Energy-Efficiency in Computer Grids

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Where do I come from?

- ENS de Lyon  http://www.ens-lyon.eu
- More than 2 000 students (400 doctoral students)
- 350 researchers and 270 professors
- 31 nationalities represented on campus
- 245 international partnerships
- LIP laboratory (47 permanent faculties and researchers and 48 PhD students)
- RESO team working on networks and distributed systems
Outline

- Definitions and examples
- Issues
- Energy consumption reductions
- Grid usage
- Energy cost of Grid servers
- EARI
- Conclusions
Definitions and Examples
Grid Computing

- Born in the early 1990s
- "A service for sharing computer power and data storage capacity over the Internet."
- "Computing resources are not administered centrally.
- Open standards are used.
- Nontrivial quality of service is achieved."

GridCafé (CERN) http://www.gridcafe.org

"What is the Grid? A Three Point Checklist" Ian Foster
Grid examples

- Desktop Grids
- Volunteer Grids
- Enterprise Grids
- E-science Grids
- Production Grids
- Sensor Grids
Grid Architecture

- **Network layer**: connects the resources
- **Resource layer**: computers, storage systems, sensors, … often heterogeneous and geographically distributed
- **Middleware layer**: provides the tools to use the resources.
- **Application layer**: where the users can interact with the Grid; provides various services
Grid Middleware

- Batch scheduler
- Data access
- Remote job initiation
- Resource discovery
- Resource co-allocation
- Location management
Energy Issues
How to measure energy consumption in Grids?

- Power usage per device, per process, per service, per rack?
- New tools: powertop
- Event counters
- Sensors

http://lesswatts.org/projects/powertop/

Understanding nodes

<table>
<thead>
<tr>
<th>Component</th>
<th>Peak Power</th>
<th>Count</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU [16]</td>
<td>40 W</td>
<td>2</td>
<td>80 W</td>
</tr>
<tr>
<td>Memory [18]</td>
<td>9 W</td>
<td>4</td>
<td>36 W</td>
</tr>
<tr>
<td>Disk [24]</td>
<td>12 W</td>
<td>1</td>
<td>12 W</td>
</tr>
<tr>
<td>PCI slots [22]</td>
<td>25 W</td>
<td>2</td>
<td>50 W</td>
</tr>
<tr>
<td>Motherboard</td>
<td>25W</td>
<td>1</td>
<td>25 W</td>
</tr>
<tr>
<td>Fan</td>
<td>10 W</td>
<td>1</td>
<td>10 W</td>
</tr>
<tr>
<td><strong>System Total</strong></td>
<td></td>
<td></td>
<td><strong>213 W</strong></td>
</tr>
</tbody>
</table>

Issues

- Bad usage of machines in companies:
  - CPU: 4 004 h of running per year (17.8 h per working day)
  - Screen: 2 510 h per year (11.2 h per working day)
- But users effectively use their machines 686 h per year (3 h per working day)
- Computers are switch on \( \frac{3}{4} \) time for nothing!
Energy consumption: some figures

- Incremental US demand for data center energy between 2008 and 2010 is the equivalent of 10 new power plants.
- Power loss of 0.01% per meter of cable above 6 meters.

“Revolutionizing Data Centre Energy Efficiency”
How to measure energy efficiency?

- Benchmarks and metrics
- PUE: Power usage effectiveness

\[ PUE = \frac{\text{Total Facility Power}}{\text{IT Equipment Power}} \]

- DCIE: Data Center Infrastructure Efficiency

\[ DCIE = \frac{1}{PUE} = \frac{\text{IT Equipment Power}}{\text{Total Facility Power}} \times 100 \]

Techniques to reduce energy consumption in data centers and grids
Different levels

- Grid level
- Data center level
- Node level
- Component level
Follow-the-\(*)\) approaches

- Follow the moon: free cooling with air from outside during cool days, and on hot weather days, computing load is shifted to other data centers
- Follow the sun/wind: use renewable energy sources
Thermal management

- Cooling costs a lot, so reduce heat production to reduce energy consumption.


On/off techniques

- Switch off unused resources
- Minimize set of active resources, adapt to the load

Issues:
- does it reduce the life time of resources?
- does it lower the reactivity of the platform?
- does the middleware consider the resources as dead?

