# Linux and Ecology

## Linux and Ecology
### Introduction to the Linux Ecology HOWTO
### Benefits from Embedded Linux Systems

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# Contents

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# Answer

Windows and Destruction of our Environment! 😉

► Each new version of Windows at least doubles the RAM, disk space and CPU power requirements. There are parts of the system that you cannot remove, even if you don't use them.

► This is particularly true with Windows Vista, which is said to obsolete 50% of existing business PCs when it came out.

► You have to replace your computer to use the latest OS and software.

► Manufacturing new computers consumes a lot of materials and discarding less recent ones generate toxic waste that has to be processed with very special care.

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# The Linux Ecology Howto

http://computerecology.org/
http://www.tldp.org/HOWTO/Ecology-HOWTO/

▶ Started in 1999 by Werner Heuser, the creator of TuxMobil (http://tuxmobil.org/), a website gathering resources for mobile GNU/Linux users (notebooks, phones and PDAs).

▶ Contributions from Wade Hampton and from other community members (and maybe one day from you too!).

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# Free Electrons contributions

Free Electrons contributions to the Linux Ecology HOWTO:

▶ Updates: updated resources and removed obsolete ones.

▶ Added new useful resources from Embedded Linux projects.

▶ Creating this overview presentation.
Many more details and ideas found on the HOWTO!

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# Switch off your computer

Switch off your computer whenever you do not use it!

▶ It's not because your computer never crashes or is very resistant to attacks from the Internet that you should always keep it on!

▶ Switching off your computer at night and during meal breaks can bring substantial power savings (roughly 2/3).

▶ System administrators: you could force automatic sleep and wakeup through the network (useful for managing nightly backups).

▶ Benefits: energy consumption and costs, longer computer life.

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# Hibernate to disk (1)

Use Hibernate to disk instead of shutting down your system
Doesn't work on very old computers without ACPI support.

▶ Booting up is much faster.
No need to wait for services and graphics to start up.

▶ Most of the time is saved by getting back to your work
as you left it before suspending your computer (open files, terminals,
browser windows). No need to re-open everything!

▶ Very useful too when you replace the battery of a laptop.

▶ Unlike Suspend to RAM, your computer can stay off and even
without a power supply as long as needed.

▶ Also useful on desktop computers!

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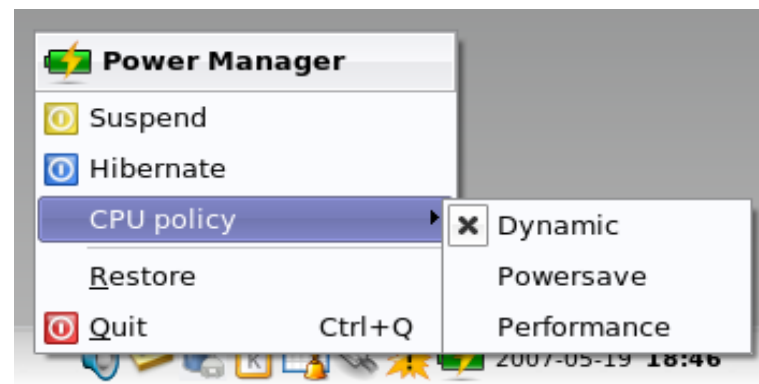
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Laptops and desktops

# Hibernate to disk (2)
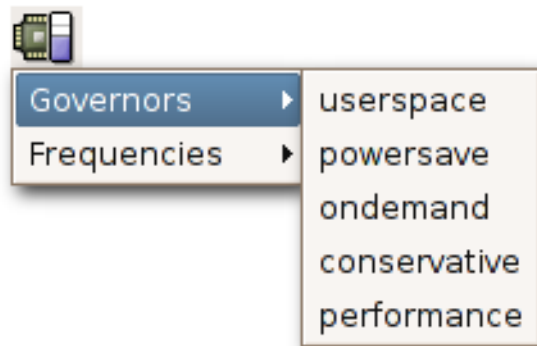
▶ Available by default in user-friendly distributions.
Example: Ubuntu (since 6.06): just choose `Hibernate`
or `Suspend` (to RAM) from the battery icon.
Also available from the shutdown (Quit) menu.

