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1 EXECUTIVE SUMMARY

1.1 General

The data centre industry has a sustained and high growth rate: A study predicts that the data centre revenue across 19 of the EU28 countries will increase from 3.2 billion Euro per annum (2010) to 7.3 billion Euro (2015), i.e. at an annual growth rate of 25% (Telecom pricing, accessed 2014), (study predicts in-house data centre, accessed 2015).

However, the rise of the ICT sector and the data centre industry comes with increasing environmental pressures, despite of growing IT performance, the growth is outpacing the technological progress (Wolf, 2014).

The key objective of EURECA is to support energy / resource efficient and environmentally sound procurement actions within the European Public Sector for data centre and related products and services.

1.2 Purpose, scope and approach of this document

The overall purpose of this deliverable is to describe approaches and methodologies for quantifying savings of primary energy and of various environmental impacts as well as cost savings, triggered by innovative public procurement using EURECA's tool and other deliverables. The methods will be used in D5.3 to evaluate the project's contribution to the call targets, as well as EU2020 targets and further benefits.

The DoW (Description of Work) specifies the following activities to be performed for this "Report on the evaluation method for measuring the energy savings and environmental benefit of the project via innovative public procurement" within work package 5:

- To develop a methodology for quantifying captured energy and environmental saving triggered by EURECA project
- To develop a methodology that captures economic savings triggered by EURECA project

This has been translated into the following approach:

- Taking into account the finding from D1.1, D5.1 builds on the framework and tool developed under WP 2, in combination with estimates for the likely uptake rate of the EURECA developments among procurers. It presents the methodology for quantifying primary energy and environmental savings triggered by EURECA project both during and after the project time. This will, next to the data centre use phase, take into account the production and end-of-life of the relevant data centre capital goods in a life cycle perspective. It will cover next to primary energy, the share of renewable energy and other environmental benefits including avoided climate change impacts.

- This report also provides the methodology that captures cost savings triggered by the EURECA project in a TCO perspective, with complimentary external cost information, providing an overall LCC information. This equally builds on the related life cycle costing method and tool support developed under WP 2.
- The increased skills of public procurers will be judged along insights and feedback from the networking and training to public sector staff in the pilot cases and through training, which build on the findings in WP1 and WP 4 due to EURECA. An approach to judge the EURECA tool success will be provided as well.
- Market uptake of innovative data centre solutions will be evaluated equally from insights of first procurement specifications and cases during the project.

2 Definition of Terms and Acronyms

C3IT stands for the EURECA partner Carbon3IT Ltd

CBA stands for Cost Benefit Analysis

CG stands for the EURECA partner Certios B.V.

D1.1 means the Deliverable identified as number D1.1 within Work Package 1 of the EURECA project

Deliverable means a formal contract deliverable item under the EURECA project

DoW means Description of Work. The EURECA project signed a project agreement identified as project number 649972 for a project under the call H2020-EE-2014-3-MarketUptake. This document contains a table with work plans, and it is this information to which this table refers

EC means the European Commission

eLCC stands for environmental (or external) life cycle costing

Energy Usage Effectiveness = Annual Energy Consumption Data Centre [kWh] / Annual Energy Consumption IT-Equipment [kWh]

ETSI means European Telecommunications Standards Institute

EUCoC means European Code of Conduct for energy efficient datacentres

EUE means Energy Usage Effectiveness

EURECA means the Data centre EURECA Project

Environmentally Sound stands for "A low overall environmental impact per provided Data Centre service (computation/data services) based on present day available solutions." This 'environmental impact' includes impacts such as climate change, acidification, particulate matter, etc. but also primary energy consumption and water scarcity.

GITA stands for the EURECA partner Green IT Amsterdam

Green stands for: see 'Environmentally Sound'

GHG stands for GreenHous Gas(ses)

(Procurement) Scenario(s) provides an indication of the scenario the Public Sector body should initiate a tender for that meets the actual procurement need (related to data centre products or services). By providing an assessment to determine the actual needs, the EURECA framework and tool can help establish the right Procurement Scenario for tendering.

ITT stands for Invitation to Tender

Industry stands for data centre and related ICT industry

eLCC stands for (environmental) Life Cycle Costing

LCA stands for Life Cycle Assessment

MAKI stands for the EURECA partner maki Consulting GmbH

PCP stand for Pre-Commercial Procurement or Pre-Competitive Procurement

PPI stands for Public Procurement of Innovative solutions

Practice stands for the use of a standard, framework, guideline, specification or KPI/metric

PU means Public dissemination level

PUE means Power Usage Effectiveness, (Total facility Power [kW] / IT-Equipment Power [kW])

RFI stands for Request for Information

RFQ stands for Request for Quotation

RFP stands for Request for Proposal

Task 1.1 stands for the first task as described in the EURECA project's DOW under WP1, consisting of a Regional analysis of green data centre procurement.

Task 1.2 stands for the second task as described in the EURECA project's DOW under WP1, consisting of a SWOT analysis of existing procurement of environmentally sound data centres and of related products and services.

Task 1.3 stands for the third task as described in the EURECA project's DOW under WP1, consisting of a GAP analysis between existing procurement and environmentally sound procurement.

Task 2.1 stands for the first task as described in the EURECA project's DOW under WP2, consisting of comprehensive framework that can guide procurers in the process of production of RFI's and RFP's, and help them differentiate data centre and related service offerings by their energy-efficiency and environmental performance.

Task 2.2 stands for the second task as described in the EURECA project's DOW under WP2, consisting of sound and robust software tool based on the requirements identified under Task 2.1.

Task 5.1 stands for the first task as described in the EURECA project's DOW under WP5, consisting of:

- methodologies to quantify energy savings, other environmental improvements and economically saving, triggered by GPP using this project's tools and other deliverables
- reasonable uptake rate of the EURECA project and also innovative solution
- overview evaluation approach to evaluate the increased skill of procurers.

TCIT stands for the EURECA partner TeleCity

TCO stands for Total Cost of Ownership

UEL stands for the EURECA partner University of East London

Work Package 1 (or WP1) of the EURECA project covers 'Green DC Procurement Analysis'

Work Package 2 (or WP2) of the EURECA project covers 'Procurement framework and Tool'

Work Package 3 (or WP3) of the EURECA project covers 'Knowledge Sharing'

Work Package 6 (or WP6) of the EURECA project covers 'Dissemination'

3 EURECA uptake rates

3.1 Purpose

In order to estimate the actual benefit of the EURECA deliverables outside the EURECA partners, we need an uptake rate estimate, that will be used in chapter 4 and 5, as part of the method to calculate the energy and environmental savings benefit thanks to EURECA developments.

This will leverage the fact that not everybody among the public sector IT participants that we train will actually use the EURECA framework and tool and directory resources for improving the energy and environmental performance of their public bodies' data centre solutions, not every participating procurement officer will build on it in tenders. And also not every procurement responsible that we inform about EURECA offerings in presentations or press releases or finds the EURECA website will use the information for DC improvement, of course.

3.2 Approach

The uptake of EURECA developments is evaluated from insights of first procurement specifications and cases during the project: Based on the share of procurement partners that participate in the project, first, the reasonable best and reasonable worse case general uptake rate and effective use of the project's tools by public organisations are estimated. The expected differences in uptake rate from trainings - where we will have a less intensive and close collaboration than with the EURECA partners - and the even less close relationship with website visitors will be estimated along additional considerations, as follows:

3.3 Uptake rate EURECA-run trainings, workshops

The following assumptions were made that will be used to estimate the energy and environmental savings via the EURECA-run trainings, workshops mechanism:

- EURECA is to train and directly involve at least 500 people during the lifespan of the project. This will be achieved via addressing these people via special interest seminars (GPP, IT procurement or Tendering processes), webinars and courses. Teaching and informing these people can be done in several ways. The EURECA project will make these trainees aware of the developments of EURECA, wake up initiatives, even before the EURECA tool is completed and the market directory fully available and filled. The dissemination of the EURECA framework will signpost answers automatically in the audience's day to day work. The final number of participants and the absolute number of represented data centres will be used (since several participants can come from the same data centre, in other cases participants that are involved in the procurement of more than one data centre product or service).

- Not all of the trainees that are willing and able to convert the EURECA knowledge into energy savings in a datacentre, moreover, will do this in the time of the duration of the project (refit or renew fraction)
- Finally, not all initiatives to improve the datacentre will be able to enjoy the full potential of the savings, only a part of it.

Combining these factors - each with a reasonably best and worst case - we will obtain the uptake rate α for EURECA-run trainings that will be used to estimate the energy and environmental savings that can be expected from this mechanism/deliverable (see chapter 4).

It can be already anticipated at this point that the savings via trainings will only start during the project duration, but mainly after its end, when all EURECA developments are fully in place and available to the trainees, and they actually face the task to improve an existing data centre or server room or go for related procurements.

3.4 Uptake rate for using EURECA developments outside the project

In a very similar way as a share of the trainees of EURECA-run trainings will make use of the various EURECA developments (framework, tool, directory ...) to improve their data centres /server rooms or affect procurement of more energy and environmentally efficient innovative solutions, also DC operators and procurers at other public bodies, that EURECA project had no direct contact with, will do so. Purpose of this second uptake rate is hence to obtain a reasonable and robust estimate for this user group.

At the same time, we can increase the amount of people that will learn about EURECA (next to making the deliverables accessible and easy to use, in the first place). Instead of relying on internet search engines and word-of-mouth alone to reach this large potential user groups, we anticipate and already engage in a range of outreach activities to inform an as large as possible number of target group public sector procurers and data centre experts, about our developments. This happens via presentations at general conferences, via press releases, scientific presentations, papers and posters, social media posts such as via Twitter and at the relevant LinkedIn interest groups, as well as using third-party website calendar and news posting options, news blogs, and mailing lists of multipliers in various EU member states with a relevant stakeholder reader/member base.

Based on estimates or where we know the number of recipients, such as for mailing lists and some other mechanisms, we can anticipate the number of Europe-wide public sector data centre and procurement experts that will be informed about the EURECA developments.

At the same time, and similar as for the EURECA-run training participants, not everybody who will be informed, will actually use the EURECA developments. Since the depth of interaction is clearly less, compared to in-person trainings and especially the direct support to the EURECA pilot partners, we have to assume a considerable lower share of actual users of the EURECA developments here.

In the end, the final uptake rate β will take all these aspects and factors into account and be expressed by the share of all EU-wide data centre procurements and self-improvement activities that will make full or partial use of EURECA developments (see chapter 4).

4 EURECA-triggered energy and environment savings

4.1 Purpose

In order to ensure a reliable evaluation of the project's achievements and in close coordination with tasks 1.4 and 1.5, and based on the framework and tool to be developed in tasks 2.1 and 2.2, a robust approach and methodology is developed here for quantifying energy savings and other environmental improvements, triggered by innovative public procurement of environmentally preferable solutions in support by the EURECA framework, tool and other deliverables. This chapter describes this approach and methodology. It will be used in D5.3 to report on the achievement of the call targets in terms of saved energy per Commission financial contribution to the project as well as the project's contributions to the EU2020 targets and increased resource-efficiency in various environmental areas.

The call target is to save at least 25 GWh annual overall primary energy savings (or replacement of fossil by renewable energy production) per 1 Mio EUR Commission contribution to the project, i.e. about 37.5 GWh annually for EURECA.

The EU2020 - the EU's growth strategy for the coming decade – aims at transforming the EU into a smart, sustainable and inclusive economy, under the Digital Agenda (EUROPE2020, accessed 2015). Regarding resource-efficiency it aims at:

"Climate change and energy sustainability greenhouse gas emissions 20% lower than 1990, 20% of energy from renewable, 20% increase in energy efficiency" (European Commission, 2010)

In addition to the Digital Agenda, another important flagship is the Resource Efficiency under Sustainable growth, aiming equally at a resource efficient, greener and more competitive economy. The scope of the Resource Efficiency initiative thereby goes beyond climate change and energy. It covers a much broader protection of the environment, reducing various emissions, and preventing biodiversity loss. The Resource topic has been strengthened by the Commission lately and with a special focus on material resource efficiency, in form of the new Initiative on the Circular Economy (European Commission, 2015). D5.3. will report on the tangible and wider expected contributions of the EURECA project to these policy targets.

4.2 Introduction and status quo

The data centre industry has a high growth rate: A study predicts that the data centre revenue across 19 of the EU28 countries will increase from 3.2 billion Euro per annum (2010) to 7.3 billion Euro (2015), i.e. at an annual growth rate of 25% (Telecom pricing, accessed

2014), (study predicts in-house data centre, accessed 2015). However, the rise of the ICT sector and the data centre industry comes with increasing environmental pressures:

Data centres are one of the largest and fastest growing consumers of electricity. In 2013, U.S. data centres consumed an estimated 91 TWh of electricity -- enough electricity to power all the households in New York City twice over -- and are on-track to reach 140 TWh by 2020 (Delforge P., 2014). This, despite of the fast technological progress of higher computational performance and efforts towards energy-efficiency. The even faster increase in demand for data services is outpacing the technological and energy-efficiency progress (Wolf, 2014).

