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1.2	3.2.3	Corrected the reference to H2020 on page 13.	R Bashroush	25/01/14

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1 EXECUTIVE SUMMARY

The purpose of this deliverable is to provide an initial overview of the Strengths, Weaknesses, Opportunities and Threats (SWOT) for existing data centre industry training and research provision. This is the 5th output of the PEDCA project (DEL 2.2: Training and Research SWOT Analysis).

This work took as input data from Task 2.3 (Technology Road Mapping, Annex A) and the output of a Systematic Literature Review (SLR) conducted on Energy Efficiency research in data centres. Deliverable 2.2 will feed into Task 2.5.

The analysis centred on answering the following research questions:

Q1 - What is the current status and potential for training in the data centre sector?

Q2 - What is the current status and prospect of data centre research?

The analysis of the internal factors (Strengths and Weaknesses) was conducted based on a number of brainstorming and discussion sessions involving stakeholders from the data centre industry (data centres, training firms, universities and representatives from the DCA). In addition, information from the survey conducted under Task 2.3 was also used. For external factors (Opportunities and Threats), data from a Systematic Literature Review was used.

Details of the methodology used can be found in section 2. The findings of the SWOT analysis for training are presented in section 3.1, and the findings of the SWOT analysis for research in section 3.2.

2 Introduction

This document reports on the initial SWOT analysis conducted on training and research requirements in the data centre industry. The work is conducted under work package 2, Task 2.4. The work took as input data from Task 2.3 (Technology Road Mapping) and the output of a Systematic Literature Review (SLR) conducted on Energy Efficiency research in data centres. The report produced will feed into Task 2.5.

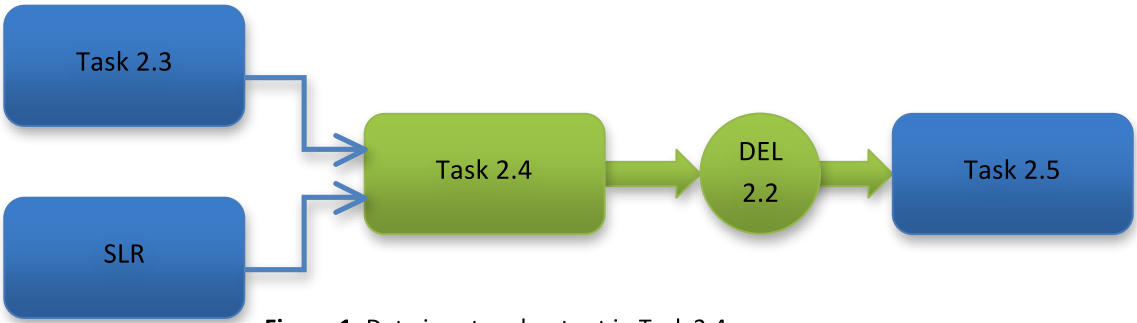

Figure 1. Data input and output in Task 2.4

2.1 Aims and objectives

SWOT Analysis is a tool that can help analyse and understand certain status quo. For the PEDCA project, the focus of the SWOT analysis was on the data centre training and research requirements. In accordance with the project proposal, the analysis centred on answering the following research questions:

Q1 - What is the current status and potential for training in the data centre sector?

Q2 - What is the current status and prospect of data centre research?

2.2 Methodology

SWOT work is usually based on two steps of analysis, which are conducted separately. The first step addresses the local (or internal) factors, which contains discussions of Strengths and Weaknesses as per the aims of the SWOT.

The second step, in which external (or global) factors are analysed, contains the discussion of relevant Opportunities and Threats. This is summarized in Figure 2 below.

Figure 2. SWOT analysis overview[1]

2.2.1 Strengths and Weaknesses

The analysis of the internal factors was conducted based on a number of brainstorming and discussion sessions involving stakeholders from the data centre industry (data centres, training firms, universities and representatives from the DCA). In addition, information from the survey conducted under Task 2.3 was also used. The analysis was based on the key components of People, Resources, Innovation, Marketing, Operations and Finance.

2.2.2 Opportunities and Threats

The analysis of external factors opens the wider field of trends, development options and possibilities. Here it was especially important to take into account only such factors that were relevant for the topic of the SWOT. For the research SWOT analysis, data from a Systematic Literature Review was used. Example aspects considered included: Political, Economic, Social, Technological, Legal and Environmental.

[1] Source: Wikipedia

2.3 Further steps / Research options

SWOT analysis is not a tool of strategy development by itself. However, the information reported in this document will feed into Task 2.5 where the academy training and research requirements will be developed. Some of the ways this information can be used in Task 2.5 to develop the strategy include:

- Recognizing chances (Strengths + Opportunities)
- Avoiding risks (Strengths + Threats)
- Utilisation of weaknesses (Weaknesses + Opportunities)
- Identifying risks (Weaknesses + Threats)

3 SWOT Analysis

In this section we report the outcome of the SWOT analysis for training (section 3.1) and research (section 3.2).

3.1 Training

3.1.1 Strengths

- Most existing training companies offering global training within the data centre sector are EU registered commercial organisations. Examples include DataCentreDynamics and CNet.

- Companies of this type contain high quality experienced trainers who are either employed or contracted to deliver the training courses they offer. The expertise required depends on the objectives and outcomes of training required.

- The content of these training courses is maturing with all aspects of data centre design, construction and operation being covered. The rising awareness of data centres is also leading to an increased variety of offerings, ranging from beginners' courses to very advanced seminars.

- Other training is carried out by industry suppliers/manufacturers, albeit this tends to be product specific.

