ETH
Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

cepe
Centre for Energy Policy and Economics
Department of Management, Technology and Economics

Energy Efficiency in the Data Centre

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1st European Workshop on HPC Centre Infrastructure, Origlio Country Club, Lugano, 2. 9. 2009

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Agenda

1. ICT → energy (general overview)
2. Past and future direct energy demand (trend and disturbances)
3. Energy efficiency (DC, infrastructure)
4. Energy efficiency (general measures)

1. ICT → Energy

What has to be considered?

What is included in ICT?

Direct electricity demand

Impact of ICT on energy demand

What has to be considered?

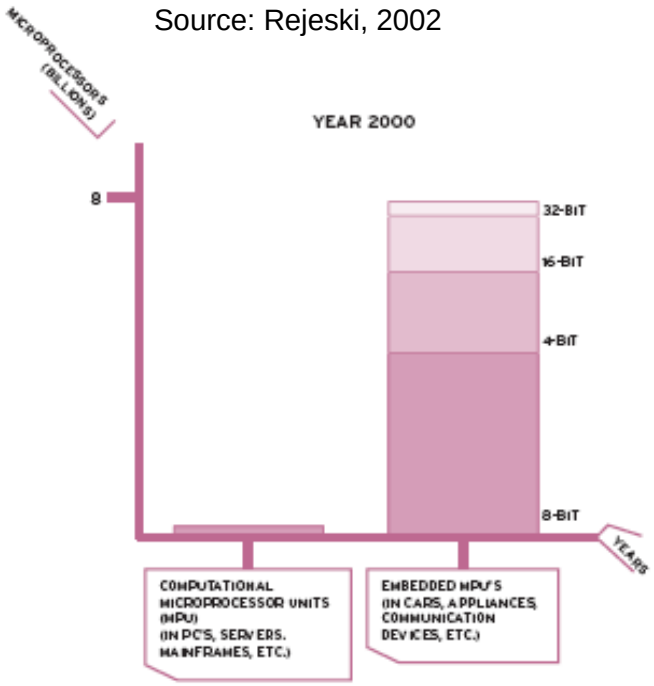
1. Direct electricity demand
2. Indirect energy demand
   - Energy over life cycle (embodied/grey energy)
   - Efficiency improvements of technical and economic processes, of vehicles/mobility, buildings
   - Structural changes / substitutions, dematerialisation
   - Faster economic growth (faster increase of productivity)

(Aebischer, 2008)

What is included in ICT?

- There could be as many as 10,000 telemetric devices per person in the industrialized countries by 2010.
- Within a decade more things will be using the Internet than people (Michel Mayer, head of IBM Pervasive Computing)

Source: Rejeski, 2002



Direct electricity demand

$$\text{Electricity}(t) = \sum_{ijk} n_i(t) * e_{ijk}(t) * u_{ijk}(t)$$

with n: number of type i
e: power in functional state j
u: intensity of use by user k

