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Bundesministerium
für Wirtschaft
und Energie

aufgrund eines Beschlusses
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Research results of the GreenPad project

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Project summary

Project title:	GreenPad – Energy-optimised ICT for regional economic and knowledge clusters
BMWi code:	01ME11043A
Term:	01/06/2011 to 31/05/2014
Consortium:	unilab AG
	University of Paderborn
	Johannes Gutenberg University of Mainz
	Fujitsu Technology Solutions GmbH
	E.ON Westfalen Weser AG
Project director:	Dr Lars Kemper, unilab AG

Website: www.green-pad.de

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Research topics

The project addresses the development, testing and market implementation of an energy-optimal cloud-based ICT infrastructure model for regional economic and scientific clusters.

- Energy-efficiency aspects when selecting devices and in IT procurement
- Measurement and analysis of energy consumption in data centres
- Development of load management methods to increase utilisation
- Study of business models for energy-efficient cloud services
- Effective use of renewable energies through availability forecasts
- Development of a holistic energy management system for a highly energy-efficient data centre operation (green control console)

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Energy measurement in the data center

In the course of establishing a new data centre (DC), at the University of Paderborn comprehensive energy consumption measurements were planned and carried out:

- Building up a network of over 200 measurement points for the establishment of continuous energy monitoring
- Practical measurement of individual energy consumption in server, storage and network technology as well as infrastructure devices in the data centre
- Analysis of the interaction between IT systems and data centre infrastructure

Insights for energy optimization in the data centre:

- Energy efficiency must be addressed holistically in the planning of data centres from the beginning, that is, taking into account all systems
- With servers and switches, oversizing or improper configuration leads to unnecessary and substantial energy losses in part
- High utilisation and the establishment of load adaptivity not only saves energy but also expensive IT resources (consolidation)

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Energy measurement of individually configured IT systems

Comparative measurement and analysis of IT performance in relation to the electrical power consumption with servers and switches configured in a variety of ways:

- Parallel measurement of electrical power consumption of three differently configured servers over all load ranges
- Measurement both with external measurement devices and reading of existing system data via the IPMI interface
- Comparison of the results with the IPMI-based values shows sufficiently precise accordance with a deviation of less than three percent
- Conclusion: For cost-effective energy analysis as well as for billing purposes, energy monitoring based on IPMI can take place

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Energy metering and load management with WLAN

In the new lecture building and on the campus of the University of Paderborn, extensive energy measurements with respect to the WLAN infrastructure were made:

- Measurement of energy consumption and utilisation of several hundred WLAN access points during classes and the semester break.
- The utilisation varies significantly both between weekday and weekend and between day and night. On average, very little use is made of 65 percent of the access points.
- Optimisation of energy consumption of the WLAN infrastructure is accomplished with a flexible algorithm that analyses RSSI signal values of the access points and takes into account the network topology.
- On this basis, antennas of individual access points were able to be temporarily disabled without loss of service in the overall coverage.

Conclusion: Load-dependent operation of WLAN access points leads to energy savings of 15 percent for the same quality of service.

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Energy measurement with thin clients

The energy requirements of a thin client solution over the entire course of transmission – from the terminal to the network to the data centre – was examined. The energy efficiency of thin clients is determined by several factors:

- Powerful but not over- or under-dimensioned network
- Effective deployment of applications on the server systems, that is, the highest possible utilisation of physical servers through virtualisation measures
- Flexible scaling of server systems (load adaptivity)
- Cloud management software such as OpenNebula, OpenStack and Eucalyptus provide graphical user interfaces for self-service as needed
- Monitoring and accounting can be implemented with a variety of tools, such as Nagios or Collectd.

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Development of a “green control console”

In order to establish energy efficiency and in particular the use of renewable energy in data centre operation, what is known as a green control console was developed and tested with the following components in the GreenPAD project:

- Hypervisor: KVM (and Libvirt as an upstream API), VMware ESX
- Cloud software including graphical user interface: OpenStack, OpenNebula
- Authentication: OpenStack Keystone, LDAP
- Monitoring: Nagios, Collectd, ICINGA, ManageNow
- Energy measurement: IPMI, external power meters
- Energy forecasts: in-house development
- Scheduler: in-house development

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Energy forecasts for renewable energy

The effective use of renewable energy sources in the context of data centres requires relatively precise availability and price forecasts:

- Forecasts for local availability of renewable energy (wind/solar) were prepared on the basis of measurements and weather forecast data
- The accuracy of the energy forecast is limited by the quality and range of the weather measurement/forecast:
  - An error of ±20% was determined for the wind speed
  - And error of up to ±40% was determined for the duration of sunshine
- Forecast quality is acceptable in view of the limited weather data:
  - The error for the wind energy forecast is up to 30%
  - The error for the solar energy forecast is up to 20%
- Since measurement values (smart meters) are missing, the forecast of the energy consumed in medium-voltage networks is difficult.
- Data privacy criteria are also important in this context

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Energy-efficient scheduler

In the project, an intelligent energy-oriented scheduler was developed that controls the temporal execution and dynamic shift of tasks with the objective of maximising the use of renewable energies.

- To assess the scheduler, the turnaround time of each job was measured, that is, the time between the arrival of jobs in the data centre until its complete execution.
- Comparative figures for the energy-efficient scheduler were generated by a traditional First-In-First-Out (FIFO) scheduler

Results:

- With the FIFO scheduler, the DC consumes about 26% renewable energy
- With the energy-efficient scheduler, up to 40% renewable energy
- The project shows that the proportion of renewable energy can be significantly increased without undue extension of the processing time
- Increase from 7.6 hours to up to 44.4 hours

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Patents and publications

Patents

- No current applications

9 national and international scientific publications

Presentations:

- IEEE/ACM Conference on Grid Computing 2011, Lyon
- International Workshop on Randomization and Computation (RANDOM'2012), Boston

Other:

- German Data Centre Prize 2014: 1st place in the category “Ideas and Research”