▶ Otherwise, get the software
from http://www.suspend2.net/
It consists of a kernel patch and a hibernate
script. Just run this script to hibernate.

▶ Requirements: a swap partition a least as big as system RAM.

▶ Very easy to install with packages!
Fedora Core example: http://mhensler.de/swsusp/

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# CPU frequency control

Supported by all kernel versions in all recent distributions

▶ Power consumption is roughly proportional to frequency.

▶ Useful to adapt the frequency to computer usage
(word processing or e-mail consumes very few CPU cycles).

▶ Not possible with all CPUs (mainly "mobile" processors).

▶ Typically available through Gnome or KDE applets

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# CPU frequency control implementation

▶ Mechanism: supplied by the kernel
Allows frequency control by reading / writing files
in `/sys/devices/system/cpu/cpu0/cpufreq/`

▶ Policy: implemented by any "governor" program.
Such programs check the system state (CPU load, battery state, board temperature) and change the frequency according to user preferences.

Governor programs are easy to write and several ones are available.
Check your GNU/Linux distribution for information
about the governor it uses.

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# Laptop mode

http://www.xs4all.nl/~bsamwel/laptop_mode/

► Ideas: spin up the hard disk only when reading uncached data, delay and group disk writes, to save battery life.

► Available in the standard Linux kernel since 2.6.6. Control scripts available through the laptop-mode-tools package.

► May not be activated by default by distros: not recommended for servers and laptops running only on AC power (risk to loose data in a crash or sudden power off).

**Laptops**

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# CPU activity control

Busy CPUs consume more than idle ones, at the same frequency

▶ Keeping CPU activity under control can save a lot of energy.

▶ In server rooms, reducing power consumption even reduces air conditioning costs, reducing even further the power bill.

So, let's find ways of reducing CPU activity! A few ideas:

▶ Desktops, laptops: disable screen savers (CPU hungry)

▶ Desktops, laptops: beware of web browsers (see next page)

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# Web browser control

Web browsers can create a lot of activity (CPU or I/O) on your computer!

▶ Web pages containing Flash, Java, or just animated images
   can consume a lot of CPU.

▶ When you leave your computer and keep it on,
   make sure you close all browser pages with animations.

▶ Disabling animated images in Mozilla Firefox
   go to `about:config`, find `image.animation_mode` and change its value
   to `none` or `once`.

▶ Otherwise, your PC may be left running at full speed while you are not using it.

