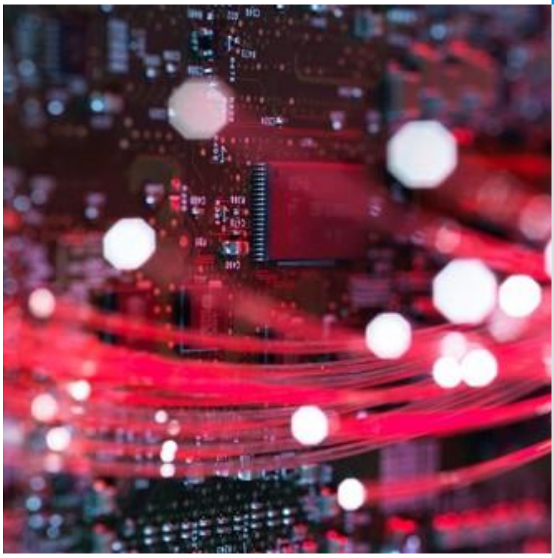

Study for the review of Commission Regulation 2019/424 (Ecodesign of servers and data storage products)

Task 6 Design Options – DRAFT

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6 Introduction to Task 6 Design Options

6.1 Identification of design options and assessment of their impacts

This section outlines various design options that have been identified for consideration. These options are presented individually, each representing a distinct approach that may or may not be integrated into subsequent modelling. The purpose of delineating these design options is to facilitate a comprehensive evaluation of potential strategies and solutions. The decision on which options to carry forward will depend on their efficacy in addressing project objectives and constraints. Task 7 activities will amalgamate and synthesize a series of these design options, to form scenario modelling. The inclusion of specific options in Task 7 will be contingent upon their compatibility, feasibility, and alignment.

6.1.1 Server Energy Efficiency Design Options

The Ecodesign regulation currently sets minimum active efficiency values and maximum idle power consumption. This is set for all servers as they enter the market, or to a configuration family. For a configuration family to be compliant, their low-end and high-end performance configurations need to be complaint. These are defined as follows:

- ‘low-end performance configuration’ of a server product family means the combination of two data storage devices, processor with the lowest product of core count and frequency (in GHz) and memory capacity (in GB) that is at least equal to the product of the number of memory channels and the lowest capacity dual in-line memory module (DIMM) (in GB) offered on the server that represents the lowest performance product model within the server product family. All memory channels shall be populated with the same DIMM raw card design and capacity;
- ‘high-end performance configuration’ of a server product family means the combination of two data storage devices, processor with the highest product of core count and frequency and memory capacity (in GB) equal to or greater than 3 times the product of the number of CPUs, cores and hardware threads that represents the highest performance product model within the product family. All memory channels shall be populated with the same DIMM raw card design and capacity;

For the following design options, energy efficiency criteria for server configuration families will need to be met not only by the low-end and high-end performance configurations, but also on *the typical configuration*. This configuration is defined as: "*a product configuration that lies between the Low-end Performance and High-end Performance configurations and is representative of a deployed product with high volume sales.*"

Ecodesign 2019/424 currently sets the active efficiency requirement for servers at:

Table 6.1 Active state efficiency requirements in 2019/424

Product type	Minimum active state efficiency
1-socket servers	9.0
2-socket servers	9.5

Product type	Minimum active state efficiency
Blade or multi-node servers	8.0

According to the SERT threshold tool[1], set at an analysis with models from 2019, these settings incur the following fail rates from the dataset:

Table 6.2 Pass rate of SERT database under efficiency requirements in 2019/424

Number of sockets	Product type	Pass rate (%)	Total sample size
1	Rack	97	60
2	Rack	100	159
2	Blade or multi-node servers[2]	100	46
4	Rack	100	25
4	Blade or multi-node	100	7

6.1.1.2 Design Option 1: Active efficiency aligned with EU GPP

This design option proposes to increase this minimum active state efficiency. The first level proposed is to raise the efficiency levels to be in line with the EU Green Public Procurement minimum requirements, such that:

Table 6.3 Proposed active efficiency requirements from EU GPP

Number of sockets	Product type	Minimum Active efficiency
1	Rack	13.0
2	Rack	18.0
2	Blade or multi-node servers	20.0
4	Rack	16.0
4	Blade or multi-node	9.6

**Note that although tower servers are defined in the GPP, they are classified as small-scale servers and are covered in the Ecodesign 617/2013 regulation.*

According to the SERT threshold tool, set at an analysis with models from 2019, these settings incur the following pass rates from the dataset:

Table 6.4 Pass rate of SERT database under EU GPP efficiency requirements

Number of sockets	Product type	Pass rate (%)	Total sample size
1	Rack	88	76
2	Rack	84	152

[1] The dataset used is The Green Grid SERT dataset from the 12th of January 2024.

[2] for blade or multi-node servers, the "number of sockets" has been equated to "number of processors" in the dataset.

Number of sockets	Product type	Pass rate (%)	Total sample size
2	Blade or multi-node servers[3]	83	60
4	Rack	88	24
4	Blade or multi-node	100	10

According to this dataset, this measure will at most remove 17% of the server families in the TGG dataset from 2019. More recent servers registered have a higher pass rate.

6.1.1.3 Design Option 2: Higher-rate active efficiency

Considering how much of the dataset already pass the EU GPP efficiency requirements, the active efficiency requirement could be considered at a higher level.

Table 6.5 Proposed higher-rate active efficiency requirements

Number of sockets	Product type	Minimum Active efficiency
1	Rack	15.0
2	Rack	20.0
2	Blade or multi-node servers	20.0
4	Rack	16.0
4	Blade or multi-node	12.0

According to the SERT threshold tool, set at an analysis with models from 2019, these settings incur the following pass rates from the dataset:

Table 6.6 Pass rate of SERT database under higher rate active efficiency limits

Number of sockets	Product type	Pass rate (%)	Total sample size
1	Rack	82	76
2	Rack	82	152
2	Blade or multi-node servers[4]	83	60
4	Rack	88	24
4	Blade or multi-node	100	10

According to this dataset, this measure will at most remove 18% of the server families in the TGG dataset from 2019.

[3] for blade or multi-node servers, the "number of sockets" has been equated to "number of processors" in the dataset.

[4] for blade or multi-node servers, the "number of sockets" has been equated to "number of processors" in the dataset.

6.1.1.4 Design Option 3: Stricter active efficiency

Considering a stricter active efficiency wherein 75% of the models from the SERT threshold tool meet the requirement.

Table 6.7 Proposed stricter-rate active efficiency requirements

Number of sockets	Product type	Minimum Active efficiency
1	Rack	15.33
2	Rack	23.36
2	Blade or multi-node servers	21.09
4	Rack	20.32
4	Blade or multi-node	22.44

According to the SERT threshold tool, set at an analysis with models from 2019, these settings incur the following pass rates from the dataset:

Table 6.8 Pass rate of SERT database under stricter-rate active efficiency limits

Number of sockets	Product type	Pass rate (%)	Total sample size
1	Rack	75%	76
2	Rack	75%	152
2	Blade or multi-node servers[5]	75%	60
4	Rack	75%	24
4	Blade or multi-node	75%	10

This measure will remove 25% of the server families in the TGG dataset from 2019.

6.1.1.5 DO1, DO2 and DO3 effects on base cases

For the Base cases modelling, this would change performance such that:

Table 6.9 Base case performance against a range of considered efficiency DOs

Product modelled	Active efficiency modelled	Idle consumption modelled (W)	Server weighted performance
Base Case 1	27.1	136	7945
Base Case 1 after DO1: EU GPP requirements	30.2	142	9196
Base Case 1 after DO2: high-rate active efficiency requirements	30.4	141	9269
Base Case 1 after DO3: Stricter active efficiency requirements	31.6	142.5	9784.8
Base Case 2	31.2	166	17934

[5] for blade or multi-node servers, the "number of sockets" has been equated to "number of processors" in the dataset.

Product modelled	Active efficiency modelled	Idle consumption modelled (W)	Server weighted performance
Base Case 2 after DO1: EU GPP requirements	33.2	172	20015
Base Case 2 after DO2: high-rate active efficiency requirements	33.2	172	20015
Base Case 2 after DO3: Stricter active efficiency requirements	34.2	182.8	21716.8

For the base case modelling purposes, the following changes are made:

Table 6.10 Modelling changes for DO1, DO2 and DO3

DO	Base Case	Change made	Percentage difference
1	1	Cost increase	0%
1	1	Active consumption figures reduced by:	11%
1	1	Idle consumption changed by:	+4%
1	1	Performance figures increased by:	16%
1	2	Cost increase	0%
1	2	Active consumption figures reduced by:	7%
1	2	Idle consumption reduced by:	6%
1	2	Performance figures increased by:	15%
2	1	Cost increase	0%
2	1	Active consumption figures reduced by:	12%
2	1	Idle consumption reduced by:	3%
2	1	Performance figures increased by:	17%
2	2	Cost increase	0%
2	2	Active consumption figures reduced by:	8%
2	2	Idle consumption changed by:	5%
2	2	Performance figures increased by:	16%
3	1	Cost increase	0%
3	1	Active consumption figures reduced by:	16%
3	1	Idle consumption reduced by:	5%
3	1	Performance figures increased by:	23%
3	2	Cost increase	0%
3	2	Active consumption figures reduced by:	10%
3	2	Idle consumption reduced by:	10%
3	2	Performance figures increased by:	21%

6.1.1.6 Server Idle efficiency

The Ecodesign 2019/424 regulation currently sets maximum idle power consumption values for servers with a base allowance and an additional power allowance due to additional components. These are defined as:

Table 6.11 Base idle state power allowances for Ecodesign 2019/424

Product type	Base idle state power allowance, Pbase (W)
1-socket servers (neither blade nor multi-node)	25
2-socket servers (neither blade nor multi-node)	38
Blade or multi-node servers	40

Table 6.12 Additional idle power allowances for extra components under 2019/424

System characteristics	Applies to	Additional idle power allowance
CPU performance	All servers	1 socket: 10 x Perf CPU W 2 socket: 7 x Perf CPU W
Additional PSU	PSU installed explicitly for power redundancy	10 W per PSU
HDD or SSD	Per installed HDD or SSD	5.0 W per HDD or SSD
Additional memory	Installed memory greater than 4 GB	0.18 W per GB
Additional buffered DDR Channel	Installed buffered DDR channels greater than 8 channels	4.0 W per buffered DDR channel
Additional I/O devices	Installed devices greater than two ports of >1 Gbit, onboard Ethernet	< 1 GB/s: No allowance
		= 1 GB/s: 2.0 W/Active Port
		> 1 GB/s and <10 Gb/s: 4.0 W/Active port
		> 10 GB/s and <25 Gb/s: 15.0 W/Active port
		> 25 GB/s and <50 Gb/s: 20.0 W/Active port
		>50 Gb/s 26.0 W/Active Port

Idle power kept as it is

For servers on the market since 2019 on the SERT database, the current idle maximum power consumption metric would allow for 13% of servers to pass without the adders metrics. However, including the adders metric regarding additional memory, this pass rate is increased to 28%. Furthermore, the CPU performance additional power allowance brings the total pass rate to 100%. Therefore, as the metric is currently operating it has limited effect at limiting idle power consumption. It is therefore suggested to consider a new metric to limit the consumption of idle energy.

