Leveraging Cloud Computing, Virtualisation and Solar Technologies to Increase Performance and Reduce Cost in Small to Medium-sized Businesses

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Abstract: Cloud computing has been available for some time and is used in large organisations across the globe. We know that cloud computing is an economically viable concept in these large global organisations, however we do not understand sufficiently whether it can reduce costs in smaller organisations, given the traditionally large investment costs. This paper performs an investigation into cloud computing concepts to understand if it is a cost-effective solution to a medium-sized business. It draws on a business case which outlines the problems and requirements for an organisation, covers the technologies that are available and then evaluates which, if any, are the most economically viable. Alongside cloud computing it also analyses virtualisation technologies for system consolidation, and also solar energy solutions to reduce energy consumption costs. It then concludes which solutions meet the business requirements.

1 INTRODUCTION

In this paper we will be discussing how cloud computing solutions can benefit small to medium-sized companies. It will follow a business case describing a company whose computing environment is no longer sufficient to their increasingly demanding IT requirements. It covers how various cloud technologies can help combat problems, provide new solutions and reduce cost.

To accompany this, we will investigate cloud computing in general. This will help us understand what is truly meant by the term, the types of cloud topologies that are available, and the benefits and drawbacks of this technology. Also, we will look into cloud infrastructure and cloud services.

This paper also covers the topic of virtualisation. Virtualisation and cloud computing work hand-in-hand; cloud computing capability would not be possible without the use of virtualisation. We will look at what virtualisation is, the different methods of virtualisation, and its benefits and drawbacks to understand its value in businesses today.

We will also analyse solar technologies to understand how solar power can be used to reduce energy costs in an organisation. This includes an investigation into whether solar power is an appropriate and economically viable solution to our business case.

Section 2 describes the business case, gives a background of the business and outlines the problems with its current IT infrastructure. In section 3 we analyse the energy consumption of the IT equipment within the business to help identify which solutions will help reduce power consumption.

In section 4 we consider virtualisation. In section 5 we perform an investigation into solar technologies and apply our findings to the business case. In section 5 we analyse specific technologies to find out which would be the most effective solution to meet the business requirements. Finally, in section 7 we conclude and summarise our findings.

2 BUSINESS CASE

This section gives a background to the business we're investigating, identifies its stakeholders and the problems with its current IT infrastructure. It also highlights the current IT configuration.

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2.1 Business Background

EMMA (East-Midlands Music Academy) is a performing arts school located in the UK that teaches degree-level subjects to its 3,000 students. Started in 2011, the company has seen a steady growth over the past 5 years and is now looking to expand their IT environment to support this, as well as future expansion.

The business currently employs 304 staff, which are made up of the following:

- Administration: 114 (38%)
- Teaching: 141 (47%)
- Senior management: 6 (2%)
- Technical: 25 (7%)
- Manual: 18 (6%)

The business is expanding rapidly taking on approximately 500 extra students each year and their IT system is no longer sufficient. There are three main areas that the academy wishes to address:

- **Insufficient Storage:** The academy is running out of storage space for its students and staff.
- **Too Much Power:** The academy would like to reduce the expenditure of running their IT equipment.
- **Under-utilisation:** Many of the servers are not fully utilised by the applications installed on them.

The key stakeholders to this project are as follows:

Table 1: Project Stakeholders.

Position	Name
CEO	Emma Bradley
CFO	Sharon Smith
VP	Graham Heart
CIO	Benjamin Foresight

At present the academy has a centralised server room containing all the servers that run common services throughout the academy. These include: directory and authentication services (Active Directory), network services (Proxy, DHCP, DNS), file and backup shares, print services, deployment services, email, web and database services. The current infrastructure consists of the following:

Table 2: Current Infrastructure in EMMA.

Server Name	**Model**	**Services**	**RAM (GB)**	**HDD (GB)**
ACD-001	HP RX2800-i2	Active Directory, DHCP, DNS	2	300
ACD-002	HP RX2800-i2	Active Directory, DHCP, DNS	2	300
ACD-003	HP RX2800-i2	Active Directory Backup	2	300
PRX-001	HP RX2800-i2	Proxy Master	2	300
PRX-002	HP RX2800-i2	Proxy Slave	2	300
FLE-001	HP RX2800-i2	File	4	2,000
BCK-001	HP RX2800-i2	Backup	2	2,000
PNT-001	HP RX2800-i2	Print	2	300
DPL-001	HP RX2800-i2	Operating System Deployme nt	2	600
EXC-001	HP RX2800-i2	Exchange Master	8	300
EXC-002	HP RX2800-i2	Exchange Slave	8	300
EXC-003	HP RX2800-i2	Exchange Backup	8	300
WEB-001	HP RX2800-i2	Web hosting	4	300
WEB-002	HP RX2800-i2	Web hosting	4	300
WEB-003	HP RX2800-i2	Web hosting	4	300
WEB-004	HP RX2800-i2	Web hosing	4	00
DTB-001	HP RX2800-i2	Database	8	300
DTB-002	HP RX2800-i2	Database	8	300
APP-001	HP RX2800-i2	Application	4	300
APP-002	HP RX2800-i2	Application	4	300
APP-003	HP RX2800-i2	Application	4	300

