Greening Terremark Data Centers

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Executive Summary

On the Wikibon blog is a picture story of the world's 10 largest data centers. The majority of these data centers are run by IT service providers. Most people in the US spend more time at work on systems run by these providers than on their own internal systems. Add personal time and homework support time and the trend is obvious; IT service providers will continue to gain traction and within fifteen to twenty years, corporate data centers in all but the largest organizations could be relics of the past alongside IBM 029 card punches.

All of these service provider data centers are green; very green compared with most corporate data centers. Given that corporate data centers are still going to be required for a long time because of the constraints on maturity, security and management, Wikibon thought it would be cool (hot) to talk to some of the IT service providers and get their take on what they are doing to drive energy efficiency. Terremark was the first to be interviewed.

What Wikibon found was a testament to the focused green approach that Terremark took. A total savings of $4.8 million or 40% of the original budget was achieved with a four-part mix of smart organization, innovative energy efficient design, server virtualization and storage virtualization/thin provisioning. The four-year Net Present Value (NPV, 5%) is over $17million. The project with the greatest percentage impact was the storage area (86%, see Table 7).

The most important recommendation (for organizations and national policy) to enable IT energy savings is to ensure that IT is fully charged with an itemized facilities bill, and move responsibility for deploying and racking IT equipment to a facilities group. Terremark's experience provides a lesson for all private IT organizations – and holds widespread implications for national energy savings, especially as virtualization spread to all parts of "IT infrastructure 2.0".

Terremark Offerings

Terremark is a leading provider of IT infrastructure services, headquartered in Miami Florida. Terremark provides traditional collocation services as well as its very fast growing cloud computing services (currently about 10% of floor space).

There are three main US data centers based in Florida, California and Virginia. Terremark is building other facilities but these are not yet in full production. The Virginia facility was just recently commissioned and since customer deployments remain in progress, was not considered for the purposes of this study. Terremark also has smaller data center facilities in South America and in Europe. The focus here is on the US facilities and considers a representative 230,000 sq. ft.

Terremark has been focusing on being "Green" both as a corporate goal and as sensible business efficiency. The Green initiatives have been centered round two main thrusts:

1. Making the power and cooling of the IT equipment in their data center facilities as efficient as possible to reduce energy consumption
2. Virtualizing as much of the equipment and services as possible, so that the equipment can be shared as much as possible and driven to much higher levels of efficiency. This leads to avoidance of having to provide or cool IT equipment.

All of Terremark's cloud offerings and many of their other offerings are based on a virtualized IT infrastructure. The main virtual compute offerings are:

- **Infinistructure™**

This service provides the ability to purchase a virtual server (Virtual Processor Unit, VPU) together with memory and storage. The average size of a virtual server is 1.2 VPU, with 2GB RAM and 20-40GB of storage. The physical servers are HP 64bit Proliant servers, and the storage utilizes multi-tenant 3PAR virtualized storage arrays. Systems are backed up to traditional tape.

- **Enterprise Cloud™**

This service is a self-service portal, where Terremark customers can buy as many GHz, of main memory and GB of storage as they need for a particular application, and pay for only what they consume. Backup is to disk including source-side de-duplication based on Asigra services.

- **vCloud Express™**

vCloud Express is a lower-cost credit-card based offering, with the simplest setup and the greatest flexibility. The equipment is virtualized using the same HP server and 3PAR storage components.

- **Storage-on-Demand**

Terremark offers an iSCSI storage service for storage requirements that are not latency dependant. It offers a Fibre Channel (FC) storage service for high performance/high transaction applications where downtime and/or data loss must be minimized. The FC offering is based on 3PAR virtualized storage arrays.

Saving Power at Terremark

Power and Cooling

The most interesting approach that Terremark has taken is to give the responsibility for rack management and deployment to facilities management. IT decides the equipment strategy, but the facilities management staff is responsible for all aspects of physical installation. The strategy that Ben Stewart, the Senior Vice President of Facility Engineering at Terremark, has focused on is managing the cold air in their hot-and cold aisle deployment. The key measurement is the cold aisle server inlet temperature, which is used to set the appropriate fan speeds on the CRAH units. The fan speed to power ratio is a cubic relationship offering significant energy savings. To further control the amount of cold air production required, cold aisle containment is employed. So far they have raised the delta t^{o} difference between the supply and return air temperatures from 6^{o} to 13 ^{o} degrees. This has been sufficient to lower the Power Usage Effectiveness (PUE) metric from 2.2 to 1.7.

