TRPC
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Briefing Paper

IIC Asia Forum
Singapore as a Data Hub

Computers, Data and Productivity

In the early 1990s economist Robert Solow observed that the impact of computers on the economy of the USA was to be seen "everywhere but in the productivity statistics".[1] This 'productivity paradox' was finally solved when it became clear that before inter-networking between businesses became commonplace, computers did increase the productivity of companies but competition was passing the benefits onto consumers in lower prices. Only in the late 1990s as computer networking spread to connect businesses to suppliers, branches, partners and customers, did the network effects begin to appear in the figures.

Since then the growth of data has spiralled along with networking to embrace all sectors of the economy and society. Today, everything digital is data and most human artifacts generating data are digital… and that data has to be stored on servers somewhere.

Originally that 'somewhere' was in-house managed data centres, then outsourced data centres and increasingly shared capacity data centres. Different industry verticals, such as banking & finance, telecommunications, pharmaceuticals, IT companies, etc., have different requirements in terms of security and levels of risk, in terms of batch data or continuous flow or real-time data or 'Big data' for business analytics, etc. For example, telecom companies need colocation facilities to support, among other things, secondary markets in bandwidth. Singapore is ASEAN's major centre for the trading of wholesale spare capacity across the region. Financial institutions and trading houses need locations close to stock exchanges with minimum latency for real time transactions, and so forth. Data centres and their managements have to focus and cater for special needs.

The importance of data centres has therefore become an issue in its own right. Attracting investment in data centres is not only a direct way to boost employment locally, but a way to strengthen the local infrastructure to support a host of industries

[1] http://www.standupeconomist.com/pdf/misc/solow-computer-productivity.pdf

that create or use data-hungry applications and content, and to reinforce the role of Singapore as a regional hub for data services. Modern fibre optical international submarine cables allow data centres to serve the world. In the view of some industry experts the trend is towards many multinational companies operating their data out of just two data centres *globally* not regionally – two for redundancy or in some cases latency issues – and the question will therefore be which are those two locations. The quality of the telecommunications infrastructure is therefore fundamental to the endeavor to create and sustain Singapore as a data centre hub.

DC Topology

Data centres come in 4 categories: Tiers I, II, III and IV with the following specifications.

Data Centres: Tier Structure

Tiers	I	II	III	IV
Basic site infrastructure	Non-redundancy capacity + 12 hours fuel storage for engine generation	Redundant capacity; non-redundant distribution path + 12 hours fuel storage for N capacity	**Concurrently Maintainable DC:** Redundant capacity and multiple distribution paths + 12 hours fuel storage for N capacity; all equipment is dual powered	**Fault Tolerant DC:** Physically isolated **r**edundant capacity and multiple distribution paths + 12 hours fuel storage for N capacity; all equipment is dual powered with continuous cooling.
Performance requirements	Sufficient capacity, but shutdown for repairs	Sufficient capacity when redundant components removed with no closure; non-redundant removals require closure	Sufficient capacity and any component can be removed without closure	Sufficient capacity and any component can be removed without closure; self-healing
Operational impacts	Site subject to planned (e.g. annual safety check) and unplanned disruptions	Site subject to planned (e.g. annual safety check) and unplanned disruptions	Site subject to unplanned disruptions	Site safe from any *single* unplanned disruption

Source: Uptime Institute *Data Center Site Infrastructure Tier Standard: Topology* http://atd.uptimeinstitute.com/PDFs/TierStandards.pdf

In addition, DC's serve different industrial functions using different business models, architectures and equipment. They are: Enterprise DCs, Hosting or IaaS DCs, Portal or Web 2.0 DCs. A useful and brief review may be found at the Datacenterknowledge.com.[2]

The Telecom Infrastructure

Singapore has two sets of competitors for being a regional DC hub: East Asia and South East Asia. In terms of competitive pricing, broadband speeds and submarine cable connections East Asia is a big challenge, but not so South East Asia which is Singapore's local regional advantage. [3]

In 2005 a TRP report found that in terms of submarine connectivity, West of Singapore there is ample capacity but dominated by just two cable systems; however East of Singapore was what experts called the "only real bottleneck" in the APAC region, partly due to capacity being withheld at that time on the C2C cable.[4] This situation has now changed.

As of August 2011, Singapore is connected to 15 active submarine cable systems, with a total potential bandwidth capacity of 67.63 Tbps.[5] They land in three designated landing sites in Singapore, namely the Changi North landing site, the Tanah Merah landing site, and the Tuas landing site. All new submarine cable systems can only be deployed to these designated landing sites and each landing site is available on a first-come-first-served basis.[6]

Singapore's Cables at Landing Stations, 2011[7]

	Changi	Katong	Tuas
In Service			
APCN-2		✓	
Asia-America Gateway (AAG)	✓		
Asia Pacific Cable Network (APCN)	✓		
BSCS (Batam-Singapore Cable System)	✓		
EAC-C2C Network	✓		
i2i			✓
JAKABARE (Java-Kalimantan-Batam-Singapore)	✓		
Matrix Cable System (MCS)	✓		
SMW-3			✓
SMW-4			✓
TIC (Tata Indicom Cable)	✓		