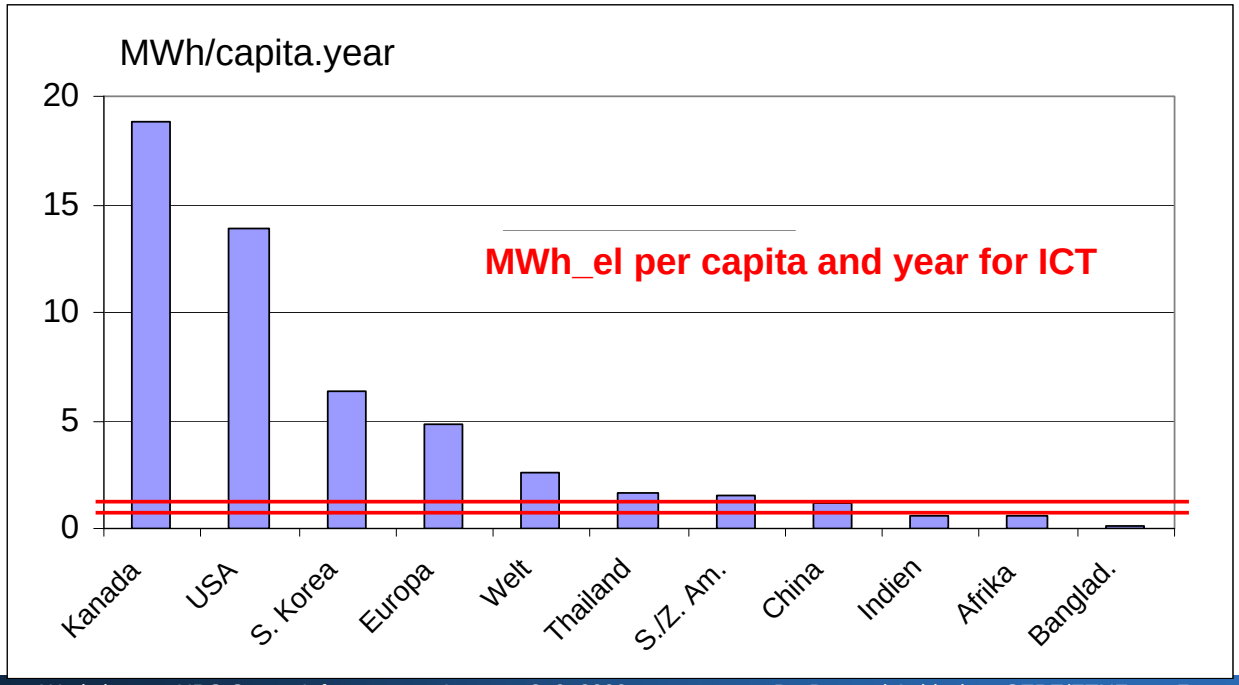
Computers, office equipment, entertainment electronics, internet, telecom, …

- About 5% of total electricity

Plus 85% of other microprocessors used elsewhere ->

- About 10% of total electricity, or
- About 1 MWh per person and year (industrialised countries)

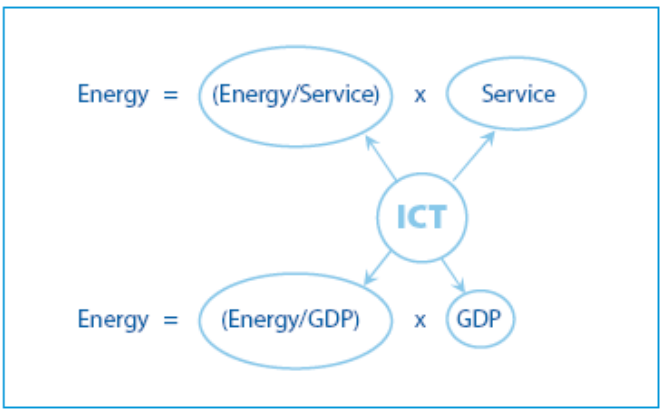
Total electricity demand per capita in different countries and electricity for ICT per capita in CH and USA



Impact of ICT on energy demand

- Micro, case studies
  - Large savings in industrial processes
  - Potentially large savings in/ with e-activities, e-services, but often additional not complementary
- Macro
  - major indicator = investments or capital stock in ICT
  - Most studies ±0
  - 1 Watt ICT →10 Watt savings! (Laitner et al., 2008)

Exhibit 4.3-3: Two approaches to studying the impact of ICT on energy demand on a national economy