6.1.1.7 Design Option 4: Idle consumption to workload ratio

A new idle efficiency metric is proposed here, to ensure that idle consumption is being optimised for use in the market, but also allow for servers with performance ratios to be included. This metric is as follows:

$$Idle\ to\ workload\ ratio = \frac{idle\ power\ (in\ Watts)}{100\%\ SSJ\ workload\ power\ (in\ Watts)}$$

This metric ensures that the smaller the ratio, the smaller the idle power contribution compared to the SSJ workload contribution. The SSJ worklet chosen represents a worklet with both CPU processing and memory activities. Therefore, a smaller ratio will mean that the idle power consumption is scaled to be more efficient versus an active workload parameter. This metric therefore serves as a method to remove products which are operating inefficiently in idle versus their maximum power consumption. As this metric is a ratio that includes the SSJ workload, this includes insight into the specificities and components of the server, such as CPU power and memory, and hence doesn't require additional allowances to be included.

Applying this idle to workload ratio to servers on the market since 2019 on the SERT database, if a pass rate of needing the idle to workload ratio to be smaller than 0.38 was set, then 75% of the BC1 servers would pass the metric. And for BC2 if idle to workload ratio was set to be smaller than 0.16, then 75% of the BC2 servers would pass the metric.

Manufacturers are already designing systems to maximise idle efficiency and power scaling to maximise their SERT scores, so there is no additional increase in cost factored into this DO.

The effect of this measure on the Base cases 1 and 2 has been estimated in Table 6.13.

Table 6.13 Modelling changes for DO4

DO	Base Case	Change made	Percentage difference
4	1	Cost increase	0%
4	1	Active consumption figures reduced by:	10%
4	1	Idle consumption reduced by:	7%
4	1	Performance figures increased by:	14%
4	2	Cost increase	0%
4	2	Active consumption figures reduced by:	1.3%
4	2	Idle consumption reduced by:	11%
4	2	Performance figures increased by:	2%

6.1.1.8 Design Option 5: Processor management functions to be mandated and shipped enabled.

The following Design option is considered:

Computer servers shipped onto the EU market must have the following power management functions and enabled by default, when shipped. All processors must *be able to reduce power consumption in times of low utilisation by reducing voltage and/or frequency through Dynamic Voltage and Frequency Scaling (DVFS).* Note whilst DVFS is commonly referred to across the industry there is no documented definition.

This measure is in two parts: the inclusion of the power management functions DVFS, and the enabling of these by default.

DVFS is a common metric which is required by the Energy Star programme. It allows for greater energy savings when switching to idle. As the feature is common, it is expected the cost on the base case to be minimal, and idle consumption to be lowered slightly.

The enabling of these by default is not expected to have any additional costs, as most servers are already equipped with this functionality. However, it is expected to lower consumption, as having the feature enabled by default will increase its use, and hence reduce idle consumption. This reduction is expected to reduce overall server energy consumption by 5%.[6,7] This reduction of 5% energy use can be applied to BC1 and BC2 modelling, with no changes to cost, materials or life expectancy.

6.1.2 Data storage product energy efficiency design options

6.1.2.1 Design option 6: Including energy efficiency requirements on data storage products

Set a SNIA performance level on storage systems

The following energy efficiency feature is set as a requirement for data storage devices. This setting aligns with the Energy Star criteria such that: each optimal configuration point submitted for a block I/O storage product or storage product family must meet the following applicable active state requirements in Table 6.14 for each workload type. For streaming workloads, the data storage product must meet either the sequential read or the sequential write requirement.

Table 6.14 Active state requirements for Block I/O Storage products

Workload Type Specific	Specific Workload Test	Minimum Performance/Watt Ratio	Applicable Units of Ratio
Transaction	Hot Band	28.0	IOPS/Watt
Streaming	Sequential Read	2.3	MiBS/Watt
Streaming	Sequential Write	1.5	MiBS/Watt

Where the optimal configuration is defined as the products maximum peak energy efficiency performance (performance/watt) for a given workload type. This configuration is provided by the manufacturer and may be optimized for the transaction, streaming and composite workload types.

[6] Power-performance tradeoffs in data center servers: DVFS, CPU pinning, horizontal, and vertical scaling - ScienceDirect {accessed 26/04/2024}

[7] Ecodesign preparatory study on Enterprise servers and data equipment, Bio Deloitte, 2015

The Hot Band workload test is an I/O load consisting of a collection of read and write requests that models areas of higher frequency I/O activity over the addressed data. This is measured in I/O per second per Watt (or IOPS/Watt).

The Sequential read workload test is an I/O load consisting of consecutively issued read requests to adjacently addressed data. This is measured in MiB (a binary megabyte, 1 MiB = 1,048,576 Byte) per second per Watt (or MiBS/Watt).

The Sequential write workload test an I/O load consisting of consecutively issued write requests to adjacently addressed data. This is measured in MiB (a binary megabyte, 1 MiB = 1,048,576 Byte) per second per Watt (or MiBS/Watt).

Power management functions: Capacity optimisation methods data be included for storage

The following energy efficiency feature is set as a requirement for data storage devices. A storage product shall make available to the end user configurable / selectable features listed in Table 6.15 in quantities greater than or equal to those listed in Table 6.16.

Table 6.15 Recognised COM features[8]

Feature	Verification Requirement
COM: Thin Provision	SNIA Verification test, following ISO/IEC 24091:2019 standard
COM: Data Deduplication	SNIA Verification test, following ISO/IEC 24091:2019 standard
COM: Compression	SNIA Verification test, following ISO/IEC 24091:2019 standard
COM: Delta Snapshots	SNIA Verification test, following ISO/IEC 24091:2019 standard

Table 6.16 COM reqs for Disk Set & NVSS Disk Set Access Online 2, 3 & 4 Systems

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

COMs are defined as **Capacity Optimising Methods**, resulting in the reduction of actual data stored on storage devices through a combination of hardware and / or software. These include:

- **Thin Provisioning**: A technology that allocates the physical capacity of a volume or file system as applications write data, rather than allocating all the physical capacity at the time of provisioning.
- **Data Deduplication**: The replacement of multiple copies of data – at variable levels of granularity – with references to a shared copy in order to save storage space and/or bandwidth.
- **Compression**: The process of encoding data to reduce its size. For the purpose of this specification, only lossless compression (i.e., compression using a

[8] ISO/IEC 24091:2019(en), Information technology — Power efficiency measurement specification for data center storage

technique that preserves the entire content of the original data, and from which the original data can be reconstructed exactly) is recognized.

- **Delta Snapshots**: A type of point-in-time copy that preserves the state of data at an instant in time by storing only those blocks that are different from an already existing full copy of the data.

Where "online" is set for storage which is accessible MaxTTFD ≤ 80ms. Maximum Time to First Data is the time required to start receiving data from a storage product to satisfy a read request for arbitrary data.

Impacts on Base case 3 modelling

The measures considered here are taken from the Energy Star data storage product requirements. According to Energy Star: *Data storage products that qualify for the ENERGY STAR are made by leading OEMs. They usually cost and perform the same (or better) than standard products, but they are designed and/or constructed to save energy.*[9] We therefore assume that for our Base case 3 modelling, there are no additional costs for including these measures.

With regards to energy savings, according to Energy Star 2014 survey indicates that 60% of data centre administrators already use data compression, 55% use deduplication technology, and 62% use snapshot technology. 40% of IT administrators are also noted to use thin provisioning. The different techniques are estimated to make savings such that a snapshot copy would use 10 to 20% of the base volume and deduplication can save data stored from 30-95%. Therefore, it is a conservative estimation that 75% of data centres already have data storage capacity optimisation methods, and hence only 25% would benefit from the new regulatory measures. Assuming these measures would deliver 40% saving in data storage, the base case 3 modelling can assume that this Design option would provide an overall 10% saving to the average purchaser. This modelling method is conservative as it does consider potential effects of reduced number of data storage products required.

6.1.3 Material efficiency

6.1.3.1 Design Option 7: Improved disassembly, repairability and recycling on servers

This Design option is composed of multiple measures to improve the disassembly, the repairability and recycling of servers.

Disassemblability requirements by class B generalist, workshop environment class A, using tools from A, B or C nomenclature.

The following measure is considered to favour repairability, reuse, refurbishment and recycling of servers and data storage products.

Servers must be disassemblable by someone with generalist repair skills, in a workshop environment and not using proprietary tools. The definition of "disassembly" is marked as "a process whereby a product is taken apart in such a way that is could subsequently be reassembled and made operational". This is the process for replacement of parts. The requirements follow the definitions from EN 45554, such that:

[9] Implement Efficient Data Storage Measures | ENERGY STAR

- ***Generalist (Class B)**: repair, reuse or upgrade process cannot be carried out by layman (class A) but can be carried out by a person with a general knowledge of basic repair, reuse or upgrade techniques and safety precautions.*
- ***Workshop environment (Class B):** If a repair, reuse or upgrade process cannot be carried out in the environment where the product is in use (class A) but does not require a production-equivalent environment.*
- *With **tools** meeting the requirements of:*
    - ***Class A:** feasible with no tool; or with basic tools (screwdriver, hex key, pliers, spanner)*
    - ***Class B:** Product group specific tools*
    - ***Class C:** other commercially available tools*

Furthermore, fasteners should all be reusable (class A) or removable (class B), following the definitions below:

<u>Fastener types:</u>

- ***Reusable (class A):** An original fastening system that can be completely reused, or any elements of the fastening system that cannot be reused are supplied with the new part for the repair, reuse or upgrade process.*
- ***Removable (class B):** An original fastening system that is not reusable, but can be removed without causing damage or leaving residue which precludes reassembly (in case of repair or upgrade) or reuse of the removed part (in case of reuse) for the repair, reuse or upgrade process.*

This shall cover the following components: CPU, PSUs, data storage devices, memory, motherboard, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

For the PSU and storage drives, the tool requirement for removal for replacement/upgrade shall be only of class A.

This measure has singled out PSUs and storage drives with a more stringent disassembly requirement, following the data from Task 3, section 3.3.4, that the most likely component failure is the PSU, motherboard and storage drives. As Motherboards are connected to all components, these cant be set at a higher stringency level. However, it is noted that PSUs and storage drives are typically set aside from the rest of the server design in order to facilitate upgrade. Hence, they are suitable for improved disassemblability requirements.

