Technical assistance study for the assessment of the feasibility of using "points system" methods in the implementation of Ecodesign Directive (2009/125/EC)

TASK 4
Case study: Data Storage Systems

Draft report v1

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Abbreviations

ASHRAE	American Society of Heating, Refrigerating and Air-conditioning Engineers
CFC	chlorofluorocarbons
CO2-eq	carbon dioxide equivalent
COM	capacity optimisation method
DC	data centre
EPA	Environmental Protection Agency
EPEAT	Electronic Product Environmental Assessment Tool
GB	gigabytes
GWP	global warming potential
HDD	hard disk drive
IOPS	input output operations per second
MiBPS	mebibytes per second
Mt	megatonnes
OS	operating system
PSU	power supply unit
PUE	power usage effectiveness
Sb-eq	antimony equivalent
SNIA	Storage Networking Industry Association
SO2-eq	sulphur dioxide equivalent
SSD	solid state drive
TWh	terawatt hours

1. Introduction to Task 4

This objective of this report is to evaluate case studies for two product groups using the method proposed in Task 3. Task 3 and 4 are carried out in parallel in order to interchange experiences.

It is important to note that the aim of the case study is to verify if the methodology can be used for a specific product group – in this particular case for the data storage devices.

It is not the intention that this case study should lead directly to regulation without any further studies and data. Many assumptions had to be made based on the study team's assessments and judgement. These assumptions would need to be further assessed and further data collection on the data storage systems had to be collected and analysed before a more concrete and detailed proposal for regulation could be elaborated.

2. Data storage systems and their environmental impact

Data storage systems are used for data storage mainly in data centres with several servers. The devices supply data storage services to clients and devices attached directly or through a network. A storage product is basically composed of the storage media where the data is stored (storage devices), storage controllers (the electronics to control and manage the activity on the storage system), network interfaces (to receive and transmit the data from and to servers and client computers) and software.

The main activity of the storage systems seen from the users' side is to store and retrieve their data, but additionally, the storage products are carrying out maintenance activity in order to optimise processes mainly with regard to access times and storage capacity.

The storage devices in the storage systems are the media on which the data is stored as non-volatile data storage, i.e. the data can be stored and retrieved after a period without power. The storage devices are typically hard disk drives (HDDs), solid state drives (SSDs) and tape cartridges.

A storage system is one functional unit, however, additionally it influences the energy consumption of related products and systems in the data centre. It is highly configurable, meaning that during purchase it is possible to select a variety of different internal components, mainly in relation to number and performance characteristics of storage devices, but also in relation to other components such as network interfaces and controllers. A storage product can have hundreds of storage devices installed. Since there are three common types of HDD and SSD, each with four or five different capacities, there are potentially millions of possible configurations per product.

The storage system is complex due to the following points:

- It is highly configurable and often customised product.
- It can be modular

- The user performance requirements cover several facets such as: storage capacity, read and write speed and response times, data security, redundancy[1] and physical size
- The data storage performance and its energy consumption is strongly dependent on the needs of the users (type of application, data stored, frequency of data reading and writing, required data security etc.)
- Measurement methods and performance vs energy metrics are complex to establish because the usage models are quite diverse over a broad range of users and usages. Furthermore, in periods with no active user data storage or user data retrieval, the system is often not idling, but rather doing maintenance (moving and optimising data) with a much higher consumption than in pure idle. Furthermore, to calculate an efficiency, it is necessary to establish a performance indicator, which is complex because there are many diverse needs regarding data storage related to e.g. access times, transfer speeds, files sizes, data security, short and long time storage, price, and product size.
- It forms part of a larger system – the data centre – where the energy consumption of the data centre is partly scaled with the energy consumption of the storage systems because all electricity for the storage system passes through the UPS (Uninterruptible Power Supply) and because all heat dissipated from the storage system due to its energy consumption will need to be removed by active cooling and/or free cooling. Both the UPS and the cooling system consume energy.
- It is most often a very expensive product that may be difficult to acquire and to test for Market Surveillance Authorities for verification purposes.
- Energy performance testing can take weeks to perform for a single configuration because to ensure the test is representative, manufacturers have to read and write data to the drives many times to simulate normal use with repeated patterns so the system can apply the data optimisation algorithms, caching, deduplication etc. For a large system, the amount of data is very large. Most of this test is automated and typically requires only a little manual input.

The main environmental impacts of the storage systems are:

- Material for the production and the production processes
- End-of-life treatment
- In-use electricity consumption for the storage system itself
- In-use electricity consumption for the directly related energy services of the data centre in which the storage systems are placed (mainly cooling, UPS system, network equipment and power distribution units).

The in-use electricity consumption for datacentre storage in the EU is current about 14.7 TWh/year. This is assumed to on course to double in 2030 in a business as usual scenario[2]. If including datacentre infrastructure (in-use electricity consumption for the directly related energy services of the data centre) these figures become 26.6 TWh/year and 46.5 TWh/year, respectively. The energy consumption including infrastructure corresponds to a total GHG emission of 10.5 Mt CO2-eq/year.

For the use of production material there are environmental impacts on ozone depletion, acidification, freshwater eutrophication and mineral, fossil and renewable resource deple-

[1] Duplicate components such as PSUs and storage devices that allow product operation to continue in the event of component failures.
[2] Approximate figures from Lot 9 Preparatory study and impact assessment

tion. The estimated savings by 2020 from the introduction of various material efficiency requirements on storage products are[2]:

- GWP (Global Warming Potential): 19.5 Mt CO2-eq/year
- Ozone depletion: 14 kg CFC-11-eq/year
- Acidification: 3.0 Mt SO2-eq./year
- Freshwater eutrophication: 5.5 t P-eq/year
- Mineral, fossil & renewable resource depletion: 10.4 t Sb-eq/year.

Figure 1 shows the main equipment of the data centre.

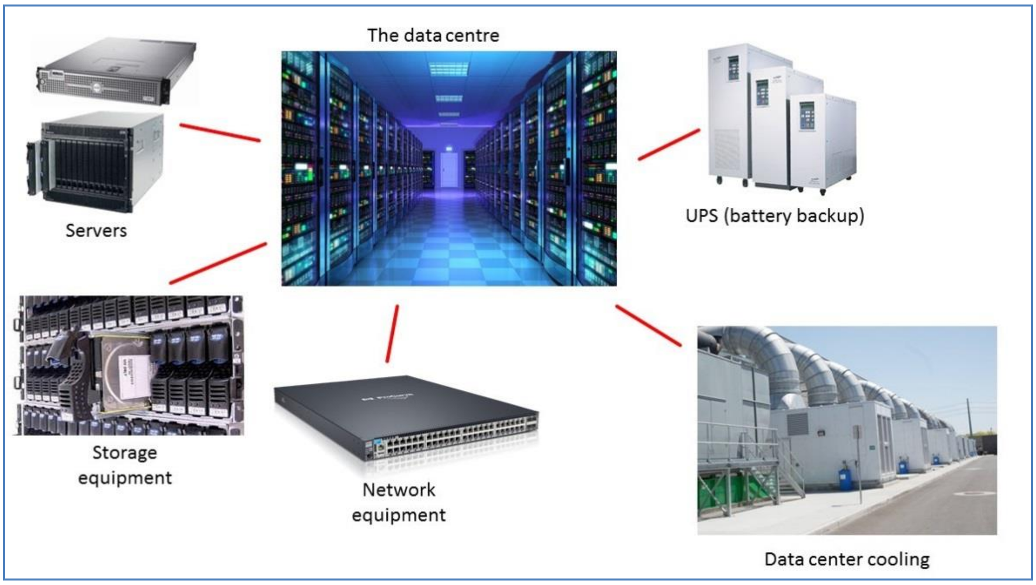

Figure 1 The data centre and main equipment.

2.1 Relevancy of applying points system to data storage systems

Following the conclusions from the Task 3 report on when a points-system approach would be more appropriate to use than a conventional regulatory approach, it can be emphasized:

- There is a mix of quantifiable and qualitative product ecodesign features yet it is necessary to also ascribe some value to the qualitative features because these are expected to bring eco-design benefits.
- Although the presence of specific ecodesign features are known to bring eco-design benefits the relative importance of the benefit to the given ecodesign performance parameter is difficult to determine in a reliable manner at the level at which the scope of a prospective regulation would apply.
- It is too complex to apply a rigorous performance assessment method in practice but a points-based approach (which awards points depending on the eco-design features used) could provide an acceptable compromise that allows requirements to be set that encourage progress in a positive direction without being overly constraining.

These conclusions are further detailed in the following sections.

3. **Regulation and schemes**

In the following sub-sections we briefly present regulations and schemes the point system for data storage systems could be based on. This is primarily the ENERGY STAR scheme and the EU's Ecodesign Regulation, however, EPEAT is also included for inspiration.

3.1 ENERGY STAR

Under the ENERGY STAR programme, a product specification for Data Centre Storage is available. The most recent version of the eligibility criteria is version 1.0 from March 2014[3] (a slightly modified version of the original version). Data Centre Storage has not been adopted as part of the EU ENERGY STAR scheme, though it is considered to fall under the scope of the agreement between the US Government and the European Commission. Currently, enterprise servers are the only data centre equipment type included in the EU ENERGY STAR programme.

The scope of the data storage product specification is basically data centre storage mainly defined by being online 2, 3 and 4 products[4] based in the Storage Networking Industry Association (SNIA) taxonomy[5]. Online is the fastest classification and means that the product can respond very quickly to a user request for data. The number that follows indicates the size of the product and how many storage devices can be installed as well as whether a number of other features are available. Online 2,3 and 4 are the most common low-end and mid-range products excluding consumer products and excluding high-end and mainframe products with limited sales due to their large size and more specialist roles.

Industry sectors have been testing storage products for the ENERGY STAR program, using the SNIA Emerald test. A limited data set is available which includes the active power tests (sequential, transaction) and the idle ready capacity for three classes of products - online 2, online 3 and online 4. There are currently 134 product test results across the 6 possible configurations (2 active tests and 3 product classes), which is reduced to 99 after having removed identical products sold under different product names.

The eligibility criteria of the specification contain the following main requirements:

- Power supply requirements targeting efficiency and power factor
- Power modelling presale tool available for purchasers (for systems that qualify using modelled data)
- Energy efficiency feature requirements:
    - Adaptive active cooling
    - For online 3 and 4 products, at least 1 COM (Capacity Optimizing Method) (see section 4.6)
- Information Reporting Requirements, where a range of product technical data and test data will be reported and displayed at the US ENERGY STAR web site including energy efficiency performance data (performance/watt) for required active and idle state tests (see section 4.3)

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[3] https://www.energystar.gov/products/office_equipment/data_center_storage/key_product_criteria
[4] The online categorisation is according to various parameters such as access pattern, connectivity, maximum configuration etc.
[5] http://www.snia.org/emerald/taxonomyoverview

- Standard Performance Data Measurement and Output Requirements for the storage products, where the products should be capable of measuring and reporting input power and inlet temperature at intervals of not more than every 10 seconds.

