An Investigation into the Use of Hybrid Solar Power and Cloud Service Solutions for 24/7 Computing

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Abstract: As the human race demands more from computing, the national grids of nations around the world subsequently have to burn additional fossil fuels to meet increased power requirements. The aim of this paper is to investigate ways in which an organisation could reduce its operational costs and therefore be greener through the implementation of either a complete solar solution or a more hybrid mix with cloud computing thrown in. Through the creation of a hypothetical UK based SME we compared solar technology currently in the market in order to understand not only the total investment required but also just how efficient solar technology is, or perhaps is not. We also investigated comparable technology from the three cloud providers (Microsoft, Amazon and Google) to discover whether replacing on-premise hardware with that available in data centres would be more cost-effective than full solar solution or reduce the total amount of solar technology required. Having conducted the research, we found that solar technology is in no way an effective solution for the total replacement of power from the national grid, it can be very pricey to implement especially on the scale of always on computing and is easily affected by the elements-which given the UK as a location is not ideal. It was also discovered that cloud computing is in no way as affordable as it is perhaps made out to be but has the benefits of being considered a) an operational expenditure, b) fully maintained and; c) fully flexible, these all being reasons which help a growing SME expand down the line without unnecessary hardware outlay. Our final recommendations provide a fair cost comparison over the total expected payback period for the solar setup of installing a solar solution to power the entire on-premise systems and simply having a hybrid of both solar and cloud.

1 INTRODUCTION

It was Guntenburg's modification to the chinese print press technique that changed the industry forever with his new approach resulting in over half a million books entering circulation by the end of 16th century (Whipps, 2008). Fast-forwarding to modern day and machines of similar technique now form an industry worth over a staggering $640 billion USD a year (Aleyant, 2015). Whilst the industry is clearly established you could argue that it faces an ever increasing threat from the invention of the 20th century, the internet. With prestigious organisations such as the Oxford English Dictionary moving to online-only production (Wang, 2014), this makes the threat evermore apparent. The Guardian, on the other hand, disagrees and claims that more than 80% of respondants still prefer to "consume articles via print" (Jamieson, 2010). Furthermore, many printers such as Exaprint have adapted to provide online-only ordering and production services which, they claim, result in upwards of 30% growth year on year (Exaprint, 2015).

In 2005 forty-five trillion pages were printed in the United States alone (Aleyant, 2015) therefore creating a demand for machinery that can offer both increased times of operation and higher production volume. With many print presses now running 24-hour operations their business owners are facing an operational strain in the form of electrical costs.

In this paper we assume the identity of hypothetical company Bristol Solar whom have recently entered the bespoke solar market. Their customer CMYK is looking for a solution to reduce the operational costs of their on-premise I.T. hardware through the introduction of solar technology. Bristol Solar's specialise in the deployment of cloud solutions in order to reduce overall energy consumption. This paper is organised as follows: Section 2 introduces and discusses the customer (CYMK) and their existing infrastructure

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and section 3 looks at the power consumption of that infrastructure. Section 4 look in detail at the types of solar panel technology and how environmental factors can affect them before finally concluding which one would suit CMYK. Section 5 presents information on cloud-computing offerings such as Infrastructure as a Service (IaaS) etc. and discusses how CMYK might introduce such offerings and Section 6 presents the conclusion and cost analysis of purely converting to solar or employing a hybrid cloud and solar solution to reduce overall energy consumption.

2 CUSTOMER SCENARIO

CMYK are a small print organisation with no more than 30 employees between them yet they each contribute to the completion of more than 1 million customer orders per year. Whilst the majority of employees are warehouse floor staff CMYK also has your typical back off staff who make use of your typical Windows operating system to operate the overall business, from finance to pre-production and management. In addition, CMYK also operate an on premise I.T. environment designed specifically for the storage of customer artwork as submitted via their online ordering system. You can find a detailed outline of CMYK's IT infrastructure in section 2.2 of this paper.

2.1 Recent Capital Investment

Ever since CMYK have moved to online sales they have seen orders sky rocket which has lead investors to require that CMYK increase their profibability by reducing operational expenditure. CMYK are therefore seeking an energy efficient solar panel solution to provide 24-hour continuous power to the in-house server room and have recently replaced all servers with those that provide more, for less power. Additionally, CMYK has done away with typical desktops in favour of an on-premise, server-driven, thinclient approach.

