A Market Transformation Programme for Improving Energy Efficiency in Data Centres

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ABSTRACT

The European Code of Conduct for Data Centres is a voluntary market transformation programme addressing primarily data centre owners and operators, and secondly the supply chain. The Data Centres Code of Conduct has been created in response to increasing energy consumption in data centres and the need to reduce the related environmental, economic and energy supply impacts. The aim is to inform and stimulate operators and owners to reduce energy consumption in a cost-effective manner without hampering the critical function of data centres. It also introduces a set of metrics to measure the energy efficiency. The data centre supply industry can join the programme by offering products and solutions to help achieve the energy savings. Since the start of the programme in 2008, 220 data centres have been certified as Participant. The core of the programme is the commitment by the participant to carry out an initial energy audit to identify the major energy saving opportunities; to prepare an action plan; to implement the action plan; and to monitor energy consumption. This paper reports on the results achieved so far in terms of energy savings and technologies adopted.

Introduction

Energy consumption in the commercial (service) sector has increased over the years, mainly due to the economic expansion of the sector, the increase in cooling load, and the increased load of Information and Communication Technologies (ICT). In the commercial sector, annual electricity consumption in the European Union (EU 28) has increased in the period 2003 to 2012 from 698 TWh to 845 TWh, i.e. a growth of 21% while total electricity consumption in the EU 28 in the same period has grown by 4%, and in the residential sector by 5%. The Joint Research Centre Energy Efficiency Status report 2012 (JRC 2012) has evaluated the data centres total annual energy consumption as 56 TWh (or 2%) of total electricity consumption per year in Western Europe and at the time it was projected to increase to 104 TWh (or 4%) per year by 2020. This is line with the US consumption of data centres representing 1.7% to 2% of US total electricity consumption (Koomey 2011). A more recent study identifies the following trends in Western Europe:

Table 1

Western Europe	2013	2014	2015	2016	2017	2018	2019	2020
Net data centre space (thousand of m2)	10256	10221	10105	10055	9875	9555	9365	9155
Average power density (kW/m2)	1.1	1.1	1.2	1.2	1.3	1.3	1.2	1.3
Total power usage (GW)	11.3	11.2	12.1	12	12.8	12.4	11.3	10.9

Source: BroadGroup 2014

Table 1 shows declining energy consumption in data centres in Europe due to consolidation, virtualization and energy efficient technologies especially in cooling. Table 1 shows data centre annual energy consumption of 80 TWh or about 3% of total European electricity consumption. It is interesting to note that another report (Datacentredynamics 2011) place global power consumption of data centres at 31GW, therefore Western Europe represents about one third of the global consumption.

Why Data Centres?

Electricity consumed in data centres, including enterprise servers, ICT equipment, cooling equipment and power equipment, is expected to contribute substantially to the electricity consumed in the European Union EU commercial sector[1] in the near future. It is therefore important that the energy efficiency of data centres is maximised to ensure the carbon emissions and other impacts such as strain on infrastructure associated with increases in energy consumption are mitigated.

In the EU there are policy actions for buildings, in particular the European Energy Performance of Building Directive (EPBD 2010), which imposes on EU Member States to adopt minimum efficiency requirements for buildings based on cost-optimality in their building codes. For equipment the Eco-design Directive introduces common minimum efficiency requirements for end-use equipment such as domestic appliances, lighting products, consumer electronics, electric motors, air-conditioners, Uninterruptable Power Supplies (UPS), computers, servers, etc. In addition to the Eco-design directive the EU has an agreement with the US on the shared use of the Energy Star labelling programme. Energy Star equipment is available in Europe and it is promoted by public authorities as well as included in public authorities' procurement practices.

It is important to note that data centres are included in buildings, occupying part of the buildings (e.g. one room or one floor), or the entire building. The Eco-design Directive introduces efficiency requirements for individual equipment present in data centres such as UPS and servers (both not yet finalized at the time of writing the paper), however the selection of efficient equipment is not guaranteeing that the data centre is efficient.

Historically, data centres have been designed with large tolerances for operational and capacity changes, including possible future expansion. Most enterprise data centres today run significant quantities of redundant power and cooling systems typically to provide higher levels of reliability. Additionally IT systems are frequently run at a low average utilisation.