3.2 EU Ecodesign and Energy Labelling Regulation

The European Commission is currently preparing a regulation under the Ecodesign Framework Directive with regard to ecodesign requirements for enterprise servers and data storage equipment. The process is still ongoing; such that currently an Impact Assessment is being conducted. A Consultation Forum meeting is anticipated in February 2017.

Several options are being considered, which could combine specific requirements on energy efficiency, material efficiency and product information.

3.3 SNIA Green Storage Initiative

SNIA[6] (Storage Networking Industry Association) is a global industry association for the storage industry having 400 member companies. Among other activities, SNIA develops specifications and global standards.

SNIA has launched the Green Storage Initiative[7] aiming at energy efficiency and energy conservation. One important activity is the development and management of the SNIA Emerald™ Program[8], which aims to provide public access to storage system power usage and efficiency through use of a well-defined testing procedure, and additional information related to system power. This program is essential to provide the information on which energy efficiency and product information requirements could be based.

The program includes a taxonomy for the storage devices and provides a standardized way of reporting vendor-performed test results that characterize the several distinct aspects of storage system energy usage and efficiency including measured test results based on performance and capacity metrics over a range of typical workloads.

The SNIA Emerald™ Program has been developed in relationship with the US EPA ENERGY STAR program, and also with links to the EU ENERGY STAR programme, even though the storage specification has not yet been included in the EU programme.

SNIA Emerald tests the following characteristics (See Section 4.3 for more information):

- Hot band workload test (IOPS/W) – this includes a mixture of semi random reads and writes of different sizes.
- Random reads (IOPS/W)
- Random writes (IOPS/W)
- Sequential reads (MiBPS/W)
- Sequential writes (MiBPS/W)
- Ready Idle (GB/W)

To ensure the tests are consistent and representative of normal performance, the products must be prepared by filling the storage with data and run for a period of time to emulate normal usage and allow the system to carry out optimisations. This can take months to complete.

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[6] http://www.snia.org
[7] http://www.snia.org/forums/green
[8] http://www.snia.org/emerald

The active tests are not exhaustive and only test a specific set of conditions as explained in the SNIA Emerald User Guide. Only the efficiency is given, and not the maximum performance; hence, it cannot be used to calculate the actual active or idle power level.

The Green Storage Initiative also includes training, promotion of storage energy efficiency, external advocacy, support of the technical work etc.

3.4 ASHRAE thermal guidelines

The organisation ASHRAE (American Society of Heating, Refrigerating and Air-Conditioning Engineers) has published thermal guidelines for data centres. A possible operating temperature requirement can be based on thermal classes (A1, A2, A3 and A4) from these guidelines (see the allowable temperature ranges further below).

Compliance with the requirements does not directly result in energy savings, but when all equipment in the data centre or in a specific zone of the data centre can withstand the higher temperatures the data centre operator is able to increase the set point temperature of the cold air and thereby reduce cooling energy demand.

Extending the operating temperature and humidity range also reduces the need for mechanical cooling of the data centre, if free air cooling is a possibility for the data centre. This allows the chillers and cooling units set points to be raised, or switched off when the outdoor air is sufficiently cool.

The allowable temperature (dry bulb) ranges for the classes are:

- A1: 15-32 ºC
- A2: 10-35 ºC
- A3: 5-40 ºC
- A4: 5-45 ºC

3.5 EPEAT

The EPEAT scheme is a voluntary scheme to rate the environmental impact of electronic equipment. It describes itself as follows:

> "EPEAT is a free and trusted source of environmental product ratings that makes it easy to select high-performance electronics that support organizations' IT and sustainability goals. The system began in 2003 with a stakeholder process convened by the U.S. Environmental Protection Agency and has grown to become the definitive global environmental rating system for electronics. Managed by the Green Electronics Council, EPEAT currently tracks more than 4,400 products from more than 60 manufacturers across 43 countries.
>
> The environmental criteria underlying the EPEAT system address the full product lifecycle, from design and production to energy use and recycling. EPEAT product assessment is based on ANSI-approved public standards developed through stakeholder consensus processes. Manufacturers' claims of compliance are subject to ongoing verification by qualified certification bodies. Products found to be in non-conformance are removed from the EPEAT registry, to ensure that purchasers worldwide are able to use the system with confidence.
>
> EPEAT currently includes product ratings for PCs and Displays (including tablets), Imaging Equipment and Televisions. Environmental leadership standards are current-

ly under development with the intent to form the basis of future EPEAT categories for Mobile Phones, Servers and other electronic products. A non-fiduciary Advisory Council provides input and advice about EPEAT expansion and other relevant issues.”

There is also a draft EPEAT scheme for servers, which has not yet been fully finalised. In the case of PCs and displays referred to above, the criteria in Table 1 are applied (criteria are marked with an ‘R’ or an ‘O’ in their title to indicate whether they are Required or Optional).

Table 1 EPEAT criteria for PCs and displays. R: Required, O: Optional.

4.1 Reduction/elimination of environmentally sensitive materials	
R	4.1.1.1 Compliance with provisions of European RoHS Directive upon its effective date
O	4.1.2.1 Elimination of intentionally added cadmium
R	4.1.3.1 Reporting on amount of mercury used in light sources (mg)
O	4.1.3.2 Low threshold for amount of mercury used in light sources
O	4.1.3.3 Elimination of intentionally added mercury used in light sources
O	4.1.4.1 Elimination of intentionally added lead in certain applications
O	4.1.5.1 Elimination of intentionally added hexavalent chromium
R	4.1.6.1 Elimination of intentionally added SCCP flame retardants and plasticizers in certain applications
O	4.1.6.2 Large plastic parts free of certain flame retardants classified under European Council Directive 67/548/EEC
O	4.1.7.1 Batteries free of lead, cadmium and mercury
O	4.1.8.1 Large plastic parts free of PVC
4.2 Materials selection	
R	4.2.1.1 Declaration of postconsumer recycled plastic content (%)
O	4.2.1.2 Minimum content of postconsumer recycled plastic
O	4.2.1.3 Higher content of postconsumer recycled plastic
R	4.2.2.1 Declaration of renewable/bio-based plastic materials content (%)
O	4.2.2.2 Minimum content of renewable/bio-based plastic material
R	4.2.3.1 Declaration of product weight (lbs)

4.3 Design for end of life

- R 4.3.1.1 Identification of materials with special handling needs
- R 4.3.1.2 Elimination of paints or coatings that are not compatible with recycling or reuse
- R 4.3.1.3 Easy disassembly of external enclosure
- R 4.3.1.4 Marking of plastic components
- R 4.3.1.5 Identification and removal of components containing hazardous materials
- O 4.3.1.6 Reduced number of plastic material types
- O 4.3.1.7 Molded/glued in metal eliminated or removable
- R 4.3.1.8 Minimum 65 percent reusable/recyclable
- O 4.3.1.9 Minimum 90 percent reusable/recyclable
- O 4.3.2.1 Manual separation of plastics
- O 4.3.2.2 Marking of plastics

4.4 Product longevity/life cycle extension

- R 4.4.1.1 Availability of additional three year warranty or service agreement
- R 4.4.2.1 Upgradeable with common tools
- O 4.4.2.2 Modular design
- O 4.4.3.1 Availability of replacement parts

4.5 Energy conservation

- R 4.5.1.1 ENERGY STAR®
- O 4.5.1.2 Early adoption of new ENERGY STAR® specification
- O 4.5.2.1 Renewable energy accessory available
- O 4.5.2.2 Renewable energy accessory standard

4.6 End of life management

- R 4.6.1.1 Provision of product take-back service
- O 4.6.1.2 Auditing of recycling vendors
- R 4.6.2.1 Provision of rechargeable battery take-back service

4.7 Corporate performance

- R 4.7.1.1 Demonstration of corporate environmental policy consistent with ISO 14001
- R 4.7.2.1 Self-certified environmental management system for design and manufacturing organizations
- O 4.7.2.2 Third-party certified environmental management system for design and manufacturing organizations
- R 4.7.3.1 Corporate report consistent with Performance Track or GRI
- O 4.7.3.2 Corporate report based on GRI

4.8 Packaging

- R 4.8.1.1 Reduction/elimination of intentionally added toxics in packaging
- R 4.8.2.1 Separable packing materials
- O 4.8.2.2 Packaging 90% recyclable and plastics labeled
- R 4.8.3.1 Declaration of recycled content in packaging
- O 4.8.3.2 Minimum postconsumer content guidelines
- O 4.8.4.1 Provision of take-back program for packaging
- O 4.8.5.1 Documentation of reusable packaging

3.6 Conclusion

The conclusion at this stage is that the existing ENERGY STAR specification, the SNIA Emerald™ Program, the ASHRAE thermal guidelines and the ongoing work on the future potential ecodesign regulation seem to provide a good basis for establishing a points-system for data storage. The draft EPEAT has not been selected, since to date no relevant criteria have been fully finalised. While it is likely that some existing EPEAT criteria could be applied, this would need to be evaluated and assessed during an investigation possibly of similar magnitude to an Ecodesign Preparatory Study. Since the EPEAT criteria development process for servers has been ongoing for 3 years, an in-depth investigation into the possible application of these EPEAT criteria for Ecodesign purposes would represent a very significant effort which is beyond the scope of this "Points System" method application case study.

However, it should be noted that the above-mentioned schemes are recognised globally. Manufacturers have been consulted during their development, and have provided considerable technical and market-based input, thereby securing their ability to work on the global marketplace without disturbing the deliveries of data storage systems required by their clients and users.

In next section, we analyse various elements that could potentially be used for a points system.

4. Analysis of possible points factors for storage equipment

4.1 Aims of the points system

We suggest that the basic aims of a points-system for data storage equipment are two-fold:

- The manufacturers design the products to reduce the current environmental impact of manufacturing and use of the products by improving several product design / use parameters.
- The purchasers and the users will be able to select products which are correctly sized and configured to their needs, and furthermore they will be able to select products which enable users to reduce the products' environmental impact during their life. This requires the manufacturers to provide more technical data and other supportive material and tools, but the actual beneficial impact will only take place if the purchasers and users change their behaviour, based on the new information and performance parameters provided by manufacturers.

4.2 Principles for selecting point factors

The principle is to select point factors which have a major environmental impact and to which points may be transparently attributed, based on objective criteria. As described in the Task 3 report, environmental impact performance criteria can be cardinal, ordinal or nominal.

The basis for the points factors for the data storage systems is:

- Overall energy consumption under certain performance conditions
- Hardware regarding energy efficiency, ambient temperature requirements, sensors for power and temperature, etc.
- Software regarding management of hardware and data through power management, energy efficiency features, data reporting, software for data deletion, etc.
- Information regarding purchase modelling tool (selecting the correct product solution and size related to the needs), efficient use including information relating to system aspects, and disassembly guidance for purchasers, users, refurbishers and recyclers.

