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SEESGEN-ICT

Supporting Energy Efficiency in Smart Generation Grids Through ICT

Thematic Network

ICT PSP Programme

ICT AND ENVIRONMENT PROTECTION

Report on ICT requirements, offers and needs

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EXECUTIVE SUMMARY

The objective of WP6 is to explore the opportunities offered by ICT systems for the protection of the Environment in the Smart grids panorama. The ICT sector itself, by increasing the efficiency and way energy is used in its primary processes is able to reduce its own carbon footprint.

On the other hand, ICT is an important component of the GHG emission monitoring and computation systems, as well as of the platforms for the GHG emission certificate trading.

Considering the specific character of these issues, it has been deemed necessary to approach them in two separate topics:

- WP6 Topic A: „ Improving energy efficiency of computing activities in Smart grids"
- WP6 Topic B: „ICT systems to encourage the application of techniques for reducing GHG emission"

The WP6 Topic A Section deals with aspects relating to Energy Efficiency in data centres: this chapter reviews the European and non-European initiatives that aim at reducing energy consumption in the data centres, the actual (existing) best practices in this field, as well as the possibility of using cloud computing and virtualization as a toll for energy efficiency. At the same time, a case study referring to energy efficiency of the data centres within ENEA is presented. Finally the Report deals with technologies and solutions to improve energy efficiency in other computing activities related to SmartGrids, such as distributed computing activities.

Within WP6 Topic B Section, after the presentation of the most relevant EU environmental policies, the results of the UK Government initiatives, also known as the "Act on CO_2" Calculator for the domestic sector, are analyzed.

The section presents a survey of equipment examples and, based on the consumed energy, the corresponding CO_2 emissions are calculated. This kind of information should increase the consumers' awareness.

Within the same WP6 Topic B an inventory of the European and non- European network operators carrying out activities for the Smart Metering implementation, as well as research projects that tackle the issue of ICT use for CO2 monitoring, has been carried out.

Each topic ends with a preliminary conclusion chapter.

Next step of WP6 will deal with the analysis of barriers to the deployment of ICT to improve Energy Efficiency and a guide to the best practices applicable to the EU countries will be, possibly, developed.

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TOPIC A: IMPROVING ENERGY EFFICIENCY OF COMPUTING ACTIVITIES IN SMART GRIDS

INTRODUCTION

This Interim Report of WP6A focuses on the improvement of energy efficiency in computing activities related to SmartGrids operation and management. We will try to pinpoint the specific requirements of ICT in SmartGrids activities and to determine which solutions and practices could be put in place to reduce their environmental impact.

The analysis is based on literature, European Commission reports, congress and workshop proceedings, interviews with partner of the SEESGEN-ICT network, company case studies. The study approach is exploratory, descriptive and explanatory, applying a broad methodological basis: a **qualitative** case study approach is combined with a descriptive presentation of **quantitative** survey data and an **analysis** of ICT adoption and its impacts.

Chapter 1 addresses the evaluation and assessment of strategies to reduce ICT's own carbon footprint in **data centres.** Objectives of the work are the identification of solutions for the improvement of energy efficiency in data centres, best practices for green data centres regarding cooling, fixtures, new generation processors and load balancing. Specific paragraphs assess current impact of cloud computing and virtualisation technologies on energy efficiency and experiences in running a specific supercomputing infrastructure in ENEA. The chapter will provide information on European and international (US in particular) experiences.

Chapter 2 deals with technologies and solutions to improve energy efficiency in other computing activities related to SmartGrids, such as **distributed computing** activities (sensors for remote measurement, controllers for monitoring, smart meters, etc.).

Conclusions are set forth in Chapter 3.

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1 ENERGY EFFICIENCY IN DATA CENTRES FOR SMARTGRIDS

A data centre is by nature a highly complex system filled with IT hardware equipment (e. g servers, data storage, network devices, monitors, etc..) used for data processing, data storage communications and racks, connected by miles of wires and cables, and complex relationships between hardware and software. IT intersects with another complex system, the data centre facility itself, delivering power, cooling and space for IT.

During the past years, increasing demand for computer resources has led to significant growth in the number of data centre servers, along with an estimated doubling in the energy used by these servers and the power and cooling infrastructure that supports them. Hence, data centres are an important target in energy saving effort. They operate continuously, which means their electricity demand always is contributing to peak utility-system demand, an important fact given that utility pricing increasingly reflects time-dependent tariffs.

According to *Gartner*, energy costs will become an increasingly significant component of IT budgets, and an increasingly tough challenge for organizations as they work to grow their computing capabilities and contain costs. In many cases, this challenge is compounded by the design constraints of existing data centres. It is estimated that a medium –sized server has roughly the same annual carbon footprint as an SUV vehicle doing 15 miles per gallon[1]. According to Forrester Research a data centre with 1000 servers will use enough electricity in a single month to power 16,800 homes for a year. The power required for a rack of high-density server blades can be 10-15 times greater than a traditional server. The approximately 6,000 data centres in the US, for instance, consumed roughly 61 billion Kilowatt-hours (KWh) of energy in 2006, according to Lewis Curtis, a strategic infrastructure architect a Microsoft[2]. The total cost of that energy, $4.5 billion, was more than the cost of electricity used by all the colour televisions in the U.S in 2006.

Most facilities today are several decades old and many are already running at or near thermal capacity. Unless energy efficiency is dramatically improved, organizations will be unable to expand their computing infrastructure without the expense and disruption of upgrading their data centre, building a new one, or migrating to a co-location facility.

Energy-efficiency best practices can hold the key to significant savings, while improving reliability and yielding other non-energy benefits. Improving data centre energy efficiency is becoming a fundamental requirement for most organizations, not only to contain operating costs, but also to support growth, extend the life of existing facilities, protect the environment, and address increasing regulatory requirements. Electricity costs are rising fast. Most businesses already spend about half as much for the electricity to power and cool their infrastructure as they do for the hardware itself, and this percentage can be expected to increase.

Energy in Data Centres - Data centres use a significant amount of energy to supply three key components: IT equipment, cooling, and power delivery (Figure 1). These energy needs can be better understood by examining the electric power needed for typical data centre equipment in and the energy required to remove heat from the data centre.

[1] Carbon Neutral Company

[2] Patrick Kurp, *Green Computing*, Communications of the ACM, Vol. 51, N. 10, October 2008.

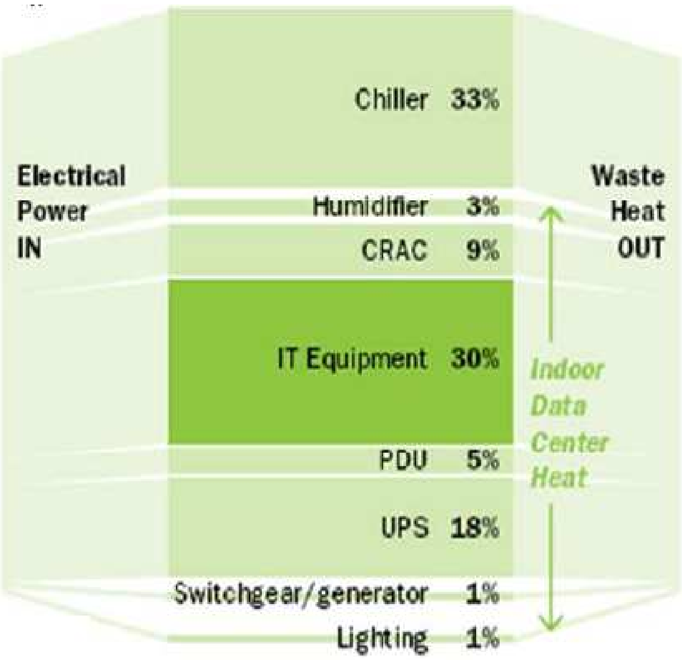

Figure 1 Total power consumed in data centres[3]

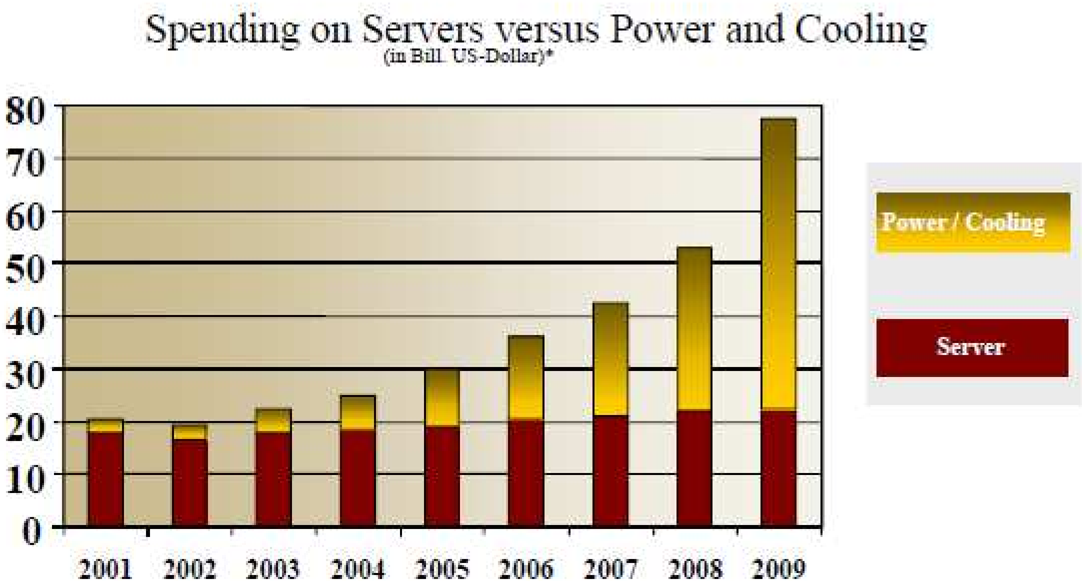

Figure 2 Energy costs account for over 60% of the total budget

In the report of Environmental Protection Agency (EPA), in 2006, it was shown that ~1.5% of national energy electricity demand came from energy consumption of data centres. It also revealed that the energy consumption of servers and data centres in the USA has doubled in the past 5 years and is expected to almost double in the next 5 years to an annual cost of $7.4 billion.

[3] Green grid data center power efficiency metrics: PUE and DCIE, WHITE PAPER # 6, The Green Grid, 2008

However, it is difficult to define ***energy efficiency*** for a complex system such as a data centre. An energy efficient product or facility is usually defined as delivering the same or better service output with less energy input. Ideally, efficiency is represented by an energy-based performance metric in which the output is measured in terms of an energy service that end users value, in the same way that household cooling equipment is rated based on its thermal cooling output. However, a data centre's output is a complex mix of computational processing; data storage; network communication; and server availability, reliability and responsiveness. The performance metric that is used affects the various competitive interests of the suppliers of data centre equipment; any definition of energy efficiency will benefit some suppliers and disadvantage others.

The difficulty in defining efficiency is especially true for a key piece of equipment in the data centre – the server. Measuring a server's output is difficult for several reasons:

1. for a given server, the output is dependent on the hardware and software configuration;
2. the primary application of the server (e.g., web applications, email, database, etc.) leads to different processing and memory requirements, which affect energy performance;
3. an individual server can provide multiple services simultaneously.

Nonetheless, significant progress has been made during the past year toward creating energy performance metrics for servers. Additional challenges emerge in attempts to derive measurements of overall data centre energy performance that include power distribution, cooling, and lighting. Different data centres will have different performance characteristics depending on their type of application, level of criticality, location, and size. Although it is a difficult process, defining "energy performance" is a prerequisite for implementation of many government and efficiency policies and programs. Energy-efficiency metrics can also be used as a benchmark for individual facilities to gauge their performance against other similar facilities. Data centre operators need to understand how much energy their equipment is using, how it fares against similar equipment, the trade-off between energy performance and other types of performance, and how these factors can be improved. These goals can only be achieved by defining a standard metric. In the absence of a metric, surveys show that while data centre operators/owners identify IT power and cooling as the primary issue facing their data centres, most say that neither IT power consumption nor cooling concerns affect their server purchases.

The **Green Grid**[4] recognizes the importance of establishing metrics for data centres efficiency, and offers guidance on technologies that claim to improve performance-per-watt. Ideally, these metrics and processes will help determine if the existing data centres can be optimized before a new data centre is needed. In the first white paper (February 2007, "Green Grid Metrics: Describing Data Centre Power Efficiency), the Green Grid proposed the use of **Power Usage Effectiveness (PUE**) and its reciprocal, **Data centres Efficiency** (DCE) metrics, which enable data centres operators to quickly estimate the energy efficiency of their data centres, compare the results against other data centres, and determine if any energy efficiency improvements need to be made. As a result, the white paper re-affirms the use of PUE but redefines its reciprocal as **data centres infrastructure efficiency** (**DCiE**). PUE is used to assess data centre efficiency. It is a ratio that shows how much of the total energy consumed by a data centre is directly used to power the servers and other ICT infrastructure within it – i.e. a PUE of 2 means that for every watt your ICT equipment uses, the infrastructure to support it needs 2 watts. The average data centre has a PUE of 2.524 and best practice PUE has been quoted as 1.325, but whatever the starting point the aim is to continually reduce the PUE through data centre initiatives and energy efficiency improvements. If using PUE to assess data centre efficiency do not lose sight of the ultimate aim by focusing entirely on PUE to the detriment of the overall energy consumption. DCiE is the direct ICT equipment power expressed as a percentage of the power consumed by the data centre, which can be shown to be improving over time as it increases towards 100%.

[4] The Green Grid, www.thegreengrid.org

The PUE is defined as follows:

PUE = Total Facility Power/IT Equipment Power (1)

and its reciprocal, the DCiE is defined as:

DCiE = 1/PUE = (IT Equipment Power/Total Facility Power) x 100% (2)

For equations 1 and 2, the Total Facility Power is defined as the power measured at the utility meter — the power dedicated solely to the data centres. In the Table 1, the example of PUE= Total Facility Power 100 KW / IT Equipment Power 40 KW = 2.5 and DCiE= 40%. The IT Equipment Power is defined as the equipment that is used to manage, process, store, or route data within the data centre.