When can we switch off?

\[
T_s = \frac{E_s - P_{OFF}(\delta_{ON\rightarrow OFF} + \delta_{OFF\rightarrow ON}) + E_{ON\rightarrow OFF} + E_{OFF\rightarrow ON}}{P_I - P_{OFF}} + T_r
\]

On/off tools

- Suspend to disk (hibernation)
- Suspend to RAM (standby or sleep)
- Wake on LAN
- IPMI (Intelligent Platform Management Interface)
- Presence proxies
- Smart PDU (Power Distribution Unit)
Does a switched off node consume energy?

Is intensive and systematic on/off the perfect approach for saving energy?

Must be done cleverly and coupled with usage prediction

Energy-Aware Task Scheduling

- Exploiting performances and energy consumptions of heterogeneous nodes
- Use first the most energy-efficient nodes

Issues:
- hot spots
- need first a measurement campaign of all the nodes
- require quick and efficient scheduling algorithms

Does homogeneous nodes have the same energy consumption?

Is the relation between CPU load and energy consumption linear?

Virtualization techniques

- Consolidation and aggregation → reduce number of servers
- Isolation → application workload characterization
- Live Migration → live adaptation

Issues:
- Time overhead, resource sharing
- Hypervisor needs resources → reduce capacities of the nodes

Does virtualization increase energy consumption?

- No paper to either deny or confirm this assumption.
- Experiments with Xen 3.2 and Xen Server 5.0
  - idle consumption identical
  - cpuburn experiments show a difference of less than 1 Watt
  - iperf experiments show a difference of 7 Watts (due to a poor management of network allocation in Xen 3.2)

Is live migration of VM free?

Dynamic Voltage/Frequency Scaling

- CPU-throttling: frequency of a microprocessor can be automatically adjusted "on-the-fly" (Cool'n'Quiet for AMD, SpeedStep for Intel)
- Different voltages/frequencies are available on the CPU
- Trade-off between time and energy
- Need to predict application profile in terms of CPU usage

“Energy-Efficient Real-Time Heterogeneous Server Clusters”, C. Rusu et al., RTAS, 2006
Code improvements

- OS code
- Green programing
- Automatically turning off unused components (USB ports, Bluetooth, Wifi, kernel modules)

http://lesswatts.org/projects/powertop/
http://www.ecoinfo.cnrs.fr/spip.php?article211
Hardware improvements

- Improve energy-efficiency of the components (power supply, fans, water cooling…)
- Energy-efficient architectures and infrastructures
- Allow components to be put into sleep modes separately (memory benches, cores, …)
- Allow different levels of usage (voltages, frequencies)
- Ecodesign and recycling
Standards, Consortiums, Projects

- Energy Star
- Green Grid
- Efficient Servers
- The green 500
- ...

EcoInfo

www.cost804.org
Action IC0804
Experimental Scenario
Objective and Methodology

How to decrease the consumption without impacting the performances?

- Switch off the unused resources;
- Predict the next use;
- Aggregate the reservations.

- Study the existing solutions for energy savings;
- Analyze a platform usage and its power consumption;
- Propose an energy-aware infrastructure for resource reservation;
- Validate experimentally this infrastructure.
Grid'5000

- French experimental testbed
- 5000 cores
- 9 sites
- Dedicated Gb network
- Designed for research on large-scale parallel and distributed systems
Lyon: a Monitored Site

- 135 nodes
- One power measurement per node and per second

“The Green Grid'5000: Instrumenting a Grid with Energy Sensors”

Resource Reservation: OAR

- Open source batch scheduler
- Resource management system of Grid'5000
- Advance reservations
- Exclusive reservation of resources (super-user)
- Image deployment with Kadeploy
  → resource reservation logs + deployment logs
# Grid view

OAR (batch scheduler and resource manager)  
Logs of 2008 year (2 GB; 1,290,000 reservations)