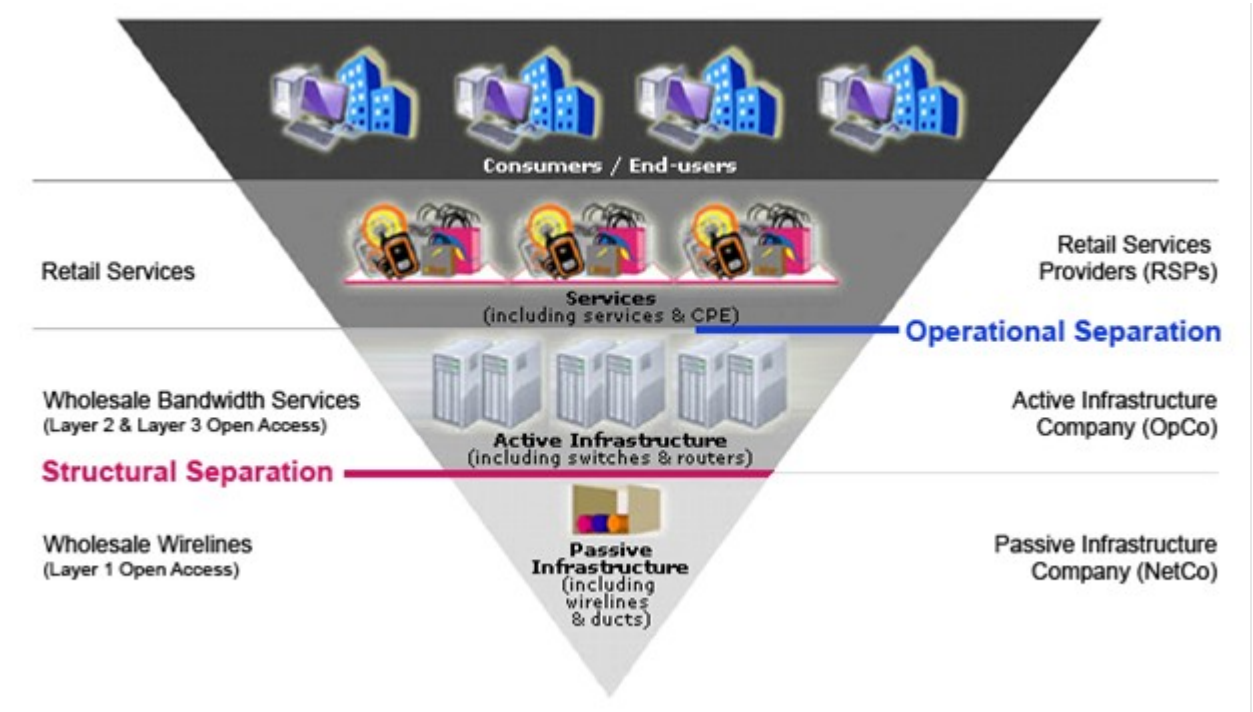
[2] See http://www.datacenterknowledge.com/archives/2010/09/23/one-size-does-not-fit-all-in-the-data-center/
[3] For regional leased circuit price comparisons, see *APCC Access Price Benchmarking, 2009*, available at http://www.trpc.com.hk/bank/reports/apcc_final_rpt_2010.pdf
[4] http://www.trpc.com.hk/bank/presfiles/ap_tech_mkt.pdf
[5] 56.1 Tbps as of June 2010 according to http://www.submarinenetworks.com/stations/asia/singapore/cls-in-singapore
[6] http://www.ida.gov.sg/doc/Policies%20and%20Regulation/Policies_and_Regulation_Level2/20100827100559/SubCableLanding.pdf
[7] Source: TRPC, T-Systems and http://www.submarinenetworks.com/stations/asia/singapore/

TGN-Intra Asia Cable System (TGN-IA)	✓		
Thailand - Indonesia - Singapore Cable Network (TIS)	✓		
MIC-1 (Moratelindo International Cable-system One)	✓		
Planned			
APG (Asia Pacific Gateway)			✓
ASC (Australia-Singapore Cable)	tbd		
ASE (Asia Submarine Express)			✓
SIC			✓
WAC			✓

Note: The *designed* capacity of the newer cables is humongous (e.g., EAC-C2C = 30.72 Tbps) compared with the oldest cables (e.g., SMW-3 = 70Gbps), but the *lit* capacity is usually less than 10% on the new cables, and the *used* capacity is even lower.

The building out of the domestic high speed fibre NGN network promises to bring to an end the era of lack of wholesale or infrastructure competition in Singapore, where M1 and Starhub have been highly dependent upon leasing lines from SingTel.[8] The IDA's solution has been one of structural separations, separating network operations from the wholesale and retail markets as illustrated in the IDA's diagram below.[9]

High Speed Fibre Next Generation Network



[8] See fn 3 above
[9] http://www.ida.gov.sg/Infrastructure/20090731125844.aspx

If Singapore can achieve, and maintain, competitive domestic prices and service quality and a plentiful supply of international bandwidth the infrastructure will support the aim of being the hub for DCs in the ASEAN region and possibly beyond.

Traffic Management

According to Cisco's Visual Networking Index: Forecast and Methodology (2010-2015) annual global IP traffic will reach the zettabyte threshold (966 exabytes or nearly 1 zettabyte per year) by the end of 2015. [10] In 2015 the gigabyte equivalent of all movies ever made will cross global IP networks every 5 minutes. Global IP networks will deliver 7.3 petabytes every 5 minutes in 2015. That's a lot of data.

