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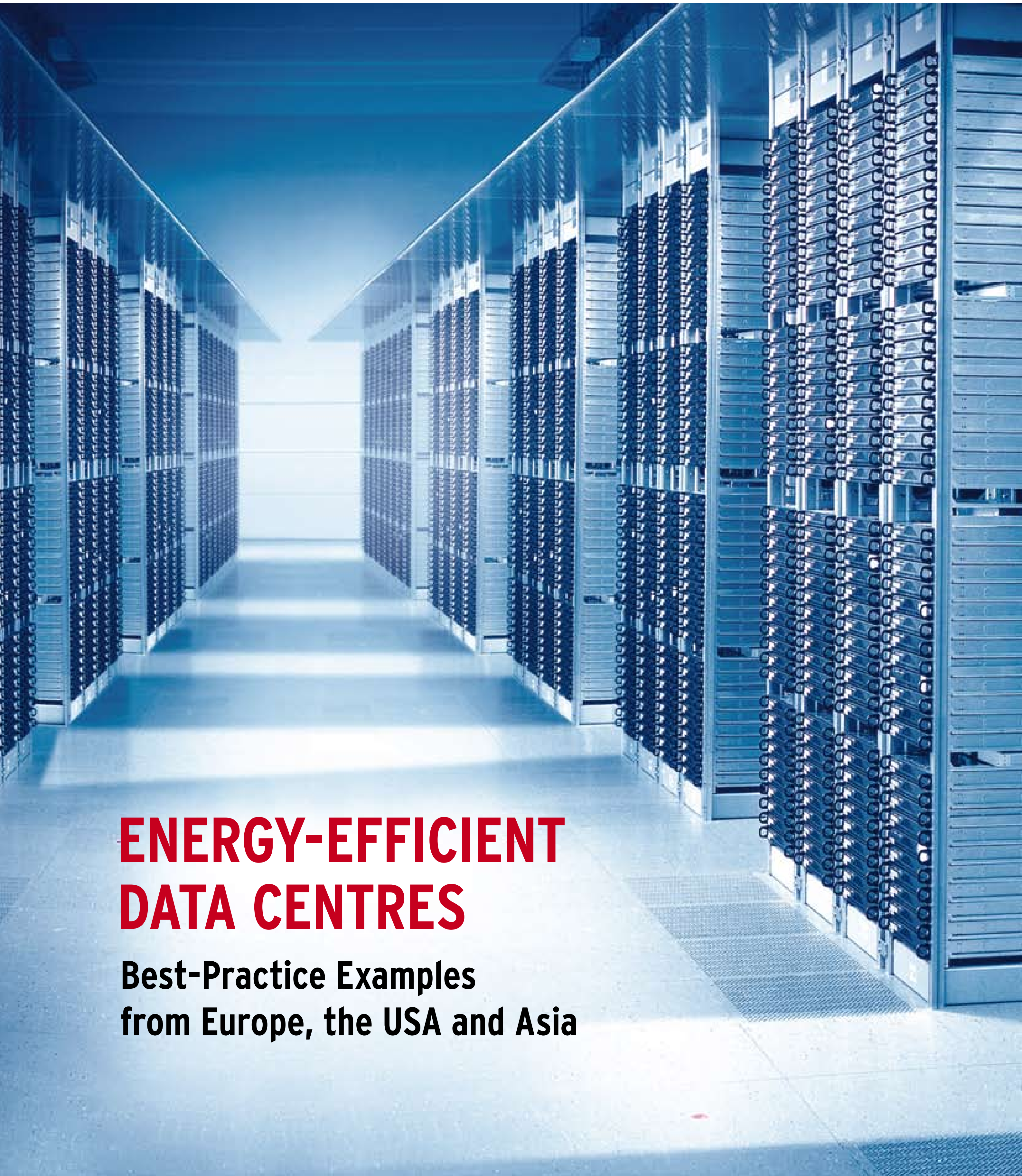

# ENERGY-EFFICIENT DATA CENTRES

## Best-Practice Examples from Europe, the USA and Asia

# IMPRINT


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# FOREWORD

## Dear Readers,

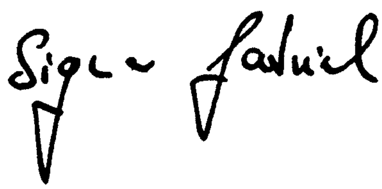
Our modern information and knowledge society is based on information and communications technology (ICT), a dynamic and innovative field which contributes considerably to economic development. In many areas of the economy and society, ICT can make an important contribution to saving resources and reducing climate-relevant emissions.

At the same time, the use of computers and the Internet involves substantial consumption of electric power. The $CO_2$ emissions generated by the power consumption of the ICT sector in Germany alone already amounted to over 28 millions tonnes of $CO_2$ equivalent in 2004, which was substantially higher than the $CO_2$ emissions caused by air travel.

The power consumption of servers and data centres in Germany came to 10.1 TWh in 2008, twice the figure for 2000. Germany's data centres today require a level of supply of electricity equal to the production of nearly four medium sized coal-fired power stations, and thus caused $CO_2$ emissions of almost 6.4 millions tonnes in 2008. Unless additional efforts towards efficient power use are made, a continued substantial rise in $CO_2$ emissions from server and data centres in Germany can be expected.
If on the other hand the energy efficiency technologies already available today and already being applied by forward-thinking companies, were to be broadly applied, a total of 25.8 TWh, or 15.3 million t $CO_2$ emissions, could be saved during the period through 2013. In this way, the operators of these data centres could save a total of €3.6 billion in electric bills by 2013. This involves easily realisable measures – "low hanging fruits", as it were – which require no investments beyond normal replacement.

In this context, the Borderstep Institute for Innovation and Sustainability has, under contract with this Ministry, investigated best practice examples of increased energy efficiency in server rooms and data centres. We would like to use these examples to highlight the feasibility of these measures for increased energy efficiency, and the savings to be achieved through them, and to call on responsible IT and data centre managers as well as planners and equipment providers for data centres, to promote energy conservation.

I would also like to express my heartfelt thanks for the co-operation and support provided by the German Association for Information Technology, Telecommunications and New Media BITKOM.



Sigmar Gabriel
Federal Minister for Environment,
Conservation and Nuclear Safety

# A WORD OF WELCOME FROM BITKOM

For the IT managers of many medium-sized and large enterprises, the energy costs for running IT equipment are an increasingly important issue – and not only since the emergence of the "green-IT debate" in 2007. Not without reason: The cost of power for data centres has more than quadrupled since 2000, according to calculations by the Borderstep Institute.

The potential for energy savings is very great. Optimised cooling, uninterruptable power supply technology (UPS), and particularly the consolidation and virtualisation of the IT landscape could reduce energy consumption by up to fifty per cent. And more importantly, energy savings usually even mean improved availability and simplified IT management.

This is not only true in theory, but also in practice – as is shown by the best-practice examples in this booklet. They range from mini-data centres with less than ten servers to major data centres with some tens of thousands of servers, which fully reflect the variety of data centres in business and management.

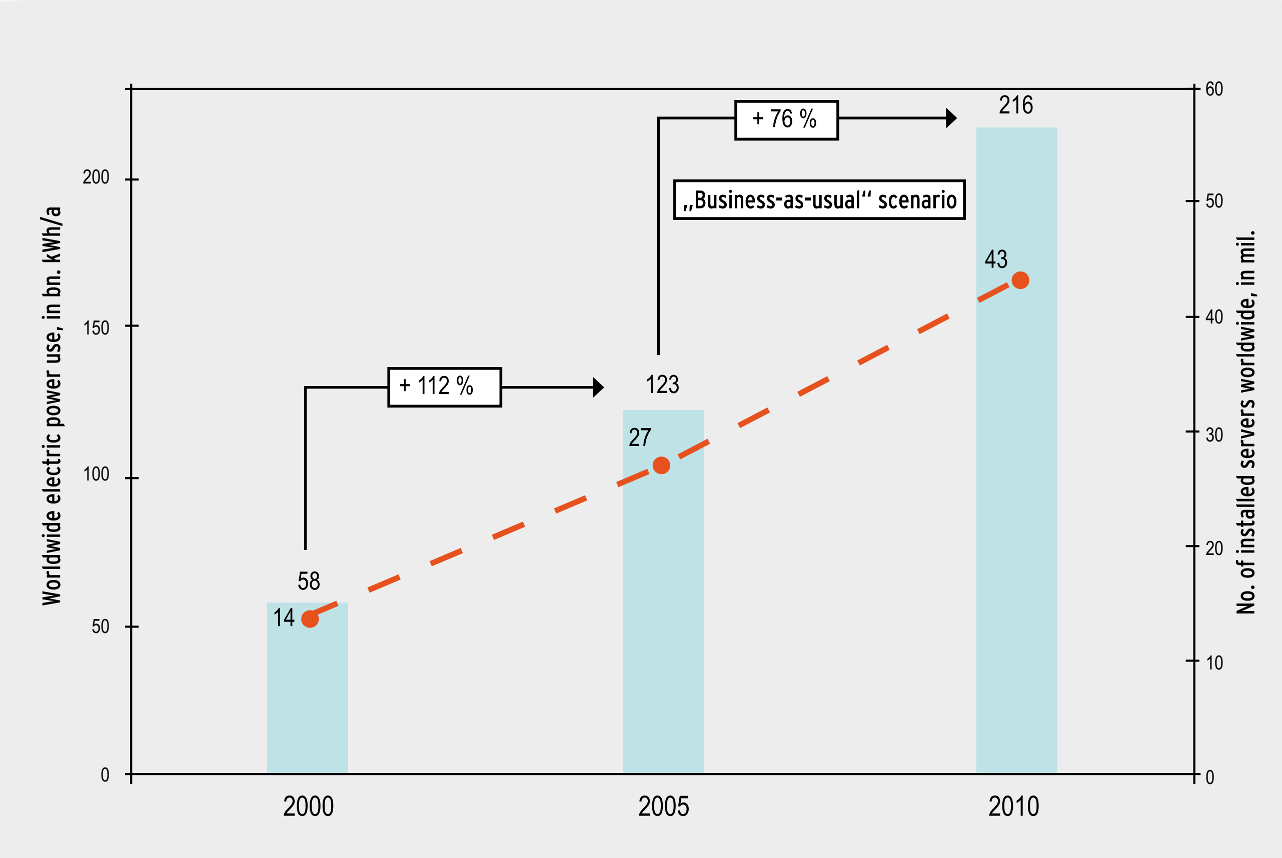
This booklet supplements the BITKOM guide Energy Efficiency in the Data Centre, which provides concrete guidelines for the planning, modernisation and operation of energy efficient data centres. Both publications can contribute to increasing the awareness for possible savings among IT and accounting managers in business and state offices, and thus support both economic and ecological developments in Germany.

Martin Jetter
Member of the Board, German Association for Information Technology, Telecommunications and New Media BITKOM
General Manager IBM Germany
Chairman of the Board of Management
IBM Deutschland GmbH

# TRENDS AND EFFICIENCY POTENTIAL

With the increasing use of the Internet, telecommunications services, and IT networks internal to organisations, the numbers of servers and their power consumption has risen rapidly over the past ten years. Based on the number of servers installed worldwide, as well typical server models, their average annual power consumption, and the infrastructure necessary for their operation (uninterruptable power supply, cooling etc.), it is possible to calculate that worldwide electric power consumption by servers has risen from 58 billion kWh in 2000 to 123 billion kWh in 2005. This represents approx. 1% of total worldwide consumption of electricity. It can be assumed that power consumption for data centres will continue to increase considerably in coming years.

**Figure 1: Number of installed servers and their electricity consumption worldwide**




Sources: IDC 2006 (number of installed servers), Koomey 2007 (electricity consumption, 2000 and 2005), and Borderstep 2008 (Power Consumption 2010).

The trend toward a rapid increase in energy consumption by servers and data centres can be observed in all OECD countries. Using the example of one OECD member state, Germany, let us here outline the trends which can be expected in the future.

The electric power consumption of servers and data centres was around 10.1 TWh in 2008, and the cost of that consumption, some €1.1 billion, according to calculations by the Borderstep Institute. This represents a share of overall consumption of electricity of approx. 1.8%, and means that four medium-sized coal power stations are needed merely to supply Germany's servers and data centres.