▶ You can also reduce disk activity by disabling the browser disk cache
   (Firefox: `browser.cache.disk.enable` set to `false` in
   `about:config`).
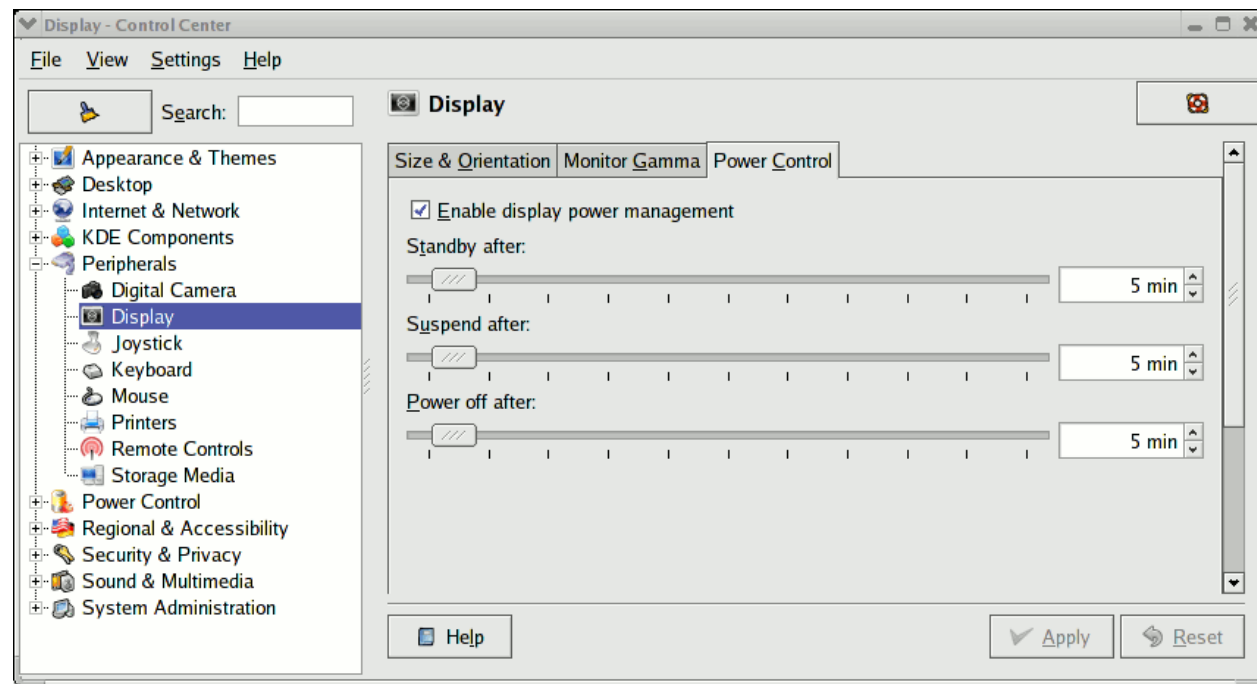
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Laptops and desktops

# Display power control (1)

Switching off the display after an inactivity timeout

▶ Easy to do in all recent GNU/Linux distributions. Configurable at least in KDE and Gnome.

▶ KDE display power management:

```
Control Center
-> Peripherals
-> Display
-> Power Control
```

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# Display power control by script

▶ If handled by your own scripts
you can control the display power with one of these commands:
```
xset dpms force standby
xset dpms force suspend
xset dpms force off
```

▶ Note that `suspend` and `off` usually save much more energy than just `standby` (which just switches off the screen, but not the control circuitry).

▶ No danger to switch off recent models of LCD displays or hard disk drives. This doesn't reduce their life cycle (according to manufacturers).

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# Virtual servers

Idea: run several virtual servers inside a real one

▶ Great for security, to isolate independent services.

▶ Shared: CPU, network bandwidth (sometimes)
Dedicated: storage space, RAM.

▶ Great for optimizing the usage of hardware resources.
Used by companies to consolidate multiple servers in just a few
ones. Otherwise, servers stay idle for most of the time.
Other advantage: easy hardware upgrades.

▶ Already very popular in web hosting.
Could be used much more often in enterprise networks!

**Servers**

# Virtual server solutions

▶ User Mode Linux - The first solution available.
http://user-mode-linux.sourceforge.net/
Allows to run 1 or several Linux kernel executables
on a Linux machine (with a standard kernel) as regular programs.

▶ Xen: http://www.cl.cam.ac.uk/Research/SRG/netos/xen/
A popular alternative, with very little performance overhead. Also allows live server migration to other hardware. Requires a patched Linux kernel.

▶ KVM: http://kvm.qumranet.com/
Virtualization supported by the mainstream kernel (no patches). Recent, but may quickly replace its competitors.

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# PowerTOP

http://linuxpowertop.org

▶ A very nice utility showing the top 10 sources of power consumption.

▶ Requirements: a tickless 2.6.21 kernel, and a "mobile" CPU. Best run on laptops running on battery (to estimate battery savings).

▶ PowerTOP measures the number of wake-ups, and counts the time spent in low-power modes.