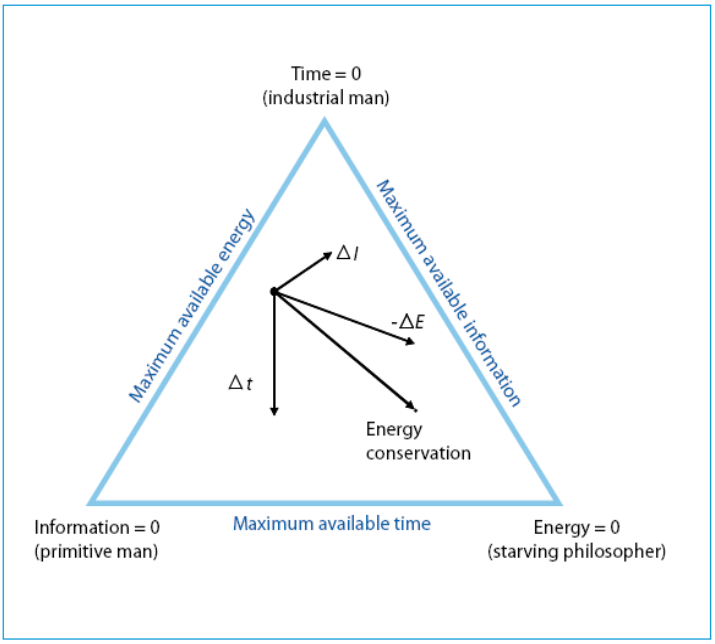


Source: Aebischer, 2008

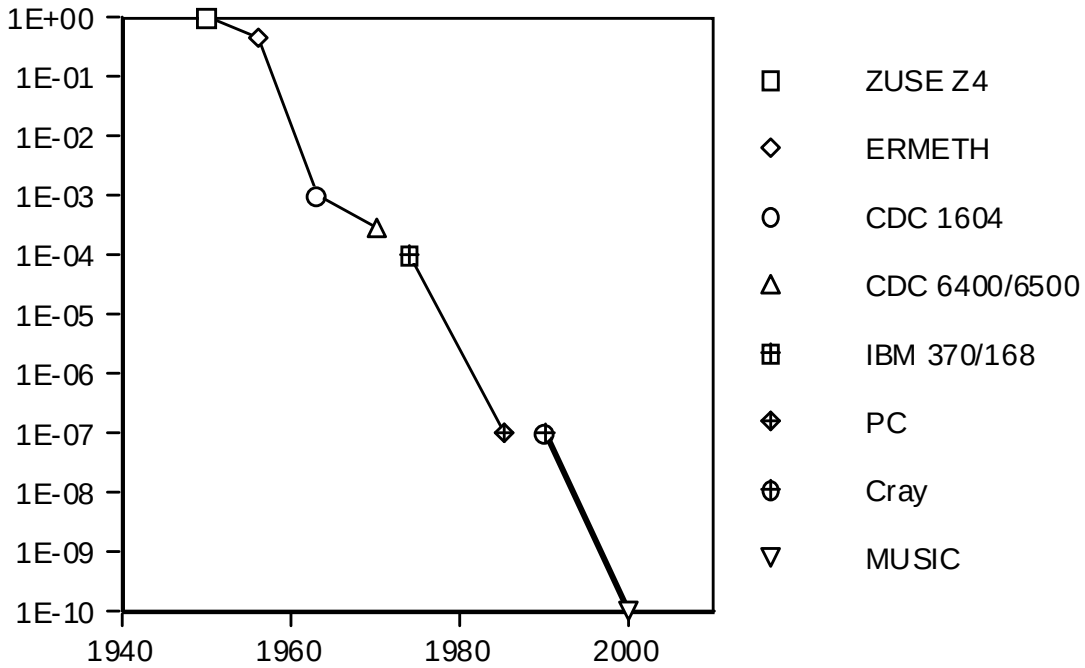
An other view: Spreng's triangle

IT can be used to substitute time by information or to substitute energy by information. IT can, in other words, both be used to speed up the pace of life (work and leisure), thus promoting a society of harried mass consumers, or it can be used to conserve precious natural resources (energy and non-energy) by doing things more intelligently and improving the quality of life without adding stress to the environment.

Exhibit 4.3-4: The time-energy-information triangle (Spreng, 1993)



2. Past and future direct energy demand (1)



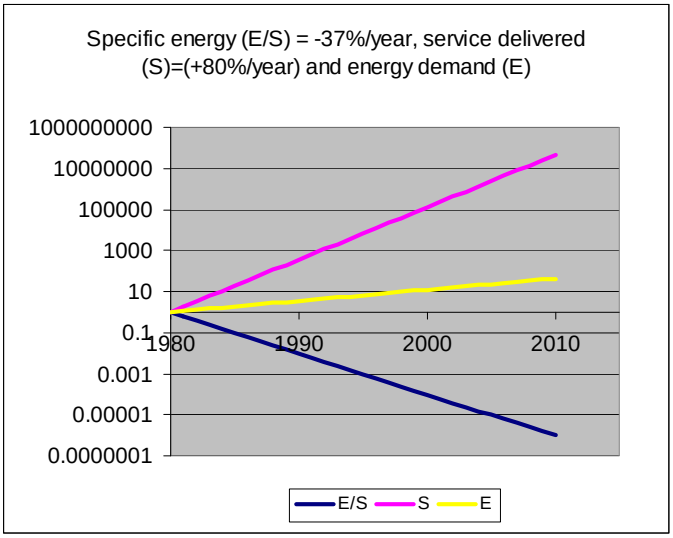
Relative variation of specific electricity demand of computers