> The Green Grid defines the Power Usage Effectiveness metric for datacenter infrastructure power as PUE = (Total Facility Power) / (IT Equipment Power):
>
> For example, a PUE of 2.0 implies that for every watt of power used by servers, storage, and networks, an additional watt is used by the site infrastructure to support the IT equipment. A PUE of 1.0 implies that all power consumed by the datacenter is used exclusively for IT equipment, no additional site infrastructure (e.g., cooling) is required. A typical PUE is around 2.0.

Table 1 shows the current power used by the representative 230,00 sq. ft. of data center raised floor. The corresponding representative total utility budget per year is $10.6 million and pulls down 12.1 MW of power.

Terremark Total Data Center Current Power & Cooling Comsumption

Location	Sq. ft.	Cost of Power/ kWhr	Annual Power for IT Equipment (MW)	Power for Cooling & UPS (MW)	Original PUE	Annual Power (MW)	Current Annual Power Budget
Total	**230,000**	**$0.10**	**5.60**	**6.50**	**2.16**	**12.10**	**$ 10,600,362**

Table 1 - Terremark Current Power & Cooling Consumption
Source: Wikibon 2010

Table 2 splits out the power usage from the two major computing functions, the Cloud-based computing services which are virtualized, and the non-cloud traditional collocation computing services. The Cloud-based services are estimated to occupy about 10% of the floor space, but consume about 20% of the power.

Terremark Total Data Center Power & Cooling Comsumption Current by Function

Function	Sq. ft.	Cost of Power/ kWhr	Annual Power for IT Equipment (MW)	Power for Cooling & UPS (MW)	Original PUE	Annual Power (MW)	Current Annual Power Budget
Non-Cloud Services	207,000	$0.10	4.48	5.20	2.16	9.68	$ **8,480,289**
Virtualized Cloud Services	23,000	$0.10	1.12	1.30	2.16	2.42	$ **2,120,072**
Total	**230,000**	**$0.10**	**5.60**	**6.50**	**2.16**	**12.10**	**$ 10,600,362**
Note: Virtualized Cloud Services occupy 10% of space and consume 20% of Power							

Table 2 - Terremark Current Power & Cooling Consumption by Function
Source: Wikibon 2010

There are two main projects to reduce power consumption. These are more efficient cooling of the entire data center, and virtualization of the Cloud services. These projects are analyzed separately.

Non-Cloud Services

By raising the delta tº difference between the supply and return air temperatures from 6º to 20 degrees, and some use of outside air to cool using economizers, Terremark plans to achieve a PUE goal of 1.5, close to the practical limit of a general purpose data center. Table 3 shows the saving in the overall power bill by reducing the power requirement to cool and provide power to the total IT infrastructure. It shows that the total power saved from reducing the PUE from an average of 2.16 to 1.5 is about 3MW, with an annual budget saving of $2.6million (31%), and a four year Net Present Value (NPV) of $9.2million.

Terremark Non-Cloud Data Center Power & Cooling Efficiency Goals (90% Original Floor Space, 80% Original Power)									
	Sq. ft.	Cost of Power/ kWhr	Annual Power for IT Equipment (MW)	Power for Cooling & UPS (MW)	Original PUE	PUE Goal	Annual Power Savings (MW)	Original Total Annual Electrical Budget	Annual Budget Saving
Total	207,000	$0.10	4.48	5.20	2.16	1.5	2.96	$ 8,480,289	$ 2,593,569
% Annual Budget Saving = 31%					Four Year Net Present Value (NPV, 5%) = $9,196,669				

Table 3 - Terremark Total Data Center Power & Cooling Efficiency Goals & Financial Impact
Source: Wikibon 2010

Cloud Computing Services

Cloud services take about 10% of the total computing space, but are a very fast growing segment of Terremark's business, and consume about 20% of the total power. With most of the traditional operational outsourcing business, the equipment and software choice is usually limited by what is already in place. However with cloud services Terremark has much more of a choice in equipment, software and strategy. The approach taken illustrates how effectively Terremark has driven data center efficiency, and this efficiency will be even more important going forward.