On global level, the electricity consumption by data centres is estimated to be about 2% (Koomey, 2011) (i.e. more than all air transport together) and to increase to 70 TWh in Europe by 2020 (UBA, 2015). In 2013 the amount of datacentre power known in the world is 38.84 GW (growth 2012-2013: +7,2%), in Europe 13.47 GW (growth 2012-2013: +6.0%), according to the Data Centre Dynamics' Industry Census 2013. The world consumed 340 TWh in its datacentres in 2013. Europe consumed 118 TWh. Figure 1 illustrates the outlook of this development (SRI Analyst of Alliance Trust Investment, Parker, 2013):

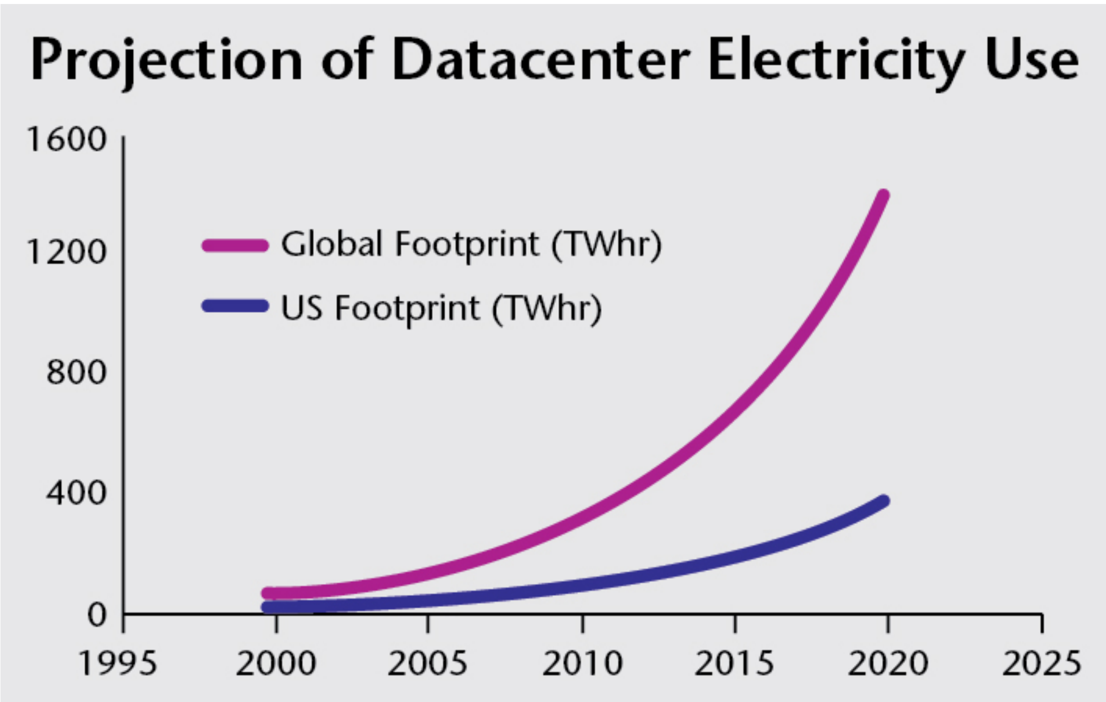

Figure 1 Projection of Global and US data centre electricity use, by SRI Analyst of Alliance Trust Investment, Parker (2013).

Another research (Andrae & Edler, 2015) comes to similar results, furthermore differentiating electricity usage into four principal categories:

1. consumer devices, including personal computers, mobile phones, TVs and home entertainment systems;
2. network infrastructure;
3. data centre computation and storage; and lastly
4. production of the above categories

The forecast is based on expected annual growth of global data centre Internet Protocol (IP) traffic between 2010 and 2030, electricity used per traffic unit, and improvements of electricity efficiencies to be achieved year by year; the capital goods production data is a rougher estimate.

Figure 2 shows the best and worst case estimates for data centre electricity use:

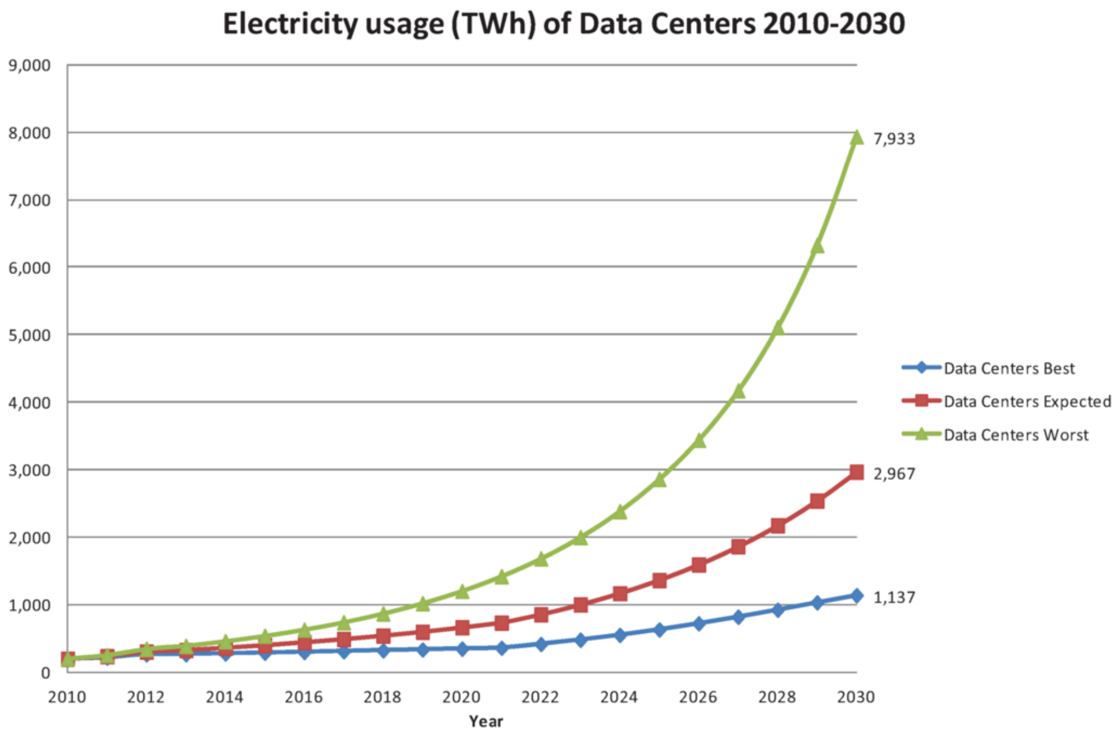

Figure 2 Best, expected, and worst case electricity consumption during use of data centres worldwide by Andrae & Edler (2015).

Insert: which savings potential has the use phase electricity consumption?

The average public datacentre has an ICT load of 500 kW (not taking into account local administration etc.), while we aim at improving the accuracy of that figure, among others via feedback from the trainees.

Active energy efficiency management of Data Centres can help to reduce up to 30% of energy consumption by implementing permanent changes through measurement, monitoring, and control of energy usage. More efforts shall be done to improve cooling management at smaller data centre granularity levels and to minimize data centre energy consumption (Feindt, 2015). The savings of use phase primary energy via an improved PUE are within reach for an average datacentre when best practises are followed and implemented. Particularly the substantial savings achieved in German data centres on federal level that have been analysed and quantified in detail by the German UBA (EPA) will feed in quantitative information. An example (Figure 3):

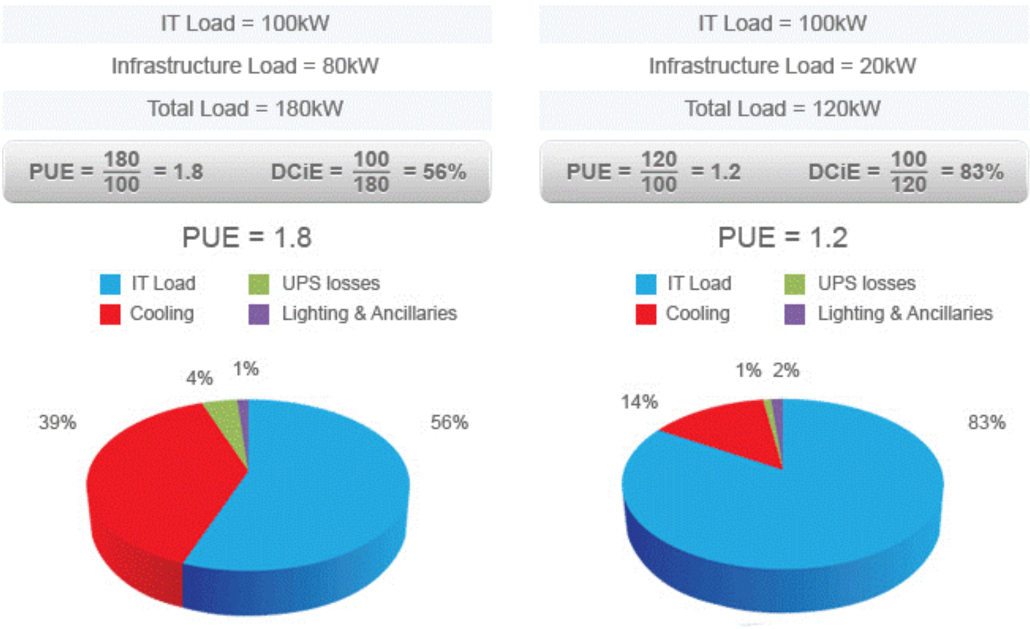

Figure 3 Use phase electricity savings effect when changing from PUE 1.8 to 1.2. Source: Future-Tech: http://www.future-tech.co.uk/data-centre-energy-efficiency/

Additional savings in both primary energy and capital goods will stem from efforts such as virtualisation and consolidation, that will have a similar level of savings on top. A more accurate estimate will be derived from analysing the business cases of EURECA pilot partners and external business cases.

Electricity consumption however is only the tip of the iceberg: the primary energy consumption is typically several times as high and a range of environmental impacts are associated with energy carrier extraction, conversion until the electricity is delivered to a data centre.

In view of the climate change impacts, projections (Climate Group and the Global e-Sustainability Initiative (GeSI), 2008) see ICT growth skyrocketing in the foreseeable future. That report contends that even with cloud-computing companies focusing more intently on energy efficiency, overall ICT-based greenhouse gas emission will increase by over 70 percent from 2007 to 2020, while the most recent GeSi report Smart2030 somehow revises this finding (GeSI, 2015). Specifically, the SMART 2020 numbers show worldwide ICT metric tonne carbon dioxide equivalent in 2020 to be 1,430 MtCO2e, with data centres accounting for 18 percent of that amount (257 MtCO2e), telecoms 25 percent (358 MtCO2e), and PCs and peripherals 57 percent (815 MtCO2e) (Webb M., 2010).

However, the trend of using renewable power is strong (Goiri and others, 2015; Oro and others, 2015) and likely many data centres can be run GHG efficient, even if they do not find ways to reduce the absolute electricity usage (Andrae & Edler, 2015).

Next to the use phase electricity consumption, what is the focus of the above data, another and increasingly relevant contribution comes with the capital goods production: the data centre building, the M&E plant as well as the servers and other IT hardware production contributes a high share as well: two more detailed studies have calculated this contribution of the capital goods to the primary energy or exergy consumption to be about 30% to 50% (Meza J.et al, 2010 , Honée C. et al, 2012). It is hence not sufficient to exclusively take into account the data centre use phase energy consumption. Moreover, capital goods generally have a higher relative contribution than electricity consumption for many other environmental impacts, ranging from acidifying and particulate emissions to depletion of metal ores. The production of capital goods – and the savings with the help of EURECA advice, such as virtualisation, consolidation, workload shifting and others that particularly reduce the amount of hardware needed for the same service – is hence to be fully considered to capture the situation in a non-distorted way. For data centres that use exclusively clean renewable energy (e.g. wind power plus storage, geothermal) for their operations, the energy that was used to produce all the hardware will still typically predominantly come from fossil energy.

Next, water consumption by data centres has come into focus, in context of the otherwise beneficial shift to water-based chillers.

While land use is not an important environmental impact for data centres, it is noted that in the EU, the total data centre 'white' space deployed amounts to 10.5 million square meters in 2012. Four markets command over one million square meters each, ranked in order: The United Kingdom, Germany, France and Italy. Spain and the Netherlands both have between 600,000 and 950,000 square metres (DCD Intelligent, 2012).