Table 2: Current Infrastructure in EMMA (Cont.).

Server Name	Model	Services	RAM (GB)	HDD (GB)
APP-004	HP RX2800-i2	Application	4	300
APP-005	HP RX2800-i2	Application	4	300
APP-006	HP RX2800-i2	Application	4	300
APP-007	HP RX2800-i2	Application	4	300
APP-008	HP RX2800-i2	Application	4	300
APP-009	HP RX2800-i2	Application	4	300
APP-010	HP RX2800-i2	Application	4	300
		Total	**116**	**12,100**

The academy hosts 28 individual servers, all of which are the same model, the only difference being the RAM and HDD capacities.

At present, the academy's servers combined offer a total storage capacity of 12.1TB. These servers run as individual units and the file server has a total capacity of 2TB. This gives students a maximum storage quota of 500MB and 1GB for staff. This is no longer sufficient and the academy would like to offer students a quota of 1GB and 2GB for staff. Also, email users have a maximum mailbox size of 50MB, they would like to increase this to 200MB.

Based on the current numbers of students and staff this requires 3.26TB of storage capacity. They would also like the system to be able to accommodate the next five years of expansion. The academy expects to enrol 500 extra students each year, totalling 5,500 students after five years. Therefore, the system needs a useable storage capacity of 7.26TB, with an additional 7.26TB for backups, in total 14.52TB.

2.2 Summary

EMMA's outlined their requirements of the system as follows:

- Storage capacity of 14.52TB or more.
- Reduce energy consumption
- Utilise system resources effectively.

Because of this, only solutions that meet those criteria will be suggested. EMMA has not specified a budget as this is just an investigative project for now. They would like to understand the potential benefits of a new IT solution vs the cost, before they allocate any funding.

3 ENERGY CONSUMPTION

To understand how much energy can be saved through various technologies, it is first important to understand the current energy consumption, along with the cost. This will then allow us to evaluate solutions and provide realistic expectations of any reductions that can be made.

EMMA's preferred IT provider is HP and therefore all servers they own are HP branded. To calculate the current energy consumption, we used the HP Power Advisor tool located at: https://paonline56.itcs.hpe.com/. The tool shows two results: the first for when the system is at idle usage, and the second at max load. See Figure 1.

Data Center Summary	
Line Voltage	240 VAC
BTU HR	33646.66 BTU
System Current	42.31 A
Total Utilization Input Power	9867.16 W
VA Rating	10133.97 VA
Total Idle Input Power	6895.96 W
Total Max Load Input Power	9867.16 W

Figure 1: HP Power Advisor Results of Current Infrastructure.

As you can see, the power usage when at idle is 6,895.96 watts and at max load is 9,867.16 watts. The system will rarely stay at either idle or max load, so for the purposes of this paper we will average out the results. The mean average of the two is **8,381.56** watts.

The average kilowatt per hour cost in the UK, at time of writing, is 12.12 pence (UKPower.co.uk Limited, 2017). Therefore, for every hour EMMA operates their IT infrastructure, it is costing them 101.58 pence, or £1.01. EMMA's IT equipment is drawing power 24 hours per day, 365 days per year. This equals £24.24 per day, £737.30 per month and **£8,847.60** per year. This was calculated using the following:

Watts / 1000 = kilowatts
Kilowatts x Cost per kilowatt hour = Cost per kilowatt hour (pence)
Cost per kilowatt hour / 100 = Cost per kilowatt hour (£)
Cost per kilowatt hour * 24 = Cost per day
Cost per day x 365 = Cost per year
Cost per year / 12 = Cost per month
Cost per year / 52 = Cost per week

4 VIRTUALISATION

In this section we will look into virtualisation technologies. Cloud computing would not be possible, or at least would be much more difficult without employing virtualisation. We will cover what virtualisation is, the types of virtualisation available and also the benefits and drawbacks of the technology.