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 Level of energy efficiency of (Power Usage Effectiveness PUE) and data centres infrastructure efficiency **(**DCiE**).**

The **IT equipment power** includes the load associated with all of the IT equipment, such as compute, storage, and network equipment, along with supplemental equipment such as KVM switches, monitors, and workstations/laptops used to monitor or otherwise control the data centres.

The **Total facility power** includes everything that supports the IT equipment load such as:

- Power delivery components such as UPS, switch gear, generators, PDUs, batteries, and distribution losses external to the IT equipment;
- Cooling system components such as chillers, computer room air conditioning units, direct expansion air handler units, pumps, and cooling towers;
- Compute, network, and storage nodes;
- Other miscellaneous component loads such as data centres lighting.
- Hence, the PUE and DCiE provide a way to determine:
- Opportunities to improve a data centre operational efficiency.
- How a data centre compares with competitive data centres.
- If the data centre operators are improving the designs and processes over time.
- Opportunities to repurpose energy for additional IT equipment.
- The Green Grid works with the industry to define energy efficiency guidelines for all of the components in the data centres. Such components include the following:
- Uninterruptible power supplies (UPS)
- Switch gear
- Chillers
- Computer room air conditioners
- Direct expansion (DX) units

- Pumps
- Cooling tower
- Generators
- Distribution losses external to the racks
- Power distribution units (PDUs)
- Batteries
- Lighting
- Servers
- Storage

Other ways to make data centres more energy efficiency are in the following table:

IT Hardware (computing, storage and network)
Operational Improvements
Turn off (ideally remove) dead, obsolete, or excess equipment
Turn off or power-manage equipment that won't be used for extended periods of time (e.g., development systems not in active use, systems for future expected increases in activity, etc…)
Enable power-management features on equipment (e.g. frequency/voltage scaling)
Maximize utilization of storage capacity through shared data storage, data compressions and data de-duplication
Design Improvements
Accept high-efficiency power supplies over full operating range (including DC-DC conversions) or directly accept moderate DC voltage
Digitally control power supplies to better match output to load
Use high-efficiency variable speed fans (within IT equipment)
Reduce energy use at lower utilizations (whether the resource is processing capacity, memory, communications, etc..). Applies to individual systems and to clusters.
Improve microprocessors to lower leakage current, increase system integration, etc…
Use storage virtualization and massive array of idle disks (MAID) technologies to allow storage power management
Use centralized servers (large systems) to improve sharing of computer resources
Improve hardware support for virtualization
Use built-in power monitoring

Table 2 Potential Energy-Efficiency Improvement Opportunities

1.1 Best-practices and solutions in data centres

There is significant potential for energy-efficiency improvements in data centres. Although some improvements in energy efficiency are expected if current trends continue, many technologies are either commercially available or will soon be available that could further improve the energy efficiency of microprocessors, servers, storage devices, network equipment, and infrastructure systems. For instance, existing technologies and design strategies have been shown to reduce the energy use of a typical server by 25% or more. Even with existing ICT equipment, implementing best energy-management practices in existing data centres and consolidating applications from many servers to one server could reduce current data centre energy usage by around 20%. Energy-efficiency strategies could be implemented in ways that do not compromise data centre availability, performance or network security, which are essential for these strategies to be accepted by the market. The “best practice” represents the efficiency gains that can be obtained by more widespread adoption of the practices and technologies found in the most energy-efficient facilities in operation today. These facilities employ proven technologies and management practices and represent the “best in class” of today’s data centres.

The latest studies on energy efficiency in data centres, have identified the following major ways to save energy. Several key trends toward more efficient microprocessors, servers, storage devices, and site infrastructure systems were identified that could have a significant impact on the future energy use attributable to servers and data centres.

The EU Code of Conduct for Data Centres was launched in November 2008 and outlines the best practices that should be implemented in any data centre whether a purpose built large facility or a small server room. It took two years to develop with involvement from many data centre experts and is the key source for information on how to run an energy efficient data centre. The Code of Conduct is a voluntary initiative that organisations can sign up to. The Best Practice Guidelines and the Reporting Form are excellent tools to help any Data Centre Manager to identify and apply the changes that are required to their data centres.

Many studies on energy efficiency strategies have identified the following major ways to save energy in data centre. A list of the most important measures includes:

Airflow Management - The space-conditioning system is affected greatly by the path, temperature, and amount of cooling air delivered to the IT equipment and the separation of hot air removed from it. Best practices include eliminating mixing and recirculation of exhaust, and maximizing return-air temperatures by supplying optimally conditioned air directly to the loads. IT equipment can be placed haphazardly throughout the room. One common best-practice configuration is shown in Figure 3, which the racks are in alternating aisles, called a hot aisle/cold aisle layout, with the hot air removed overhead. The IT equipment is mounted in racks that are positioned together in long rows. The racks are placed on a raised floor, which delivers conditioned air. In fact, it is standard terminology to refer to the computer room floor area as the *raised floor area* (even though some computer rooms don’t have raised floors).

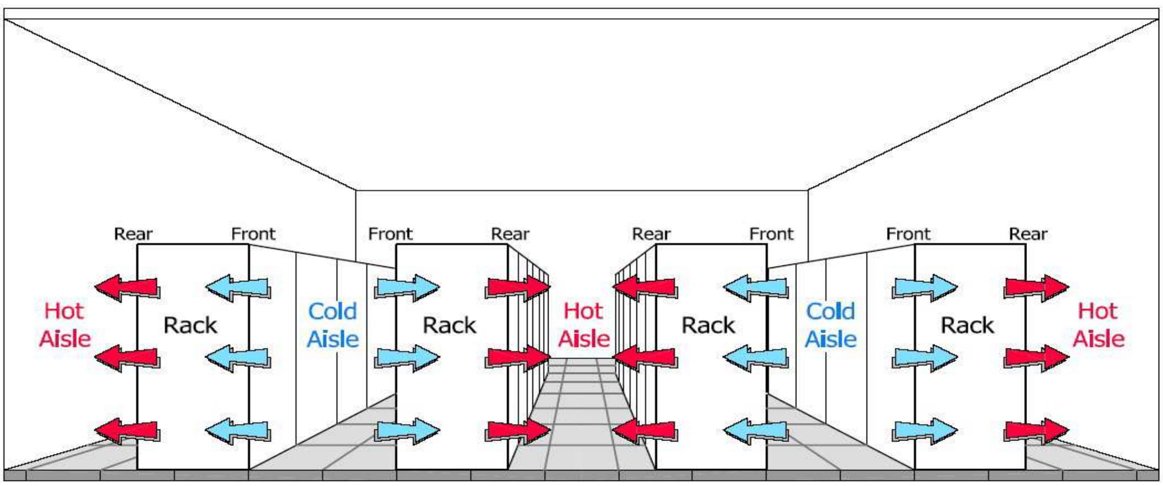

Figure 3 Typical hot-aisle/cold-aisle arrangement

Air Handler (AC) Systems - The air handler fan is typically the second largest energy user in the mechanical system. Optimizing it for data centre use, as opposed to relying on rules developed for office systems, can save energy.For a great capacity data centres, including insulated office buildings, evacuation of excessive heat and provision of a suitable microclimate for the server optimum operation by means of AC installations installed in certain points is uneconomical, as the heat exchange between the two environments is the more efficient the larger the contact surfaces are. Therefore, centralized AC solutions such as „Centralized Air Handling" have been found. These systems are usually used for the entire building and have air conditioning and preparation batteries with regeneration units. They include nitrogen and oxygen tanks, great capacity recirculation pumps, heat exchangers and double transport-ventilation circuits. In each room a constant temperature can be set by means of combined systems operating in fluid-air exchanger operating conditions (regime). The two circuits are reversible according to the season and permanently pass through the fresh air reserve. All the elements of the system are controlled by a computer. Due to the fact that the transport circuits are well insulated, the heat losses are low and if we consider the fact that great power synchronous engines operating under steady state conditions are used, there results that the efficiency of this system is higher than the summed up same efficiencies of all the subassemblies.

Air-side economizer -This method has been successfully used during night time and the cold season in the temperate climate zones and almost permanently in the cold climate zones.

In many cases, in order to cool data centre 's individual air conditioning systems, including great electricity consumers such as compressor and fan systems, are used. That is why the "open windows" method should be considered. This method mainly presupposes extraction of the warm air accumulated in the superior part of the room and its discharge into the atmosphere after filtering and purifying it; at the same time with the warm air discharge through depression, an equal amount of cool air, that has been previously filtered and purified, is naturally aspired in the lower part of the room. This is how quasi-natural ventilation at atmospheric pressure and with minimum energy consumption occurs

Water-side economizer -This method, as well as the method that has been briefly presented before, is efficient in the cold geographic areas and in the cold season in the temperate zones. It saves about 70% of the consumed energy. The main system of the water-side economizer is made up of two variable volume heat exchangers (water– water and water–air) and a simple pump. Its operation consists in taking over the water that has warmed up within the premises of the data centres, introducing it into a heat exchanger that reintroduces it into the cooling circuit at a lower temperature on the basis of the cooling tower principle. In order to increase efficiency of the heat exchange within the data centres premises a fan blowing air over a serpentine where cold air flows can be used.

Humidification - Standard requirements are broad and often too tight. A careful site specific design can avoid energy waste. Maintaining humidity within constant technological limits in the data centres requires observance of a certain standard and greatly influences both the component computer unit operation and energy consumption. In general, the data centres servers are located in several neighbouring rooms that communicate physically which, in general, are not tightly insulated. That is why it may be difficult to maintain humidity constant if humidity control is not performed independently, by each room; this statement is also supported by the location, class and verification stage of the used sensors, as well as by the possibility to insulate the respective rooms from the interior. In case these requirements cannot be observed it is recommended to use data centres humidity central control, the variation law being adiabatic, based on a unique sensor in the open room, the variation law being an adiabatic one. It is known that any computer unit releases dry heat. This does not mean that humidity in the room decreases at the same time with heating or that it remains constant. The cooling systems used, either individually or in a centralized way, can operate on part of the interior air (centralized system), but fresh air input is also achieved, the humidity of which is determined by the weather conditions or the geographic zone. The input of wet air (even previously filtered air) into the data centres rooms can determine a massive increase in the humidity index due to the heat released by the servers. In this case, it is necessary that this mixture be removed from the room and cooled up to the condensation temperature (5-7℃) through dehumidification. After it is mixed with fresh air, temperature should be increased up to the value set for operation, which requires that energy be consumed twice, once for cooling and once for heating, thus reducing energy efficiency.

In order to maintain high data centres energy efficiency it is necessary that humidity control be treated together with temperature control by means of a single installation for the whole premise. Thus, the effort made for dehumidification and reheating is balanced with the effort for cooling.

Moving to liquid cooling - This method consists in replacing all the cooling fans of the computers that are equipped with cooling systems inside with liquid, driven by very small power pumps. Practically, each system is made up of a liquid tank connected to a pump; the liquid flows through a closed circuit and passes through special tanks that are directly fitted to the processors, thus replacing the old radiators. Thus, in a centralized way, each unit will be equipped with a small power fan cooling the liquid from the circuit in a small radiator- serpentine which acts as a heat-air heat exchanger. The maximum power consumed is not greater than a few watts and can be withstood by the source of each unit. By means of this close circuit cooling system the hot air emissions within the data centres are substantially diminished which makes AC operation unnecessary within the premises.

Free Cooling - Free cooling is the use of outside air or water cooling by cooling towers only. It allows one to turn off compressor systems and save energy. This option works during colder months or cold nights. In most climates, it is effective at least half the time.

Commissioning and Retro-Commissioning - An efficient data centre requires not only reliable and efficient design, but proper construction and operation as well. Commissioning is a methodical and thorough process to ensure that systems are installed and operating correctly and efficiently. It can also be employed regularly to ensure proper operation. After all, data centres are hardly static environments. Workloads, requirements, equipment, and regulations all change. What was efficient when the data centre was first built may be far from optimal later. Maximizing energy efficiency while maintaining data centre performance and reliability is not just a matter of implementing better technologies and operating procedures. It also requires effective systems integration throughout. That is, organizations must implement design-intent documentation, harmonize energy management with core business decision making, perform benchmarking, and build in-house expertise through training.

On-Site Power Generation – Savings can be obtained by avoiding the transmission losses and use of the waste heat in absorption or adsorption chillers.

Relaxing environmental conditions – Most centres are overcooling or providing unnecessary humidity control.

Chilled Water Plant Optimization - High-efficiency chillers and variable-speed drives can garner large savings. Proper sizing can reduce initial costs dramatically.

IT Equipment Selection - More efficient gear has become available recently, thereby reducing the need for mechanical infrastructure. For example, efficient power supplies, reduced power modes, and multi-core processors can all lower power requirements.

Electrical Infrastructure - Backup power facilities themselves can use a large amount of power. Careful design, selection of efficient UPS systems, and on-site self-generation can reduce the usage. Shifting to a direct-current power infrastructure can produce significant savings.

1.2 Green data centre experiences

Green computing is the study and practice of using computing, resources efficiently, by reducing the use of hazardous materials, maximizing energy efficiency during the product's lifetime, and promoting recyclability or biodegradability of defunct products[5]. Toward that end, the US **Environmental Protection Agency** (**EPA**)[6] launched **Energy Star** (www.energystar.gov), a voluntary labelling program designed to promote and recognize energy-efficiency in monitors, climate control equipment, and other technologies. In October 2006, the EPA and the US Department of Energy took joint ownership of Energy Star and added stricter efficiency requirements for computer equipment, along with a tiered ranking system for approved products. In the past, the sole focus was on ICT equipment processing power and associated equipment spending. The infrastructure – power, cooling, data centres space – was always assumed to be available and affordable. In Figure 4, there are the key elements of the Green efficiency data centre. Another recommendation is to eliminate inefficient equipment and simply turn off devices that aren't in use. Remove rogue servers that use energy needlessly when existing sanctioned servers could handle the load.