Most of that data will be stored somewhere and transmitted as data traffic in some form or another. Secure data transmission is at a premium for certain types of data and the efficient transfer of data is a vital component of any business. Making sure the right data reaches the right places in the right order and at the right time and in good condition is what traffic management is all about. Traffic management *within* a DC is the job of the DC management itself, but traffic *in and out* of the DC is the job of carriers or specialist traffic management companies in two areas: 1) traffic management with respect to overlay networks such as content delivery networks (CDNs), and other means of traffic management between DCs and Internet-based users and 2) traffic management in and out of DCs over external/leased connections.

Overlay networks (networks built on top of another network[11]) for traffic management over the Internet come in a number of forms, such as CDNs and also a number of peer-to-peer focused models. CDNs have been the most prominent commercially, and are built upon the concept of 'edge computing', where content delivery resources are decentralised and data transfer optimised based on a data requester/user's location. Singapore is a POP (point of presence) or edge location for a number of CDNs such as Akamai, Limelight, L3, EdgeCast, Amazon.

The consolidation of DCs into unified facilities (whether physically, or operationally through the use of technologies such as virtualization) is also impacting on traffic management. For example, in 2009 Singapore set up the Singapore Internet Exchange (SGIX) to promote its status as an international IP exchange, thus saving on the need to send purely regional traffic to peer in the USA. Singapore has also established itself as a centre for international bandwidth trading by regional carriers. So whether it is public Internet 'best effort' data, such as email, SNS or texting, or high-value time sensitive such as financial data or real-time broadcast content data where the quality must be the highest, latency the lowest, streaming of audio and visual perfectly synchronized, etc., the management of the traffic is a vital part of Singapore's future as an data centre hub for the region.

[10] http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-481360_ns827_Networking_Solutions_White_Paper.html

[11] In the case of fibre networks the overlay will use its own partitioned wavelength

In an interview 20 September 2011 with Asia Cloud Forum, Equinix director Clement Goh noted that "We have identified carriers and content providers as the key contributors to the increase in network traffic and corresponding growth in data volumes with 64% and 36% share respectively… cloud computing is still the main driver for customer-led data centre deployments in Asia. About 40% of organizations using our data center services are cloud customers."[12] Overall for Equinix, Singapore traffic reached 55 Gbps "the highest amount of traffic registered in Asia Pacific and 250% growth over a 12-month period."

Cross border data

One 'soft' issue that is growing in significance is data protection. Under what circumstances will DCs agree to locate or not locate in a given jurisdiction? If companies storing data in a DC fear that their data may be transferred to a jurisdiction that does not apply adequate protection of their data they will think twice and impose conditions. The issues can be seen as falling into 4 categories: cyber security, IPRs, liability issues and personal data protection. Cyber security speaks for itself in an age in which cyber spying and cyber theft is taking place on an industrial scale, including state-sponsored, worldwide. IPR issues are often complex, and the local terms and conditions upon which inventions, designs, formulae, songs, prose, etc., can be downloaded from servers located anywhere in the world is fraught with industry, trade and civil rights issues.

The Internet has also spawned a series of high profile cases about who carries liability for content that may be deemed illegal or unacceptable or in some cases subject to taxation in different jurisdictions, and the storage and availability of that content from servers in DCs spread across the globe is a challenge to policy makers. Finally, the principle that data collected about individuals should not be used for purposes other than those agreed to by those individuals can be difficult to implement and to police. In some cases its opt-in and in some its opt-out; in some cases, like Singapore, government held data about citizens is not restricted; and there are many gray areas such as where an innovative product or service that was unforeseen at the time of data protection is dependent upon the use of such data. Most seriously perhaps for trade-related issues and the role of data transfers is the conditional protection and liability concerning data handed from the original collector of the data to an overseas party who may store or user that data.

The OECD Guidelines on the Protection of Privacy and Transborder Flows of Personal Data ("OECD Guidelines"),[13] the EU Data Protection Directive,[14] and the APEC Privacy Framework[15] expressly affirm the importance of maintaining information flows to sustain social and economic growth while protecting privacy. In

[12] http://www.asiacloudforum.com/content/cloud-computing-drives-data-center-deployments?section=news&utm_source=lyris&utm_medium=newsletter&utm_campaign=cloud
[13] http://www.oecd.org/document/18/0,3746,en_2649_34255_1815186_1_1_1_1,00&&en-USS_01DBC.html
[14] http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:1995:281:0031:0050:EN:PDF

producing the Consultation Paper on the Proposed Consumer Data Protection Regime for Singapore,[16] MICA and the IDA are aiming to bring Singapore into line with these guidelines and go beyond the existing voluntary Model Data Protection Code[17] with a baseline framework for the private sector, using a complaints-based as opposed to an audit-based approach to minimize the costs of business compliance. On top of the baseline there remain in place specific data protection requirements for sectors such as banking and finance, the health sector, the telecoms sector, etc.

Data Centres

Currently there are over 20 data centres in Singapore (see Appendix). The IDA, the EDB, the Energy Authority and the JTC Corporation are collaborating on a project to open a Data Center Park by 2013 offering 120,000 sqm.[18] A report in January 2011 by Frost & Sullivan for the Government of Hong Kong[19] suggested two major constraining factors in attracting DCs to locate in the territory: 1) the cost of supplying energy and the need to cluster DCs to generate the economies of scale required to justify electric power generating plants; 2) the lack of skilled staff for operational management, repairs and maintenance. Similar challenges will face Singapore, but in meeting them Singapore will position itself above its immediate neighbours.