Various scenarios can be called upon to address the question as to how the electric power consumption picture of data centres in Germany will develop. We will here limit our considerations to three scenarios:

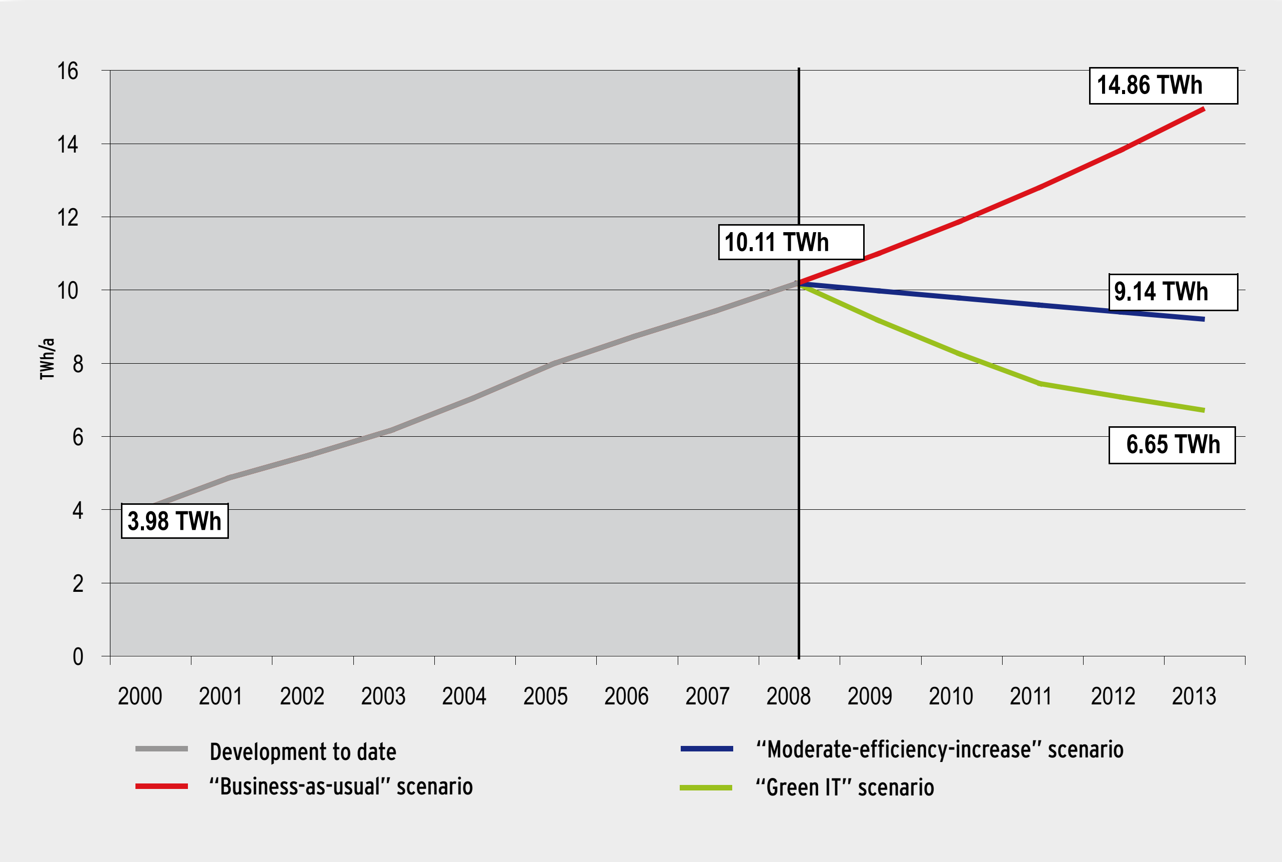
The "business-as-usual" scenario describes a situation in which those trends towards more efficiency (server virtualisation etc.) which are already operating will continue, but in which no additional efficiency measures would be adopted by the state, the IT manufacturers, or the operators of data centres. In this case, the power consumption of German data centres would rise from 10.1 TWh to 14.86 TWh during the period between 2008 and 2013. This would represent a 47% increase in power consumption. Under this scenario, the costs for electric power for German data centres would double to €2.2 billion by 2013.

If, on the other hand, additional efficiency increase measures were to be implemented by business and the state, and some of the best-practice solutions already available today were to be adopted by at least approx. half of all data centres, a reduction in electricity consumption of about 10% would be possible. If this "moderate-efficiency-increase" scenario were to be implemented, the electric power consumption of German data centres would drop to 9.14 TWh by 2013.

Assuming, finally, that the best energy efficiency technologies and solutions available today were to be broadly implemented through massive efforts, i.e. at approx. 90% of all data centres, electric power consumption by servers and the data centre infrastructure would drop to 6.65 TWh by 2013. In the case of this "green-IT" scenario, the electricity consumption of data centres would drop by almost 40% within only five years, despite a continuous rise in computer and storage capacities. Under this scenario, the expenditures for electricity would in fact drop significantly in absolute terms, to €998 million, despite a further rise in the price of electric power through 2013.

[1] Calculation based on Federal Ministry of Economics 2007. Power prices (without VAT) have been corrected for inflation and indexed to 2000. The calculation e.g. for 2008 was based on a power price of €0.11/KWh, which industry experts assumed to apply to data centres in Germany, on average.

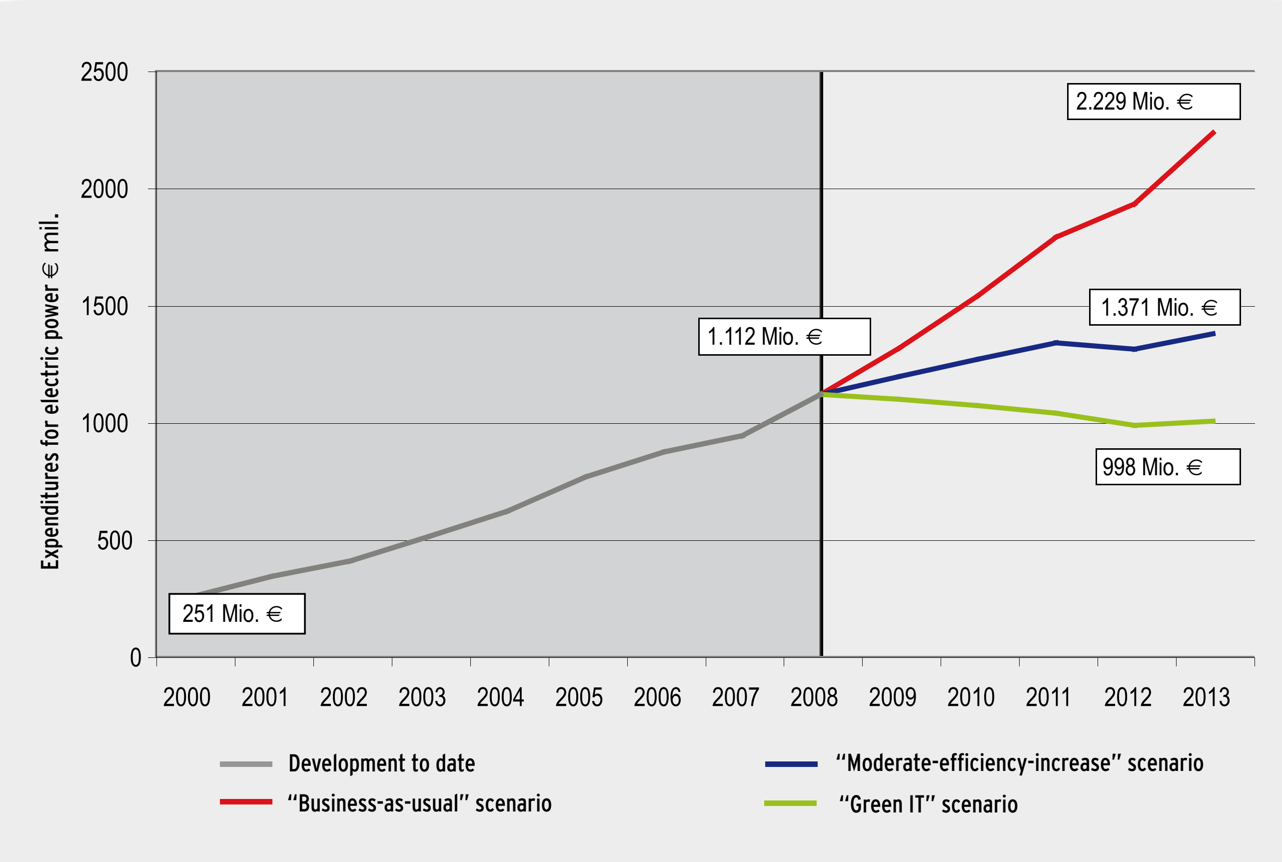
**Figure 2: The electric power consumption of servers and data centres in Germany**




Source: Borderstep 2008

The operators of data centres are already being forced, simply for reasons of technology and energy costs, to deal with questions of electricity savings and energy efficiency. At issue is both guaranteeing the availability and efficiency of a data centre and also, increasingly, savings in expenditures for electricity and an overall reduction in the total cost of ownership. The economic importance of the cost of power for data centres is shown in Figure 3.

**Figure 3: Trends for the cost of electricity for servers and data centres in Germany**




Quelle: Borderstep 2008

The differences between business-as-usual and the concerted adoption of additional energy efficiency measures – or "green-IT" – are considerable. The total difference between the two future options for the period from 2009 through 2013 amounts to potential savings for the operators of data centres in Germany of €3.6 billion in expenditures for electricity within only five years, if there was broad implementation of efficiency solutions which are already available and have been successfully put to use today by vanguard providers – despite further increases in the price of electricity!

# APPROACHES FOR INCREASING ENERGY EFFICIENCY IN DATA CENTRES

There are a number of measures which can be taken in data centres to increase energy efficiency. How to proceed and which measures to apply at which points is described in a number of guides and support aids which are now available, and can be of use to data centre planners, IT managers and building managers; see "Secondary Literature and Links" for a list of such materials. In the following, we will therefore give only a brief overview of approaches for increasing the energy efficiency of data centres.

The chain of effects starts with applications, and continues through the IT hardware and the power supply, right up to building planning and cooling as well as energy management. The most important basic fact is that measures are most effective at the start of this chain of effects. If an application is no longer needed and the accompanying server is therefore switched off, less power is used, the losses in the UPS system decline, and the cooling load is reduced.

## First dimension: Applications and data

The first point of departure for an energy efficient data centre is the critical questioning of the applications and the data. It often happens that, although a third of all applications is no longer needed, they nevertheless continue to operate on the server. And the difference in the extent to which certain largely identical applications use up hardware resources is often not insignificant. In its guide *Energy Efficiency in Data Centres,* BITKOM expresses the suspicion that in many companies, photo, video and MP3 files make up a large part of the data quantity, even though they are not needed for business operations at all. For the management of the energy efficient data centre, this means that the applications and the data must be examined regularly, and that applications and data which are no longer needed should be deleted if possible. If users are also billed for the maintenance of applications and data, a motivation for an additional increase in efficiency is created.

In software procurement too, it is recommended that applications also be compared from the point of view of the hardware and energy expenses involved, and that the need to examine the expected essential differences in hardware resources be seen as a factor in procurement decision-making.

## Second dimension: Virtualisation

The progress to be achieved through virtualised environments is considerable. The utilisation of the servers can be increased by from between 5% and 15%, to 60% and sometimes even to 85%. Some data centres have halved their electricity consumption by investing in new hardware and virtualisation. But not every customer of a data centre will accept the fact that his application runs on virtual equipment. For some, virtualisation still appears unsafe, and these customers insist on physical servers. But their number is already decreasing, and it can be expected that a large share of all applications will be running on virtual equipment in a few years. For an energy efficient data centre, virtualisation is almost always a "must".

## Third dimension: IT hardware

There are many different reasons for producing certain IT components – functionality, compatibility with the available infrastructure, links to the manufacturer, etc. In the past, it has hardly been possible to take such factors as energy efficiency of servers into account in procurement, since no standard for comparison existed. This has changed since the end of 2007, when the SPECpower metric was introduced, which measures energy output and input in the measurement unit "ssj_ops/Watt". While there has been criticism of the fact that its stress test can be run only with a Java application, this is nonetheless a beginning.

In December 2007, the first twelve tests were published, with the leader scoring 698 ssj_ops/Watt. By the end of 2008, the scores of the best server in the test had already almost doubled to 1135 ssj_ops/Watt. The highest efficiencies have not been achieved by the units with the highest performance. And particularly in the medium range, for equipment with a peak performance around 200 ssj_ops, energy effi- ciency scores vary by a factor of three.

There are already signs that test server configurations are being adapted by manufacturers in view of these results. They are dispensing with what they can do without, in order to achieve good scores. Considerable progress can be expected over the next few years. Accordingly, it will in future be appropriate to take energy efficiency into account when purchasing servers, in addition to the usual criteria.

Data storage promises additional gains in energy efficiency. Here, there are now a variety of different storage types, again dependent on performance and availability requirements. Thus for example, 2.5-inch hard disks consume considerably less power than 3.5-inch sized devices, and data to be permanently stored can also be filed on magnetic tape.