2.2 Existing Infrastructure & its Purpose

CMYK use a combination of Hewlett-Packard systems and DELL servers each running virtualisation software such that they operate the main website, the online ordering system and your typical Windows Server operating systems. In quarter one of 2015 alone CMYK had stored terabytes of historical customer media alone. The majority of hardware has recently been introduced/replaced as part of capital investment, see 2.1. In addition to general power efficiency afforded by solar technology, CMYK are also looking for a recommendation as to reducing on premise hardware operational expenditure and have asked for advice on cloud offerings which, as it happens, Bristol Solar specialise in. The servers/equipment CMYK currently use are as follows:

1. HP ProLiant ML110 Gen9 Server, Xeon E5-2600, 60GB Memory. Used to operate the majority of print system software and operations in addition to the hosting of the company's websites and order systems.
2. HP ProLiant ML110 Gen9 Server, Xeon E5-2600, 180GB memory. Used to operate the compaies terminal services computing virtulisation. CMYK make use of HP t520 thin client machines to connect to this server.
3. Dell PowerEdge T110 II compact tower server, Xeon E3-1200, 20GB Memory. Used to operate Windows Servers, Active Directory, Print Servers and general back office systems.
4. HP 3PAR StoreServer File Controller.
5. HP 3PAR StoreServ 8450 Storage unit. In place to service CMYK's future storage needs.

2.3 Customer Location

For the purposes of working out solar panel efficiency, CMYK are located in Avonmouth just off the M5 in Bristol and have a purpose build building that is complete with a flat roof surface, perfectly suited for the installation of solar panels.

3 EXISTING POWER CONSUMPTION

The aforementioned infrastructure has the following power consumption requirements expressed in KWh.

HP ProLiant ML110 Gen9 Servers

0.55 KWh – When looking at the data sheet provided by HP for their Proliant ML110 Gen9 series server they listed the power requirement for one individual unit in standard use at 350W. With that said, no standard power supply unit can typically provide 100% efficiency and therefore HP claim 8% power is lost during AC or DC conversion.

With this in mind, the true power draw for this machine must be at least 381W. Converting from W to KWh is as simple as converting from litre to millilitre. See this equation:

The power P in kilowatts (kW) is equal to the power W in Watts divided by 1000. Expressed as,

$$P(Kw) = W(W) \div 1000$$
$$P(Kw) = 381(W) \div 1000$$
$$P(Kw) = 0.381$$

Given CMYK operate two of these systems the total power is therefore 0.762Kw.

Dell PowerEdge T110 II compact tower server

2.11KWh – According to the hardware datasheet we know that the PowerEdge T110 II uses between 90 – 264 Voltage AC power depending on use. We also know that the machine, when converting the power for its own use operates at 80% efficiency and based on a UK supply of 240V understand the unit to require 10 Amp supply. Knowing all of this, it is possible to convert to KWh using the following math equation.

The power P in kilowatts (kW) is equal to the power factor PF times the current I in amps (A), multiplied by the voltage V in volts (V) divided by 1000. Expressed as,

$$P(Kw) = PF \times I(A) \times V(V) \div 1000$$
$$P(Kw) = 0.80 \times 10(A) \times 264(V) \div 1000$$
$$P(Kw) = 2.112$$

HP 3PAR StoreServer File Controller

1.6KWh – The 3PAR StoreServer data sheet highlights that this controller system makes use of 2 x 800W power supply units encased within the chassis. This time, however, unlike the HP ProLiant ML110 we are not provided with any information on the expected power draw as this varies massively dependant on the amount of storage devices you typically install in to the controller. For the purposes of this research we shall presume the controller draws with a similar efficiency to the ProLiant server above and only uses the second PSU as a backup, using say 10% when idle. Applying the logic from the calculation of the ProLiant, we arrive at 736 Watts (main) and 8 Watts (idle). When added together we get 816 Watts of consumption, espressed as 0.816 KWh.

HP 3PAR StoreServ 8450 Storage

1.11KWh - It is with this unit where things become a little more complex. With each additional plug-and-play hardware device, such as a Fibre Channel card, comes additional wattage power requirements. In it is standard configuration the unit can share power with the File Controller. The unit on its own with no drives draws 803W of power. 24 drives of a reasonable capacity (2TB each) draw 13.1 Watts and a 10Gb/s network card draws 5.71 Watts. Adding these together we see a total requirement of 1123.11W. Otherwise known as 1.12KWh.

Total Annual KWh Requirements

Based on the above calculations, and the fact CMYK require their I.T. infrastructure to operate 24 hours a day, 7 days a week, the total kilowatt power requirements over a 365-day period expressed as TP (Total Power) is,

$$TP(Kw) = (0.762 + 2.112 + 0.816 + 1.11)$$
$$TP(Kw) = 4.8 * 24$$
$$TP(Kw) = 115.2 * 365$$
$$TP(Kw) = 42{,}048$$

According to statistics published by the (Energy Saving Trust, 2015), the total average cost per KWh of electricity in England is 14.05 pence and using this figure would indicate that it costs CMYK a total of £5,907 per annum, or £492 per calendar month to run its I.T. server infrastructure.

4 SOLAR PANELS

In the year 2015 solar panel technology is more widespread than even half a decade ago and America's Fortune Magazine confirms they are not "just for rich home owners anymore" (Fehrenbacher, 2015). As adoption levels increase, with the UK now within the global top ten (Solar Trade Association, 2014), so does the differing number of technologies which satisfy the same goal. In this section of the paper we take a look at the different types of solar technology and make a recommendation as to the most suitied for CMYK.