<table>
<thead>
<tr>
<th>Site</th>
<th>number of cores</th>
<th>number of reservations</th>
<th>Mean number of resources per job</th>
<th>Mean duration of a job (mn)</th>
<th>Percentage of activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bordeaux</td>
<td>650</td>
<td>356,222</td>
<td>7.44</td>
<td>41</td>
<td>53.20 %</td>
</tr>
<tr>
<td>Lille</td>
<td>618</td>
<td>344,538</td>
<td>8.11</td>
<td>53</td>
<td>72.89 %</td>
</tr>
<tr>
<td>Lyon</td>
<td>322</td>
<td>138,217</td>
<td>4.39</td>
<td>62</td>
<td>69.27 %</td>
</tr>
<tr>
<td>Nancy</td>
<td>574</td>
<td>74,592</td>
<td>14.63</td>
<td>149</td>
<td>60.08 %</td>
</tr>
<tr>
<td>Orsay</td>
<td>684</td>
<td>92,862</td>
<td>14.58</td>
<td>104</td>
<td>57.82 %</td>
</tr>
<tr>
<td>Rennes</td>
<td>714</td>
<td>58,843</td>
<td>27.32</td>
<td>118</td>
<td>64.58 %</td>
</tr>
<tr>
<td>Sophia</td>
<td>568</td>
<td>58,142</td>
<td>22.14</td>
<td>146</td>
<td>81.51 %</td>
</tr>
<tr>
<td>Toulouse</td>
<td>434</td>
<td>166,191</td>
<td>6.29</td>
<td>37</td>
<td>61.67 %</td>
</tr>
</tbody>
</table>

- Lots of variations from one site to another.  
- Operational Grid: between 60 and 70% of usage.  

"How are Real Grids Used? The Analysis of Four Grid Traces and Its Implications" A. Iosup et al., Grid Computing, 2007.
Zoom on a site: Lyon site
Heterogeneous Resources

Maximal resource's states per week for Lyon – number 195

Median resource's states per week for Lyon – number 28
Impact of Usage on Power Consumption

Idle consumption really high, no prediction possible
→ Huge energy savings are possible
Power Consumption Logs: Failures

- 6 months logs:
  - from 1st Sep. 2009 to 27th Feb. 2010
- 135 2-CPU nodes
  - 56 IBM eServer 326
  - 79 Sun Fire V20z

<table>
<thead>
<tr>
<th>Start Time</th>
<th>Duration</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>06-09-2009 04:25:41</td>
<td>01:11:34</td>
<td>Failure in the wattmeters.</td>
</tr>
<tr>
<td>17-09-2009 13:30:56</td>
<td>00:02:40</td>
<td></td>
</tr>
<tr>
<td>19-09-2009 08:31:26</td>
<td>01:11:34</td>
<td>Failure in the equipments responsible for measuring the power consumption.</td>
</tr>
<tr>
<td>20-09-2009 04:30:25</td>
<td>01:11:34</td>
<td></td>
</tr>
<tr>
<td>27-09-2009 04:25:02</td>
<td>01:12:33</td>
<td></td>
</tr>
<tr>
<td>24-10-2009 13:33:52</td>
<td>00:17:51</td>
<td></td>
</tr>
<tr>
<td>25-10-2009 05:34:31</td>
<td>01:11:34</td>
<td></td>
</tr>
<tr>
<td>01-11-2009 05:25:16</td>
<td>01:12:05</td>
<td></td>
</tr>
<tr>
<td>15-11-2009 05:25:16</td>
<td>01:11:34</td>
<td></td>
</tr>
<tr>
<td>22-11-2009 05:25:05</td>
<td>01:12:56</td>
<td></td>
</tr>
<tr>
<td>13-12-2009 05:25:08</td>
<td>01:13:40</td>
<td></td>
</tr>
<tr>
<td>20-12-2009 05:25:46</td>
<td>01:11:34</td>
<td></td>
</tr>
<tr>
<td>10-01-2010 05:25:13</td>
<td>01:13:11</td>
<td>Failure in the equipments responsible for measuring the power consumption.</td>
</tr>
<tr>
<td>17-01-2010 05:25:13</td>
<td>01:11:34</td>
<td></td>
</tr>
<tr>
<td>31-01-2010 05:25:33</td>
<td>01:13:19</td>
<td></td>
</tr>
<tr>
<td>07-02-2010 05:25:37</td>
<td>01:11:34</td>
<td></td>
</tr>
</tbody>
</table>
Global Energy Consumption
Global Energy Consumption

The graph shows the energy consumption (KWh) and resource utilization (%) from September 2009 to February 2010. The data for the month of November 2009 is not available.