## Fourth dimension: Uninterruptable power supply

An uninterruptable power supply (UPS) ensures availability in case of short-term power outages. In most cases, a battery-operated UPS is used. The alternating current of the grid is converted to direct current, fed into the battery and immediately turned back into alternating current to provide the power supply for the IT hardware. In case of a power failure, the battery can thus access the power supply with no interruption. The reasons for power outages are often trivial: even simple voltage fluctuations or short failures of the power supply system can suffice to damage hardware or software, or can disrupt it so seriously that errors occur. Particularly in smaller data centres, an inattentive electrician or the cleaning staff may unplug a unit simply in the course of cleaning or maintenance.

Each of the components of a UPS system can have higher or lower degrees of efficiency. Certain losses occur in each component. A high-quality, high-performance UPS can today reach a degree of efficiency of more than 96%. Even smaller investments should have at least a 90% degree of efficiency.

It is important that the UPS system, like other components of the infrastructure, is not oversized. For example, a UPS in a government ministry provided rated power of 100 KVA to supply a small data centre with an electricity consumption of approx. 12 kW. This “cautious” over-capacity caused unnecessary annual power expenditures of about €2,000 - more than the cost of a new UPS system of the appropriate output level would have cost.

## Fifth dimension: Air conditioning

Air conditioning has in the past been the central point of departure for making data centres more energy efficient. And without doubt, air conditioning is of great importance, especially for large data centres. For older data centres, energy use for cooling can certainly be as expensive as the use of the IT hardware. Even today, a high-availability data centre like TIER 4, which is over five years old, will hardly be able to achieve a data centre energy efficiency level in excess of 50% (DCiE cf. p. 15), even when exhausting the available measures, since a wide range of measures is required for the efficient air conditioning of large data centres. This starts with loss-free air circulation and separate cold and hot aisles, includes the need for efficient cooling equipment, and even extends to issues of building planning.

A DCiE value of 50% is no longer acceptable for new data centres being planned today. DCiE values of 70% are achievable for large data centres (cf. p. 15), and smaller data centres can lower the cost of cooling even more. If for instance data centres with twenty or thirty inefficient older servers are modernised and equipped with virtualised IT hardware, the total connection output of the servers can, conditions permitting, be reduced so greatly that no air conditioning at all is needed.

Such modern cooling technologies as geothermal water cooling are so energy efficient that a DCiE value of 85% has been achieved in one of the best-practice examples cited in this booklet. Here, the cooling output at a coefficient of performance of approx. 20, i.e. 20 kWh of cooling output per kWh of electricity, requires only 10% of the expenditure of energy needed for the operation of the IT hardware.

Two of the data centres, a small one and a large one, have increased their operating temperatures to between 33°C and 35°C, and can thus cool freely almost year-round. For these systems too, coefficients of performance for cooling are possible that still seemed unthinkable only a few years ago.

## Sixth dimension: Building planning and heat use

If a building with a large data centre is to be kept cool inside, keeping heat irradiation low is not the least important consideration. Building planning which permits as little irradiation as possible, which provides shading of the façade by trees, and that has a shady location for the heat exchangers that is as cool as possible are important goals for such planning.

However, the question of waste heat use is also important. Due to the gradual increase in the acceptable high-temperature limit in data centres, waste-heat flows are increasingly suitable for heating office space. Provision of waste heat to neighbouring properties may also contribute to energy efficiency in some cases.

A small data centre of 48 sq. m. was planned in the middle of an office loft. Given the temperature of 33° to 35°C usually prevailing there, the office could be heated with the waste heat of the data centre at outside temperatures of as low as -7°C, thus saving considerable quantities of primary energy.

## Seventh dimension: purchasing power

Arithmetically, the $CO_2$ emissions from the operation of a data centre can also be lowered by buying environmentally-friendly power. A number of data centres, particularly larger ones, have recognised environmentally-friendly power as a way to improve their corporate image, so that they publicly proclaim the fact that they buy power from “green” suppliers. Critically, the point could be made that, as with $CO_2$ compensation for airplane flights, the supply of inefficient data centres with environmentally-friendly power has the aura of the sale of indulgences for salvation. Therefore, buying “green” power should not be seen as a licence to waste energy, but should rather be a significant supplement to a policy of high energy efficiency, together with the other measures described here.

## Eighth dimension: Management and accounting of energy efficiency

Energy efficiency does not come by itself. It must be seen as an important issue by top management, as many of our best-practice examples show. A responsible employee must be assigned, and it is worthwhile to regularly gather data, to assess it and to integrate energy efficiency in target setting, planning and operations. Questions of energy efficiency and energy cost should be a frequent subject of team meetings. Accounting might also be involved. It is helpful to calculate the energy cost caused by individual clients and to bill for electricity according to consumption. This might enable customers to realise the consequences of their decisions, and generate efficiency related learning.

# ENERGY-EFFICIENCY INDICATORS

Although there are not to date any uniform worldwide metrics for the energy consumption of data centres, or for describing their energy efficiency, much has been done in this area in very recent times. In addition to preliminary work in the scientific area (Greenberg et al. 2006; Aebischer 2008), a number of strategies and suggestions from networks of companies and associations are now available. This includes the work of the Green Grid (2008), the Uptime Institute (Brill 2007), BITKOM (2008 B) and the European Union (2008).

An energy efficiency indicator which places the energy consumption of IT systems – server, storage,

and network infrastructure – into the context of the overall energy consumption of a data centre is presently central to the discussion. The basic idea behind this indicator is that as much as possible of the energy used should be directed to those points where a real function and capacity of a data centre is located – to the computer performance and services of the IT (the server, the storage etc.). Thus, as little as possible of the overall energy consumption of a data centre should be allotted to the uninterruptable power supply, the cooling and air conditioning, and other "energy consumers" within the infrastructure. Hence, "Data Centre Infrastructure Efficiency" is a good initial indicator which can be used to measure and appraise the energy efficiency of a data centre.

The "Data Centre Infrastructure Efficiency" (DCIE) indicator is defined as follows in the EU Code of Conduct for Data (2008):

$$\text{DCIE} = \frac{\text{Main IT equipment energy consumption}}{\text{Total facility energy consumption of the data centre}} \times 100\ \%$$

In the best case, the DCIE indicator is 100%. Of course, especially for larger data centres, this is only a theoretical target value, since an uninterruptable power supply is among the prerequisites for high availability. The metric "Power Usage Effectiveness" (PUE), which is defined as the quotient of total energy consumption and IT energy consumption, is merely an inverse way of showing the DCIE indicator.

An important feature of this indicator is that it can be related both to the power consumption (kW) and to the energy consumption (kWh) of a data centre. While $DCiE_{power}$ is the metric for power consumption (kW) at full load operation and indicates a selective measurement, $DCiE_{energy}$ is the metric for energy consumption (kWh) within a defined time period (a day, week, month, or year). Both options have their purpose, but what is ultimately important is the real energy consumption of a server room or a data centre, so that in this booklet, the indicator $DCiE_{energy}$ has been used whenever possible to indicate energy efficiency.

The figures in the following best-practice examples are based on information from the respective data centre operators, and have been reported according to their best knowledge and belief. The details have been checked for plausibility by the Borderstep Institute; however, that did not include any on-site check of measurement procedures or of the documentation of the measurement process.

The figures for the individual examples are not directly comparable, since the server rooms and the data centres varied considerably in size, function and structure, and have not been examined according to any uniform measurement standard, since to date, no such standard has existed (cf. the explanations in "Outlook").

# The Data Centre at Host Europe GmbH in Cologne

Patrick Pulvermüller, Managing Director of Host Europe GmbH in Cologne

## Facts & Figures

**Operator:** Host Europe GmbH
**Site:** Cologne
**Area:** 550 sq. m.
**Number of servers:** Currently 4,200 Dell servers
**Function:** IT hosting for service and trades
**Average server utilization, mid-2008:**
40%; potential for increase to 80% expected
**Data centre infrastructure energy efficiency (DCIE):**
69% (PUE = 1.45)
**Utilization gain, early 2007 to mid-2008:** +166%.
**Energy consumption 2007:** 4,000,000 kWh
**Internet:** www.hosteurope.de

Host Europe GmbH has provided Internet services to private and business customers in Germany, Austria and Switzerland since 1997. Host Europe operates two spatially separate data centres of its own in Cologne, which provide space for a total of approx. 24,000 servers. While Host Europe had rented the data centre of a large telecommunications company since 2001, they in November 2005 they developed a plan to build their own new data centre themselves. Even then, Patrick Pulvermüller, managing director of Host Europe, and his colleagues saw potentials for improvement: "There were many things where we thought, 'there must really be a better way to do that. Efficiency should really be higher, because we did feel the pain of the electricity bill every month." The new data centre was to be oriented towards a fifteen to twenty year future. For the management team at Host Europe, sustainability – and particularly energy efficiency – was quite simply part of capability for the future. The idea of trying out what might be possible arose very fast.

Contacts with subcontractors were made at the beginning of 2006. The statements of all these companies were ultimately similar: in a large data centre for about 10,000 servers, a PUE value of about 1.6 could be achieved, with considerable effort. This would, however, mean additional costs in the range of a 20% rise, which would be amortised within three to four years after the centre reached full utilisation. Although the IT business is particularly prone to short-term thinking, the management of Host Europe decided to try this perspective. With the firm conviction that the price of electricity, which was already high in 2005, would continue to increase further, they decided in August 2006 to implement an energy efficient data centre with a PUE target value of 1.6. The decision motivated the workforce, and spurred them on to surpass even that target. The responsibility for energy efficiency was with management from the beginning of the project.

The procedure covered activities in many areas. It started with the architectural planning, which minimised heat irradiation into the building, as well as optimising its orientation and its surfaces. The installation of the heat exchanger in a shady area of the building improved its efficiency without additional expense. But very often, the equipment is installed in the wrong place, as Pulvermüller said.

Another key point was the integrated cooling and heat supply for the building. In order to provide

Key Measures

- ▶ **Efficiency-oriented overall planning**
- ▶ **Use of waste heat to heat the office space via a heat pump**
- ▶ **Virtualisation**
- ▶ **Energy management and continuous improvement process**

Heat exchanger in the shade of the building

the 75 kW needed to heat the 2,500 sq. m. of office space above the data centre in winter, a part of the waste heat is "pumped up" to a temperature level suitable for heating by means of a heat pump. Thus, the only primary energy required for heating purposes is that used for the operation of the heat pump. For the cooling plant, several alternatives were examined and compared by external air conditioning engineering specialists. The cooling system ultimately chosen operates at temperatures between 40° and 6°C, and at outside temperatures below 6°C, already gets by with completely free cooling. The use of fans with variable speed control also contributed to efficiency.

Another area which promises increased efficiency is virtualisation. Two years ago, there was hardly a customer who would be willing to buy virtualisation. However, Patrick Pulvermüller sees a positive trend: "There are still customers who say, 'Virtualisation, I don't like it.' But their numbers are getting smaller all the time. Our server utilisation was still 15% at the beginning of 2007; it rose to about 40% by mid-2008." By mid-2008, the now approx. 8,000 physical servers at Host Europe already contained about 20,000 virtual machines. Pulvermüller sees the potential for a further increase in server utilisation to approx. 80%. The utilisation level is also currently limited not only by customer desires, but also by the input/output performance of the hard disks and other hardware factors. A coordinated development of customer contracts, hardware equipment and virtualisation software will ultimately be needed for any additional increase in the utilisation level.

Additional efficiency potential is currently being obtained by a switch to Quadcore processors. The choice of servers using the criterion of maximum data power per watt is however a goal for future years. The results of the server benchmark $SPEC_{power}$_ssj2008 are already being closely observed, however.

The planning also involved the integration of a relatively large number of consumption measurement points, in order to ensure a good overview of energy consumption, and also to enable further progress via regular weak-point analyses and improvement programmes. The data centre was opened with 100 servers in January 2007; by the end of 2007, some 3000 servers had been installed, and about 150 are being added monthly.
In preparations for a next step, a consistent cold-aisle containment is currently being carried out on 15% of the data centre area. The goal is to increase the intake temperature at the air conditioner from the present 20°C to 27 to 28°C, which would mean further efficiency gains in the cooling process. Following the successful test in a part of the area, the rest of the data centre was also gradually converted. There was also the hope of achieving considerable gains by moistening the heat exchanger areas in the outside area, so as to make use of evaporation cooling. However, the heat exchanger area is so big that no net economies can currently be expected from this measure.