The largest provider of colocation DC services across Asia-Pacific is Equinix according to TeleGeography's *Colocation Database*[20] which covers the 10 largest DCs providing colocation facilities. Equinix has also been the most expansive globally.

[15] http://www.ag.gov.au/www/agd/rwpattach.nsf/VAP/%2803995EABC73F94816C2AF4AA2645824B%29~APEC+Privacy+Framework.pdf/$file/APEC+Privacy+Framework.pdf
[16] http://www.mica.gov.sg/DPConsultation/DP_Public_Consultation_Paper.pdf
[17] http://www.trustsg.sg/downloads/Data_Protection_Code_v1.3.pdf
[18] http://www.ida.gov.sg/doc/Infrastructure/Infrastructure_Level2/20090204132625/DCP_SOR.pdf
[19] Frost & Sullivan/OGCIO (2011) *Economic Benefit Analysis of Developing HK into a Regional Data Centre Hub* http://www.ogcio.gov.hk/eng/pubpress/download/eeba-es-full.pdf
[20] TeleGeography kindly gave permission to reproduce these charts. See http://www.telegeography.com/page_attachments/products/website/research-services/colocation-database/0002/4735/executive-summary.pdf

Operators with Largest Amount of New Colocation Site Capacity by Region
2009–2011 (sq ft)

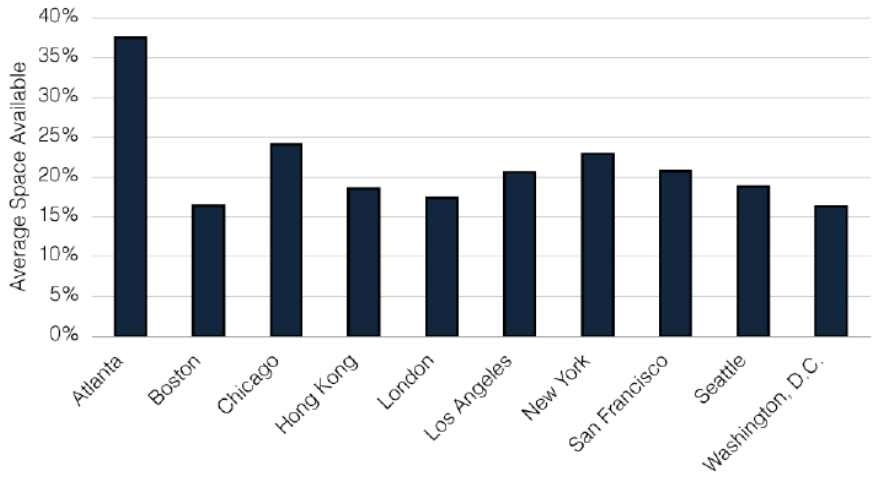
Operator	North America	Europe	Asia-Pacific	Latin America	Net Increase
Equinix	373,829	627,288	342,016	155,643	1,498,776
Quality Technology Services	1,370,000				1,370,000
i/o Data Centers	831,000				831,000
Interxion		162,524			162,524
European Data Hub		161,459			161,459
KVH			151,341		151,341
TelecityGroup		123,785			123,785
SAVVIS	77,968		18,629		96,597
Gyron Internet		88,000			88,000
Internap	73,000				73,000

Notes: Based on data collected by TeleGeography in 2011 from survey responses and public information. Companies that requested data confidentiality are not shown. "New Colocation Capacity" refers to square footage of new colocation sites launched by operators between September 2009 and September 2011.

Source: TeleGeography research

The demand for colocation has grown with the demand for telecom and Internet services in particular. In TeleGeography's selected metro areas all but one of the colocation DCs were working to over 75% capacity in 2011.

Average Colocation Space Available in Select Metro Areas, 2011



Notes: Based on data collected by TeleGeography in 2011 from survey responses and public information. Percentages represent weighted average floor space, in order to account for the relative sizes of sites reporting.

Source: TeleGeography

Energy Costs and Efficiencies

The standard measurement of DC energy-efficiency is PUE (Power Usage Effectiveness or *total* DC power used/IT equipment power used). For example, a study by Koomey assumes a PUE of 2.0 which implies that there is 1 KWh of electricity used for infrastructural operations for every kWh used for the IT component.[21] According to Koomey, in the case of cloud computing "which typically have much higher server utilization levels and infrastructure efficiencies than do in-house data centers" the PUE can be as low as 1.1. Concern with energy saving began in earnest around 2005/2006 when the US EPA (Environmental Protection Agency) sponsored industry seminars on the subject, and in 2007 when the European Union issued a voluntary Code of Conduct on energy-saving best practices.

In 2010 Koomey estimates that data centres accounted for 1.3% of the world's energy *consumption*, while a report by McKinsey & Co. estimates that the energy consumption accounts for 0.2% of global energy *production*, adding that between 2000 and 2006 DC energy consumption had doubled "and today the average data center consumes as much as 25,000 households."[22] The report adds that "[w]ith their enormous appetite for energy, today's data centers emit as much carbon dioxide as all of Argentina. Left on their current path, data center output will quadruple by the year 2020."