This measure is expected to have some slight cost increases to redesign products for disassembly. However, these costs should be minimised once the disassemblability design features have been created and carried forward through to new product generations.

The benefits of this measure are to increase the rate of repair, refurbishment, reuse of parts and recycling of server and data storage products.

Information provided to professionals on how to disassemble.

This measure follows from the previous one, to ensure that repair professionals have the required information to appropriately disassemble, and hence repair, servers and data storage products. This would take the form of:

- *the unequivocal product identification;*

- *a disassembly map or exploded view;*
- *wiring and connection diagrams, as required for failure analysis;*
- *electronic board diagrams;*
- *a list of necessary repair and test equipment;*
- *technical manual of instructions for repair, including marking of the individual steps;*
- *diagnostic fault and error information (including manufacturer-specific codes, where applicable);*
- *component and diagnosis information (such as minimum and maximum theoretical values for measurements);*
- *instructions for software and firmware (including reset software);*
- *information on how to access professional repair, including the internet webpages, addresses and contact details of professional repairers registered in accordance with points 2 (a) and (b).*

This information shall be made available on the manufacturers website, indicating the process for professional repairers to register for access to information.

This measure is estimated to have some additional costs to provide the administration for the information provision. The benefits are that this may improve the rate of repair of products (hence extend life expectancy), refurbishments, reuse of components and recycling.

Availability of spare parts

This measure is considered to ensure that repair can be done on servers.

Manufacturers, importers or authorised representatives of computer servers shall make available to professional repairers at least the following spare parts, for a minimum period of 5 years after placing the last unit of the model on the market:

- *memory cards*
- *CPU*
- *Motherboard*
- *Graphic cards*
- *PSU*
- *Chassis*
- *Batteries*
- *Fans*
- *Integrated switch*
- *RAID controllers*
- *Network interface cards*

This measure is expected to have a small additional cost in order for manufacturers to ensure that they have spare parts available as they ship. The benefits are that this may improve the rate of repair of products (hence extend life expectancy).

Preventing parts pairing

The following measure is considered to favour repairability, reuse and refurbishment of servers and their components.

For serialised parts, the manufacturers shall provide non-discriminatory access for professional repairers to any software tools, firmware or similar auxiliary means needed to ensure the full functionality of those spare parts and of the device in which such spare parts are installed during and after the replacement;

Whereby a serialised part means a part which has a unique code that is paired to an individual unit of a device and whose replacement by a spare part requires the pairing of that spare part to the device by means of a software code to ensure full functionality of the spare part and the device;

This shall cover the following components: CPU, PSUs, data storage devices, memory, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

These measures are expected to have an administrative cost to create and host websites to provide access to repairers to serialised software or firmware tools. However, these costs should be minimised once the processes have been created and carried forward through to new product generations.

The benefits of this measure are to increase the rate of repair, refurbishment and reuse of parts for server and data storage products.

Provision of hardware component level performance and material content compatibility in information sheet.

This measure is considered for that recycling industry can better target their recycling efforts to recover these materials.

Servers should be sold with an Ecodesign information sheet which details the following components, along with their performance capabilities and compatibility metrics (including pins design and number).

Indicative weight ranges of bulk materials and specific targeted ranged for the following critical raw materials:

- tantalum in all components (weight range: less than 0,01 g, between 0,01 g and 0,1 g, above 0,1 g);

- gold in all components (weight range: less than 0,02 g, between 0,02 g and 0,1 g, above 0,1 g);

- Germanium in all components (weight range: less than 0,02 g, between 0,02 g and 0,1 g, above 0,1 g);

- Dysprosium in all components (weight range: less than 0,02 g, between 0,02 g and 0,1 g, above 0,1 g);

- Silicon in all components (weight range: less than 5 g, between 5 g and 25 g, above 25 g);

This should cover the following components: CPU, PSUs, data storage devices, memory, motherboard, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

This product information datasheet should include a list of the components, their number codes and their material content (both bulk and targeted CRMs: Cobalt, neodymium, silicon, germanium, silicon, tantalum, gold, dysprosium). This list will allow recyclers to identify which component streams will have the most concentrated CRM.

This measure is estimated to have not to have any additional cost as it is not a material impact but an administrative burden for manufacturers to track their components. The benefits are that this may improve the rate of recycling.

6.1.3.2 Design Option 8: Improved disassembly, repairability and recycling on data storage products

This Design option is composed of multiple measures to improve the disassembly, the repairability and recycling of data storage products.

Disassemblability requirements by class B generalist, workshop environment class A, using tools from A, B or C nomenclature.

The following measure is considered to favour repairability, reuse, refurbishment and recycling of servers and data storage products.

Data storage products must be disassemblable by someone with generalist repair skills, in a workshop environment and not using proprietary tools. These definitions follow EN 45554, such that:

- ***Generalist (Class B)****: repair, reuse or upgrade process cannot be carried out by layman (class A) but can be carried out by a person with a general knowledge of basic repair, reuse or upgrade techniques and safety precautions.*
- ***Workshop environment (Class B):*** *If a repair, reuse or upgrade process cannot be carried out in the environment where the product is in use (class A) but does not require a production-equivalent environment.*
- *With* ***tools*** *meeting the requirements of:*
    - ***Class A:*** *feasible with no tool; or with basic tools (screwdriver, hex key, pliers, spanner)*
    - ***Class B:*** *Product group specific tools*
    - ***Class C:*** *other commercially available tools*

Furthermore, fasteners should all be reusable (class A) or removable (class B), following the definitions below:

<u>*Fastener types:*</u>

- ***Reusable (class A):*** *An original fastening system that can be completely reused, or any elements of the fastening system that cannot be reused are supplied with the new part for the repair, reuse or upgrade process.*
- ***Removable (class B):*** *An original fastening system that is not reusable, but can be removed without causing damage or leaving residue which precludes reassembly (in case of repair or upgrade) or reuse of the removed part (in case of reuse) for the repair, reuse or upgrade process.*

This shall cover the following components: CPU, PSUs, data storage devices, memory, motherboard, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

For the PSU and storage drives, the tool requirement for disassembly shall be only of class A.

This measure has singled out PSUs and storage drives with a more stringent disassembly requirement, following the data from Task 3, section 3.3.4, that the most likely component failure is the PSU, motherboard and storage drives. As Motherboards are connected to all components, these can't be set at a higher stringency level. However, it is noted that PSUs and storage drives are typically set aside from the rest of the device design in order to facilitate upgrade. Hence, they are suitable for improved disassemblability requirements.

This measure is expected to have some slight cost increases to redesign products for disassembly. However, these costs should be minimised once the disassemblability design features have been created and carried forward through to new product generations.

The benefits of this measure are to increase the rate of repair, refurbishment, reuse of parts and recycling of server and data storage products.

Information provided to professionals on how to disassemble.

This measure follows from the previous one, to ensure that repair professionals have the required information to appropriately disassemble, and hence repair, servers and data storage products. This would take the form of:

- *the unequivocal product identification;*
- *a disassembly map or exploded view;*
- *wiring and connection diagrams, as required for failure analysis;*
- *electronic board diagrams;*
- *a list of necessary repair and test equipment;*
- *technical manual of instructions for repair, including marking of the individual steps;*
- *diagnostic fault and error information (including manufacturer-specific codes, where applicable);*
- *component and diagnosis information (such as minimum and maximum theoretical values for measurements);*
- *instructions for software and firmware (including reset software);*
- *information on how to access professional repair, including the internet webpages, addresses and contact details of professional repairers registered in accordance with points 2 (a) and (b).*

This information shall be made available on the manufacturers website, indicating the process for professional repairers to register for access to information.

This measure is estimated to have some additional costs to provide the administration for the information provision. The benefits are that this may improve the rate of repair of products (hence extend life expectancy), refurbishments, reuse of components and recycling.

Availability of spare parts

This measure is considered to ensure that repair can be done on servers.

Manufacturers, importers or authorised representatives of data storage products shall make available to professional repairers at least the following spare parts, for a minimum period of 5 years after placing the last unit of the model on the market:

- *memory cards*
- *CPU*
- *Motherboard*
- *Graphic cards*
- *PSU*
- *Chassis*
- *Batteries*
- *Fans*
- *Integrated switch*
- *RAID controllers*
- *Network interface cards*

This measure is expected to have a small additional cost in order for manufacturers to ensure that they have spare parts available as they ship. The benefits are that this may improve the rate of repair of products (hence extend life expectancy).

Preventing parts pairing

The following measure is considered to favour repairability, reuse and refurbishment of servers and their components.

For serialised parts, the manufacturers shall provide non-discriminatory access for professional repairers to any software tools, firmware or similar auxiliary means needed to ensure the full functionality of those spare parts and of the device in which such spare parts are installed during and after the replacement;

Whereby a serialised part means a part which has a unique code that is paired to an individual unit of a device and whose replacement by a spare part requires the pairing of that spare part to the device by means of a software code to ensure full functionality of the spare part and the device;

This shall cover the following components: CPU, PSUs, data storage devices, memory, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

These measures are expected to have an administrative cost to create and host websites to provide access to repairers to serialised software or firmware tools. However, these costs should be minimised once the processes have been created and carried forward through to new product generations.

The benefits of this measure are to increase the rate of repair, refurbishment and reuse of parts for server and data storage products.

Provision of hardware component level performance and material content compatibility in information sheet.

This measure is considered for that recycling industry can better target their recycling efforts to recover these materials.

Data storage products should be sold with an Ecodesign information sheet which details the following components, along with their performance capabilities and compatibility metrics (including pins design and number).

Indicative weight ranges of bulk materials and specific targeted ranged for the following critical raw materials:

- tantalum in all components (weight range: less than 0,01 g, between 0,01 g and 0,1 g, above 0,1 g);

- gold in all components (weight range: less than 0,02 g, between 0,02 g and 0,1 g, above 0,1 g);

- Germanium in all components (weight range: less than 0,02 g, between 0,02 g and 0,1 g, above 0,1 g);

- Dysprosium in all components (weight range: less than 0,02 g, between 0,02 g and 0,1 g, above 0,1 g);

- Silicon in all components (weight range: less than 5 g, between 5 g and 25 g, above 25 g);

This should cover the following components: CPU, PSUs, data storage devices, memory, motherboard, graphic card, chassis, batteries, fans, integrated switch, RAID controllers and Network Interface Cards.

This product information datasheet should include a list of the components, their number codes and their material content (both bulk and targeted CRMs: Cobalt, neodymium, silicon, germanium, silicon, tantalum, gold, dysprosium). This list will allow recyclers to identify which component streams will have the most concentrated CRM.

This measure is estimated to have not to have any additional cost as it is not a material impact but an administrative burden for manufacturers to track their components. The benefits are that this may improve the rate of recycling.