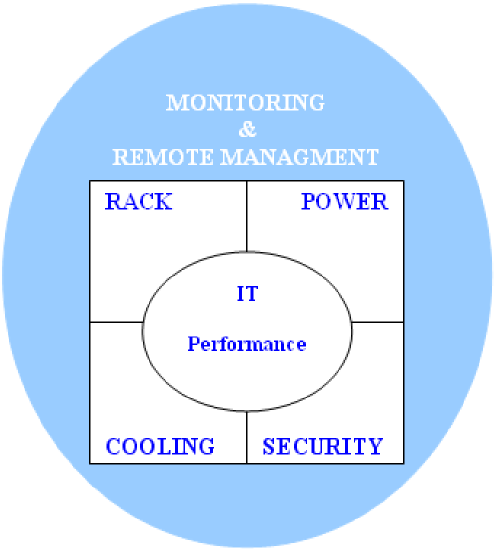

Figure 4 Data centres more energy efficiency

Investing in green ICT technologies has the potential to increase energy efficiency; more attention must be devoted to data centres' ever-increasing power density and heat removal, as evidenced by the following series of European and international green-initiatives/projects

The Green Grid is a global consortium involving European and non-European of computer companies, such as AMD, DELL, IBM, Sun Microsystems, and VM-ware, organized in 2007, with goal of improving energy efficiency in data centres and business computing systems. To achieve

[5] Linda Wilbanks, *Green my favourite colour*, **IT Pro**, Nov. /Dec. 2008, Published by the IEEE Computer Society.

[6] EPA released its "**Report to Congress on Server and Data Center Energy Efficiency**" in August 2007 to prioritize efficiency opportunities and policies that could lead to additional savings.

that goal, The Green Grid collaborates with individual companies, government agencies, and industry groups to provider recommendations on best practices, metrics and technologies that will improve data centres' energy efficiency. "The Green Grid" has developed a series of papers and documents tackling all the issues related to data centres energy efficiency increase: economic methods related to energy for maintaining (preserving) the data centres microclimate, energy efficiency increase in operation, etc.

The EU Code of Conduct for Data Centres Energy Efficiency is an initiative of the EC Joint Research Centre and represents a voluntary agreement of the data centres owners and managers. By adhering to the "Code of conduct" the signatory parts agree to reduce the data centres energy consumption by a certain percentage. The fulfilment of the proposed objectives is monitored by a committee at the level of the EC Joint Research Centre that issues the guiding documents, studies the best practices solution and quantifies the results.

DOE Data Centre Energy Efficiency Program is an initiative of the U.S. Department of Energy Efficiency and Renewable Energy together with the U.S. Environmental Protection Agency (EPA) coordinating various activities for the energy optimization of a data centres. The goal of this programme is to create favourable conditions for increasing energy efficiency by 10% in the US data centres by the beginning of 2011.

The **SPEC** Power and Performance Committee began developing benchmarks for evaluating energy efficiency in server-class computers in January 2006 (www.spec.org/specpower/).

The Green500 list's website (www.green500.org) launched in November 2006 to provide a ranking of the most energy efficient supercomputers in the world.

Green Destiny, the first major instantiation of the Supercomputing in Small Spaces Project at Los Alamos National Laboratory (http://sss.cs.vt.edu), was arguably the first supercomputing system built with energy efficiency as its guiding principle. Green Destiny was a 240-processor Linux based cluster with a footprint of only 5 square feet and a power appetite of as little as 3.2 kW when booted diskless. Its extraordinary power efficiency also made it extremely reliable. It ran in a dusty 85℉ warehouse at 7,400 feet above sea level with n o unscheduled downtime over its lifetime (from 2002 to 2004), and it did so without any cooling, air filtration, or air humidification.

HEC research[7] community started exploring green data centre as a way to achieve autonomic energy and power savings with little to no impact on performance; where for performance is defined as speed[8].

In Australia, the **Equipment Energy Efficiency Committee** within the Dept. of Environment & Water Resources is also responsible for encouraging and monitoring the data centres energy efficiency increase. Within this initiative studies and reports on the situation of the energy efficiency of the data centres from Australia and New Zealand are developed.

Data Centre in India – is an ECO-III project initiative (funded by USAID/India Mission in partnership with the Bureau of Energy Efficiency) and Asia-Pacific Partnership (funded by US Department of Energy). The project objectives consist in establishing a public-private partnership to support the efforts of data centres from India and improve energy efficiency. One of the activities envisaged within this project is identification of the actual situation in this field, publication of a best-practices manual, organization of workshops.

Google data centres - As one of the largest users of data centres in the world, Google pays a lot of attention to efficient operation of these facilities.[9] On their website they show the performance of

[7] US domination of high-end computing (HEC)

[8] **TOP500 list** include the world's fastest supercomputers.

[9] http://www.google.com/corporate/green/datacenters/index.html

all Google-designed data centres with an IT load of at least 5 MW and time-in-operation of at least 6 months[10]. A graph with the values for the Power Usage Effectiveness (PUE) is displayed below. From the graph one can conclude that Google already achieves a very high PUE value of around 1.2 in the data centres that they design and operate themselves. From other sources it is known that in data centres that Google does not operate, the PUE can be significantly higher. This can be attributed to institutional factors, such as division of responsibilities between the data centre operator (hosting service provider) and the data centre user and the cost structure for each of the parties.

Secondly, one can see that the PUE value is dependent upon the time of year. Apparently Google removes the heat more efficiently in quarters 4 and 1, when it is winter time in the Northern hemisphere. Thirdly there seems to be a downward trend in the PUE value for the facilities A-F that are operated over a longer time. This points to the importance of good energy monitoring to optimise the operation of the data centres.

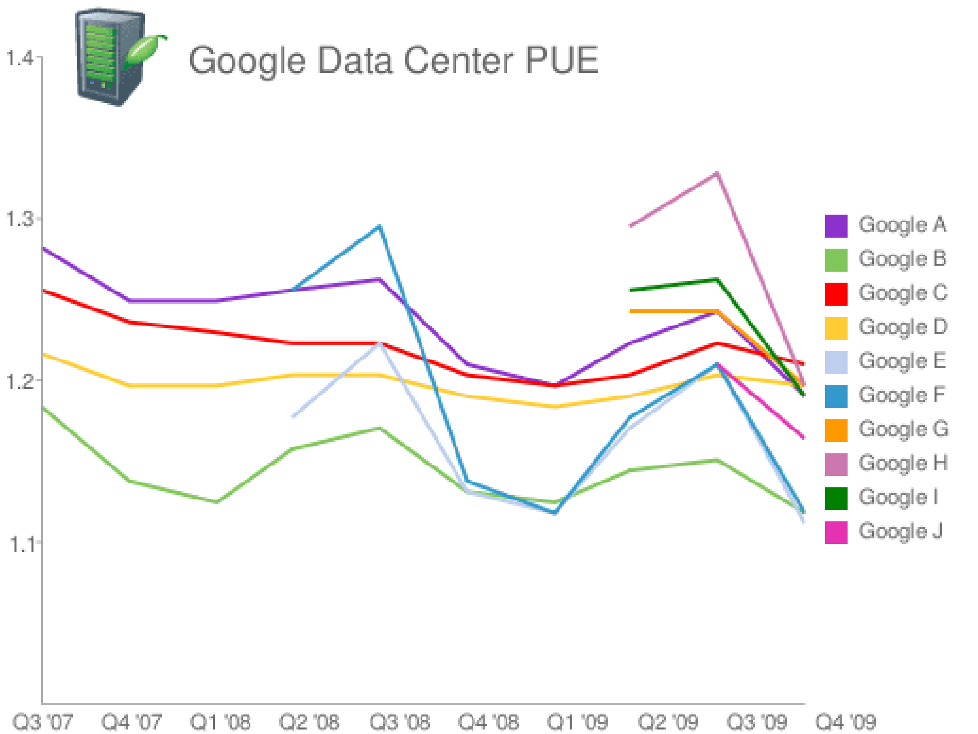

Figure 5 Power Usage Effectiveness (PUE) of Google's data centres (source: Google)

Google also shows that the load of the data centres is not constant throughout the day, as can be seen in figure 6 below. This implies that the design and control of the data centres should not only be targeted at the peak load conditions. During partial load of the computing equipment the power supply and cooling facilities should also be able to operate under partial load If this control is implemented well, the PUE during partial load can be lower than that under peak load conditions.[11]

[10] http://www.google.com/corporate/green/datacenters/measuring.html

[11] On the other hand, if this control is not implemented or maintained in the right way, the PUE under partial load will be higher than the PUE under peak load.

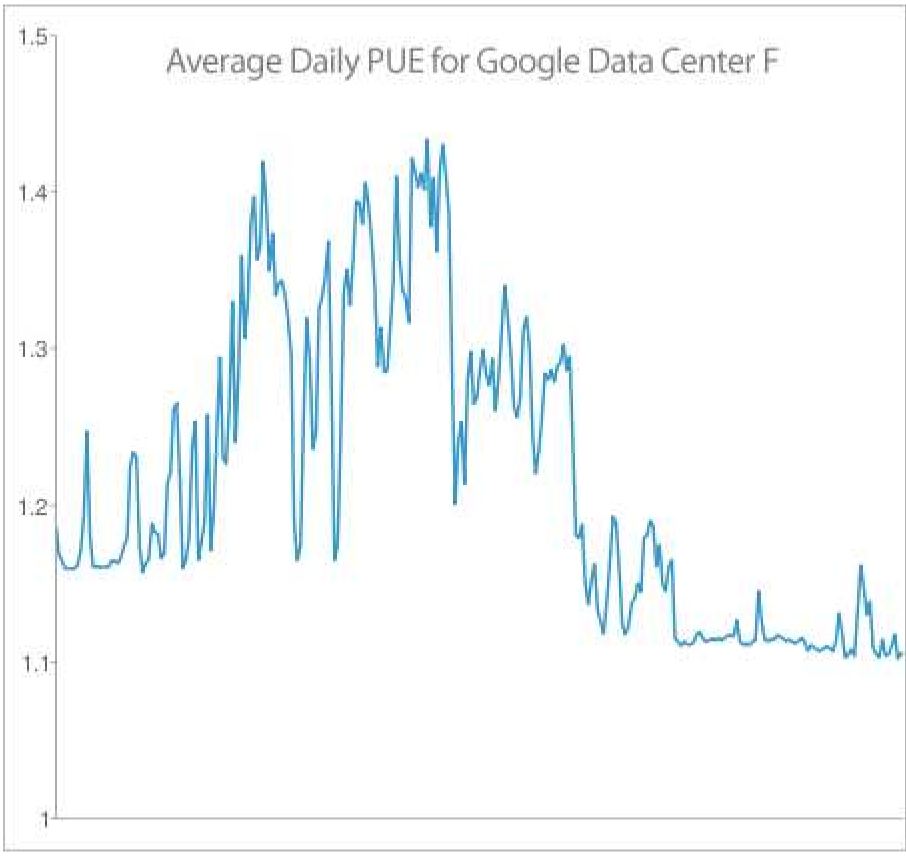

Figure 6 Daily average PUE data for a new Google data centre currently in bring-up (source: Google)

1.3 Cloud computing, virtualisation, etc. as a tool for energy efficiency

The European Commission in COM(2009) 111 identifies in emerging solutions in computing, such as Distributed computing, Grids, Cloud Computing, service oriented architecture, virtualisation, Web 2.0 and other emerging technologies, the innovative ICT technologies that can reduce wasteful consumption of energy.

1.3.1 *Virtualization*

Many new server microprocessors are designed to facilitate **virtualization**. Virtualization allows to replace several dedicated servers that operate at a low average processor utilization level with a single "host" server that provides the same services and operates at a higher average utilization level. Virtualization may offer significant energy savings for volume servers because these servers typically operate at an average processor utilization level of only five to 15 percent (Dietrich 2007, US EPA 2007). Virtualization will increase the processor utilization level of the host server (both because multiple virtual servers are running and because of a small processor utilization "overhead" associated with virtualization software), thereby increasing energy use[12]. However, this incremental gain in host server energy use is more than offset by the savings from eliminating the significant energy load associated with running multiple servers at low utilization rates. Virtualization software must also coordinate power-management capabilities across virtualized servers In essence, virtualization technology allows a single computer to run several independent

[12] An inefficient truth, global action plan, Report December 2007

operating system instances simultaneously. In so doing, a server's processing power can be fully harnessed, maximizing its productivity and minimizing inefficient use of energy.

The use of virtualization technology to improve utilization and reduce number of physical servers user. An example of improved energy efficiency through greater server virtualization is the case study of John Lewis Partnership (JLP)**Errore. Il segnalibro non è definito.** In fact, after an initial pilot of 20 virtual servers, JLP has rapidly increased to an estate of nearly 150 virtual servers. In 2008 more than half of JLP' s computing power will be virtualised. This project has saved over £100,000 in new server purchases, 120 units of rack space, 1.5 tonnes in weight of equipment, numerous network and SAN connections, £8,000 in consumed power over five months, additional air conditioning costs and 250 tonnes of CO2 annually.

1.3.2 *Cloud Computing*

"Cloud computing describes both a platform and type of application. A cloud computing platform dynamically provisions, configures, reconfigures, and deprovisions servers as needed", where servers can be both physical and virtual[13]*. Cloud applications are applications that are extended to be accessible through the Internet. These cloud applications use large data centres and powerful servers that host Web applications and Web services.*

A cloud computing platform dynamically provisions, configures, reconfigures, and deprovisions servers as needed. Servers in the cloud can be physical machines or virtual machines. Advanced clouds typically include other computing resources such as storage area networks (SANs), network equipment, firewall and other security devices. Cloud computing also describes applications that are extended to be accessible through the Internet. These *cloud applications* use large data centres and powerful servers that host Web applications and Web services. Anyone with a suitable Internet connection and a standard browser can access a cloud application.

Cloud computing environments support grid computing by quickly providing physical and virtual servers on which the grid applications can run. Cloud computing should not be confused with grid computing. Grid computing involves dividing a large task into many smaller tasks that run in parallel on separate servers. Grids require many computers, typically in the thousands, and commonly use servers, desktops, and laptops.

Clouds also support non grid environments, such as a three-tier Web architecture running standard or Web 2.0 applications. A cloud is more than a collection of computer resources because a cloud provides a mechanism to manage those resources. Management includes provisioning, change requests, workload rebalancing, deprovisioning, and monitoring.