- Processes used by some providers to create courses are of high quality and involve cooperation with higher education institutes and qualification awarding bodies.

3.1.2 Weaknesses

- Costs for training tend to be geared to corporate payment of fees and hence are extremely high for individuals entering the data centre sector.
- There is a lack of clear guidelines on appropriate training strategy mapped to individual staff career development and business goals
- There is a lack of clear commercially neutral curricula or even industry standard guidelines. "Sponsored by" seminars always tend to have a certain flavour.
- Competitive commercial pressures lead to a fragmented landscape
- There is high reliance on a limited pool of experienced trainers. The vast majority of these are not from universities or research and usually don't have any qualification in teaching.
- Access to training is limited to a few geographic locations in Europe.
- It remains very difficult to receive a certificate or diploma that is comparable with other, more traditional, training/education programs, resulting in portability restrictions and lack of transferability from the data centre industry to organizations outside the sector, limiting the appeal of these offerings.
- There is a lack of ability of market participants to differentiate between certification and qualification.
- Access to developing markets is restricted by language/translation associated costs.
- There is cultural resistance to investment in training in the EU compared to other parts of the world.
- There is an overreliance on 'in house' training (meaning doing the same thing over and over again).
- There is a lack of trusted information for those investing in training.
- Practical "real world" hands-on training is difficult to offer due to the mission-critical nature of data centres.
- Product specific training, whilst necessary, is of limited value due to the fragmented nature of the data centre equipment supply and the relatively short-term need for the acquisition of general data centre skills.

3.1.3 Opportunities

- There now exist maturing industry association bodies such as the DCA
- There are maturing standards at ISO and EN levels
- Dependence on data centres is increasing. Data centres have emerged as critical infrastructure for a successful digital economy. The increasing dependency on reliable infrastructures is driven by economic necessities and regulatory requirements (Basel III etc.).
- Current European climate change policies have created the perfect environment to drive strong investment in data centre energy efficiency skills and training
- FP 7 Data centre project PEDCA is a stepping stone to a product-independent insights into the changing demand for quality training.
- Scarcity of energy combined with surging future energy prices will create need. C-levels of organizations will stimulate training of employees who drastically need training to improve the energy efficiency of organizations' data centre(s).
- Increasing demand for skilled data centre operators and managers will make it more appealing for employees to attend relevant training courses to advance their careers to include such roles.
- To ease the hiring process, standardization of skills through training is stimulated by the data centre industry.
- It is widely acknowledged now that a large percentage (70%-90%) of outages in data centres are due to human error. This further strengthens the business case for more staff training.
- The skills shortage in the data centre sector is now generally recognized.

3.1.4 Threats

- There is an increasingly global competitive landscape from regions outside the EU that continues to grow in strength and influence.
- There is exponential growth and reliance on digital services and technology outside Europe.

- Rising total cost of energy could be a threat to the sustainability and competitiveness of the data centre sector within Europe.

- The maturity of the industry is limited. Disruptive breakthrough technologies may wipe the value of certain training programs off the table.

- There is the risk of low quality, cheap entrants (web based, handing out qualifications too easily). Consequently there is a need for quality assurance/board for training institutes.

- There is the lack of credibility of some training offerings that rely on vendor supplied trainers (e.g. from big names such as HP, Rittal, Cisco, Schneider, etc.).

- There may be de-facto standards (and operations manuals etc.) from non-EU providers rolling processes and procedures that may not be applicable in the EU (e.g. due to data protection or similar regulations).

- There are still major technical differences in the various commercial global hotspots (e.g. in terms of voltage, frequency, access to resources, etc.).

- Currently there is no legislation for industry governance on qualifications.

3.2 Research

3.2.1 Strengths

- The European commission has invested in data centre research as part of the FP7 framework programme. Examples of research projects funded include COOLEMALL[2], ALL4GREEN[3], GAMES[4], FIT4Green[5], PEDCA[6], and more recently DC4CITIES, DOLFIN, RENEWIT[7] and GREENDATANET, to name just a few.

- World leading work is being conducted in the EU by industry and research institutes. For example, in 2012 ABB and Green announced the opening of Zurich-West, then the world’s most powerful HVDC (380V Direct Current) data centre, an area of emerging technologies identified in Annex A.

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[2] http://www.coolemall.eu/
[3] http://www.all4green-project.eu/
[4] http://www.green-datacenters.eu/
[5] http://www.fit4green.eu/
[6] http://www.pedca.eu/
[7] http://renewit-project.eu/

- Given the EU's leading international standing in the data centre industry, most major data centre providers, both colocation and hosting as well as enterprise, and OEM suppliers, have established presence in the EU.

3.2.2 Weaknesses

- One of the main challenges facing data centre research is the disjoint research community. Data centre research crosscuts multiple research areas, ranging from power and cooling to hardware and software. Thus, in order to address many of these challenges of scope, these communities would need to work closer and think outside traditional boundaries.

- There has been limited involvement of European data centres in research projects. This is also reflected in their limited participation in EU funded projects. Thus, there is a strong need for industry associations such as the Data Centre Alliance to raise awareness of the importance of research in order to maintain the EU's competitive edge.

- Although there is a well-established data centre industry in the EU, that industry is largely located within limited geographical areas/cities driven by business, infrastructure and market needs.

- The technology roadmap in Annex A has indicated that a significant proportion of the future research in developing energy efficient data centres would be directed at improving IT energy efficiency. Therefore data centre research and development within the EU would be highly dependent on technological developments from outside the EU.