- **Energy Consumption** (red line)
- **Resource Utilization** (blue dashed line)

The graph indicates fluctuations in energy consumption and resource utilization over the specified period.
Platform downtime and switch off

Downtime

Switch off

Data not available
Energy consumption during the day

![Energy Consumption Graph]

- Energy Consumption in KWh
- Sep 2009 to Feb 2010
Resource Reservations
**Energy consumed by reservation categories**

<table>
<thead>
<tr>
<th>Number of nodes used</th>
<th>Number of reservations</th>
<th>Overall consumption in KWh</th>
<th>Average Watts per Node</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 2</td>
<td>3844</td>
<td>1529.77</td>
<td>197.23</td>
</tr>
<tr>
<td>3 to 5</td>
<td>681</td>
<td>1203.71</td>
<td>192.36</td>
</tr>
<tr>
<td>6 to 10</td>
<td>611</td>
<td>7384.92</td>
<td>200.44</td>
</tr>
<tr>
<td>11 to 30</td>
<td>7408</td>
<td>35371.17</td>
<td>216.49</td>
</tr>
<tr>
<td>31 to 70</td>
<td>205</td>
<td>9821.79</td>
<td>178.78</td>
</tr>
<tr>
<td>71 to 100</td>
<td>45</td>
<td>1918.33</td>
<td>185.91</td>
</tr>
<tr>
<td>101 to 135</td>
<td>50</td>
<td>5447.23</td>
<td>185.85</td>
</tr>
</tbody>
</table>

→ reservations with up to 30 nodes tend to consume more energy
Energy consumed by reservation groups

<table>
<thead>
<tr>
<th>Duration</th>
<th>Number of nodes</th>
<th>≤ 10 nodes</th>
<th>&gt; 10 nodes</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 1 hour</td>
<td>SN (27.18%)</td>
<td>SW (47.26%)</td>
<td></td>
</tr>
<tr>
<td>&gt; 1 hour</td>
<td>LN (12.81%)</td>
<td>LW (12.75%)</td>
<td></td>
</tr>
</tbody>
</table>

**Average Weighted Power Consumption**

\[ AWPC = \frac{\sum_{j \in \tau_k} p_j \cdot m_j \cdot wn_j}{\sum_{j \in \tau_k} p_j \cdot m_j} \]

<table>
<thead>
<tr>
<th>Reservation Group</th>
<th>Overall Consumption in KWh</th>
<th>Average Watts per Node</th>
<th>AWPC</th>
</tr>
</thead>
<tbody>
<tr>
<td>SN</td>
<td>278.29</td>
<td>198.78</td>
<td>191.46</td>
</tr>
<tr>
<td>SW</td>
<td>6406.21</td>
<td>217.72</td>
<td>207.09</td>
</tr>
<tr>
<td>LN</td>
<td>9840.11</td>
<td>193.10</td>
<td>197.84</td>
</tr>
<tr>
<td>LW</td>
<td>46152.31</td>
<td>205.42</td>
<td>184.23</td>
</tr>
</tbody>
</table>
Energy Cost of Resource
Under-Utilisation
Consumption during late deployment

![Graph showing consumption during different phases.](image)
Idle Power Consumption

The chart shows the idle power consumption in watts across different cluster nodes. The x-axis represents the range of cluster nodes, while the y-axis represents the power consumption in watts. The bars indicate the average power consumption with error bars showing the variability. Each cluster node range is labeled, and the graph provides a clear visualization of how power consumption varies with different node counts.
Busy Power Consumption

![Busy Power Consumption Graph]

- **Average busy consumption**
- **Dynamic consumption**

Power Consumption in Watts

Lessons Learnt
Lessons learnt

- Dynamic energy consumption corresponds to **3.05%** of the overall energy consumed during reservations. → maximum that CPU throttling can save currently
- Idle power consumption is really high.
- Energy consumed during pre-deployment phase corresponds to **14.41%** of the overall energy.
- Small reservations are more resource intensive. → Users behavior should be taken into account.
ICT Energy logs

http://www.ens-lyon.fr/LIP/RESO/ict-energy-logs/

Motivation and Goals

The goal of this site is to provide (anonymized) workload, energy and power consumption traces from large-scale distributed environments to researchers and to practitioners alike.

Large-scale distributed systems are widely used for DNA sequence analysis to economic forecasting. Driven mostly by application performance, these systems have constantly increased in size and computing power of their resources.

The power supply requirements of these systems have increased in a similar fashion, which has raised concerns about the energy they consume. Power management of resources is then required on the basis of real power consumption measurements.