Cloud computing infrastructures can allow enterprises to achieve more efficient use of their IT hardware and software investments. They do this by breaking down the physical barriers inherent in isolated systems, and automating the management of the group of systems as a single entity. Cloud computing is an example of an ultimately virtualized system, and a natural evolution for data centres that employ automated systems management, workload balancing, and virtualization technologies. A cloud infrastructure can be a cost efficient model for delivering information services, reducing IT management complexity, promoting innovation, and increasing responsiveness through real time workload balancing.

1.4 Case study: data collection of energy consumption on a specific supercomputing infrastructure (ENEA)

The main objectives of the study are:

[13] download.boulder.ibm.com/ibmdl/pub/software/dw/wes/hipods/Cloud_computing_wp_final_8Oct.pdf.

1. to determinate an empirical energy usage pattern of data centres under typical Mediterranean conditions;
2. to understand data centre's design, and examine the opportunities for improving energy saving performance;
3. to provide a methodology for evaluating data centre's energy saving performance.

In this study, for the evaluation the data centre's energy performance we use the **PUE** and **DCiE** indicator (see Eq. 1 and 2) and compare our energy consumption with the Table 1.

In this Interim Report, the data centre selected for case study is the CRESCO facility, located in ENEA – Portici Research Centre and completed at the end of 2008. The CRESCO High Performance Computing infrastructure, with a total power of over **20 Teraflops**, consists of three sections with the following features:

1. **Section 1**: 42 nodes IBM x3850-M2 SMP with 4 Xeon Quad-Core Tigerton E7330 (32/64 GByte RAM 2.4GHz/ 1066MHz/6MB L2) - total 672 cores Intel Tigerton;
2. **Section 2**: 256 nodes IBM HS21 blade with 2 Xeon Quad-Core Clovertown E5345 (2.33GHz/1333MHz/8MB L2), 16 GB RAM - total 2048 cores Intel Clovertown;
3. **Section 3**: 4 nodes IBM QS21 blade with 2 Cell BE Processors 3.2 Ghz each. 6 nodes IBM x3755, 8 Core AMD 8222 FPGA VIRTEX5 4 nodes IBM x 3755, 8 core AMD 8222 with NVIDIA Quadro FX 4500 X2

The CRESCO data centre was put in place for the study of Complex Systems, but it presently gives support to all High Performance Computing activities performed by ENEA and many of its project partners. The operating hours are 24h a day, all year round.

Shortly after the facility was first put into operation (June 2008), it was noticed that power demand was unexpectedly high and a worrying number of failures in servers' chips occurred. A number of tests proved that this was due to inefficient cooling.

The data centre architecture was therefore modified and a number of panels was installed in the room in order to force a better cooling air flow. This brought the result of a significant reduction in power consumption and in the number of damaged electronic components.

For the evaluation of present data centre's energy efficiency, we logged the data for two weeks and considered the following indicators:

- CRESCO Average Power ($\mathbf{P}_{CRESCO}$) = **150 KW**
- COOLING System Average Power ($\mathbf{P}_{C}$) = **72 KW**
- UPS Average Power ($\mathbf{P}_{UPS}$) = **60 KW**

In the following equations the indicator *Total Facility Power* includes the measures of $\mathbf{P}_{C}$, $\mathbf{P}_{UPS}$ and $\mathbf{P}_{CRESCO}$ and the indicator *IT Equipment Power* is equal to $\mathbf{P}_{CRESCO}$. Thus:

$$\mathbf{PUE} = (\mathbf{P}_{CRESCO} + \mathbf{P}_{C} + \mathbf{P}_{UPS}) / \mathbf{P}_{CRESCO} = 282/150 = \mathbf{1,88} \quad (3)$$

and

$$\mathbf{DCiE} = 1/PUE = \mathbf{P}_{CRESCO} / (\mathbf{P}_{C} + \mathbf{P}_{UPS} + \mathbf{P}_{CRESCO})*100 = \mathbf{53\%} \quad (4)$$

Average Power	%
$\mathbf{P}_{CRESCO}$	53%
$\mathbf{P}_{C}$	26%
$\mathbf{P}_{UPS}$	21%

Table 3 Breakdown of energy use in CRESCO data centre

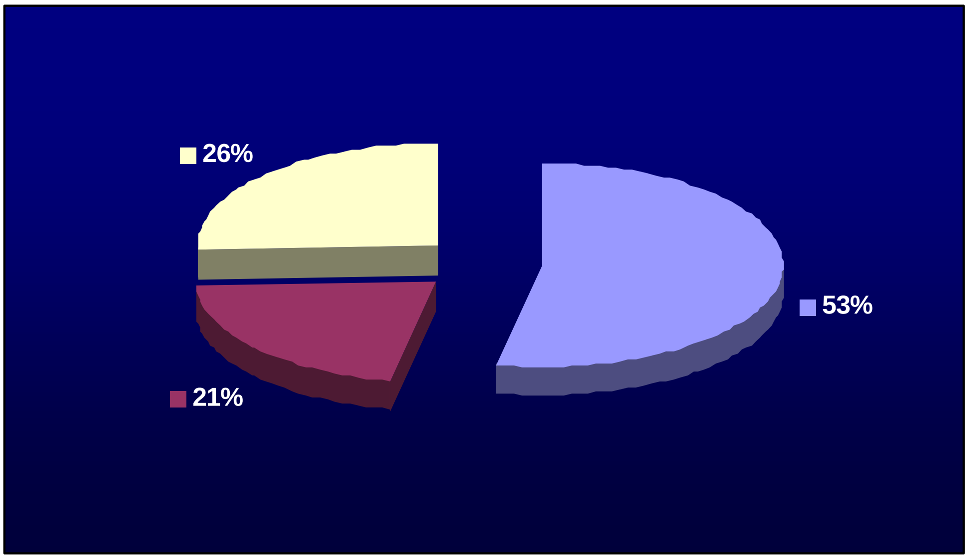

Figure 7 Floor area breakdown of energy end-use of CRESCO data centre

Comparing the experimental results obtained for CRESCO (Table 3) with the definitions on **Table 1** we can say that **CRESCO has an AVERAGE level of energy efficiency**.

If we intend to analyse the factors affecting this 53% **DCiE** it must be noticed that the total power losses are due for a **26%** to power required by the **cooling systems** (in yellow in Figure 7) and to **21%** to power losses in the **alimentation-UPS** (red in Figure 7). These values are equal to a 0.48 “Cooling Load Factor (CLF)” and a 0,4 “Power Load Factor (PLF)” according the specific metrics proposed in the white paper[5].

Comparing these data with average Data Centre values[14], CRESCO could be considered very good in cooling performances, because the power usually required for cooling is greater, but not so good in the UPS performance.

The better cooling performances are due to the architectural solution which improves the air flow among the hot-aisles and cold-aisles of the data centre.

On the other hand, CRESCO power losses in the power system could be improved. This is because the electric power systems devoted to CRESCO are – at this moment – over-dimensioned. In particular, the UPS is working with a low load factor (40%).

This is not due to a bad electric system design but to a forward-looking economic choice of over-dimensioning the power system in order to allow power supply to future upgrading of the system.

Thus, when new machines will be integrated in the CRESCO facility it will be not necessary to buy another electric transformer and another UPS. In this case the overall efficiency of the facility would rise considerably.

[14] H. S. Sun, S. E. Lee, **Case study of data centres’ energy performance**, Energy and Buildings 38 (2006) 522-533.

2 ENERGY EFFICIENCY IN DISTRIBUTED COMPUTING ACTIVITIES IN SMART GRIDS

This chapter deals with the possibility of improving energy efficiency in SmartGrids facilities and equipment deployed on production and transmission sites, i. e. outside of data centres. In principle, any part of the grid is open for redesign, leading equipment manufacturers to develop new platforms, merge and enhance functionalities, employ intelligent equipment and relay controllers.

The global need for CO2 reductions is a major driver for updating and retrofitting the SmartGrids and requires a new way of thinking about the processing power that is deployed in the infrastructure. This is closely connected with the general emphasis, in the world of ICT, on the adoption of new generation processors (or green processors) - designed to optimize energy usage – and on adopting of standard measures to asses energy consumption.

In order to asses the energy consumption, organizations without the resources to perform internal tests might want to consider using the new **SPEC**power (Standard Performance Evaluation Corporation[15]) benchmark that tracks the relationship between power and performance metrics in computer systems benchmarks (under an example workload). This new industry standard benchmark measures system level performance for a typical java workload and provides a score that represents energy efficiency across all operating conditions. It can help organizations compare server energy efficiency using consistent and reliable metrics.

Another important topic in this field is the optimization of energy consumption in machines that are idling a considerable percentage of the time. A study of Barroso & Holzle[16] for systems running different generations of the *Intel Xeon processors* shows that each of the machines consumes more than 50% of its maximum consumption when idle. The contribution of *idle power* is even more significant if we take into account the fact that server utilisation is commonly less than 50%. This results in a significant amount of wasted energy. Many studies demonstrate that total energy savings of at least 50% could be attained through appropriate actions aimed at the reduction of idle power.

Strategies for reducing idle power can be extended to the point of *switching off* idle machines whilst fully utilising those which are active. Other solutions are possible: for example, *Load Concentration*[17]is a technique in which incoming jobs are directed to a minimal number of busy machines allowing the idle remainder to save power. This approach can be successful – energy consumption is potentially reduced by 30-80%) but requires specific capabilities from the server applications.

To evaluate the impact of the adoption of new generation processors on energy efficiency of ICT activities we have to switch back to data coming from the world of data centres (but the same conclusions can be drawn for distributed ICT) An excellent estimate is provided by CERN[18]. The best strategy CERN has found to increase energy efficiency in its ICT activities is to replace its older servers based on single-core processors with newer servers based on the latest 45nm *Intel Xeon processors*, which have four cores per processor (Figure 8-9). The latest Intel Xeon

[15] http://www.spec.org/power_ssj2008/docs/SPECpower-Methodology.pdf

[16] Barroso L., Holzle U., The case for energy proportional computing. *IEEE Computer* , 40, 33-37, 2007

[17] Pinheiro E., Bianchini R., Carrera E., Heath T., Dynamical cluster reconfiguration for power and performance, *Compilers and and operating systems for low power*, pp. 75-93, 2003

[18] Reducing Data Center Energy Consumption, A summary of strategies used by CERN, the world's largest physics laboratory, **White Paper -** Intel Xeon Processor Data Center Optimization.

processors provide significant gains. Indeed, a processor with multiple execution cores can perform far more work than a single-core processor, while consuming about the same amount of energy and taking up the same amount of space. This is because each individual core can be run at a lower frequency. A small reduction in frequency causes a small reduction in the amount of work performed, but a relatively large drop in the amount of energy consumed. As a result, more cores running at lower frequencies can deliver substantial gains in total performance per Watt.

The latest Intel Xeon processors incorporate a number of advanced energy-saving technologies:

- Intel's industry-leading 45nm process technology improves energy efficiency at the most fundamental level, by reducing the amount of energy required per transistor.
- Intel Intelligent Power Capability adds to these advantages, by powering up only those components of the processor that are needed to process a given workload.

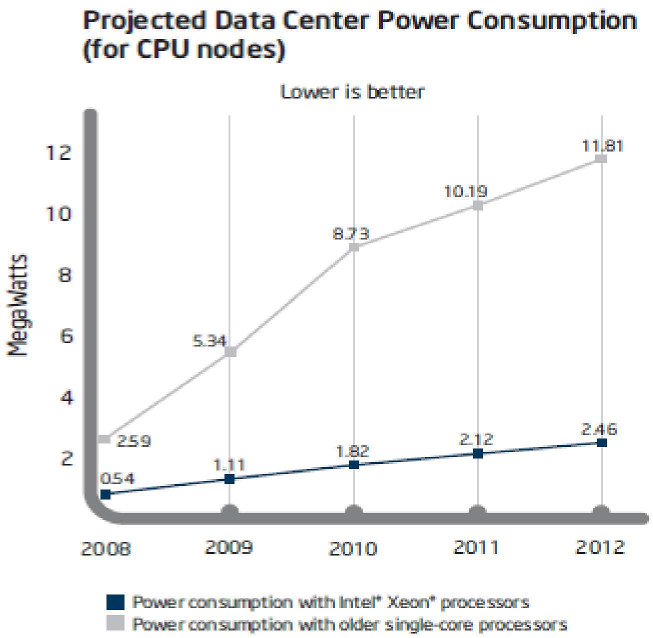

Figure 8 Based on CERN's projections, the organization could reduce total power consumption almost five times by using the latest Intel Xeon processor based servers rather than older single core Intel Xeon processor-based servers

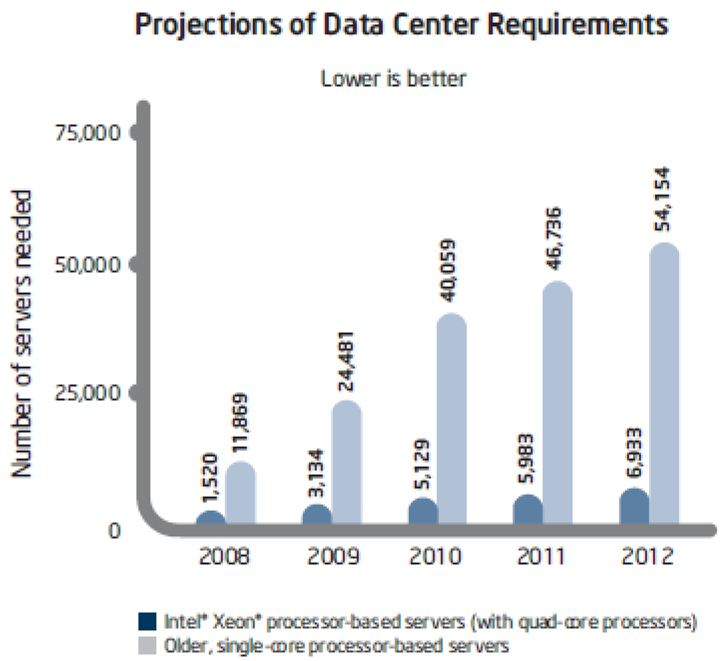

Figure 9 The use of Intel Xeon processors reduces the total number of servers that CERN need by nearly a factor of 8.