3.2.3 Opportunities

- The data centre industry is maturing with substantial standardization work in progress (e.g. by ISO and EN). This should help resolve issues that could limit progress in some research areas (e.g. measurement of energy efficiency and the PUE, development of better KPI's, and so on).

- The European commission (and accordingly member states) has committed in the Digital Agenda and Europe 2020 to achieving 20% increase in energy efficiency by 2020. Given the energy consumed by data centres and their current level of efficiency, this means more attention will have to be given to data centres. This is being reflected in policy development, funding schemes, EU Code of Conduct, etc. which should in turn incentivise data centres to become more involved in research activities. Clear directions of potential technological development are identified in Annex A.

- The new EU Research and Innovation framework programme for the 2014 to 2020 period, Horizon 2020, has committed to continue supporting data centre research under different 'societal challenges', ranging from smart cities to energy efficiency.

- Data centre research has been picking up thrust over the last few years, particularly since 2009. From a Systematic Literature Review (SLR) conducted at the University of East London, we found clear evidence of an uptrend in research output in some data centre research areas such as energy efficiency. For example, a summary showing the number of papers (that were identified by the SLR) published per year can be seen in Figure 3 below.

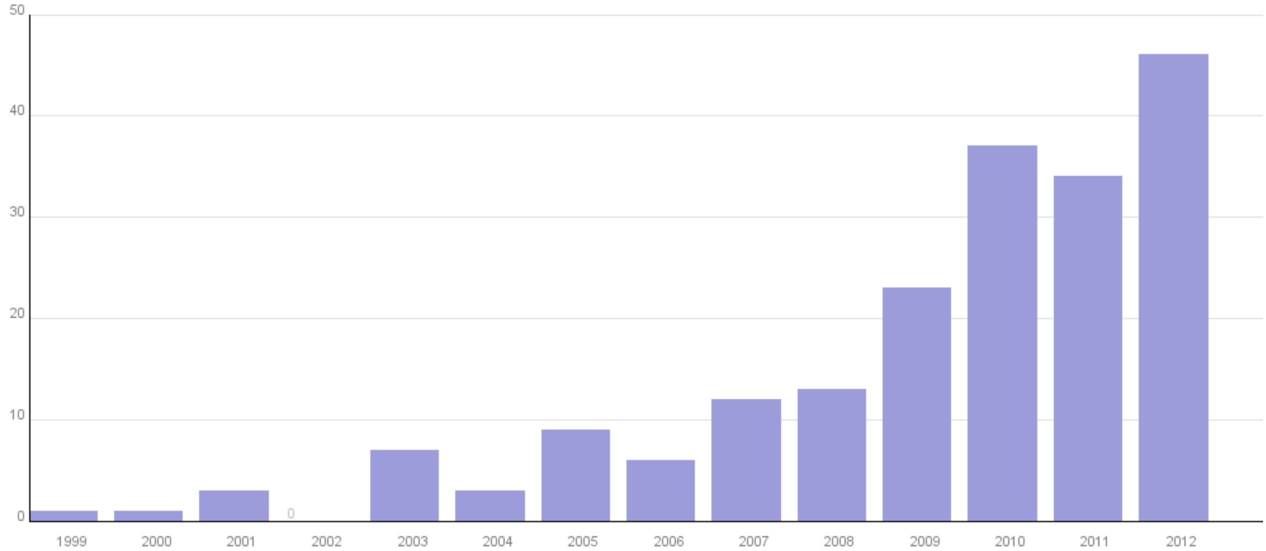


Figure 3. Number of primary studies (identified by the SLR) published per year [8]

3.2.4 Threats

- There is a significant reliance on data centre equipment manufacturers and suppliers who largely come from outside the EU in particular in the IT hardware, where technological developments identified in Annex A have the potential to disrupt the industry.

- There is strong competition from the international community, particularly the USA. In a Systematic Literature Review that we conducted to study one of the main research areas in data centres (energy efficiency), we found that the USA produces more research literature than the rest of the world combined. This is demonstrated in Figure 4 below.