In the following, we have considered a range of areas to be included in the points system for storage products based on the schemes presented in Section 3.

4.3 Active and idle performance

There are many factors that affect the purchasing decisions of storage products that may be very difficult to assess. These factors can have a substantial impact on both the product performance and energy performance, and can lead to product over-specification and related increases in energy consumption. However, this is considered to be outside the scope of configuring the ecodesign points at present (although professional procurement services could be considered separately).

Capacity (GB) and ready idle (GB/W)

This is the raw storage capacity ("raw" meaning the amount of data on the media not taking into account RAID systems, compressed data etc.), measured in GB. More storage generally requires more devices (HDDs, SSDs) which consume energy and/or efficient devices which tend to have lower Input/Output (I/O) performance. Maximising energy performance means maximising the number of GB per Watt of power consumed by the hardware. This gives the best indication of the overall power consumption of the product, since the capacity is generally easily quantified. However, current data shows active power to be 2%-20% higher than consumption for maximised performance systems and this also needs to be taken into account. The SNIA Emerald tests report on "ready idle", and this is reported in the ENERGY STAR.

Input/Output performance measures the amount of data being transferred to and from the client. There are two main performance measurements that are used, transactional and sequential.

Transactional performance (IOPS) and transactional energy performance (IOPS/W)

IOPS measures the number of discrete transactions completed per second, often from multiple processes and clients. The data transferred in each transaction tends to be small and random. Optimising for performance favours the use of SSDs and small, fast-rotating HDDs. Two additional techniques can be used to improve the transactional performance, while also trying to maximise the capacity and GigaBytes/Watt performance:

- Caching: Some data is more frequently accessed than others e.g. new emails and latest articles on a webpage – rather than being truly random. Caching uses a mixture of hardware and software to identify the most commonly accessed data and to place it in higher-performance temporary storage.
- Auto-tiering: This is similar to caching, but sorts the data on the permanent storage between storage devices of different performance.

Because the data is not accessed completely randomly in real life situations, a performance test can be designed to access particular subsets of data more frequently. This is known as hot band testing, which also measures the benefit of caching and auto-tiering.

Sequential performance (MiBPS) sequential energy performance (MiBPS/W)

Throughput refers to the amount of data transferred per second and is used for measuring sequential performance, where larger quantities of data are being accessed contiguously in a stream.

Regarding read/write performance, transactional and sequential I/O performance can be further divided into "reads" and "writes". This is not addressed in this case study, due to the limited product test data available, as well as the lack of usage data, but it is recognised that it can have a large impact on performance and efficiency.

4.4 Power Supply Unit (PSU) efficiency

In this case study, we define the PSU energy efficiency in the same way as is done in the ENERGY STAR program, in order to align ourselves with international practice and to be able to use Energy Star data. We have included here the efficiency requirements. These efficiency requirements represent a cardinal criterion, and relate directly to the overall product energy efficiency and energy consumption. These requirements also have an impact on the infrastructural energy consumption (UPS, cooling etc.).

We have not included the power factor requirements, mainly because they have been proposed as part of the draft regulation for Lot 9

The criteria considered can be proposed in the following form (copied from the draft regulation for Lot 9 discussed at the Ecodesign consultation forum meeting of 17/02/2017; for brevity, only the requirements for the first tier are shown):

Table 1 Minimum PSU efficiency and power factor requirements from 1 January 2019

	Minimum PSU efficiency				Minimum power factor
% of rated load	10%	20%	50%	100%	50%
Non redundant	-	90%	92%	89%	0.90
Redundant	-	88%	92%	88%	0.90

In principle, points could be allocated according to the percentage efficiency at the various loads or at an average of the three load points, which requires an assumption on the average duty profile. The criteria may be updated based on the currently ongoing Impact Assessment of servers and storage systems, where the efficiency figures are slightly adjusted.

PSU efficiency will be reflected in the active and idle performance levels but will not cover the full range of PSU load levels. It is often considered as a separate item because raising PSU efficiency is very effective at ensuring higher component level efficiency, especially when it is difficult to set sufficiently challenging active and idle power efficiency targets.

4.5 Power modelling presale tool available

A power modelling tool helps purchasers to select the right storage system for their needs, and to optimise their energy performance.

The criterion is based on ENERGY STAR:

> Power Modeling Presale tool: For systems that qualify using modeled data, EPA expects that a power modeling tool characterizing the storage product will be made available to manufacturer qualified purchasers of the product. The power modeling tool must provide an estimated energy efficiency performance of a deployed configuration based on user-selected configuration characteristics. Systems that are qualified using modeled data are expected to make performance/watt data available to manufacturer qualified purchasers of the product.

It can be included for all systems (not only those that qualify using modelled data). Points could be allocated if the tool is available.

4.6 Energy efficiency feature requirements

We include here the requirements on specific energy efficiency features. The first is that of Adaptive Active Cooling, based on ENERGY STAR. The criterion is nominal, and relates solely to the energy consumption of the cooling technology in the storage equipment (e.g. fans).

The criterion is as follows (copied from the ENERGY STAR specification):

Adaptive Active Cooling: Primary components of a storage product must utilize adaptive cooling technologies that reduce the energy consumed by the cooling technology in proportion to the current cooling needs to the storage product. (e.g., reduction of variable speed fan or blower speeds at lower ambient air temperature). This requirement is not applicable to devices that employ passive cooling.

A certain points score could be given if the product either has adaptive active cooling or passive cooling and no points if this is not the case.

The next criteria relate to COM (Capacity Optimising Methods) features, also based on ENERGY STAR. The criteria are explained as follows.

A storage product shall make available to the end user configurable/ selectable features listed in Table 2, in qualities greater than or equal to those listed in Table 2.

Table 2 Recognised COMs Features

Feature	Verification Requirement
COM: Thin Provisioning	SNIA verification test
COM: Data Deduplication	SNIA verification test
COM: Compression	SNIA verification test
COM: Delta Snapshots	SNIA verification test

Table 3 COM requirements for Online 2, 3 and 4 Systems

Storage Product Category	Minimum number of COMs required to be made available
Online 2	0
Online 3	1
Online 4	1

Each COM makes better use of the available storage:

- Thin provisioning allocates the minimum amount of space required to each application or server, to minimise the amount of unused space. More space is then allocated as demanded. This differs from thick provisioning where the future maximum space required is allocated, leading to a large proportion of unused space, sometimes up to 90%.
- Data deduplication analyses the data stored and removes duplicate versions of the same data, and replaces it with a reference pointing to the original data. A simple example of this is sending an email attachment to multiple users on a company email server. Rather than storing a separate copy of the attachment for every user, the storage will keep the original copy and each email will reference it.
- Compression uses special algorithms to reduce the size of individual files, or groups of files by identifying and eliminating statistical redundancy.

- Delta snapshots compare the difference between multiple copies of files or datasets. Rather than storing the whole file, it compares the difference and stores only the changes (delta).

These criteria are nominal and indirectly affect the energy consumption of the overall product. All the features help to maximise the amount of useful data that is stored per unit of RAW capacity available from the storage devices. This allows the user to select a smaller storage product with fewer energy consuming storage devices installed. The impact could be substantial – the product could have less than half the number of storage devices (with associated reductions in energy consumption) - but it also depends on the following factors: the type of data stored, the number of users, the frequency of data edits etc. It naturally also depends on the active use of the features over the lifetime of the products.

4.7 Commissioning guidance

After configuration of the hardware, the product software and settings are still highly configurable by the end user. This is necessary to maximise the performance and efficiency against the actual workload. The impact and work required to optimise the product depends on the size and complexity of the system as well as the workload itself. Guidance can assist the user to configure the product; however, as complexity increases, it becomes a more involved problem, requiring assessment of the workload both before and after purchase. Therefore, commissioning guidance delivered by an external professional would optimise the storage. This could be included in the points system, however, it could increase verification complexity for market surveillance authorities.

4.8 Information reporting requirements

Information reporting requirements can ensure that detailed data is provided to enable purchasers to select the right storage system according to their needs and the environmental performance required. The ENERGY STAR information reporting criteria are shown below, and specify the data which product suppliers need to publish. The ENERGY STAR specification specifies several requirements for the test configurations and the measurements behind these data.

The following information will be displayed on the ENERGY STAR website:

Product model name, model number, and SKU or other configuration identification number;

A list of important product characteristics, including;

(a) System configuration;

(b) Storage controller details (e.g. model name and number);

(c) Software configuration;

(d) Storage controller power supply information;

(e) Storage device drawer power supply information;

(f) Storage devices used per optimization points;

(g) Input power and environmental characteristics during testing;

(h) System power optimization capabilities;

(i) Inlet air temperature and power consumption reporting capabilities.

A list of qualified system configurations, including maximum, minimum and optimal configurations of qualified product families; and disclosure of the time period used for data averaging.

A list of power management and other power saving features available and enabled by default;

Specified thermal measurements conducted during testing;

For product families, a list of qualified storage products within the family; and

Energy Efficiency Performance data (performance/watt) for required active and idle state test reporting specified in Table 7 below:

Active and Idle State Efficiency Test Results Displayed on the ENERGY STAR Website

Workload Test	Transaction Optimization	Streaming Optimization	Capacity Optimization
Hot Band	Yes	No	No
Random Read	Yes	No	No
Random Write	Yes	No	No
Sequential Read	No	Yes	No
Sequential Write	No	Yes	No
Ready Idle	Yes	Yes	Yes

This criterion is nominal and indirectly affects the energy consumption of the overall product, because it stimulates the purchaser to use the criteria to select a more optimised and more energy efficient product than the purchaser would have otherwise selected.

Points could be given if the information is publicly available for the purchaser.

4.9 Standard performance data measurement and output requirements

The criterion is based on ENERGY STAR. The criterion is:

> 3.7.1 Data Elements: Online 3 and Online 4 storage products shall be capable of measuring and reporting the following data elements at the storage product level:
>
> i. Input Power, in watts. Input power measurements must be reported with accuracy within ±5% of the actual value for measurements greater than 200 W, through the full range of operation. For measurements less than or equal to 200 W, the accuracy must be less than or equal to 10 W multiplied by the number of installed PSUs; and
>
> ii. Inlet Air Temperature (optional), in degrees Celsius, with accuracy of ± 2°C.
>
> 3.7.2 Reporting Implementation:
>
> i. Data shall be made available in a published or user-accessible format that is readable by third-party, non-proprietary management systems;
>
> ii. Data shall be made available to end users and third-party management systems over a standard network connection;
>
> iii. Data shall be made available via embedded components or add-in devices that are packaged with the storage product (e.g., a service processor, embedded power or thermal meter or other out-of-band technology, iPDU, or pre-installed OS);
>
> iv. When an open and universally available data collection and reporting standard becomes available, manufacturers should incorporate the universal standard into their products.