(Aebischer/Mutzner/Spreng, 1994; Aebischer/Bradke/Kaeslin, 2000)

2. Past and future direct energy demand (2)

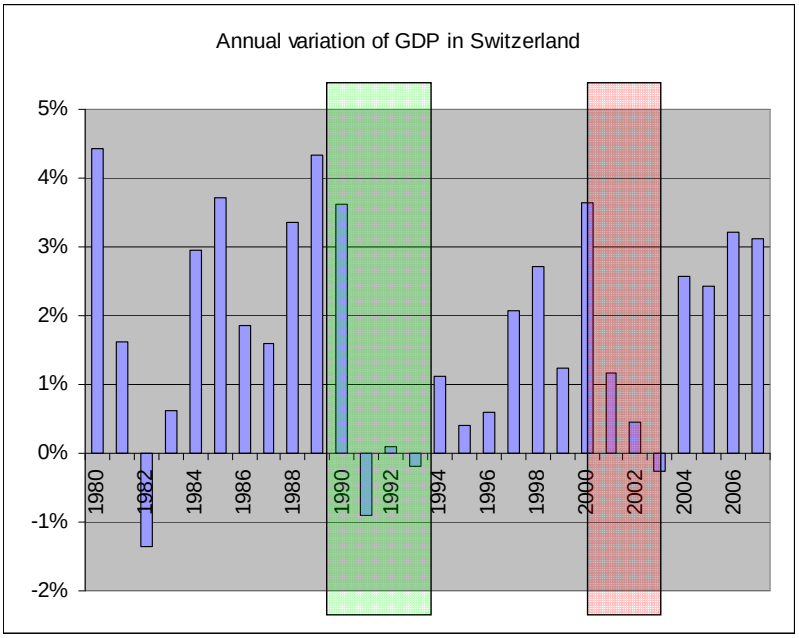
Energy demand = service delivered * (energy/unit-service)

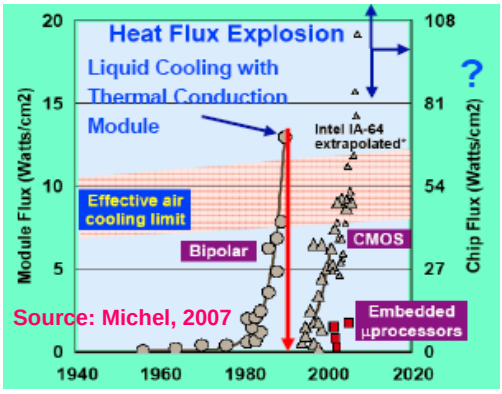
- Trend of specific consumption, e.g. energy/MIPS: reduction by factor **100** in 10 years!
- Energy demand: increase by factor **2-5** in 10 years
- Service delivered: increase by factor **200-500** in 10 years!