▶ It detects issues in both kernel space (drivers) and user space.

▶ It already uncovered several bugs in today's distributions. Expect next distributions to save more battery time.

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# PowerTOP in action

```
   PowerTOP version 1.0       (C) 2007 Intel Corporation

Cn            Avg residency (5s)   Long term residency avg
C0 (cpu running)       ( 3.8%)
C1               0.0ms ( 0.0%)                      0.0ms
C2               4.4ms (57.3%)                      4.4ms
C3              10.0ms (31.1%)                     10.0ms
C4               2.3ms ( 7.7%)                      2.3ms

Wakeups per second :  193.6
Power usage (ACPI estimate) :  13.0 W (6.5 hours left)

Top causes for wakeups:
  35.2%        <interrupt> : i8042
  28.4%        <interrupt> : yenta, i915@pci:0000:00:02.0
  13.6%        <interrupt> : ipw2200, Intel 82801DB-ICH4
   4.6%              Xorg : do_setitimer (it_real_fn)
   3.7%       firefox-bin : schedule_timeout (process_timeout)
   3.5%             xchat : schedule_timeout (process_timeout)
   1.6%       firefox-bin : schedule_timeout (process_timeout)
   1.3%    gnome-terminal : schedule_timeout (process_timeout)
   1.1%   gnome-power-man : schedule_timeout (process_timeout)
   1.1%           emerald : schedule_timeout (process_timeout)


Suggestion: Enable the CONFIG_USB_SUSPEND kernel configuration option.
This option will automatically disable UHCI USB when not in use, and may
save approximately 1 Watt of power.
```

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# Reducing power consumption - Summary

▶ Power controls are now easy to use in GNU/Linux distributions. Just need to know how to use a mouse. 😉

▶ In particular, hibernation to disk works almost everywhere.

▶ CPU frequency scaling (if supported by the CPU) is easier too.

▶ Unlike in proprietary systems:

    ▶ Extreme flexibility in choosing power saving policy.

    ▶ Unlimited capability to get involved and cooperate. Unlimited capability to detect issues and fix them. No black boxes, no hidden parts.

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# Saving paper and ink

Printing multiple pages per sheet

▶ KDE and Gnome have print configuration tools

▶ If not available in your application, choose "Print to file".
This will create a PostScript file (example: `doc.ps`)

▶ With `psnup` (`psutils` package):
`psnup -4 doc.ps > doc4p.ps` (4 pages par sheet)
`lpr doc4p.ps` (printing)

▶ With `mpage` (http://www.mesa.nl/pub/mpage/):
`mpage -4 doc.ps` (transforming and printing)

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# Double sided printing (1)

On printers supporting duplex printing

▶ Can be enabled by default.
On most distributions with the CUPS printing system,
very easy to configure: open `http://localhost:631/` with a
browser, authenticate, and configure your printers.

▶ Can also be set on a job by job basis
through the KDE and Gnome print helper programs.

▶ From the command line, can also be done with the `lpr-wrapper`
program (http://www.mscs.dal.ca/~selinger/lpr-wrapper/):
`lpr-wrapper -od doc.ps`

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# Double sided printing (2)

Manually, on printers with no duplex support

▶ Many graphical applications (such as OpenOffice.org)
  let you print on odd (right) pages first,
  then on even (left) pages.

▶ Otherwise, you can print to a file and print with `mpage`:
  `mpage -j 1%2 doc.ps` (only odd pages)
  `mpage -j 2%2 doc.ps` (only even pages)

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Using computers longer

Small GNU/Linux distributions

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# Damn Small Linux

http://www.damnsmalllinux.org/

▶ Full featured Live-CD distro derived from Knoppix.
Very active community!

▶ Fits within 50 MB
Runs fine on a 486 PC
with 16 MB of RAM.

▶ Software: Firefox, xmms, xpdf, Sylpheed, FluxBox WM, Siag spreadsheet, Ted word processor...