4.1 Benefits

Virtualisation can offer several benefits including:

- **Lower Infrastructure Costs:** By utilising more resource per server, less servers are needed, therefore reducing implementation and running costs.
- **Simplified Management:** Hypervisors offer centralised management of guest operating systems.
- **Business Continuity:** Virtualisation reduces reliance on physical servers,hk and virtual machines can be replicated and easily migrated to different physical hosts. This redundancy allows for users to continue working undisrupted if a problem occurs.
- **Energy Reduction:** As less physical servers are used, less energy is expended.
- **Flexibility:** Resources allocated to applications can be flexible. If an application outgrows the specification of its environment, administrators can simply allocate more resource.

4.2 Drawbacks

- **High Risk with Small-scale Systems:** If virtualisation is used in small-scale systems, the impact of a physical problem with a server is magnified. For example, if you consolidate your five physical servers into one, any physical fault on that server will bring down all services hosted from all virtual machines.
- **Performance:** Virtual machines cannot give the same performance in comparison to running a machine directly on the underlying hardware. There is an extra layer added to computing processes, the hypervisor.
- **Complicated:** Implementing a virtualised environment is far more complicated than setting up a traditional one. It requires someone with knowledge of virtualisation to install, configure and maintain.
- **Unsupported:** Some applications will simply not work on virtualised machines. So, compatibility issues may arise if not investigated properly.

4.3 Virtualisation Software Vendors

There are multiple vendors that produce hypervisor software. For the purposes of this paper we will discuss two; VMWare and Microsoft Hyper-V.

4.3.1 VMWare Vs. Hyper-V

Both VMWare and Microsoft Hyper-V are very similar, and both offer feature rich virtualisation software. However, there are some differences.

One advantage to a hypervisor is being able to dynamically allocate RAM to machines, as and when they need it. Both offer this, but Hyper-V can only adjust RAM on guests running the Windows operating system. In terms of scalability, Hyper-V hosts can support up to 320 logical processors, whereas VMWare can support just 160. Hyper-V servers can utilise up to 4TB of RAM, whereas can utilise VMW just 2TB. Also, a Hyper-V cluster can include up to 63 nodes and support up to 8,000 virtual machines. VMWare can include just 32 nodes and supports a maximum of 3,000 virtual machines.

Another advantage of Hyper-V is its licensing. Hyper-V comes as standard with the Windows Server 2012 operating system. If you purchase a Datacentre Edition, each virtual machine that you run on the host can run Windows 2012 without needing an additional licence. Given that Windows Server licenses are very pricey, roughly £500 per licence, this can be a major cost saving (Posey, 2013).

5 SOLAR TECHNOLOGIES

In this section, we perform the necessary calculations required to prove whether the installation of solar panels at EMMA would be a feasible solution to reduce their energy costs. We compare two different types of solar panel, a low cost and premium one, and calculate the total power output from each. This calculation requires the understanding of the amount of sunlight that will penetrate the solar panels at EMMA's specific geographic location. The academy is keen to reduce their energy bill and this section will evaluate which, if any, solution would be economically viable.

We first need to work out how much power can be generated from the academy. To understand this, we need to know the roof space available for the installation of solar panels, as well as the elevation roof angle. These are:

- **Roof space:** 40m²
- **Roof elevation:** 40 degrees

The academy is connected to the national electricity grid, and have said that they do not wish to invest in solar batteries to store power generated from the panels. Any excess energy produced will be fed back into the national grid.

Solar panels have different efficiency ratings; the power output of the solar panels is reflective of this. For the purposes of this paper we will be comparing two models of solar panel: a low cost one – the Amerisolar AS-6P30-260W, and a premium one – the Panasonic VBHN240SA06. To calculate the output from these we need to know the price per square metre and the efficiency rating. These are as follows:

Table 3: Solar Panel Information.

	Amerisolar AS-6P30-260W	**Panasonic VBHN240SA06**
Price per m²	£49.31	£385.00
Efficiency rating	0.16	0.22

The amount of power output from a solar panel, at any given time, is in direct correlation to the amount of sunlight hitting the panel and the angel of that sunlight. A solar panel will generate maximum power when the rays of the sun are perpendicular to the surface of said panel.

The amount of sunlight available and the angle are dependent on the geographic location of the solar panels. So to calculate this, we must first gather historical data of solar elevation for the latitude and longitude of EMMA – 52.829290, -1.331927. This can be shown in Figure 2 which plots solar elevation throughout the months between the Summer and Winter solstices of 2016.