6.1.3.3 Effects of DO7 and DO8 on the base cases

The principal effect of these measures together are:

- An increased cost to manufacturers of servers and data storage products, in order to facilitate a new design which is disassemblable, providing information to repairers on how to disassemble. This is estimated to cost an additional 5% to the product.
- An increase in manufacturer cost to have spare parts available in stock. This is estimated to cost an additional 5% to the product.
- The additional material impacts of spare parts used in the repair. For servers, it is noted in Task 3, section 3.3.4, that the most likely component failure is the PSU and the motherboard. We shall mark this as a 0.5% increase in the use of both of those parts. For data storage products, Task 3, section 3.3.4 noted that HDDs last for 1.5 million hours, versus 2 million hours for SSD. These hours estimate a rate of failure for SSDs after 228 years and 171 years for HDDs. We therefore estimate a replacement rate for HDDs of 0.5% per year, and 0.4% per year for SSDs, which will be used as increased materials requirements reference.
- The lifetime of a server or data storage product is estimated to increase by 50% when the product is repaired. We estimate that these measures will increase the

rate of repair by 10%. Therefore, the average product life expectancy will increase by 5%.

- According to the Task 3, Table 3.6, the current reuse of electronic components in servers is only 1%, and 25% for data storage products. Assuming these measures double the reuse of electronic components, we model this in the model such that the R1 recycled content of electronic components in the inputs are doubled.
- The measures for improved disassemblability and information provision, is estimated to provide improved identification, and reduced effort for material recycling. Hence this increases the business case and reduce the costs for businesses to collect and recycle materials. Therefore, we assume that collection rates are increased from 40% to 50%, which increases the R2 recycling output rates in the Ecoreport tool.

6.1.4 Design Option 9: Combined measures servers, BC1 and BC2

For servers, BC1 and BC2, the following DOs have been combined:

- DO3 stricter-active efficiency server
- DO4 idle consumption to workload ratio
- DO5 processor management function
- DO7 material efficiency

This design option combines the DO3, DO4, DO5 and DO7.

For Base case modelling, DO3 and DO4 would change performance as given in Table 6.17 with additional 5% reduction in idle consumption due to DO5. DO7 will increase the cost by 10%.In this DO, the pass rate for BC1 will be 65% and for BC2 60%.

Table 6.17 Modelling changes for DO9

DO	Base Case	Change made	Percentage difference
9	1	Cost increase	10%
9	1	Active consumption figures reduced by:	19%
9	1	Idle consumption reduced by:	2%
9	1	Performance figures increased by:	27%
9	2	Cost increase	10%
9	2	Active consumption figures reduced by:	8.1%
9	2	Idle consumption reduced by:	7%
9	2	Performance figures increased by:	15%

6.1.5 Design Option 10: Combined measures data storage products, BC3

The data storage product combined DO should consider the measures of DO6 on energy efficiency, and DO8 on material efficiency. These measures do not directly clash, and hence the impacts on data storage products can be directly summed.

6.1.5.1 DO6 energy efficiency

The Base Case 3 modelling can assume that this Design option would provide an overall 10% saving to the average purchaser.

We therefore assume that for our Base Case 3 modelling, there are no additional costs for including these measures.

6.1.5.2 DO8 material efficiency

The principal effect of these measures together are:

- An increased cost to manufacturers of servers and data storage products, in order to facilitate a new design which is disassemblable, providing information to repairers on how to disassemble. This is estimated to cost an additional 5% to the product.
- An increase in manufacturer cost to have spare parts available in stock. This is estimated to cost This is estimated to cost an additional 5% to the product.
- The additional material impacts of spare parts used in the repair. For servers, it is noted in Task 3, section 3.3.4, that the most likely component failure is the PSU and the motherboard. We shall mark this as a 0.5% increase in the use of both of those parts. For data storage products, Task 3, section 3.3.4 noted that HDDs last for 1.5 million hours, versus 2 million hours for SSD. These hours estimate a rate of failure for SSDs after 228 years and 171 years for HDDs. We therefore estimate a replacement rate for HDDs of 0.5% per year, and 0.4% per year for SSDs, which will be used as increased materials requirements reference.
- The lifetime of a server or data storage product is estimated to increase by 50% when the product is repaired. We estimate that these measures will increase the rate of repair by 10%. Therefore, the average product life expectancy will increase by 5%.
- According to the Task 3, Table 3.6, the current reuse of electronic components in servers is only 1%, and 25% for data storage products. Assuming these measures double the reuse of electronic components, we model this in the model such that the R1 recycled content of electronic components in the inputs are doubled.
- The measures for improved disassemblability and information provision, is estimated to provide improved identification, and reduced effort for material recycling. Hence this increases the business case and reduce the costs for businesses to collect and recycle materials. Therefore, we assume that collection rates are increased from 40% to 50%, which increases the R2 recycling output rates in the Ecoreport tool.

6.1.6 Information sharing

The following measures may have benefits at the level of the datacentre system, as they encourage better product utilisation, datacentre facilities management and improved purchasing practices. These are therefore not expected to have direct impacts on the Base Cases to be modelled in the Task 6. However, their impacts will be considered in the Task 7 system impacts.

6.1.6.1 Data Sharing

Server real time utilisation and power consumption reporting

The following design option is considered:

A computer server must provide real-time data on input power consumption (W) and average utilisation of all logical CPUs. Data must be made available in a published or user-accessible format that is readable by third-party, non-proprietary management software over a standard network. For blade and multi-node servers and systems, data may be aggregated at the chassis level.

Processor utilization: Average utilization must be estimated for each logical CPU that is visible to the OS and must be reported to the operator or user of the computer server through the operating environment (OS or hypervisor); This should be reported under the ITEUSV ISO/IEC 30134-5:2017 metric.

Input power: Measurements must be reported with accuracy of at least ±5% of the actual value, with a maximum level of accuracy of ±10W for each installed PSU (i.e., power reporting accuracy for each power supply is never required to be better than ± 10 watts) through the operating range from Idle to full power;

This measure is estimated not to have any costs to include as this requires for updated software reporting to be included, which is irrelevant of the hardware used. It is also a requirement for Energy Star, making it a common requirement for all products to align with. The measure is expected to increase product utilisation and therefore decrease the total need for hardware.

Server thermal management and monitoring

The following design option is considered:

A computer server must provide real-time data on inlet air temperature (°C) monitoring and fan speed management capability that is enabled by default. Data must be made available in a published or user-accessible format that is readable by third-party, non-proprietary management software over a standard network. For blade and multi-node servers and systems, data may be aggregated at the chassis level.

Inlet air temperature: Measurements must be reported with an accuracy of at least ±2°C.

This measure is estimated not to have any costs to include as this requires for updated software reporting to be included, which is irrelevant of the hardware used. It is also a requirement for Energy Star, making it a common requirement for all products to align with. The measure is expected to improve datacentre facilities management and hence overall energy efficiency of the datacentre under the PUE. This is not expected to affect Base case consumption.

Data storage products performance reporting

The following design option is considered:

Data storage products with an Online 3 and Online 4 capability shall be capable of measuring and reporting the following;

- *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

- *Inlet Air Temperature, in degrees Celsius, with accuracy of ± 2°C.*

The data shall be made available in a published or user-accessible format that is readable by third-party, non-proprietary management systems. This data shall be available over a standard network for end users and third-party management systems.

This measure is estimated not to have any costs to include as this requires for updated software reporting to be included, which is irrelevant of the hardware used. It is also a requirement for Energy Star, making it a common requirement for all products to align with.

The measure is expected to improve datacentre facilities management and hence overall energy efficiency of the datacentre under the PUE. This is not expected to affect Base case consumption.

6.1.6.2 Labelling for server products

The following design option is considered:

Servers should be sold with an energy label which includes the following information:

- *Server form factor*
- *Server active efficiency*
- *Server active Performance score*
- *Idle power consumption (in Watts)*
- *ASHRAE temperature range*

For servers which are part of a server configuration family, the "typical server configuration" data should be reported.

This measure could also be considered to be run via a QR code set directly on the server which links to a webpage with the information.

This measure is estimated to have not to have any additional cost than that of the typical server configuration testing. However, that test is currently required under Energy star, and will be required under the above Ecodesign active efficiency and idle consumption design options.

This measure is expected to show benefits to encourage the purchase of more efficient servers over time. In this manner, the measure is expected to have a system improvement effect and not an effect on the Base case modelling.

6.1.7 Product exemptions and scope

Review from Phase 1 the exemptions and scope changes proposed to the regulation. These measures will not affect the Base case modelling, and hence will not be considered under the Task 6 modelling. However, they may have an effect under the total server and data storage impacts which will be modelled in Task 7.

Server appliances

Under this design option, the server appliances product will be brought into scope of the regulation but kept out of scope of the energy efficiency requirements set out in Annex II point 2.1 and point 2.2 of Regulation 2019/424.

This is not expected to increase cost to consumers, but will ensure that server appliances are provided with the appropriate material information and can have an increased recycling rate.

Fully fault tolerant

Under this design option, the fully fault tolerant servers are brought into scope of the regulation but kept out of scope of the energy efficiency requirements set out in Annex II point 2.1 and point 2.2 of Regulation 2019/424.

This is not expected to increase cost to consumers, but will ensure that server appliances are provided with the appropriate material information and can have an increased recycling rate.

Hyperconverged servers

Under this design option, the hyperconverged servers are brought into scope of the regulation but kept out of scope of the energy efficiency requirements set out in Annex II point 2.1 and point 2.2 of Regulation 2019/424.

Hyperconverged Server will be defined under this design option as: *A highly integrated server which contains the additional features of large network equipment and storage products.*

This is not expected to increase cost to consumers, but will ensure that server appliances are provided with the appropriate material information and can have an increased recycling rate.

Large servers

Large servers are currently out of scope from SPEC SERT, EPEAT and IEC 21836:2020. They therefore do not have an energy measurement standard.

Under this design option, we propose to include large servers into the regulation, but kept out of scope of: the PSU requirements set out in Annex II point 1.1, the energy efficiency requirements set out in Annex II point 2.1 and point 2.2 of Regulation 2019/424. Most large servers would also be exempt from the information requirements from Annex II 3.1 as they generally meet the exemption criteria of being "*custom made servers, made on a one-off basis"* as currently set in the regulation.

This will ensure that large server providers must provide firmware support for 6 years, allow for part harvesting, provide availability of spare parts, disassemblability and repair, along with information provision on materials used.

6.1.8 Other measures not taken forward

The scope of the review study had set out a number of aspects to consider in the Phase 1 of the study. These elements were complimented with the stakeholder engagement and research undergone in this study to determine what design options to consider. Below are noted the elements which were considered for design option, but not taken forward, along with the reasoning for it. For more details on these decisions, please refer to the Phase 1 report.

PSU energy efficiency metrics

This energy efficiency metric is not being proposed for increase, as Phase 1 research shows that the current regulation already requires best in class PSUs for servers and data storage products.