4.1 Differences in Technology

There are many different types of solar panel technology in the world but in the mainstream market there are typically three different types of panel in use, each with its differing uses. We explore each of them here with information made available with thanks to Alternative Technology Association (herin ATA) and the Energy Informative (herin EI).

Monocrystaline

Figure 1: Monocrystalline Silicon Solar Cells (Maehlum, 2015).

According to the ATA, Monocrystalline panels are cut in thin wafers from a single piece of silicon and all associated conductive cabling is integrated in the surface of the solar panels themselves. This therefore produces a very efficient solar panel which, at the time of writing, EI claim to be the most effeicent in the entirety of the U.S. market.

EI tell us “Monocrystalline solar panels produce up to four times the amount of electricity as thin-film solar panels” and in April 2013 the solar company SunPower announced their new X-Series panel. This new panel could produce an average of 21.5% efficiency – one of the highest ever seen from a panel of this type.

At the time of writing, panels of this type are widely manufactured by companies such as LG, Sharp among others. What is more, many of the aforementioned have faith in their technology by providing warranties as long as 25 years.

The ATA say that whilst these panels may be very efficient they certainly come at price but continue to say that whilst initially expensive they would pay for themselves within 5 years in most cases.

For all of their positives though, this type of panel certainly has one key negative. EI claim that should only one unit be covered by shade, snow or anything else it could have an adverse affect on the energy production rate of the entire collection of units. However, EI continue to say this affect can be reduced with additional equipement, a micro-verter, albeit at increased cost.

EI tell us that Polycrystalline cells often cost less as a result of a cheaper production process and according to ATA this panel type is made from separate wafters of silicon as opposed to one entire cut, resulting in less chemical waste.

Polycrystaline

Figure 2: Polycrystalline Silicon Solar Cells.

ATA claim that this type of panel has a higher space efficiency as a result of its square moulded appareance. By contrast, Monocrystalline are often more circular and you are therefore unable to house as many cells within a single unit. Whilst EI agree, they do say that Polycrystalline’s depedenance on several silicon wafers as opposed to a single cut of Monocrystalline significantly reduces the output effieciency by as much as 8%. Therefore, EI continue by saying you would require many more panels in order to compensate for difference you could otherwise achieve with Monocrystalline units.

It would seem from this research that the Polycrystalline units, whilst more affordbale, are a lot less effecient and are perhaps not suitable for a commercial environment. EI claim that most concerns they bring up would not really affect someone in a home, but may be the deal breakers for business.

Amorphous / Thin Film

Figure 3: Thin-Film Solar Cells.

This type of panel is produced by affixing thin strips of solar technology on to a substrate such as glass or metal and according to EI this makes it perfectly suited to production en-masse. What is more, this type of panel is not impacted by heat and shading issues experienced by Polycrystalline and Monocrystalline respectively.

EI say that of the three panel types thin film is the least economical with figures around 7-13% mark. This would arguably see it much less suited to an at-home environment. However, with that said, thin-film is very flexible and as a result can be placed over a much larger surface area and even in places traditional panels would otherwise not be able to go.

Example uses of Thin-Film Solar Cells include devices such as watches and calculators all the way up to large-scale solar farms, as pictured.

Recommendation at this Point

Based on CMYK's initial requirements and flat roof, Bristol Solar recommends Monocrystaline panels due to the higher likelihood of seeing a return linked to their higher efficiency ratings. Whilst they may initially cost more to install, the consistently higher energy production rates will ensure CMYK see a faster return.

4.2 Efficiency Ratings

Understanding which technology is best suited to CMYK is one thing, but are the panel types truly efficient enough for the customer's requirements? Wind&Sun, a UK distributor of solar panels state that "Modules nearly always produce less than their rated peak power in real-life conditions" highlighting you can not simply rely on a manufacturers specification sheet alone. So how exactly do you calculate the true efficiency of a solar panel? Answering this question will help Bristol Solar in recommending a suitable panel solution.

Using calculations on the Civic Solar's website we can immediately determine the extent to which solar technology lacks compared with fossil fuel. The example claims 14.5% efficiency and this highlights the very important need to research and shop around to ensure CMYK buy with long-term efficiency in mind rather than the figure on the invoice.

The 14.5% system in question has a total input of 1.6KWh from the sun (based on reversing the calculation), but loses a staggering 85.5% of this in generating and converting its output 0.24KWh. This is without taking other facts such as hours of sunlight, panel elevation and shade in to consideration. We look at these factors in 4.3.

The efficiency calculation is as follows, where E is efficiency, W is the manufacturers rating in Watts and SA equals the surface area of the solar panel in question.

$$E(\%) = W(W) \div SA$$

4.3 Efficiency Factors

Whilst sunlight is one of the only natural resources that keeps on giving day in, day out, rain, wind or shine, constant energy generation can not be as simple as installing it and there must be factors that prevent maximum energy generation. In this section we take a look at factors which impact maximum solar panel efficiency to ensure we can product installation recommendations.