The data centres in the public sector therefore can play a key contribution to help meeting the EU2020 targets of increased energy-efficiency, increased share of green energy, and reduced greenhouse gas emissions, as well as the wider EU environmental targets – if their environmental footprint can be stronger reduced than expected. This is where EURECA will contribute.

4.3 Approach

As to the DoW, a quantitative life cycle based approach will be used in EURECA to calculate the overall project "impact" (i.e. saving of primary energy and environmental impacts) by the EURECA project's deliverables. By taking into account the whole lifecycle of datacentres, it will be assured that all relevant data centre related energy and environmental impacts are considered - from raw material extraction, component production, use phase until the end of life. This is necessary also to avoid a shifting of burdens from use phase, which often is the only scope of analysis of ICT products, to other product stages.

The lifecycle wide environmental impact savings due to EURECA of the data centre capital goods production, use and end-of-life are calculated using the EURECA framework (D2.1) and tool (D2.2). Applying the EURECA framework and tool to evaluate the impact of the EURECA project is also in line with the latest Impact Assessment Directive of the EU (European Commission, 2015b), which refers explicitly to using the developments of the European Platform on LCA, which are namely the ILCD Handbook, the ELCD database and the PEF guide which form the basis of the quantitative life cycle approach of the framework D2.1. As D2.1 is due by end of November, i.e. one month after D5.1, a brief summary is given here below:

Insert: summary of the quantitative life cycle part of the EURECA framework, of D2.1:

Formula 1 shows the high level calculation of the annual environmental burden associated with a data centre per year. Figure 4 shows the concept schematically.

Formula 1 $E = (E_r + E_{eol})/n + E_u - E_c/n$

With

E = environmental and energy burden of data centre (e.g. primary energy, climate change etc.) per year

E_r = environmental burden and energy in raw material extraction and production phase of capital goods (building, servers, UPS …)

E_{eol} = environmental and energy burden in the end-of-life phase of the capital goods

E_u = annual environmental and energy burden during data centre use phase (electricity, coolant loss, water consumption, …)

E_c = environmental and energy credit from recovery of secondary materials and energy at end-of-life treatment

n = lifetime of capital goods [a]

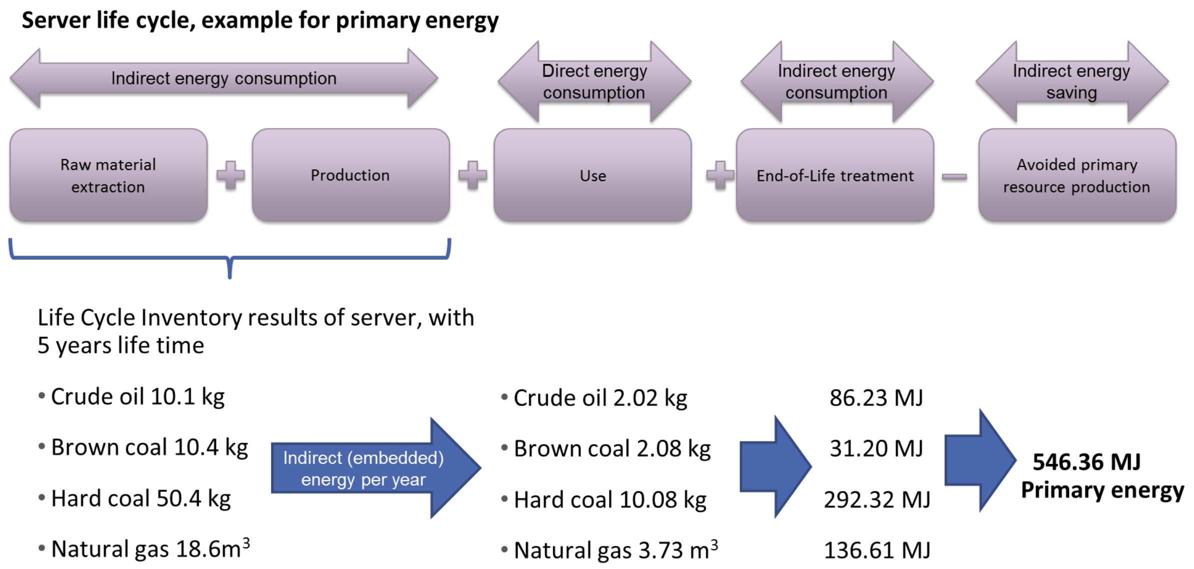

Figure 4 Schematic view of life cycle of a server, focussing on production and primary energy use, on the level of the inventory results, for illustration. After further aggregation, all energy and environmental impacts for the whole life cycle will be expressed in 15 numbers for the whole data centre (i.e. for the 15 impact and resource categories, one of which is the primary energy). These can optionally be further aggregated to 1 number representing the annual overall environmental and resource impact of the data centre, for clearer decision support.

The quantitative life cycle part of the framework builds on the relevant European Commission life cycle method developments and data, with the Product Environmental Footprint guide and the related PEFCRs for UPS, HDD, metal sheets, copper and batteries (PEFCR UPS 2015, PEFCR HDD 2015, PEFCR Metal sheets 2015, OEFSR Copper 2015, PEFCR Batteries 2015), the preparatory studies for Enterprise servers (Bio by Deloitte & Fraunhofer IZM, 2015), and the study on enterprise servers by the Commission's JRC (Talen Peiro L. & Ardente F., 2015). Sector-specific recommendations by ETSI (ETSI, 2011), the green grid on life cycle assessment of data centres (Green grid, 2012), as well as the GHG Protocol (GHG Protocol, 2013) are used as guiding principles. At the same time, and given the complexity of ICT products and data centres and limitations of the availability of comparable life cycle guides for data centres, as well as to ease the effort for data centre goods and services vendors, some simplifications are made. Moreover, where specific information or data is not available, suitable default values are used. In result, the framework allows to quantify in a robust manner the environmental and energy efficiency of the data centre, substantially more complete and reliable than the best practice in procurement that uses weak proxies for use phase energy only.

The following environmental and energy indicators will be calculated: primary energy, renewable primary energy, climate change, acidification, eutrophication, ozone depletion, summer smog, particulate matter, ionising radiation, human toxicity, and ecotoxicity, land use, water scarcity, all in life cycle perspective.

The calculation of EURECA-related savings of primary energy and environmental impacts is divided into three components. The three components are:

- Net savings due to EURECA framework and tool supported (or avoided) procurements and self-improvements by the EURECA pilot partners. Some of these savings will be initiated during the project duration, others only afterwards.
- Net savings due to EURECA-run trainings, using the various EURECA developments.
- Net savings of EURECA framework and tool supported (or avoided) procurements and self-improvements initiated outside the EURECA project, until 2020.

For each of these, the direct (i.e. DC operation) and indirect (capital goods production and end-of-life treatment/benefication) will be reported separately.

Note that only savings are taken into account that occur before the end of 2020.

Figure 5 illustrates how the components of the overall expected net savings due to project's deliverables are anticipated:

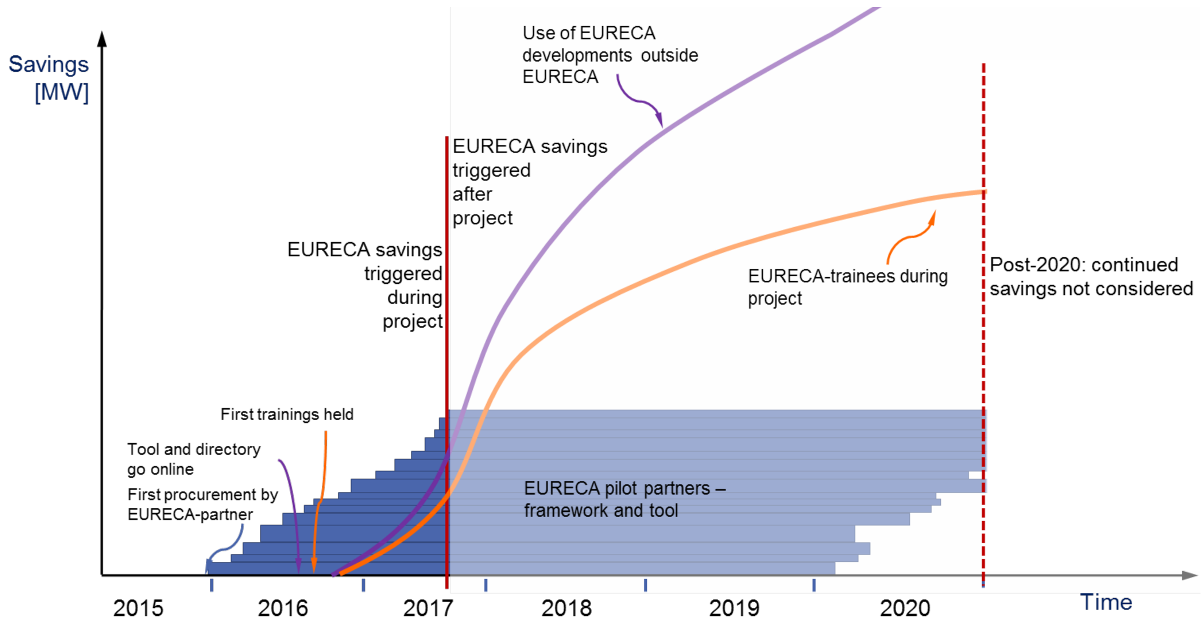

Figure 5 Savings of primary energy and environmental impact due to the various EURECA measures; illustrative. Each bar represents one data centre, with all impacts of production, use and end-of-life are shown averaged over the expected duration of the data centre use (e.g. 5 years). Note that the data is not stacked, i.e. the total is the sum of the savings due to the three measures. The highest absolute savings are expected from use of the EURECA developments by public bodies outside the pilot partners and the EURECA-run trainings, including due to its maintenance after the end of the project with updating technology and other data, expanding the online directory, etc.

4.4 Methodology

As introduced above, the overall savings due to the EURECA deliverables consists of three parts:

4.4.1 Calculated and expected net savings of EURECA-supported (or avoided) procurements and self-improvements by EURECA partners initiated during the project

The absolute annual energy-savings and environmental benefits are calculated compared to a "business-as-usual" or autonomous procurement scenario (see Formula 2). This approach estimates expected savings and benefits as illustrated in Figure 6:

Formula 2 $Bp = E_b - E_e$

With

Bp = Annual savings of data centre energy and environmental impact from EURECA, via EURECA partners

E_b = Annual environmental burden of data centre in "business as usual" scenario

E_e = Annual environmental burden of data centre using EURECA framework and/or tool

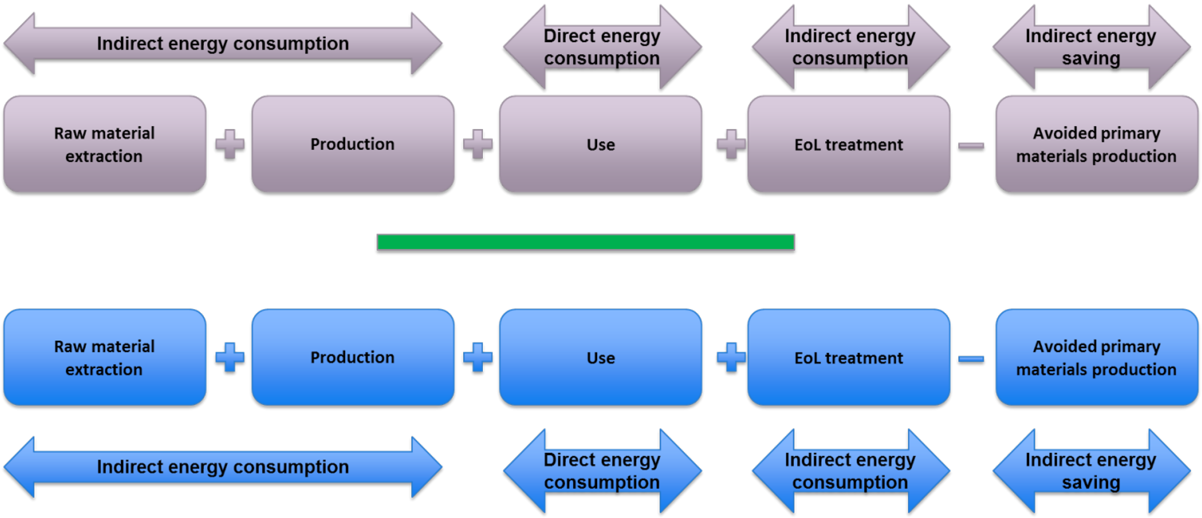

Figure 6 illustrates life cycle based calculation of net benefit of EURECA-supported (or avoided) procurements initiated during project time plan, by the EURECA partners; with the example of primary energy

For calculation the environmental burdens of the "business as usual" and the EURECA-supported procurement, specific data provided by the procurers is preferable. The requested input data that will be used by the framework to calculate the energy and environmental performance are: (selection of key data, details described in D2.1)

- Type and server/storage performance/capacity
- Usage / load of servers and storage
- Location
- Electricity consumption
- Water consumption
- Specification and performance of cooling system
- Specification and performance of server and storage equipment
- Specification and performance of UPS
- Building specification on high level

If the specific data is not possible, e.g. product type average or country specific information will be used as default values (details described in D2.1). For selected products it will be possible to provide specific environmental performance data by the provider (optional).