Over provisioning, ensuring availability and associated costs were previously considered, as a negligible risk to business performance because energy costs were relatively small in comparison to the IT budget, and environmental and energy responsibility was not considered to be under the control of the IT department. However, with rising energy prices this is no longer the case, and the issue of energy consumption at the individual data centre level is becoming increasingly important as operational energy expenditures and environmental impact of the energy consumed begins to play an ever important role in overall cost of ownership of data centres.

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[1] The commercial sector is also referred as the tertiary sector and it includes both private and public buildings that host data centers. In this case energy consumption of data centres of companies in the industrial sector is included.

Preliminary evidence and the increasing willingness of manufacturers and vendors to compete on the basis of energy efficiency in data centres confirms that there are efficiency gains (for example simply by using existing power management technologies) still to be realised without prohibitive initial costs that can lower the Total Cost of Ownership (TCO).

Many data centres operators are simply not aware of the financial, environmental and infrastructure benefits to be gained from improving the energy efficiency of their facilities. Even awareness does not necessarily lead to good decision making, simply because there is no framework in place for the operators to aspire to. Making data centres more energy efficient is a multidimensional challenge that requires a concerted effort to optimise power distribution, cooling infrastructure, IT equipment and IT output.

The European Code of Conduct

In order to improve energy efficiency, policy makers have the choice between voluntary approach and regulation. For sectors that are hard to reach, or with several decision makers involved, it could be difficult to mandate through legislation efficiency requirements and the voluntary approaches could be adopted. such as voluntary agreement between public authorities and private enterprises. Voluntary agreements have proven to be effective in improving energy efficiency in Europe in different sector (Rezessy 2012). Voluntary agreements have also been particularly successful in the use in the frame of the Energy Star programme for buildings and industry.

In Europe some voluntary programmes for the ICT sector have been introduced at the beginning of 2000, the Codes of Conduct. Now there are four Codes of Conduct in operation for ICT products: External Power Supplies, Digital TV Systems, Broadband Equipment and UPS. All these Codes of Conduct impose energy consumption limits or minimum efficiency for specific products. Participation by equipment manufacturers is on a voluntary basis, but when the join any of the Code of Conduct they have to meet the performance level and report once a year on the energy consumption of the products they place on the market.

It was decided to follow the same approach for improving energy efficiency in data centres. However it was not possible to set a minimum efficiency requirements for data centres given the diversity of data centres, the different level of responsibilities in data centres (some company being only responsible for the infrastructure, while other being responsible for the IT equipment selection and operation). In addition, a good metric to measure data centre efficiency is not yet available (see discussion later on the paper).

Therefore it was decided that the key criteria for the data centre Code of Conduct (CoC) was to ask participating companies to monitor their energy consumption and to adopt a set of established best practices.

For the purposes of the CoC, the term “data centres” includes all buildings, facilities and rooms which contain enterprise servers, server communication equipment, cooling equipment and power equipment, and provide some form of data service (e.g. large scale mission critical facilities all the way down to small server rooms located in office buildings).

Objective and Aims of the Code of Conduct

The CoC is a “multipurpose” programme, allowing different stakeholders to commit to improve efficiency in their own areas of competence. The primary target of the CoC is the data centre owner / operator, who is encouraged to commit to undertake and implement energy efficient solutions in existing or new data centres, whilst respecting the life cycle cost effectiveness and the performance availability of the system.

The CoC aims to:

- Develop and promote a set of easily understood metrics to measure the current efficiencies and improvement.
- Provide an open process and forum for discussion representing European stakeholder requirements.
- Produce a common set of principles to refer to and work in coordination with other international initiatives.
- Raise awareness among managers, owners, investors, with targeted information and material on the opportunity to improve efficiency.
- Create and provide an enabling tool for industry to implement cost-effective energy saving opportunities.
- Develop practical voluntary commitments which when implemented improve the energy efficiency of data centres and in so doing minimise the TCO.
- Determine and accelerate the application of energy efficient technologies.
- Foster the development of tools that promote energy efficient procurement practices, including criteria for equipment based on the Energy Star Programme specifications, and other Codes of Conduct[2].
- Monitor and assess actions to properly determine both the progress and areas for improvement.
- Provides reference for other participants.