Many organizations and/or infrastructures can obtain similar values replacing older processing systems with more powerful and energy efficient systems.

3 CONCLUSIONS: ASSESSMENT OF ICT REQUIREMENTS AND PRIORITIZATION OF SOLUTIONS

As this is an interim report, conclusions presented in this chapter should be considered as preliminary. They will be validated and elaborated in the light of the future (SEESGEN) survey results, of additional case studies that will be carried out and of the analyses on the improvement of energy efficiency in computing activities related to SmartGrids operation and management.

Information and Communication Technologies are becoming more and more widespread and pervasive in SmartGrids.

From a general point of view, it is certain that a considerable impact can be achieved in activities that take place in data centres, whereas it is doubtful that the same results could be reached through actions aimed on remote apparatuses and infrastructures. In the latter case, energy efficiency results can be obtained through the substitution of remote processing units with new, more performing ones, or through appropriate actions aimed at the reduction of idle power.

In data centres, on the other hand, a number of areas where efforts could be focused can be identified, such as:

- evaluation and assessment of strategies to reduce ICT's own carbon footprint and identification of solutions in order to maximise energy efficiency in computing;
- best practices for green data centres buildings and computing architectures - cooling, fixtures, new generation processors, load balancing, etc;
- energy efficiency metrics in data centres – benchmarking of data centres' performances;
- monitoring and optimising performance of the control of the computing facilities, cooling facilities and power supply equipment;
- adoption of cloud computing, virtualisation technologies etc.

This report includes a case study concerning the collection of data on energy consumption on a specific supercomputing infrastructure (owned by ENEA), that represents a typical example of state of the art High Performance Computing infrastructure. The case study complements data gathered from general surveys on (green) data centres experience and gives some useful insight on this sector.

The report shows that there is ample opportunity in SmartGrids and data centres to improve energy efficiency. In following reports technical and non-technical barriers to the implementation of these energy efficiency measures will be studied, as well as solutions to these barriers.

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TOPIC B: ICT SYSTEMS TO ENCOURAGE THE APPLICATION OF TECHNIQUES FOR REDUCING GHG EMISSIONS

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INTRODUCTION

The relationship between energy, climate changes and economic competitiveness are becoming increasingly evident in most European policy documents. To prioritize, the European Union has agreed upon the following overall objectives:

- Reduction of Greenhouse Gases (GHG) up to 20% by 2020, based on 1990 levels - Increase in the share of Renewable Energy Sources (RES) from less than 7% in 2006, to 20% of the total RES up to 2020
- Increase in the share of biofuels to at least 10% of the total used fuels in 2020
- Reduction in the primary energy consumption by 20% by 2020

To carry out these objectives, in January 2008, the European Commission launched an energy package on climate changes so the Member States could make clear changes with quantitative results, related to emission reduction,energy efficiency and, an increased share share of RES. Furthermore, the policy framework to enable sectors to meet these objectives were set forth by issuing a series of of EU Directives :buildings, GHG trade, energy services and final users, renewable energy sources and, highly efficient co-generation.

The most important EU environomental policies are:

The Green Paper of Energy Efficiency or to do more with less (COM(2005)265 final)

The meaning of the term energy efficiency is:

- A better utilization of energy by increasing efficiencies by means of higher performance technologies and equipment, respectively
- Change in the behavior of consumers and their orientation to lower energy consumption products/services

The document considers that the most important barrier to energy efficiency increase is the lack of information on:

- Availability and costs of the new technologies and equipment
- Costs of own energy consumption

The Green Paper on the market instruments used for environmental policy purposes (COM (2007) 1 final)

The European Union has ambitious objectives in the field of sustainable development in general, and GHG emissions, in particular. These objectives cannot be fulfilled without the public intervention and the firm commitment of all the parties involved. The EU has increasingly encouraged using market instruments because they are flexible, efficient and can be more profitable. To promote the increased utilization of the market instruments, the "Green Paper on the market instruments used for objectives relating to environmental policy (COM (2007) 1 final)" has been developed. The EU recommends instruments such as taxes and fees, targeted subsidies, tradable emission certificates, etc.

At the same time, market instruments do not represent a solution to the issues. Market solutions need clear regulatory framework and are often used in combination with other measures. Nevertheless, if market solutions are correctly selected and applied, they can have certain advantages as regulatory instruments.

Directive 2006/32/EC on energy efficiency and energy services

This directive represents the legislative document at the EU level aiming at applying the energy efficiency strategy provisions. The EU Member States have pledged to reduce energy consumption by about 1% annually against the average of the last five years for which there are statistical available data in nine years (2008-2016). Thus, by 2016 energy savings representing at least 9% of the average on the last five years for which there are available data will have to be made. Each country will also have to establish an intermediary target for the year 2010. The Commissions shall validate both the final target and the intermediary one.

Each Member State shall develop National energy efficiency action plans (NEEAP) to be submitted to the European Commission. Thus:

- The first NEEAP the latest by June 30, 2007
- The second NEEAP the latest by June 30, 2010
- The third NEEAP the latest by June 30, 2014

All the NEEAP describe the measures envisaging energy efficiency increase and implementation of the national target. The Directive explicitly specifies that the NEEAP should include distinct measures on the public sector and the provision of information and counselling to final consumers. The NEEAP are evaluated by the European Commission (assisted by a committee). The Commission evaluates to what extent they guarantee the fulfilment of the target objective at the national level and publishes reports including its conclusions. The energy efficiency strategy explicitly specifies the fact that the public sector has to set an example relating to energy efficiency at the national level. The Directive 2006/32/EC includes several provisions to this goal. Thus, the Member States shall take the following measures:

- establish and publish the guidelines in the energy efficiency field that will serve as evaluation criteria for the adjudication of the public markets
- observe at least two of the obligations specified in Annex VI to the Directive
- Take measures at the national/regional/local levels in the form of legislative initiatives, voluntary agreements or other instruments having an equivalent effect
- Inform the citizens and /or companies on the concrete actions carried out by /in the public sector
- Appoints at least one existing or newly established organization to carry out the management, administration and application of the energy efficiency increase measures

The Directive explicitly mentions that the measures included in NEEAP should be accompanied by the quantitative estimation of their effects. This estimation should be carried out both ex-ante, and ex-post. The ex-ante evaluation is carried out during the phase preceding the actual application of the measures, in the phase when NEEAP are being developed, respectively. This compulsory character does not apply to the first NEEAP, but it applies to the second and third ones. The ex-post estimation carried out within the second and the third NEEAP refers to the estimation of energy savings actually obtained. For measuring the energy savings it is recommended to use a harmonized calculation model, based on a combination of the top-down and bottom-up methods.

Directive 2009/28/EC on the promotion of the use of energy from renewable sources

The Directive reiterates that by 2020 the energy share from RES should represent at least 20 % of the final gross energy consumption and establishes the overall (global) national mandatory objectives for each Member State. The Member States should take steps to ensure that the share of energy from RES be greater or equal to the value represented by the orientation trend. In order to fulfil the established objectives, the Member States can take, among others, the following measures:

Support schemes

- Cooperation between different Member States and third countries

- Each Member State should make sure that the share of energy from RES utilized in all types of transport in 2020 represents at least 10 % of the final energy consumption in transports in the respective state.
- Each Member State shall adopt a National Action Plan in the field of Renewable Energy (NREAP). The national plans establish:
- The objectives of the respective Member State concerning the share of energy from RES to be consumed
- The measures that should be adopted for attaining the respective global national objectives

Directive 2009/29/EC to improve and extend the greenhouse gas emission allowance trading scheme of the Community

The European Council of March 2007 made a firm commitment to reduce the overall greenhouse gas emissions of the Community by at least 20 % below 1990 levels by 2020, and by 30 % provided that other developed countries commit themselves to comparable emission reductions and economically more advanced developing countries contribute adequately according to their responsibilities and respective capabilities.

The Community –wide quantity of allowances issued each year starting in 2013 shall decrease in a linear manner beginning from the mid-point of the period from 2008 to 2012. The quantity shall decrease by a linear factor of 1.74 % compared to the average annual total quantity of allowances issued Member states in accordance with the Commission Decisions on their national allocation plans for the period from 2008 to 2012.

From 2013 onwards, Member States shall auction all allowances which are not allocated free of charge

At least 50 % of the income obtained from the quota auctioning should be utilized for financing certain actions aiming at reducing GHG emissions (promotion of energy efficiency and use of RES, CO2 caption and geological storage, avoiding deforestation and increasing reforestation, etc)

Apart from the directives there is an ongoing discussion about the climate. In the recent Copenhagen climate conference, though it didn't end with a legally binding decision, it result a politically binding one. According to the Decision -/CP.15, The Conference of the Parties, takes note of the Copenhagen Accord of 18 December 2009. In the article 2 it is mentioned that the States 'agree that deep cuts in global emissions are required according to science, and as documented by the IPCC Fourth Assessment Report with a view to reduce global emissions so as to hold the increase in global temperature below 2 degrees Celsius, and take action to meet this objective consistent with science and on the basis of equity.' Again in Article 7 the States 'decide to pursue various approaches, including opportunities to use markets, to enhance the cost-effectiveness of, and to promote mitigation actions' [1]

By 2020, the power generation sector will be subject to 100% CO2 auctioning, while required to reduce its emissions by more than 200 Mt CO2. Around 140 GW of new capacity was constructed in EU between 2000 and 2005 the majority of which were CO2 emissions intensive thermal plants. Currently CO2 emissions certificates are relatively cheap, and have insufficient financial impact on the utilities. From 2013 to 2020 however the electricity sector will have to auction 100% of its needed allowances, increasing costs for both the utilities and the end customer. Apart from utilities, other players may take part in the Emissions Trading Scheme, creating the urge of communicating environmental information.

Studies, depicted in Table 1, prove that Demand Response (DR) alone could achieve between 25-50% of the EU's 2020 targets concerning energy savings and CO_2 emission reductions, as well as pre-empting the need for the equivalent of 150 medium size thermal plants, thereby facilitating an estimated €50bn in avoided investment relating to peak generation capacity. In addition to these benefits, it is further presumed that DR related measures represent a major opportunity for the utilities to mitigate some of the relative unpredictability of renewable energy, through effective demand side measures. This in turn will reduce the need for investment in compensatory schedulable energy sources, typically fossil fuel generation. Under expected circumstances however (the Moderate Scenario), the benefits of DR are predicted to shrink to just around one third of their realistic potential, representing a missed opportunity of sizable proportions. For the better efficiency of DR techniques, the need for the environmental impact representation and thus the direct connection of the consumption with its result becomes essential. This representation is usually referred as carbon footprint throughout literature. [2]

	Moderate Scenario	Dynamic Scenario	Dynamic % of EU 2020 Targets
Energy Savings	59 TWh	202 TWh	50%
CO2 Emissions reduction	30 Mt	100 Mt	25% [illegible]
Peak Generation Capacity Avoided	28 GW [illegible]	72 GW [illegible]	
Avoided Investment	€ 20 billion	€50 billion	
Notes: [illegible]			

Table1 Key predicted benefits of Demand Response,
Source: VaasaETT (2008)[19]

A carbon footprint is a measure of the impact our activities have on the environment, and in particular climate change. It relates to the amount of greenhouse gases produced in our day-to-day lives through burning fossil fuels for electricity, heating and transportation etc.

The carbon footprint is a measurement of all greenhouse gases we individually produce and has units of tonnes (or kg) of carbon dioxide equivalent.

[19] Demand Response: a decisive breakthrough for Europe Capgemini Report – (2008)

4 ICT REQUIREMENTS FOR CO2 INCLUSION

ICT technologies are essential to cope with the environmental demands as well as the general EU policies and framework. The issue of provision of environmental information is not an easy aspect to manage as certain concerns in different levels must be taken into account. How to measure and communicate the CO2 info is under consideration at this point. Criteria and methodology is essential to be clarified and commonly accepted in a broad basis. The principles should take into account the grant open access to all companies (including SMEs), the tension to support innovation (for the devices as well), the urge to safeguard the Internal Market and international trade, the need to assess the different stages that affect the environmental impact. For example, in order to provide a realistic picture of the overall environmental performance of the energy delivered, the assessment should – as much as possible - cover the stages with the most significant impacts. Depending on the network this may include one or more stages, such as industrial processing, transport, retail & distribution, consumption. Another consideration would be to update the information provided according to the changes in the energy sector, so the depicted estimations provided by ICT technologies would be accurate.

The estimations on the carbon footprint, for converting the electrical consumption to its carbon dioxide equivalent is based most of times on a grid average (mean factor of kg CO2/kwh) and this is a common practice for the majority of metering systems. However, when using a factor to estimate emissions in line with Climate Change Agreements (CCAs), then the marginal, lower figure should be used based on marginal emissions (which are usually those from high efficiency Combined Cycle Gas Turbines - CCGT). This figure may also be the more appropriate factor when estimating energy savings. All figures exclude the incremental emissions due to other GHGs such as CH_4 and N_2O [3, 4].

The more upgraded calculations within the metering systems use the electricity generation mix of coal, nuclear, gas turbines etc. In this case the factor that is included is calculated as follows:

[kWh*∑(%power_production_of_unit*factor_of_type_of_power_unit(CO2kg/kWh)]

More accurate calculations take into account grid losses. The issue that has to be considered is whether the data of the emissions factors should be included in the metering systems or sent to them from the TSO. That would strongly have to do with the usage of the measuring device. Should the device be used by a company participating in the Emissions Trading Scheme, the calculations have to be accurate, depicting if possible the hour change of the total system emissions factor, because of the change of the generation mix. In the event of using CO2 emissions information in metering systems to mobilize end users for DR techniques the accuracy wouldn't affect the end user to the same extent. In any case common and standard ways of depicting the CO2 emissions should be followed since many differences are observed in the metering equipment available.

