization has been fully paid for.

[351] Using a 50% annual load factor, an average commercial U.S. electricity price (commercial rate) of $0.1021/kWh, an average U.S. grid emission factor of 1526 lb$CO_2$e/MWh, and an average U.S. offset price of $5.3/tCO2e.
(a) Power Prices: U.S. EIA 2010b
(b) Grid Emission Factor: U.S. EPA 2011b
(c) Offset cost: Ecosystem Marketplace and Bloomberg New Energy Finance 2010

[352] McDonald 2011

## Appendix – Assumptions Used in Exhibit 45

This section contains the assumptions used to calculate the effective cost $CO_2$ emission reductions sourced from carbon offsets, unbundled RECs, bundled RECs, and illustrative on-site solar PV and fuel cell generation.

Our calculations of the effective cost of $CO_2$ emission reductions sourced from on-site solar PV and fuel cell generation account for the cost of avoided grid electricity consumption. This avoided cost is calculated using the 2009 national average retail cost of electricity (commercial rate) of $0.1021/kWh.[353] If an organization participates in a net metering program, it will not necessarily receive the full retail electricity rate for the sale of its on-site energy production.

**Exhibit 46: Assumptions for the Comparison of Effective Cost of $CO_2$ Emission Reductions from RECs, Offsets an On-site Renewable Generation**

| Product | Provider | Levelized Cost of Electricity (fuel cell, solar PV) or REC Cost ($/MWh) | Grid Emission Factor Assignment for $/tCO2e Calculation | Grid Emission Factor (lb $CO_2$e/MWh) | Technology Emission Rate (lb $CO_2$e/MWh) | Cost ($/Mt$CO_2$e) |
|---|---|---|---|---|---|---|
| Fuel Cells (Natural Gas Feedstock) | | 176 | National | 1526 | 951 | |
| Solar PV | | 341 | National | 1526 | 0 | |
| Bundled RECs (Arizona): Solar PV, Landfill Gas | Tucson Electric | 100 | AZNM (WECC Southwest) | 1215 | 0 | |
| Bundled RECs (Vermont): Miscellaneous | Green Mountain Power | 30 | NEWE (NPCC New England) | 1210 | 0 | |
| Bundled RECs (Florida): Solar PV, Wind, Landfill | Gainesville Regional | 20 | FRCC (FRCC All) | 1291 | 0 | |

[353] U.S. EIA 2010

| Product | Provider | Levelized Cost of Electricity (fuel cell, solar PV) or REC Cost ($/MWh) | Grid Emission Factor Assignment for $/tCO2e Calculation | Grid Emission Factor (lb $CO_2e$/MWh) | Technology Emission Rate (lb $CO_2e$/MWh) | Cost ($/Mt$CO_2e$) |
|---|---|---|---|---|---|---|
| gas | Utilities | | | | | |
| Bundled RECs (Idaho): Miscellaneous | Idaho Power | 10 | NWPP (WECC Northwest) | 1285 | 0 | |
| Unbundled RECs (BEF): Solar PV | Bonneville Environmental Foundation | 56 | National | 1526 | 0 | |
| Unbundled RECs (3Degrees): Wind | 3Degrees | 15 | National | 1526 | 0 | |
| Unbundled RECs (Carbonfund): Wind | Carbonfund | 5 | National | 1526 | 0 | |
| Offsets: Solar | | | | | | 34 |
| Offsets: Wind | | | | | | 9 |
| Offsets: Afforestation/Reforestation | | | | | | 4 |
| Offsets: Agricultural Soil Management | | | | | | 1 |

Sources:
(a) Grid Emission Rates: U.S. EPA 2011b
(b) Bundled and Unbundled REC Programs and Prices: U.S. DOE 2010a and U.S. DOE 2010b
(c) Average Offset Prices: Ecosystem Marketplace and Bloomberg New Energy Finance 2010
(d) Fuel cell and solar PV assumptions: see Exhibit 47 and Exhibit 48 below for details

**Exhibit 47: Assumptions for Estimation of Levelized Costs of Electricity (LCOE) for On-site Generation**

| Variable | Units | Amount | Source |
|---|---|---|---|
| Fuel Cell (Using Natural Gas Feedstock) | $/MWh | 176 | Average of Lazard 2010 estimates |
| Low | $/MWh | 111 | Lazard 2010 |
| High | $/MWh | 241 | Lazard 2010 |
| Solar PV | $/MWh | 341 | NREL 2011f |
| Solar PV Capital Cost | $/kW$_{AC}$ | 4438 | Wesco Distribution 2011 |
| Solar PV Capital Cost (Post ITC) | $/kW$_{AC}$ | 3106 | Wesco Distribution 2011 |
| Fixed O&M | $/kW-yr | 20 | Average of NREL 2010 Estimates |
| Book Life | Years | 20 | General Assumption |
| Discount Rate | % | 12.5 | General Assumption |
| Capacity Factor | % | 15 | General Assumption |

**Exhibit 48: Fuel Cell Emission Assumption**

| Fuel Cell Type | $CO_2$ Emission Rate (lbs/MWh) | Source |
|---|---|---|
| Bloom ES-5000 Energy Server | 773 | Bloom Energy 2011a |
| FuelCell DFC3000 | 980 | FuelCell Energy 2011 |
| UTC PureCell Model 400 | 1100 | UTC Power 2011 |
| Average | 951 | |

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