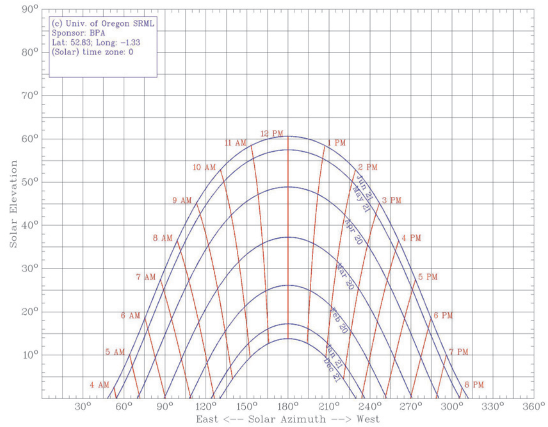

Figure 2: Elevation of the sun above the horizon. Chart generated from http://solardat.uoregon.edu/SunChartProgram.html.

To understand a realistic power output for the solar panels, we must work out the power output for the days mentioned above, which we can then apply an average to. This can be achieved using the following formulae:

Symbols are used in this which are explained below:

Table 4: Symbols used in equation for calculating solar output.

Description	**Symbol**	**Value**	**Units**
Power of sunlight on 1m² the Earth's surface	PSUN	1000	W/m²
Elevation of the sun above the horizon when facing due south	ESUN	Taken from solar elevation chart	Degrees
Elevation of roof angle	EROOF	40	Degrees
Solar panel efficiency	C	0.16 or 0.22	No units
Roof area	A	40	m²
Cost for solar panel per square metre	M	49.31 or 385.00	£ / m²

Table 5: Equation(s) for calculating solar power output.

Description	Equation	Units
Elevation angle of sun on solar panel	ESUNROOF = ESUN + EROOF	Degrees
Total power generated by solar panel	PPANEL = C x PSUN x A x sin(ESUNROOF)	W
Total installation cost for solar panels	MTOTAL = A x M	£
Cost of solar power generated	F = MTOTAL / PPANEL	£ / W

As the solar elevation values change every hour, we must perform these calculations for each hour of sunlight every day. For example, in the month of December the values will be the following: (The value of F is dependent on the solar solution chosen, in this example we will base it on the Amerisolar system).

Table 6: Power output from solar system in December 2015.

Time	ESUN	ESUNROOF	PPANEL	F
08:00	0 (Below horizon)			
09:00	5	50	4902.684	£0.40
10:00	10	55	5242.573	£0.38
11:00	13	58	5427.508	£0.36
12:00	14	59	5485.871	£0.36
13:00	14	58	5427.508	£0.36
14:00	10	55	5242.573	£0.38
15:00	5	50	4902.684	£0.40
16:00	0 (Below horizon)			
Average			**5233.057**	

For the month of June, the values will be the following:

Table 7: Power output from solar system in June 2016.

Time	ESUN	ESUNROOF	PPANEL	F
03:00	0 (Below horizon)			
04:00	2	47	4680.664	£0.42
05:00	10	55	5242.573	£0.38
06:00	18	63	5702.442	£0.35
07:00	27	72	6086.762	£0.32
08:00	36	81	6321.205	£0.31
09:00	45	90	6400.000	£0.31
10:00	53	98	6337.716	£0.31
11:00	58	103	6235.968	£0.32
12:00	62	107	6120.35	£0.32
13:00	58	103	6235.968	£0.32
14:00	53	98	6337.716	£0.31
15:00	45	90	6400.000	£0.31
16:00	36	81	6321.205	£0.31
17:00	27	72	6086.762	£0.32
18:00	18	63	5702.442	£0.35
19:00	10	55	5242.573	£0.38
20:00	2	47	4680.664	£0.42
21:00	0 (Below horizon)			
Average			**5233.057**	

By doing this for every hour of every day in the months specified, and applying a mean average, the results for each solar technology were as follows:

AmeriSolar AS-6P30-260W

- **Average output power from solar panels:** 5,960.057 Watts
- **Average daylight hours per day:** 12 hours
- **Average cost of solar power generated:** £0.33
- **Average output power from solar panels per year:** 26,033,528.976 Watts

Panasonic VBHN240SA06

- **Average output power from solar panels:** 8,195.078 Watts
- **Average daylight hours per day:** 12 hours
- **Average cost of solar power generated:** £1.88
- **Average output power from solar panels per year:** 35,796,100.704 Watts

EMMA’s current IT infrastructure consumes 8,381.56 watts per hour which yearly equates to 73,221,308.16 watts. Therefore, the Amerisolar system is capable of providing 35% of the power required by the academy, whilst the Panasonic system can provide 48%. The Amerisolar system can generate 5.9 kilowatts of power on average, for a price of £0.33. Buying the equivalent amount of energy from the national grid would cost £0.72. The Panasonic system can generate 8.2 kilowatts of power on average, for a price of £1.88. Buying the equivalent amount of energy from the national grid would cost £0.98. EMMA wants to reduce their energy expenditure, which therefore rules out the Panasonic system, meaning the Amerisolar system would be the best suited solution. It fits the business requirements and will cover 35% of their annual electricity bill for the datacentre. This will save them on average £3,075.30 per year.