Host Europe does not currently plan to obtain energy efficiency certification. The many suppliers who are already lining up for this are not very convincing as yet. What would be helpful would be a recognised standard which could develop from the EU Code of Conduct, and would permit a uniform language of energy efficiency to emerge.

# Next Generation Data Centre in Bangalore with Dynamic Smart Cooling

Chandrakant Patel, HP Fellow and director of Sustainable IT Ecosystem Lab at HP

## Facts & Figures

**Operator:** HP
**Location:** Bangalore, India
**Space of data center: 6,500 sq. m.**
**Application:** Lab data centre for research and testing
**Energy savings through DSC upon start-up:** 20% of cooling energy: ~ 3,750,000 kWh per year
**Planned energy savings after full implementation of DSC:** 40% of cooling energy: ~ 7,500,000 kWh per year
**Internet:** www.hp.com/go/powerandcooling

In 2007, HP began building a 6,500 square meter data center in Bangalore, India, combining the computing power of fourteen existing facilities under one roof. The site uses HP Dynamic Smart Cooling (DSC), which reduces energy and costs by adjusting cooling to the needs of the servers, rather than continually cooling throughout the data centre. This was the largest deployment to date of HP Dynamic Smart Cooling technology.

In 2000, the company's central research organisation, HP Labs started to develop the DSC technology. "The vision was to dynamically provide cooling commensurate with the heat loads in a data centre, and to provision computing, and thus ensure heat loads, based on the available cooling resources." says Chandrakant Patel, HP Fellow and director of the Sustainable IT Ecosystem Lab at HP´s central lab in Palo Alto, California.

At HP Labs, Patel pioneered a holistic approach to power and cooling that encompasses everything from chips and systems to racks and the data centre itself. He also played a key role in establishing energy-efficient computing by founding HP Labs' thermal technology research programme in the early 1990s, and subsequently the data centre architecture programme. Patel suggested that the "data centre is the computer", with its walls akin to the walls of a system enclosure, and it needed an end to end management system with a focus on managing energy as a key resource.

Initial work resulting from the smart data centre research in the late 90s led to creation of computational fluid dynamics modelling techniques and thermo-fluids metrics to statically optimise the data centre at design time. Dubbed "static" smart cooling, this became a service from HP that has been applied to statically provide power and cooling resources in many data centres. The natural evolution from static provisioning was a dynamic solution that would provide cooling resources based on the need at runtime. The resulting Dynamic Smart Cooling solution was first applied in a test at the HP Labs data centre in Palo Alto, California. It was later deployed on a large scale at the new data centre in Bangalore in 2007.

Patel and his team wanted to demonstrate the scaling of its cooling control technology in a real-world, heterogeneous data centre environment. The result is one of the most sensor-rich data centres in the world, yielding a 20 percent reduction in cooling power consumption upon start-up.

The Bangalore centre has 7,500 sensors that monitor equipment environment temperatures and ad-

**Key measures**
- **Consolidation (combining 14 existing lab data centers under one roof)**
- **Implementation of Dynamic Smart Cooling**

just the air conditioning accordingly. Through this design, the data centre yields up to a 40 percent reduction in energy consumption over today's typical data centre cooling methods. The Dynamic Smart Cooling-based data centre is expected to save 7,500 megawatt-hours (MWh) annually – equal to the power consumption of more than 750 US homes – and reduce carbon dioxide emissions by approximately 7,500 tonnes annually.

The project involved consolidating fourteen laboratory data centres in Bangalore into a high-density, 6,500 square metre data centre, one of the largest in India. It is composed of a mix of older equipment and newer server racks and blades, which is common for IT environments deployed in production today.

Real-time data centre air-temperature measurements are obtained from the network of 7,500 sensors deployed on the IT racks – the most ever deployed in a single data center. An agile mechanism responds to facility failures, anomalies and brown outs. The implementation of Dynamic Smart Cooling technology at the Bangalore data centre was conducted remotely from HP Labs in Palo Alto, in conjunction with the HP Systems Technology Software Division team in Bangalore. Today, Patel can manage the DSC system remotely from California, e.g. while sitting on a bus, commuting to work. In future, HP plans to use the data centre to advance technology through research on management of physical resources, including power profiling and data analysis.

Dynamic Smart Cooling consists of advanced software residing in an intelligent control node that continuously adjusts air conditioning settings in

Dynamic Smart Cooling Sensors

HP Site in Bangalore

a data centre, based on real-time air-temperature measurements from a network of sensors deployed on IT racks. The technology actively manages the environment to deliver cooling where it is needed most, enabling essential cost savings and improved utilisation to customers. Unlike other industry solutions, Dynamic Smart Cooling actively manages data centre cooling, while reducing cooling power consumption. "Today the inlet temperature to the server racks in our data centre in Palo Alto is 25° C. In Bangalore we run our data centre at 27° C and we are planning to raise the temperature beyond that point, but of course we first have to know, what effects this has on stability and uptime. We want to conduct thorough researched, based on our product lifecycle perspective, in order to get the most out of operational energy savings by increasing the temperature to the server racks, and applying thermo-mechanical techniques to gain of the end of life consequences of higher temperatures," says Chandrakant Patel.

When asked whether data centre managers will accept new approaches in order to save energy, he draws attention to an experience he had some years ago: "In a speech at a conference for IT and facility managers in 2002, I was promoting the idea of energy efficiency in data centres using numerical model-ling and controls to increase the temperature to minimize thermodynamic work, and to minimise flow work. One of the attendees suggested that no data centre manager is fired for wasting energy, but would be fired if the IT system shutdown. Today it is clear, that both reasons are sufficient to fire a data centre manager!"

# Server Based Computing at a Secondary School in Hanover

Senior teacher Claus-H. Schröder at the server rack at the Humboldt School

## Facts & Figures

**Operator:** Humboldt School, Hanover
**Site:** Hanover
**Area:** 28 sq. m.
**Server number:** 7 servers, 94 CPUs
**Function:** Data centre for all educational and management software
**Average server exploitation 2008:**
5% to 10%; peak 30%
**Data centre infrastructure energy efficiency (DCIEpower):**
86%; (PUE energy = approx. 1.16)
**Energy consumption in comparison with a conventional solution:** 50%.
**Internet:** www.humboldtschule-hannover.de

Like many schools, the Humboldt School in Hanover had no data centre on its premises at all just a few years ago. However, the number of PCs has risen constantly. Everything started in the nineties. "When we had only one room and fifteen PCs, exactly one teacher did it all," reports the school's manager, senior teacher Claus H. Schröder.

But then, the number of the PCs increased continuously. For first network functions, two servers were acquired and the PCs integrated into a network over the course of time. Today, the school has approximately 100 workstations, but they are no longer PCs. The maintenance effort for individual PCs grew out of all proportions. Finally, before the data centre was reequipped, the constant re-start-up of crashed PCs was such an added work load on the responsible teachers and an Employment Office-assigned worker, that often 30% of the PCs were down. In some places, it was necessary to wait three months for a truly educationally capable device to be working again. The situation could not continue in this manner. "We simply were not able, due to time constraints, to install a hundred PCs locally as single user stations," says Schröder.

In the spring of 2007, Schröder and his colleagues developed a plan to acquire additional servers and replace the school's PC stock with terminal workstations which would no longer run software of their own, but which would merely organise the data traffic between the server, the keyboards and the screens. Later, these would be replaced by "thin clients", which lower the expenditures for both replacement procurement and energy consumption, and increase the lifespan of terminals.

Environmental protection has been important at the Humboldt School for a long time. It was therefore important for the teaching staff that the design of the data centre should also meet the demands for energy efficient equipment.

In response to a tender, a regional system provider offered to deliver energy saving servers. A comparison of bids showed that in addition to the two available servers, either five conventional or five energy-saving servers should be used. The electricity consumption was estimated at approx. 120 watts for the conventional equipment and 35 watts for the energy-saving variant. The new e-mail server actually gets by on 22 watts. The decision was made in favour of the energy saving servers, which were installed during the summer holiday in 2007.

**Key Measures**
- ▶ **Energy saving server**
- ▶ **Planned switch to the thin client based computing**

Due to the low energy consumption of the servers, no air conditioning was necessary in the basement room of the data centre. Even after a long heat wave at the beginning of July 2008, only 29°C were measured in the data room. Since the UPS and the lighting, which only run during maintenance periods, are the only power users other than the IT hardware, a PUE value of 1.16 was achieved.

Today, all the school's software runs in the data centre. This includes the software for the maths and data science lessons, the photo editors in art classes, multimedia use in language instruction, Internet searches, and the management programmes for the school administration and schedule management. Basically, there is no longer any software, other than that for a few exceptional single user datas. This is essentially the reason that the disturbance reports have decreased considerably. The availability of the work-stations has increased from about 70% to about 95%. As to the saved work for re-starts of PCs, Schröder says: "The work time may have dropped a little, but I can now work much more efficiently during the time I have."

There was no opposition to the reorganisation of the EDP structure to a purely server based system. The teaching staff and management left such planning and decision-making entirely to the two competent teachers. All of them have ultimately profited from the new structure, since it provides considerably higher use availability for everyone. It was difficult, however, to convince the city, which runs the school, of this solution. Since the investment costs had to be borne by the city, it had to be convinced of the profitability of the solution. Here, the guarantee of high availability of EDP capacities played an important role. The fact that the approx. €23,000 server solution promised a relatively moderate expenditure for electricity of approx. €600 annually made the decision easier, and was a clear argument in favour of the choice of the energy saving servers, without which the cost of electricity would have been twice as high.

The responsibility for the operation, and also for the energy efficiency of the data centre, lies with the two competent teachers. They run the entire data centre for the school with its staff of ninety teachers, together with the assistant provided by the Employment Office, who changes frequently. Since the above average energy efficiency is achieved through the infrastructure and not through any particular manner of operation, neither special responsibilities nor regular consumption measurements have been introduced to date.

The perspective for the near term is that there is a good chance for further expansion of the data centre. Since certain classes are equipped with notebooks, on which a client is also to be installed, the use of the data centre will increase. With further development, it could become even more efficient due to virtualisation, which has not been used to date.


The energy saving server consuming only 35 Watt

# NetApp, Sunnyvale, proves Big Energy Savings through Free Cooling

Dave Shroyer, Controls engineer at NetApp© data center, Sunnyvale, California

## Facts & Figures

**Operator:** NetApp
**Location:** Sunnyvale, California
**DC floor space: 700 sq. m.**
**Rack area: 676 sq. m.**
**Application:** Company internal processing, testing
**Building certifications:** LEED Green Building Rating System™
**Data centre infrastructure efficiency (DCiE) 2006:** 67% (PUE = 1.48)
**Data centre infrastructure efficiency (DCiE) 2007:** 84% (PUE = 1.2)
**Total annual energy use 2006:** 6,051,709 kWh
**Total annual energy use 2007:** 6,764,350 kWh
**Internet:** www.netapp.com

Implementing an air side economiser and using free cooling solutions can yield big energy savings, as the NetApp Building 11 Data Center in Sunnyvale, California, has proven. NetApp is a leader in storage and data management solutions. Founded in 1992, the company with its headquarters in Sunnyvale, today has more than 8,000 employees and 130 offices worldwide, and is a member of the Nasdaq 100. In 2008, NetApp was honoured for its innovative storage efficiency, data centre design, and techniques to reduce power consumption in its data centre. It was also selected as a winner of the Green Enterprise IT Award by the Uptime Institute.

The energy conservation measures implemented in the NetAPP Building 11 Data Center were mainly triggered by two things:
First, the environmental targets set within the NetApp Environmental Management System, implemented in 2004 and certified according to ISO 14001: As part of its environmental programme, NetApp set an energy savings target of 2% per year for the whole company. "This target activated us to look for additional energy saving potentials," says Dave Shroyer, controls engineer at NetApp and responsible for building control infrastructure at the company's headquarters . "A second cause for looking into new energy saving possibilities was the Energy Watch Partnership Program of the Silicon Valley Leadership Group."

The NetApp Building 11 Data Center has a total area of 6,764 sq ft. It is cooled by eight (N+1) 33 tonne computer room air handling (CRAH) units. Each unit has an airside economiser, chilled water cooling coils, two supply fans powered by two 7.5-hp motors, and two exhaust fans powered by two 2-hp motors. Each set of motors is controlled by a variable frequency drive. Supply air is conveyed to the data centre via an overhead ducted distribution system and return air is conveyed back to the unit or to the outside by the exhaust, via the ceiling plenum. Two 250 tonne electric chillers provide the chilled water to the CRAH units. A cogeneration plant powers the three 100 tonne adsorption chillers. The cogeneration system and the adsorption chillers operate only during peak and/or part-peak hours (based on an economical dispatch model): May to October, 11:30 a.m. - 6:00 p.m., Monday through Friday.