Servers

That's the bad news. The better news is that energy consumption 2005-2010 seems to have slowed down. According to Koomey between 2000-2005 it doubled, but 2005-2010 worldwide it increased only 56%, and even less in the US by 36%. The principal reasons are attributed in part to the general economic downturn and in part to improvements in *virtualization* – using the common resources of a server to allocate an on-demand 'virtual' server service to an individual user – which led to a "significant reduction in actual server installed base in 2010 compared with the IDC installed base forecast published in 2007." (Koomey, p.iii)

The big problem with the conventional use of servers is their under-utilization. Koomey cites anecdotal evidence that 10%-30% of servers in DCs are no longer delivering computing services. The McKinsey report suggests even lower rates. Server utilization "rarely exceeds 6% and facility utilization can be as low as 50%." And a survey of 525 DC executives published by the Uptime Institute in October 2011 found that 10% of servers in a DC "are likely sitting idle on the raised floor".[23]

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[21] Jonathon Koomey (2011) 'Growth in Data Center Electricity Use 2005-2010' Report by Analytics Press for *The New York Times*, http://www.missioncriticalmagazine.com/ext/resources/MC/Home/Files/PDFs/Koomey_Data_Center.pdf

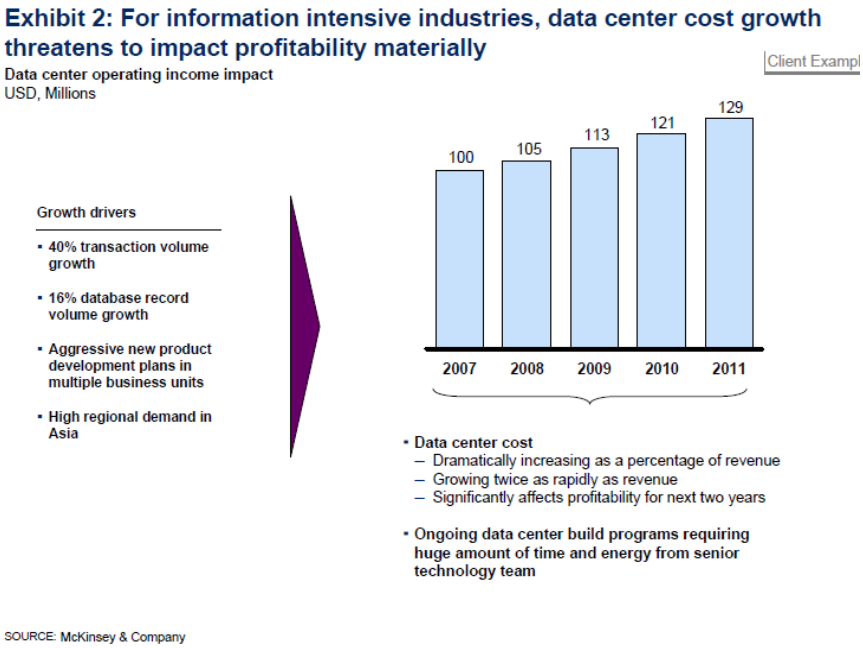
[22] James Kaplan, William Forrest and Noah Kindler (2008) 'Revolutionizing Data Center Energy Efficiency' McKinsey & Co., http://www.mckinsey.com/clientservice/bto/pointofview/pdf/Revolutionizing_Data_Center_Efficiency.pdf

[23] Uptime Institute Server Roundup! http://uptimeinstitute.com/

Speaking to the Business Times in October, Mr Soh, IT Business VP for Schneider Electric “noted that a typical system that is loaded at 30 per cent of rating would cost about US$2,300 per kW per year. If the same system was right- sized, the load will fall to US$1,440 per kW per year, resulting in 38 per cent savings in electrical costs.” He added that virtualisation “always dramatically reduces the number of installed servers… [and] the elimination of a server is a structural consumption avoidance of approximately 200-400kW, depending on the type of technology used.”

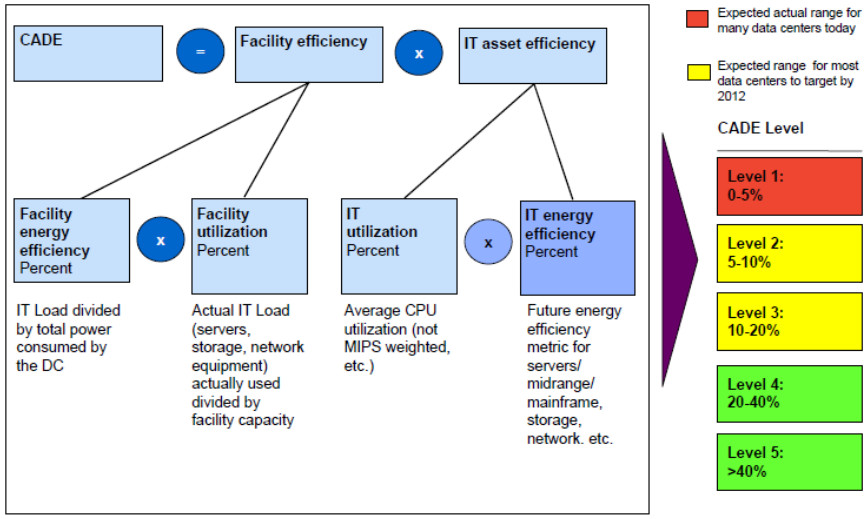
Costs

The McKinsey report notes that “[f]ive years ago, a typical data center cost US$150 million to build. Today a similar sized data center costs several times that amount.” The lifespan averages 10-12 years. They estimate that “data centers account for approximately 25% of the total corporate IT budget when you take into account facilities, servers, storage and the labor to manage them.” The report goes on to develop a methodology CADE (Corporate Average Datacenter Efficiency) for identifying the true costs of energy consumption based upon the TCO in terms of energy. The critical issue is TCO because the DC opex tends to be spread across a large number of corporate business units each using its own accounting system that may not break-out DC energy or computing costs as separate items, far less aggregate them across the company. The following McKinsey diagram illustrates the typical cost-drivers involved.