The values of the CoC goes beyond the number of companies that sign and commit themselves, as the principles can be implemented also by other companies, which may not decide to make a public commitment. The existence of the European CoC introduces targets and guidelines which are open to every data centre.

The focus of this CoC covers two main areas:

- IT Load – this relates to the consumption efficiency of the IT equipment in the data centre and can be described as the IT work capacity available for a given IT power consumption. It is also important to consider the utilisation of that capacity as part of efficiency in the data centre
- Facilities Load – this relates to the mechanical and electrical systems that support the IT electrical load such as cooling systems (chiller plant, fans, pumps) air conditioning units, UPS, PDU's etc.

However the Code of Conduct will consider the data centre as a complete system, trying to optimize the IT system and the infrastructure together to deliver the desired services in the most efficient manner.

The Code of Conduct has both an equipment and system-level scope. At the equipment level, the Code of Conduct covers typical equipment used within data centres required to provide data, internet and communication services. This includes all energy using equipment within the data centre, such as:

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[2] e.g. the Code of Conduct for UPSs.

- IT equipment (e.g. rack optimised and non-rack optimised enterprise servers, blade servers, storage and networking equipment);
- cooling equipment (e.g. computer room air-conditioner units);
- power equipment (e.g. uninterruptible power supplies and power distributions units); and
- miscellaneous equipment (e.g. lighting).

At system level the CoC proposes actions which optimise equipment interaction and the system design e.g.:

- improved cooling design,
- correct sizing of cooling,
- correct air management and temperature settings,
- correct selection of power distribution, to minimize overall energy consumption.

Data centre owners and operators can join the CoC by becoming Participants by committing to implementing the recommended Best Practices with an indicative timeline and regularly reporting the result achieved. Though not entailing legally binding obligations, Participant status requires strong commitment and a substantial contribution to the objectives of the CoC. Each participant will set the areas of responsibility (defining which parts of the data centre they are responsible for implementing the efficiency improvements), the coverage (defining the data centres / building / sites at which energy efficiency actions will be undertaken) and the nature (specifying the actions that the enterprise proposes to carry out at each location) of its commitment.

Many data centre operators do not control the entire data centre but still may participate in the Code, for example colocation operators or their customers. In order to include these operators as Participants their partial control is recognized and they should implement the practices that fall within their control and endorse the practices outside of their control to their suppliers or customers as appropriate.[3]

Participants are grouped into categories according to which parts of each data centre they have control over and responsibility for possible efficiency improvements;

- Operator
- Colo[4] Provider
- Colo customer
- Managed service provider
- Managed service provider in Colo

Efforts to improve efficiency differ in the level of commitment and investment ranging from simple energy management practice and low cost solutions, to exploring alternative, energy efficient opportunities before specifying or replacing IT equipment and supporting infrastructure,

3 See the Best Practice Guide for further details of the Best Practices, types of operator and areas of responsibility.

4 A colocation (colo) is a data center facility in which a business can rent space for servers and other computing hardware. Typically, a colo provides the building, cooling, power, bandwidth and physical security while the customer provides servers and storage. Space in the facility is often leased by the rack, cabinet, cage or room. Many colos have extended their offerings to include managed services that support their customers' business initiatives.

to designing new highly efficient data centres or upgrading existing ones to very high level of efficiency. Participants are expected to select, adopt and implement a subset of the recommended best practices.

For existing data centres participant application starts with an initial energy measurement of at least one month and energy audit or assessment to identify the major energy saving opportunities. The applicant should prepare an action plan and supply a completed reporting form with their application. The reporting form should identify the Best Practices[5] already implemented and those to be adopted within three years of the application date with a description of the action plan to achieve this. From 2010 onwards new data centres (under construction or recently completed) should identify in the reporting form the practices adopted to make the data centre "best in class" for their application.

Data Collection

In order to qualify as a Participant, applicants must describe simple physical and operational characteristics of the data centre, and the most recent one month facility and IT energy consumption data. The monthly facility and IT energy consumption shall be reported once per year. The IT energy consumption is measured at the UPS outputs.

Some operators may not be able to obtain the full facility energy consumption, for example an operator whose data centre is in a shared office building and uses the building chilled water system for cooling may not be able to meter the data centre part of their cooling system energy consumption. Operators unable to provide both the total facility energy and IT energy should provide the information available and an action plan to achieve metering where feasible.