The three virtual server based offerings described above (Infinistructure, Enterprise Cloud and v-Cloud Express) run on VMware. The storage component is run on 3PAR's virtual storage platform.

This section looks at the overall contribution to the cloud services business of the Data center power & cooling efficiency savings, the savings from virtualizing the servers, and the savings from virtualizing storage.

The Data Center Power & Cooling Budget for Cloud-based services without any power efficiency projects would have been about $2.1million, based on 20% power requirement from the overall total power requirement of 12.1 MW and the original PUE ratio of 2.16 (from Table 1). This baseline for Cloud services is shown in Table 2 above. The current total power requirement was 2.42 MW, with an overall power density of 105 Watts/sq. ft.

Virtual Servers

The three virtual server based offerings described above (Infinistructure, Enterprise Cloud and v-Cloud Express) run on VMware. Across the three services, the average number of virtual machines that run on a physical HP Proliant server is in the range 10-11. This compares to a typical single processor utilization of less that 10%; overall Terremark achieves a processor utilization of 75-80% and memory utilization is 60-70%.

Table 4 assumes that 10 physical low powered servers (350Watts/server) would be required compared with just one larger fully configured HP Proliant server (1,000Watts/server) with virtualization. The total power savings (which includes not only the reduction in power to operate fewer more highly utilized servers, but also the lower associated infrastructure costs since there are less servers to cool and lower UPS/distribution losses) are calculated in Table 4 as $1.2million per year (71% of the original budget). The four year NPV is $4.3million. This is for a small subset of all the servers installed by Terremark. As this philosophy is extended to additional servers, the savings will be in the many millions more.

Terremark Data Center Cloud Server Virtualization Power & Cooling Savings									
a	b = a x 10	c	d	e = b x d x .35 / 1000	f=a x d x 1 / 1000	g = e - f	h = e x 1000 x 365 x 24	j = f x 1000 x 365 x 24	k = h - j
# Virtualized Servers (1,000 Watts / Server)	# Traditional Physical Servers (10x, 350 Watts / Server)	Cost of Power / kWhr	Original PUE	Cloud Server Power non-Virtualized (MW)	Cloud Server Power Virtualized (MW)	Cloud Server Virtualization Power Savings (MW)	Annual Power Budget for Cloud Servers non-Virtualized	Annual Power Budget for Cloud Servers Virtualizated	Annual Power Budget Savings
256	2,560	$0.10	2.16	1.936	0.553	1.383	$ 1,696,058	$ 484,588	$ 1,211,470
% Annual Budget Saving = 71%				Four Year Net Present Value (NPV, 5%) = $4,295,812					

Table 4 - Terremark Data Center Server Virtualization Power & Cooling Savings
Source: Wikibon 2010

Virtual Storage

The complement for virtual servers is virtual storage. Traditional storage is laid out in LUNs, which are consecutive big "chunks" of data that require a system restart to move around and a lot of people to manage. Virtualized storage is broken down into small "chunklets" of data that be placed anywhere, can be moved dynamically to other places, use storage only when the data is written as opposed to when it is allocated, and takes far fewer staff to manage it.

Terremark's storage strategy for all the cloud services and "storage on demand" service is based on 13 virtualized InServ storage arrays from 3PAR. These arrays only consume storage when data is actually written, and storage taken from a pool of chunklets. This process is called thinning, and thin provisioning and thin copying are important technologies for reducing the amount of storage that is required, and the energy consumed.

Figure 1 shows the savings in storage capacity that is realized by virtualization and the thin technologies that are enabled by virtualization. The storage the system would have required with traditional arrays is 532 terabytes, and the storage required with virtualization and thin provisioning is 105 terabytes. The current implementation is for a subset of the installed storage. Figure 1 shows that only 20% of the storage is required when thin provisioning is turned on.