Standby readiness

Given this functionality is not currently available on the market and that consumer demand for this functionality appears low, this functionality will not be set as a design option.

DC power supply

The current evidence does not support the argument that DC servers systems are more efficient than AC server systems. Therefore, this functionality is not set as a design option in this study.

High Performance Computing and servers with integrated APA exclusions

The exclusion on energy efficiency metrics (annex II point 2.1 and point 2.2) for High Performance Computing (HPC) servers and servers with integrated APA. These products are currently out of scope of the testing standards SPECT SERT tool and the ISO/IEC 21836.2020. Therefore, no design option is set out for these products.

Ban of particular polymer combinations

Stakeholders indicated that recycling of plastics in servers can be a concern if particular polymer combinations which are difficult to separate (and hence recycle). This combination problem comes in two parts:

- bonded parts with multiple plastics - might not separate on shredding so can't be reliably sorted and may not be compatible if they're mechanically recycled together.
- plastic and plastic alloys that don't really work well with regular recycling processes.

Although these concerns for recycling exist, this measure was not taken forward as a design option. The concern here is that clear evidence is needed to determine which are the polymer combinations of concern and what problems are explicitly being caused. To mandate a removal of these, it would be preferable to have an industry-wide agreement on which of the polymers are the most problematic and what replacement options exist.

Liquid cooling

Liquid cooling of servers is becoming more common. It is done in multiple ways, the first is with indirect liquid cooling, where the liquid cooling pipes are applied to the rack, these are sold as separate equipment to the server and are therefore out of scope of the Ecodesign regulation. The second is immersion liquid cooling, where servers are immersed in a cooling fluid. This is irrespective of the server design, and hence is out of scope of Ecodesign regulation.

The third is liquid cooling to the chip itself. This can be done with setups where third parties will attach a device to the chip and allow for the liquid cooling. These are done irrespective of the product design. And lastly, there are products designed with liquid cooling done directly to the chip, which is largely limited to HPC systems, which are out of scope of the regulation. Furthermore, the regulated server products are currently tested under SERT in an air-cooled configuration.

Due to the limited scope of products currently designed for liquid cooling specifically, and tested under SERT as such, there is no recommendation to consider Design Option for this technology. However, as this is marked as a growing technology, these should be considered in the scope of the next regulatory review.

Waste heat recuperation

The recuperation of waste heat is beyond the scope of the Ecodesign product regulation as this relates to the system and not the product itself. However, waste heat recuperation could be enabled further by increasing the operating range of servers (hence higher temperatures to recuperate), or by enabling liquid to chip cooling system which would be more effective at recuperating heat. As indicated in Phase 1, setting higher operating temperatures may lead to higher overall energy consumption and is therefore not advised to be mandated. For liquid-to-chip, a test standard under SERT needs to be determined for measuring the active efficiency. Therefore, no Design option is suggested for waste heat recuperation.

Firmware provision

The Ecodesign regulation already has the Annex II article 1.2.3, which stipulates that manufacturers must provide the latest firmware for products at least 8 years after their placing on the market. This allows for products to be repaired. It was suggested that this measure was increased to cover not only the sharing of the latest firmware but also the previous firmware versions, in order to allow for the server repair industry to better integrate older components which would require the older firmware. However, this measure is not taken forward as it has the risk of exposing servers to cybersecurity risks, which are often what firmware updates are patching for.

Custom servers

Custom servers are defined in the current regulation as " Custom made server, made on a one-off basis". Under this regulation, these servers are exempt from providing information requirements. They are however, still required to meet the remaining regulatory requirements.

Resilient servers

There are few models of resilient servers, which are more expensive than other servers due to their redundancy requirements. These are maintained as being excluded from the energy efficiency requirements of the regulation. Their small number of models, make them difficult to benchmark and distinguish performance requirements for a regulation. Furthermore, their increased costs of manufacture ensure that they do not create a regulatory loophole.

Setting minimum operation range requirement to be ASHRAE A2. (or ban A1)

Under the Ecodesign regulation, servers must currently reveal in their information requirements if they meet the environment standards under ASHRAE of A1, A2, A3 or A4. These environment requirements extend the allowable range of operation for servers in terms of temperature and humidity. It was proposed that this range should be extended to allow for servers to operate at higher temperatures, which would therefore mean reduced cooling needs, and higher temperature heat recovery.

However, it should be noted, that although servers under an A3 ASHRAE condition class can be allowed to operate at a higher temperature, this is meant to be the allowable range, for temporary operation. For longer periods of time, all servers are still recommended to be operated within the recommended range 18 – 27 Degrees Celsius. If servers are operated for an extended period of time at higher temperatures than the recommended range, their internal fan consumption will increase. This has been shown to mean that although cooling costs would reduce, the energy consumption of the server itself would increase, which would overall increase the energy consumption of the datacentre. It is therefore not recommended to increase the ASHRAE range of server operation requirements.

6.2 Assessment of environmental impacts, life cycle costs and purchase price

6.2.1 BC1: Rack Server

Task 5 identified the Life Cycle cost and Environmental Impacts of BC1.Within Task 6, different design options applicable to Base Case 1 and their impact analysis was done.

Table 6.18 below shows the primary energy consumption and life cycle cost of all design options compared to the Base Case 1.

Table 6.18 Primary energy consumption & LCC of design options compared to BC1

	BC 1	DO 1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
Primary Energy Consumption (MJ)	5.85E+04	5.18E+04	5.13E+04	4.89E+04	5.21E+04	5.63E+04	5.45E+04	4.64E+04
% change with BC		-11	-12	-16	-11	-4	-7	-21
Life Cycle Cost (euro/yr)	15,591	14,478	14,399	13,989	14,525	15,232	15,510	14,169
% change with BC		-7.14	-7.65	-10.28	-6.84	-2.30	-0.52	-9.12

Figure 6.1 shows the relative impact on the primary energy consumption for each of the design options compared to the Base Case 1.

Figure 6.1 Primary energy consumption for Design Options compared to BC1 (%)

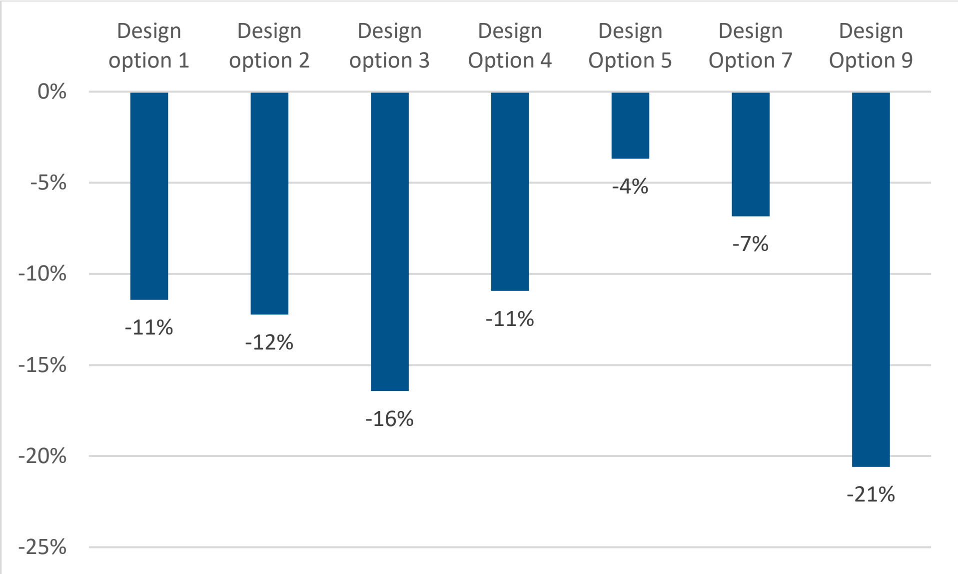
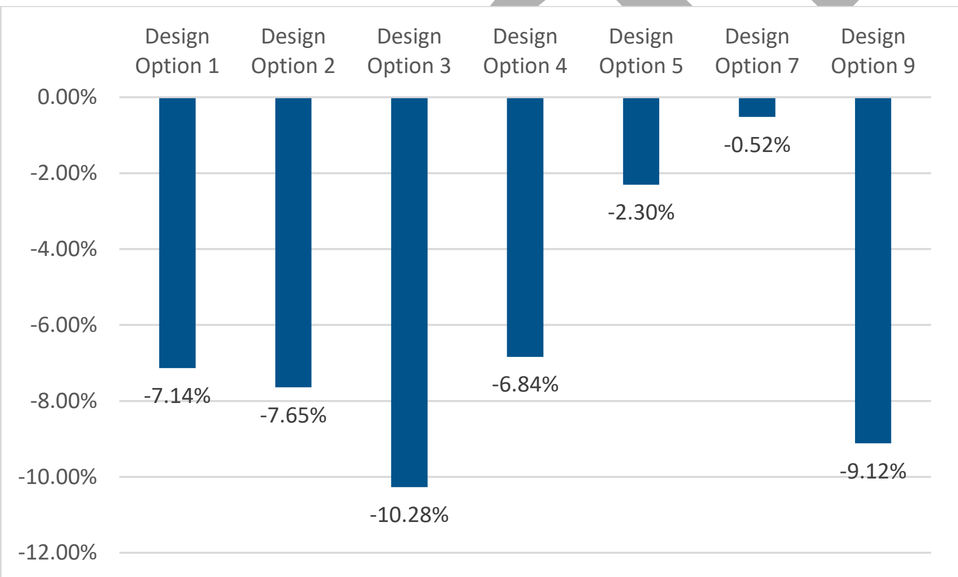


Figure 6.2 shows the relative impact on the life cycle cost for each of the design options compared to the Base Case 1.

Figure 6.2 Life Cycle Cost as compared with BC1 (%)



Each of the design options applicable to Base Case 1 and its relative impact on climate change, resource use (minerals and metals) and resource use (fossils) compared the base-case are shown in **Error! Reference source not found.**.

Table 6.19 Impact on climate change, resource use (minerals and metals) and resource use (fossils) of each Design Option compared to BC1

Life-cycle indicators per unit	Unit	BC 1	DO 1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
Climate change, total	kg CO2 eq	6.77E+03	5.99E+03	5.93E+03	5.65E+03	6.02E+03	6.51E+03	6.77E+03	5.36E+03
	% change with BC		-11	-12	-17	-11	-4	0	-21

Particulate Matter	disease incidence	2.26E-04	2.02E-04	2.00E-04	1.91E-04	2.03E-04	2.18E-04	2.26E-04	1.82E-04
	% change with BC		-11	-12	-16	-10	-4	0	-20
Acidification	mol H+ eq	2.14E+01	1.90E+01	1.89E+01	1.80E+01	1.91E+01	2.06E+01	2.14E+01	1.71E+01
	% change with BC		-11	-12	-16	-11	-4	0	-20
Resource use, minerals and metals	kg Sb eq	7.04E-02	7.02E-02	7.02E-02	7.02E-02	7.02E-02	7.04E-02	7.04E-02	7.01E-02
	% change with BC		-0.28	-0.30	-0.40	-0.27	-0.09	0	-1
Resource use, fossils	MJ	1.17E+05	1.04E+05	1.03E+05	9.77E+04	1.04E+05	1.13E+05	1.17E+05	9.28E+04
	% change with BC		-12	-12	-17	-11	-4	0	-21

All the Life Cycle Indicators per unit of product for different design options of Base Case 1 are annexed in Table A1.1.