6 SOLUTION

This section of the paper analyses various solutions we could use to combat the problems described by EMMA. We investigate different server technologies, and compare that with the cost of implementation, to understand the economics of each solution. This will allow us to conclude which solution, if any, is viable.

6.1 Virtualisation

EMMA currently runs 28 servers to support their network. These are individual units and the applications run directly on the physical machine. Many of the applications installed on these servers are (1) not utilising the resources available to them, and (2) not in use all the time. For example, one of the application servers hosts a student attendance application that runs once in the morning, and once in the evening; the rest of the time the system is idle. This is not an efficient use of resources and virtualisation could help combat this problem.

Through employing virtualisation, the university could consolidate the individual servers into just a handful of physical units, therefore reducing power consumption and running costs. In all solutions offered next, a prerequisite is that virtualisation is used.

I've identified three possible solutions for EMMA – a blade server implementation, a new rack server implementation and lastly, re-using and re-configuring the existing infrastructure.

6.2 Solution 1 – Blade Server

The first solution is to use Blade servers. They offer a high-performance system and minimise footprint in the datacentre. They also allow for easy expansion. Blade servers fit into a blade enclosure which can host 8 individual servers, yet only takes up 6 units in a rack. With EMMA's current infrastructure, 6 units in their rack accommodates just three of their servers.

The blade model we will look at here is the HP ProLiant BL460c Gen9 server. This server allows for two high performance Intel Xeon processors to be installed and accommodates up to 2TB of RAM.

The cost of the BL460c, with 128GB of RAM installed, is £5,990.58. This would meet the computing power needed for EMMA's entire network.

With regards to storage, blade servers do not offer large interior storage capabilities. This model only has two hard drive bays which would not provide sufficient storage for EMMA. Blade servers would usually interact with an external storage solution such as a NAS device or a SAN. Due to this, we will evaluate two exterior storage options that would work with our blade setup, the HP MSA2040 and the HP P4500.

6.2.1 HP Msa2040

The HP MSA2040 is a storage solution offered by HP. It is a dedicated storage system that can be accessed from servers using fibre channel, Ethernet or SCSI. Depending on the technology used, data transfer speeds to and from the device range from 1Gbps to 4Gbps.

The MSA2040 allows for 12 hard drives to be installed giving a total capacity of 120TB. The system's modular design also allows expansion through adding drive enclosures. Each enclosure can host a further 12 drives, and a total of 7 extra drive enclosures can be added. This system can support up to 800TB of storage space.

It is a redundant solution and offers hot swappable components, meaning that hard drives, power supplies and fans etc, can be removed and added to the device with no need of turning the system off. It also allows RAID arrays to be configured, meaning data can be mirrored and/or striped across multiple disks. Therefore, if one hard drive were to fail, the system would ensue no data loss.

Prices for the MSA2040 start at £3950.00, but that excludes any hard drives. Without adding further drive bays, EMMA would need 12x 2TB hard drives. This would cost a further £840.00 with each hard drive costing roughly £70.00. So, all-in-all the system would cost in the region of £4,790.00.

6.2.2 HP P4000

The HP P4000 is a fully-featured, IP-based Storage Area Network solution. Traditionally, Storage Area Networks are built with the intention of using Fibre optics to connect servers to the device. However, this solution works on existing Ethernet infrastructure. This therefore eliminates the high costs of installing expensive Fibre channel and reduces the complexity of setting up the solution.

It is designed as a high-availability device offering redundant hot-swappable power supplies and hard drives, dual network connectivity and robust power and cooling diagnostics. With its modular design, additional hardware can be added when needed. It also offers intelligent software which allows for the virtualisation of storage systems into pools (i.e. multiple hard drives are seen as one) and automated failover.

The storage capacity of the system ranges from 4.8TB, on basic models, to 21.6TB and more with modular expansion.

The P4000 costs £4,680.00 but again that excludes hard drives, 12x 2TB hard drives would also be required totalling £840.00. This system would cost in the region of £5,520.00.