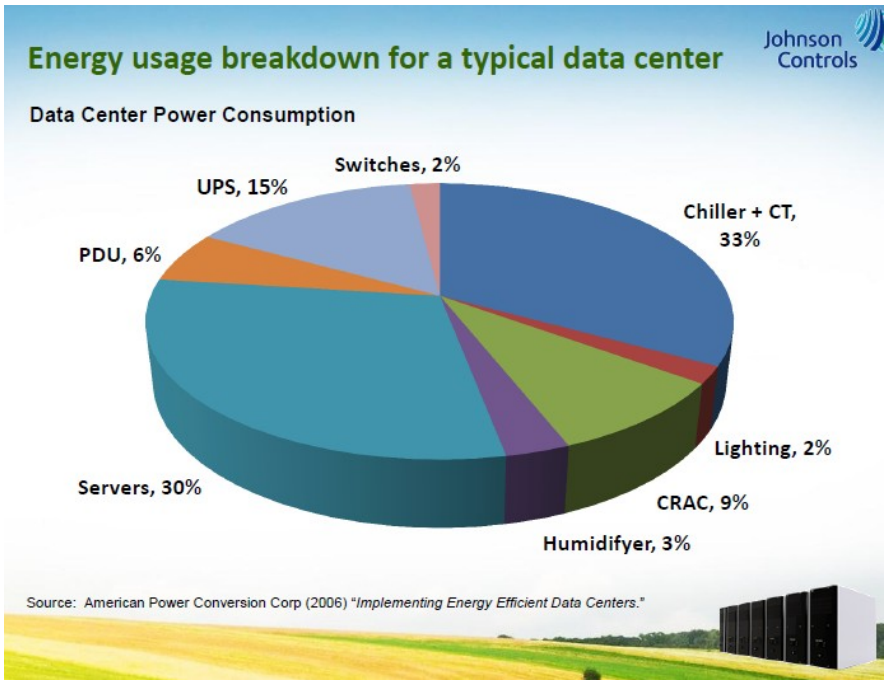
The McKinsey CADE methodology is shown below.

Exhibit 9: Implement metrics for data center energy efficiency



SOURCE: McKinsey & Company; Uptime Institute

An energy usage breakdown of a typical DC is provided in the following chart, cited by Rob Moult of Johnson Controls in his Data Centre Performance Management presentation to the Green Data Centre Forum 2011.[24]



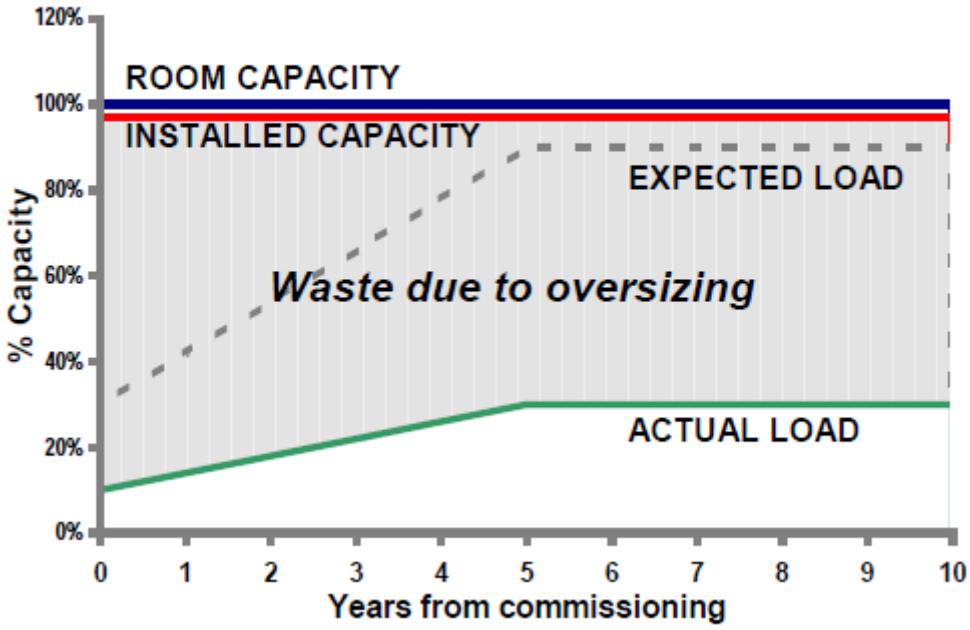
Part of the challenge lies in what economists call the peak-loading problem. Typically a utility like an electricity supply or a telephone exchange has to provision for peak hours during the day. In the case of a DC the provision of facilities has to cater for peak loading a few years hence. For example, if a DC in year 2 has only 15% capacity utilization, it is difficult to cool only that part of it. The cooling system must