Operators in a shared building who have a shared power delivery path or shared HVAC system and insufficient metering to be able to extract and report the facility energy should: i) provide an explanation of the issue preventing metering of the facility energy; ii) provide IT electrical energy measurements; iii) present an action plan to improve the metering; and iiii) provide any meter data available for the building including a description of exactly what parts of the data centre or other loads are on each meter.

Metrics

In common with other industry bodies the CoC initially used the ratio of IT Load to Facilities Load as the key metric in assessing infrastructure efficiency. This is known as ‘facility efficiency’, or Data Center Infrastructure Efficiency (DCIE), which is 1/PUE. The Code of Conduct is also concerned with the efficiency with which the IT equipment utilises the power delivered, this will be known as ‘asset efficiency’. The Code of Conduct aims to adopt more comprehensive metrics which may also cover the IT system design, the IT hardware asset utilisation, and the IT hardware efficiency.

The European CoC decided to use available metrics, such as power utilization effectiveness metric (PUE) and to contribute to the definition of additional metrics, through the International Taskforce[6] for the Harmonisation of Metrics for Data Centre Energy Efficiency. The

[5] The list of Best Practices is contained in a document available of the website and it is updated once per year.

[6] The following organisations participate in the Task Force: the U.S. Department of Energy’s Save Energy Now and Federal Energy Management Program (March 2009 – October 2012); the U.S. Environmental Protection Agency’s ENERGY STAR Program; the European Commission Joint Research Centre Data Centres Code of Conduct; Japan’s

Task Force in 2011 specified a detail measurement protocols for the PUE. In October 2012, the Taskforce provided measurement guidelines for three additional metrics: green energy coefficient (GEC), energy reuse factor (ERF), and carbon usage effectiveness (CUE).

Furthermore, the Taskforce worked on effective energy efficiency metrics that measure the actual IT work output of the data centre compared to its actual energy consumption. For this the task force recommended that a data centre defines attributes and measure data centre energy productivity (DCeP) according to the following: DCeP is an equation that quantifies useful work that a data centre produces based on the amount of energy it consumes. DCeP is computed as useful work produced divided by total energy consumed by the data center. As this was a very complex task the Taskforce also worked on metrics to measure the potential IT work output compared to expected energy consumption, and to measure the operational utilization of IT equipment. To this end the Taskforce studied a wide range of proxies for data center productivity and has narrowed the field to three proxies that each addresses this outcome in a different way, however no agreement was reached in endorsing and recommending any of the three proxies.

Results and Analysis

At the time of writing the paper 221 data centres have submitted data and are included in the analysis here presented.

Table 2. Average data

Total dataset	221	
Total annual electricity consumption	3 223 500 00	MWh
Average DC floor area	2 500	m^2
Average Rated IT load	1 900	kW
Average annual electricity consumption	14 400	MWh
Average PUE	1.77	
Average high temp setpoint	24.3	degC
Average low temp setpoint	20.2	degC
Average high humidity setpoint	62.4	% RH
Average low humidity setpoint	33.4	% RH

Ministry of Economy, Trade and Industry; Japan’s Green IT Promotion Council; and The Green Grid. Is there a report that came out of this Task Force?

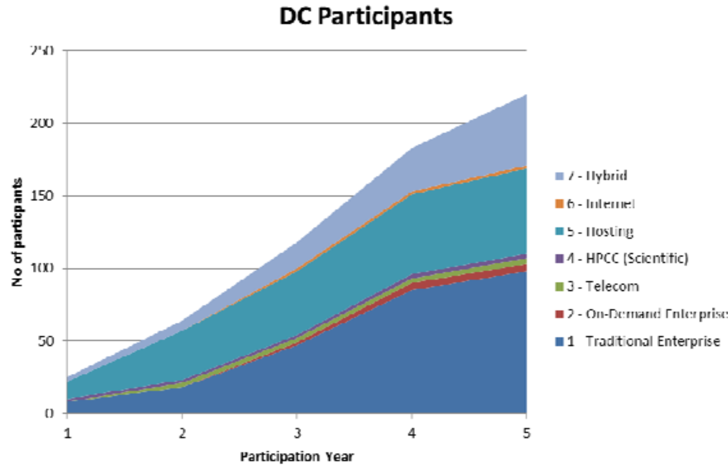

Figure 1 Type of sectors participating in the Code of Conduct.