6.2.3 Blade Summary

Alongside storage, blade servers need to be installed in an enclosure, which creates an extra cost. The HP C3000 enclosure would be required to support the BL460c blade server, which costs £2829.15.

In total, the cost for a blade system, along with its supporting storage solution, would be in the region of £14,000.00. Also, as shown in Figure 3, according to HP's ProLiant's Business Value Calculator, the total cost of ownership of the blade server over the next five years, (excluding the storage solution), is £46,000.

Looking at the energy savings from consolidating the infrastructure to a blade system, as shown in Figure 4, the energy consumption for this single blade and its enclosure is 624.11 watts at idle and 1,865.68 watts at max power. Comparing this to the 8,381.56 watts consumed currently, this would cost the academy £1,961.20 to run annually, saving them £6,886.40. (This does not include energy consumption from the storage solution).

With Blade servers offering such large computing performance, the academy would need only one blade server to meet their requirements for at least the next five years. If they require more afterwards, buying another blade server would increase their computing power to a level that is unnecessary. Blade servers are only cost-efficient when multiples are used, so providing the enclosure and a SAN to provide storage for just one blade server is rather excessive, and would not be an appropriate solution for EMMA.

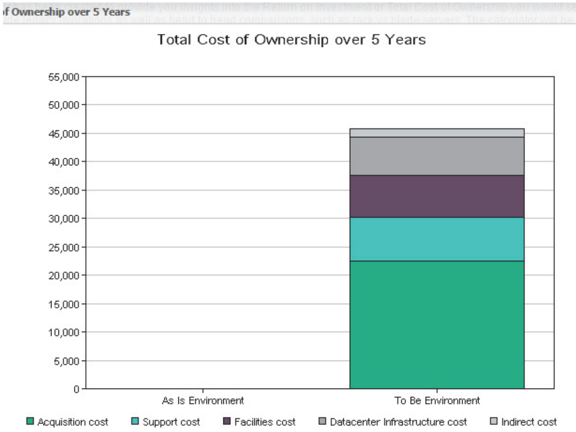

Figure 3: Total Cost of Ownership, HP Blade Solution.

Data Center Summary	
Line Voltage	240 VAC
BTU HR	5308.24 BTU
System Current	6.62 A
Total Utilization Input Power	1556.67 W
VA Rating	1588.44 VA
Total Idle Input Power	624.11 W
Total Max Load Input Power	1865.68 W

Figure 4: Energy Consumption, HP Blade Solution.

6.3 Solution 2 – New Rack Server

The second solution is to purchase new, higher performance and more efficient rack servers. With the progression in technology over the past few years, technically EMMA could consolidate all their servers onto one more powerful server running virtualisation. The model we are looking at here is the HP ProLiant DL180 Gen 9. This model of server allows for two high performance Intel Xeon processors, a total of 512GB of RAM to be installed, and up to 8 hard drives, meaning a total potential capacity of 120TB. These specifications more than meet the needs of the academy.

Moving to a one server setup, the running costs of the single server, compared to the current 28, are dramatically less. As Figure 6 shows, the energy consumption of this setup would be 127.73 watts at idle, and 383.74 watts at max power. Over a year the energy cost of this server would be £403.39 which would save the academy £8,444.21 per year.

The Total Cost of Ownership over 5 years of this server (Figure 5) would be roughly £41,000. The energy savings from implementing this server over 5 years would be £42,221.05. This means the academy's cost vs savings from buying this server would pretty much break even.

Also, having your entire IT solution housed on one server does come with some associated risks with regards to redundancy. For example, if there was a failure on that server, your entire network could potentially grind to a halt. This is not good risk management; although the server has redundancies built in, such as multiple hard drives and dual power supplies etc, if that server lost power for any reason, your entire infrastructure would suffer.

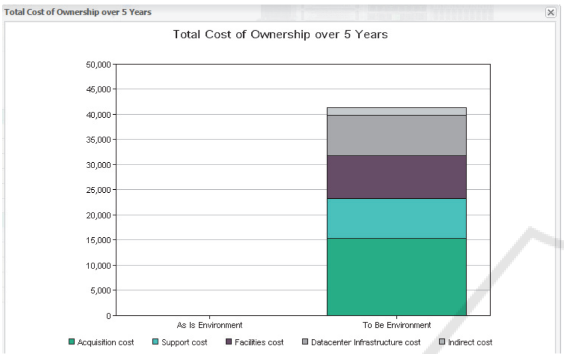

Figure 5: Total Cost of Ownership, HP Rack Solution.