5 ICT-CO2 APPLICATIONS

5.1 Best-practices and solutions

A number of applications are currently available and introduced in the market, and more specifically metering equipment for electricity consumption also indicating CO2 emissions because of the consumption (i.e. ecometer, kW series Power Meter, EMON D-MON Green meter etc). Companies in Europe and worldwide include CO2 data in their metering systems realizing that DSM strategies can become more effective by informing end-users about environmental impact. Moreover companies active in the field of offering electricity services while exploiting metering devices, mainly observed in UK, constantly inform their clients about their consumption along with their emissions due to it. Some of the devices produce CO2 data according to ISO 14001 2004 standard that is an environmental standard which specifies a set of environmental management requirements for environmental management systems. (The purpose of this standard is to help all types of organizations to protect the environment, to prevent pollution, and to improve their environmental performance).

Throughout Europe, smart meters are being tested and/or installed in a number of consumer and commercial environments. The devices are being considered for their potential to drastically reduce carbon emissions because of their ability to assist consumers as they conserve energy. Smart meters not only can precisely measure the amount of energy used, but they can also measure when it was used which allows power providers to charge different rates according to supply and demand. Accenture believes that "as the energy industry faces up to ever-deeper cuts in carbon emissions over the coming decades, the installation of smart meters in customers' homes is becoming increasingly important because of its potential to change consumers' behaviour and reduce energy consumption."

Among other things, these devices and applications can relay directly to the end-user data on CO2 emissions related to their energy consumptions.

Analyses carried out in several countries (among these, UK, Canada, USA) have demonstrated that the installation of these devices induces a modification in the behaviours of consumers leading to an energy saving ranging between 7 and 15%. However, several authors object that these effects are quite temporary if not in conjunction with other measures that introduce incentives for the end-users that modify their consumption strategies.

This is, in effect, the spirit of the UK strategy described in the **UK Low Carbon Transition Plan**. The Plan provides for the installation of smart meters in every home by the end of 2020, in order to enable people to understand their energy use, maximise opportunities for energy saving, and offer better services from energy companies. The provision of smart displays for 2-3 million existing meters is also included. These measures are taken together with plans to introduce reward systems to end-users for changing their behaviours. These plans will have to be put in place in collaboration with the energy companies. The Government-funded Energy Saving Trust will also develop other services to make sure that the right advice reaches people at the right time and to help them get from the advice stage to implementation more easily.

There is no evidence of the development of applications or **metering devices in Italy** specifically designed for the presentation to the end user of data on CO2 emissions. On the other hand, with almost 30 million smart meters already installed, Italy is the first country to install smart meters nationwide. Other countries in Europe, such as France and the Nordic countries are in the process of undertaking similar efforts.

Electronic meters have allowed the introduction of multi-hour tariffs as an incentive to the users that move their usage on low-load periods such as nights, weekends, etc. and contribute to a better load balancing and therefore efficiency of the national electrical system.

The introduction of a **new domestic display** to be coupled with the metering device is now being taken into consideration. The display will make available a large body of information on energy consumption and contracts, such as comparisons in usage profiles in different periods, information on new commercial offers, alerts to signal periods of low-cost tariffs, etc. Of course, these devices could also provide direct information on CO2 emissions associated with the end-users behaviours/consumption. This poses no particular technological challenge, but simply a matter of calculating these quantities more or less accurately.

5.1.1 *Learning from the government's Act on CO2 Carbon Calculator for the UK domestic sector*

In June 2007, the UK government, in partnership with the Energy Saving Trust, launched its first official carbon calculator aimed at the general public. The main aims of the calculator were to educate the British public regarding what a carbon footprint is, to allow the public to calculate their own footprint quickly and easily and compare this with national averages and other comparators. Finally to provide the user with a personalised 'Action plan' with tips and actions based on their individual answers (a first in terms of existing calculator tools) in order to help them reduce their carbon footprint.

Two years after launch the Calculator had proven exceedingly successful. In the first 24 months it had attracted over 1.7 million unique visitors and has an unprecedented completion rate of 40% (for which it has won a 'Best Use of Web' award in the New Media Age awards 2008, among other awards). The completion rate is particularly exceptional as the user has to answer up to 70 questions regarding their Home Heating, Lighting and Appliances, Personal Transport and Flights, and the questionnaire can take up to 10 minutes to complete. The questions cover all aspects of the fabric and heating systems of the home, as well as covering both ownership and, most importantly, usage of the entire major domestic energy-using products and appliances, and hence have provided a very rich dataset in which approximately 500,000 footprints have been analysed to reveal the most comprehensive view of UK consumer's energy use ever created.

Over the last 2 to 3 years there has been an explosion in the number of 'carbon footprinting' tools available to the UK public. These tools vary from the 'single issue' calculation, where they are invited to calculate their carbon footprints for an individual flight for example, to a 'whole house' approach to calculating all the fuel they use for their heating, lighting and powering appliances.

The main concern with the plethora of tools available was that there was **no standardised methodology or even any consistency in the carbon factors and assumptions made**. This led to a confusing situation where the public could complete a number of different calculator tools, using the same lifestyle answers, and **get dramatically varying answers in terms of the tonnage of CO_2 that their home emits**. This inconsistency does little to help educate the British public on what a carbon footprint is; what exactly a tonne of carbon represents; and can cause confusion and scepticism where, for example, a consumer can shop around on various carbon offsetting websites to find the smallest amount of CO_2 that they then pay to offset a flight. In early 2007, the UK's Department of Environment, Food and Rural Affairs (DEFRA) and Energy Saving Trust partnered in a project to create the first official UK government-backed carbon footprint calculator. Its aim was to build a robust, transparent methodology as well as coming to a consensus around government departments as to which assumptions and factors to use when calculating the footprint. The aim was to make this underlying methodology and code 'open source' to allow any interested party to replicate the model and calculations, and hence produce the same result without having to start development from scratch, but giving them the freedom to create any frontage to their calculator that they required. Another important aim of the project was to produce a calculator that gave the user as much choice as possible. Previously, the vast majority of calculators have only allowed calculations when the user could supply bill data of some kind – either the Kilowatt hours (KWh) they used or the amount of money they paid for their energy through billing. This had the effect of alienating a great number of users who were unaware of their Kilowatt hours of use and also had no idea of how much their energy bills amounted to. Hence it was a key deliverable of the project that the calculator would allow people to complete the calculator without having to put in any bill data whatsoever. The other information collected regarding their house type, age and heating system, alongside information about ownership and use of their appliances, would provide enough data to perform modelled calculations which would give the user a reasonably approximately estimate of their carbon footprint for their Home and Appliance sections. The calculator would also allow users to choose to calculate either a 'Household' or an 'Individual' footprint. The household approach was the more common approach of other calculators of the time, but it was deemed useful to allow people to calculate their individual footprint to attain a 'per capita' carbon footprint comparator.

5.1.2 *Results from the analysis of footprint profiles*

The analysis of the footprint data was primarily undertaken to allow the implementation of a new piece of functionality in Version 2.0 entitled 'People like you'. **The first version of the calculator allowed users to compare their carbon footprint to the UK national average for the domestic sector**. This was a highly averaged top down approach of calculating what the average household's CO_2 emissions are based on taking the national total of domestic CO_2 emissions and dividing by the number of UK dwellings (approximately 26million).

This approach was sufficient in putting an individual household's emissions into a context of a national average, however it had many limitations in that the housing stock and family unit structure within the UK has much variation and hence could only give a very approximate idea of whether that particular household is doing well or otherwise in terms of its carbon emissions.

The 'compare with other users' (People like you) tool is new to V2.0 of the Act on CO_2 Calculator and is based upon the anonymous aggregated footprint data profiles discussed above and gathered over the past two years from responses to the Calculator since its launch. This new section allows the user to compare themselves to people (who have also filled in the Calculator) who have similar circumstances. This comparison is made in terms of house and heating characteristics; the number of people in the home and whether they are located in an urban or rural area (relevant for travel). The purpose of this functionality is for the user to more specifically tailor comparisons to fit their own circumstances and lifestyles. This variation in the comparison has been intentionally limited to criteria where a particular parameter has a direct and significant relationship to the energy use / CO_2 emissions.

The Act on CO_2 calculator has proved a popular and useful tool in the education of the British public in terms of improving their carbon literacy. The popularity and number of carbon footprints completed within the calculator has allowed in-depth analysis of a large number of UK household's lifestyle details which have assisted in the creation of some good benchmark figures for how much carbon dioxide is generated from the various types of homes and appliances within the UK. This has allowed the tool to develop and become more useful to users who can now benchmark themselves against other UK citizen who have similar lifestyles – hence ideally provoking them into action and carbon reductions if they find themselves with a much higher footprint than their norm grouping [5, 6].

5.2 Surveys in industry and research organisations that develop or use ICT for CO2 monitoring

Numerous energy displays have now been developed and put on the market. These have used a variety of different approaches to providing customer feedback and are examined in the section below. Their purpose is to communicate customers to allow them to monitor their present and past data on energy consumption, costs and CO_2 emissions.

A notable development in recent years has been the emergence of ZigBee enabled displays in the US market, such as the Tendril Insight, Ambient Home Joule and the Aztech In-Home. Some of these are based on the new ZigBee energy profile and depend on the widespread installation of Zigbee enabled meters by US utilities. These displays can be offered by the utility or directly to the customer. This trend gives a glimpse of how the European market might develop if AMM meters were widely installed and were fitted with a standard local interface. It can be expected that the competing network protocols will seek to emulate the growth of the ZigBee device range.

A number of these devices also link to software packages allowing the customer to carry out more detailed analysis. Some US utilities are also providing access for customers to web sites where they can see their energy consumption, current and predicted future bills and guidance on making energy saving measures. Some of these sites, such as the Greenbox, claim to provide real time energy usage data.

Although not widespread, meter linked displays are being developed and tested in Europe. The ecoMeter from Landis+Gyr is being used in a large number of trials. The PowerPlayer is being developed for use in the Netherlands and has been based on EMSA feedback conclusions.

EcoMeter

The EcoMeter was developed by Landis+Gyr in Australia and has been brought into the European market. It is being widely used in smart meter trials, notably in the UK Energy Demand Reduction Project. The display has wireless links to electricity, gas and water meters as well as offering two way communications with the utility.

Figure 1 EcoMeter

PRI Home Energy Control

An interesting example of how the technology may develop is the PRI Home Energy Controller. This is based on the ZigBee energy profile and provides both feedback and control of the central heating system. Much of the interest in smart metering in the US is driven by concern over air conditioning loads and technology is being developed to manage this load. However, this is an insignificant residential load in Northern Europe, where heating, often gas, is the major residential load. The PRI HEC is an indication of the sort of smart home devices that can be expected to be supplied for this market.

Figure 2 PRI Home Energy Controller

PowerPlayer, The Netherlands

The PowerPlayer has been developed as part of the roll out of smart metering in the Netherlands. The approach to the design has reflected the conclusions of the analysis of feedback carried out by ESMA[xvi] and features a simple and clear display.

Figure 3 PowerPlayer

EWE- Box

This is an energy monitoring system that has been developed by the Frauenhofer Institute for Solar Energy Systems. This is being trialled in Germany by the utility EWE and provides feedback on the customer's electricity and gas consumption.

Figure 4 EWE – Box

AzTech Insight

The AzTech Insight is a good example of the different approaches to displays being explored by different developers. It uses a ZigBee wireless link to connect to the meter and other ZigBee enabled devices in the home. The display provides two way communications to the utility and provides updates on tariff rate changes. The display has a multi-coloured bar on its top that can be used to provide additional feedback. The designers have likened the display to an electronic game console and have reported a good reaction by children to the display and energy management.

Figure 5 AzTech Insight

Tendril Insight

The Tendril Insight is a one of a number of displays that have been designed to use the ZigBee energy profile to link with ZigBee enabled meters and access the meter data. Other examples are the L.S. Research RATE$AVER and the AzTech In-Home.

Figure 6 Tendril Insight

A more detailed list of applications is shown in the table below [7]:

Display Name	Data Source	Customer Interface	Features	Link
Internet based				
Modstroeam	Utility, ZigBee device, manual entry	Web site	House energy analysis, link to ZigBee devices for home automation and data collection, link to participating utility meter data	DEST
VEAB EnergiKollen	Utility	Web site	Customers can view their energy usage and compare this with other users	VEAB
DTE Energy MyEnergy Analyzer Based on Aclara EnergyPrism	Utility	Web site	Customers can view their bills, energy usage, get advice on energy reduction. The utility can target specific customer groups	EnergyPrism
Energy Depot	Utility	Web site	Allows customers t o calculate their predicted energy costs, compare with bills and analyses cost saving measures	Energy Depot
Greenbox	Utility	Web site	Provides real time feedback and allows customers to identify savings opportunities. Links to ZigBee network to provide control function	Greenbox
H-Net	Utility	Web site	Customers can view their bills, energy usage and forecast future usage	H-Net

Display Name	Data Source	Customer Interface	Features	Link
In-house displays linked to meter data				
ecoMeter	Meter and utility data link, wireless or wired	Display unit	Shows multi utility meter outputs, cumulative demand, coloured lights related to consumption level and communications with utility	ecoMeter
PowerPlayer	Meter via wireless link	Display unit	Shows energy usage, carbon for electricity and gas and forecast costs	
EWE Box	Meter via M-Bus	Display unit plus web site	Weekly or daily consumption on display, annual and monthly data on web site.	EWE Box
EMS-2020	Meter via wireless link	Display unit	Daily and monthly display of energy and costs	EMS-2020
PRI Home Energy Control	Meter via wireless link	Display	Multi utility display of instantaneous and cumulative multi utility data. Can control heating system	Home Energy Control
Home Joule	Wireless connection to meter and utility AMM network	Display mounted on plug top	Display shows consumption, weather forecast, current electricity tariff and coloured light indicating the relative cost of power	Ambient
AzTech In-home	Wireless link to meter	Display and optional link to computer software	Display shows instantaneous or 30 day rolling average consumption and cost. Has light to show level of consumption. Can control thermostat via ZigBee interface	In-home
Tendril Insight	Wireless link to meter	Display	Instantaneous and cumulative energy and cost plus forecast monthly bill. Communications with utility	Insight
HEMS Technology HEMS-DR	Wireless link to meter (L+G Focus meter)	PC	Comprises a wireless mesh linking meter, socket monitors and thermostats, these can be monitored and controlled	HEMS-DR
L.S. Research RATE$AVER	Meter via wireless link	Display	ZigBee energy profile compliant display, shows current and cumulative	RATE$AVE
In-house displays linked to separate power transducer				
The Energy Detective	Current transformers and wireless link to display.	Display, this unit also links to software package called Footprints	Has voltage pick up to provide true active energy measure	TED