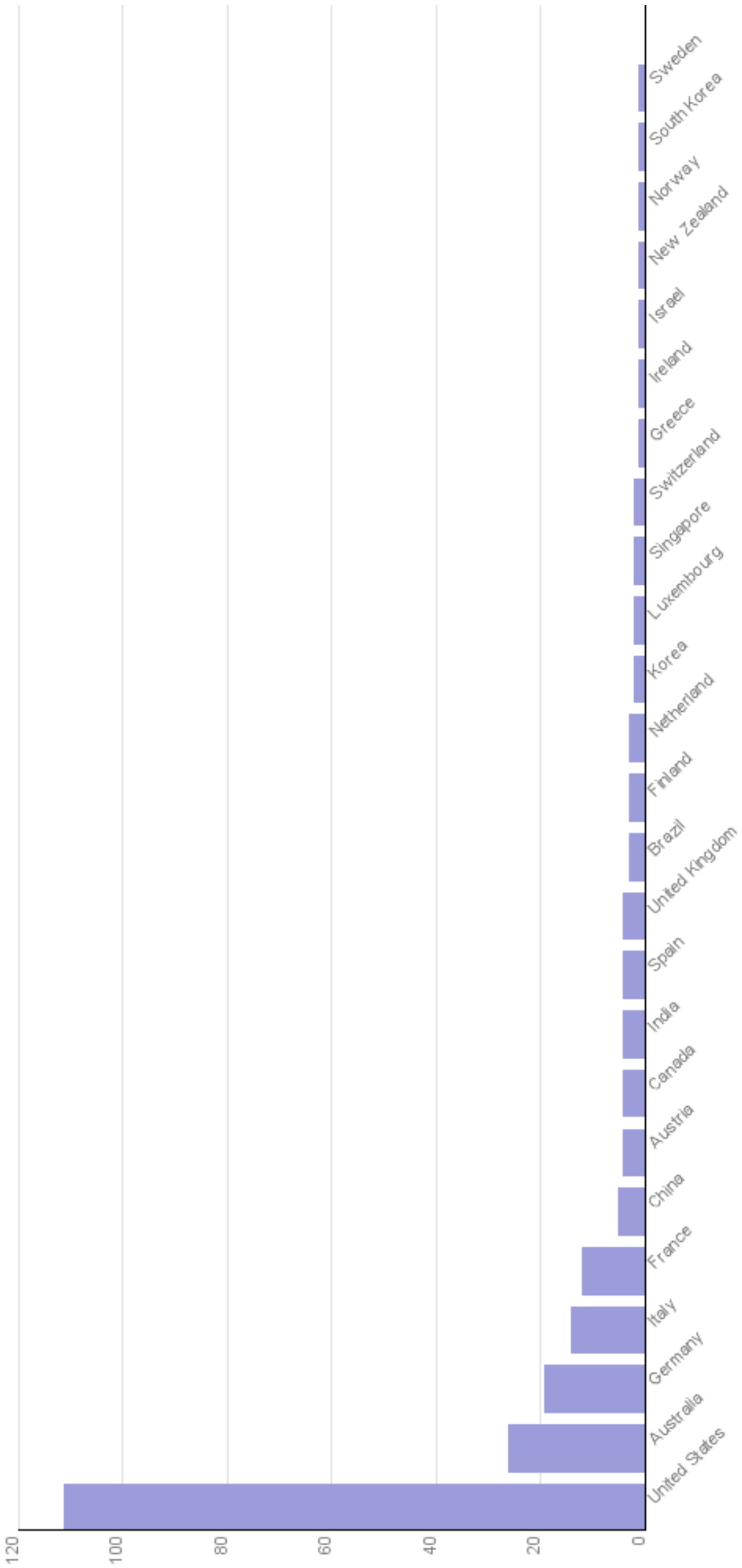


Figure 4. Number of primary studies (identified by the SLR) published per country [8]

4 Glossary

Commission The European Commission

D2.2 Deliverable identified as number 2.2 within Work Package 2 of PEDCA

DCA Data Centre Alliance Ltd

Deliverable A formal contract deliverable item under the PEDCA project

HVDC High Voltage Direct Current (in data centres this is circa 380V)

KPI Key Performance Indicator

PEDCA Pan-European Data Centre Academy

PU Public dissemination level

PUE Power Utilization Efficiency

SLR Systematic Literature Review

Work Package 2 The second work package of PEDCA project covering Training and Research Requirements

5 Annex

5.1 Annex A: Technology Road Mapping

The roadmap identifies key potential technological and operational innovations that could be used to meet the key industry drivers and social trends and developing legislative requirements of the future.

The predominant market drivers are that[3]:

- Data centre energy costs are 10~30 times (or higher) those of typical office buildings.
- Overall cost of power will be 3 x cost of hardware.
- Data centre operating costs are 3-5 times capital costs over 20 years.
- 80% of data centres built before 2001

Power and cooling are the biggest problems data centre operators face and key trends and issues include:

- Controlling costs via: reduced electricity consumption; lower consumables; decreased operational expenditure.
- Need to improve sustainability of IT infrastructure and overall energy efficiency.
- Making applications available on demand, platforms on demand, infrastructure on demand etc.
- Moves towards extremely large facilities, particularly internet data centres which require highly trained staff.
- Increasing obsolescence and inefficiency of many existing data centres: e.g. new low cost technologies such as blades consume 20-30kW per rack – whereas they were only designed for 2-3kW per rack.

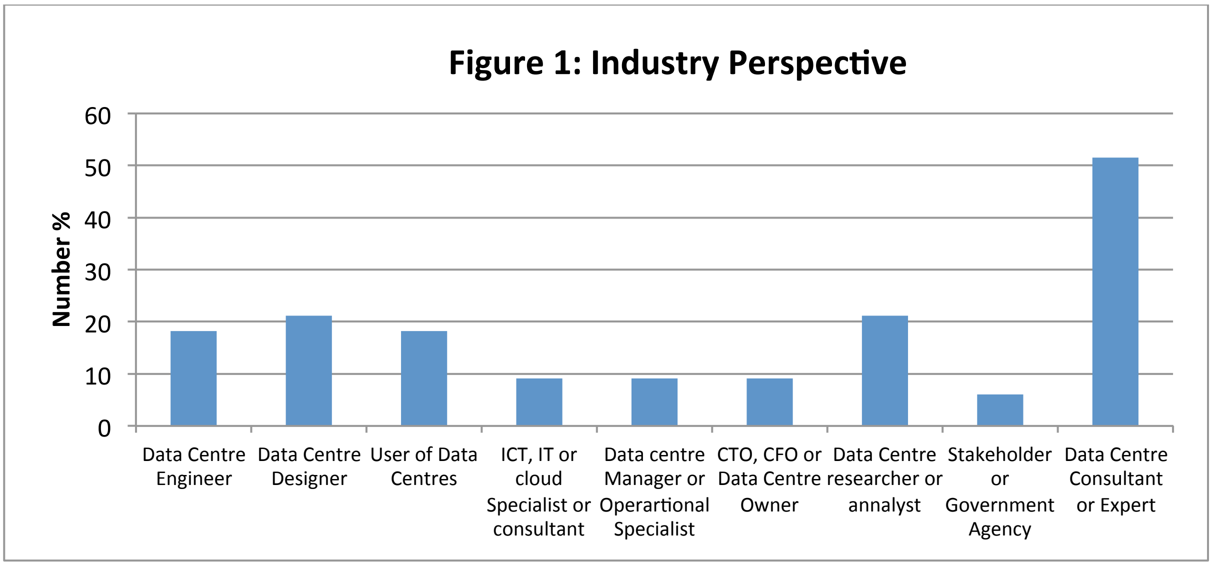
A recent report by the US Department of Energy[1], provided the vision that the data centre industry would need to:

- Increase computer power/Watt by an order of magnitude
- Reduce power losses by 50%
- Reduce cooling energy to < 20% of ICT and < 5% for new construction data centres.

It proposed classifying technologies and innovations in the three functional areas of Equipment & Software, Power Supply and Cooling[1].

The Data Centre Alliance has provided an online technology road mapping survey[7], the views of respondents with a wide range of expertise has been sought for 11 technology areas within data centre build and operation. The key technologies considered in the survey are: 1) power distribution, 2) cooling, 3) aisle and rack arrangements, 4) cabling, 5) fire detection, 6) physical security, 7) energy efficiency and management, 8) power generation, 9) operation and monitoring, 10) overall design, and 11) ICT hardware equipment.

The breakdown of the industrial perspectives of the respondents is shown below in Figure 1.



EQUIPMENT AND SOFTWARE

Server Technologies

It is recognised that there are a range of current server technologies being used at present[3]. These include: a) *mainframes* which are still used to scientific and engineering applications, typically with very high utilisation; b) *mini systems* e.g. HPUX, AIX, SUN-Solaris, which tend to run on proprietary applications; c) *Wintel servers* – Windows Operating System on Intel processors; d) *Server Operating Systems on Applications* – powerful and customised towards specific applications; e) *Virtualisation*, which started around 2003 and is now having a major impact in the Data Centre industry[2]; f) *Blade Servers* – self-contained high density computer servers. *Multi-core* servers are already having a big impact on the data centre industry. *Low power servers* with low power chips could improve IT utilisation rates and reduce the cooling requirements.

There will be a move towards hardening IT equipment - making IT equipment less sensitive to temperature and humidity levels. Potential innovations include the use of Gallium Nitride (GaN), Silicon Carbide (SiC) or nanomagnetic devices using magneto-restrictive RAM, which can operate at much higher temperatures.

Storage and Storage Area Networks (SANs)

Storage is roughly the third most energy consuming part of data centres (~30% total power)[2]. The following issues have been identified[3]. There will be:

- An increase in disk size (driven by need to store large images and video files)
- Increasing speeds of SAN communication with Drives – will grow up to 16 Gbps and perhaps 100Gbps in the future.

Data de-duplication and SAN replication will be key to future storage design in data centres. This will allow the use of combinations of lower tier data centres to provide required redundancy at lower cost. Other innovations that could improve energy efficiency of storage are: *Data Layout Optimisation* to reduce total data processing – this could reduce processing times by up to 50%[1]. *Nanobased memory* - carbon nanotube electromechanical switches which do not require electric power to maintain information.

A recent report by 451 Research[2] identified Flash Storage (solid state) as the most likely disruptive technology influence on data centres. Key benefits of flash storage are significantly reduced power consumption and greater resiliency, with one example citing 80% less power consumption over disk storage. HP and IBM are investing in a semiconductor technology known as *memristors* which would allow applications to be run in main memory, leading to low energy computers and vast amounts of onboard storage. These are considered to be more promising in the longer term[2].

Network Technologies

A recent Data Centres Technology Roadmap[3] predicted that

- Ethernet will remain the dominant means of connecting servers to users, printers and computers and that RDMA (Remote Direct Memory Access) over 10 Gbps Ethernet will provide much higher throughput and reduced latency.
- Routers and switches will also become more energy efficient.
- WAN speeds will also increase to 10Gbps and will probably grow to 100 Gbps in the longer term.
- Cabling – structured cabling will become less dominant and innovations such as overhead cables, patch panels will become more popular. These new cabling configurations will provide space savings, increased data densities and improved cooling.

It has also been noted that interconnect power consumption is becoming a big problem. Technologies such as silicon nanophotonics or GaN optical circuits could lift limitations of conventional electronic networks by using optics to deliver much higher bandwidth with the same power budget and reduce heat generation compared with copper interconnects.

Silicon photonics is probably still some way off from widescale adoption in the Data Centres industry. However, IBM announced in December 2012[5] that 90nm CMOS integrated nano-photonics technology for 25Gbps wavelength division multiplexing optical communication capabilities. This was followed in September 2013[6] by Intel' announcement that laser silicon photonics microprocessors are possible with 100Gpbs data connection speeds

The PEDCA technology roadmap survey[7] asked respondents for their views on the ICT hardware in the data centre – what is considered legacy, state-of-the-art, emerging and future technologies. Less than 50% of the respondents gave views on this topic. Legacy was considered to be standard x86, pizza box style, air-cooled with conventional hard drives (HDD). State-of-the-art was perceived to include higher density, lower power CPUs with lower idle power consumption and flash drives (SSD). The views on emerging ICT hardware technologies overlapped with state-of-the-art, where respondents highlighted power proportional computing, hybrid systems, e.g. mix of CPU, GPU, ARM, etc., perhaps with full virtualisation, scalable power to use ratios and full power management. The view of what the future technology would look like was more varied, including a mention of non-silicon base processing and a focus on low energy consumption with high performance. Disaggregated servers, liquid cooled and virtualisation at the data centre level was also considered as the way in which the data centre of the future would evolve to.