The criterion is qualitative and can affect the energy consumption of individual components separately and the overall product, respectively – depending on how the data is used. In principle, points could be awarded if the data measurement and output requirements features are present in the product. Points could be awarded proportional to the number of aspects of the full feature set that are implemented.

4.10 Minimum operating condition

This criterion is based on the work being conducted under Ecodesign DG Growth Lot 9, which is currently undergoing an Impact Assessment. The criterion is based on the fact that if the storage product can withstand larger variations in surrounding temperatures and humidity, the energy consumption and related cost can be reduced. E.g. if the storage product is well-functioning at 30 ºC instead of at 25 ºC, the inlet air temperature needs to be cooled less with reduced energy consumption as a consequence.

Therefore, an ordinal requirement for the minimum specific level to comply with according to the table below could be included. Lower row in the table indicates larger temperature and humidity ranges allowed and less energy consumption.

There are a fewer negative consequences of allowing increased inlet air temperatures: The product's energy consumption, noise emissions and failure rates are slightly increased. However, in most cases, the net result is positive.

The basis for the criteria is the table reproduced below, from "ASHRAE TC 9.9. 2011 Thermal Guidelines for Data Processing Environments – Expanded Data Center Classes and Usage Guidance".

Classes (a)	Equipment Environmental Specifications							
	Product Operations (b)(c)					Product Power Off (c) (d)		
	Dry-Bulb Temperature (˚C) (e) (g)	Humidity Range, non-Condensing (h) (i)	Maximum Dew Point (˚C)	Maximum Elevation (m)	Maximum Rate of Change(˚C/hr) (f)	Dry-Bulb Temperature (˚C)	Relative Humidity (%)	Maximum Dew Point (˚C)
Recommended (Applies to all A classes; individual data centers can choose to expand this range based upon the analysis described in this document)								
A1 to A4	18 to 27	5.5ºC DP to 60% RH and 15ºC DP						
Allowable								
A1	15 to 32	20% to 80% RH	17	3050	5/20	5 to 45	8 to 80	27
A2	10 to 35	20% to 80% RH	21	3050	5/20	5 to 45	8 to 80	27
A3	5 to 40	-12˚C DP & 8% RH to 85% RH	24	3050	5/20	5 to 45	8 to 85	27
A4	5 to 45	-12˚C DP & 8% RH to 90% RH	24	3050	5/20	5 to 45	8 to 90	27
B	5 to 35	8% RH to 80% RH	28	3050	NA	5 to 45	8 to 80	29
C	5 to 40	8% RH to 80% RH	28	3050	NA	5 to 45	8 to 80	29

In principle, points could be awarded according to the A-level, i.e. A1, A2, A3 and A4, which are those classes relevant for data centres. This is further described in the next section.

The energy consumption for cooling depends on the specific data centre design and cooling solution selected and the climatic condition at the data centre location. The climatic condition has an impact on cooling needs and the cooling system efficiency. Typically, the climatic conditions only have a smaller impact on the energy consumption for cooling. The reason is that the proportion of the total data centre consumption for cooling is around 30 % and even with a variation of 30 % due to the climatic conditions between the warmest and coolest locations, the variations in the overall data centre consumption would be less than 10 %.

The efficiency of the data centre infrastructure (power and cooling equipment) is measured by the PUE[9] (Power usage effectiveness). PUE is a metric indicating the proportion of the total power consumption (infrastructure and IT) as a ratio compared to the power consumed by the critical IT equipment only. That is, if no power is used by the infrastructure, the PUE is 1. As the infrastructure consumes more energy, the PUE ratio increases. Common PUE values range from 1.1 to 3, with an average assumed to be around 1.67 (i.e., this means that the infrastructure and cooling power consumption amounts to roughly two-thirds of the power consumed by the IT equipment, and must then be added to the IT power consumption to be a measure of the total power consumption). The PUE value is also correlated with the data centre size due to a combination of technical reasons and lack of expertise and resources in smaller data centres (DCs). Smaller data centres typically have larger PUEs. Since product size tends to also be correlated with the data centre size, it may be possible to correlate them directly.

[9] http://www.thegreengrid.org/~/media/WhitePapers/White_Paper_6_-_PUE_and_DCiE_Eff_Metrics_30_December_2008.ashx?lang=en

4.11 Material efficiency

The criterion is based on the work under Ecodesign DG Growth Lot 9, which is still undergoing an Impact Assessment. It may include allocating points to a list of components, which can be accessed and removed, e.g. disks, memory, electronic boards, power supply and chassis. Furthermore, points could also be awarded for the provision of built-in software for secure data deletion and for the availability to provide firmware updates. If the owner or user of the storage product could be sure that all data – also highly confidential and critical data – had been securely deleted, the owner/ user should have no issues with delivering the full product for reuse. However, if this is not the case, they may destroy the storage media, for security/ commercial confidentiality reasons.

Regarding availability of firmware updates, it would increase the value of the storage product if it could be delivered with fully updated firmware because otherwise it would be difficult to reuse the product if the firmware does not include the most recent bug fixes etc. Currently, not all manufacturers deliver firmware updates outside the partner companies connected to the manufacturer.

Material efficiency has not been included in the Ecodesign, partly because for keeping the case study example less complex, partly because requirements have been proposed as part of the draft regulation for Lot 9.

4.12 Summary of Ecodesign Parameters

The table below summarizes the Ecodesign parameters.

Table 4 Summary of Ecodesign Parameters

Parameter/feature	Environmental impact	Boundaries	Cardinal/ Ordinal?	Origin	Measurement standard
Active and idle performance	EE	DS on mode	Cardinal	E Star & SNIA	• ENERGY STAR® Program Requirements. Product Specification for Data Centre Storage Eligibility Criteria. Version 1.0. Rev. March-2014
PSU efficiency	EE	DS on mode	Cardinal	E Star	• ENERGY STAR® Program Requirements. Product Specification for Data Centre Storage Eligibility Criteria. Version 1.0. Rev. March-2014
Power modelling presale tool available	Energy consumption through right sizing	DS + cooling system	Qualitative	E Star	• ENERGY STAR® Program Requirements. Product Specification for Data Centre Storage Eligibility Criteria. Version 1.0. Rev. March-2014
Energy efficiency feature requirements	EE cooling, EE indirect, material efficiency	DS + cooling system	Nominal/ Ordinal/Cardinal	E Star	• ENERGY STAR® Program Requirements. Product Specification for Data Centre Storage Eligibility Criteria. Version 1.0. Rev. March-2014 • SNIA verification test
Commissioning guidance	Energy consumption through configuration of the DS	DS + cooling system	Qualitative		
Information reporting requirements (Active and idle state efficiency disclosure and other data)	EE indirect	DS	Nominal	E Star	• ENERGY STAR® Program Requirements. Product Specification for Data Centre Storage Eligibility Criteria. Version 1.0. Rev. March-2014
Standard performance data measurement and output requirements	EE indirect	System and component	Nominal	E Star	• ENERGY STAR® Program Requirements. Product Specification for Data Centre Storage Eligibility Criteria. Version 1.0. Rev. March-2014
Minimum operating condition	EE cooling	DS + cooling system	Nominal /Ordinal	Lot 9	ASHRAE TC 9.9. 2011 Thermal Guidelines for Data Processing Environments – Expanded Data Centre Classes and Usage Guidance
Material efficiency requirement	Material efficiency	DS info on dismountability and increased reuse	Nominal	Lot 9	

In the following section has been a number of the above ecodesign parameters been selected for further analysis focusing on energy performance and energy efficiency parameters.

5. Proposal for an Ecodesign points-system for data storage

5.1 Methodological framework

The methodological framework is described in detail in the Task 3 report. Nine well-defined assessment steps are used for the determination of whether a points system approach is justified and feasible in principle and, if this is confirmed to be the case, for awarding points.

In the following, we apply these steps to the case of data storage.

5.2 Step 1 Assessment of key lifecycle stages

This step has already been fully addressed by the preparatory study for data centres: DG ENTR Lot 9 - Enterprise servers and data equipment[10], which included storage equipment, and the subsequent and currently ongoing Impact Assessment. Figure 2 is reproduced from the preparatory study and, as discussed in previous sections, shows that the major impacts are:

- Material for the production and the production processes
- End-of-life treatment
- In-use electricity consumption for the storage system itself
- In-use electricity consumption for the directly-related energy services of the data centre in which the storage systems are placed (mainly cooling, UPS system, network equipment and power distribution units).

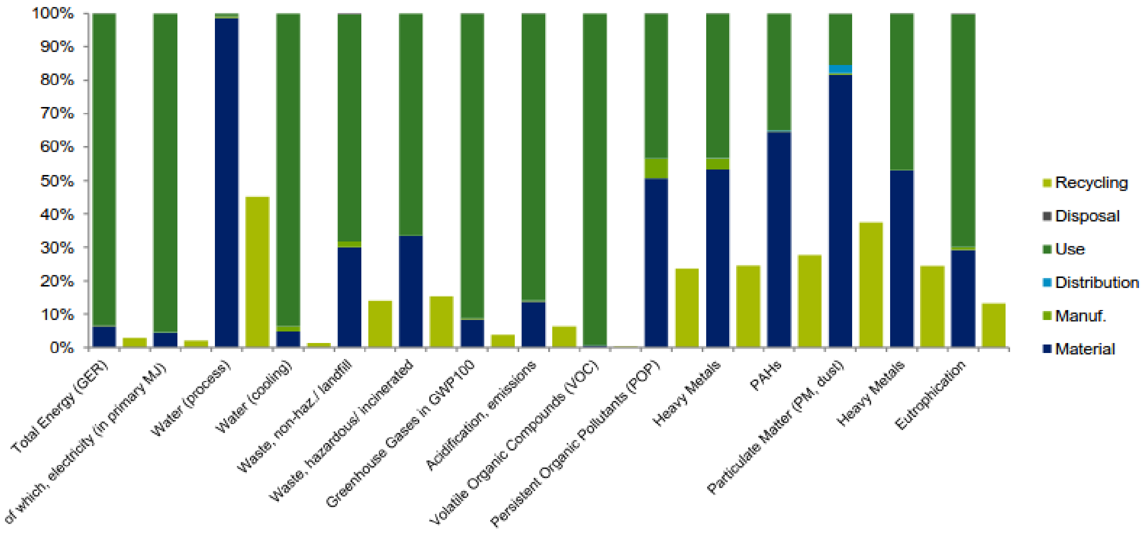

Figure 2 Distribution of environmental impacts by life cycle phase[11]

[10] http://www.eup-network.de/fileadmin/user_upload/2015/BIO_ENTR_Lot_9_Task_5_FV_20150731.pdf
[11] http://www.eup-network.de/fileadmin/user_upload/2015/BIO_ENTR_Lot_9_Task_5_FV_20150731.pdf

5.3 Step 2 Assessment of product scope boundaries and associated impacts at the wider (extended product or product-system) level

The data storage system has impacts both on an extended product level and on a product system level.