UK Weather

The existence of the word 'solar' in solar panelling is indicative of a relationship with the sun. Therefore, deductive reasoning can conclude that solar panels require the sun in order to function. Whilst an overcast day might not be very sunny, the sun is still present and therefore panels do continue to function, although at what we presume would be a less efficient rate of energy production.

We felt it rather important to see just how much sunlight Avonmouth, the location of the CMYK facility, received on an annual basis. According to the Met Office the nearest official weather station to Avounmouth is Filton, a total of 8 miles away by road. It is worth noting here that whilst this paper was written in the years 2015/16, the Met Office data relates to the 29-year period ending in 2010. With data spanning such a wide time period it is more than likely, almost certain infact, that any averages created from it will vary significantly from the annual sunlight hours in 2010 alone, or 2015 for that matter. This is most likely due to changes in both climate and the angle of the sun since records began. Nevertheless, the fact records exist in the first place enables us to improve the findings of our research investigation.

In Table 1, we can see the total number of sunlight hours received at Filton weather station per year is an average of 1627. We can calculate this as a rounded average of 4 hours of direct sunlight per day. When comparing the sunlight of Avonmouth with that of a mainland European city, Barcelona, there will be a distinct difference. Using data from Weather2Travel.com we could produce the table found in the adjacent column.

Table 1: A table to show the average number of sunlight hours in the Avonmouth area on a month by month basis.

Month	Sunshine (Hours)
Janurary	58.5
February	74.8
March	112.7
April	170.8
May	199.6
June	214.7
July	217.7
August	201.8
September	149.9
October	104.8
November	69.1
December	52.7
Annual	1627.0

Table 2: A table to show the average number of sunlight hours in the Barcelona area on a month by month basis.

Month	Sunshine (Hours)
Janurary	155
February	140
March	186
April	210
May	248
June	270
July	310
August	279
September	210
October	186
November	155
December	155
Annual	2499

You can see that Barcelona receives an annual average of 2499 sunlight hours. As a rounded daily average this can be expressed as 7 hours of direct sunlight. That is a 75% increase over Avonmouth! With such a stark difference in this figure we can conclusively say that solar panel technologies will already be at a significant disadvantage in the United Kingdom on sunlight hours alone. This is essential knowledge as with most solar panels producing energy with at most a 21.5% efficiency rate, every single hour of sunlight counts if the final solution is to produce a worthwhile return on investment.

How and why Does Shade Impact a Panel?

To provide the best solution for CMYK we need to understand why shade impacts a panel and how it actually does it. In this section shade refers to any time where the sunlight is not directly upon the panel surface. This can be caused by overcast skies, or any object overshadowing a solar panel unit, such as a tree - although, one would hope a panel never be installed in close promximiity to a tree in the first place.

There are two definitions for shade on a panel: soft and hard sources. A soft source is something such as the shadowing from tree leaves, roof vent or chimney. Further, a soft source may not be present all of the time and is usually caused by the suns position in the sky. A hard source on the other hand is deemed to be caused by something physically in contact with the solar panel unit. For example, a tree branch, a blanket or perhaps an animal/bird sat on top of it. The same paper continues to say that in tests of an array of solar panels, simply one unit being partially hard-shaded drops the power generating capability of that unit by half and a completely covered unit would produce no output whatsoever and actually end up costing money.

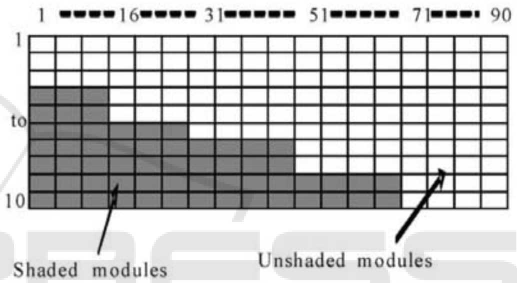

Figure 4: A graphic produced to demonstrate the impact soft-shading can have on an array of solar panels.

A typical installation of solar panels sees units arranged in series and parallel. According to research, connecting them in this way enables them to produce an output voltage and current typical to most common applications - something a single panel would not be able to achieve on its own. During our research, it was observed that whilst linking panels produces a positive result, it can be adversely affected in times of shade.

Further, when a cell is shaded, the number of electrons it can pump from one side to the other drops. This would not be a huge problem for a single cell although in most environments units are interconnected to form arrays. It is in these situations, that shade has an impact on the amount of power a units' neighbour can subsequently produce too. The output of the shaded unit then becomes the input of its neighbour. You can see an example in Figure 4. A completely shaded unit can impact the efficiency of the entire array by as much as 50%.

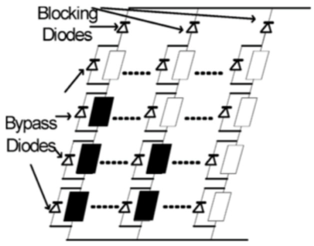

Figure 5: An example solar array with both bypass and blocking diodes present.