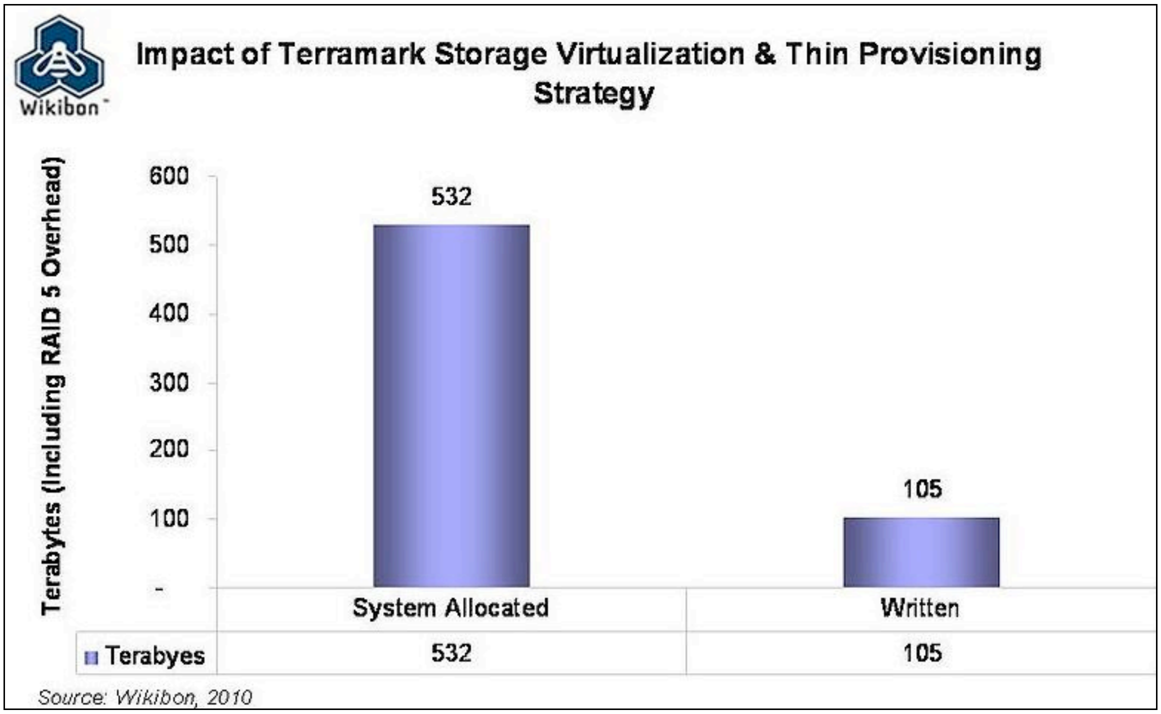

Figure 1 - Impact of Virtualization & Thin Provisioning Technologies on Storage Required

Table 5 shows the projected power savings for a full implementation of thin provisioning on all 2,613 3PAR drives installed. This would avoid installing over 10,000 drives, and save over $500,000 in power costs (80%) which not only includes the reduction in power to operate fewer drives, but also the lower associated infrastructure costs since there are less drives to cool and lower UPS losses. The four year NPV is $1.8million. This project is expected to be completed in 2011.

Terremark Data Center Cloud Storage Virtualization Power & Cooling Savings									
a	b = a x 10	c	d	e = b x d x .025 / 1000	f=a x d x .025 / 1000	g = e - f	h = e x 1000 x 365 x 24	j = f x 1000 x 365 x 24	k = h - j
# Virtualized Storage Drives (25 Watts / Drive)	# Traditional Physical Drives (25 Watts / Drive)	Cost of Power / kWhr	Original PUE	Cloud Storage Power without non-Virtualized (MW)	Cloud Storage Power Virtualized (MW)	Cloud Storage Virtualization Power Savings (MW)	Annual Power Budget for Cloud Storage non-Virtualized	Annual Power Budget for Cloud Storage Virtualized	Annual Power Budget Savings
2,613	13,287	$0.10	2.16	0.718	0.141	0.577	$ 628,761	$ 123,643	$ 505,119
% Annual Budget Saving = 80%					Four Year Net Present Value (NPV, 5%) = $1,791,126				

Table 5 - Projected Storage Power & Cooling Annual Savings
Source: Wikibon 2010

Cloud Services Power Improvement Conclusions

Table 6 shows the impact of the three projects on the total power requirements for the cloud services part of Terremark's business.