▶ Used a lot on USB flashdisks.

# Basic Linux

Basic Linux: http://www.volny.cz/basiclinux/

The lightest distro for old PCs!

▶ Just needs 3 MB of RAM
and 6 MB of disk.

▶ Features: X graphics, window
manager, clock, calculator,
text based e-mail reader, browser
(links), presentations (MagicPoint),
network dial-up...

▶ Great for using an old PC as an X terminal!

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# Gentoo Linux

http://www.gentoo.org/
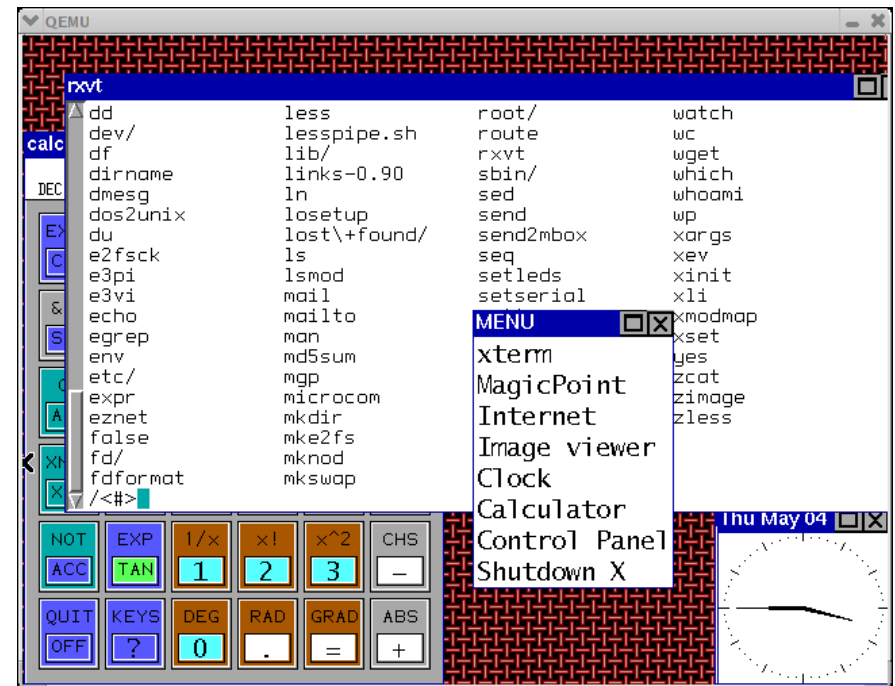
▶ Gentoo Linux is a GNU/Linux distribution targeting maximum configurability.

▶ This is ideal for older systems:
you only add what you actually need and you don't compile applications with capabilities you don't need (often causing more libraries to be needed in your system).

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Using computers longer

Reducing storage space

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# Stripping

▶ Applications and libraries are compiled by default with extra information useful for debugging (to study core dumps, for example).

▶ Stripping removes such extra information, which most users cannot exploit anyway. This can reduce the size of executables from 20% (big executables) to 40% (small executables)!

▶ Use the file command to tell whether a file needs stripping:
```
file hello
hello: ELF 32-bit LSB executable, Intel 80386,
version 1 (SYSV), for GNU/Linux 2.2.5, dynamically
linked (uses shared libs), not stripped
```

▶ To strip an executable or library:
```
strip hello
```

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# Filesystem compression (2)

Read-only compressed filesystems

▶ Idea: store parts of the system (typically executables, libraries and kernel) in a separate read-only partition. Best for speed and security, but makes software upgrades more difficult.

▶ CramFS: http://en.wikipedia.org/wiki/Cramfs
Original solution. Dramatically outperformed by SquashFS.

▶ SquashFS: http://squashfs.sourceforge.net/
Unlike CramFS, no filesystem and file size limitation.
Achieves much better compression and read speed (at least 5x faster).
Much faster than ext2 on slow storage (like USB flash disks).