In a separate paper on this topic, H. Patel et al. produce a software simulation of solar panel shading. Through various simulations they discovered that the use of bypass and blocking diodes, within an array significantly improves its performance (see Figure 5). The presence of such diodes sees that units with the poorest performance are simply bypassed therefore removing the opportunity for energy loss. Whilst this is great in theory, MidSummer are quick to say that there are still many cells within a poorly performining unit that collect energy exactly as expected. It would be a shame to simply discount it, they say, and comment that this is the main reason manufacturers place diodes at a cell level. As an example let us look at the 3rd set of shaded modules in Figure 4. A manufacturer may choose to install bypass diodes at the tip of the shaded segment thus meaning all energy generated from cells 16 to 31 simply enter above the shade of cells 31 to 50. MidSummer suggest three solutions for solar shade:

1. Install as normal and have poor performance.
2. Act for a smaller array, only installing panels in areas with consistent sunshine. The cost saved can be invested in higher effeciency solar panels.
3. Split an array in to smaller arrays by installing an inverter on each section so to collect and consume or store the generated energy.

These three solutions are all valid. Which to use however would depend on the owner of the new solar panels. In the case of CMYK it would make sense to follow the latter option as if shade impacted energy production significantly then it would defeat the objective of having them in the first place as they would need to draw from the grid in order to power their servers. MidSummer say that splitting arrays costs significantly more as inveters and diodes do not come at a cheap price. But, it would be a fair to say you get what you pay for.

Elevation of the sun

With a new understanding of how solar energy is impacted by shade we felt it important to continue research in to external factors. The level of shade a solar panel could experience is most likely itself impacted by the evevation of the sun. In this section we will research the elevation of the sun over the CMYK building and how elevation affects a solar panel. It is with thanks to the University of Oregon's Solar Radiation Monitoring Laboratory, that I was able to generate a sun elevation graph using the latitude and longtitude of Avonmouth, given by Google Maps as 51 degrees, 30 minutes and 11.9 seconds North and 2 degrees, 41 minutes and 51.8 seconds West. See Figure 6 for the resulting solar representation.

Whilst on first glance this graph appears to be confusing you begin to realise its value rather quickly once you understand that the y axis is the suns elevation in the sky and the x axis is the location of the sun in the sky from east to west. Furthermore, each red marking indicates an hour of time and the blue markings indicate the suns journey through the sky in a given period of time as per the indicated date. With this new understanding we can use the data to see that in the height of an Avonmouth Winter (December) the suns typical elevations are:

- Sunrise is ~8:30am at elevation 1.5°
- Mid-Morning is at elevation 10°
- Mid-Day is at elevation 12.5°
- Mid-Afternoon is at elevation 4.5°
- Sunset is ~3:45pm at elevation 1°

When comparing this to the height of Summer (June) we see that:

- Sunrise is ~4am at elevation 2°
- Mid-Morning is at elevation 52°
- Mid-Day is at elevation 62°
- Mid-Afternoon is at elevation 46°
- Sunset is ~8pm at elevation 2°

There is of course a huge degree of variance in this data

Fig. 6. A graph of sun elevation in the Avonmouth area. Generated using a tool from the Universiy of Oregon.

from month to month but in picking out Winter and Summer we can demonstrate, quite clearly, that solar panels *will* be significantly affectled in Winter. This poses the question, where is the best place to install a solar panel, given this variance in the location of the sun.

Charles Landau believes he has the answer and through his research set out to establish the best installation location with a specific focus on angle of attack. He tells us that "Solar panels should always face true south if you are in the northern hemisphere, or true north if you are in the southern hemisphere".