6.2.2 BC2: Blade Server

Task 5 identified the Life Cycle cost and Environmental Impacts of BC2.Within Task 6, different design options applicable to Base Case 2 and their impact analysis was done.

Table 6.20 below shows the primary energy consumption and life cycle cost of all design options compared to Base Case 2.

Table 6.20 Primary energy consumption & LCC of design options compared to BC2

	BC 2	DO1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
Primary Energy Consumption (MJ)	5.74E+05	5.43E+05	5.39E+05	5.28E+05	5.64E+05	5.64E+05	5.74E+05	5.36E+05
% change with BC		-5.5	-6.2	-8.03	-2	-2	-0.13	-6.7
Life Cycle Cost (euro/yr)	72249	66961	66344	64566	70502	70591	72460	66004
% change with BC		-7	-8	-11	-2.4	-2.3	0.3	-8.6

Figure 6.3 shows the relative impact on the primary energy consumption for each of the design options compared to the Base Case 2.

Figure 6.3 Primary energy consumption for Design Options compared to BC2 (%)

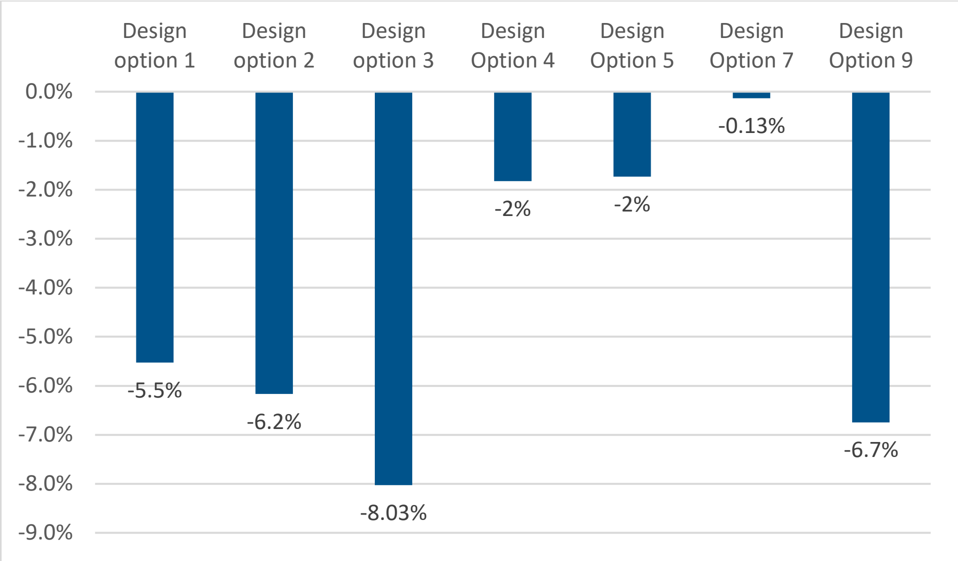
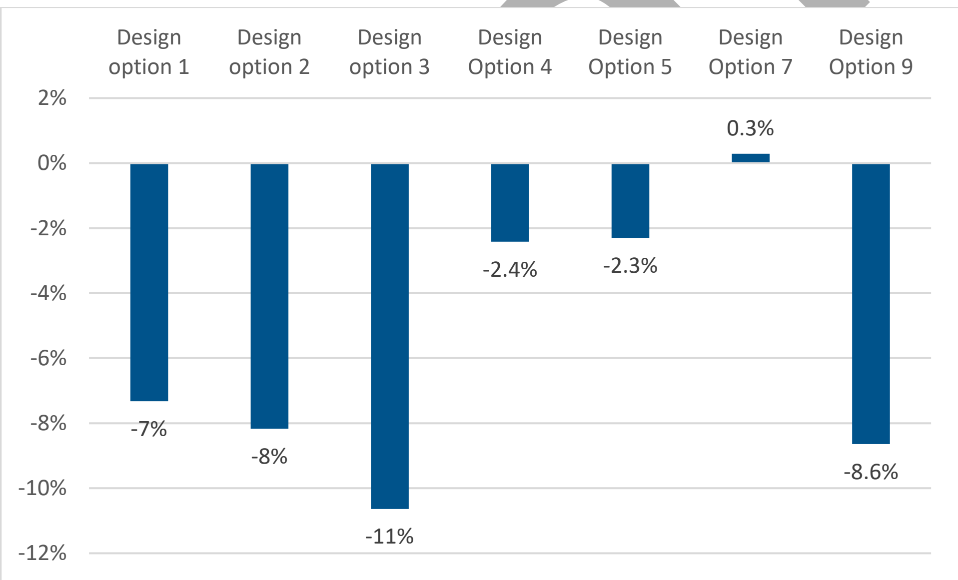


Figure 6.4 shows the relative impact on the life cycle cost for each of the design options compared to the Base Case 2.

Figure 6.4 Life Cycle Cost as compared to BC2 (%)



Each of the design options applicable to Base Case 2 and its relative impact on climate change, resource use (minerals and metals) and resource use (fossils) compared the base-case are shown in Table 6.21.

Table 6.21 Impact on climate change, resource use (minerals and metals) and resource use (fossils) of each Design Option compared to BC2

Life-cycle indicators per unit	Unit	BC 2	DO 1	DO 2	DO 3	DO4	DO 5	DO 7	DO 9
Climate change, total	kg CO2 eq	6.04E+04	5.67E+04	5.63E+04	5.50E+04	5.92E+04	5.93E+04	6.04E+04	5.59E+04
	% change with BC		-6	-7	-9	-2	-2	-0.09	-7

Particulate Matter	disease incidence	3.35E-03	3.23E-03	3.22E-03	3.18E-03	3.31E-03	3.31E-03	3.34E-03	3.21E-03
	% change with BC		-4	-4	-5	-1	-1	-0.3	-4
Acidification	mol H+ eq	3.48E+02	3.36E+02	3.35E+02	3.31E+02	3.44E+02	3.44E+02	3.47E+02	3.34E+02
	% change with BC		-3	-4	-5	-1	-1	-0.3	-4
Resource use, minerals and metals	kg Sb eq	1.47E+00	1.47E+00	1.47E+00	1.47E+00	1.47E+00	1.47E+00	1.46E+00	1.47E+00
	% change with BC		-0.06	-0.07	-0.09	-0.02	-0.02	-0.48	-0.08
Resource use, fossils	MJ	1.00E+06	9.40E+05	9.32E+05	9.11E+05	9.83E+05	9.84E+05	1.00E+06	9.26E+05
	% change with BC		-6	-7	-9	-2	-2	0	-8

All the Life Cycle Indicators per unit of product for different design options of Base Case 2 are annexed in Table A1.2.

6.2.3 BC3: Storage Unit

Task 5 identified the Life Cycle cost and Environmental Impacts of BC3.Within Task 6, different design options applicable to Base Case 3 and their impact analysis was done.

Error! Reference source not found. below shows the primary energy consumption and life cycle cost of all design options compared to the Base Case 3.

Table 6.22 Primary energy consumption & LCC of design options compared to BC3

	BC 3	DO 6	DO 8	DO 10
Primary Energy Consumption (MJ)	1.82E+05	1.71E+05	1.73E+05	1.66E+05
% change with BC		-6	-5	-8
Life Cycle Cost (euro/yr)	21708	19962	21979	20940
% change with BC		-8	1	-4

Figure 6.5 shows the relative impact on the primary energy consumption for each of the design options compared to the Base Case 3.

Figure 6.5 Primary energy consumption for Design Options compared to BC3 (%)

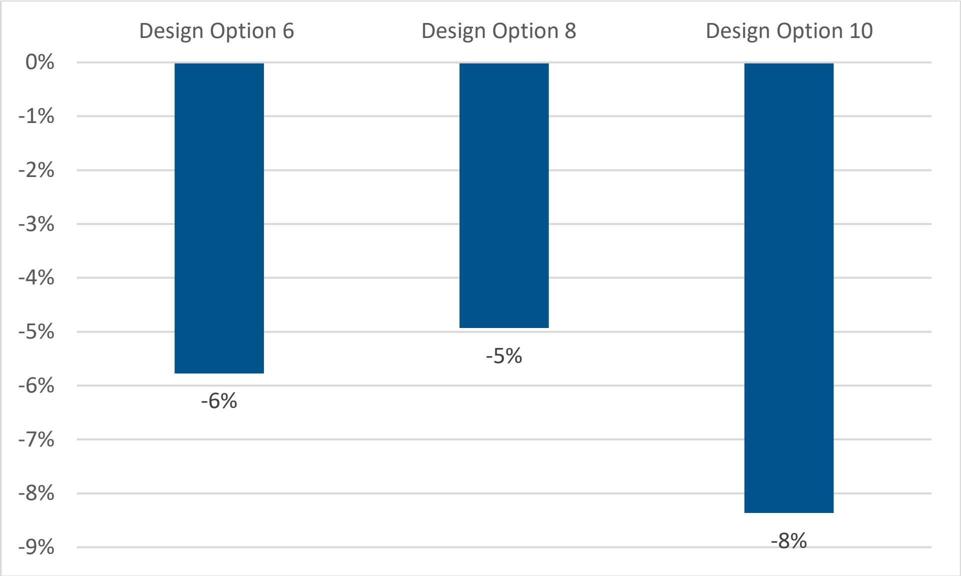
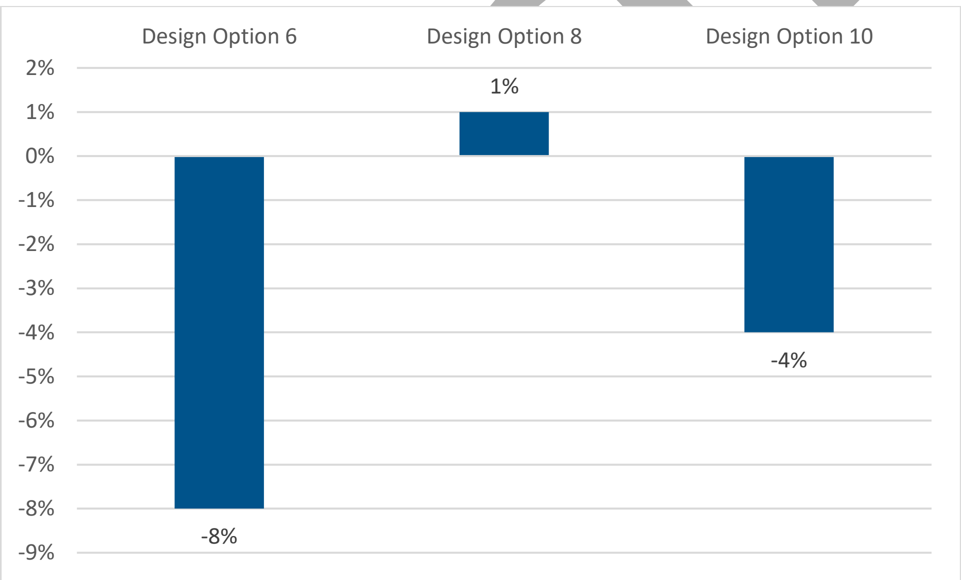


Figure 6.6 shows the relative impact on the life cycle cost for each of the design options compared to the Base Case 3.