The impact on the extended product level is due to the varying loads on the data storage systems in dependency of the usage pattern.

The product scope boundaries should be all of the data centre because there is a direct impact of the product's energy consumption on the overall data centre energy consumption primarily due to the losses in the UPS system (through which all the electricity provided to the data storage system passes) and due to the associated energy consumption of the cooling system needed to remove the heat dissipated by the storage system.

5.4 Step 3 Selection of environmental impact criteria

As described in the previous sections, the electricity consumption during the use phase on the product system level (the product itself and the data centre) and the material efficiency are the most important environmental impact criteria the points-system should target.

5.5 Step 4 Determination of the phases at which product design may influence lifecycle impacts

The product design will influence substantially the use phase and the end of life phase. During the product design, the required and desired level of energy performance during use will be decided and similarly design choices for easy re-use, disassembly and recycling etc. can be taken.

5.6 Step 5 Assessment of whether a points system approach is potentially merited or not

The Task 3 report provides three questions to ask and if the answer is Yes to any of those, then a points approach may be appropriate:

a) There are a mix of quantifiable (cardinal) and more qualitative product ecodesign features yet it is appropriate to also ascribe some value to the qualitative features because these are expected to bring eco-design benefits?
   - Yes, this is the case for storage systems as the previous section clearly shows.

b) Although the presence of specific ecodesign features are known to bring ecodesign benefits the relative importance of the benefit to a given ecodesign performance parameter is difficult to determine in a reliable manner at the level at which the scope of a prospective regulation would be expected to apply?
   - For some of the features yes, others no

c) It is too complex to apply a rigorous performance assessment method in practice but a points-based approach (which awards points depending on the eco-design features used) could provide an acceptable compromise that allows requirements to be set that encourage progress in a positive direction without being overly constraining?
   - It is especially complex to set requirements on the energy performance of the storage systems because a test method would be complex[12] and because the performance activity varies a lot between the users of storage systems.

[12] Due to the complexity of the storage products, in particular potentially hundreds of storage devices, and the algorithms which manage and optimise the system over time based on the use patterns, it is not possible to

5.7 Step 6 Assessment of the implications of product modularity

The modularity of data storage systems mainly concerns the size of the data storage capacity and the configurability of the system e.g. regarding network interfaces.

It would be possible to allocate points on a module–by-module basis, and to aggregate them upwards to attain an overall score.

5.8 Step 7 Assessment of the implications of product performance sensitivity to the final application

Typically, the specific storage product has one main application, i.e. to store and give access to data, though within the overall storage category, there are more types of applications defined according to e.g. access times and data security. However, the main uncertainties regarding the applications concern the duty profile of the product, i.e. with respect to:

- the kind of storage products being used.
- the kind of data to be stored and how often they are stored and retrieved
- the variation in the usage pattern over the day, the week and the year, etc.

In principle, some types of overall representative duty profiles could be defined (e.g. for storage related to traditional office productivity, large database management, banking systems, etc.). However, these would be very rough, and would not cover all types of applications. The preparatory study did not develop application-specific duty profiles and there is not enough data available to create such a specific profile. Thus, for absolute clarity, it should be emphasised that this case study is not based on a duty profile.

Rather than use a duty profile across all these parameters, SNIA and ENERGY STAR have developed a testing method which tests the efficiency of the product under the performance parameters described in section 4.3. These performance characteristics are associated with particular types of applications, and are split into capacity, transaction and streaming (see description in the following). The current testing methodology and the environmental impact budgets has been designed to create metrics that are largely representative of these three application groups (see SNIA Emerald test description for details on the various types of tests):

- **Capacity applications** simply store a very large amount of data and are not sensitive to the I/O (input / output) performance. Therefore, efficiency is measured (by use of SNIA Emerald test) only by how much data can be stored per Watt of power, i.e. the ready idle test. The active tests are not relevant.
- **Transactional applications** tend to be the most common type and include databases, virtualisation, web servers etc. In this situation, the data transaction are mostly small and random and therefore the hot band test and ready idle are both relevant measures of energy performance.
- **Streaming applications** such as backup/recovery and streaming media files involve reading and writing large files and blocks of data in sequence. In this situation, the sequential tests and ready idle are both used to measure energy performance.

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produce a realistic test results on a new product. The product must be prepared with data transactions for days, or weeks to reach a steady state for every individual test being performed. Without preparation there is too much variability in the results.

Table 5 Relationship between three principal application groups and the SNIA Emerald energy performance tests.

	Hot band test IOPS/W	Sequential test MiBPS/W	Ready idle capacity GB/W
Capacity applications	N	N	Y
Transactional applications	Y	N	Y
Streaming applications	N	Y	Y

Data storage devices are typically configured and optimised to one of the three above principal application groups and it is therefore sufficient to have an individual metric for each of those. The configuration is mainly related to hardware e.g. number, size and type of disks.

In practice, virtually all applications will have a fraction of other types of workloads (e.g. sequential logging for database applications), and some users will have very mixed workloads. This issue of users using a product differently than the marketed product use is common for many products under ecodesign regulations and it is not seen as an important barrier to the positive environmental impact.

It may though be possible to address the issue of mixed workload with more test data for the storage system.

5.9 Step 8 Determination of environmental impact budgets

This sub-section relates directly to the analyses in Section 4. In the following, we go through the individual areas and provide a proposal on the impacts.

The areas are divided into the following, each with one or more individual ecodesign options:

- Energy performance (Ecodesign options 1-5)
- Energy efficiency feature - COMs (Ecodesign option 6)
- Energy efficiency feature - Minimum operating condition (Ecodesign option 7)
- Energy efficiency feature - Good Commissioning Guidance (Ecodesign option 8)

Additional areas have been assessed in the following text, but not included.

This case study is developed on the data available (from Energy Star) and only covers the in-use energy performance factors. There are a number of possible shortcomings which are also discussed in this section. This does not necessarily imply that the Ecodesign methodology is limited, but it does highlight the importance of the test data and testing standards to the success of this methodology.

Energy performance (Ecodesign options 1-5)

Without power consumption information, and associated usage data, it is not possible to create a duty profile and thus calculate the energy consumption. It should also be noted that the active tests are carried out at 100% load, which is very unlikely in real life. However, using only the idle test may also be misleading, since the active power of present-day products can be up to 20% higher than at idle.

Therefore, in this exercise weightings are applied to the efficiency test results, based on a professional judgement of the relative importance of the test and how representative it is of the overall efficiency. Note that in a full-scale professional application of this methodology for Ecodesign Directive purposes, this would need to be verified in an Ecodesign Preparatory Study before it could be applied in any Ecodesign implementing measure.

Due to the number of possible hardware configurations, potentially millions per product, as well as different set-ups and software optimisations, only one optimised configuration is tested and reported for the three different applications. This is referred to as the 'best foot forward' configuration by SNIA[13]. The optimal configuration is determined by modelling the performance of different product configurations and identifying inflection points where performance stops increasing, or slows down.

It is assumed that the optimised configuration for the testing is representative of the performance for other optimal configurations for specific user workloads of the same application type. This means that the user can compare the efficiency rating between products for the application type required, and this will indicate the relative efficiencies of the products when configured for the user's workload.

Basic analysis of the ENERGY STAR data across all product classes does not show any correlation between the performance efficiency tests. This is due to the complexity of the products. A more in-depth, but still preliminary analysis, has been completed by The Green Grid[14]. Using solely energy performance data, without any product performance data, it is not possible to group and compare products with similar performance levels. Instead, all the available data were used.

Based on previous sections and the team's assumptions based on experience and judgement, the example weighting of the idle and active tests are below.

Table 6 Estimated weightings applied by energy performance test for each of the principal application types

	Hot band workload test IOPS/W	Seq read workload test MiBPS/W	Seq write workload test MiBPS/W	Ready Idle workload test GB/W
Transactional applications	37.5%	0%	0%	62.5%
Streaming applications	0%	22%	11%	67%
Capacity applications	0%	0%	0%	100%

[13] The SNIA User Guide for the SNIA EmeraldTM Power Efficiency Measurement Specification states: "The Best Foot Forward (a.k.a." sweet spot") as a methodology for testing product/family configurations at the peak values of the power efficiency metrics was introduced in Section 3.4. The stated benefit of this approach is to reduce the testable sets from a large variable range to fewer in number (potentially just one) with the test results representative of the entire product family." The guide describes a method for finding the Best Foot Forward configuration by using prediction tools. Using the method, a large range of configuration variables can be evaluated and the predicted sweet spots arrived at relatively quickly.

[14] http://www.snia.org/sites/default/files/emerald/EPA_Storage_Stakeholders_Nov-2015/TGG_Emerald_Analysis_Discussion.pdf

The active power tests (i.e. the hot band and the sequential tests) have lower weightings because they are less representative of the actual power consumption, while the capacity is more closely related to the overall power. The weightings are combined using the arithmetic mean, which is appropriate for a duty profile where the usage in each mode is fixed. However, the geometric mean may be more appropriate, because this is not based on usage time, but rather on independent performance aspects.

Based on these weightings, the first five ecodesign options are developed based on the ENERGY STAR data (the data refer to the BAT of storage devices). These are independent of each other.

- Reference case – this is based on the average energy performance taken from the ENERGY STAR data, calculated used the estimated weightings in table 6 for each of the applications.
- Ecodesign option 1 – this is based on the product model and configuration in the ENERGY STAR data with the highest hot band performance. Option 1 is only relevant for transactional applications.
- Ecodesign option 2 – this is based on the product model and configuration in the ENERGY STAR data with the highest sequential read performance. Option 2 is only relevant for streaming applications.
- Ecodesign option 3 – this is based on the product model and configuration in the ENERGY STAR data with the highest sequential write performance. Option 3 is only relevant for streaming applications.
- Ecodesign option 4 – this is based on the product model and configuration in the ENERGY STAR data with the highest ready idle performance. Option 4 is relevant to all applications.
- Ecodesign option 5 – this is based on the product model and configuration in the ENERGY STAR data with the highest overall performance calculated using the estimated weightings for each application. This is thus the BAT of the data storage devices (but not an optimised BAT for a theoretical device with BAT of all components are composed)

Energy efficiency feature - COMs (Ecodesign option 6)
There are four COMs methods available (deduplication, thin provisioning, delta snapshots, compression), and their benefit differs depending on the application. For simplicity, Ecodesign option 6 assumes that either all the COMS are available and will be applied, or otherwise, no benefit is given.

COMS effectively increase the amount of capacity without increasing the number or size of the energy-consuming storage devices, and therefore the COMS improve the ready idle performance. The precise reduction is not known, and depends on the application. Due to the lack of data, the improvements must be estimated, and this is reflected in its relative weighting. Streaming applications often include incompressible data, or use software with COMS function already built-in, and therefore the COMS weighting for the product is reduced.