The goal of this website is to provide a virtual meeting place where practitioners and researchers can exchange energy traces.

Contributing

If you have traces from your large-scale distributed system (data center, grid, cloud, network), either complete or partial, please contact us. We will help you gather the traces, we will anonymize and process the traces, we will publish with your consent the traces, and we will give credit where its due.

latest news

November 9, 2010
Official launch of the ICT Energy Logs for all web page

July 6, 2010
Grid5000 Logs are available!!
Description of the logs can be found here.
Energy-Aware Reservation Infrastructure
Energy-Aware Reservation Infrastructure (EARI)

The main features are:

- **Switch off** unused computing resources;
- **Predict** next use;
- **Aggregate** the reservations by giving green advice to the users.
Architecture
After a reservation request

Reservation submission:
\[ R = (l, n_0, t_0) \]

- Compute earliest possible start time: \( t_1 \)
- Compute energy costs of:
  - reservation at \( t_0 \) or \( t_1 \)
  - reservation at \( t_{\text{end}} \)
  - reservation at \( t_{\text{start}} \)
  - reservation at \( t_{\text{slack}} \)
- Give the consumptions and the start times to the user
- Validate the reservation
- Update the agenda

User's choice between the 4 proposals
At the end of a reservation

Reservation end:
R' frees M nodes

Compute the energy used by R'

Give this information to the user

per resource:
Does the resource have an imminent reservation?

yes
- Considered as busy
- It stays awake

no

- Estimate next reservation R = (l, n, t_0)
- Look if there are awake resources
- For each of the m awake resources:
  - look if it can be used for R
- Keep min(m, n) resources awake if
  - R is imminent
- Turn off the remaining resources

At next submission:
- compute the error
- turn off idle resources
Predictions

What :
- Next reservation (size, duration, start time)
- Next empty period
- Energy consumption of a reservation

With :
- Recent history (last reservation) + feedback
- Recent reservations days + feedback
- User history + resources

How to validate the predictions?
Prediction evaluation based on replay

Example: Bordeaux site (650 cores, 45K reservations, 45% usage)
100% : theoretical case (future perfectly known)
Currently (always on) : 185% energy
Green Policies

- **user**: requested date
- **25% green**: 25% of jobs follow Green advices – the rest follows user request
- **50% green**: 50% of jobs follow Green advices – the rest follows user request
- **75% green**: 75% of jobs follow Green advices – the rest follows user request
- **fully green**: solution with uses the minimal amount of energy and follows Green advices
- **deadlined**: fully green for 24h – after: user
Evaluation on Lyon example

Example of Lyon site (322 cores, 33K reservations, 46% usage)

Current situation: always ON nodes (100 %)
All glued: unreachable theoretical limit
For Lyon site: saving of 73,800 kwh for 2007 period
Experimental validation of EARI

- Real traces of an experimental Grid: Grid'5000
- 4 different sites, one year period
Extrapolation to the whole Grid

209,159 kWh for the full Grid'5000 platform (without aircooling and network equipments) on a 12 month periods (2007)

It represents the consumption of a french village of 600 inhabitants.

So roughly, a village of 1200 inhabitants for the whole infrastructure.
Conclusions

- Proposition of an energy-aware infrastructure for resource reservation
  - simple and quick in terms of computing time
  - including heuristics
  - proposing energy saving solutions to the users without forcing them and impacting performances
  - leading to important energy savings.


Green Open Cloud
Cloud Features

- Virtualization
- Resources as a service
- Accounting, pricing
- Scalability, reliability
- Security
Differences between Grids and Clouds (that interest us)

- Agenda (reservations in advance)
- Virtualization
- Possibility to use live migration
- Usage predictions
- Resource management
Energy Cost of VMs

- **Energy analysis** of virtual machines using **energy sensors** plugged on the cloud nodes during typical and advanced **cloud operations** (boot of a VM, run, halt, migration)

- Case of computing jobs (worst case for the energy consumption)
Experimental Conditions

- 2 HP Proliant 85 G2 Servers (2.2 GHz, 2 dual core CPUs per node)
- XenServer 5.0
- VMs : - Debian Etch 4.0
  - 1 virtual CPU + 512 Mo
  - 6 VMs maximum per node
Boot, Run and Halt