Data Center Summary	
Line Voltage	240 VAC
BTU HR	1308.57 BTU
System Current	1.67 A
Total Utilization Input Power	383.74 W
VA Rating	400.51 VA
Total Idle Input Power	127.73 W
Total Max Load Input Power	383.74 W

Figure 6: Energy Consumption, HP Rack Solution.

6.4 Solution 3 – Reconfiguring Existing Hardware

The final solution is to reconfigure the existing hardware in a more efficient way. As we discussed before, the existing system does not use any form of virtualisation. The servers already installed are capable of running virtual machines, and across all the servers the computing capability is there. All the machines are the same model, meaning parts are interchangeable, so rather than buying an entire new solution we can swap parts around and reconfigure the servers. Based on the services and applications that EMMA needs to host, we would suggest the following machine setup:

Table 8: Machine Setup, Reconfiguring Existing Infrastructure.

Server Name	**Virtual Machines**	**Services**	**RAM**	**HDD**
SVR001	ACD001	Active Directory, DHCP, DNS	2GB	60GB
	ACD002	Active Directory, DHCP, DNS	2GB	60GB
	PRX001	Proxy	2GB	60GB
	PNT001	Print	2GB	60GB
	DPL001	Operating System Deployment	2GB	500GB
	EXC001	Exchange	8GB	1.2TB
		Total	**18GB**	**2TB**
SVR002	ACD003	Active Directory Backup	2GB	60GB
	PRX002	Proxy Slave	2GB	60GB
	EXC002	Exchange Slave	8GB	1.2TB
		Total	**12GB**	**1.4TB**
SVR003	FLE001	File	**4GB**	**7TB**
SVR004	BCK001	Backup	**4GB**	**7TB**
SVR005	WEB001	Web	4GB	100GB
	WEB002	Web	4GB	100GB
	WEB003	Web	4GB	100GB
	WEB004	Web	4GB	100GB
		Total	**16GB**	**400GB**
SVR006	DTB001	Database	8GB	500GB
	DTB002	Database	8GB	500GB
		Total	**16GB**	**1TB**
SVR007	APP001	Application	4GB	200GB
	APP002	Application	4GB	200GB
	APP003	Application	4GB	200GB
	APP004	Application	4GB	200GB
	APP005	Application	4GB	200GB
	APP006	Application	4GB	200GB
	APP007	Application	4GB	200GB
	APP008	Application	4GB	200GB
	APP009	Application	4GB	200GB
	APP010	Application	4GB	200GB
		Total	**40GB**	**2TB**
		Total System	**110GB**	**20.8TB**

By doing this the academy's energy consumption would reduce to 1,948.47 watts at idle and 2,796.16 watts at max power (Figure 7). This is a reduction of 5-6,000 Watts. Looking at the max power figure, this would amount to an annual cost of £2,939.32

compared to the current £8847.60, equalling savings of £5,908.28 yearly. This solution would also support the academies next 5 years of growth.

Data Center Summary	
Line Voltage	240 VAC
BTU HR	9534.82 BTU
System Current	11.96 A
Total Utilization Input Power	2796.16 W
VA Rating	2868.01 VA
Total Idle Input Power	1948.47 W
Total Max Load Input Power	2796.16 W

Figure 7: Energy Consumption, Reconfiguring Existing System.

6.5 Outsourcing Services

As we discussed previously, there are many third-party companies offering cloud services you can buy to remove the need of certain services in your network. There are many different types of services available for purchase, and for the purposes of this paper we will refer back to the services we touched on earlier – the Office 365 service from Microsoft and the S3 service from Amazon. We will look at the costs of each to identify whether either would reduce costs to the EMMA datacentre.

6.5.1 Microsoft Office 365

Microsoft Office 365 is a cloud service that enables IT Administrators to offload their Email, SharePoint, video conferencing and file storage services to Microsoft. By doing so, Administrators do not need to host the services internally, allowing them to save costs on the implementation of infrastructure and software. Office 365 offers three different packages: Office 365 Business Essentials, Office 365 Business and Office 365 Business Premium. The features of each package are outlined below.

6.5.2 Office 365 Business Essentials

- **Price:** £3.80 per user per month
  - **Email:** Hosts email with each user having 50GB mailbox.
  - **Storage:** 1TB file storage for all users
  - **Office Online:** Users can access office applications e.g. Word, Excel online.
  - **HD Video Conferencing:** Users can communicate with other users through video conferencing.