The Code of Conduct covers 3.2 TWh of electricity consumption, which is between 3 to 5 % of the total data centres consumption in Europe. The majority of data centres (57%) are stand-alone data centres. In terms of the sector covered, the traditional enterprise is the dominating sector followed by hosting (figure 1).

By analysing the data reported we can see an increase of efficiency over time (only the initial data reported has been analysed, i.e. subsequent annual energy consumption reports have not been included). In 2013, the average efficiency is around a PUE just under 1.7. It is worth noting that the Digital Realty Trust Campos survey published in January 2013 found that Europe's average PUE is 2.53 (2.62 the previous year).

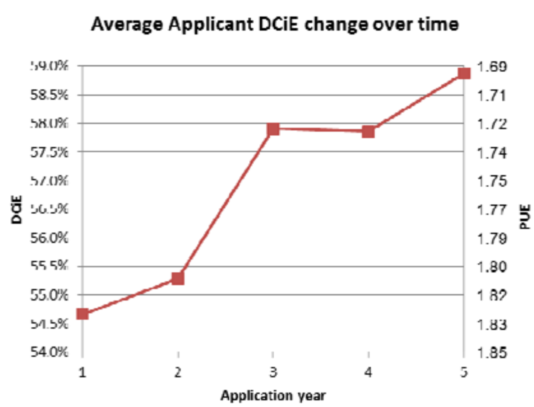

Figure 2. Average applicant DCiE change over time.

A more detail analysis (figure 3) shows that Efficiency is slowly increasing with a slow decline in the least efficient data centres, particularly those with PUE worse than 2 and recently a more even spread in efficiency distribution with PUE between 2 and 1.43, rather than very clear peaks in early years.

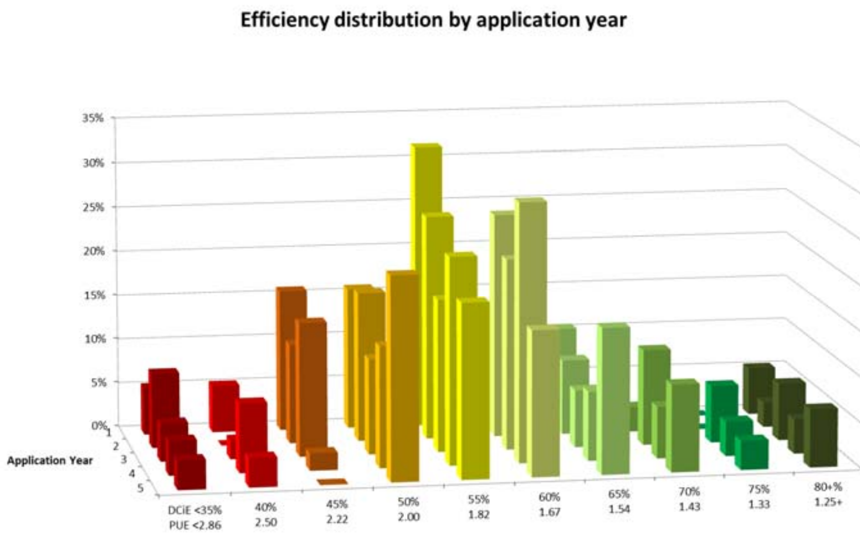

Figure 3. PUE and DCiE distribution by application year.

Two other important parameters supplied by participants, i.e. temperature and humidity set points have been analysed. The Code of Conduct places a lot of emphasis on raising the temperatures set point (the Best Practices document recommends that data centres are designed and operated at their highest efficiency to deliver intake air to the IT equipment within the temperature range of 10°C to 35°C and with a wide range of humidities). From the data reported the relative humidity is diverging (figure 4). Please note that this graph doesn't show DCs with no humidity control with is now becoming more common. It is not possible to detect any change over time for the high temperature set point which seems to be fairly constant at around 25 °C.