The PEDCA survey[7] also asked about cabling infrastructure. A number of respondents regarded CAT5/100Mbps data over copper and no rack level cable management to be legacy. The views on state-of-the-art focussed on CAT7/10GbE and fibre/infiniband technologies and in agreement with the views of the published technology road map[3], cassette/modular based and overhead cabling were also viewed as state-of-the-art. The emerging technologies are considered to be fibres running at 100Gbps, more manageable fibres, dense port presentation with up to 576 fibres per 1U, and out of rack solutions. The future of data cabling was regarded to be around low-latency, high-bandwidth photonics with the use of 60GHz radio over fibre and the use of LED communication. Some respondents believe that busbar type and/or pre-terminated modular fibre systems will be developed for data transmission in the future.

Software

IT Virtualisation will continue to have a major impact on the data centre industry as a means of increasing IT utilisation rates beyond the low average levels (~10%) achieved today.

Innovations that could be highly influential in the data centres industry and which a recent 451 Research report[2] highlight as being particularly promising include:

- Software technology for reducing the need for redundancy (e.g. using two lower tier data centres with synchronous back-up, referred to as *cloud-level resiliency*[2]) has been identified as one of the most likely technologies to be disruptive in the data centres industry. This potentially offers a cheaper means of achieving high tier resiliency.

- Advanced Data Centre Infrastructure Management (DCIM) – a suite of systems akin to an operating system that can be used for optimisation and automation. These could include dynamic tuning and configuration tools that enable applications to manage themselves. This would provide e.g. the information that would make it easier to raise data centre temperatures, maintain temperatures in a target range rather than a fixed set point and achieve higher utilisation. This system integration could lead to 30% energy savings[2].

There will also be a continued growth in:

- Grid and Utility computing (take a set of resources and provide them in a way that can be metered)
- Cloud Computing– computing or storage that can be carried out in a different physical location.
- Software as a Service (SaaS) – applications delivered usually over internet by a third party.

Facilities Management

There will be general moves towards:

- Prefabricated Modular Data Centres – smaller systems with fewer variables which enable faster and lower risk deployment of data centre capacity.
- Hybrid Data Centre Deployment – using technologies such as cloud-level resiliency to combine different tiers of data centres combined based on application criticality.
- Centralised humidity control - can ensure that the same space is using the same humidification mode. A properly controlled economiser should be able to minimise latent heat load.

Data centre operation and monitoring was considered by the PEDCA technology road mapping survey[7]. Building Management System (BMS) was almost unanimously considered as legacy. State-of-the-art was viewed to be between BMS+ and DCIM and for some respondents a combination of the two systems. For the category of emerging technologies in data centre operation and management, some considered this to be simply DCIM, but others viewed this to be an integrated DCIM with BMS with differing levels of unmanned/automated control. An advanced DCIM with full automatic control that would manage both IT and physical infrastructure was considered to be the future. These views are in line with Advanced DCIM identified as an emerging disruptive technology within the data centre.

Energy efficiency and management is a technology that intersects with the technology area of data centre operation and management. In the PEDCA survey[7], the views of what is legacy were diverse covering the use of Computer Room Air Conditioning (CRAC) and handling (CRAH) units with the use of DX, uncontained aisles between the racks and no actual measurements apart from the facilities kW usage. In the state-of-the-art category, respondents perceived EMS within DCIM or BMS monitoring to feature, but also higher temperature set points, variable speed fans and aisle containment approaches are also considered to fall into the same category. Respondents also covered a number of cooling technologies as a component of energy efficiency – these are included later under the heading of cooling. Waste heat reuse, the adoption of more advanced DCIMs and removing the dependence on compressor based cooling technologies are considered to be emerging. Respondents gave a mix of views on what the future holds in this category, but mostly they focused on methods and approaches that involve data centre monitoring with optimised automatic dynamic control, which may include IT workload scheduling for reduced energy consumption.

POWER SUPPLY

Necessary innovations in power supply for data centres include:

<u>Reducing power draw from processors and network devices when demand is low</u>

Most IT equipment wastes a lot of energy when it is doing very little, leading to unnecessary power throughout the power supply chain. The goal is to develop technologies that reduce time spent at low loads and achieve *power proportional computing*[2] where devices consume power proportional to their load. This will require the development of:

- Compute policies and algorithms tailored to saving energy when demand is low.
- Advanced clock and clock distribution techniques and memory architectures, which could reduce energy consumed by between 30 and 75%[1].
- Alternative synchronization schemes to slow down components within required timeframe.
- Optimal chip architectures for specific applications. Specialised technology can offer 50x power benefit over conventional chips. Tailoring data centre designs to workload could yield 20 fold improvements.

<u>Minimising Power Conversion Steps and Losses</u>

Telecom centres typically use Direct Current (DC) and data centres use Alternating Current (AC) power distribution systems. However servers in Data Centres require Direct Current and there are typically 5 conversion steps, each with a power loss that generates heat. The conversion steps typically result in ~ 40% power losses. This problem could be tackled by:

- Eliminating power conversion losses by using Direct Current (DC) instead of AC. This is a very promising approach. DC distribution would require only one AC to DC conversion. An energy-efficient DC system could reduce energy consumption by up to 10%.
- Developing more efficient AC distribution. Step-down transformer losses can be eliminated by converting UPS output power to 415V AC. The 415V three-phase input provides 240V single phase directly to the server. Emerson Network Power suggested a potential 2% reduction in energy use with 415V AC power distribution.
- Develop more efficient power conversion circuit designs with new architectures and converter technologies to increase conversion efficiencies. These will enable the peak efficiencies of rectifiers to be maintained – these are currently underutilised due to the need to provide required redundancy levels. These could provide up to 4% in power savings.
- Increasing usage of three-phase power. This can have important benefits over single-phase circuits: one study found that 73% more power could be transmitted with only a 50% increase in copper and losses[3].