Terremark Cloud Services Virtualized Data Center Power & Cooling Efficiency Budget Goals (20% Original Power, 10% Original Space)

	Cost of Power/ kWhr	Annual Power non-Virtualized (MW)	Annual Power Virtualized (MW)	Annual Power Savings (MW)	Original PUE	PUE Goal	Annual Power Budget non-Virtualized	Annual Power Budget Virtualized	Annual Power Budget Savings	% Savings
Server Virtualization	$0.10	1.94	0.55	1.38	2.16		$ 1,696,058	$ 484,588	$ 1,211,470	71%
Storage Virtualization	$0.10	0.72	0.14	0.58	2.16		$ 628,761	$ 123,643	$ 505,119	80%
Other Equipment	$0.10	1.73	1.73	-	2.16		$ 1,511,842	$ 1,474,563	$ -	
Total	$0.10	4.38	2.42	1.96	2.16		$ 3,836,661	$ 2,082,794	$ 1,716,589	45%
Facility PUE Efficiency	$0.10		2.42	0.74	2.16	1.50			$ 648,392	
Total Savings	$0.10	4.38	1.68	2.70			$ 3,836,661	$ 1,434,402	$ 2,364,981	62%
% Annual Budget Saving = 62%							Four Year Net Present Value (NPV, 5%) = $8,386,106			

Table 6 - Impact of Virtualization and PUE projects on Power requirements for Cloud Services
Source: Wikibon 2010

The savings from the server and storage virtualization projects are taken from Tables 4 & 5. It has been assumed that there is no significant change to equipment other than servers and storage. The Facility PUE efficiency savings specifically for cloud services come from improving the PUE from an average of 2.16 to 1.5, using the energy efficiency methods previously described. The PUE improvement savings are over $600,000 dollars per year.

The total pie in Figure 2 represents the $3.8 million power budget required if there was no server or storage virtualization and no PUE improvement project. The savings from PUE, Server virtualization and Storage virtualization are shown, leaving a projected power budget of just over $1.4million, a saving of $2.3 million or 62% of the original budget.