This combination of detailed values with fall-back options ensures that missing data will not impact the ability to obtain figures.

4.4.2 Expected net savings due to EURECA-run trainings

Due to participation in the EURECA trainings, procurers will have a better knowledge on environmental (including energy) efficiency. The procurers therefore will be able to procure more environmentally sound and energy-efficient data centre solutions.

However, based on various studies, there are ongoing improvements in the market also without EURECA, of course (i.e. autonomous development); details see annex 9.1. Thus the expected savings due to EURECA-run trainings are to be calculated from the differences between interpolation/extrapolation of energy saving in the pilots with the potential saving without EURECA (see Formula 3):

Formula 3 $$Bt = [Bt_e - Bt_w] * \alpha$$

With

Bt = Benefit from EURECA due to EURECA-run trainings

Bt_e = Estimated savings of data centre energy and environmental impact using EURECA developments, per year

Bt_w = Estimated savings of data centre energy and environmental impact without EURECA, per year

α = uptake rate among EURECA-run training participants (≤ 100%); see chapter 4.4.2

The estimated savings are interpolated and extrapolated savings from pilots that are engaged in the project (i.e. the EURECA pilot partners from public sector), calculated with the EURECA framework/tool. This considers at least the size of the data centre (if available) and country-specific differences when extrapolating.

Another important element is the current status of the data centres that are represented by the participants in the training. It is therefore beneficial to get the necessary information from procurers who participate in the training either by interview or survey. The following questions are examples to indicate the ex post evaluation after the training that will be detailed under WP4:

- Are the trained people able to influence the energy efficiency of "their" public organisation's data centre(s)?

- What are the individual 'takeaways' from the training, what are they actually going to do with the newly acquired knowledge?
- Where is the current data centre located?
- What is the computation and storage load of data centre?
- What is the size (kW) of their data centre(s) and what is/are the PUEs (or which default we can assume should that info not be available)?
- Is there already a planning for refit or renewal of the data centre (products/services)?

The above will be used to fine-tune the initial estimate of feasible savings (see chapter 3.3 on the uptake rate).

4.4.3 Expected net savings using EURECA developments outside the project

The estimated annual energy-savings and environmental benefits are again calculated compared to an autonomous development scenario. The key difference to savings by EURECA pilot partners where we have direct access to information, is that here the number and size of procurement cases and self-improvement activities is to be estimated via the market uptake rate β (see chapter 3.4): the estimated environmental and energy benefit cannot be related to specific data centres / procurers (as in the EURECA partners and EURECA-run trainings). The average/typical situation will be used, drawing on the average achievements that were identified from the more accurate data obtained from the EURECA pilot partners.

Also these wider EURECA users will use any of the following developments: EURECA framework and/or tool supported (or avoided) procurements, non-EURECA-run trainings and workshops, and via use of the online directory incl. webinars.

The estimated savings insights without EURECA come again from specific business cases inside and outside EURECA (examples are below), transforming the information from those cases (e.g. PUE change, procurement of new servers, annual electricity purchase, estimated coolant loss, virtualization, switch to free cooling etc.) into input data for the framework/tool (details in D2.1). This is done, in order the whole range of environmental and energy savings can be calculated in the analogous way and completeness as done for the benefits via the EURECA pilot partners.

See Formula 4:

Formula 4 $Bo = [Bo_e - Bo_w] * \beta$

With

Bo = Annual net savings and benefits from EURECA-developments outside the project

Bo_e = Estimated saving of data centre impact using EURECA developments outside the project, per year

Bo_w = Estimated saving without EURECA, per year

β = uptake rate among ALL EU public data centres (≤ 100%); see chapter 3.4

The benefits due to these three outreach mechanisms constitute the total savings benefit due to EURECA, while the different robustness of these estimates will be considered.

<u>Specific business cases outside EURECA, examples/insights on autonomous development:</u>

As mentioned above, independent from the project, there are ongoing efforts and savings in public data centres due to interests in (energy and hardware) cost savings and environmental awareness. This and other business cases and insights will be used to get a better picture at the achievable savings in individual public sector data centres, which form an important factor when estimating the benefit of EURECA outside the project 's pilot partners.

For example, business case building permits in the Amsterdam region (Gemeente Amsterdam, 2015) require:

- restricting the new datacentres to an EUE of a maximum of 1.2
- prescribing a datacentre room (inlet) temperature between 24-27 Celsius.

The environmental management act in the Netherlands (Dutch Government - "Overheid", 2014), enforced by the "omgevingsdiensten" has been very effective in the Amsterdam region. At the core of this act is the legal obligation for every company consuming over 200 MWh/year to take all energy efficiency measures that have a payback period shorter than 5 years (legislation: Milieuwet, Article 2.15, 2014). Although this approach might appear different than demand driven efficiency improvement, the common element is that all plans and actions are formulated, initiated and actuated by the consumer. Such strong legislative push will however mean that EURECA has to deliver on top – or help to identify such saving potentials where they were previously undetected.

Another example is the municipality of Amsterdam that intends to procure sustainable ICT, resulting in voluntary actions taken by the data centre industry. The 40 major DC's in Amsterdam area, use 11% of the city's power used by all of its 22,000 companies (Gemeente

Amsterdam, 2015), a total of 460 GWh in 2013, but with plans to lower this usage by 68 GWh, aiming at savings of 15% in the near future (Gemeente Amsterdam, 2014).

According to another report, the energy savings potential is an annual 80 GWh in the Netherlands, according to extrapolations (Gemeente Amsterdam Dienst Milieu en Bouwtoezicht, 2012). 60 GWh of which has been found attainable through more energy efficient cooling, an additional 20 GWh by using better ICT hardware.

In Germany, on federal level the aim was set to reduce overall energy consumption from 2008 until 2013 by 40% [Köhn 2015]. This was indeed achieved (-36%), even not taking into account the increased amount of digital services that were provided. These savings had virtualisation and consolidation as the main contributors. Beyond 2014, it is foreseen that the overall energy consumption of federal data centres shall not increase, despite of increased amount of data managed and stored [Köhn 2015].

These results demonstrate the effect that can be obtained by demanding better data centre performance, either by governments or by customers. Some business cases of actual savings in public organization data centres are below to see how savings are reaped.

- Business case "City of Amsterdam": to change the data centre from an old inefficient one (PUE 2.5) into a new 500 KWh data centre (PUE 1.3), saves Amsterdam annually 5.2 GWh (see Dutch presentation movie: https://youtu.be/9H_DOprUVJU).
- Business case HHD: 30% savings, thanks to the outsourcing of its small data centre of around 30 KW of ICT load, the data centre saves annually around 0.2 GWh.
- Business case Dutch Central Government: 107 GWh annually by reducing the number of its data centres from 64 to 4 (Kerssens, 2015).
- Business case of Amsterdam, Omgevingsdienst Noordzeekanaalgebied (ODNZKG): through the application of the environmental management act, 68 GWh is saved annually (Harryvan, 2014).

These and other cases will be used to calculate the environmental benefit without EURECA active involvement.

5 EURECA cost/benefit analysis

5.1 Purpose

In order to ensure a reliable evaluation of the project's economic achievements and in close coordination with and based on the framework developed in task 2.1, a robust approach and methodology is developed here for quantifying cost savings, triggered by innovative public procurement of environmentally preferable solutions in support by the EURECA framework, tool and other deliverables. This chapter describes this approach and methodology. It will be used in D5.3.

5.2 Introduction

Before we ascertain the cost/benefit analysis approach and calculation method, we must first advise that there are a number of factors that will affect the result:

- "Cloud First" policies in various EU countries will dilute and render largely invisible the energy and environmental efficiency of the individual data centres that contribute to the cloud and that are run by various private organisations. These organisations may not have the will to undertake detailed studies on their energy use or environmental impact unless it will be business relevant. This is valid, except for government cloud solutions with government-run data centres only. On the other hand, in other EU member states, the political aim to keep physical control of the data centre location - i.e. "no cloud" - are relevant developments, such as in Germany, that bring the individual data centres into focus.
- Rapid pace of technology development particularly for the IT components means that data could be out of date in a relatively short period of time.
- Not replacing services or equipment but adding to them due to a lack of knowledge, i.e. where additions are made to data centres or server rooms without decommissioning existing services, results in an increased energy and environmental burden.
- Particularly for innovative technologies the true Total Cost of Ownership (TCO) will not be known that precisely, as experience is lacking by definition.
- External costs to society due to emissions over the life cycle of the data centre are less "hard" figures, compared to TCO figures, what needs to be understood and considered in cost-based decision making.

The project has a target of assisting the EU Public sector with at least ten published tenders (D5.5, due Month 30).

The most reliable and hence relevant information source for the cost savings (or case-wise increase) due to using the EURECA developments are the tenders that are published or even implemented by the EURECA pilot partners. At this stage, we are still in the process of identifying suitable public sector organisations that are seeking to issue tenders for new data centres. We have 11 possible candidates at the time of publication of this report (Oct 2015) with discussions going on with others.

5.3 Approach

As to the DoW, a quantitative life cycle based approach will be used in EURECA to calculate the overall project "cost impact" (i.e. cost savings or higher costs in TCO perspective, plus reduced externality cost due to reduced environmental impacts over the life cycle of the data centre or other procured goods and services). Reporting both TCO and external costs, we provide an complete environmental life cycle costing (eLCC) information of the EURECA project's deliverables' impact (see Figure 7).

By taking into account the whole life cycle of data centres, it will be assured that all relevant costs of data centre are considered – investment cost (hardware and other capital costs, data centre operation electricity costs, Software Licensing Costs, and Personnel Costs (Facilities/IT)), annual operation cost (during use-stage), end-of-life management cost and also externality costs to society. The life cycle cost benefit due to EURECA of the data centre capital goods production, use and end-of-life are calculated using the EURECA framework (D2.1) and tool (D2.2).

The detailed TCO approach for data centres is described and formulated in the upcoming D2.1 that forms the formal basis of this D5.1. The complementary eLCC details are described here more below.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649972.