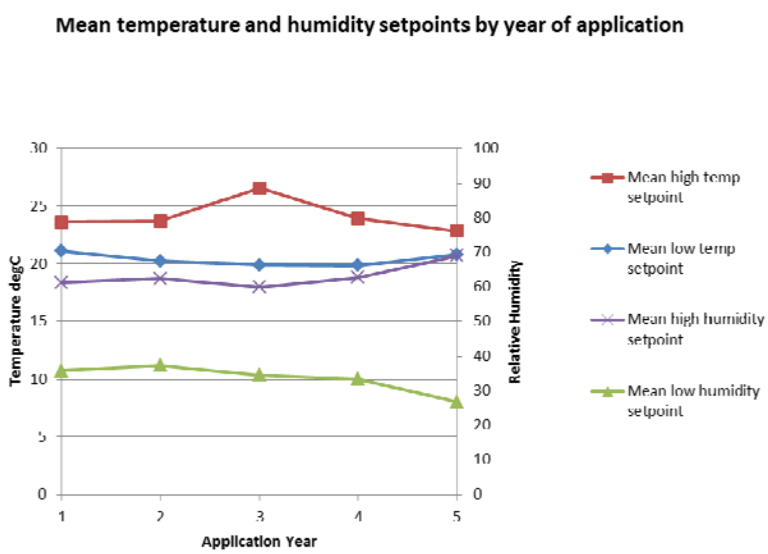

Figure 4. Mean temperature and humidity setpoints by year of application.

The analysed data shows that there is a small correlation between the PUE and the upper temperature set point (figure 5). The size of the ball in the graph is the temperature range from min to max set point. A larger ball means a larger range.

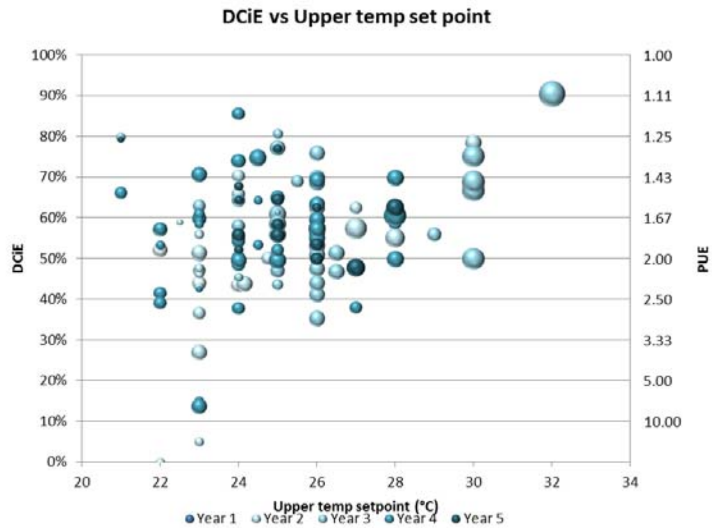

Figure 5. DCiE vs upper temperature set point.

In the past year the Code of Conduct started collecting information on the types of economizers being used. This is a relatively small dataset of 80 or so DCs. In figure 6 the bar graph shows the proportion of data centres using each type of economizer. The high-low line shows the min and max PUE while the cross shows the average. Around 55% of DCs use an economiser of some sort. If it wasn't already clear, it shows it's definitely a mainstream technology. Encouragingly water chillers and DX appear to be able to achieve very high efficiencies with a min PUE of 1.17. The big improvements in efficiency don't seem to be fully realised with economiser use. However, we need to bear in mind this is a very small dataset with only four DCs using direct water side economisers that have been operating long enough to collect data. What it does show is there's more to efficiency than just installing an economiser.