6.5.3 Office 365 Business

- **Price:** £7.90 per user per month
  - **Email:** Not included
  - **Storage:** 1TB file storage for all users
  - **Office Applications:** Users can install office applications e.g. Word, Excel on their devices.

6.5.4 Office 365 Business Premium

- **Price:** £9.40 per user per month
  - **Email:** Hosts email with each user having 50GB mailbox
  - **Storage:** 1TB file storage for all users
  - **HD Video Conferencing**
  - **Office Applications:** Users can install office applications on their devices.

EMMA requires email access which rules out Office 365 Business package. It does not need users to be able to install office applications on their own devices, so Office 365 Business Premium is not necessary. Looking at the Office 365 Business Essentials package, it costs £3.80 per user per month. Over the next five years the academy needs to support 5,500 student email accounts and 304 staff email accounts, totalling 5,804 accounts. To buy this service from Microsoft the academy would pay £22,055.20 per month and £264,662.40 per year. In this case the service would not be economically viable.

6.5.5 Amazon S3

Amazon S3 (Simple Storage Service) is an online storage solution that is accessible through a web interface. Users can store as much data as they wish and the consumer only pays for the storage that they use. Amazon offer three bands of pricing. For your first 50TB of data stored, per month you will pay $0.024 per GB. For the next 450TB of data stored, per month you will pay $0.023 per GB. Finally, for anything over 500TB, you will pay $0.022 per GB per month. EMMA could potentially use this service to back up their file, email and database servers. Over the next 5 years they will require a backup repository size of roughly 7TB. To use the service from Amazon, this would cost the academy in the region of £10,080 for that entire period.

It is also important to note that this calculation has been based on the academy using 7TB of storage immediately, whereas in reality this may or may not be reached over the 5-year period.

7 CONCLUSIONS

To conclude, we will firstly glance back at section 2 where we defined the requirements for this project. They were:

- Increase storage space
- Reduce power usage
- Utilise servers more effectively

Looking at all the solutions outlined above, the most cost-efficient solution is to reconfigure the existing IT infrastructure and employ virtualisation to consolidate the 28 servers onto just 7 physical servers. By doing so, this will increase storage space to cover the current and future needs of the business. It will also reduce power consumption by 67% and utilise the servers more effectively, thus meeting the requirements as outlined by the organisation.

If we pair this with the installation of the solar technology chosen in section 6, with a total power output from the solar panels being 5,960.057 watts, and the power requirements for the new system being just 2,796.16 watts, the solar installation will cover the entire power needs of the IT equipment. The academy could then use the remaining power elsewhere in the academy for further savings, or sell it back to the national grid.

Given the savings made from implementing such a system, using external cloud services for email or data backups etc, would not be necessary, and in this instance would not result in any savings. The only potential benefit of using a cloud service would be for data redundancy. For example, if you backed up files to the Amazon S3 service, due to them being geographically separate from the primary data store, there is less risk of permanent data loss. But with data redundancy not being top priority for the academy at this time, using such a service is not necessary.

In this paper, we feel all the requirements EMMA specified have been sufficiently met and that the outcome is more favourable than we had initially thought it would be. Without performing any research into the various topics covered in this paper, we feel that traditionally the solution would have been to rip out the old equipment and start a fresh. However, by employing a different approach we have managed to cut costs dramatically whilst almost eradicating any investment needed.

This proves that ultimately it is not always about buying into the latest technologies and having the crème-de-la-crème. If we leverage what we've got and focus on the customer needs more than our own, we can come up with better solutions that reduce wastage and costs, yet still provide a more than capable solution. To answer the question posed at the beginning of this paper; can cloud computing save costs in small to medium-sized businesses, it is our opinion that yes, in very small organisations with just 10 or 20 employees, using cloud computing services can indeed save the cost of installing your own IT infrastructure. It also means that no IT support staff are required etc. However, the larger an organisation gets, the more it costs to use cloud services, and as demonstrated in the business case outlined in this paper, using the Microsoft Office 365 service would have cost the academy £22K per month. We think the larger an organisation gets, implementing your own private cloud can work out in reduced savings, i.e. by consolidating computing power onto less machines, having applications delivered over the network rather than maintaining them on all employee devices etc. However, buying cloud services from third-party companies will need to be evaluated on a case-by-case basis.

As a final note, it is important to consider the fact that our business case had a large existing set of IT infrastructure available to use. If this wasn't the case, using cloud services may have been more cost-effective than buying new equipment. Also, the prices quoted for the cloud services in this paper were from the standard consumer boards. We are sure that the third-party companies can negotiate a better deal with larger organisations.

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