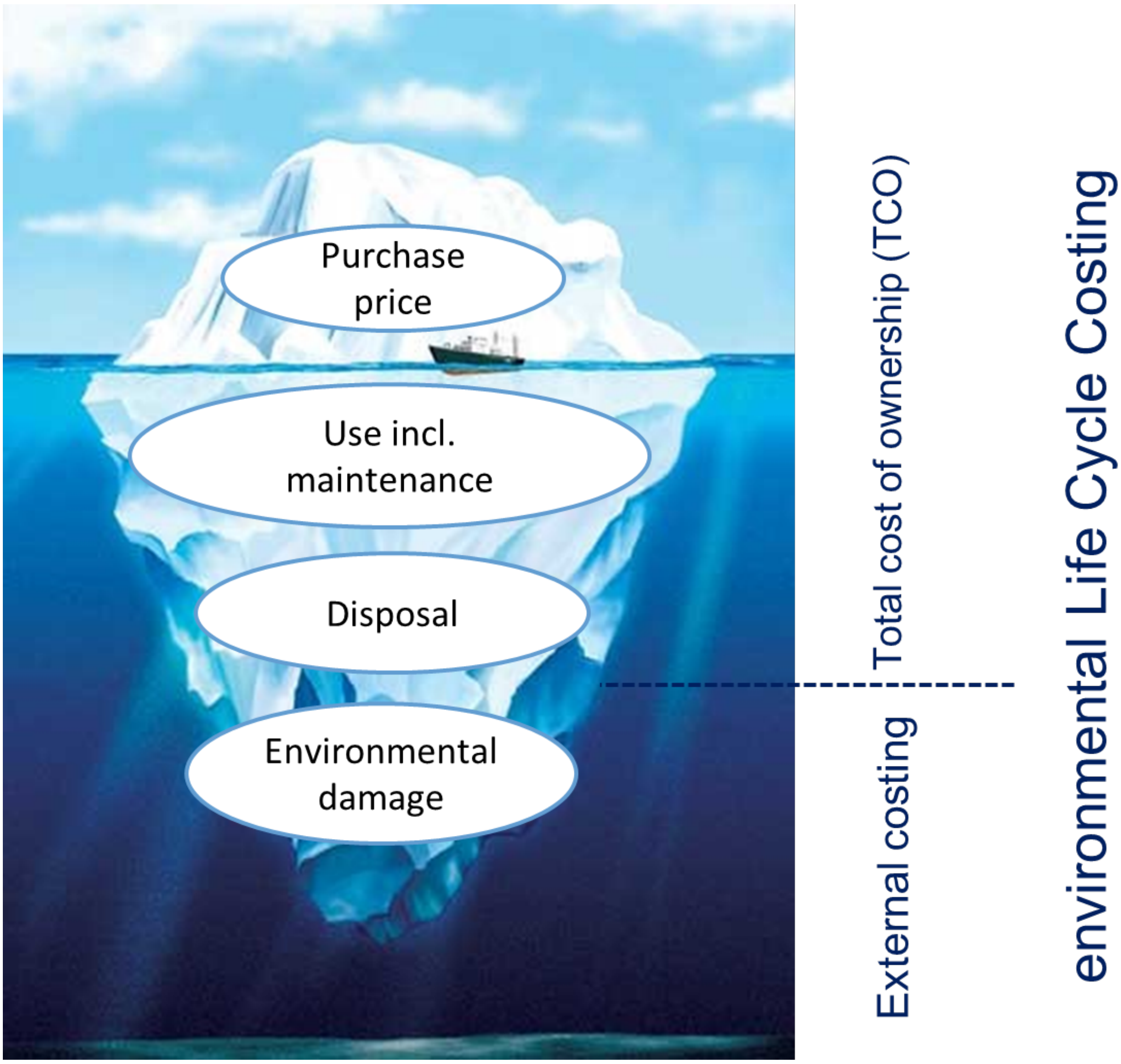

Figure 7 Illustration of environmental Life Cycle Costing, and its components TCO and external costing.

5.4 Methodology

Analogously as for the environmental benefit in chapter 4, the cost saving can be divided into three outreach/involvement levels of public procurers and data centre experts (see Formula 5):

Formula 5 $$Net_{Saving} = Net_{Fra} + Net_{Tra} + Net_{Oth}$$

Where

Net_{Fra} = Net savings due to EURECA framework and tool supported (or avoided) procurements and self-improvements by the EURECA pilot partners.

Net_{Tra} = Net savings due to EURECA-run trainings, using the various EURECA developments

Net_{Oth} = Net savings of EURECA framework and tool supported (or avoided) procurements and self-improvements initiated outside the EURECA project, until 2020

Some of these savings will be initiated during the project duration, other only afterwards

The absolute savings are calculated compared to a "business-as-usual" or autonomous procurement scenario (Detail in chapter 5) (see Formula 6).

Formula 6 $Net_{Xxx}=eLCC_{eureca}-eLCC_{bau}$

Where

Net_{xxx} = either Net_{Fra} (Net savings due to EURECA framework and tool supported (or avoided) procurements by the EURECA pilot partners) or Net_{Tra} (Net savings due to EURECA-run trainings, using the various EURECA developments) or Net_{Oth} (Net savings of EURECA framework and tool supported (or avoided) procurements and self-improvements initiated outside the EURECA project, until 2020). Expressed in [Euro]

$eLCC_{eureca}$ = environmental life cycle costing when implementation according to EURECA framework and/or tool [Euro]

$eLCC_{bau}$ = environmental life cycle costing for "business as usual" case [Euro]

On top of reporting the TCO and external cost figures separately, the overall environmental life cycle costing can be calculated combining the TCO (total cost of ownership) plus the externality cost; see Formula 7. To be in line with Clean Vehicle Directive, only four elementary flows in climate change are foreseen to be considered i.e. CO2, NOx, NMVOC and Particulate matter. Table 1 shows the default cost factors. The life cycle wide emission data are the result of the EURECA tool calculations along the modelling and calculation method as detailed in D2.1.

Formula 7 $eLCC = TCO + Ext$

Where

eLCC = environmental Life Cycle Cost [Euro]

TCO = Investment cost + Operational cost + End-of-life management cost [Euro]

Ext = externality cost [Euro]

The TCO costs will take into account capital costs / interest rates etc.

The externality cost is calculated as follows:

Formula 8 *Ext = f * Emission*

f = cost factor for individual emission; see Table 1 [Euro/kg]

Emission = emission flow [kg]

Table 1 The default cost for emissions (European Commission,2015c).

Emission	**External cost to society**
CO_2	0.03-0.04 EUR/kg
NO_x	4.4 EUR/kg
NMHC	1 EUR/kg
Particulate matter	87 EUR/kg

It is to be highlighted that the Clean Vehicle Directive does not take into account other emissions and resource depletions than from the vehicles off gas, hence will be clearly incomplete for data centres and miss out e.g. coolant loss, water scarcity and other emissions and resources. We nevertheless will provide the necessarily incomplete externality cost results, to improve the available information for making decisions.

When presenting the cost results in D5.3, it is foreseen to separately present the results of the TCO (for each of the three contributing figures) and eLCC, given the different level of robustness and nature of the cost data.

6 Increased skills of the procurers

From the feedback at our first public events, interviews and surveys, it is clear that the skill levels of public sector procurement and technical staff is limited when applied to the use of energy efficiency best practices, global best practices for operations and procurement of innovative data centre related solutions.

The project team feels that public sector employees are often and largely excluded from the data centre industry per se, with respect to attendance at industry events and publications and therefore are not aware of the latest innovations in cooling, the implementation of energy efficient best practice and emerging international standards such as ISO30132/33/34 for PUE and ERF and the EU Code of Conduct for Data Centres (Energy Efficiency) and the Green Grid's Maturity Model. This also affects procurement of innovative, energy-efficient and more environmentally sound data centre solutions in public sector organisations. Criteria on energy and environment are not included or limited (see also D1.1). Notable differences exist at least on Federal level in Germany, thanks also to the efforts on developing the first Type I Ecolabel (Blue Angel) for data centres a few years ago.

The use of the EURECA toolset and the associated training programme will however address this more common issue of limited knowledge and usage of more advanced ways to capture the environmental and energy performance of data centre products and services.

Whilst the content of the training curriculum has yet to be formally structured and defined, as this is contained within WP4, our approach will be to develop two sets of training programmes, directed at two distinct target audiences: The first programme will be directed at procurement staff and the second programme at technical staff.

Our thoughts at this point are to provide, for both technical and non-technical routes, an overview of energy efficiency and sustainability in the data centre per se, and this will include information on the EU Code of Conduct for Data Centre (Energy Efficiency) (or the impending EN 50600 TR 99-1), the Green Grid's Data Centre Maturity Model and other relevant documents identified in D1.1.

Building on life cycle costing, which is widely known and required to be including in public procurement, moreover the environmental side of life cycle thinking will be introduced to procurers, with information on available policy developments such as the Energy-related Products Directive activities on Enterprise Servers and industry-wide activities to develop life cycle based labels for e.g. UPS and hard disks.

The first session will also include real life examples of public and private sector data centres that have used innovative solutions and after some time the projects that have been assisted with the EURECA tools.

The second and subsequent sessions are foreseen to provide an overview of the toolsets, including detailed scripts and flowcharts of the information required in each module to achieve an optimum result.

The results will provide an organisation with the necessary information to build a procurement tender and associated documentation.

A key message will be that collaboration between the various departments including procurement, legal, service delivery, estates/facilities and IT functions will be required and is essential to successfully design, build and operate an energy efficient and sustainable data centre using innovative solutions.

The information provided by the training sessions will allow both procurement, non-technical and technical personnel within the public sector to have the necessary skillsets to implement energy efficient and sustainable data centre solutions and/or services or to seek the same from the colocation and cloud providers within the EU.

We aim to provide the necessary knowledge to procurement personnel to question technical staff regarding the provisional design of the project with respect to the use of innovative solutions, alternatives such as cloud or colocation in a recognised energy efficient facility, energy efficient equipment etc.

Technical staff will be made aware of the high level view of climate change, energy scarcity, the various global standards and guidelines for use in data centres, a review of some of the most common innovative solutions available for use in the data centre environment and finally introducing the concept of the circular economy where data centre outputs such as waste heat can be harnessed to provide heating for office environments or for other industrial uses.

Training for the industry is covered elsewhere in the work packages under the EURECA project and will follow a similar line to those provided for the public sector.

This will allow the industry to be "EURECA" aware, and to provide upon request or in competitive tendering situations the information that we will impart to the public sector.

The project aims to train 500 public sector personnel to gain the necessary knowledge to ask data centre designers, colocation and cloud suppliers about their energy efficient and sustainable product offerings.

The people that will have been trained by EURECA will be approached with the following frequency, in order to identify the success of the training and how the training and the other deliverables of EURECA have effectively contributed to increased skills of the procurers and of public sector IT staff that are involved in data centre procurement or operation.

The training sessions will start within the lifespan of the project. During the web registration of people to be trained, people will be informed and consent to the fact that they will be approached according to the frequency mentioned hereunder.

<u>Getting data on success</u>

EURECA needs to get information on how successful the training is. During the EURECA training and webinars, this will extensively have been explained. There will be the following ways of gathering data and information on the success of the EURECA trainings and other deliverables:

1. Asking the trainees directly.

Time will be spent to motivate the trainees to react and answer these questions that will be asked them, over time. The questions will be explained and the trainers will explain how the trainees should measure and gather data in order to come up with answers.

EURECA will ask the following type of questions, both before the training or webinar and afterwards (potentially with a follow-up 6 months later). Some questions are more directed at technical (IT) staff:

- Are you aware of the EUCoC?
- Do you know and measure the PUE of your data centre?
- Which environmental aspects of the data centre operation matters relevantly, next to electricity consumption?
- Which environmental and energy aspects are relevant for servers, for UPS?
- Which cooling technology is the most energy-efficient, is the most environmentally friendly one?

Other questions are directed at procurement officers:

- What does the Procurement Directive say about using energy and environmental criteria in public procurement?
- Did you already include energy and environmental criteria in ICT procurement, in DC procurement (and if so which)?

The logic of the questions and how to interpret the answers will be worked out in detail and in close coordination with developing the training curriculum, to derive comparable levels of learnings via a point system. This information can be used in future training sessions too. The answers will also be used to improve the tool.

2. Ask procurers in Europe

EURECA will ask procurers in Europe feedback on their knowledge of the innovative data centre technologies, of environmental and energy aspects of data centres in general, and of specific elements.

This will be done during network activities, seminars, with the help of questionnaires and interviews. Where consortium members speak (networking, events, presentations), there is always a possibility to send and get information. The database of procurers that EURECA is building, through the several events throughout of Europe will be having data on who EURECA may approach (consent) asking questions (mail, questionnaires, etc.). Over a certain amount of time it is expected that the amount of people that will be asked questions, will grow during the lifespan of the project.

7 Innovative solutions uptake

The uptake of innovative solutions largely depends on the "risk appetite" of the procuring body, some public sector bodies will perceive that the provision of "information and digital solutions" needs to be as simple and secure as possible and thus unlikely to adopt any innovative solutions, such as the adoption of the EUCoC and DCMM methodologies, new cooling systems, load sharing and renewable energy solutions if they act alone to procure or specify data centre services.

An added issue is the drive towards the use of cloud services (SaaS, IaaS, PaaS and XaaS) by public sector organisations where the "data centre" is largely hidden from view.

Add the fact that most public sector organisations will be tied into Managed Services Providers (MSP) contracts that prevent the adoption of unusual solutions, indeed the drafting of the principal contract may not even include any reference to energy saving or the use of innovation.

Some of these problems will be addressed by increasing skills of procurers addressed in Chapter 7, however the EURECA project needs to engage with the suppliers of MSP solutions to ensure that they are aware of the EURECA tool and the directory of innovative solutions.

The EURECA project team has engaged directly with end users and will commence discussions with MSP's to identify suitable candidates for the projects as well as the public sector bodies themselves, and as of this date (October 2015) has 2 confirmed meetings that will cover 11 possible projects.

Our approach with regard to the uptake of innovative solutions is twofold: The first is to identify suitable public sector organisations that are at the first stage of public procurement and who are seeking expert assistance; these were identified through the use of public procurement portals.

The second is to engage with MSP's with public sector clients, these include consortium partners and other organisations associated with the DCA, it is intended that 6 EURECA pilot partners of this group will be identified by Dec 2015 via this route.

Due to the nature of a procurement exercise, it is essential to capture organisations at a pre tender stage. The use of the EU procurement guidelines 2014 to use external consultants for design assists the EURECA project in this requirement, however, not all EU countries have shifted to the new directive yet and this may hamper activities in certain countries.