Table 7 Estimated COMs ready idle improvement weighting[15]

	Ready idle improvement
Transactional applications	40%
Streaming applications	17%
Capacity applications	45%

Eodesign option 6 - use of COMs - is applied on top of the elements already contained in Ecodesign option 5. To calculate the "Ready idle" performance for transactional application Ecodesign option 6, for example, the ready idle performance is taken from Ecodesign option 5 (588.1 GB/W Table 8) and multiplied by an additional estimated improvement of 40%, to thus give 823.3 GB/W. The total performance is then recalculated using the weightings in Table 6.

The table below summarises the performance from the ENERGY STAR performance tests and COMS for transactional applications. The 'a' assignation to the ecodesign options means that all product data available is used. The total performance is calculated as the arithmetic mean of the performance tests using the estimated weightings in Table 6. Options 2a and 3a are marked n/a because sequential performance does not apply to transactional applications.

The performance test results are indicated as figures with units (e.g. IOPS/W), however, these figures are directly converted to points without units without changing the figure. This is to be considered as a point scale for each of these four parameters, where the scale number-wise is one to one.

E.g. for the transactional applications in Table 8, we use this point scale:

- Hot band workload test: 1 IOPS/W corresponds to 1 point
- Readly idle capacity workload test: 1 GB/W corresponds to 1 point

The point scale is based on expert estimations and may be re-assessed in a further study, because the scale is fundamental to the calculated performance level of the device.

After having applied these points, they can be summed to one total performance figure, which is representative of output/Watt.

[15] These values are the expert team's best estimate. The savings are potentially much higher but due to the uncertainty the estimated savings are reduced in line with the methodology.

Table 8 Energy budget for transactional applications based on SNIA tests and COMs. Seq read and write coloumns do not contain figures because this table is for transactional applications

Transactional Applications					
	Hot band workload test (IOPS/W)	**Seq read workload test (MiBPS/W)**	**Seq write work-load test (MiBPS/W)**	**Readly idle capaci-ty workload test (GB/W)**	**Total performance**
Reference case	6.6			97.1	63.2
Ecodesign option 1a (BAT Hot band workload test)	157.0			94.5	117.9
Ecodesign option 2a (BAT Seq read workload test)					n/a
Ecodesign option 3a (BAT Seq write workload test)					n/a
Ecodesign option 4a (BAT Ready Idle workload test)	8.4			588.1	370.7
Ecodesign option 5a (BAT Total Perfor-mance Score)	8.4			588.1	370.7
Ecodesign option 6a (case 5a including COMS)	8.4			823.3	517.7

Example of calculation for the reference case, where the weightings from Table 6 have been applied to the figures in Table 7:

Total performance of the reference case = (37.5% x 6.6) + (62.5% x 97.1) = 63.1625 (rounded to 63.2).

Since the values presented in the tables above are expressed as ratios where a higher number is better (because this is the format of the available data), we have chosen to invert them so that a lower value is superior, to thus make it resemble an energy efficiency index more closely. The way to do this is to invert the total performance score value, as shown in the table below.

Table 9 Inverted Energy budget for transactional applications based on SNIA tests and COMs

Transactional Applications		
	Total performance	**Inverted total performance**
Reference case	63.2	0.01583
Ecodesign option 1a (BAT Hot band workload test)	117.9	0.00848
Ecodesign option 2a (BAT Seq read workload test)	n/a	n/a
Ecodesign option 3a (BAT Seq write workload test)	n/a	n/a
Ecodesign option 4a (BAT Ready Idle workload test)	370.7	0.00270
Ecodesign option 5a (BAT Total Performance Score)	370.7	0.00270
Ecodesign option 6a (case 5a including COMS)	517.7	0.00193

In some situations, the ecodesign option results in poorer efficiency compared to the reference. This results in an EEI greater than 100% because the reference case has EEI = 100%. This occurs in the streaming applications below where selecting the highest performance sequential read/write products in ecodesign options 2 and 3 results in a much larger drop in performance of the ready idle which harms the overall result.

Table 10 Energy budget for streaming applications based on SNIA tests and COMs

Streaming Applications					
	Hot band workload test (IOPS/W)	**Seq read workload test (MiBPS/W)**	**Seq write workload test (MiBPS/W)**	**Readly idle capacity workload test (GB/W)**	**Total performance**
Reference case		5.68	4.66	54.4	38.0
Ecodesign option 1a (BAT Hot band workload test)					n/a
Ecodesign option 2a (BAT Seq read workload test)		21.59	14.24	23.0	21.7
Ecodesign option 3a (BAT Seq write workload test)		21.59	14.24	23.0	21.7
Ecodesign option 4a (BAT Ready Idle workload test)		9.54	2.84	743.6	498.1
Ecodesign option 5a (BAT Total Performance Score)		9.54	2.84	743.6	498.1
Ecodesign option 6a (case 5a including COMS)		9.54	2.84	870.0	582.4

Table 11 Inverted Energy budget for streaming applications based on SNIA tests and COMs

Streaming Applications		
	Total performance	**Inverted total performance**
Reference case	38.0	0.02628
Ecodesign option 1a (BAT Hot band workload test)	n/a	n/a
Ecodesign option 2a (BAT Seq read workload test)	21.7	0.04605
Ecodesign option 3a (BAT Seq write workload test)	21.7	0.04605
Ecodesign option 4a (BAT Ready Idle workload test)	498.1	0.00201
Ecodesign option 5a (BAT Total Performance Score)	498.1	0.00201
Ecodesign option 6a (case 5a including COMS)	582.4	0.00172

Table 12 Energy budget for capacity applications based on SNIA tests and COMs

Capacity Applications					
	Hot band workload test (IOPS/W)	**Seq read workload test (MiBPS/W)**	**Seq write workload test (MiBPS/W)**	**Ready idle capacity workload test (GB/W)**	**Total performance**
Reference case				77.9	77.9
Ecodesign option 1a (BAT Hot band workload test)				n/a	n/a
Ecodesign option 2a (BAT Seq read workload test)				n/a	n/a
Ecodesign option 3a (BAT Seq write workload test)				n/a	n/a
Ecodesign option 4a (BAT Ready Idle workload test)				743.6	743.6
Ecodesign option 5a (BAT Total Performance Score)				743.6	743.6
Ecodesign option 6a (case 5a including COMS)				1078.2	1078.2

Table 13 Inverted Energy budget for capacity applications based on SNIA tests and COMs

Capacity Applications		
	Total performance	**Inverted total performance**
Reference case	77.9	0.01284
Ecodesign option 1a (BAT Hot band workload test)	n/a	n/a
Ecodesign option 2a (BAT Seq read workload test)	n/a	n/a
Ecodesign option 3a (BAT Seq write workload test)	n/a	n/a
Ecodesign option 4a (BAT Ready Idle workload test)	743.6	0.00134
Ecodesign option 5a (BAT Total Performance Score)	743.6	0.00134
Ecodesign option 6a (case 5a including COMS)	1078.2	0.00093

The above analysis is repeated, this time excluding the highest performing 10% of products in each application; this is done because of the large variations observed in products. For example, there is a flash storage product where each storage drive costs

$16000, compared to under $1000 for other products. These exceptionally high performance products are therefore assumed to be cost–ineffective, based on least lifecycle cost. These products are still in the market because the performance level is needed for some applications. Performing life cycle costs or grouping products by performance is not possible since this data is not available.

Ecodesign options including the 10% highest performing products are all labelled 'a' while those excluding the highest performing 10% are given the suffix nomenclature 'b'. The team made this reduced data set 'b' because the data for the 10% highest performing products seemed to be very specialised products with high performance and high price or simply with measurement errors. The team therefore concluded that excluding these products might provide a more representative data set closer to standard data storage devices.

This approach should be reviewed if a follow-up preparatory study will be launched and if more test data will be available resulting in a much larger and potentially more representative dataset of the marketed data storage devices.

Table 14 Energy budget for transactional applications based on SNIA tests and COMs for a reduced data set for standard products (excluding the top 10% highest performing products, i.e. showing "b" suffix ecodesign option products)

Transactional Applications (excl. top 10%)					
	Hot band workload test (IOPS/W)	**Seq read workload test (MiBPS/W)**	**Seq write workload test (MiBPS/W)**	**Readly idle capacity workload test (GB/W)**	**Total performance**
Reference case	6.6			97.1	63.2
Ecodesign option 1b (BAT Hot band workload test)	97.6			10.8	43.4
Ecodesign option 2b (BAT Seq read workload test)					n/a
Ecodesign option 3b (BAT Seq write workload test)					n/a
Ecodesign option 4b (BAT Ready Idle workload test)	9.2			163.1	105.4
Ecodesign option 5b (BAT Total Performance Score)	18.9			149.6	100.6
Ecodesign option 6b (case 5b including COMS)	18.9			209.4	138.0

Table 15 Inverted Energy budget for transactional applications based on SNIA tests and COMs for a reduced data set for standard products (excluding the top 10% highest performing products, i.e. showing "b" suffix ecodesign option products)

Transactional Applications (excl. top 10%)		
	Total performance	**Inverted total performance**
Reference case	63.2	0.01583
Ecodesign option 1b (BAT Hot band workload test)	43.4	0.02306
Ecodesign option 2b (BAT Seq read workload test)	n/a	n/a
Ecodesign option 3b (BAT Seq write workload test)	n/a	n/a
Ecodesign option 4b (BAT Ready Idle workload test)	105.4	0.00949
Ecodesign option 5b (BAT Total Performance Score)	100.6	0.00994
Ecodesign option 6b (case 5b including COMS)	138.0	0.00725

Table 16 Energy budget for streaming applications based on SNIA tests and COMs for a reduced data set for standard products (excluding the top 10% highest performing products, i.e. showing "b" suffix ecodesign option products)

Streaming Applications (excl. top 10%)					
	Hot band workload test (IOPS/W)	**Seq read workload test (MiBPS/W)**	**Seq write work-load test (MiBPS/W)**	**Readly idle capaci-ty workload test (GB/W)**	**Total performance**
Reference case		5.68	4.66	54.4	38.0
Ecodesign option 1b (BAT Hot band workload test)					n/a
Ecodesign option 2b (BAT Seq read workload test)		21.59	14.24	23.0	21.7
Ecodesign option 3b (BAT Seq write workload test)		21.59	14.24	23.0	21.7
Ecodesign option 4b (BAT Ready Idle workload test)		2.34	0.68	219.2	146.7
Ecodesign option 5b (BAT Total Perfor-mance Score)		6.77	5.77	108.0	74.2
Ecodesign option 6b (case 5b including COMS)		6.77	5.77	126.4	86.4