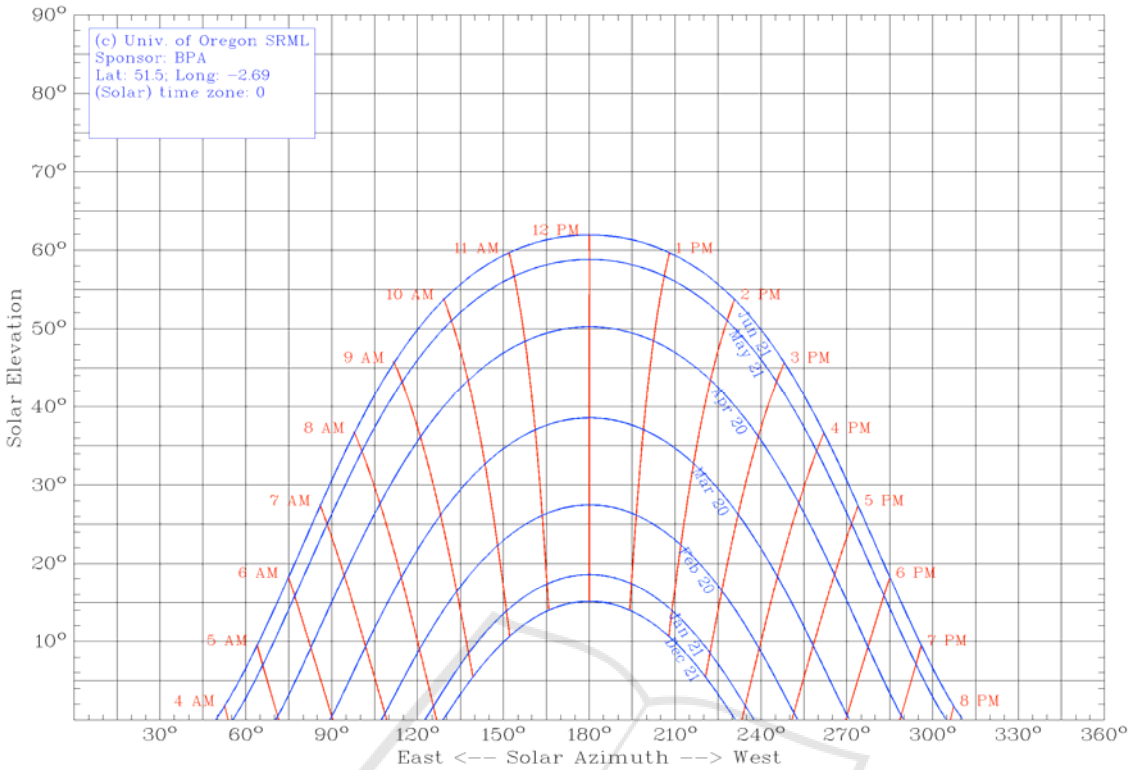

Figure 6.

He claims that doing this ensures every panel receieves exposure throughout the entire day, as opposed to only receiving it in the morning if installed facing eastwards, for example. On it is own this information is not overly helpful because even panels installed on flat roofs may be rotated to face north/south. Thankfully, Landau has this base covered too and tells us that panels should be installed at your latitude plus 15° in winter and minus 15° in summer months. He claims that adjusting your panels twice a year provides “a meaningful boost in energy” especially when the sun is typically lower in the sky.

Armed with Landau’s claims we would therefore say that effective power generation at Avonmouth would require all panels to face true south at a pitch of 66° in winter or 36° in summer. The dates of change should be March 30th for summer and September 12th for Winter. Doing this will see panels generate 74% optimum power. When faced with criticism over the accuracy of his calculations Landau states “we are considering the whole day, not just noon. In the morning and evening, the sun moves lower in the sky and also further north (if you are in the northern hemisphere). It is necessary to tilt less to the south (or more to the north) to collect that sunlight”. Whilst this is a very valid response Landau’s admits that should the installation location be blocked by trees or other buildings etc, then other calculations will need to be considered. However, for the purposes of this research paper we will not discuss those here.

Recommendation at this Point

With all of the findings to this point we can say that CMYK most effective solution should continue to consider Monocrystaline panels. Any panels installed should be both south facing and angled to calculate for changes in the suns location. What is more, in order that CMYK can account for poor performance from shaded panels they should separate panels in to arrays and make use of bypass and blocking diodes. In section 5 we will look at a selection of Monocrystaline panels and discuss which would be most suitable to CMYK.

5 PUBLIC CLOUD OFFERINGS

5.1 How Much Does It Cost?

Perhaps the most important question here is *how* *much does it cost an organisation to move to the cloud?* Well, we have already established in section 7.4 bullet point 3 that there is zero capital expenditure to move to the cloud – so that is a great plus for CMYK. Admitedly, CMYK have already spent a significant amount of money on new equipment, but even so we shall investigate the costings involved here. As established in section 7.3, we compare the cost accross Microsoft, Amazon and Google where possible.

When deciding which services would suit CMYK we take a look at their existing hardware with a specific focus on those which consume the most energy both now and in the future. From this we can see that costs could potentially be reduced by replacing both the Dell server and HP Storage Arrays. Considering the Dell is a physical machine offering Windows Server features a PaaS solution would be approrpaite here. For the Storage Array we shall look at STaaS.

IaaS – Replacing the Dell

Given that the CMYK have their Dell server configured with 20GB of memory we shall look at the next best comparison here to provide at least 20GB as a minimum from each of the providers. The prices will also factor in a 365-day operation.