Our measurement options (at present) will be limited to those organisations that the project collaborates with. This will be reported by a case study that provides the details on the innovative solutions adopted in a particular facility.

In the future, our follow up tasks triggered by the use of the tool will provide additional data for analysis.

From our experience, parts of the colocation market are adapting designs to include some of the less innovative solutions, such as free cooling, use of boreholes for cooling and recharge, some limited renewable energy either on or off site, but has yet to engage with other organisations to adopt load sharing, renewable energy rebalancing, and waste heat solutions.

Finally, special attention will have to be laid on the question what actually and rightfully constitutes an "innovative" technology or other measures, as vendors tend to market much of their products as "innovative". We will differentiate this per procurement scenario and also reflect this differentiation in the market directory.

Our initial thoughts are to measure on a case by case basis, our rationale is that even a small change to a design, for instance raising the inlet temperature to the higher levels of ASHRAE's allowable range will yield significant improvement. The adoption of the EU Code of Conduct for Data Centres' 155 best practices at a very basic level (the best practices that are not capex intensive) will result in an even greater saving and may not be as a result of a procurement exercise, but due to the other deliverables of EURECA.

8 References / Sources

42U (2015, April 20). retrieved from http://www.42u.com/

Andrae, S. G. & Edler, T. (2015, April 22). On Global Electricity Usage of Communication Technology: Trends to 2030. Retrieved from http://www.google.de/imgres?imgurl=http%3A%2F%2Fwww.mdpi.com%2Fchallenges%2Fchallenges-06-00117%2Farticle_deploy%2Fhtml%2Fimages%2Fchallenges-06-00117-g004-1024.png&imgrefurl=http%3A%2F%2Fwww.mdpi.com%2F2078-1547%2F6%2F1%2F117%2Fhtm&h=666&w=1024&tbnid=gbHFTT5NQBc7pM%3A&docid=0GC_WldezGD1BM&ei=Cy8vVtwmh7GwAeDAtegE&tbm=isch&iact=rc&uact=3&dur=1109&page=4&start=135&ndsp=48&ved=0CMoBEK0DMEI4ZGoVChMInNjGvJfiyAIVhxgsCh1gYA1N

Bio by Deloitte & Fraunhofer IZM (2015). Preparatory study for implementing measures of the Ecodesign Directive 2009/125/EC. DG ENTR Lot 9 - Enterprise servers and data equipment. Task 5: Environment & Economics. Draft final report, June 2015

Climate Group and the Global e-Sustainability Initiative (GeSI). (2008). *SMART 2020: Enabling the low carbon economy in the information age*. Retrieved from http://www.smart2020.org/_assets/files/02_smart2020Report.pdf

Cruz M., Pérez M., Almarza F., Cortés A., Pascual J., (2012). 2nd Annual Report on Exploitation Actions and Impact Assessment D7.5

DCD Intelligent (2012). 2012 Census Report: WESTERN EUROPE DATA CENTER MARKET TRENDS 2012-2013 A Market Research & Analysis Report

Delforge P. (2014). America's Data Centers Are Wasting Huge Amounts of Energy- Critical action Needed to save Billions of Dollars and Kilowatts IB14-08-A August 2014

Dutch Government - "Overheid". (2014, February 26). Activiteitenbesluit milieubeheer, artikel 2.15. Retrieved from http://wetten.overheid.nl/BWBR0022762/Hoofdstuk2/Afdeling26/Artikel215/geldigheidsdatum_26-02-2014

ETSI (2011). Technical specification: Environmental Engineering (EE); Life Cycle Assessment (LCA) of ICT equipment, networks and services; General methodology and common requirements 103 199 V1.1.1

European Commission (2010). COM(2010) 2020 final Brussels, (3.3.2010) EU2020 A strategy for smart, sustainable and inclusive growth

European Commission (2015 a). Circular Economy Strategy roadmap

European Commission (20215b). COM(2015) 215 final- Better regulation guideline

European Commission (2015c). Clean vehicle directive.http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32009L0033&from=EN

EUROPE2020 (2015, June 15). Retrieved from http://ec.europa.eu/europe2020/europe-2020-in-a-nutshell/priorities/sustainable-growth/index_en.htm

European Commission, Directorate-General JRC, Joint Research Centre. (2015). EU Code Of Conduct In Data Centres On Energy Efficiency. Retrieved from http://iet.jrc.ec.europa.eu/energyefficiency/ict-codes-conduct/data-centres-energy-efficiency

Feindt, S. (2015). EU CODE OF CONDUCT IN DATA CENTRES ON ENERGY EFFICIENCY. Retrieved from http://www.digitaleurope.org/Ourwork/MinimisingourEnvironmentalImpact/EnergyEfficiency/EUCodeofConductinData centresonEnergyEfficiency.aspx

GeSI (2015). Smarter2030 Retrieved from http://smarter2030.gesi.org/the-opportunity/

Gemeente Amsterdam. (2014). *Amsterdam datacentres Save Energy!*. Retrieved from file:///Users/Frank/Downloads/20140502_dro_datacenters_uk.pdf

Gemeente Amsterdam Dienst Milieu en Bouwtoezicht. (2012). *Energiebesparing bij datacentres*. Retrieved from file:///Users/Frank/Downloads/eindrapport_energiebesparing_bij_datacenters.pdf

Gemeente Amsterdam. (2015, March 13). Bouwbrief 2014-129 Energieprestatie-eis nieuwe datacentres. Retrieved from https://www.amsterdam.nl/wonen-leefomgeving/bouwen-verbouwen/bouwbrieven-0/bouwbrieven/bouwbrief-2014-129/

GHG Protocol (2013). GHG Protocol Product Life Cycle Accounting and Reporting Standard ICT Sector Guidance

Green grid (2012). Data Centre Life Cycle Assessment Guidelines

Goiri, Í.; Haque, M.E.; Le, K.; Beauchea, R.; Nguyen, T.D.; Guitart, J.; Bianchini, R. Matching renewable energy supply and demand in green datacentres. Ad Hoc Netw. 2015, 25, 520–534.

Google (2015). Google Data Centers. Efficiency: How we do it. Website. https://www.google.com/about/datacenters/efficiency/internal/ . Accessed 14 Oct 2015.

Harryvan, D. (2014, May 21). ZERVERS. Retrieved from https://www.amsterdam.nl/wonen-leefomgeving/duurzaam-amsterdam/publicaties-duurzaam/rapport-zervers/

Honée C., Hedin D., St-Laurent J., Fröling M. (2012). Environmental Performance of Data Centres - A Case Study of the Swedish National Insurance Administration

Kerssens, D. (2015, May 29). Smart sharing van ICT infrastructuur - kan het duurzamer?. Retrieved from http://www.surfsites.nl/duurzaamheid/symposium/presentaties)

Köhn, M. (2015). EURECA interview, August 2015

Koomey J. (2011). Growth in Data center electricity use 2005 to 2010. Oakland, CA: Analytics Press. August 1. http://www.analyticspress.com/datacenters.html

Koomey, J. G. (n.d.). Implications of Historical Trends in the Electrical Efficiency of Computing. *IEEE Annals of the History of Computing*, *03*(33), 46-54.

Korbee H., Smolders B., Stofberg F. (1979). Milieu voorop bij uitwerking van een globaal bestemmingsplan, TH Delft, afd. Bouwkunde, in: BOUW, no. 22, 27 oktober 1979

Meza J., Shih R., Shah A., Ranganathan P., Chang J., Bash C.. (2010) Lifecycle-based Data Center Design. HPL-2010-117

Parker, H. (2013, February 19). Projection of datacentre Electricity Use. Retrieved from http://www.alliancetrustinvestments.com/sri-hub/posts/Energy-efficient-data-centres

PEFCR UPS (2015a). Product Environmental Category Rules for Uninterruptible Power Supply (UPS). First Draft PEFCR, European Commission Product Environmental Footprint (PEF) pilot phase.

PEFCR HDD (2015b). Product Environmental Footprint Categories Rules for IT Equipment (storage). First Draft PEFCR, European Commission Product Environmental Footprint (PEF) pilot phase.

PEFCR Metal sheets (2015c). Product Environmental Footprint Categories Rules for metal sheets for various applications. First Draft PEFCR, European Commission Product Environmental Footprint (PEF) pilot phase.

PEFCR Batteries (2015d). Product Environmental Footprint Categories Rules for High specific energy rechargeable batteries for mobile applications. First Draft PEFCR, European Commission Product Environmental Footprint (PEF) pilot phase.

Study_Predicts_Inhouse_Data_Centre (2015, June 15). Retrieved from http://www.cio.com/article/501527/Study_Predicts_Inhouse_Data_Centre_Capacity_Decline

Talens PeiroL., Ardente F. (2015). Environmental Footprint and Material Efficiency Support for product policy - Analysis of material efficiency requirements of enterprise servers ISBN 978-92-79-51893-5

Telecoms Pricing (2015, June 15). Telecoms Pricing- European Data Centre revenue to double over the coming 5 years: Retrieved from http://www.telecomspricing.com/news_detail.cfm?item=2592

Webb, M. (2010). SMART 2020: Enabling the low carbon economy in the information age. Report, The Climate Group on behalf of the Global eSustainability Initiative (GeSI)

Oró, E.; Depoorter, V.; Garcia, A.; Salom, J. (2015). Energy efficiency and renewable energy integration in data centres. Strategies and modelling review. *Renew. Sustain. Energy Rev.* 2015, *42*, 429–445.

UBA (2015). Leitfaden zur umweltfreundlichen öffentlichen Beschaffung von Produkten und Dienstleistungen für Rechenzentren und Serverräume

Wolf, M.-A. (2014). KPIs for Green Data Centres. Background report for stakeholder meeting 1st April 2014, Brussels.

9 Annex

9.1 'Autonomous' development and improvement potential for energy efficiency and environmental performance

9.1.1 Hardware energy efficiency

The improvement of energy efficiency of ICT and data centre infrastructure hardware causes an autonomous increase in overall ICT energy efficiency. Think of cooling machines, servers, switches, storage, UPS, generators. The main influencers here are the different ways of cooling efficiency (traditional and innovative) and the ICT hardware energy consumption (mainly the servers, also UPS); see Figure 8.

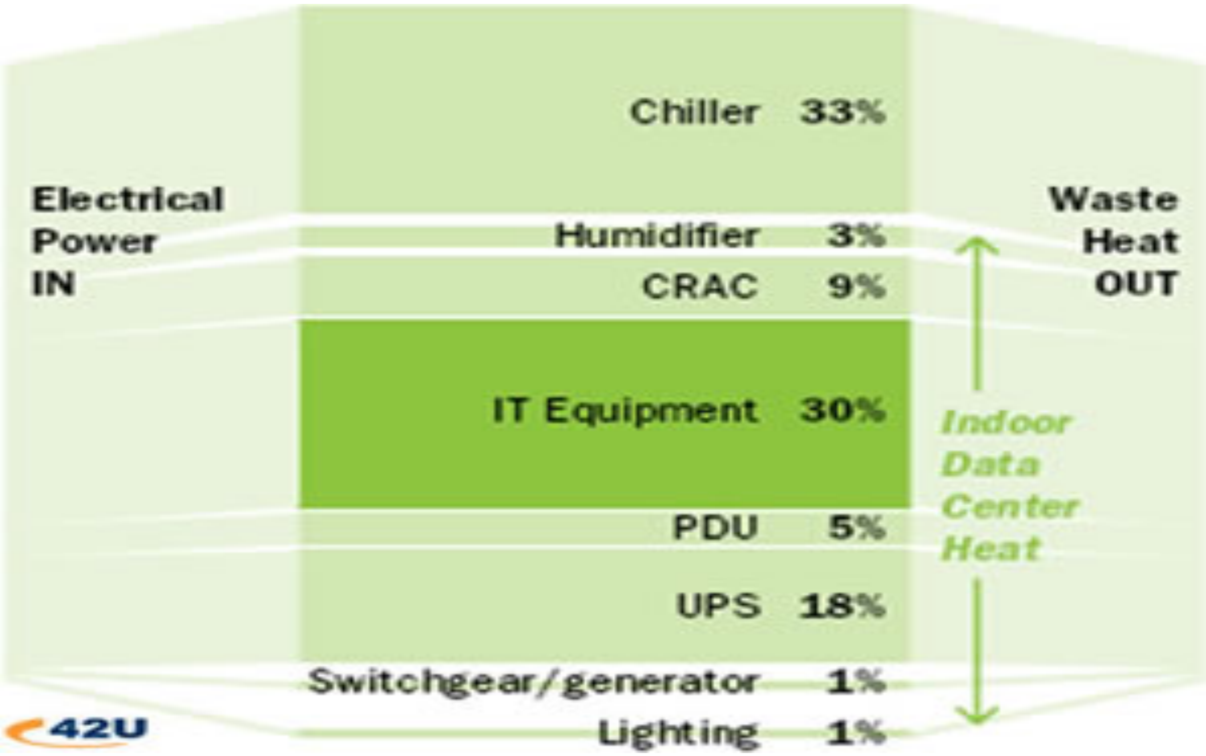

Figure 8 Typical profile of energy consumers in a data centre, contribution to overall kWh/year (Source: 42U, 2015)

Saving IT energy saves a lot more in primary energy: 30% of the datacentre energy is IT energy. Of the 100% energy that is being transported to be used in the datacentres, only 33% is left for use in the datacentre; only 9,9% is effectively being used in the IT equipment

It is therefore very important to have energy efficient IT hardware. Servers consuming energy without processing data (idle), is very inefficient. Project ZERVERS pointed to another >66% saving potential

9.1.2 Traditional cooling hardware

Equipment efficiency improvement of high capacity water chillers is nearly flat, as can be derived from the ANSI/ASHRAE/IESNA Standard 90.1-2004/2007/2010, specifically shown in table 6.8.1C (see below), the minimum efficiency requirement for electrically driven positive displacement chillers has changed very little over a period of 6 years.