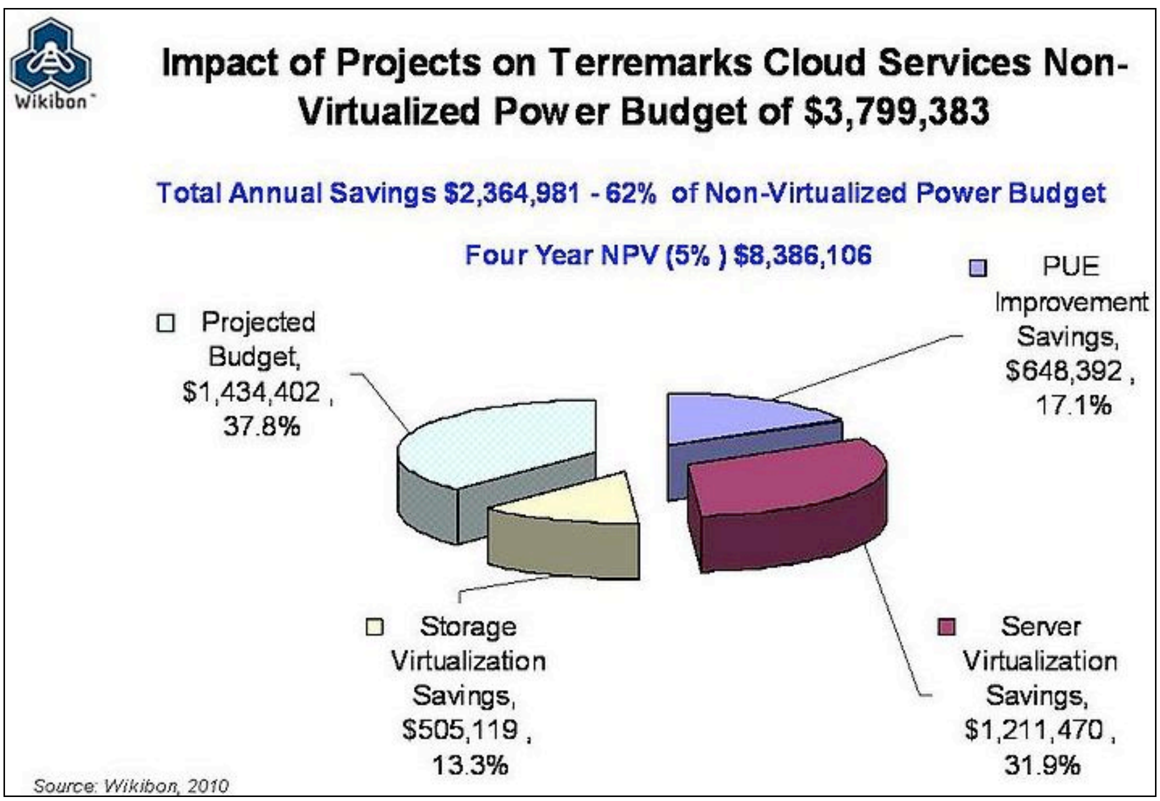

Figure 2 - Total Power Budget Savings for Terremark's Cloud Services from Virtualization & PUE improvements

Overall Conclusions

Terremark focused on three project areas to reduce IT energy consumption:

1. #Improving PUE ratios
2. #Virtualizing servers
3. #Virtualizing storage

Table 7 summarizes the savings from these three projects:

Terremark Power & Cooling Efficiency Budget Savings from PUE Improvements, Virtualized Servers & Virtualized Storage Projects

	Cost of Power/ kWhr	Annual Power without Projects (MW)	Annual Power with Projects (MW)	Annual Power Savings (MW)	Original PUE	PUE Goal	Annual Power Budget without Projects	Annual Power Budget with Projects	Annual Power Budget Savings	% Savings
Server Virtualization	$0.10	1.94	0.38	1.55	2.16	1.50	$ 1,654,237	$ 328,090	$ 1,326,148	80%
Storage Virtualization	$0.10	0.72	0.10	0.62	2.16	1.50	$ 613,258	$ 83,712	$ 529,546	86%
Other Equipment	$0.10	1.73	1.20	0.53	2.16	1.50	$ 1,474,563	$ 1,023,590	$ 450,973	31%
Total Cloud Computing	**$0.10**	**4.38**	**1.68**	**2.70**	**2.16**	**1.50**	**$ 3,742,058**	**$ 1,435,392**	**$ 2,306,666**	62%
Non-Virtualized Services	**$0.10**	**9.68**	**6.72**	**2.96**	**2.16**	**1.50**	**$ 8,271,186**	**$ 5,741,568**	**$ 2,529,618**	31%
Total Savings	**$0.10**	**14.06**	**8.40**	**5.66**	**2.16**	**1.50**	**$ 12,013,245**	**$ 7,176,960**	**$ 4,836,285**	40%
% Annual Budget Saving = 40%					Four Year Net Present Value (NPV, 5%) = $17,149,227					

**Table 7 - Overall Terremark Power Savings from PUE Improvements and Virtualization Projects
Source: Wikibon 2010**

The savings from the current strategies will be $2.4 million per year within the cloud services offerings from Terremark. The total savings from improving just the PUE from 2.2 to 1.5 in the non-cloud traditional data services is $2.6 million per year. The overall savings are $4.8million per year (40%), with a four-year NPV of $17.6million.

These savings will grow significantly as virtualization is spread to all parts of the IT infrastructure.

Service providers such as Terremark have the scale and motivation to drive an effective green strategy and reduce energy costs to a minimum. Most IT departments do not even see the facilities bill for energy consumption. By separating out the responsibility for facilities to a senior executive and having economies of scale, Terremark has been able to drive savings and greenness at a much faster rate than traditional data centers. Specifically, Terremark has improved its PUE from 2.2 to 1.5 inside two year’s time whereas traditional data centers would typically take 3-4 years to achieve similar results—if they could get there at all.

Action Item

To improve energy consumption within IT, organizations should ensure that that IT is fully charged with an itemized facilities bill, and facilities should be responsible for deploying and racking IT equipment. However, in the long run outsourcing of IT infrastructure services to service providers is likely to have the largest “green” impact, as service organizations such as Terremark will continue to lead in improving the greenness and cost efficiency of computing facilities.