**Key measures**
- **Re-setting supply air temperature to servers**
- **Wireless sensors to enable computer room air handling**
- **Free cooling**
- **Plastic curtains and plates to segregate hot and cold aisles**


Physical barriers between hot and cold aisles

In 2006 NetApp formed a cross-organisational, multifunction team to approach the task of reducing power consumption and increasing energy efficiency in its data centre. “Teaming up for improvement and close cooperation between the IT folks and the building and infrastructure engineers certainly is a key success factor in identifying and implementing energy saving measures in data centres”, says Dave Shroyer. The NetApp-team shared ideas and know-how, and developed efficient storage and innovative design techniques to optimise overall power efficiency through the modification of NetApp’s data centre power delivery and cooling systems. Energy conservation measures (ECM) were implemented. One of those measures was the Data Center Cooling Control Program (DCCCP), which consisted of the following:

- Plastic curtains and blank off plates to segregate hot and cold aisles (May 2007)
- Installation of an array of wireless sensors at the face of the information technology (IT) equipment racks to enable computer room air handling (CRAH) unit supply air temperature (SAT) to be controlled by the temperatures from those sensors (June 2007), as well as hot aisle wireless sensors for measurement of air flow efficiency.
- Control sequence to allow CRAH unit fans to be controlled based on the cold aisle temperature measured by the new wireless sensors (July 2007)
- A control sequence, to optimise the economisers (July–September, 2007)

One key finding of the measures was that the physical barrier reduced the mixing condition substantially. In the pre installation condition, the temperature differential across the hot and cold aisles averaged 6°F. Installing the curtains increased the temperature differential to an average of 22°F. This means that the heat exchange across the aisles improved by a factor of greater than 3. Immediately after the curtains were installed, a 41 kW reduction in demand was observed.

Another key finding was that it is possible to deactivate the cogeneration plant completely (based on gas prices vs. energy costs ) and use a complete free cooling solution in certain times of the year. In 2007, NetApp provided five days to test the performance of the data centre’s HVAC systems with the cogeneration plant deactivated. The data collected was used to calculate the energy savings.

For all the measures together NetApp calculated annual energy savings of 1,159,065 kWh, and a reduction of annual electrical energy costs of $134,400. This is a reduction of 19.2 % over baseline annual usage. The total energy use of the data centre in 2006 was 6,051,709 kWh. This led to an improvement in data centre infrastructure efficiency (DCiE) from 67% in 2006 to 84% in 2007. The data centre now meets or exceeds the EPA’s 2011 energy usage state-of-the-art data centre maximum achievable scenario.

NetApp also dramatically increased storage utilization and reduced power consumption through innovative data management and design. NetApp consolidated its storage systems and replaced fifty systems with ten NetApp® storage systems, increasing capacity utilisation to more than 60%. In addition, NetApp reduced its data centre footprint from 24.83 to 5.28 racks.

Despite of the fact, that energy efficiency improved substantially, total energy use of the NetApp Buildung 11 Data Center grew from 6,051,709 kWh in 2006 to 6,764,350 kWh in 2007. The simultaneous increase in energy efficiency and total energy use might sound contradictory, but it is due to the increase in the number of servers and storage units. Dave Shroyer concludes: “This increase would have been dramatically larger had we not implemented energy savings.”

# Consolidation and Virtualisation of the City of Copenhagen Data Centres

Data Centre Team City of Copenhagen

## Facts & Figures

**Operator:** City of Copenhagen
**Location:** Copenhagen
**Space of data center:** 230 sq. m.
**Application:** Central IT for te city administration
**Number of servers:**
before project: 700 after project: 80
**Total annual energy use 2007 (before project):** 1,400,000 kWh
**Planned server utilisation level:** 70%
**Planned energy savings through consolidation and virtualisation:**
75% of total energy consumption
**Internet:** www.kk.dk

The City of Copenhagen used to run its IT system at fifteen different server locations. The total number of servers in these small data centres was about 700, and their total electricity consumption totalled 1.4 million kWh per year. In general, the diffusion of small data centres throughout the city was not efficient. In 2007, it was therefore decided to centralise the IT system in a new shared service centre, at a single location.

The new IT unit was formed in 2007 and employs 250 persons. Twenty of them work directly with servers, storage area network (SAN) and data centre operations.
The IT unit is responsible for all IT tasks necessary for the 40,000 employees of the city administration, some 20,000 to 25,000 of whom are frequent users of IT services.

One of the first big projects to be carried out was a project to consolidate all fifteen data centres to two central server rooms of 180 sq. m. and 50 sq. m., respectively. For the management of this project, the City of Copenhagen's internal consulting group was employed. Andreas Hare acted as external consultant of this project, the main objective of which was to save money and to make the work more efficient. The project started in 2007 and the new data centre will be in full operation in early 2009.
The project started by forming a team and performing a status analysis of the existing IT with its software and hardware components. The conclusion was that 650 of the total of 700 servers were running applications which could also be run on virtual machines. Fifty old servers were busy with applications which did not seem to be suitable for virtualisation. It became clear that virtualiszation software was necessary, and also that new servers had to be chosen. Andreas Hare reported that energy efficiency was an important objective within the team: "You can say that energy efficiency saves money, so that was an important factor. We were focusing a lot on that when we spoke with the team. It was a very important part of the project."

The project is also contributing to the realisation of the vision for climate policy for the City of Copenhagen, which calls for a $CO_2$ emissions reduction of 20% by 2015. This project reduces the $CO_2$ emission from server operations by 75%, or about 1000 tonnes of $CO_2$ per year.

Subsequently, IT suppliers were taken into the team to support the detailed planning process. Another supplier was to focus on such data centre infrastruc-

**Key Measures**

- Consolidation
- Virtualization
- Efficient Servers
- Free cooling
- Hot and Cold aisle segregation

ture as power supply, server racks and cooling. Regrettably, the co-operation of the IT-people and the infrastructure people was initially not very good. The problem was overcome by a large number of meetings, at which all problems were repeatedly discussed, until there was consensus on a common solution.

The outcome of the planning process was a set of detailed plans for the two new server rooms. "About 650 physical servers will be virtualizsed on thirty-two physical machines as virtual hosts, reducing the number of physical servers by a factor of twenty," says Andreas Hare, describing the plan. Together with an additional fifty old servers which would not be virtualised during the first phase of the project, a total of eighty servers could in future carry the IT load of Copenhagen's administration. The average utilisation level, which is now below 20%, will rise to around 70%. The projected energy consumption of the new server rooms is 300,000 kWh/a to 400,000 kWh/a, resulting in a reduction of about 75% to 85%.

During the process, the data centre infrastructure too was optimised. A 200 sq. m. concrete room was prepared to host the main part of the data centre. The servers have been built in two rows of server racks. The space between these server racks forms the hot aisle, which is usually run at a temperature of 30°C or more. The space around the servers forms the cold aisle, and is kept at 22°C.

The cooling is mainly done by free cooling. Huge free coolers are situated in the shadow on the north side of the building, and enable the system to rely on free cooling when the outside temperature is less than 2°C below the temperature of the returning water, with a current load between 17 and 18°C . In Copenhagen, this is the case about eight months of the year. The free coolers cool down a water cycle, which in turn cools the hot aisle. A number of compressors will kick in and cool the remaining portion if necessary. The water is cooled down to 12°C, which means that with an outside temperature of 10°C or less, the compressors do not run at all. During the project, it was decided to make no use of the waste heat. There was no possible economically viable use of a heat source of 30°C.

The electricity supply of the data centre mainly relies on the Copenhagen electricity grid. A generator is available to take over in case the grid supply breaks down. Moreover, a high efficiency uninterruptible power supply, with an efficiency rate of 94%, has been installed.

Since the final objectives of the project were cost reduction and work efficiency, there was no person ultimately responsible for energy efficiency. On the other hand, in all negotiations with suppliers, energy efficiency was a matter of concern.

All in all, about 1 million kWh per year will be saved, leading to a cost reduction of about €220,000 per year. The overall cost reduction of the new data centre is estimated to be at least €600,000 annually. Measured against the overall IT budget for server operations and data centres of around €3 million annually, that is a considerable saving.


Dell R 900 Servers hosting, 20 virtualised old servers each

# The Vision of the "One Percent Data Centre" of b.r.m. Technologie & Managementberatung, Bremen

## Facts & Figures

**Operator:** b.r.m., Bremen
**Area:** 48 sq. m.
**Server number:** 56 blade servers
**Function:** IT-Hosting for Service and industrial clients
**Average server exploitation 2008:**
50% to 60%
**Data centre infrastructure energy efficiency (DCIE):**
80%; (PUE = 1.25)
**Energy consumption 2003 – 2007:** -48%.
**Internet:** www.brm.de

Harald Rossol, Founder of the b.r.m. technology- and management consulting, in front of the Blade Server

Since 1994 the company b.r.m. – Business Resource Management Technologie- und Managementberatung has operated a data centre which runs a wide variety of applications for customers from the service and production industries. Initial measures for increased energy efficiency were already undertaken before 2003: regular maintenance work was performed on the air conditioner, optimal air circulation was ensured, and the fans were regularly checked.

But by February 2003, these measures no longer satisfied b.r.m. founder Harald Rossol. Further expansion of the air conditioning system seemed necessary: "I was in the server room and was annoyed. It just couldn't be that we put 1 kWh for the operation of our servers, and then the same amount or even more into removing the excess heat." Harald Rossol did not just swallow his annoyance; he started to rebuild his data centre completely. "It simply seemed absurd to us to supplement technology which produces a lot of heat by more technology to cool the room down again."

Harald Rossol quickly realized that statements in the literature and in the claims of various suppliers on degrees of effectiveness, recommended room temperatures and other matters, were often contradictory. Summing up his experience in early 2003, he recalls, "We questioned everything, we believed nothing!" The restructuring process started with the integration of the first blade servers in March 2003. Rossol selected this server type because it was designed well and seemed likely for thermodynamic reasons not to exceed the permitted maximum processor temperature, even at exceptionally high room temperatures. One blade server replaced approx. fourteen conventional servers. This measure was accompanied by a gradual increase in room temperature from 21°C then to 33°C to 35°C today. This rise was accompanied by extensive measurement measures, with which various temperature standards were monitored at the servers. To this day, there has been no temperature-related failure of the IT hardware. Rossol makes the point: "It's like spinach: The statement that the temperature in a data centre must be exactly 21°C is just as wrong as the accepted scientific statement that spinach contains a very large amount of iron."

**Key Measures**

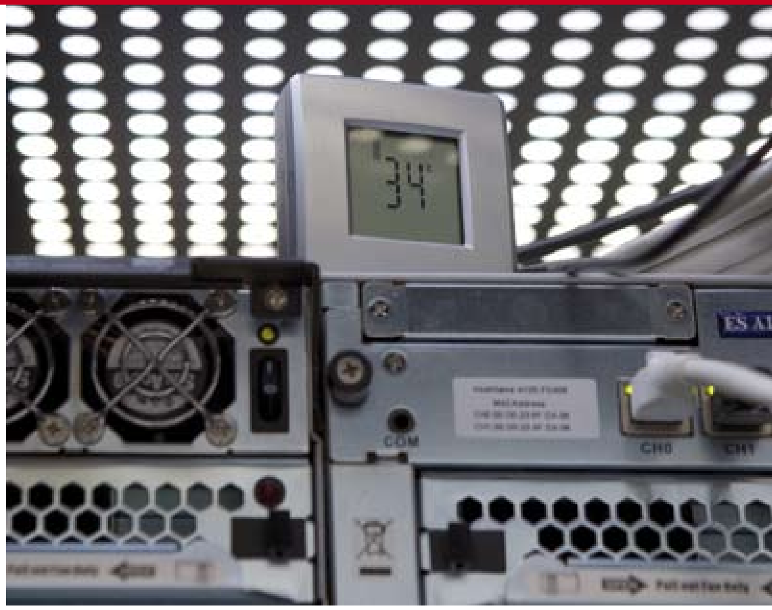
- ▶ Increased room temperature
- ▶ Waste heat used for heating the office space with a fan
- ▶ Free cooling almost year-round
- ▶ Virtualisation

One objection to high temperatures is that one cannot expect mechanics to put up with them. b.r.m. solves this by planning. In case of planned installation work, the data centre is cooled down to a tolerable temperature within six to eight hours, or overnight. Today, moreover, maintenance work on the server is generally carried out via teleservice. "And another scenario: a total crash of a hard drive: You go in there, pull out the hard drive, and shove a new one in. That takes two minutes. And you can handle doing that at 35°C," Rossol says.