- *Microsoft Azure*
  Microsoft offer their IaaS Virtual Machine in a variety of pre-configured plans. Each plan differs in processing power and memory allocated to the VM. Based on the Dell's initial configuration the A6 plan is the next most suitable comparison. Offering 4 processor corses, 28GB memory and 285GB of inclusive storage the hourly pay-as-you-go rate is £0.4155. The total cost over a 365-day period is therefore £3,639.78. Whilst 28GB is 8GB more than currently available, this is close enough to be considered comparable given the matching core count.
- *Amazon Web Services*
  Amazon's take on IaaS is called EC2 but unlike Microsoft's offering the EC2 pricing structure pages can get quite complicated. Nevertheless, given the requirements of CMYK the closest matching service is 'm4.2xlarge' which offers 8 virtual CPU cores and 32GB of memory. The hourly pay-as-you-go rate is £0.69 and the 365-day operation is therefore £6,049 but depending on whether CMYK require the full 8 cores and 32GB of memory there is a lower plan which offers 4 cores and 16GB memory, with a pay-as-you-go rate of £0.34 per-hour and an annual cost £2,978. Whilst Azure bundles each VM with some basic storage, Amazon does not do this so additional storage purchases are necessary atop of the infrastructure costs, more on how much this costs in the STaaS heading.
- *Google Cloud*
  Similar to Amazon Web Services, none of Google's standard packages suit the initial needs of CMYK like-for-like. There is a plan below, and a plan above and prices for both are include here. The smaller of the two plans 'n1-standard-4' offers 4 cores and 15GB of memory and the larger 'n1-standard-8' offers 8 cores and 30GB of memory. The pay-as-you-go and annual pricing for the former is £0.22 and £1927.20 respectively whilst the latter is £0.44 and £3854. Like Amazon, these prices do not include any bundled disk space and therefore this would be as an additional cost. This is discussed in more detail under the STaaS heading.

From this comparison of providers, it becomes clear that Microsoft's Azure offering is the most suited to CMYK given its close match to the specification of the DELL server. The Azure VM is by no means the cheapest, with one of Google's offerings being below £2,000 but we aimed to find the most comparable offering. In adopting the Azure product CMYK could completely remove the requirement for the DELL server and instead transition to Thinclient operations resulting in an annual saving of 18,429 Kw from the server alone removing the need for such to be covered by solar energy.

STaaS – Replacing the Storage Arrays

CMYK plan to store all of their customers' data on a storage array offered by HP. Initially it would appear CYMK's intentions were to run the storage array rather empty with only a few drives in operation. Given the power draw of the drive controllers the company could offload storage to the cloud and prevent any future increase in energy demands as their usage increases. Going back to the research in point 7.4 we know that cloud services are rather flexible so CMYK could simply expand their storage requirements as needed and later shrink them. As for IaaS we shall compare storage services across all three providers.

- *Microsoft Azure*
  Microsoft describes their storage offering as "durable, highly available and massively scalable" and offers its service with fees based on the amount of space you truly use, not what you initially request. The price list is structured as £0.0147 per GB for the first terabyte per month followed by £0.0145 per GB for the next

49 terrabytes per month. So, given CMYK's current 48TB usage they would be looking at £14.70 for the first 1TB and £681.50 for the next 47TB meaning CMYK will be charged £696.20 per month for their current storage requirements or £8,354 for the year.

- *Amazon Web Services*
  Called Simple Storage, or S3 for short, Amazon provides three variations on its' storage product. Standard, Infrequent and Archive. The former is a typical storage similar to Azure's, the latter is as the name suggests, data archiving and infrequenty is similar to Standard although provides lower pricing on the assumption data will only be accessed infrequently. Given the requirement of CMYK the Standard offering is most suitable. Pricing is fairly similar to Microsoft's Azure. The first 1TB is priced at £0.021 per GB with the subsequent 49TB charged at £0.0206 per GB. It is clear that Microsoft's Azure offering comes out on top here where price is concerned. CMYK's 48TB would cost them £21 for the first 1TB followed by £968.20 making a total of £989.20 per month or £11,870 per annum. This is a 42% premium over Microsoft's Azure offering which is rather significant.
- *Google Cloud*
  Google's cloud storage offering somewhat imitates the exact offering of Amazon in the sense they offer Standard storage, Infrequent storage marketed as DRA and Archive marketed as Nearline. Google also claim they offer "low cost" storage with no teir pricing. Google's Standard offering comes in at a flat rate of 2p per GB resulting in 48TB costing a total of £960 a month or £11,520 per annum.

With the comparisons above we can tell that Microsoft's Azure storage appears the most affordable with continued discounts available based on the amount of storage used thanks to its tiered offering. It is worth noting that one area that has not been researched is network traffic. The above cloud providers each charge for the movement of data from their data centres across the internet, referred to as Bandwidth in IaaS terms or Egress when related to STaaS. Such charges could increase the overall cost of one provider against another although such cost investigations are beyond the scope of this paper.

6 THE FINAL RECOMMENDATION

Based on CMYK requiring 42,048KW of energy for a round-the-clock operation Bristol Solar would in the first instance recommend that the business reassesses to what extend they would require the complete 48TB of storage space and based on the response would recommend one of two possible outcomes as described under the solution one and two headings below.

The Panels

We established in section 4.1 of this paper that Monocrystaline panels provide the edge over competing technology due to their typically higher energy ratings and subsequent likelihood for a return on investment. When it came to the panels themselves we concluded in section 5 that Sharp's ND-F4Q300 offered the most output at 300 Watts with each unit costing £244+VAT. Section 4.2 saw us learn that panels should be installed in a southerly direction in smaller arrays each equipped with their own bypass and blocking diodes such to attain the best possible energy generation potential.