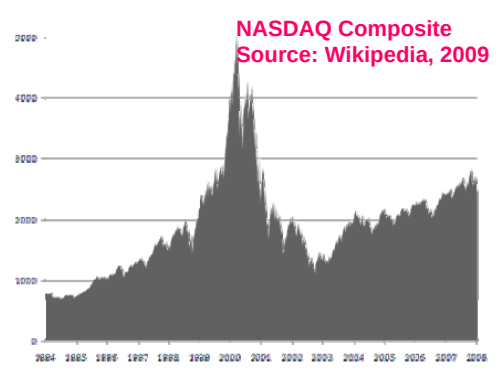


But "disturbances": technical, economic; use/operation

Example of technical and economic disturbance

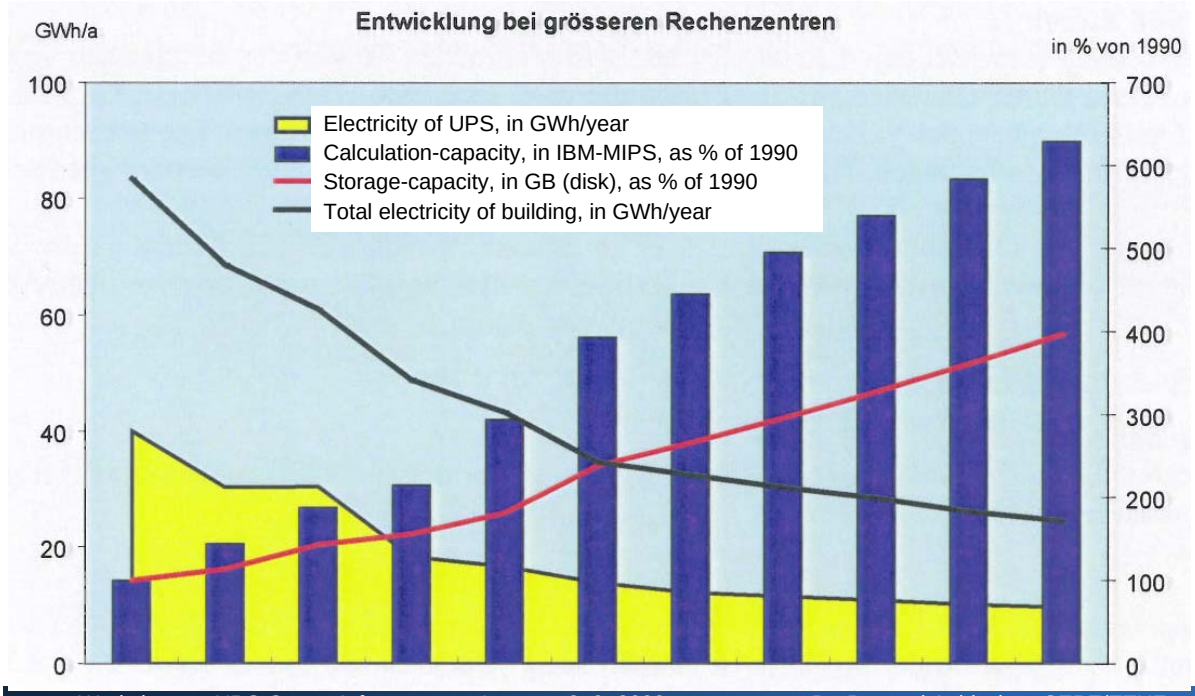






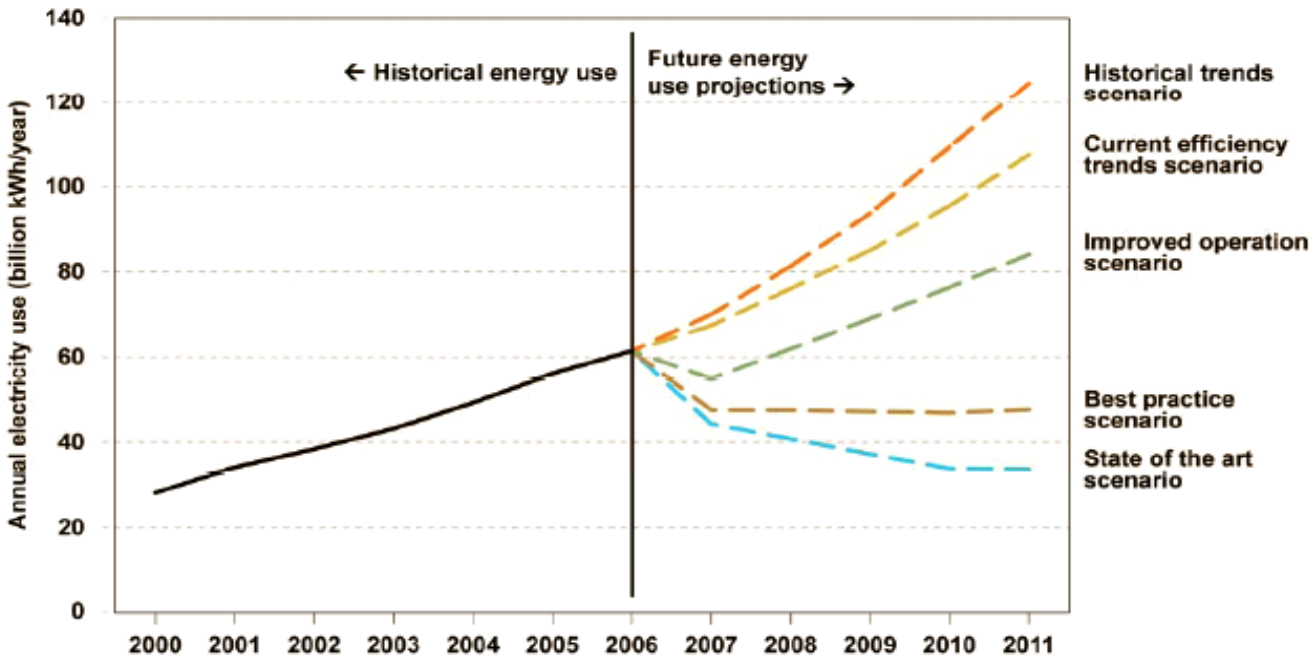
Energy Demand

Monitoring and planning of electricity demand in a DC of a Swiss bank between 1990 and 2000



Source: Bänninger, 1996

Electricity demand of servers and infrastructure in the US



Source: EPA, 2007, Figure ES-1

3. Energy efficiency in DC

Efficiency metrics: useful work / total energy

Useful work in a **data center** (DC) can take many forms.