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# Lightweight tools

**Use the lighter uClibc C library**
(http://uclibc.org).
Takes 400 KB instead of 1700 KB.
Used in many embedded systems and in tiny Linux distributions.
Caution: must recompile all applications!

**Use Busybox (http://busybox.net),** a toolbox implementing most Unix commands. Takes at most 500 KB instead of approximately 10-30 MB from GNU! Used by almost all embedded Linux projects and small Linux distros.

**Busybox commands:**
Most commands are there! Even includes `vi`, `wget`, a http server, a dhcp client and server... You hardly make the difference!

**So many other tools available!**
Very often from embedded Linux: lightweight web servers, GUI libraries and many more!
Quite exhaustive review on:
http://free-electrons.com/training/devtools

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# A smaller kernel
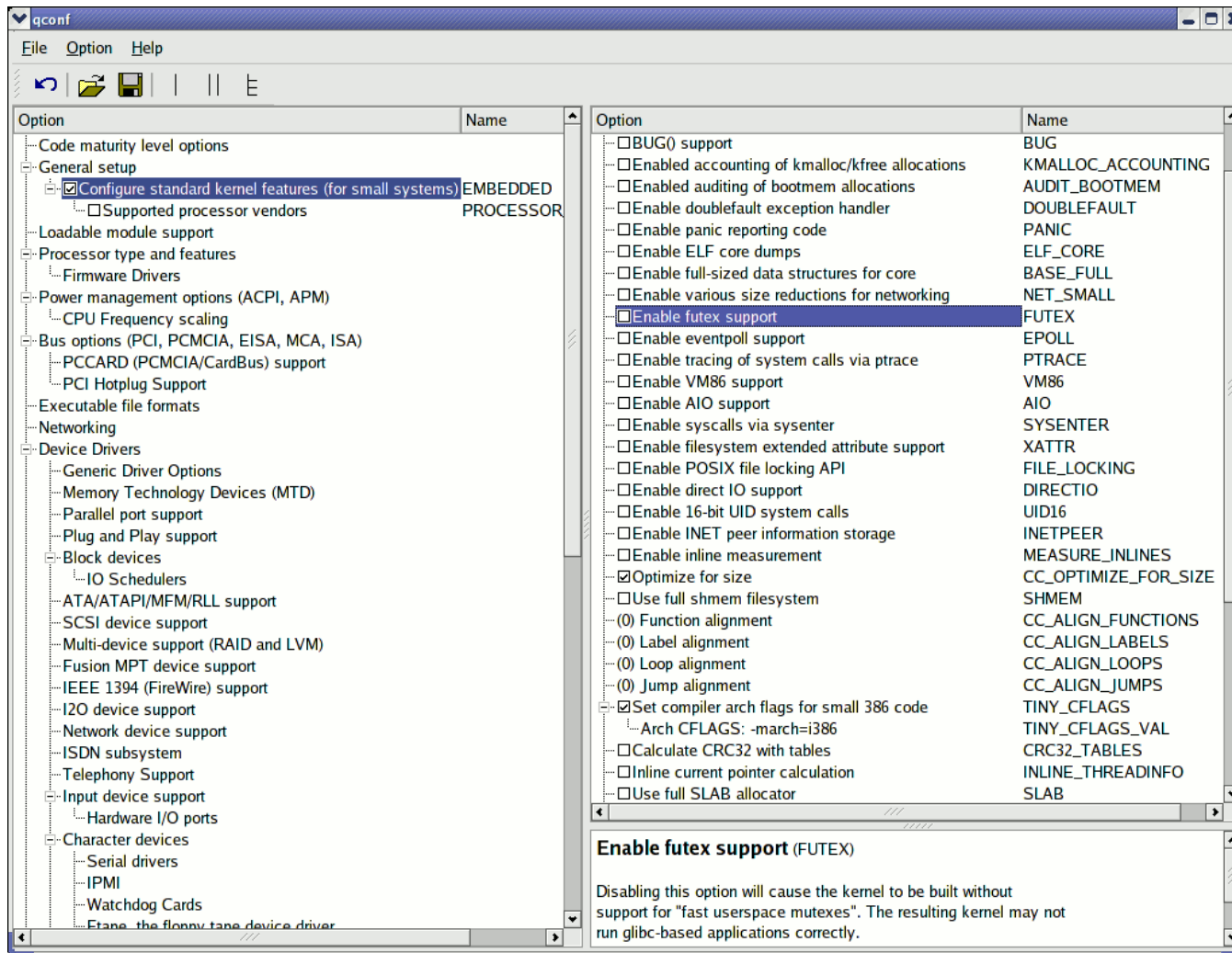