Increasing Efficiency of Backup Power

Main conclusions from recent studies[3]:

- Rotary UPS is a rapidly maturing technology and should be considered when choosing a UPS system.
- UPS efficiency could be improved by adopting a line-interactive topology instead of double-conversion (this supply load directly from the source and is typically 97-99% efficient).

On-site DC generation

Data centres need to consider: cost-effective sources of onsite power generation; more cost-effective storage technology to enable use of variable energy sources such as wind and solar; improve reliability of alternative energy sources for on-site generation; robust Combined Cooling Heating and Power technologies; R&D on waste heat recovery technologies (e.g. advanced thermoelectric generators); renewable energy sources will integrate well with DC power generation facilities. At present, distributed generation technology (combined heat and power systems) is difficult to apply in mission-critical environments. Micro-grids can combine power from multiple sources and distribute it continuously to critical loads, however this is currently too costly and impractical for most data centres[2]. In the longer term, incorporating CHP into microgrids for data centres could increase input energy efficiency by up to 70%.

Power distribution was also considered in the PEDCA survey[7]. The respondents viewed inefficient monolithic UPS systems (<94%) as legacy, in addition to non-intelligent Power Distribution Units (PDU) and single phase distribution to the rack. Efficient *modular* UPS systems (>94%) for all load conditions, three phase rack level AC power distribution with remote access intelligence was regarded as state-of-the-art in this category. Respondents had mixed views about whether chemical energy (battery) storage or kinetic energy (mainly rotary) was considered to be legacy or state-of-the-art. In the category of emerging power distribution technologies, opinion focussed on greater efficiency (eco-mode) UPS systems with distribution of higher voltage direct current (HVDC) with the possibility of local power generation, potentially from renewable power resources. Respondents provided a broad set of views on the future of power distribution in the data centre, ranging from clean, smart energy supply with load sensing and balancing to full HVDC to the concepts of virtual power distribution, using software managed smart PDUs and UPSs.

On the subject of power generation local to the data centre, the PEDCA survey[7] provided views that ranged from standard diesel generation being considered to be legacy to co- or tri-generation with smartgrid integration as being where the future lies. For the state-of-the-art in this area, the respondents believed that co-generation, on-site generation, the use of diesel and gas generators for backup with scalable UPS was being adopted with the potential to aid national electricity grids by peak power shaving. The focus for emerging technologies was on the use of offset renewable generation, fuel cells and photovoltaic systems. Similar responses were given for what was perceived to be future technologies: use of renewable and fuel cells and on-site power generation with the view that data centres would become energy neutral.

COOLING

In a typical data centre, mechanical chillers use energy to chill water in a coil in a Computer Room Air Handling (CRAH) unit. This cools air in data centres by blowing it over the coil and then blowing the cooled air through the electronic equipment to cool it. This form of cooling typically accounts for between 30-40% of the energy costs in a data centre so more energy efficient, targeted cooling technologies are urgently needed. A number of technologies are being developed to meet the need for more efficient cooling and higher cooling capacities to deal with high performance microprocessors dissipate $100W/cm^2$ with localised heat fluxes up to $1000W/cm^2$ or more.

Direct liquid cooling

This refers to different cooling approaches that transfer heat to a liquid at or near to where the heat is generated. The much higher heat capacities of liquids means that this approach can cope with much higher heat densities and is more efficient than air cooling since circulating a liquid requires < 10% of energy needed to distribute air. Overall, liquid cooled systems have the potential to reduce cooling by 70% and lower capital expenditures by up to 50%. Examples of specific, on-demand cooling technologies include:

- Microfluidic cooling using liquids in chip architectures
- Phase change solutions to cool localised heat spots using heat spreaders with enhanced boiling from micro-fabricated structures.
- Direct immersion cooling of processors using dielectric liquids

Although promising, these technologies have to overcome resistance to adopting liquids due to the wide perception of risk of spilling liquid and damaging systems.

Chiller-free Data Centres – Free Cooling

Data centres are increasingly using *free cooling* by filtering outside air and expanding the range of temperatures and humidity for operating environments[2]. Free cooling reduces demands on the utility and is cheaper than traditional, mechanically-cooled facilities. Intel research suggests that air conditioning costs to be reduced by up to 7% for each degree C increase in the data centre set point temperature. As noted above, more resilient, hardened IT equipment which can operate at higher temperatures and humidity will enable these potential gains to be exploited fully.

Thermal bumps

Provide localised cooling by solid state heat pumps which pull heat from one side of the device to the other as current is passed through the thermoelectric material.

Data centre cooling was one of the areas highlighted in the PEDCA survey[7]. Legacy cooling systems were primarily considered, by most respondents, to be mechanically (i.e. compressor) based cooling systems, where the data centre uses CRAC units and DX chillers. The state-of-the-art in data centre cooling was regarded by most respondents to be making use of free cooling, whether this is compressor free with CRAH units in the data centre or evaporative cooling with indirect air heat exchangers, both use local outside environmental conditions to provide cooling to the data centre. The views of what is considered as emerging cooling solutions for the data centre were not so unified apart from the potential developments in proximity liquid cooling technology, such as direct to chip liquid cooling or full liquid immersion. In terms of the future technological developments of cooling data centres, the view from the respondents was diverse, but a common theme of direct liquid cooling and elevated temperatures came through in various guises.