- High performance computing (HPC) centers may measure work in terms of the number of proteins folded, genomes calculated, or weather models iterated.
- Web-search data centers might measure the number of queries served or the number of pages indexed.
- Corporate data centers might handle a mixture of emails, web pages, application transactions, and even voice traffic using Voice Over Internet Protocol (VOIP).

Proxys for useful work and productivity in a data center

(Haas et al., 2009)

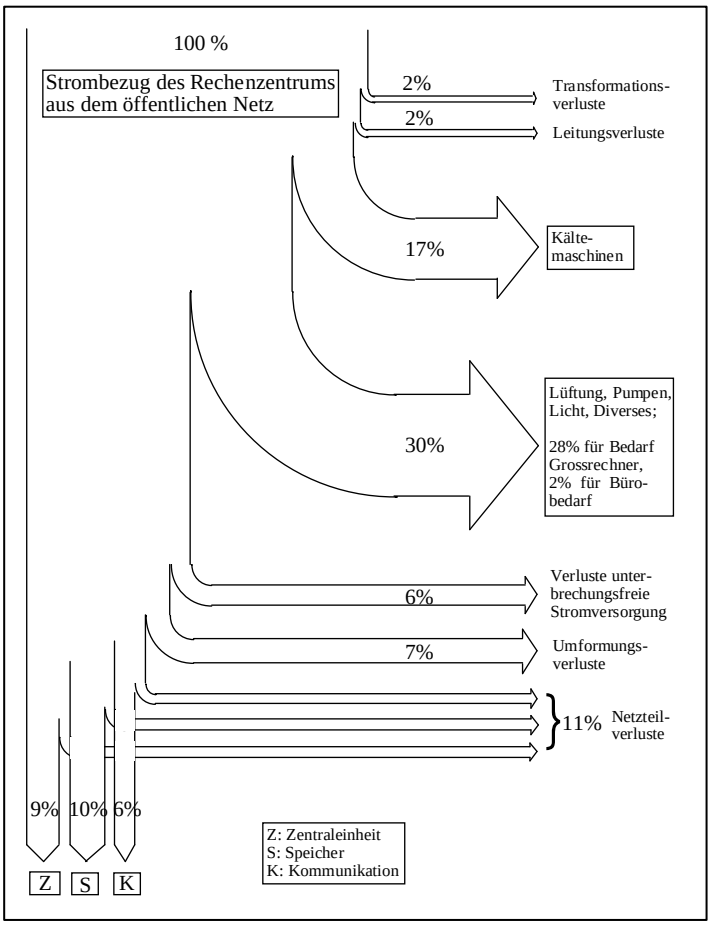
Energy flow in a DC of 4 MW

50% chiller, heat evacuation

25% electricity trans-mission and transfor-mation, incl. UPS

25% CPU (Z), storage (S) and communication (K)