Display Name	Data Source	Customer Interface	Features	Link
Eco-eye	Current transformers and wireless link to display.	Display	Display shows consumption, cost and carbon and can store data to give cumulative data	Eco-eye
Wattson/Holmes	Current transformers and wireless link to display.	Display, this unit also links to software package called Holmes	Display shows consumption, cost and carbon, software package stores data to give cumulative data	Wattson
Energy Orb	Wireless link to Internet	Coloured glass globe, colour is linked to energy consumption or energy price	Very simple user interface, can be modified to display energy usage data	Ambient
Sentec Coracle	Power analysis of supply with wireless link to display	Display with options for web access to data	Calculates disaggregated appliance usage from total supply signal	Coracle
Green Energy Options Home Energy Hub	Current transducer at supply point and point of use transducers with wireless links	Display, simple option or duel option with heating, hot water and individual appliance loads	The advanced options allows for control of appliances via smart plugs.	Energy Hub
Wattwatcher	Current transducer at point of supply with wireless link to display	Display and link to computer programme for energy analysis	Option for additional appliance sensors. Part of larger programme with community and web site support	Wattwatcher
Cent-a-meter (Australia) Owl (UK)	Current transducer at supply point with wireless link to display	Display, shows instantaneous power, cost and carbon plus temperature and RH	Display has option to accept multiple inputs.	Cent-a-meter
The Meter Reader EM-2500	Current transducer and voltage sensor with wired link to display	Display showing	1% accurate through power, peak power, estimated bill, voltage	EM-2500 measurement of voltage and current
Current Cost	Power transducer with wireless link to display	Display showing instantaneous and cumulative power and cost	Optional link to computer package to review consumption	Current Cost

Worldwide there are companies that develop or provide CO_2 emissions monitoring-management systems. Characteristically, we can mention the TechniData Environmental Performance Solutions

(EP) that supports a business compliance management which covers all regulatory requirements in the environmental domain. Typical examples include support with recording and submitting emissions data to national or international pollutant registers such as **EPRTR** (European Pollutant Release and Transfer Register), managing plant monitoring and reporting processes (e.g. in accordance with the **German Federal Emission Control Ordinance (BImSchG)** or the **U.S. Title V**), or tracking corporate programs like **carbon footprint** initiatives worldwide. Also part of the Environmental Performance Solutions is the TechniData EPM which collects sustainability data, analyze performance and generate reports for targeted stakeholders that impact companies' business. In addition, TechniData offers measuring networks: TechniData ENVINET . This product offering includes stationary and mobile measuring stations that collect relevant environmental data.

Another example would be SAP, which taking into account that companies need to track, measure, and comply with emissions requirements, ensuring compliance with regulations, automating data collection, emissions tracking, and calculations, develops appropriate software solutions. This impacts all roles in the organization, from the risk management and sustainability office to the CFO and supply chain lead. Effective emissions tracking and reporting help ensure compliance and the ability to more accurately forecast emissions and ultimately manage cap-and-trade programs, minimize emissions-related costs, and improve emissions-conscious distribution and fulfilment opportunities.

5.3 Surveys among network operators that apply ICT for CO2 monitoring

Among industry the list of identified Smart Metering projects are depicted in the following table [8]:

Ref	Utility	Country	No of meters	Energy streams	Vendors	Start date	End date	Comments
Europe								
**	Energie AG	AT	10 000	e	--	2007	2008	Trial
	Feldkirch	AT	3 000	e	Echelon	--	--	Trial
	Linz Strom	AT	75 000	e	--	--	--	Trial
	Cez	CZ	400	e	Echelon	2008	2008	Trial
	E.ON Czech Republic	CZ	4 000	e	--	2006	--	Trial
	EnBW	DE	1 000	e	--	--	--	Trial -ongoing
	EWE	DE	400	e	--	2008	2009	Trial
**	Mulheim an der Ruhr	DE	--	e	--	2008	2010	Trial
	RWE Mulhiem	DE	100 000	e	--	2008	--	Trial, cost of €20m
	Stadtwerk Duesseldorf	DE	1 000	e	L+G	2008		Trial
	Stadtwerk Hassfurt	DE	10 000	e	Echelon	2008	2011	Trial
	Stadtwerke Bochum & EVB	DE	500	e	Echelon	2008	--	Trial
	TWK Kaiserslautern & EVB	DE	1 000	e	Echelon	2007	--	Trial
	Yello Strom	DE	1 000	e	--	--	2008	Trial

Elro Net	DK	50 000	e	Echelon	2007	2010	
EnergiMIDT	DK	170 000	e	Echelon	2008	2010	
NRGI	DK	52 000	e	Echelon	2008	2011	
Odense Energi	DK	72 000	e	L+G	--	2009	
SEAS-NVE	DK	390 000	e	Echelon , Gorlitz	2008	2011	Use M-Bus link to legacy gas, water, heat meters
Syd Energi	DK	250 000	e	L+G	2004	2008	
TRE-For	DK	200 000	e,h,w	L+G	--	--	
Empresa Electrica Quito	EC	700 000	e	--	2007	2009	BPL focus
Fortum Espoo Oy	FI	63 000	e	L+G	--	2007	
Haukiputaa Electricity Cooperative	FI	9 000	e	L+G	2008	2011	
Helsinki Energy	FI	120 000	e	Aidon Oy	2008	2010	
Jyvaskylan Energia	FI	4 000	h	L+G	--	--	
Kainuun Energia	FI	55 000	e	L+G	--	2008	
Kemin Energia	FI	15 000	e	--	--	--	
Satapirkan Sähkö Oy	FI	70 000	e	L+G	2008	2012	
Tampere City Electric Works	FI	4 700	e,h	L+G	2008	2010	Electricity metering -, April 2008 about 25 000 customers haveAMR, all 100 000 customers will haveAMR by the end of 2010. Customers have internet access to their own consumption measurement data. Heat metering -may be more meters
Tornion Energia	FI	11 000	e	L+G	2008	--	replacing old meters at end of their life
ERDF	FR	30 000	e	L+G	2010	--	trial -leading to 35m meters, L+G have33% of meter sales
ESB	IR	21 000	e	Sagem, Elster, Trilliant, Aclara	2008	2010	Trial, expected to do all homes for €4b -1.8m homes
Acea Distribuzione	IT	1 500 000	e	L+G	--	2009	
Oxxio	Ne	100,000	e		2006	--	Rolling out to all customers
Kragero Energi	NO	8 600	e	L+G	2007	--	
Sweden is undertaking a full roll out of AMR and there are numerous projects; those shown below have been reported in							

the pres but do not constitute a comprehensive list								
	E.ON Sverige	SE	390 000	e	Echelon	2007	2009	
	Fortum Espoo Oy	SE	900 000	e	L+G	--	2008	Full AMR implementation, Fortum has nearly 600 000 distribution customers in Finland and is planning to start full AMM implementation soon.
	Goteborg Energi AB, Lerum Energi AB	SE	100 000	e	Kamstrup		2009	well over 100,000 meters for €6.6m
	Gothenburg Energy	SE	270 000	e	Nuri	--	--	
	Halmstad Energi	SE	38 000	e	Echelon	2007	2009	Also SCADA system
	PiteEnergi	SE	20 000	e	L+G	--	2007	
	Staffanstop Energi AB	SE	6 000	e	L+G	--	2008	
	Vaxjo Energi AB (VEAB)	SE	20 000	e	Logica	--	2008	web based portal
	Vattenfall Distribution	SE	900,000	E	Several	--	2008	Also in Finland 360,000 Iskra meters
	Elektrovojvodina D.O.O.	Serbia	30 000	e	--	2007	2010	
**	Opus Energy	UK	--	--	--	--	--	£5m programme
**	Orsis	UK	--	e,g	--	--	--	
	UK Energy Demand Reduction Project	UK	--	e,g	various	2007	2010	Trial
Americas								
	BC Hydro	CA	1 900 000	e	--	--	--	start of procurementprocess
	Consumers Energy	CA	3 500 000	e,g	--	2008	2014	1.8m e, 1.7g add on comms
	Enersource Hydro Mississauga	CA	185 000	e	Elster	2007	2010	
	Horizon Utilities	CA	231 000	e	Elster	2007	2010	
	Hydro One, Hydro One Brampton, Milton Hydro Distribution	CA	350 000	e	Trilliant, L+G	2006	--	6.5% demand reduction in trial
	Hydro Ottawa	CA	230 000	e	--	2006	2008	
	Manitoba Hydro	CA	750 000	e,g	Itron	2008	--	
	Peterborough Distribution	CA	35 000	e	--	--	2010	
	PowerStream	CA	237 000	e	Sensus	2006	--	
	Toronto Hydro-	CA	680 000	e	--	2007	2009	

Electric System Limited							
Alliant Energy	US	626 000	e,g	Sensus	2008	--	450000e, 176000g
Ameren Illinois Utilities	US	1 100 000	e	L+G	2006	2008	Aiming for 1.1m -linked to scadasystem
American Electric Power	US	5 000 000	e	--	2008	2015	
Arizona Public Service	US	800 000	e	Elster	--	--	
Arizona Public Service	US	800 000	e	--	2006	2013	
Atlantic City Electric	US	500 000	e	--	2008	2013	
Austin Energy	US	234 000	e	Cellnet	2002	2008	
Burbank Water and Power	US	45 000	e	--	--	--	
Central Vermont Public Service	US	152 000	e	--	2011	2013	
Centrepoint Energy	US	3 000 000	e,g	Itron	2008	2014	5 years upgrading AMR to AMI
Clarksville Department of Energy	US	54 000	e	muNet	--	--	
Commonwealth Edison	US	120 000	e	--	2008	2013	Trial
Cumberland Maryland	US	11 000	w	Sensus	--	--	
Delmara Power	US	300 000	e,g	--	2009	--	aiming for 500,000 electric and 121,000 gas meters
DTE Energy	US	2 700 000	e,g	Itron	2009	2012	Pilot
Duke Energy (Kentucky)	US	21 000	e,g	--	--	--	120000 e. 90000 g
EPB	US	500 000	e	--	2008	2012	
Florida Power & Light	US	4 500 000	e	--	2008	--	
Georgia Power	US	2 000 000	e	Itron	2007	2012	
Iowa Exercises	US	1 400 000	e,g	--	--	--	
Modesto irrigation District	US	112 000	e	L+G	--	--	
Pacific Gas and Electric	US	5 000 000	e,g	GE, L+G	2007	2012	Not signed yet, $1.7b for whole programme, $450m for meters, 10,000-12,000 meter install per day5.1 million electricity4.2 million gas meter
Portland General Electric Co.	US	850 000	e	Sensus	2008	2010	

	Potomac Electric Power Co	US	256 000	e	--	2008	--	Proposal, moving to ami for all 1.8m customers
	Progress Energy	US	2 700 000	e	Itron	--	--	AMR only
	Public Service Electric and Gas Company	US	32 500	e	--	2008	--	trial
	Salt River Project	US	--	e,w--	Elster	--	--	
	San Diego Gas and Electric	US	2 300 000	e,g	Itron	2009	2011	waiting for approval from Californian Public Utilities Commission1.4m e, 0.9m gas amr modules
	Southern California Edison	US	5 300 000	e	Itron	2009	2011	$480m for comms plus 80% of meters
	Southern Company	US	4 300 000	e	Sensus	--	--	
	Sulphur Springs Valley Electric	US	30 000	e	Cellnet	--	2010	
	Tallahassee	US	220 000	e,g,w	Elster	2007	2010	110,000e, 25,000g add ons, 85000w
	Xcel Energy	US	100 000	e	--	2008	--	
	Oncor Electric Delivery Company	US	3 000 000	e	L+G	--	2012	Contract signed
Rest of World								
	blacktown Solar City	AU	10 000	e	--	--	--	environmental initiative, total meters split across a number of projects
	Country Energy	AU	10 000	e,g	IBM	--	--	Trial
**	New South Wales	AU	--	e	--	2008	2018	announcement
	Victoria	AU	--	e	--	2010	2013	
	ELEKTROPRIVREDA HZ HB MOSTAR	BA	200	e	Echelon	--	--	Trial, aiming to move to 200000
	Gripal Energy Management	IN	500 000	e		--	2010	
	Contact Energy	NZ	500 000	--	Vector, Siemens	2008	2013	
	Genesis Energy	NZ	600 000	e,g	Vector, Siemens	2008	2012	Contract signed with meter provider Vector NGC metering
	Mercury Energy (Metrix) (Mighty River Power)	NZ	340 000	--	Elster		shortly	successful 5000 home trial
	Meridian Energy	NZ	200 000	e	Arc Innovations	2008	--	

--	RU	375 000	e	Echelon , ECA	--	2008	$6800000 for 80,000
Eskom	SA	120 000	e	--	2008	--	
Trinidad and Tobago Electricity Commission	TT	400 000	e	Itron	2007	2009	AMR only
United Arab Emirates	UAE	--	e	--	--	--	Based on energy efficiency
Total Rest of World		3 055 200					
Total worldwide		64 43 300					

Private households emit around 160 million tonnes of the greenhouse gas carbon dioxide into the atmosphere every year, accounting for a significant amount of all CO2 emissions. For this reason EWE launched a pilot project in collaboration with the district of Emsland in 2006 **which will allow private households to trade CO2 reduction certificates in the future**. The project is the only one of its kind in the country.

Around 150 homeowners are taking part in the research project, which is scheduled to last four years. Participants are given CO2 credits for emissions which they manage to reduce via energy efficiency measures. These credits are paid out to the owners through a fund. EWE and the district of Emsland are using the project to establish an important basis for evaluating CO2 reduction certificates in private households and send a clear message about the importance of climate protection.

5.4 Surveys in other projects that apply ICT for CO2 monitoring

5.4.1 *MEREGIO project*

In February 22, 2009 a SmartGrids project begun, to cut energy consumption and minimize CO2 emissions by integrating an entire power grid system – generation, distribution and consumption - into a single, interactive real-time network.