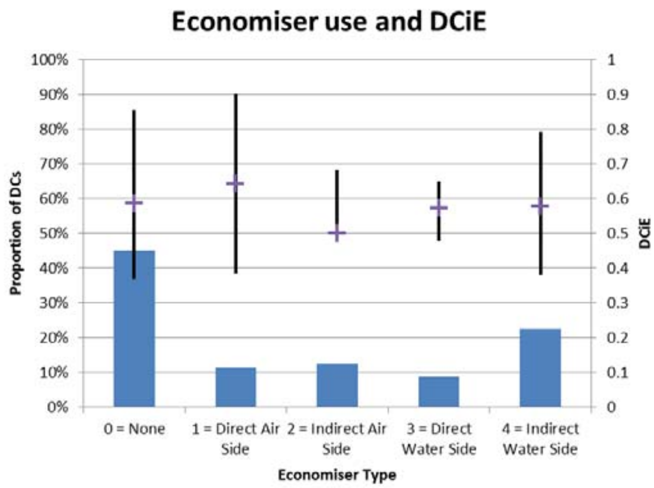

Figure 6. Economizer use and DCiE

An in depth analysis of the best practices adopted has been carried out on a reduced sample of data centres. The top Implemented Best Practices are in the table 3. It is clear that the majority of the top implemented practices are those that do not require capital expenditure or major changes to business practices, indeed all of the practices could be considered to be the "low hanging" fruit.

Table 3. Top implemented best practices

Best Practice	Brief Description	No of Implementations
3.1.1	Group Involvement	49
3.3.1	Build resilience to business requirements	49
3.3.3	Lean Provisioning	49
3.3.4	Part Loading	49
5.1.1	Design Contained Hot/Cold	49
5.1.2	Blanking Plates	49
5.1.8	Design Hot/Cold	49
5.1.11	Perforated Doors	49
6.1.2	High Efficiency UPS	49
7.1.1	Turn off lights	49
7.1.2	Low Energy Lighting	49
9.1.2	IT Energy Consumption Meters	49
9.2.1	Periodic Manual Readings	49

The lowest implemented Best Practices are in table 4 below.

Table 4.

Best Practice	Brief Description	No of Implementations
4.1.6	Power Management	39
4.2.4	Select Efficient S/W	41
4.2.5	Develop efficient S/W	42
5.2.3	Review Cooling	42
5.2.4	Review Cooling Strategy	43
6.1.3	UPS Operating Modes	41

"Enable Power Management Features" was the worst performing in terms of adoption by participants, there are a number of reasons why applicants have not implemented this best practice, these include: CoLo Provider do not have direct control over hardware settings, it is thought to introduce IT instability. CoLo providers should be endorsing the Code of Conduct formally or informally to clients. It may be the case that the business cannot allow the downtime required to implement the best practice at a hardware level, that technical staff are not aware of the nuances of power management and how it will effect normal operation or that they are unaware that there are power management features and services available.

The "*Selection of efficient software*" is problematic as no software markets itself as being "energy efficient", however it seems that many organizations have developed procurement clauses that would require an "energy efficient software" decision point, in some cases the use of virtualisation software or work stream dynamically control resource software is being used. Some applicants, as CoLo providers would not have control over the selection of software.

In the absence of global "green coding" guidelines or standards it is difficult for applicants to understand and implement the practice *"Develop efficient software"*, however green coding is gaining ground and workshops are available in certain countries, it may be the case that a general "coding" best practice includes energy efficiency techniques.

Many of the applicants who are not implementing the best practice *"Review Cooling*" are CoLo providers stating that they are reliant on customers informing them of equipment changes.

Concerning the best practice "*Review Cooling Strategy*", most of the applicants cite that there is a balance between energy efficiency and operational requirements.

There are two main reasons why the best practice "*UPS operating modes*" has not been implemented, these are: that the UPS installed in the facility does not have an "eco mode" or the "eco mode" itself does not provide sufficient rapid fail over for use within the facility.

Conclusions

The Code of Conduct is the only independent pan-European scheme in the EU to certify that a data centre has adopted energy efficiency best practices. There is increasing interest in the Code of Conduct among data centre operators. It is still too early to evaluate the overall impact of the Code of Conduct on energy savings. The implementation of best practices shows that the most cost-effective and short payback period best practices are mostly implemented. Through the collection of the data centres energy consumption (total facility and IT) we will be able to track efficiency improvement over time. The dataset of over 200 data centres with the energy data and the technologies adopted provided a very interesting data set for further analysis. There are already a number of showcase data centres with PUE below 1.2 which have gained the Annual Award for the best implementations (both for new and retrofitted data centres). The Code of Conduct has so far received good feedback from participants and industry (with over 200 companies that have endorsed it). With the feedback provided by participant the Code of Conduct will be improved in the communication with market actors and the outreach activities will be further strengthen in 2014 in order to substantially increase the number of participants.

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