[24] http://www.greeninfocomm.sg/B9.pdf

be installed to cater for higher rates of usage. Furthermore, as Koomey observes, “peak power per server (which seems to be increasing) may be diverging from annual electricity use per server (which is growing more slowly than peak power and may actually be declining)’ adding that this ‘divergence is an important area for further research.” (p.8)

The following diagram from Schneider Electric illustrates the problem.[25]

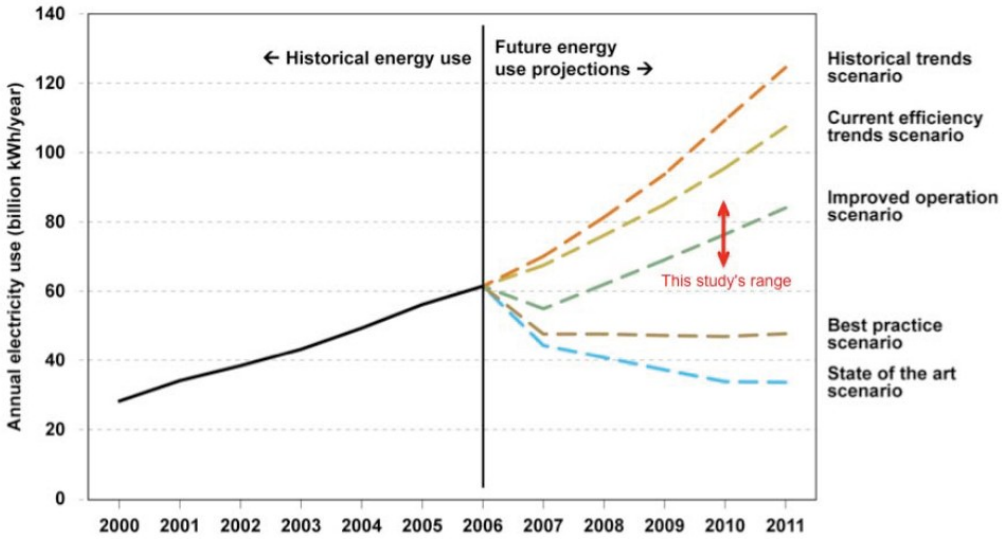
Figure 1 – Design Power Capacity and requirement over the lifetime of a data center



Koomey reproduces electricity usage from the EPA report and extrapolates future usage across five possible scenarios.

Predicted US electricity use for data centres from the EPA report to Congress (EPA 2007) and the range estimated by Koomey

[25] Neil Rasmussen *Avoiding the Costs of Oversizing Data Center and Network Room Infrastructure*, White Paper 37, Schneider Electric http://dnscoinc.com/avoidingoversizing.pdf



Green Standard

Commercial data centre space in Singapore 2010-2015 has been forecast to grow 71% (BroadGroup's 2009 *Data Centres in South East Asia*[26]*).* Because energy costs are expected to make up as much as 50% of operational costs – the 10 largest DCs in Singapore consume energy equivalent to 130,000 households or more than 10% of all households in Singapore[27] – the need to introduce greener designs is evident. In its 2007 *Report to Congress on Data Center and Server Energy Efficiency*, the EPA estimated that up to US$5 billion can be saved in power costs annually if the data centres were to go green, but there are no universally accepted green standards and therefore no universal guidelines for governments to apply to incentive schemes and procurement policies; hence the joint initiative by the IDA[28] and the National IT Standards Committee to promote a local Green Data Centre standard.[29]

IDA cites the example of the joint initiative that resulted in the Nanyang Technological University's (NTU) High Performance Computing (HPC) Centre, opened February 2010. The NTU HPC Centre is a collaboration between NTU, IBM, Red Hat and Jardine One Solution and is "ranked the 6th most energy efficient in the world based on x86 architecture – the universal platform found in computers today,

[26] http://www.telecomsmarketresearch.com/research/TMAAAVVH-Data-Centres-South-East-Asia.shtml
[27] 'New green standard for Singapore's DCs' *Channel News Asia*, 31 March 2011, http://www.eco-business.com/news/new-green-standard-for-singapore-data-centres/
[28] IDA is a member of the Green Grid, an international organization of professionals dedicated to increasing DC efficiency, see http://www.thegreengrid.org
[29] See http://www.greenbusinesstimes.com/2011/08/12/ss-5642010-green-data-centres-energy-and-environmental-management-systems-development/ As of September 2011 the following DCs were in receipt of Singapore's Green Standard SS564: 1-Net, IBM, Keppel Datahub, HPCC (NTU). National Library Board, Resorts World Sentosa and SingTel

and the 29th most energy-efficient system on the Green500 list at 274.64 Mflops (millions of floating point operations per second) per watt. It reduces electricity consumption as it can automatically adjust to specified energy usage levels and specified transaction speeds."[30]

The need to reduce electricity consumption to keep servers cool was highlighted by Facebook's recent decision to build its first data centre (290,000 square feet for phase 1) outside the USA near a hydro-power facility in the very cold climate climate of Lulea in northern Sweden, roughly the same latitude as Alaska and with an average *high* temperature of 5 degrees C.[31] By contrast Google has opted for DCs in Hong Kong, Singapore and Taiwan, but Google also claims that through state-of-the-art designs their DC energy needs have been cut by 50%. Through efficiency innovations, Google claims to have cut the energy needs of its data centres by 50%, including doing away with the need for chillers.[32] And according to the BroadGroup report, Google has recently filed a patent application for a water-based data centre, where ocean waves and water are to be used for power and cooling. According to the EDB, "the Keppel Corporation would be a forerunner to host such a centre: its offshore and marine division is the leader in floating storage construction, while its onshore facility, Keppel Digihub, is a major data centre operator."[33]

Conclusion

Currently, Singapore has the advantage of hard infrastructure (telecoms, energy supply) and soft infrastructure (DC management, traffic management) as well as geography on its side. MICA/IDA are planning to add data protection measures to ensure Singapore as an attractive place to store data and to transfer data to and from. It is difficult to see Singapore's neighbours in SE Asia being able to match these advantages any time soon.