The high room temperature of the data centre makes it the heating room. Since 2006 the company with its current eight employees has been located in a 6 m high loft on the Weser in Bremen. The data centre with its fifty-six blade servers and 200 CPUs is a large 48 sq. m. cube in the middle of the space. And thanks to a controllable ventilation system, that data centre the only "heater" in the loft for temperatures of -7°C or more. Only at temperatures below that, which are rare in Bremen, is additional heating necessary. The high temperature in the data centre also makes it possible to operate at ambient temperatures of more than 25°C without using the chiller, except at peak load times and on some summer days. The result is a PUE value of 1.25.

For Rossol two other aspects are particularly important, in addition to the right server type and the high room temperature. On the one hand, there are efficient power supplies which make additional economies possible at low additional cost. On the other, there is virtualisation of applications. Average server utilisation was 5 to 20% before virtualisation; today it is at least 40%, and can reach 80%; average utilisation is 50 to 60%.

As the owner and managing director of b.r.m., Rossol considers himself responsible, too, for energy efficiency. And for good reason, for the innovative experience which b.r.m. has gained also opens up markets in green-IT counselling. Many partners have been important for b.r.m. along the way – plumbers, climate specialists, IT experts... He could only make his vision come true with his team – but he is not finished: "In a few years, I want to have realised the 1% data centre – a data centre with the same data power as in 1998, but which consumes only a hundredth of the energy of that data centre." Although many laughed at him in 2003, when his target was a 40% drop in energy consumption, that target has long been achieved, and the sceptics have



34°C in the data centre

shut up. In 2009 and 2010, Rossol still wants to realise a number of measures, and to take another big step towards his goal.

The energy savings from all measures have been approx. 65% to date. Power consumption, temperature and humidity are constantly measured inside and out, for purposes of documentation. The energy-saving high-end data centre is characterised by numerous synergies, in addition to the primary benefit of some 50% lower power use:

- the energy requirement for the heating system has been reduced
- very minimal noise emissions and highly integrated servers permit completely new structural integration
- a very efficient server management lowers personnel costs
- the image gain brings new customers.

To boost the image advantage even more, an energy consumption certification is currently being planned. The drop in power consumption has also meant cost advantages – from about 120,000 kWh in 2003 to 62,000 kWh in 2007, although data capacity increased by 30% during the same period. The cost of electricity was thus reduced by about €11,000 a year. Ultimately, energy costs amounted to only 10% of business expenses for the data centre. In addition, approx. €3,000 in heating and hot-water expenditures were saved annually. Reduced air conditioning and cooling in the building saved approx. €2,000 per year.

# EvoSwitch: The Climate-Neutral Data Centre in Amsterdam

Laurens Rosenthal, co-founder and innovation manager at EvoSwitch

## Facts & Figures

**Operator:** EvoSwitch
**Site:** Amsterdam
**Area:** 9,000 sq. m.
**Server number:** currently, 14,000 servers; goal, approx. 40,000 servers
**Function:** IT hosting for Internet suppliers
**Average server utilization, mid-2008:** differs according to customer
**Data centre infrastructure energy efficiency (DCIE), early 2007:** 56% (PUE = 1.8)
**DCIE 2008:** 63% (PUE = 1.6)
**Planned DCIE (final state):** 83% (PUE = 1.2)
**Energy consumption in 2007:** 44,000,000 kWh
**Internet:** www.evoswitch.com

EvoSwitch is a co-location data centre in which many carriers, ISPs and Internet Exchanges in the Amsterdam area are located; the company was founded in 2006. The parent company OCOM (www.ocom.com) has ninety employees today, of which twenty-five are in the data centre. The building housing the centre was built at the time of the New Economy hypes around the turn of the millennium, but was never brought into operation at all, since the builder went bankrupt at that time.

In 2006, a group of three experienced Internet specialists who wanted to start up a data centre of their own, got together. Laurens Rosenthal, one of the founders, was in charge of innovation. The group acquired the unfinished data centre and started a fundamentally new type of planning of technology. The core idea was to build a powerful and energy efficient data centre. The fact that this was a start-up was also an advantage, since it made them independent of "tried-and-true technologies", and they could plan on a virtually fresh field, as it were.

They were cooperating with the Dutch Organisation for Applied Scientific Research (TNO), but also with many specialists from the industry. In the course of planning, it rapidly became clear that the entire infrastructure already installed had to be called into question. Thus, the existing uninterruptable power supply (UPS) was considered too inefficient, and replaced. Rosenthal remembers: "There was a UPS in the infrastructure which had already been installed. Unfortunately, it did not meet our expectations in the efficiency test. It also proved to be very maintenance intensive and not reliable enough. We ended up dismantling and replacing this UPS. Today, EvoSwitch has a UPS with delta conversion and a degree of effectiveness of approx. 97%.

The development of EvoSwitch was carried out in three phases. The first 2,000 sq. m. with some 900 racks were brought into operation at the beginning of 2007. Another area of equal size could be brought into operation in the summer of 2008. Finally, 5,000 sq. m. are to go into operation in the third and another 6.000 sq. m. in the fourth phase.

The separation from cold and hot aisles is important for the overall efficiency of the data centre, because only by means of the consistent separation of the cold and hot aisles do the high temperatures become possible. The cold aisles are provided with air of 24°C, in the hot aisles, temperatures of approx.

**Key Measures**
- ▶ **Efficiency-oriented overall planning**
- ▶ **High temperatures in the hot aisles and free cooling**
- ▶ **The customers are billed for energy expenditures**

35°C prevail. In turn; only these high temperatures in the hot aisles permit a major share of the cooling to be accomplished freely rather than via chillers. The COP value of the cooling could in this way be increased to a value of about 9, i.e., for every kW of electrical power output, 9 kW of heat energy could be removed. EvoSwitch has had a free cooling system installed – an energy-saving cooling strategy, in which cool outer air is skilfully used. Given the temperatures prevailing in the Netherlands, the compressor is necessary for only about 200 hours per year. Currently, EvoSwitch is developing and testing new methods of free cooling aimed at achieving a COP in excess of 20 when  the last 5,000 sq. m. goes into operation.. the idea, says rosenthal, is "to use all the heat sinks that Mother Nature has given us in Holland."

This continual improvement in cooling, together with an efficient UPS, make a continuous reduction in the PUE value possible. It was 1.8 at the time the system went into operation, the 1.6 mark was reached in the summer of 2008, and the target is 1.2 to 1.3 – a figure which is remarkable for such a large data centre.

Generally, co-location data centres have few possibilities of affecting the nature of the hardware installed, or its energy consumption. In order to nevertheless promote energy conscious behaviour on the part of the customers, EvoSwitch has installed electricity meters for each customer. The power consumption is not only measured separately for each rack, but is also billed separately for each customer as a supplemental item. For many new customers who were used to all-inclusive prices from their previous data centres, with a flat rate for energy, this involves some reorientation. Generally, however, EvoSwitch has experienced appreciation of the extra invoice from its customers.  "And issues of efficient software, consistent virtualisation and efficient hardware components will be decisive for energy efficient data centres in future. Our role is to advise the customers, and support their learning on issues of energy efficiency," says Rosenthal.
On the customer side, Rosenthal is currently observing the "roll-out" of virtualisation. However, while interest in energy efficient hardware is growing, the availability of benchmarks and clear technical data is still limited.

Ultimately, the commitment of the three founders has been the key to driving the move towards energy efficiency. The issue is regularly mentioned at management and design meetings. In addition to the certifications under ISO 9,001 (quality management) and ISO 27,001 (IT security), they are currently seeking certification under ISO 14,001 (environmental management) as well. On the other hand, the proceedings for energy efficiency certification will only make sense for EvoSwitch if publicity makes them an important factor for customers.

EvoSwitch is a member of "The Green Grid", and buys renewable power generated by wind, solar and biomass. To compensate for such non-sustainable energy consumption as emergency generating sets and company cars, EvoSwitch has initiated compensation projects together with the Climate Neutral Group.


Cold aisle at EvoSwitch

# Cooling with the Earth at Bechtle in Solingen

Bernhard Margos, Managing Director of Bechtle Solingen, in front of a side cooler

## Facts & Figures

**Operator:** Bechtle GmbH
**Site:** Solingen
**Area:** 40 sq. m.
**Number of Servers:** 6, plus backup servers
**Function:** Internal IT and application proof-testing for customers
**Average server utilitsation, mid-2008:** 30 -40 %
**Data centre infrastructure energy efficiency (DCIE):** 85% (PUE = 1.17)
**Total energy consumption, 2007:** approx. 184,000 kWh/a
**Total energy consumption 2008:** approx. 72,000 kWh/a
**Consumption reduction:** 61% over 2007
**Internet:** www.bechtle.com

The system house Bechtle operates a small data centre for its internal IT and for application prooftesting for customers at its site in Solingen, as well as at other sites. The planning of measures for the modernisation of the data centre started in August 2007. The main purpose was to introduce virtualisation, but also a modern cooling system.

Bernhard Margos, managing director of Bechtle solingen, first discovered geothermal cooling of servers, at a customer's: "One of our customers was doing something like that. We offered him a classic split air conditioner, but he took care of his server cooling for half the price with geothermal energy. That annoyed me greatly. We were using a technology which was not only outdated, but also twice as expensive as geothermal energy."

Experts of the North Rhine-Westphalian energy agency supported Margos in his efforts to implement geothermal cooling at Bechtle, too. Shortly thereafter, Bechtle came upon the concept of lateral rack cooling, the so-called side cooler, which enabled the removal of high output densities using water as the coolant. That fit perfectly into a combination with the cooling water obtained from geothermal energy. Roughly, a COP of about 20 was to be expected from the new cooling technology, since about 500 watts of pumping power could provide water with a cooling capacity of approx. 10 kW. Compared with cooling with groundwater, this technology has the advantage that it does not face any major permit hurdles. While permits for groundwater withdrawal are only seldom issued, a permit for geothermal investment is no major problem. In 2007 alone, heat pump systems for the heat supply for about 45,000 detached homes were approved and installed. In order to provide the cooling performance of 12 kW planned by Bechtle, three drillings of 80 m each were undertaken. The drillings are 6 m apart. Two circulation pumps working redundantly and fed via the UPS reliably maintain the cooling supply, with access to the different drillings.

The two side coolers installed to the right and left of the racks must be provided with a flow pipe temperature of 14°C to ensure condensate free operation. At a depth of 80 m, a largely constant temperature of approx. 11°C prevails, so that the brine mixture emerges from the soil at a temperature of approx. 11°C. The inflow pipe temperature regulation provides a constant temperature of 14°C, which is passed on to the side coolers. The heat from the EDP components – the servers and other active components – is drawn into the side coolers, which heats

**Key Measures**

- ▶ Geothermal water cooling
- ▶ Virtualisation
- ▶ 2.5 in. drive technology

The earth coolness comes out here

the brine to approx. 19°C. The warm brine is then passed back into the soil via the return pipes with the help of the circulation pump, where the heat is withdrawn again. The warm brine of 19°C is thus cooled down to 11°C again. The 11°C brine is then passed back to the side coolers.

The second major measure was the virtualisation of the servers. Since April 2008, all eighty-nine virtual machines have been operated on six physical blade servers with twenty-two CPU cores. Server utilisation has been increased by means of this measure from approx. 10% previously to 30 to 40% today. Margos considers it possible that a further optimisation of the hardware could increase this figure to approx. 50 to 60% in the medium term.
On the IT hardware side, a decision was made in favour of the energy-saving 2.5 inch hard drive technology, both for the virtualised storage and for the blade servers.

The result of this combination of measures was that the previous annual consumption of the data centre of 184 MWh in 2007 could be lowered to about 72 MWh in future. The major share was provided by the virtualisation, which caused an electric power consumption drop from 126,000 kWh to 61,500 kWh in the IT hardware. But the new cooling concept, too, is important. In 2007, cooling with conventional split air conditioning still caused a power consumption of approx. 50,000 kWh; with geothermal cooling, this dropped by more than 90%, to 4,500 kWh. These measures also reduced the PUE value from approx. 1.46 to 1.17.

Managing Director Bernhard Margos is himself responsible for the data centre, and he is also in charge of the IT division, with its sixty employees. The goal of the data centre is not only to handle the internal and external applications, but also to prooftest new technologies, to gain experience for the customer advisory service. At Bechtle's future Solingen site, plans already call for connecting geothermal cooling with geothermal space heating. This can ensure that even over the long run, the soil will not gradually heat up due to the constant influx of heat. For in winter, the same holes would be used to withdraw heat again, for heating purposes.