Possibility to disable features not needed in a simple system.
Saves a few hundred KB

Kernel configuration interface for small systems

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# Keeping older computers in use

Possible to reuse older computers as

▶ Print server

▶ File server (Samba or NFS) or media server

▶ HTTP, FTP, BitTorrent server

▶ Firewall, gateway, proxy

▶ Video server (webcam)

▶ Industrial control, home automation control

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# Using non-PC Linux machines (1)

No need to buy a PC to perform the services mentioned in the previous slides. You just need a machine running Linux!

▶ Linksys NSLU2: http://www.nslu2-linux.org/
Price: 90 € / USD!!!
Features: 266 MHz ARM CPU, 8MB of flash, 32MB of SDRAM
Connectivity: USB (for attached storage) + Ethernet + serial port
Extremely popular. Many use cases!

▶ ASUS WL-500g Premium: http://wl500g.dyndns.org/
Price: 100 € / USD
125 MHz MIPS CPU, 8 MB flash, 32 MB RAM
Connectivity: 4x Ethernet, WAN, WiFi, 2x USB 2.0
Perfect to install a Debian GNU/Linux server booting from a US

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# Using non-PC Linux machines (2)

▶ Devices based on the Linksys WRT chipset: http://openwrt.org/
Price: 50 - 100 € / USD
Typical config: 125-200 MHz ARM CPU, 4 MB flash, 16 MB RAM
Connectivity: Ethernet, WiFi, USB (sometimes), serial (often)
Very popular too!

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# Using non-PC Linux machines - Advantages

Many advantages

- ▶ Much reduced power consumption compared to a PC

- ▶ Produced with much less materials

- ▶ No fan: no noise pollution

- ▶ Significant costs savings (of course)

- ▶ Increasingly easy to get tools for other CPU platforms:
  packages, cross-compiling tools, distributions (Debian)

- ▶ Many lightweight tools available.
  Standard desktop tools easy to compile with less features.

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# Real-time preemption patches

Linux kernel patches from Ingo Molnar
http://people.redhat.com/~mingo/realtime-preempt/

▶ Available for any recent kernel version (> 2.6.12)

▶ When full preemption is enabled, add unprecedented responsiveness to the Linux kernel. Less latency, suitable for real real-time systems (less than 100 us!).

▶ Definitely worth trying on old systems to improve the user experience!

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# Repairing instead of replacing

▶ BadRAM patch
http://rick.vanrein.org/linux/badram/
Makes it possible to live with partially defective RAM modules.

▶ Sites collecting repairing, upgrading, disassembling
or modding instructions:

| | |
|---|---|
| Laptops: | http://repair4laptop.org/ |
| PDAs / Handhelds: | http://repair4pda.org/ |
| Cell phones: | http://repair4mobilephone.org/ |
| Mice: | http://repair4mouse.org/ |
| Printers, toners and ink cartridges: | http://repair4printer.org/ |

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# Energy consumption

- Refrain from buying new computers (a lot of energy and materials consumed at manufacturing time). Buying one also means discarding another.