Solution One – Keeping full storage & No Cloud

Should CMYK decide to keep the storage hosted locally then the final solution will need to be able to provide enough energy for the annual requirement of 42,048KW. This of course includes overnight power. Based on this CMYK would need the following (inc. tax):

- 141 Sharp ND-F4Q300 Panels (£41,284.80).
- Applicable mount brackets, etc. (N/A)
- 8 Lead Acid Batteries (£1,536)
- Applicable convertors etc.
- Installation Labor

The batteries and solar panels will cost a total of £42,820.80. Based on CMYK's £5,907 electricity bill this would take 7 years and 3 months to pay for itself in savings. As above, £42k is the minimum cost for this solution. It is highly likely that additional grid power will also be required should panels drop below the marketed efficiency.

Solution Two – Using only the Required Storage

If CMYK decide that infact 48TB of data storage capacity is too much for them then they could switch to a cloud service provider for the majority of their storage needs thus removing the requirements for the HP storage controller and array. This solution also factors in the removal of the least energy efficienct server, the DELL. We established in section 7.4 that cloud would afford CMYK the flexibility to expand storage and computing power as required and that disaster recovery could also be factored in too, if required. Simply removing the above mentioned devices from CMYK will see a deduction in their energy bill of 35,372.88KW or in monetary terms a saving of £4,969.88 meaning their overall annual bill would then be £938. Given the new consumption of 6,775.12KW CMYK would then only require the following (inc Tax):

- 23 Sharp ND-F4Q300 Panels (£6734.40)
- Applicable mount brackets, etc. (N/A)
- 2 Lead Acid Batteries (min value £1500)
- Applicable convertors etc.
- Installation Labour

The batteries and solar panels will cost a total of £8,234.40 and based on this solution being designed to replace £4,969.88 of electricity per year then the equipment can be seen to pay for itself within 1 year and 8 months. Costs that are yet to be considered are those involved in the operation of the new cloud environment which we established in section 7.4 would cost £5,556.18 per annum with 10TB of storage from the get go. The new annual cost of the CMYK I.T. environment would come in at £6,494.18 per annum after considering the existing £938 energy cost.

Solution Comparison

Here is the monetary comparison:

- Solution One:
  - **First Year:**
    - £42,820.80+ Hardware
  - **Future Years:**
    - Depends on any additional grid power requirements as on premise hardware out grows solar setup.
- Solution Two:
  - **First Year:**
    - £8,234.40+ Hardware
    - £938 Grid Power
    - £5,556.18 Cloud Services
  - **Future Years:**
    - £938 Grid Power
    - £5,556.18 minimum cost for cloud services. This will increase alongside CMYK's consumption of cloud services.

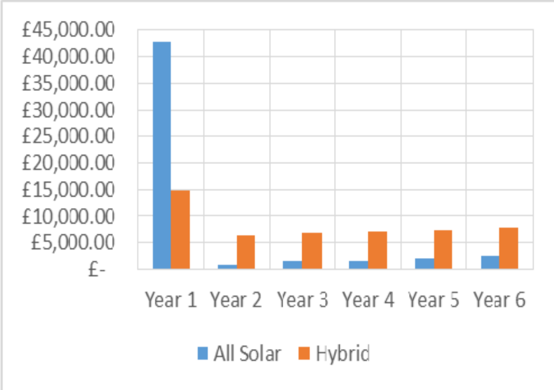

Figure. 9: A graph to compare both the cost of investment and future costs associated with an all solar solution and the hybrid solar and cloud offering.

It is worth noting at this point that the first solution is presuming electrical requirements are not going to change and that each panel will produce 300W of energy. This is highly unlikely in the British Isles. Solution Two is presuming the same, but each panel is only there to service a small KW requirement by comparison and the additional electricity charges would likely be minimal should the grid need to be called for. However unlike solution one, solution two provides elasticity from the cloud perspective and incorporates 10TB of disk storage from the get-go yet should CMYK uses less then they could bring this cost down significantly. Cloud computing with its significantly lower setup costs can also be seen as a form of operational expenditure (OpEx) which has the potential to offer tax advantages to CMYK but those will not be discussed here.

Figure 9 highlights the differing cost of each solution and it is immediately clear that an all solar solution has Year 1 costs 190% higher than that those of the hybrid offering. Although the former sees a lower year on year cost from Year 2, this will undoubtedly increase when the solar equipment can no longer meet future power demands. Whilst a hybrid setup requires less power from solar panels for on premise hardware, it has the potential to become expensive overtime especially when you factor in redundancy services and bandwidth etc. so ultimately the final choice would be down to CMYK's own budgets. With that said, Bristol Solar would recommend cloud computing as it would cost significantly less down the road, enable rapid deployment and affords so much flexibility down the road as the business grows.

N.B. Each solution's' prices include VAT but would be subject to change once brackets, cabling and any associated labour were to be included.

N.B. Cloud service provider bandwidth/egress is not factored in to the final price. As a result, any purchase decision based on this research should consider this in more detail.

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