# The Integrated Energy Strategy at the Fraunhofer ITWM Data Centre in Kaiserlautern

## Facts & Figures

**Operator:** Fraunhofer ITWM
**Site:** Kaiserslautern
**Area:** 120 sq. m.
**Server number:** 180 servers for IT services and > 400 in the HPC area
**Function:** Internal IT as well as scientific HPC applications
**Average server utilisation:**
Terminal server 10%, HPC 70%
**Data centre infrastructure energy efficiency (DCIE):** 70%
(PUE = 1.43)
**Total energy consumption:**
approx. 1,600,000 kw/a
**Internet:** www.itwm.fraunhofer.de
**Green 500:** www.green500.org

Dr. Franz Josef Pfreundt and the computer Pegasus, no. 1 of the "Green500" ranking list and with that the most energy efficient supercomputer of the world in June 2008

In 2002, the Institute for Technical and Economic Mathematics (ITWM) of the Fraunhofer Society in Kaiserslautern decided upon a new building. The energy efficiency of the building, which was brought into use in 2006, profited from the happy coincidence that Dr. Franz Josef Pfreundt was not only director of the Competence Centre for High Performance Computing (HPC) and the visualisation and IT manager of the ITWM, but was also involved in the coordination of the project planning. In this capacity, he was able to implement a vision: An integrated plan for the building aimed at minimising energy consumption, using the necessary energy efficiently, keeping primary energy consumption as low as possible, and creating a pleasant work atmosphere. The energy consumption for the IT operation and the use of the the waste heat of the data centre were key elements in this concept.

The points of departure for the concept were measures taken at the building itself, which were as passive as possible, designed to reduce the heating and cooling requirements, and to use environmental energy – cold outside air and sunshine. Thus, the reorientation toward thin client and server based computing was addressed very early. That permitted the workplace PCs, with approx. 80-200 watts of connection performance each, to be replaced by thin clients of approx. 20 watts, which reduced the cooling needs in the offices. At the same time, the required servers could be consolidated in the data centre. That reduced overall electricity consumption, and allowed the remaining heat to be used for heating purposes centrally and more efficiently. It is thus not lost, and certainly must not be "cooled down" again year-round at great expense.

HPC systems are extremely power-hungry. In an internal research project in 2004, strategies for an energy efficient HPC cluster were developed and tested in practice. The Linpack benchmark, used since 1993 to measure computer performance in high performance computing, was used as the metric for the consumption of the computer systems. "Since the test is performed at nearly 100% utilization of the machines, the measured result in MFlop/Watt is the right one for the HPC system – you will hardly get higher power consumption than that," said

Key Measures

- Cooling with outside air
- Thin-client application
- Regulation of waste air temperature to approx. 30°C
- Waste-heat use in atriums
- Generation of cooling via absorption refrigeration, driven by exhaust heat from block-scale power plant
- Hardware procurement using energy efficiency as criterion

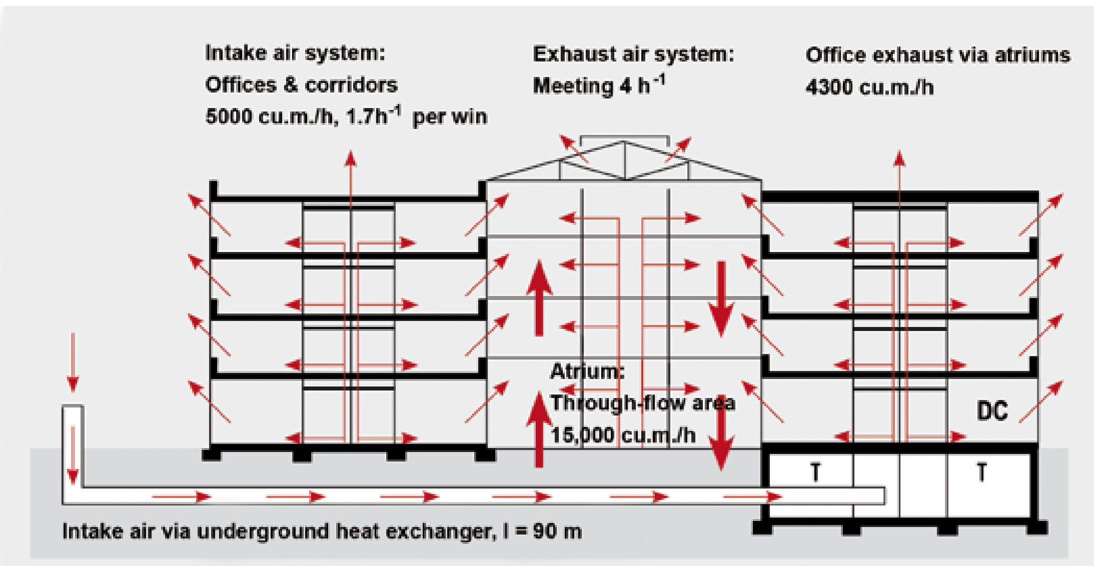
Pfreundt, assessing the significance of the test. That would mean an energy reduction potential of 50%, if all components – fans, fan speed, power supply, low-voltage CPUs and the hard drive – were optimised. The invitation to tender required the suppliers to measure and document energy indicators. With its latest system, a cell cluster purchased in 2008, the Kaiserslautern institute even advanced to the worldwide peak of the "Green 500" list of the most energy efficient supercomputers.

A further component of the energy strategy is the high waste air temperature, which represents the controlled variable within the system. "When we started operations, the waste air was removed at 25°C. We have now increased this value to 30°C over time. Nevertheless, we do not get excessive temperatures at the components. We check that by measurement," says Pfreundt. Although the "cooler" waste air could, at 25°C, also be used for warming the atriums, the rise of waste air temperature would still make free cooling possible for a longer period of time during the year, which is today accomplished by the introduction of fresh air up to an outside temperature of 18°C.

Nevertheless, the facility must be additionally cooled in summer. The cooling output of the basic load is therefore provided by a 200 kW absorption which is powered by the waste heat of the gas driven 240 kWel block-scale power plant. It can thus also be operated in summer, and some of its waste heat used. Compression chillers with 460 kW of capacity are also available to cover peak loads, and to provide the required redundancy in cooling.

Two years after being brought into operation, the energy technology is still being continuously optimised. Particularly the power consumption of the ventilation still seems too high. Generally however, Pfreundt is satisfied with the energy concept implemented. We reach a DCiE value of 67 % in winter and 77 % in summer. "We are thus in the peak group amongst modern data centres."
The planning of the data centre and the overall energy strategy of the new ITWM building was a challenging and creative project. There were no suitable consultants for such a specific and integrated project. There were specialists and competent suppliers for each individual technology, but the merger of the ideas and technologies to an integral whole was carried out by the ITWM team in cooperation with the architects. Particularly the construction specialists often had to be convinced of the feasibility of new and unconventional solutions. And keeping within the budget was also a challenge. The budgeted costs established in 2002 could not be exceeded. The planning of the atriums and the expensive technology caused considerable cost, which had to be compensated for elsewhere. The atriums could be justified by their increased energy efficiency due to their smaller external surface, and also because they could be heated with the waste heat. Their inner walls also contributed since they had sliding windows, which are not usual in Germany, but were very practical and cheap, also saving money.

However, it was not possible to use the data centre also as hot water source.. A hot-water temperature of 50°C seems attainable over the medium term via CPU cooling, but the appropriate water-cooled processors are not yet available.




Ventilation situation of the ITWM in winter

# Strato AG: Energy and Cost Reduction by Intelligent Load and Air Flow Management


René Wienholtz, director for technology and innovation of STRATO AG

## Facts & Figures

**Operator:** Strato AG
**Site:** Berlin and Karlsruhe
**Area:** 4,500 sq. m.
**Server number, both centres:** 27,000
**Function:** Webhosting, rental servers, online shops
**Certification:** TÜV ISO 27001
**Average server utilization, Karlsruhe Centre, 2007 (Shared Webhosting):** 80 - 85%
**Average server utilization, Berlin Centre, 2007 (Dedicated Server):** 30 %
**Data centre infrastructure energy efficiency (DCiE) 2007:** 59% (PEU = 1,69)
**Total energy consumption, both centres, 2007: 30,000,000** kWh
**Internet:** www.strato.de

As Europe's second-largest webhost, Strato does business in six European countries and provides its customers with everything in the area of domains and home pages ("webhosting"), rental servers, and online shops. The company, with around 500 employees, has two geographically separate data centres. The data transmission between Karlsruhe and Berlin ensures a robust data storage system, resilient in any situation. In 2007, some 27,000 physical servers were in operation in the two centres, serving approx. one million customers. The data centres are certified by the German Technical Control Board (TÜV) according to standard ISO 27001. They cope with a monthly transfer volume of 3.5 million gigabytes and approximately 200 million e-mails per day.
Strato addressed the energy efficiency issue at an early stage. "It was clear to us that this would save us money," said René Wienholtz, the company's director for technology and innovation, and added: "We were one of the first companies to calculate the full cost of a hosting platform for its entire lifespan. So, the question as to how energy-intensive the whole thing would be was an obvious issue."

Strato had taken over the premises of its two data centres from other operators in 1999 and 2001. Energy-saving measures implemented by Strato therefore include the interior design much rather than exterior features of the building. "We already took the question of energy optimisation into account before implementation," said Wienholtz. For example, the Berlin data centre was equipped right from the start with extensive measurement technology which makes detailed and continuous energy consumption monitoring possible. Energy data logs are installed at all relevant consumption points, so that energy consumption can be ascertained right down to the level of single servers and racks. This was and is an important foundation for making the success of energy efficiency raising measures measurable and comprehensible.

In the area of hardware, the shared webhosting platform was switched over to Sun T2000 and T5220 servers. This permitted a savings of 90% of electricity on a CPU basis. In absolute terms, the switch from the old servers to T5220 ones means an annual reduction of energy consumption of 56,000 kWh, as well as a €6,500 reduction in the cost of electricity.

Key Measures
- ▶ Revised system architecture
- ▶ Use of energy-efficient servers and processors, switches and server boards
- ▶ Intelligent power load management
- ▶ Self-developed software, optimally adapted to hardware
- ▶ Air management: Hot aisle cold aisle
- ▶ Free cooling

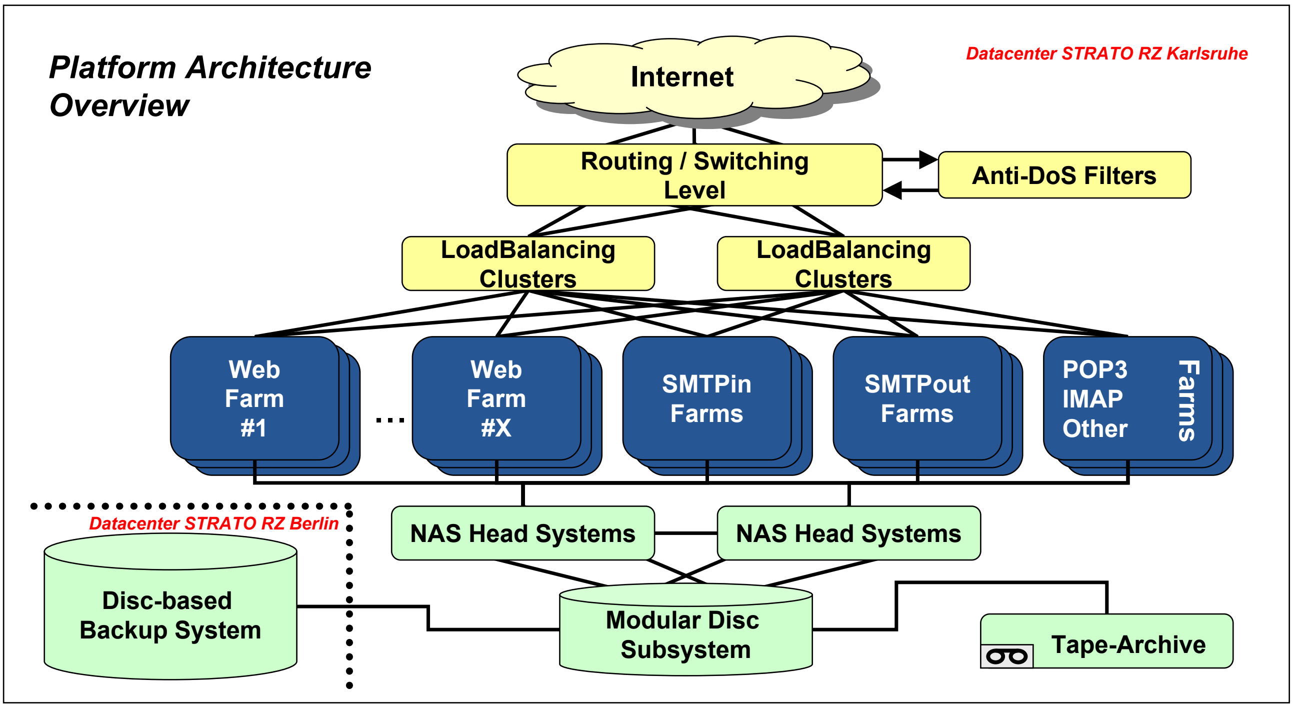
A 75% energy savings on CPU basis was obtained at the dedicated servers through the use of AMD OpteronTM processors of the High Efficiency series. The reorientation of the mass memory platforms to NetApp FAS 6070 also contributed considerably to the increase in energy efficiency. Strato has benefitted from the development partnerships with the companies AMD and Sun. The Webhost helps design, test and install particularly energy efficient hardware before it becomes available on the market.