Table 2 Equipment efficiency improvement of high capacity water chillers (ANSI/ASHRAE/IESNA 2004, 2007, 2010) COP= coefficient of performance, IPLV= Integrated Part Load Value

Year of publication	minimum COP	minimum IPLV
2004	5,50	6,15
2007	5,50	6,15
2010	5,67	-

This chiller type is most commonly at the heart of the cooling infrastructure of larger data centres, why we can derive that cooling efficiency improvements cannot be expected from pure chiller efficiency but must be obtained from better practices, including but not limited to variable speed fans and pumps, higher ambient temperatures and broader humidity ranges.

9.1.3 Innovative cooling methods and hardware

There is a lot of discussion within the industry over the best and most efficient way to cope with the produced heat. New methods of dealing with the produced heat may cause huge energy savings. Going from traditional energy consuming DX kind of cooling systems to new systems like adiabatic or 'free' cooling variants brings down the PUE dramatically. Many data centres have improved their cooling and gained on energy efficiency. Figure 9 shows the example of Google:

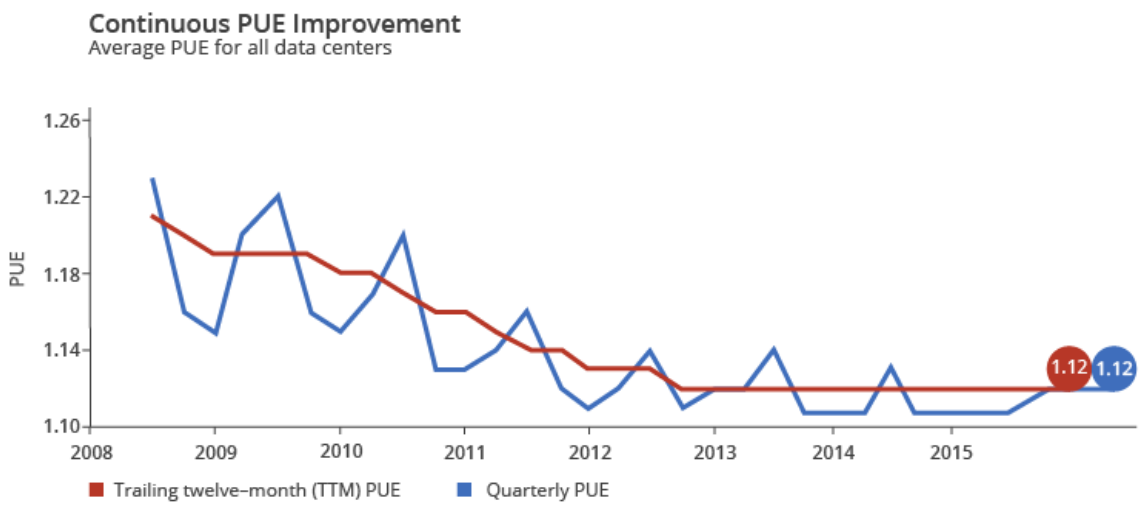

Figure 9 Google actively promotes its progress on reducing its PUE (Google 2015).

9.1.4 ICT hardware (servers)

Much attention has been given to the energy consumption of servers. ICT hardware vendors are competing on server's energy efficiency. The costs of energy of a server during its (short) lifespan, is higher than the price to buy a server. Energy consumption is therefore crucial to make purchase decisions and to the operation costs of a data centre. Koomey (n.d.) showed that computation capacity doubles every 18 months. This means, every 18 months servers become twice as efficient. With the same IT load one could do with half of the number of server. Young servers in the data centres save energy during, they have a better energy-use performance: "Using historical data, the research team created a graph comparing the amount of computing power of the average computer (from supercomputers to laptops) with the amount of electricity it needs and found that over time, energy efficiency improvements from the 1950's till now, have moved in virtual lockstep with increases in the amount of processing power1: energy efficiency, they found effectively doubled every 1.57 year, or 18 months" (see Figure 10).

[1] Actually, Moore used the number of processors on a chip. This may not be the exact proxy for the amount of processing power.

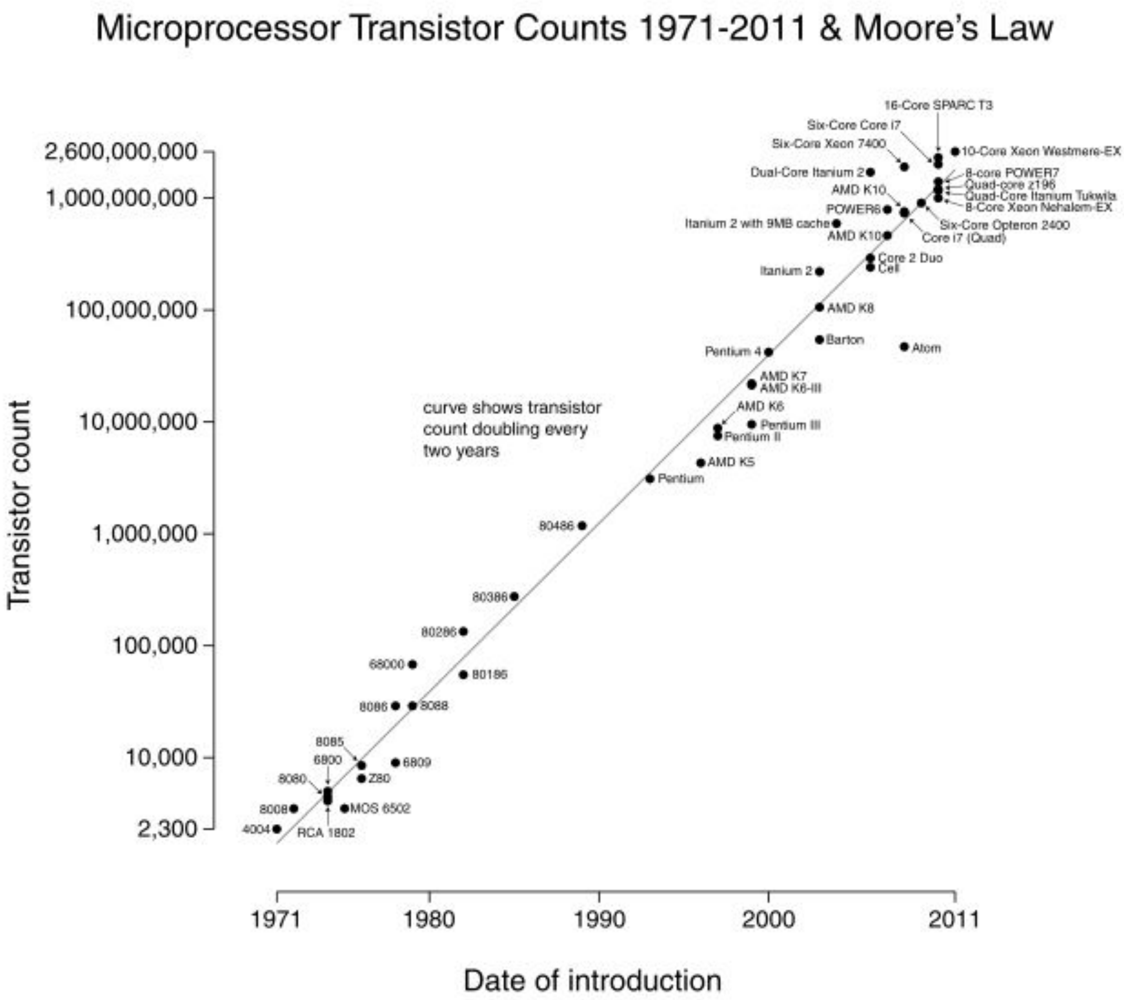

Figure 10 Moore's Law of increased computational performance with time. (http://phys.org/news/2011-09-koomeys-law-power-efficiency-parallels.html#jCp).

9.1.5 Data centre efficiency in general

Data centres are improving the energy efficiency, also without EURECA. The energy efficiency in data centres has a relation with the work (proxy: traffic in) and the energy used of data centres. The European code of conduct for Energy efficiency in Data Centres (EUCoC) registers the Power Usage Effectiveness (PUE) of participants, with the PUE as proxy for data centre energy efficiency (assuming no differences in computational performance and load). The 110 participants with their 235 data centres (October 2015), register the Total Facilty energy and IT energy as separate items, and the calculation for PUE is determined from this information. The participants use altogether a total of over 2 TWh annually. The average

Power Usage Effectiveness (PUE) is on average around 1.7. The improvement potential, judged from current state-of-the-art data centres claims PUE's below 1.2.

There is a noticeable trend within the data centre industry to increase energy efficiency. There will be data centres that are very concerned with the environment, while some of the drivers will be more mundane:

- cost reduction of operation to improve margins
- pressure on prices
- increased competition
- consolidation of the number of data centres
- the invested sums require profits
- the management/financial need to fill up data centres space asap
- Public bodies require PUE <=1.2, (Gemeente Amsterdam, 2015) for new consolidated (from 70 to 4) data centre architecture, similar in Germany
- Repeated threats of increased energy prices.

9.1.6 The PUE as a proxy for datacentre efficiency

How to calculate a PUE is already a discussion for some times. Certain types of measuring are inspired by the wish to show a low and preferable PUE, for commercial purposes; see Figure 11.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 649972.

$$PUE = \frac{Total\ Facility\ Power}{IT\ Equipment\ Power}$$

$$DCiE = \frac{IT\ Equipment\ Power}{Total\ Facility\ Power}$$

PUE	DCiE	Level of Efficiency
3.0	33%	Very Inefficient
2.5	40%	Inefficient
2.0	50%	Average
1.5	67%	Efficient
1.2	83%	Very Efficient

Table 1. Source: The Green Grid

Scenario	PUE
Current Trends	1.9
Improved Operations	1.7
Best Practices	1.3
State-of-the-Art	1.2

Source: EPA Estimated PUE Values in 2011

Figure 11 PUE and DCiE as proxies for data centre energy efficiency (Green Grid 2012).

Owners of data centres, want to show their customers that their datacentre is efficient.

9.1.7 Limitations of the PUE for comparisons and for energy and environmental impacts/savings

Having said all this, a few peculiarities are to be highlighted about the PUE:

- The more energy efficient the IT hardware becomes (servers, storage and switches), the higher the PUE gets
- Also virtualisation can counteract the PUE or is not captured by it. Virtualisation was the by far main source for reducing Germany's federal level ICT electricity consumption by 40% from 2010 to 2014 (Köhn, 2015).
- As the PUE is unrelated to the performance of the servers, two otherwise identical data centres, one with brand new servers, one with 20 year old server models and hence orders of magnitude lower calculation performance, will have the same PUE.
- Production of the capital goods is not captured by the PUE, as are …
- the energy sources sued to produce the electricity.

The PUE is hence not a good proxy for environmental and energy performance of different centres, is valuable only for improving certain aspects of existing data centres, respectively needs to be part of a more comprehensive package of evaluation information and indicators to actually capture the energetic and environmental performance of data centres. Apart from this, the PUE alone does also not deliver information on the absolute amount of electricity spent and hence primary energy used or saved.

9.1.8 Speed of PUE improvements

However, the datacentre energy efficiency improvement is slow: Digital Realty Trust's 2014 research with interviews in the mid sector of datacentres learns that "only 27% of the interviewee's thought their firm measures PUE, while 42% said the plan to do so in the future. Of those that thought PUE was being measured, 73% could not cite the value. The median PUE for those that did know was 2.0. Bottom line is that only 20% of these "senior level decision makers with responsibility for data centers" knew the most basic indicator of their facilities' energy efficiency".