6% increase of energy with 1 VM running
Migration

Bad moment in energy during the migration
Green Open Cloud Features

- Switch off unused resources
- Predict usage
- Aggregate reservations (live migration)
- Green policies for the users
- Network presence proxy
GOC Architecture

Users → PORTAL

PORTAL → RMS

RMS → Network Presence Proxies

Network Presence Proxies → EARM

EARM → Energy Aware Resource Manager

Green advice

Energy logs

Green resource enforcement

Cloud Resources

VM → Migration

Trust delegation

Energy Sensors
GOC Resource Manager

- Smooth integration in Cloud infrastructure
Algorithm for the end of a reservation

Algorithm At the end of each job

For Each totally or partially free resource M Do
  Predict the next use of M.
  If M will be used in less than $T_s$ Then
    Nothing to do for M.
  Else
    If M is totally free Then
      Switch off M.
    Else
      If the job(s) of M will end in more than $T_m$ Then
        Try to migrate the remaining VMs of M on other partially free resources to minimize the number of used resources.
      Else
        Nothing to do for M.
Experimental Methodology

Cloud job arrival example:

- $t = 10$: 3 jobs of 120 s. + 3 jobs of 20 s.
- $t = 130$: 1 job of 180 s.
- $t = 310$: 8 jobs of 60 s.
- $t = 370$: 5 jobs of 120 s. + 3 jobs of 20 s. + 1 job of 120 s.

→ limited time experiment
→ identical nodes
Experimental Methodology

- Two different simple **schedulings**: *round-robin* and *unbalanced*.

- Four **scenarios**:
  - *basic*: nothing to do;
  - *balancing*: use migration to balance the load;
  - *on/off*: switch off unused nodes;
  - *green*: switch off unused nodes and use migration to unbalance the load.
Round-Robin with Basic Scenario

- Identical nodes
- Energy levels
Round-Robin with Green Scenario

- Migration
- More energy efficient
Unbalanced with Green Scenario

- Less migrations
- More energy-efficient

Graph showing power consumption over time for Cloud Node 1 and Cloud Node 2.
Comparison between the scenarios

Same execution time for all the experiments
Conclusions

- Analysis of energy usage of VM in Cloud context
- Test on real nodes leads to 25% of energy saved with GOC
- Significant energy savings are achievable.
- GOC can be integer in current and future Cloud infrastructures (with reservation, accounting, ...
Publications


Conclusions
Conclusions

- Issues about energy efficiency in Grids
- State of the art on energy saving techniques used in Grid environments
- Analysis on 6 months energy and reservation logs of a Grid'5000 site (experimental Grid).
- Proposition of EARI and validation on traces with measured parameters
- Proposition of GOC and validation on real nodes
Bad good ideas

• Give 50 pages to read
• Two solutions:
  - usb key + 2 hours of computer and screen working
  - print on a color laser printer (front and back) on regular paper
Bad good ideas

Human Health

Ecosystem Quality

Resources

Human health
ecosystem quality
resources
Bad good ideas (2)

- New scenario:
  500 pages
 usb key with 20h of computer working
Bad good ideas (2)

For 20h working, the impact of the computer is greater than the impact of the usb key.
Top of the iceberg

How are the CO₂-e-emissions of the Desktop-PC ESPRIMO E9900 0-Watt distributed?

5% Transport/Distribution
Including transport of:
- Pre-products to assembly,
- The desktop to the customer and
- The desktop to Recycling Center in Paderborn

42% Raw materials
- Extraction, treatment and transport of raw materials
- Manufacturing of pre-products

52% Use phase
Assumption:
- Use phase of 5 years
- Annual energy consumption of 114 kWh (according to whitepaper energy consumption)
- Use in Germany (German energy mix)
- Spare parts in proportion to their failure rate

1% Assembly
Desktop and mainboard assembly in Augsburg

Recycling
By means of secondary raw materials from recycling and electricity/heat from waste incineration, CO₂-e-emissions can be avoided.

The “avoided” CO₂-e-emissions of recycling are deducted from the total Product Carbon Footprint.

→ 48 years in France, 5 years in Germany without screen

Fujitsu, Fact Sheet: CO2-Footprint of a Desktop-PC ESPRIMO E9900
Top of the iceberg

- Production + Transport often dominates the carbon footprint
- Lots of other criteria to take into account
- Need to take the whole loop into account → Life Cycle Assessment
- Standards required
Thank you for your attention!

Questions?

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