Known as MEREGIO, the project is currently under development for pilot deployment in the Karlsruhe-Stuttgart region of southern Germany, one of the most densely populated areas of the country and widely considered Europe's biggest manufacturing and high-tech hub.

The objective of the project is to create an optimized and sustainable power network that reduces CO2 emissions to as close to zero as is technically feasible and humanly possible – a so-called Minimum Emissions Region (MEREGIO).

The solution will integrate clean energy generated by solar panels, wind turbines, fuel cells and other sources of distributed generation and provide the grid operator with real-time information about the entire power network in terms of supply and consumer demand.

This will enable the operator to predict power flow, adapt rapidly to changing situations, send price signals to the consumer to encourage demand or restrain it if there is risk of a bottleneck, and create a regional energy market that incorporates end customers.

Consumers will be able to monitor their energy consumption and CO2 footprint, respond to price signals and adapt consumption according to price and availability, and sell surplus power from their own generators to the grid when price conditions are most favourable.

MERIGIO is a collaborative project between ABB and consortium partners IBM, SAP, EnBW (Germany's third largest utility), Systemplan Engineering and the University of Karlsruhe.

Recently selected by the German Federal Ministry of Economics and Technology as a winner of the "E-Energy: ICT-based Energy System of the Future" award, the pilot will incorporate about 1,000 households, industrial consumers, generating units and energy storage units, each equipped with a smart meter.

5.4.2 *ADDRESS project*

Italian companies and research centres are particularly active in R&D projects devoted to the development of SmartGrids and of new-generation measuring systems.

ENEL coordinates the FP7 project **ADDRESS** (http://www.addressfp7.org). ADDRESS is a large-scale Integrated Project in the Energy area for the "Development of Interactive Distribution Energy Networks". Its target is to enable the Active Demand in the context of the SmartGrids of the future, or in other words, the active participation of small and commercial consumers in power system markets and provision of services to the different power system participants.
ADDRESS is framed in the Smart Grids European Technology Platform, whose vision for the electricity networks of the future may be expressed in just 4 words: flexibility, accessibility, reliability, economy.
The project started on June 1st 2008 and will last 4 years (2008 - 2012). The aim of the project is to develop a comprehensive commercial and technical framework for the development of "Active Demand" in the SmartGrids of the future. "Active Demand" (AD) means the active participation of domestic and small commercial consumers in the power system markets and in the provision of services to the different power system participants. The project is not, therefore, primarily centred on DSM issues, although these issues are in many ways connected with the project's activities and findings. A specific workpackage is devoted to the study of acceptance and benefits for the users. Within its frame recommendations for accompanying measures with regard to social acceptance of new SmartGrids technologies will be developed.

5.4.3 *OPEN meter project*

The European Commission document COM(2009) 111 addresses the topic of **"mobilising Information and Communication Technologies to facilitate the transition to an energy-efficient, low-carbon economy".** Paragraph 4.2 of the document is devoted to "Encouraging an enduring shift in the behaviour of consumers, businesses and communities". The Commission communication is centred on smart metering. The role that smart metering can play in lowering energy consumption is recognized, stating, among other aspects, that "the roll-out of smart metering can lower energy consumption by up to 10%, depending on the context and quality of the information fed back to the consumer". However, there is a need for a correct implementation of smart meters. Often only one-way information flows (from end-user to supplier or network operator) are enabled, and the advantages of communication are lost. The Communication therefore calls for an agreement among Member States on a "minimum level of functionality for smart metering so that the same minimum options can be offered to all consumers, irrespective of where they live and who provides the service, and to ensure interoperability".

At the beginning of 2009 the Enterprise and Industry Directorate-General of the European Commission issued Mandate M/441 to the European standardization bodies CEN, CENELEC, ETSI to create "European standards that will enable the interoperability of utility meters (water, gas, electricity, heat), which can improve the means by which customers' awareness of actual consumption can be raised".

The project **OPEN meter** (Open Public Extended Network metering, http://openmeter.com) is one of the instruments put in place by the Commission to enable the production of these standards.

The project's aims go beyond the simple measurement of the main commodities, in that it is intended to make available also tools for the provision of innovative energy services, such as demand management and the enabling of "prosumers" (producers-consumers) to be included in intelligent electrical networks. The results of OPEN meter will be open, public standards available for all stakeholders, i. e. a common knowledge base. The project is participated by 19 European partners of 7 different countries (in Italy by ERSE, ENEL, ST Microelectronics).

The project kicked off at the beginning of 2009, and so far communication requisites and functional requisites for the system as a whole and for specific measuring devices have been analysed.

Functions to be performed by the measuring systems have been categorised in three different levels: minimal, advanced, optional.

Minimal functions, mandatory for all European devices, include measurement reading (on demand and for billing), remote tariff programming, remote connection/ disconnection, power limitation/cut down, recording of information on interruptions in the service, etc.

Advanced functions include the communication with devices for other utilities (gas, heat, water), the automatic adaptation to variations in the topology of the network.

Optional functions include load management, SmartGrids enabling services, and other national requisites.

5.4.4 *Aim project*

The residential area accounts for the largest part of CO2 emissions, considering that about 35 percent of the energy production of power stations is consumed by households. This leads us to the question, how effective existing CO2 control mechanisms are for households. Massive installation of smart metering devices could solve the problem of energy metering, and thus address **the issue of calculating CO2 emissions**, but at the expense of extra energy. The alternative: recently emerged technologies enable the automated calibration of energy consumption on the basis of user-configurable thresholds.

Looking at the energy control problem from a different perspective, the AIM project, www.ict-aim.eu, positions the user in the centre of energy management mechanisms. The main objectives of AIM in this respect are to develop management mechanisms for ultra-low energy consumption and to establish a user-centric approach in energy management that is based on the concept of "user programmes". With this approach, AIM will create awareness among people on the environmental impact of the use of household appliances. Understanding how much energy an appliance consumes, gives users an active role in the fight against global warming by reducing power usage in the household.

As an alternative to approaches based on an energy metering architecture, AIM has developed a profiling technology that allows determining the energy consumption of household appliances via user programmes. Thus, even inexperienced users will be better able to realise how much energy is spent, when an appliance is switched on or is left in standby mode. In comparison to existing energy saving solutions, the AIM system does not require extra components and exploits any home network infrastructure for the exchange of status and control messages between the central monitoring mechanism and the appliances

At the core of the AIM concept is the Energy Monitoring Device (EMD), which is based on the concept of message exchange in the implementation of energy control applications. For households equipped with networked appliances, EMD is a slim software entity hosted on the residential gateway that "talks" to the respective appliance whenever the predefined energy consumption level is exceeded

5.4.5 *DEHEMS project*

The Digital Environment Home Energy Management System (DEHEMS), http://www.dehems.eu project is a European Union funded project looking at how technology can improve domestic energy efficiency. The project partnership includes a mix of European local authorities, private business and universities. The intention is to develop and test a home energy management system for the home market using Living Labs in 5 cities across Europe.

The aim is **to improve the current monitoring approach to levels of energy being used by households, with an overall aim of reducing CO2 emissions** across Europe. The project is supported by the EU under Framework Programme 7**.**

The system must allow users to set thresholds on average household energy usage per week and per calendar month, **in terms of kWH or CO2 footprint**. Within the project questions to be answered are: In what ways can motivations be changed to move more towards environmentally motivated behaviours? (E.g. shift from cost consciousness towards CO2 emission awareness as the key motivator, playing games, compete...) Is CO2 trading 'the right' way forward in order to achieve the objectives of the DEHEMS project? How can DEHEMS support the creation of a CO2 trading market place or support trading activity that will encourage absolute CO2 reduction, generation of green energy?

5.4.6 ***BeyWatch project***

BeyWatch, http://www.beywatch.eu, is a 30-month research project supported by the European Commission (DG Information Society and Media) aiming at ICT tools for environmental management and energy efficiency. BeyWatch will develop an energy-aware and user-centric solution, able to provide intelligent energy monitoring/control and power demand balancing at home/building & neighbourhood level. To reach its objectives, BeyWatch has undertaken the following:

Design ultra-low energy-consumption white-goods, implement methods, techniques and services to reduce the power consumption in smart/green homes/blocks/neighbours by intelligent control of electrical devices, generate hot water and electricity from renewable energy sources at building level, elaborate business plans and business support system (BSS) applications that will help the users and providers to reach beneficiary contracts, motivate user's awareness, towards less CO2 emissions on the whole energy value chain (production, transportation, distribution, supply) and cleaner environment. Energy is essential in almost every aspect of our lives and global emissions are having severe impacts on our climate and the global economy. We face two long-term energy challenges:

tackling the global climate change by reducing carbon dioxide (CO2) emissions and ensuring secure, clean and affordable energy, as most countries become increasingly dependent on imported fuel (oil or gas). According to the World Energy Outlook the global energy demand is expected to be more than 50% higher in 2030 than today, with energy related greenhouse gas emissions around 55% higher. In this context, BeyWatch actively supports the European Commission's proposals to save 20% of the EU's energy consumption through improved energy efficiency by 2020. The starting point of the BeyWatch energy policy is to save energy by making users aware of their energy expenses and enabling them to intelligently control the home energy consumption (both hot water and electricity energy). As a second step, BeyWatch aims to efficiently distribute the home preserved/spare electricity energy at neighbouring level, allowing for electricity load balance and flexible electricity energy consumption contracts. Improving the energy efficiency of homes and neighbourhoods, BeyWatch aims to reduce the carbon dioxide (CO2) emissions and the energy bills.

5.5 Surveys for companies that may be part of the Emissions Trading scheme

The companies that intensively produce CO2 emissions are part of the CO2 trading scheme, typically Oil&Gas, Power Production, Paper, Steel, etc. Concerns have also risen in electricity markets where entities will have to deal with their carbon emissions in a new mandatory carbon trading program (for example UK). Many large organizations not covered by the European Union Emissions Trading Scheme will be included in the Carbon Reduction Commitment. The cap-and-trade will be mandatory and cover up to 10,000 entities such as supermarket and hotel chains, government departments, banks and cinemas.

In UK after an extended period of consultation the Government announced, in May 2007, that it intends to introduce the Carbon Reduction Commitment ("CRC"), a new mandatory emissions trading scheme. The CRC is a mandatory auction-based emissions trading scheme that will apply to large non-energy intensive organisations in both the private and public sector. The CRC is expected to deliver carbon reductions of 1.1MtC/ year by 2020. The UK Government aims to begin the scheme in January 2010.

The CRC will extend the concept of emissions trading to many new business sectors which are not currently subject to the EU Emissions Trading Scheme (which applies to energy intensive sectors such as power generation, steel production and the oil and gas industry).

The CRC will be a "cap-and-trade" scheme. This means that the Government will set a cap on the amount of CO2 that a particular organisation can emit. CO2 emissions include **not only direct emissions to the atmosphere, but indirect emissions arising from energy use**.

At the end of each year the organisation has to surrender allowances equivalent to that cap. If the organisation has an excess of allowances, it can sell these on the market and where an organisation has a shortfall it will have to buy allowances.

The CRC covers emissions for all energy sources, not just electricity. An organisation will have to add up the total amount of electricity, gas and other fuels from its respective bills or meters and convert each of them into a tonnage equivalent of CO2 using a conversion method.

The framework for the scheme has been settled but the detail remains to be finalised. A "Consultation on the implementation of the Carbon Reduction Commitment" was published in June 2007 and this aims to solve the key outstanding issues. The consultation has now closed and the Government's response is due to be published by the end of the year.

Who does it affect?

Any organisation in the UK with an annual electricity consumption of more than 6,000MWh from mandatory half-hourly meters will be subject to the CRC unless an exemption applies. This threshold corresponds to an annual electricity bill of approximately £500,000. Exemptions are available to those organisations already covered by the EU Emissions Trading Scheme and (subject to a threshold) those with Climate Change Agreements with the UK Government.

The key organisations likely to be affected by the CRC are: large retailers, hotel chains, fitness centre chains, multiplex cinemas, mobile phone operators, rail operators, large office-based organisations, light industry and manufacturing, government departments, large hospitals, universities and local authorities.

The current intention is that the UK parent company of an organisation will be responsible for its subsidiaries if the organisation has a combined annual consumption of over 6,000MWh per year from mandatory half-hourly meters and will assume compliance obligations on behalf of the group [9].

6 CONCLUSIONS: ASSESSMENT OF ICT REQUIREMENTS AND GAPS ON THIS TOPIC

By 2020 financial analysts predict a carbon-trading market valued at US$1 trillion a year. Managing GHG certificate trading effectively avoids penalties and costs, but companies have the potential to do more. By effectively managing certificates and optimizing decisions around production, energy usage, and external investments, companies can capture potential revenues. • Key performance indicators (KPIs) and dashboards – Market interviews have made it clear that, in the context of GHG, there is a lack of effective tools for setting KPIs, defining and tracking reduction programs, and supporting management decisions. State-of-the-art software tools of today are effective in supporting performance management in other areas but have to be extended to include GHG. • Reporting − A company needs to report its GHG footprint in an auditable way for both external and internal stakeholders. Different stakeholders require different standards and sometimes different methodologies. In cases in which financial institutions are focusing on “carbon risks,” certification institutions will look for a much more detailed picture and governments will push companies to meet reduction targets.

Transparency on GHG Footprinting has several dimensions of complexity. Managing this complexity cannot be done in an efficient and effective way without significant software support. Enterprise software delivers much of the information and data necessary for foot printing. Software also has to support new requirements, like automated metering or additional data on products and raw materials. Strategic IT Management Tools Market interviews clearly show that there is room for improvement on management tools on several levels: • Cap and trade − The need for effective cap-and-trade management systems is already clear.

In the event of the domestic sector participation in the Emissions Trading Scheme, it is clear that the metering-monitoring of the CO2 footprint will become a core issue for the software of metering devices. For the commercial sector participation in the same scheme, the urge of accuracy on measurements plays a more critical role.

Data standards should be expandable to allow inclusion of entities required to show environmental impact, such as carbon equivalent (for example, kg CO2/kWh) of the energy stream.

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