Table 17 Inverted Energy budget for streaming applications based on SNIA tests and COMs for a reduced data set for standard products (excluding the top 10% highest performing products, i.e. showing "b" suffix ecodesign option products

Streaming Applications (excl. top 10%)		
	Total performance	**Inverted total performance**
Reference case	38.0	0.02628
Ecodesign option 1b (BAT Hot band workload test)	n/a	n/a
Ecodesign option 2b (BAT Seq read workload test)	21.7	0.04605
Ecodesign option 3b (BAT Seq write workload test)	21.7	0.04605
Ecodesign option 4b (BAT Ready Idle workload test)	146.7	0.00682
Ecodesign option 5b (BAT Total Performance Score)	74.2	0.01349
Ecodesign option 6b (case 5b including COMS)	86.4	0.01157

Table 18 Energy budget for capacity applications based on SNIA tests and COMs for a reduced data set for standard products (excluding the top 10% highest performing products, i.e. showing "b" suffix ecodesign option products)

Capacity Applications (excl. top 10%)					
	Hot band workload test (IOPS/W)	**Seq read workload test (MiBPS/W)**	**Seq write workload test (MiBPS/W)**	**Readly idle capacity workload test (GB/W)**	**Total performance**
Reference case				77.9	77.9
Ecodesign option 1b (BAT Hot band workload test)					n/a
Ecodesign option 2b (BAT Seq read workload test)					n/a
Ecodesign option 3b (BAT Seq write workload test)					n/a
Ecodesign option 4b (BAT Ready Idle workload test)				149.6	149.6
Ecodesign option 5b (BAT Total Performance Score)				149.6	149.6
Ecodesign option 6b (case 5b including COMS)				216.9	216.9

Table 19 Inverted Energy budget for capacity applications based on SNIA tests and COMs for a reduced data set for standard products (excluding the top 10% highest performing products, i.e. showing "b" suffix ecodesign option products)

Capacity Applications (excl. top 10%)		
	Total performance	**Inverted total performance**
Reference case	77.9	0.01284
Ecodesign option 1b (BAT Hot band workload test)	n/a	n/a
Ecodesign option 2b (BAT Seq read workload test)	n/a	n/a
Ecodesign option 3b (BAT Seq write workload test)	n/a	n/a
Ecodesign option 4b (BAT Ready Idle workload test)	149.6	0.00668
Ecodesign option 5b (BAT Total Performance Score)	149.6	0.00668
Ecodesign option 6b (case 5b including COMS)	216.9	0.00461

Energy efficiency feature - Adaptive active cooling (not included)

Without adaptive cooling, the fans run at very high speed, consuming a high amount of power, and they are also extremely noisy. As a result, it is assumed that adaptive cooling is found on all products, which largely seems to be true in practice. Due to being a mainstream technology, it is not included as a separate option. Without adaptive active cooling, power consumption increases by ~5%.

Energy efficiency feature - Power Supply Unit (PSU) efficiency (not included)

The PSU efficiency is assumed to be adequately assessed by considering the active and idle performance efficiency metrics in Ecodesign options 1-5 and therefore not included as a separate option.

Energy efficiency feature - Minimum operating condition (Ecodesign option 7)

To determine the savings from increasing the minimum operating condition, it is first necessary to model the power and cooling energy consumption. For this case study, it is assumed that the same proportion of efficiency can be applied to all types of products and data centres. If an Ecodesign Preparatory Study showed that this was not the case, it would be possible to split the cases further. It is assumed that the average data centre PUE is 1.67.

ASHRAE defines four classes of operating conditions, and all products now meet an A2 level or better. Ecodesign option 7 raises the ASHRAE class to A3 and A4. It is assumed that the broader A4 range is not utilised further than the A3 range given the European climate and A3 and A4 are therefore assumed to result in same saving impact. In addition, only a small proportion of data centres will increase their operating range and benefit from additional savings. Therefore, the average reduction in power and cooling consumption is assumed to be 4% (note that this would need to be confirmed in an Ecdesign Preparatory Study).

Table 20 Estimated power and cooling reduction for extended minimum operating conditions

ASHRAE class	Energy reduction
A3	4%
A4	4%

The table below shows the additional power and cooling module for transactional applications. The product performance is taken directly from the inverted total performance in the previous stage. Based on the estimated PUE of 1.67 (1.6666..), the power and cooling is 0.67 (0.6666..) times the product performance per se. Ecodesign option 7 is then calculated by applying the estimated 4% energy reduction to the power and cooling performance of Ecodesign option 6 for all applications types (i.e. 0.00483 (cell above for 6b) multiplied with (1-0.04=0.96)).

The combined total value is a sum of the values of product performance and power and cooling performance. This is thus expressing a combined value of an Extended Product System consisting of two discrete sub-system (the data storage device and the infrastructure i.e. the power supply and the cooling system).

Table 21 Energy budget for transactional applications including power and cooling, excluding the top 10% highest performing products. Product performance is from Table 14 (inverted total performance). The power and cooling performance is the figure for product performance multiplied with 0.6666.

Transactional Applications (excl. top 10%)			
	Product perfor-mance	**Power and cooling performance**	**Combined total (sum of the values of prod perf + pow. and cool perf)**
Reference case	0.01583	0.01055	0.02639
Ecodesign option 1b (BAT Hot band workload test)	0.02306	0.01537	0.03843
Ecodesign option 2b (BAT Seq read workload test)	n/a	n/a	n/a
Ecodesign option 3b (BAT Seq write workload test)	n/a	n/a	n/a
Ecodesign option 4b (BAT Ready Idle workload test)	0.00949	0.00633	0.01581
Ecodesign option 5b (BAT Total Performance Score)	0.00994	0.00663	0.01657
Ecodesign option 6b (case 5b including COMS)	0.00725	0.00483	0.01208
Ecodesign option 7b (case 6b but with higher Minimum Operating Condition)	0.00725	0.00464	0.01189

Table 22 Energy budget for streaming applications including power and cooling, excluding the top 10% highest performing products

Streaming Applications (excl. top 10%)			
	Product perfor-mance	**Power and cooling performance**	**Combined total**
Reference case	0.02628	0.01752	0.04381
Ecodesign option 1b (BAT Hot band workload test)	n/a	n/a	n/a
Ecodesign option 2b (BAT Seq read workload test)	0.04605	0.03070	0.07676
Ecodesign option 3b (BAT Seq write workload test)	0.04605	0.03070	0.07676
Ecodesign option 4b (BAT Ready Idle workload test)	0.00682	0.00454	0.01136
Ecodesign option 5b (BAT Total Performance Score)	0.01349	0.00899	0.02248
Ecodesign option 6b (case 5b including COMS)	0.01157	0.00772	0.01929
Ecodesign option 7b (case 6b but with higher Maximum Operating Condition)	0.01157	0.00741	0.01898

Table 23 Energy budget for capacity applications including power and cooling, excluding the top 10% highest performing products

Capacity Applications (excl. top 10%)			
	Product perfor-mance	**Power and cooling performance**	**Combined total**
Reference case	0.01284	0.00856	0.02140
Ecodesign option 1b (BAT Hot band workload test)	n/a	n/a	n/a
Ecodesign option 2b (BAT Seq read workload test)	n/a	n/a	n/a
Ecodesign option 3b (BAT Seq write workload test)	n/a	n/a	n/a
Ecodesign option 4b (BAT Ready Idle workload test)	0.00668	0.00446	0.01114
Ecodesign option 5b (BAT Total Performance Score)	0.00668	0.00446	0.01114
Ecodesign option 6b (case 5b including COMS)	0.00461	0.00307	0.00768
Ecodesign option 7b (case 6b but with higher Maximum Operating Condition)	0.00461	0.00295	0.00756

Energy efficiency feature - Good Commissioning Guidance (Ecodesign option 8)

The impact of the guidance is not known, and would require more research in an Ecodesign Preparatory study to adequately determine this. The high uncertainty and its dependence on product size mean that a conservative estimate of 3% improvement is assumed (note, this would also need to be assessed in a Preparatory Study).

Table 24 Estimated energy savings from good commissioning guidance

Ecodesign option	Energy reduction
Good commissioning guidance	3%

The Good Commissioning Guidance is added on top of ecodesign option 7b resulting in ecodesign option 8. The Combined Total figure from the previous tables for option 7b is thus reduced with 3% for a Combined Total figure for option 8b.

The energy use is based on the combined total from the calculations for Ecodesign option 8. Ecodesign option 8 represents the 3% reduction applied to Ecodesign option 8. Since Ecodesign options 6 to 10 have been applied successively on top of one other, every sub-sequent option is more efficient, concluding with option 10 as the most efficient.

Summary tables for all Ecodesign options

The tables below summarise all the Ecodesign options for all the applications. Ecodesign options 1-8 are taken directly from the combined total energy, as referred to in previous tables.

Table 25 Energy budget for transactional applications for all ecodesign options, excluding the top 10% highest performing products

Transactional Applications (excl. top 10%)	
	Energy
Reference case	0.02639
Ecodesign option 1b (BAT Hot band workload test)	0.03843
Ecodesign option 2b (BAT Seq read workload test)	n/a
Ecodesign option 3b (BAT Seq write workload test)	n/a
Ecodesign option 4b (BAT Ready Idle workload test)	0.01581
Ecodesign option 5b (BAT Total Performance Score)	0.01657
Ecodesign option 6b (case 5b including COMS)	0.01208
Ecodesign option 7b (case 6b but with higher Minimum Operating Condition)	0.01189
Ecodesign option 8b (case 7b but with good commissioning guidance)	0.01153

Table 26 Energy budget for streaming applications for all ecodesign options, excluding the top 10% highest performing products

Streaming Applications (excl. top 10%)	
	Energy
Reference case	0.04381
Ecodesign option 1b (BAT Hot band workload test)	n/a
Ecodesign option 2b (BAT Seq read workload test)	0.07676
Ecodesign option 3b (BAT Seq write workload test)	0.07676
Ecodesign option 4b (BAT Ready Idle workload test)	0.01136
Ecodesign option 5b (BAT Total Performance Score)	0.02248
Ecodesign option 6b (case 5b including COMS)	0.01929
Ecodesign option 7b (case 6b but with higher Minimum Operating Condition)	0.01898
Ecodesign option 8b (case 8b but with good commissioning guidance)	0.01841

Table 27 Energy budget for capacity applications for all ecodesign options, excluding the top 10% highest performing products

Capacity Applications (excl. top 10%)	
	Energy
Reference case	0.02140
Ecodesign option 1b (BAT Hot band workload test)	n/a
Ecodesign option 2b (BAT Seq read workload test)	n.a
Ecodesign option 3b (BAT Seq write workload test)	n/a
Ecodesign option 4b (BAT Ready Idle workload test)	0.01114
Ecodesign option 5b (BAT Total Performance Score)	0.01114
Ecodesign option 6b (case 5b including COMS)	0.00768
Ecodesign option 7b (case 6b but with higher Minimum Operating Condition)	0.00756
Ecodesign option 8b (case 8b but with good commissioning guid-ance)	0.00733

5.10 Step 9 Normalisation and awarding of points

Based on the energy budget for each ecodesign option, the EEI is calculated as a proportion of the reference case. The Ecodesign option 8, which combines all the possible ecodesign options, has the lowest EEI and represents the maximum efficiency seen among the products in the Energy Star database. In accordance with the Task 3 methodology the points to be awarded are calculated as the reverse of the EEI, ie an EEI of 17% EEI is awarded 100-17=83 points. The tables below show the points awarded by Ecodesign option for each of the three application types (Transactional, Streaming and Capacity) and first for the cases where the top 10% of products are included and secondly for the case where they are excluded. This may though not be needed if it does not give any added value and it could be seen as optional.