Strato was able to realise considerable energy savings by introducing an intelligent power load management system for the shared-webhosting platform in Karlsruhe. Computer utilization might change tremendously over the course of a day as usage patterns, hence power loads, vary. Therefore it makes sense to distribute the work load as evenly as possible between the server clusters, i.e. between the web farms, mail-farms and database-farms, so as to make full use of capacities. "In case of e-mail load peaks, for example, the systems are reconfigured automatically, so that free resources are assigned to the e-mail farm," says Wienholtz. For this purpose, a so-called "load-balancer" is installed between the data and the service requirements incoming via the Internet, and the servers. Thus, the servers are addressed in a weighted manner, and the computing load (CPU load) is distributed intelligently. In 2007, average server utilisation levels of between 80 to 85% could be achieved at the Karlsruhe data centre, which houses the shared webhosting platform.

Further major factors for increased energy efficiency included optimisation of the cooling and air conditioning of the Strato server rooms in recent years. For example, an increase in the inlet temperature for cooling, for example, from 20.5°C to 23.5°C leads to an increase in energy efficiency by 20%. The construction of an intelligent air management flow - so to speak warm and cold aisles - was another factor contributing considerably to energy savings. At outside temperatures of up to 8°C, the outside air provides the cooling for the Berlin data centre. Merely with this so-called free cooling, Strato has achieved a savings of 25% in cooling energy.

Behind the various optimisation measures at Strato, there is a systematic and team-oriented management process. "Many ideas for improvements come from our data centre operators" says Strato Board Member Wienholtz. "We implement good suggestions, and take care that the management provides the necessary resources."

In 2007, Strato was awarded the Berlin Environmental Prize by the environmental organisation BUND, for its various measures to increase energy efficiency – and not just for that: Strato is also the first webhost to run its data centres with 100% certified regenerative power.



# Pushing the Envelope of Data Centre Energy Efficiency for a New Supercomputing Facility in California

Planned NERSC-data center, Berkeley, California (realisation 2009-2012)

## Facts & Figures

**Operator:** Lawrence Berkeley National Laboratory
**Site :** Oakland, California (current), after 2012: Berkeley, California
**Area :** 1,600 sq. m (current), after 2012: 3,200 sq. m
**Function:** Basic research, scientific applications
**Data centre infrastructure energy efficiency (DCIE) 2007:** 68% (PUE = 1.47)
**Planned data centre infrastructure energy efficiency (DCIE) 2012:** 83% (PUE = 1,20)
**Planned energy use for 2012: 42,000,000** kWh
**Internet:** www.lbl.gov

The Computional Research and Theory Facility (CRTF) is the flagship scientific computing facility for the Office of Science in the U.S. Department of Energy. As one of the largest facilities in the world devoted to providing computational resources and expertise for basic scientific research, CRTF is a world leader in accelerating scientific discovery through computation. Most of the CRTF staff, as well as the high performance computing and storage systems, are located at Berkeley Lab's Oakland Scientific Facility in downtown Oakland, California.

The more than 3000 computational scientists who use CRTF perform basic scientific research across a wide range of disciplines. These include climate modelling, research into new materials, simulations of the early universe, analysis of data from high energy physics experiments, investigations of protein structure, and a host of other scientific endeavours. CRTF resources include a supercomputer called "Franklin", which is a Cray XT4 supercomputer with 9,660 compute nodes. Each node has dual-core AMD processors running at 2.6 GHz. Franklin has 19,320 processor cores available for scientific applications, with 4 GB of memory per node and a total 350 TB of usable disk space.

The CRTF data centre facility in Oakland occupies 1,600 sq. m. of a 6,000 sq. m. multi-level building. The data centre houses servers (computer equipment), storage drives and a control room, and operates twenty-four hours a day.

In 2002, the CRTF data centre was one of fourteen facilities of a data centre energy benchmarking project carried out by the Lawrence Berkeley National Laboratory (LBNL) Environmental Energy Technologies Division. The project included 12 facilities in Northern California and two in New York (http://hightech.lbl.gov/dc-benchmarking-results.html). During the study, the CRTF data centre was expansion. Measurements in 2002 showed that its data centre infrastructure energy efficiency (DCiE) was at 68%, for a PUE of 1,47, one of the best values of all data centres analysed within the LBNL benchmarking project.

Today, the CRTF facility is still undergoing expansion. Since the present building is limited in space, and is only leased by CRTF, it is planned to construct a new data centre building on the LBNL site in nearby Berkeley. "A key idea of improving the energy efficiency of the new CRTF data centre is to avoid unnecessary redundancy in regard to uninterruptible power supply, cooling energy and other support equipment", says William Tschudi, the programme manager in the LBNL Environmental Energy Technologies Division, and member of the planning team. "Of course a data centre for scientific computing has other redundancy requirements from those of data centres for co-location or financial institutions. Each type of data centre has its specific requirements, but it is important to plan and design a facility with the redundancy which it really needs."

The construction of the new Computational Research and Theory Facility (CRTF) will start in 2009, and it is scheduled to be operational in 2012. The building will be owned by the University of California. With a construction budget of $90 million, the CRTF will be a building of 140,000 gross square feet, including 32,000 assignable square space in high-performance Data Center floor, plus offices and support areas. The initial electrical power requirement will be 7.5 megawatts (MW), expandable to 17MW. Approximately 300 staff will occupy the centre and associated office space.

The CRTF has a goal of a minimum Data Centre Infrastructure Efficiency (DCIE) of 83%, which would be better than any data centre this size benchmarked to date. In addition to achieving this energy performance, the building must maintain the flexibility needed to house numerous generations of supercomputing systems over the next few decades that have unknown power and cooling needs. It is intended to take full advantage of the information technology (IT) equipment manufacturers' temperature and humidity limits, as well as Berkeley's mild climate and minimal requirements for uninterruptible power supply (UPS) backup.

The planning team has integrated a comprehensive set of energy efficiency measures into the building design, so as to contribute to overall energy savings.

Key Measures

- **Limiting redundancy to an absolute minimum**
- **Increasing computer room temperature within the allowable range**
- **Free cooling**
- **Low-pressure ventilation**
- **Wall and roof insulation, to reduce solar irradiation load and wintertime heat loss**

The measures include:

- **High Performance Computing (HPC)** constitutes the most significant load in the building. To reduce the operational cooling energy of HPC, the allowable air supply conditions were expanded beyond the recommended ASHRAE range, but within the allowable range. The air systems are thus designed for a computer room temperature specific supply range of 15-24°C DB and 30% to 60% RH. This results in significant cooling savings by allowing economiser hours for most hours in the year. Chillers are provided to serve HPC during extreme warm conditions and for dehumidification purposes.
- **Direct Evaporative System:** The air handling units will incorporate a direct evaporative section. The direct evaporative components in the air handling units are sized for humidification during the winter months. The capacity thus designed for will be used for pre-cooling during the summer months.
- **Low pressure ventilation:** The air systems are designed to have lowest possible pressure drops, to reduce fan energy consumption to an optimal level. Low duct velocities (~1,500 fpm) are used.
- **Walls & Roof:** Improved insulation of the walls and roof reduces solar load and winter heat loss.
- **Efficient Chiller:** The water-cooled chiller efficiency (COP=8) is higher than required by ASHRAE 90.1-2004.

The key energy efficiency metric for the planned CRTF-supercomputing facility is data centre infrastructure efficiency (DCiE). While the present data centre has a DCiE value of 68% ($PUE_{power}$= 1.47), the target for the new facility is 80% ($PUE_{power}$ = 1.2). The planning team thinks that the real energy efficiency improvements will even be higher. Data centre energy expert William Tschudi expects a $PUE_{power}$ (Total Facility Load / IT Load) value of 1.11 (5,295 kW/4750 kW), which equals a DCiE power value of 90%. If the annual energy consumption is taken as the basis of calculation instead of the power load, the metrics are even better. "We calculated the annual energy use of the new CRTF facility to be about 42,000,000 kWh, with 97% of the energy to be used by IT-equipment, and only 3% by support infrastructure, such as UPS and cooling systems. That yields a $PUE_{energy}$ value of 1.03, which means that the system design for the new CRTF data centres is really very efficient."

# OUTLOOK

As the best-practice examples in this booklet demonstrate, even today there are many possibilities for reducing the energy consumption of servers, server rooms and data centres, and for increasing their energy efficiency considerably. In short: practicable and economic solutions are available; what are the next steps?

- **Implementation of best-practice solutions on a broad scale:** In view of the overall energy consumption level of data centres, it does little good if only a few vanguard companies increase their energy efficiency considerably. The existing solutions must be adopted and implemented in as many server rooms and data centres IT as possible.
- **Support for data centre operators via counselling and promotional programmes:** As a rule, it is especially small and medium-sized companies and managements that have trouble with systematic energy optimisation, since they lack the capacities, and in some cases, also the know-how, for it. As of 2009, the German federal government will provide support through a number of programmes, targeted towards small and medium-sized companies to increase the energy efficiency of their servers and server rooms.
- **Standardisation of the measurement of energy consumption in data centres:** Initial suggestions have already been made in this area (Aebischer et al. 2008; BITKOM 2008; EU Commission 2008, Green Grid 2008). However, they will have to be coordinated and standardised internationally over the next few years in the relevant associations and committees.
- **Further development and standardisation of energy efficiency metrics:** This is already in progress; however, it too must be developed further and standardised internationally over the next few years. The key focus here should be on indicators, which relate energy use to IT services.
- **Energy auditing and certification of data centres:** Some testing institutions already offer a neutral and independent energy auditing and certification of data centres. This is an important first step, particularly for large data centres and IT providers, but it must be developed further and standardised industry-wide and internationally, on the basis of the measurement standards and indicators to be established criteria.
- **Benchmarking programmes:** Experiences from various industries show that anonymised benchmarking programmes can substantially support the continuous improvement on energy efficiency. This can also be transferred to data centres, and should be organised by the data centre operators and the relevant associations.
- **The $CO_2$ neutrality of data centres:** Increased energy efficiency is an important, but not the only goal, from the point of view of sustainable development. Climate neutrality, i.e. operating IT and data centres without harmful effects on the world's climate, is likewise an important objective. The German Federal Government is setting a positive lead here, and plans over the medium term to run all federal data centres in a climate neutral manner.
- **Innovations for "green" data centres:** The best-practice solutions and technologies available today can make a major contribution in the short and medium term to the increased energy efficiency of data centres. However, in view of the continuing rapid growth in the use of the Internet and the mobile media, what is needed in the long term is fundamental innovation to reduce overall energy consumption in the ICT industry. Innovations of this kind should be systematically supported by governments and international programmes.

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*U.S. Data Center Energy Efficiency Information Program: The U.S. Environmental Protection Agency (EPA) and the U.S. Department of Energy (DOE) have initiated a joint national data center energy efficiency information program. The program coordinates a wide variety of activities from the DOE Industrial Technologies Program Save Energy Now initiative, the DOE Federal Energy Management Program (FEMP), and the EPA ENERGY STAR program. EPA http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency*

The **EU-Code of Conduct on Data Centres** aims at the continuous improvement of energy efficiency in the operation and planning of data centres. Central to the Code is the self-commitment of data centres to regularly submit and develop improvement programmes, based on an initial ascertainment of energy use. The Code contains such documentary aids as measurement procedures and an extensive best-practice list. Data centres whose improvement programmes have been recognised by the EU Commission may use the Code logo. Particularly good data centres are to be cited annually. Quantitative minimum requirements are also to be formulated over the medium term.

The establishment of the **Server Benchmarkt Test** of the U.S. Standard Performance Evaluation Corporation (SPEC) has brought momentum into the race for the efficiency of IT hardware. The criticism is that server performance is currently measured only by a Java application; nevertheless manufacturers are doing their best to build and test efficient configurations. After the first results were published in December 2007, the first leader was IBM with the 854 ssj_ops; it was then surpassed by Intel with the 910 ssj_ops, which has now yielded to Fujitsu-Siemes with 1,124 ssj_ops.

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