Figure 6.6 Life Cycle Cost as compared to BC3 (%)



Each of the design options applicable to Base Case 3 and its relative impact on climate change, resource use (minerals and metals) and resource use (fossils) compared the base-case are shown in Table 6.23.

Table 6.23 Impact of climate change, resource use (minerals and metals) and resource use (fossils) of each Design Option compared to BC3

Life-cycle indicators per unit	Unit	BC 3	DO 6	DO 8	DO 10
Climate change, total	kg CO2 eq	1.79E+04	1.67E+04	1.73E+04	1.66E+04
	% change with BC		-7	-4	-8
Particulate Matter	disease incidence	1.28E-03	1.25E-03	1.18E-03	1.15E-03
	% change with BC		-3	-9	-10
Acidification	mol H+ eq	1.37E+02	1.33E+02	1.25E+02	1.22E+02
	% change with BC		-3	-9	-11
Resource use, minerals and metals	kg Sb eq	6.90E-01	6.90E-01	6.03E-01	6.02E-01
	% change with BC		0	-13	-13
Resource use, fossils	MJ	2.89E+05	2.68E+05	2.81E+05	2.68E+05
	% change with BC		-7	-3	-7

All the Life Cycle Indicators per unit of product for different design options of Base Case 3 are annexed in Table A1.3.

6.3 Analysis of BAT and Least Life Cycle Costs (LLCC)

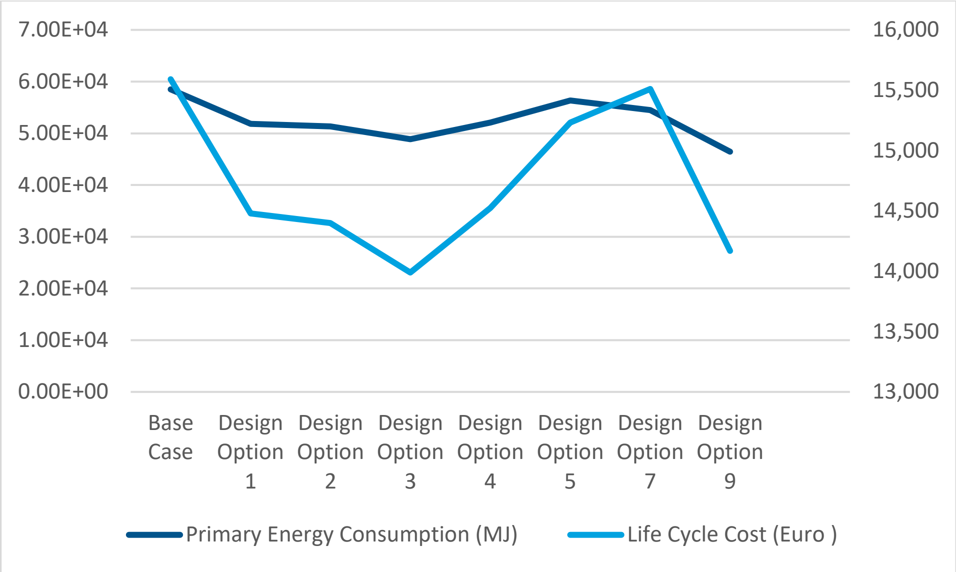
The design options are ranked to identify improvement options with the least cycle environmental impacts (BAT) and the Least Life Cycle Costs (LLCC). Energy-LCC curve (Y-axis = energy consumed and LCC, X-axis = options) allows the LLCC and BATs to be identified.

The performance of each Design Option is compared with the base case. The comparison is done in terms of primary energy consumption and Life Cycle cost (LCC) as described in Task 5.

6.3.1 Base Case 1

Figure 6.7 shows the LLCC curve for Base Case 1. The comparison is done in terms of primary energy consumption and Life Cycle cost (LCC)

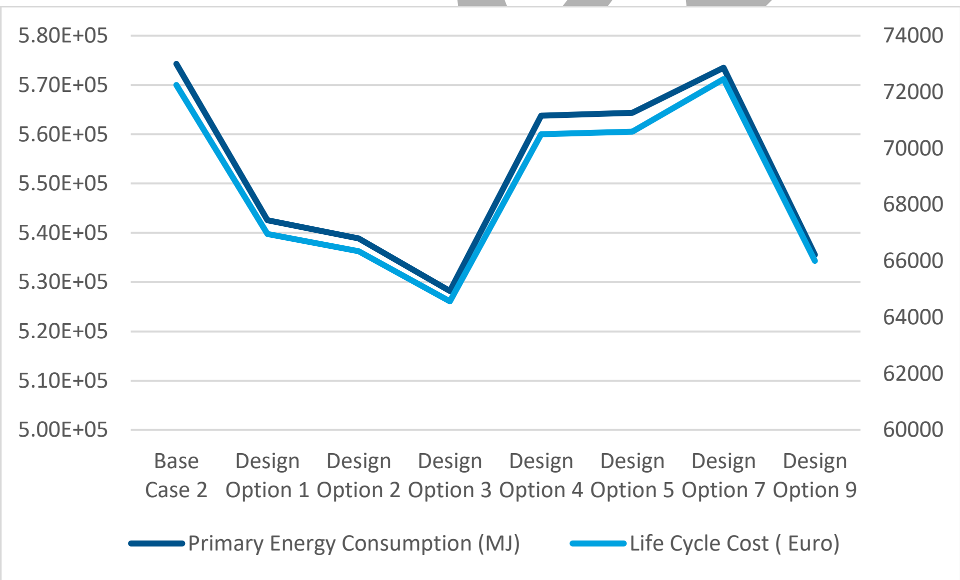
Figure 6.7 LLCC curve for Base Case 1



6.3.2 Base Case 2

Figure 6.8 shows the LLCC curve for Base Case 2. The comparison is done in terms of primary energy consumption and Life Cycle cost (LCC)

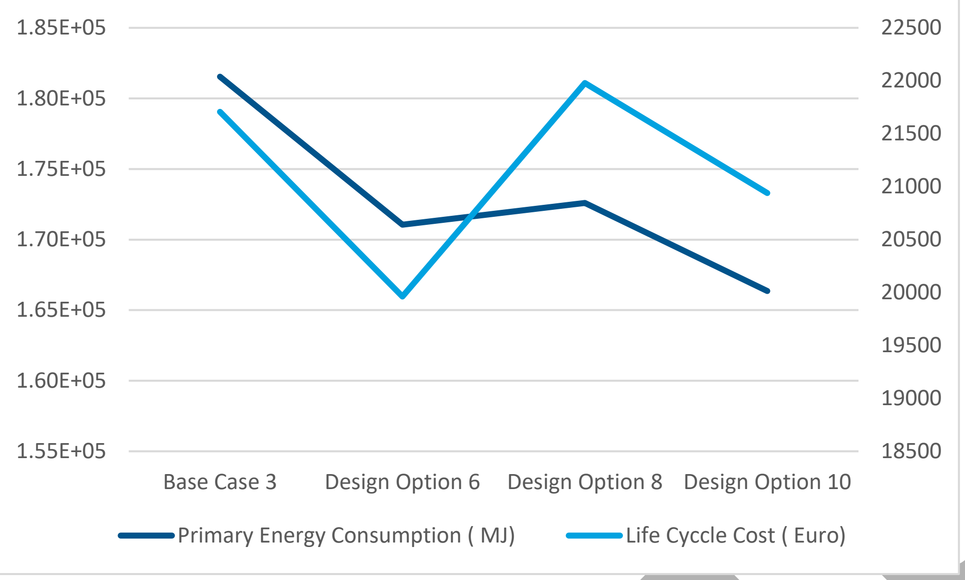
Figure 6.8 LLCC curve for Base Case 2



6.3.3 Base Case 3

Figure 6.9 shows the LLCC curve for Base Case 3. The comparison is done in terms of primary energy consumption and Life Cycle cost (LCC)

Figure 6.9 LLCC curve for Base Case 3



6.4 Long term potential (BNAT) & System analysis

TBC

Annex 1 All Life Cycle Indicators per unit for design options

This annex presents all Life cycle indicators per unit of different design options for the three Base Cases.

A1.1 Base Case 1

Table A1.1 All Life cycle indicators per unit of the different design options for BC 1

Life-cycle indicators per unit	Unit	BC 1	DO 1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
Energy Consumption									
Electricity	kWh	15,919.1	14,063.5	13,931.3	13,248.8	14,142.2	15,320.8	14,806.9	12,573
	% change with BC		-11.66	-12.49	-16.77	-11.16	-3.76	-6.99	-21.02
Thermal Energy	MJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
	% change with BC		0	0	0.00	0.00	0.00	0.00	0.00
PEF Impact Categories									
Climate change, total	kg CO2 eq	6.77E+03	5.99E+03	5.93E+03	5.65E+03	6.02E+03	6.51E+03	6.77E+03	5.36E+03
	% change with BC		-11	-12	-17	-11	-4	0	-21
Ozone depletion	kg CFC-11 eq	2.53E-06	2.24E-06	2.22E-06	2.12E-06	2.26E-06	2.44E-06	2.53E-06	2.01E-06
	% change with BC		-11	-12	-16	-11	-4	0	-21
Human toxicity, cancer	CTUh	1.13E-06	1.01E-06	9.97E-07	9.49E-07	1.01E-06	1.09E-06	1.13E-06	9.02E-07
	% change with BC		-11	-12	-16	-11	-4	0	-21
Human toxicity, non-cancer	CTUh	2.37E-05	2.11E-05	2.09E-05	1.99E-05	2.12E-05	2.28E-05	2.37E-05	1.90E-05
	% change with BC		-11	-12	-16	-11	-4	0	-20
Particulate Matter	disease incidence	2.26E-04	2.02E-04	2.00E-04	1.91E-04	2.03E-04	2.18E-04	2.26E-04	1.82E-04
	% change with BC		-11	-12	-16	-10	-4	0	-20
	kBq U235 eq	2.84E+03	2.51E+03	2.48E+03	2.36E+03	2.52E+03	2.73E+03	2.84E+03	2.24E+03