Due to the typical usage of storage products where the product is categorised into the usages: transactional, streaming and capacity, it is sufficient to have separate indices for each usage. If it should be necessary to report a single index e.g. if a product does not have a specific usage, weighting should be applied for the three usage cases. This may be a simple arithmetic mean of the indices, or a more complex weighting could be applied, which should be developed in a preparatory study.

In some situations, the ecodesign option results in worse efficiency. This results in an EEI greater than 100% and negative points. This occurs in the streaming applications where selecting the highest performance sequential read/write products in ecodesign options 2 and 3 results in a much larger drop in performance of the ready idle.

Table 28 EEI and points for transactional applications for all ecodesign options

Transactional Applications (inc top 10%)		
	EEI	**Points**
Reference case	100%	0
Ecodesign option 1a (BAT Hot band workload test)	54%	46.4
Ecodesign option 2a (BAT Seq read workload test)	n/a	n/a
Ecodesign option 3a (BAT Seq write workload test)	n/a	n/a
Ecodesign option 4a (BAT Ready Idle workload test)	17%	83.0
Ecodesign option 5a (BAT Total Performance Score)	17%	83.0
Ecodesign option 6a (case 5a including COMS)	12%	87.8
Ecodesign option 8a (case 6a but with higher Minimum Operating Condition)	12%	88.0
Ecodesign option 10a (case 8a but with good commissioning guidance)	12%	88.4

Table 29 EEI and points for streaming applications for all ecodesign options

Streaming Applications (incl. top 10%)		
	EEI	**Points**
Reference case	100%	0
Ecodesign option 1a (BAT Hot band workload test)	n/a	n/a
Ecodesign option 2a (BAT Seq read workload test)	175%	-75.2
Ecodesign option 3a (BAT Seq write workload test)	175%	-75.2
Ecodesign option 4a (BAT Ready Idle workload test)	8%	92.4
Ecodesign option 5a (BAT Total Performance Score)	8%	92.4
Ecodesign option 6a (case 5a including COMS)	7%	93.5
Ecodesign option 8a (case 6a but with higher Minimum Operating Condition)	6%	93.6
Ecodesign option 10a (case 8a but with good commissioning guidance)	6%	93.8

Table 30 EEI and points for capacity applications for all ecodesign options

Capacity Applications (incl. top 10%)		
	EEI	**Points**
Reference case	100%	0
Ecodesign option 1a (BAT Hot band workload test)	n/a	n/a
Ecodesign option 2a (BAT Seq read workload test)	n/a	n/a
Ecodesign option 3a (BAT Seq write workload test)	n/a	n/a
Ecodesign option 4a (BAT Ready Idle workload test)	10%	89.5
Ecodesign option 5a (BAT Total Performance Score)	10%	89.5
Ecodesign option 6a (case 5a including COMS)	7%	92.8
Ecodesign option 8a (case 6a but with higher Minimum Operating Condition)	7%	92.9
Ecodesign option 10a (case 8a but with good commissioning guidance)	7%	93.1

Table 31 EEI and points for transactional applications for all ecodesign options, excluding top 10% highest performing products

Transactional Applications (excl. top 10%)		
	EEI	**Points**
Reference case	100%	0
Ecodesign option 1b (BAT Hot band workload test)	146%	-45.7
Ecodesign option 2b (BAT Seq read workload test)	n/a	n/a
Ecodesign option 3b (BAT Seq write workload test)	n/a	n/a
Ecodesign option 4b (BAT Ready Idle workload test)	60%	40.1
Ecodesign option 5b (BAT Total Performance Score)	63%	37.2
Ecodesign option 6b (case 5b including COMS)	46%	54.2
Ecodesign option 8b (case 6b but with higher Minimum Operating Condition)	45%	55.0
Ecodesign option 10b (case 8b but with good commissioning guidance)	44%	56.3

Table 32 EEI and points for streaming applications for all ecodesign options, excluding top 10% highest per-forming products

Streaming Applications (excl. top 10%)		
	EEI	**Points**
Reference case	100%	0
Ecodesign option 1b (BAT Hot band workload test)	n/a	n/a
Ecodesign option 2b (BAT Seq read workload test)	175%	-75.2
Ecodesign option 3b (BAT Seq write workload test)	175%	-75.2
Ecodesign option 4b (BAT Ready Idle workload test)	26%	74.1
Ecodesign option 5b (BAT Total Performance Score)	51%	48.7
Ecodesign option 6b (case 5b including COMS)	44%	56.0
Ecodesign option 8b (case 6b but with higher Minimum Operating Condition)	43%	56.7
Ecodesign option 10b (case 8b but with good commissioning guidance)	42%	58.0

Table 33 EEI and points for capacity applications for all ecodesign options, excluding the top 10% highest performing products

Capacity Applications (excl. top 10%)		
	EEI	**Points**
Reference case	100%	0
Ecodesign option 1b (BAT Hot band workload test)	n/a	n/a
Ecodesign option 2b (BAT Seq read workload test)	n/a	n/a
Ecodesign option 3b (BAT Seq write workload test)	n/a	n/a
Ecodesign option 4b (BAT Ready Idle workload test)	52%	47.9
Ecodesign option 5b (BAT Total Performance Score)	52%	47.9
Ecodesign option 6b (case 5b including COMS)	36%	64.1
Ecodesign option 8b (case 6b but with higher Minimum Operating Condition)	35%	64.7
Ecodesign option 10b (case 8b but with good commissioning guidance)	34%	65.7

5.11 Calculation guide

We provide in the following Table a guide in how to calculate the points for a specific model and configuration based on manufacturer information.

The table divides the calculations into 5 steps and presents the information and data required and the calculations to perform with reference to the descriptions above in Sections 5.9 and 5.10.

Table 34 Calculation guide for a specific model and configuration

<table>
<tr><th>Step</th><th>Description</th><th>Information required</th><th>Calculation</th></tr>
<tr><td>1</td><td>Product performance based on SNIA Emerald test results</td><td>The principal application of the product and configuration informed by the manufacturer.
SNIA Emerald test results relevant for that application based on table below informed by the manufacturer.
<table>
<tr><th>Application</th><th>Hot band test IOPS/W</th><th>Sequential test MiBPS/W</th><th>Ready idle capacity GB/W</th></tr>
<tr><td>Transactional</td><td>Y</td><td>N</td><td>Y</td></tr>
<tr><td>Streaming</td><td>N</td><td>Y</td><td>Y</td></tr>
<tr><td>Capacity</td><td>N</td><td>N</td><td>Y</td></tr>
</table>
Result of COMs tests from SNIA Emerald.
For Market Surveillance Suthorities, SNIA operates a ‘recognised tester program’, who are able to carry out testing.</td><td>If COMs are available, increase Ready Idle test result by the percentage given in the table below:
<table>
<tr><th>Application</th><th>Ready idle improvement</th></tr>
<tr><td>Transactional</td><td>40%</td></tr>
<tr><td>Streaming</td><td>17%</td></tr>
<tr><td>Capacity</td><td>45%</td></tr>
</table>
Product performance is the weighted arithmetic mean of the test results weighted according to the table below.
<table>
<tr><th>Application</th><th>Hot band workload test
IOPS/W</th><th>Seq read workload test
MiBPS/W</th><th>Seq write workload test
MiBPS/W</th><th>Ready Idle workload test
GB/W</th></tr>
<tr><td>Transactional</td><td>38%</td><td>0%</td><td>0%</td><td>63%</td></tr>
<tr><td>Streaming</td><td>0%</td><td>22%</td><td>11%</td><td>67%</td></tr>
<tr><td>Capacity</td><td>0%</td><td>0%</td><td>0%</td><td>100%</td></tr>
</table></td></tr>
<tr><td>2</td><td>Product energy budget</td><td>Product performance from previous step.</td><td>Inverse of the product performance:
Energy budget = (product performance)$^{-1}$</td></tr>
<tr><td>3</td><td>Total energy budget including power and cooling</td><td>ASHRAE operating condition informed by the manufacturer.</td><td>Total energy = PUE x energy budget
Where PUE = 5/3 for ASHRAE 1 or 2
PUE = 5/3 x 0.96 for ASHRAE 3 or 4</td></tr>
<tr><td>4</td><td>Guidance total energy budget</td><td>Is good guidance provided by the manufacturer with the product or online?
The case study does not specify how to evaluate the quality of the guid-ance.</td><td>If good guidance is provided:
Total energy = Step 3 total energy x 0.97</td></tr>
<tr><td>5</td><td>EEI and points</td><td>Reference case total energy budget from regulation.</td><td>EEI = Total energy / reference case total energy
Points = 1- EEI</td></tr>
</table>

5.12 Conclusion

This case study shows that the Task 3 points system methodology can be adapted and applied to data centre storage products. The methodology allows ecodesign options and data with different units, as well as quantitative and qualitative data to give a complete picture of options and relative efficiencies. However, it is clear that in this case more data is required to apply the methodology with a high degree of confidence but this is merely a question of having more devices tested with the existing SNIA Emerald test method. The high uncertainty in many ecodesign options means that only incremental improvements are calculated.

Lack of data to create duty profiles may be resolved with additional research during a product-specific Ecodesign Preparatory Study only covering data storage (data storage systems were included in DG Growth Lot 9, but bundled with other data centre products).

Duty profiles are based on combinations of different product classes, data centre sizes, and business types. Due to the extremely high level of customer-specific configurability, and number of classes of storage products, there is a continuum of duty profile options between a single generic ecodesign option and splitting into a few or tens or hundreds of applications.

Without duty profiles, the first stage in calculating the energy budget is based on the weighted efficiency data (see Table 6, previously). This weighting influences the overall result and there is presently no clear guidance as to how this weighting could be developed, and nor do we propose it within the remit of the present study. In this case, expert judgement is used, which might be too subjective, given its overall importance. This could be sufficient, however, it should be further assessed during a more detailed study.

A way forward could be to include more expert judgements and ending with a sufficiently realistic weighting, which would be sufficiently exact for the purposes of establishing an ecodesign regulation.