But the life expectancy of a DC is around 10 years. In 10 years' time global transmission speeds, penetration rates and storage capacity will have transformed yet again. One trend could well be towards just two or three DCs worldwide for major users. Another may well be towards using the oceans and ocean platforms for water cooling. In other words, economics and innovation are likely to be the two drivers on the supply side.

Appendix

[30] IDA 'Towards a Green Data Centre Standard' 3rd March 2010
http://www.ida.gov.sg/insg/post/Towards-a-Green-Data-Centre-standard.aspx
[31] http://www.datacenterknowledge.com/archives/2011/10/27/facebook-goes-global-with-data-center-in-sweden/
[32] http://www.google.com/about/datacenters/inside/efficiency/
[33] http://www.edb.gov.sg/future_ready.html/future_ready_today/articles/info_tech.html

Data Centres in Singapore (maybe incomplete)

1. Asia Data Center Alliance (ADCA)
2. NSC
3. Ascenix
4. NTT Data Centre
5. AT&T
6. Nucleus
7. British Telecom/Frontline
8. PacNet
9. Datacraft Asia
10. Phoenix
11. DataOne
12. Pihana Pacific
13. Digital Reality
14. Resorts World Sentosa
15. Epsilon
16. Savvis
17. Equinix 1
18. SingTel 1
19. Equinix 2
20. SingTel 2
21. Fujitsu
22. SingTel 3
23. Global Switch 1
24. SingTel 4
25. HPCC (NTU)
26. SingTel 5
27. 1-Net
28. Softlayer
29. IBM Singapore
30. ST Electronics
31. International Business Exchange (IBX)
32. Tata Communications
33. KDDI (Telehouse)
34. Telin
35. KAZ Computer Services
36. The Art of Cross Stitch
37. Keppel Digihub
38. T-Systems
39. Keppel T&T
40. Verizon
41. M1 Broad Band
42. W3Hub
43. National Library Board

Compiled by TRPC and T-Systems

ABOUT IDA
The Infocomm Development Authority of Singapore (IDA), a statutory board of the Singapore Government, was formed on 1 December 1999 when the government merged the National Computer Board (NCB) and Telecommunication Authority of Singapore (TAS), as a result of a growing convergence of information technology and telephony. IDA aims to grow Singapore into a dynamic global infocomm hub and to leverage infocomm for Singapore's economic and social development. IDA plays four key roles in driving Singapore's transformation into an Intelligent Nation and a Global City through infocomm: infocomm industry development, e-government, sector transformation through infocomm and people sector enrichment through infocomm

ABOUT AKAMAI
Akamai® is the leading cloud-based platform for delivering secure, high-performing user experiences to any device, anywhere. The Akamai Intelligent Platform™ provides pervasive reach, coupled with unmatched reliability, security, visibility and expertise. Removing the complexities of reaching mobile work-forces, 24/7 consumers, and global audiences, Akamai enables companies to transform and

reinvent their online business. To learn more about how Akamai is accelerating the pace of innovation in a hyperconnected world visit www.akamai.com

ABOUT CSF ASIA PTE LTD

“CSF Group is principally engaged in the business of providing a full range of services associated with design, development and operations of data centers, both for “green site” and “brown site” development. In 2003, the Group completed the development of its own high-end commercial Data Centre in Cyberjaya, branded as CX1 (Computer Exchange). On the success of CX1, the Group completed a much larger Data Centre known as CX2 Computer in January 2009. Both CX1 and CX2 are located in Cyberjaya. By end of 2011 with the completion of CX 3 and CXJ (in Jakarta) CSF will be the largest high-end commercial Data Centre provider in South East Asia. The Group sees itself as an Asian Data Center brand and has started to expand its business into Singapore, Vietnam and Thailand, and intends to also expand into China and India in the medium term.”

ABOUT T-SYSTEMS

Deutsche Telekom AG is one of the world's leading telecommunications and information technology service companies. We have almost 200 million customers and offer them all kinds of products and services for connected life and work. Deutsche Telekom has an international focus and is represented in approximately 50 countries. In 2010, the Group generated revenue of EUR 62.4 billion, over half of it outside of Germany. It has 247,000 employees.

T-Systems is Deutsche Telekom’s corporate customer arm. Using a global infrastructure of data centers and networks, T-Systems operates information and communication technology (ICT) systems for multinational corporations and public sector institutions.

With offices in over 20 countries and global delivery capabilities, T-Systems serves companies in all industries – from the automotive industry to telecommunications, the financial sector, retail, services, media, energy and the manufacturing industry all the way to government agencies and the healthcare sector. Approximately 47,600 employees worldwide use their industry expertise and ICT know-how to provide top-quality service. T-Systems generated revenue of around EUR 9.1 billion in the 2010 financial year.