The Uptime Institute's annual survey shows the same picture: Starting with PUE 1.89 in 2011 as an industry result, average PUE among the companies surveyed went down to 1.8 in 2012 and further down to 1.67 the following year of 2013. In 2014, however, it was slightly up to 1.7:

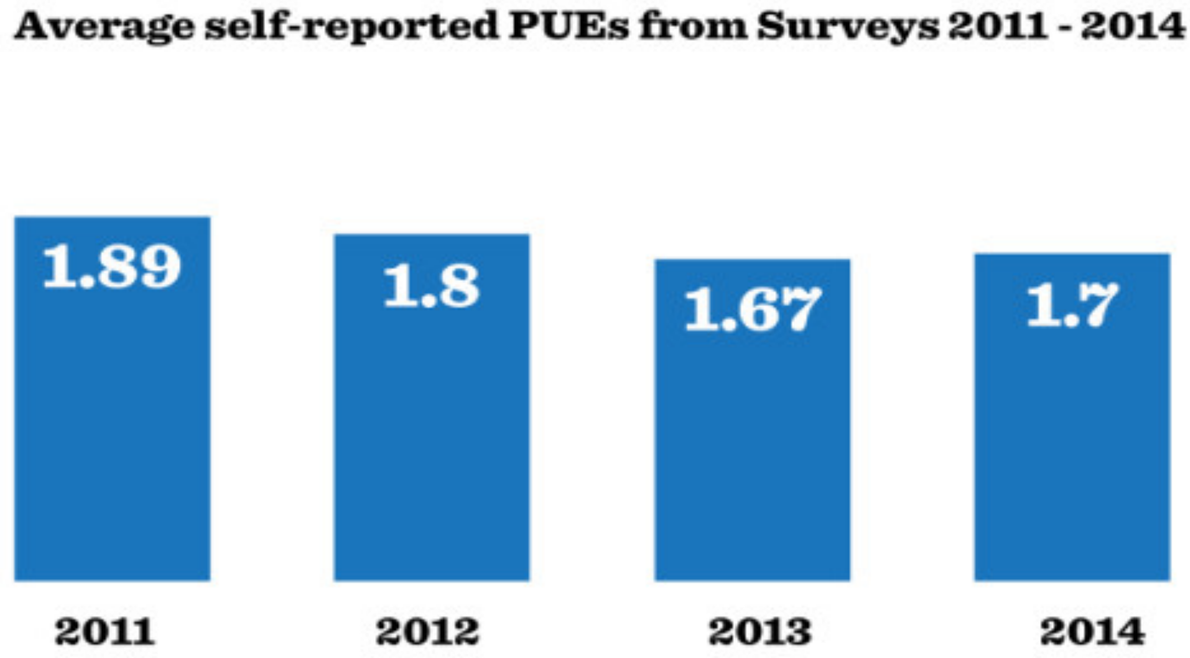

Figure 12 **PUE values' change with time, based on the survey participants' self-assessment (Uptime Institute, 2014). From Bron : http://www.datacenterknowledge.com/archives/2014/06/02/survey-industry-average-data-center-pue-stays-nearly-flat-four-years/**

An earlier Digital Realty Trust's 2013 research showed many data centres operating above 2.0 PUE.

"12% of the respondents is unfamiliar with the term PUE. 19% doesn't know their PUE. The average reported PUE is 2.53. 6% report a PUE of 3 or more; 28% report a PUE below 2.0."

The feedback received from the European Code of Conduct for datacentres shows that the ±100 participants report a PUE around 1.8-1.7.

9.1.9 Energy efficiency and reuse

The energy used in data centres is often restricted only to the energy the data centre consumes, and takes from the grid. The waste, i.e. the heat that a data centre produces is cooled away, with free cooling (i.e. natural outside cold air or water flow) as its most energy efficient variant. The reuse of energy is often overlooked but in certain data centres the newest developments. Examples are a proprietary data centre (2010) of the City of Amsterdam and the KPN Eindhoven datacentre (2014) that offers all kind of colocation services. Both innovative datacentres offer the produced heat into an efficient heating system for offices in the proximity. These initiatives and examples are hard to find but the way to go. The wasted heat (even with 'free' cooling) has a residual energy value that helps increase the energy efficiency, when reused properly, i.e. when it meets a real need and then replaces alternative ways to produce the heat (e.g. natural gas based heating).

At the same time, one has to be aware that the loss of primary energy will still be large (given the losses of between 40 and 70% when converting energy carriers to electricity) and that rarely a year-round demand for the waste heat exists. Reuse (or more precisely: further use) of the waste heat is hence only an additional option, where it makes sense. Priority will always be to reduce energy consumption first.

9.1.10 Use of power in datacentres

The general statement is that the energy demand is growing fast. Research indicates that the growth of the power demand in datacentres is more or less stable. This trend is confirmed by the DatacentreDynamics 2013 report, that has been forecasting a very small decrease in total datacentre energy use for 2016, after years of constant growth, what would reversely confirm the fact that average equipment utilization is either stable or slightly decreasing. The future has to show the real development.

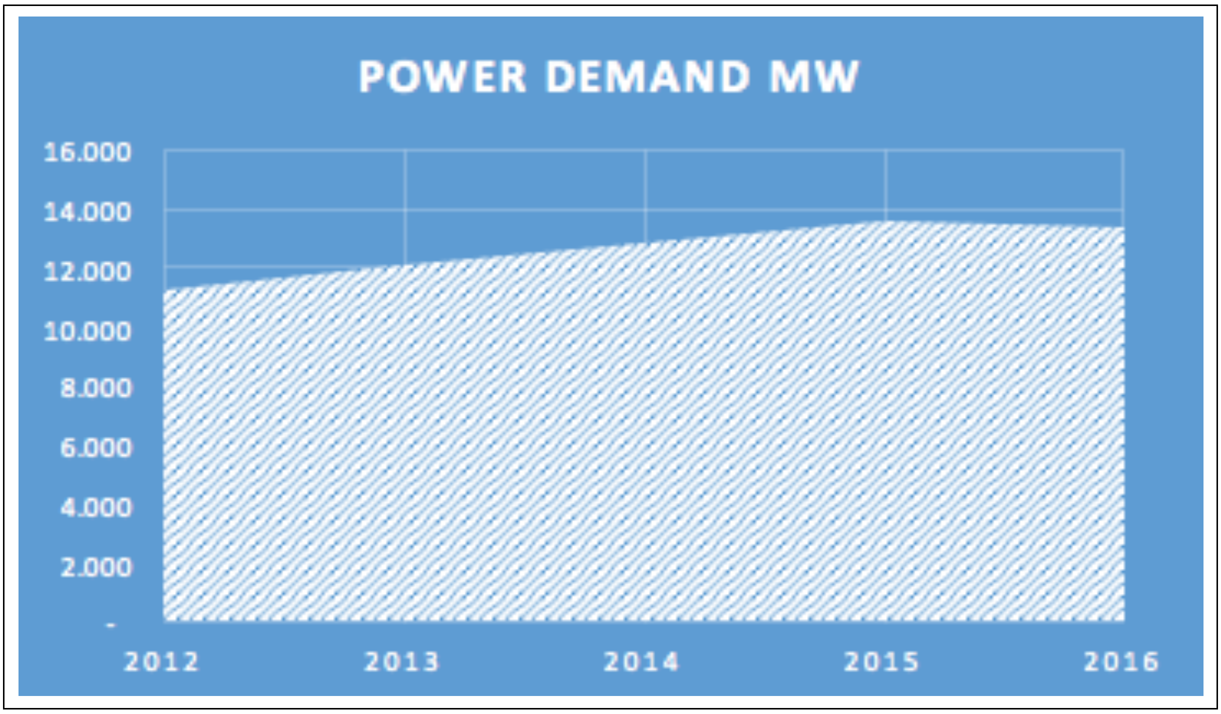

Figure 13 **Global data centre energy demand forecast of 2013 (DatacenterDynamics 2013)**

9.1.11 Trias Energetica

The most energy efficient way to reduce the use of energy or power needed is to reduce the waste of energy, particularly the amount of non-essential work. This is not within the scope of the project. The growing amount of remote data processing and storage is a given fact for

EURECA. Still, it will be an advice to public sector organisation to check e.g. for data storage need and – in same cases – whether video and other data intensive applications are the most suitable way to meet the actual service behind.

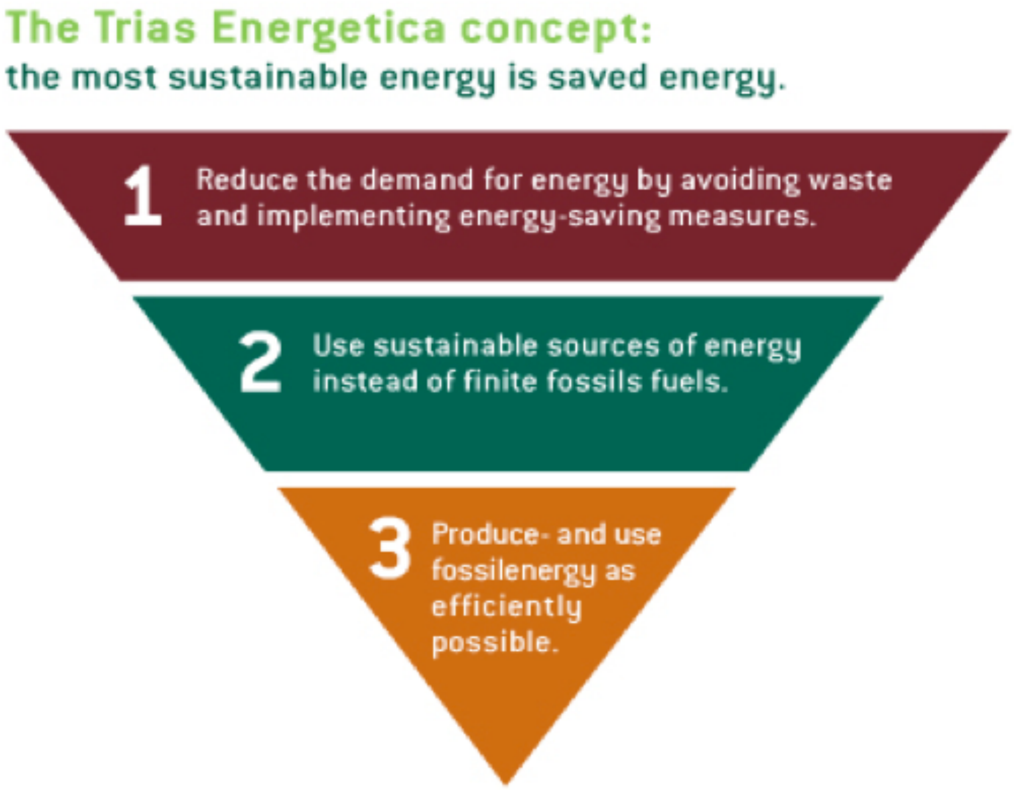

Figure 14 **The Trias Energetica concept; see text (based on Korbee et al. 1979)**

The other way of saving energy is to use different ways of carrying out the work. Use more energy efficient cooling, software, hardware, etc. It is all easy to find what to do, what kind of best practises to implement and reduce the unnecessary inefficient use of energy in the data centre.

9.1.12 Conclusions on autonomous development

Assuming no change in server utilisation percentage, a resulting decrease in total energy use may be expected.

Combining the effects of a near flat PUE, a near flat ICT equipment utilisation and an ICT capacity (demand) usage growth of 60% CAGR that nearly matches the ICT equipment efficiency improvement (70% CAGR) leads us to the phenomenal energy savings potential of demand driven best practices in datacentres.

It is widely accepted that strict adherence to the best practices detailed in the EUCoC would lead to data centres with an average PUE of 1.2. The potential energy savings resulting from following all recommendations of the EUCoC adoption would hence be 30% of total usage.

These savings reflect exclusively the however important use phase efficiency improvement in datacentre facilities. The increase in ICT equipment utilisation from 10% to 40% average utilisation, at the same time, would lower the total energy required for running this ICT load with a factor of 3. Since the components interrelate in the data centre system, the savings cannot simply be summed up. An estimation of the total effect in the order of 70% decrease in total use phase energy requirement is however reasonable. Increased utilization of the hardware would on top reduce the number of servers and storage equipment (and the other capital goods of the data centre that relevantly contribute in life cycle perspective) to provide the same service, further and substantially contributing the overall savings potential.

In conclusion, there are large potentials beyond the PUE that are to be identified by the EURECA consortium over the coming months, be connected to procurement scenarios, and finally tender specifications that meet the specific demand of the public body.