Source:
Spreng/Aebischer, 1990

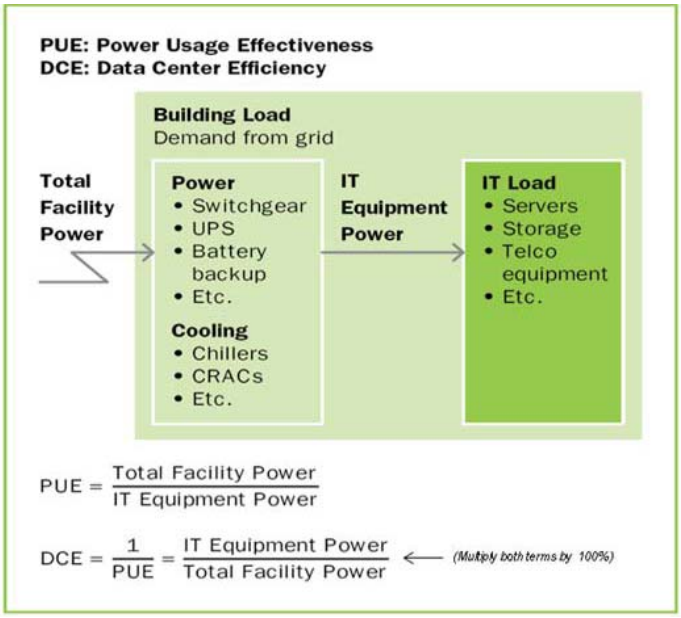


Energy efficiency of central infrastructure

Indicator: DCiE = 1/PUE

Useful for

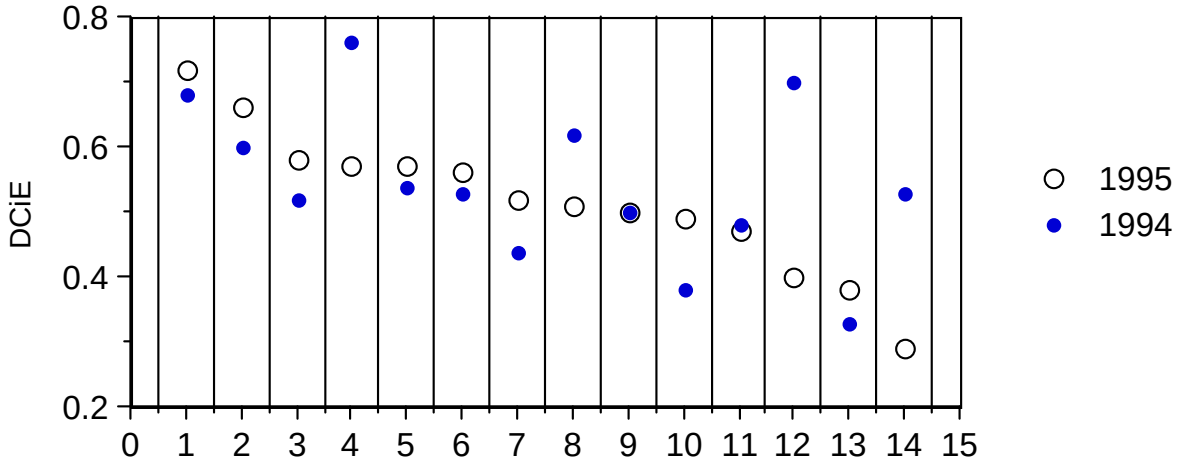
- monitoring of 1 single DC
- comparing to other DCs and to „best practice“
- setting standards, minimal requirements



Source: The Green Grid

K = C1 = DCiE = 1/PUE is a good indicator

… but a good enough **measuring concept** – with energy and not power to be measured - is essential



DCiE in 1994 and 1995 in 14 computer centres in Switzerland

Source: Bänninger (1996) in Aebischer (1996)