- Buy low consumption systems, in particular with "mobile" processors, supporting frequency scaling. Laptops consume 50 to 80% less power. On the other hand, their batteries contain toxic materials and they are more difficult to repair or upgrade.

- Buy LCD instead of CRT monitors
  (consume 60% less and emit less mercury).

- Switch off your DSL modem / wireless router / ISP box / printers at night or during vacations if you don't use them. These devices consume quite a lot (typically 15W).

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# Measure your consumption

▶ You can buy a wattmeter to identify the most consuming devices, or to measure the impact of power saving techniques.

▶ Also measure consumption when devices are switched off. Some power adapters (usually old, big and heavy) remain warm and still drain power.

Solution: also switch off the power adapter!



Wattmeter (Brennenstuhl PM 230)
Price: 30-40 EUR / USD



Multi-socket with individual switches (Brennenstuhl Premium Line)

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# System life

▶ Battery life: use your batteries only when you are away from a power source. That's probably better to remove the battery when your notebook remains plugged in for a long time (could depend on the battery type).

▶ Use electrical surge protection devices to protect your equipment.

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# Managing electronic waste

▶ Some countries (like France) now mandate electronics / electric device stores to accept old devices for free when you buy a new one, to ensure suitable processing of waste.

▶ Idea: you may store your hardware waste in your cellar or attic (if you have enough room), waiting for mature waste processing channels or technologies to be available in your country.

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# Useful resources

- Of course, the Linux Ecology HOWTO!
  This was just an introduction.
  http://www.tldp.org/HOWTO/Ecology-HOWTO/

- Embedded Linux system techniques for reducing size,
  increasing speed, reducing power consumption:
  http://free-electrons.com/articles/optimizations/

- Lightweight tools and libraries for use in systems
  with limited resources:
  http://free-electrons.com/training/devtools

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# Conclusions

With Linux and Free Software...

▶ Possible to significantly reduce power consumption.
No black box you have no control on.

▶ Possible to extend the lifetime of your computer.
This reduces the consumption of materials.

▶ No need to run old software on old computers.
Lots of reuse from the hottest embedded Linux projects!

▶ Possible to run on low profile computers:
old computers or Consumer Electronics devices.

In a nutshell, lots of things you can't do with proprietary software!

# Thanks

- To the OpenOffice.org project, for their presentation and word processor tools which satisfied all my needs

- To http://openclipart.org project contributors for their nice public domain clipart.

- To the members of the whole Free Software and Open Source community, for sharing the best of themselves: their work, their knowledge, their friendship.

To Werner Heuser and Wade Hampton for the Linux Ecology HOWTO To people who helped, sent corrections or suggestions:

Alain Anglade, Sébastien Chaumat, Sébastien Blondeel, François Déchelle

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# Related documents

All our technical presentations
on http://free-electrons.com/docs

▶ Linux kernel
▶ Device drivers
▶ Architecture specifics
▶ Embedded Linux system development

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Audio and multimedia
System optimization

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System optimization
Application and interface development

### Consulting and technical support

Help in decision making
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System design and performance review
Development tool and application support
Investigating issues and fixing tool bugs
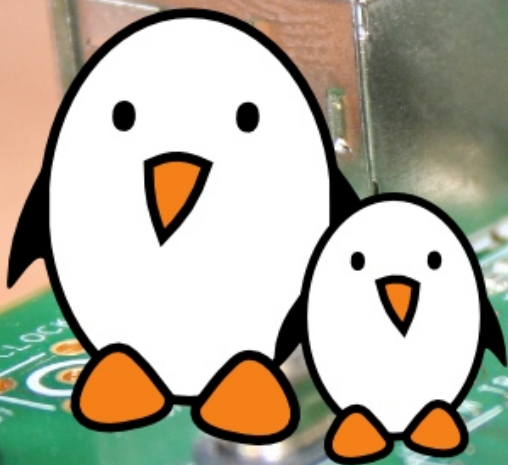
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