Data centre rack layout is now considered as very important to improve energy efficiencies by not mixing cool conditioned IT intake air with the hotter IT exhausted air. The PEDCA survey[7] canvassed views on the development trends of data centre aisle and rack arrangements. Legacy was considered to be racks arranged into hot and cold aisles with no containment to maintain separation of the hot and cold air streams. A number of technologies were considered to be state-of-the-art, which includes hot and/or cold aisle containment, in-row cooling, using floor grommets, layout decisions based on computational fluid dynamics (CFD) analysis of the airflows, and liquid to the rack. Some respondents considered containerised/modular data centres as an emerging technology. Others perceived emerging technologies to include chimney based ducting and the removal of the under floor plenum. In terms of future technology developments there was no clear view, but the removal of aisles, or back to back racks and the use of close-coupled direct liquid were listed in this category as was new rack designs that are wider, adaptable and that modularise IT components.

OTHER TECHNOLOGIES CONSIDERED BY THE PEDCA SURVEY

The PEDCA survey[7] canvassed opinion on technological developments in fire detection systems. In terms of what was considered to be legacy, most respondents identified sprinkler and mist systems with a certain amount of pre-action. Toxic/poisonous gas fire suppression was also mentioned as being legacy. Under state-of-the-are category double knock, full range sensors, inert gas, Very Early Smoke Detection Apparatus (VESDA) with infra red were identified. Water misting was considered to be legacy by some respondents, but emerging by others. One clear technology was identified as emerging at that was one based on reduced oxygen (hypoxic systems). There were fewer responses to what was considered to be the future of data centre fire protection. Some considered this to be no requirement for a fire detection system or the use of electronic sniffing with pinpoint accuracy to make use of localised prevention even before any fire has broken out.

Physical security was also listed by the PEDCA survey[7]. The use of keys and low resolution CCTV were considered to be legacy. Whereas electronic/biometric access systems, individual tracking systems, HD CCTV monitoring, maglocks, and zoned alarms, to name a few, were identified as being state-of-the-art technologies. Biometric based systems came up again under the category of emerging technologies in DC physical security. Respondents considered asset tagging, no need for physical entry and advanced/enhanced biometric control to be the future of physical security.

There are no blueprints for the design of data centres. The PEDCA survey[7] sought views on the developments in data centre overall design. There was no unified view on what was regarded as legacy. Some respondents highlighted legacy to be large monolithic designs, with a focus on reliability and low CAPEX. Dedicated data centre space, which is flexible and scalable, was identified as state-of-the-art, possibly along the lines of pre-fabricated modular design. The theme of modularity and scalability continued to be the view for emerging technologies with better monitoring, process management approaches and looking at higher IT inlet temperatures. There was some consensus on opinion as to what future data centre design technologies would include – distributed data centres, working together pushing resilience and redundancy up to the data centre, i.e. being N+1 or 2N at the data centre level. On site power generation was considered to become an integral part of the data centre design.

SUPPORTING TECHNOLOGY NEEDS

Many of the biggest challenges for the data centres industry are non-technical. For example in achieving better energy efficiencies, technologies and procedures are often not implemented because of organisation barriers. There is a need for:

- Energy efficiency metrics which are system-level data centre efficiency metrics that can capture trade-offs. Existing metrics such as PUE, though useful, can drive perverse behaviours leading to increases in overall energy consumption despite a lowering of the reported PUE[4].
- Open network and communication standards for energy management of facilities and national mandatory standards on green computing;
- More Public/Private Partnerships. For example, funding a Data Centre Test facility where technological innovations could be tested and optimised in a transparent manner.
- Better Education: particularly with regard to the sharing of best practices and widespread adoption of metering systems that generate cost signals. There is also a general need to stimulate interest in power engineering education.
- Incentives for innovation with grants, rebates etc.
- Market pull from government organisations and large industries.

The PEDCA survey[7] asked what is considered to be a top priority for future (3 to 5 years from now) improvement in data centres and 50% of those that responded identified IT energy efficiency to be the most important.

6 References

1. US Department of Energy. Routing Telecom and Data Centers Toward Efficient Energy Use. May 2009.
2. 451 Research. Disruptive Technologies in the Datacenter: Ten Technologies Driving a Wind of Change, May 2013.
3. T. Daim et al. Data Center Technology Roadmap. 2012.
4. G. Brady, N. Kapur, J. Summers, H. Thompson, 'A case study and critical assessment in calculating power usage effectiveness for a data centre', *Energy Conservation and Management*, **76**, 155-161, 2013.
5. IBM Press Release, December 10, 2012 http://researcher.ibm.com/researcher/view_project.php?id=2757
6. Computing News, September 4, 2013 http://www.technologyreview.com/news/518941/intels-laser-chips-could-make-data-centers-run-better/
7. An online PEDCA Survey delivered by the DCA Data Central has been operating from October 2013: http://www.data-central.org/surveys/?id=Technology_Roadmap
8. R. Bashroush, "*The Holistic Approach to Energy Efficiency in Data Centres: Its Implication on Current Practice, Training and Standards*", presented at the DataCenter Dynamics CONVERGED - Towards Software Defined, EXCEL London, Nov 2013