Ionising radiation, human health	% change with BC		-12	-12	-17	-11	-4	0	-21
Photochemical ozone formation, human health	kg NMVOC eq	1.14E+01	1.01E+01	1.00E+01	9.56E+00	1.02E+01	1.10E+01	1.14E+01	9.10E+00
	% change with BC		-11	-12	-16	-11	-4	0	-20
Acidification	mol H+ eq	2.14E+01	1.90E+01	1.89E+01	1.80E+01	1.91E+01	2.06E+01	2.14E+01	1.71E+01
	% change with BC		-11	-12	-16	-11	-4	0	-20
Eutrophication, terrestrial	mol N eq	4.26E+01	3.78E+01	3.75E+01	3.57E+01	3.80E+01	4.10E+01	4.26E+01	3.40E+01
	% change with BC		-11	-12	-16	-11	-4	0	-20
Eutrophication, freshwater	kg P eq	1.38E-02	1.22E-02	1.21E-02	1.15E-02	1.23E-02	1.33E-02	1.38E-02	1.10E-02
	% change with BC		-11	-12	-16	-11	-4	0	-21
Eutrophication, marine	kg N eq	4.01E+00	3.56E+00	3.53E+00	3.36E+00	3.58E+00	3.86E+00	4.01E+00	3.20E+00
	% change with BC		-11	-12	-16	-11	-4	0	-20
Ecotoxicity, freshwater	CTUe	3.10E+04	2.75E+04	2.72E+04	2.59E+04	2.76E+04	2.99E+04	3.10E+04	2.46E+04
	% change with BC		-11	-12	-16	-11	-4	0	-21
Land use	pt	8.54E+04	8.20E+04	8.18E+04	8.05E+04	8.22E+04	8.43E+04	8.54E+04	7.93E+04
	% change with BC		-4	-4	-6	-4	-1	0	-7
Water use	m3 water eq. of deprived water	2.30E+03	2.04E+03	2.02E+03	1.92E+03	2.05E+03	2.22E+03	2.30E+03	1.82E+03
	% change with BC		-12	-12	-17	-11	-4	0	-21
Resource use, minerals and metals	kg Sb eq	7.04E-02	7.02E-02	7.02E-02	7.02E-02	7.02E-02	7.04E-02	7.04E-02	7.01E-02
	% change with BC		-0.28	-0.30	-0.40	-0.27	-0.09	0	-1
Resource use, fossils	MJ	1.17E+05	1.04E+05	1.03E+05	9.77E+04	1.04E+05	1.13E+05	1.17E+05	9.28E+04
	% change with BC		-12	-12	-17	-11	-4	0	-21
Primary energy consumption	MJ	5.85E+04	5.18E+04	5.13E+04	4.89E+04	5.21E+04	5.63E+04	5.45E+04	4.64E+04

	% change with BC		-11	-12	-16	-11	-4	-7	-21

A1.2 Base Case 2

Table A1.2 All Life cycle indicators per unit of the different design options for BC 2

Life-cycle indicators per unit	Unit	BC 2	DO 1	DO 2	DO 3	DO 4	DO 5	DO 7	DO 9
Energy Consumption									
Electricity	kWh	116,592.6	107,778.5	106,750.9	103,787.8	113,679.7	113,828.7	116,592.6	105,832
	% change with BC		-7.56	-8.44	-10.98	-2.50	-2.37	0.00	-9.23
Thermal Energy	MJ	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0
	% change with BC		0	0	0.00	0.00	0.00	0.00	0.00
PEF Impact Categories									
Climate change, total	kg CO2 eq	6.04E+04	5.67E+04	5.63E+04	5.50E+04	5.92E+04	5.93E+04	6.04E+04	5.59E+04
	% change with BC		-6	-7	-9	-2	-2	-0.09	-7
Ozone depletion	kg CFC-11 eq	1.86E-05	1.72E-05	1.71E-05	1.66E-05	1.81E-05	1.82E-05	1.86E-05	1.69E-05
	% change with BC		-7	-8	-11	-2	-2	-0.01	-9
Human toxicity, cancer	CTUh	1.16E-05	1.10E-05	1.09E-05	1.07E-05	1.14E-05	1.14E-05	1.16E-05	1.08E-05
	% change with BC		-5	-6	-8	-2	-2	-0.1	-6
Human toxicity, non-cancer	CTUh	2.73E-04	2.60E-04	2.59E-04	2.55E-04	2.69E-04	2.69E-04	2.72E-04	2.58E-04
	% change with BC		-5	-5	-7	-1	-1	-0.2	-6
Particulate Matter	disease incidence	3.35E-03	3.23E-03	3.22E-03	3.18E-03	3.31E-03	3.31E-03	3.34E-03	3.21E-03
	% change with BC		-4	-4	-5	-1	-1	-0.3	-4
Ionising radiation, human health	kBq U235 eq	2.13E+04	1.97E+04	1.95E+04	1.90E+04	2.08E+04	2.08E+04	2.13E+04	1.94E+04
	% change with BC		-7	-8	-11	-2	-2	0.0	-9

Photochemical ozone formation, human health	kg NMVOC eq	1.27E+02	1.21E+02	120.4	1.18E+02	1.25E+02	1.25E+02	1.27E+02	1.20E+02
	% change with BC		-5	-5	-7	-2	-1	-0.2	-6
Acidification	mol H+ eq	3.48E+02	3.36E+02	3.35E+02	3.31E+02	3.44E+02	3.44E+02	3.47E+02	3.34E+02
	% change with BC		-3.2	-3.6	-4.7	-1.1	-1.0	-0.3	-4
Eutrophication, terrestrial	mol N eq	4.47E+02	4.25E+02	4.22E+02	4.15E+02	4.40E+02	4.40E+02	4.47E+02	4.20E+02
	% change with BC		-5	-6	-7	-2	-2	0	-6
Eutrophication, freshwater	kg P eq	1.21E-01	1.13E-01	1.12E-01	1.10E-01	1.18E-01	1.18E-01	1.20E-01	1.11E-01
	% change with BC		-6	-7	-9	-2	-2	0	-8
Eutrophication, marine	kg N eq	4.19E+01	3.98E+01	3.96E+01	3.89E+01	4.12E+01	4.13E+01	4.19E+01	3.93E+01
	% change with BC		-5	-6	-7	-2	-2	0	-6
Ecotoxicity, freshwater	CTUe	2.88E+05	2.72E+05	2.70E+05	2.64E+05	2.83E+05	2.83E+05	2.88E+05	2.68E+05
	% change with BC		-6	-7	-8	-2	-2	0	-7
Land use	pt	2.81E+05	2.65E+05	2.63E+05	2.58E+05	2.76E+05	2.76E+05	2.81E+05	2.61E+05
	% change with BC		-6	-6	-8	-2	-2	0	-7
Water use	m3 water eq. of deprived water	1.87E+04	1.74E+04	1.73E+04	1.68E+04	1.82E+04	1.83E+04	1.87E+04	1.71E+04
	% change with BC		-7	-8	-10	-2	-2	0	-8
Resource use, minerals and metals	kg Sb eq	1.47E+00	1.47E+00	1.47E+00	1.47E+00	1.47E+00	1.47E+00	1.46E+00	1.47E+00
	% change with BC		-0.06	-0.07	-0.09	-0.02	-0.02	-0.48	-0.08
Resource use, fossils	MJ	1.00E+06	9.40E+05	9.32E+05	9.11E+05	9.83E+05	9.84E+05	1.00E+06	9.26E+05
	% change with BC		-6	-7	-9	-2	-2	0	-8
Primary energy consumption	MJ	5.74E+05	5.43E+05	5.39E+05	5.28E+05	5.64E+05	5.64E+05	5.74E+05	5.36E+05
	% change with BC		-5.5	-6.2	-8.03	-2	-2	-0.13	-6.7

A1.3 Base Case 3

Table A1.3 All Life cycle indicators per unit of the different design options for BC 3

Life-cycle indicators per unit	Unit	BC 3	DO 6	DO 8	DO 10
Energy Consumption					
Electricity	kWh	29223	26313	29360	27628
	% change with BC		-9.96	0.47	-5.46
Thermal Energy	MJ	0	0	0	0
	% change with BC		0.00	0.00	0.00
PEF Impact Categories					
Climate change, total	kg CO2 eq	1.79E+04	1.67E+04	1.73E+04	1.66E+04
	% change with BC		-7	-4	-8
Ozone depletion	kg CFC-11 eq	4.65E-06	4.20E-06	4.66E-06	4.39E-06
	% change with BC		-10	0	-6
Human toxicity, cancer	CTUh	4.07E-06	3.87E-06	3.87E-06	3.75E-06
	% change with BC		-5	-5	-8
Human toxicity, non-cancer	CTUh	9.40E-05	8.99E-05	8.77E-05	8.53E-05
	% change with BC		-4	-7	-9
Particulate Matter	disease incidence	1.28E-03	1.25E-03	1.18E-03	1.15E-03
	% change with BC		-3	-9	-10
Ionising radiation, human health	kBq U235 eq	5.47E+03	4.95E+03	5.46E+03	5.15E+03
	% change with BC		-9	0	-6
Photochemical ozone formation, human health	kg NMVOC eq	4.35E+01	4.15E+01	4.07E+01	3.95E+01
	% change with BC		-5	-6	-9
Acidification	mol H+ eq	1.37E+02	1.33E+02	1.25E+02	1.22E+02
	% change with BC		-3	-9	-11
Eutrophication, terrestrial	mol N eq	1.49E+02	1.41E+02	1.40E+02	1.35E+02
	% change with BC		-5	-6	-9
Eutrophication, freshwater	kg P eq	3.44E-02	3.19E-02	3.33E-02	3.19E-02
	% change with BC		-7	-3	-7
	kg N eq	1.39E+01	1.32E+01	1.31E+01	1.27E+01

Eutrophication, marine	% change with BC		-5	-6	-9
Ecotoxicity, freshwater	CTUe	8.88E+04	8.32E+04	8.49E+04	8.16E+04
	% change with BC		-6	-4	-8
Land use	pt	7.54E+04	7.01E+04	7.48E+04	7.16E+04
	% change with BC		-7	-1	-5
Water use	m3 water eq. of deprived water	5.14E+03	4.73E+03	5.04E+03	4.80E+03
	% change with BC		-8	-2	-7
Resource use, minerals and metals	kg Sb eq	6.90E-01	6.90E-01	6.03E-01	6.02E-01
	% change with BC		0	-13	-13
Resource use, fossils	MJ	2.89E+05	2.68E+05	2.81E+05	2.68E+05
	% change with BC		-7	-3	-7
Primary energy consumption	MJ	1.82E+05	1.71E+05	1.73E+05	1.66E+05
	% change with BC		-6	-5	-8