Measuring concept/protocol

- Energy - not power!
- Reporting frequency at least monthly
- Precise enough defined measuring points

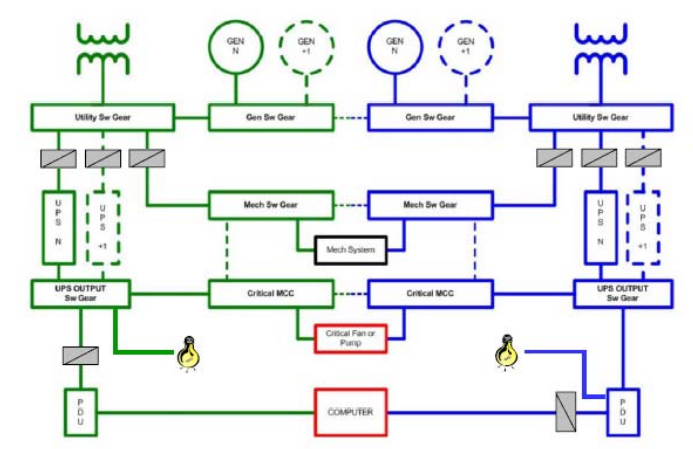
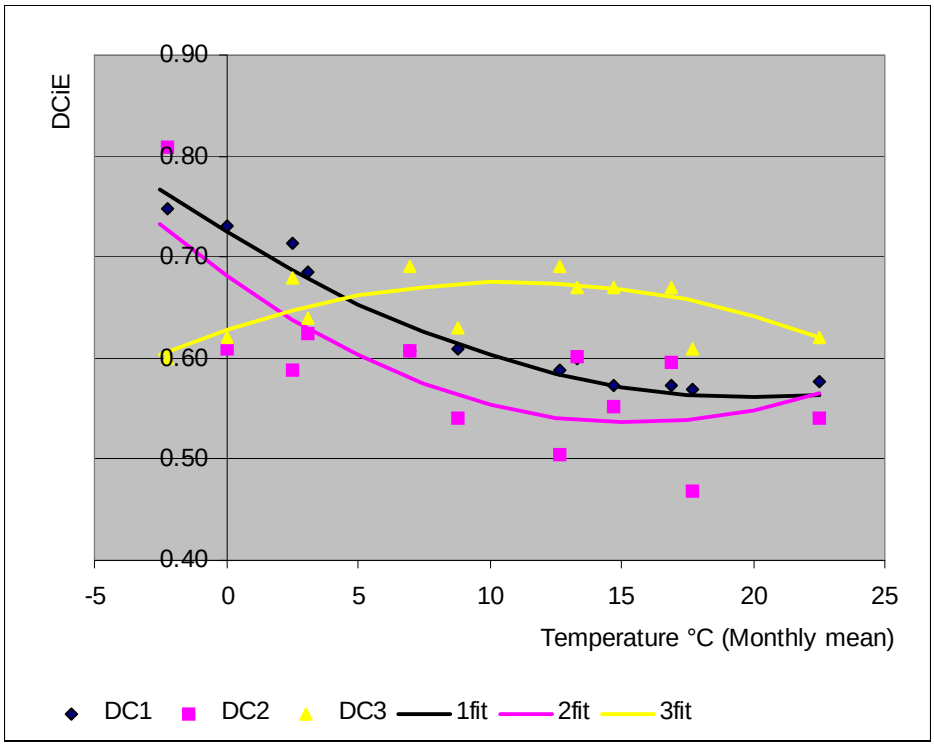


Figure 4 : principe de mesure avec production de froid dédiée et 2 variantes éclairage

measuring points for tier IV DC with proper/own cold production

Source: Uptime Institute, 2006 and Maucoronel/Duc/Willers, 2008

DCiE in function of monthly mean outdoor temperature



Source:

Swiss DCEE Group, 2007;

Bänninger, 2007

4. Measures to improve energy efficiency (1)

Overall efficiency

- Buy new equipment
- Migrate to other equipment (main frame <-> blade server)
- Use equipment more efficiently (consolidation, virtualisation)
- Improve programming, other software
- Question “service”
- Question “security standards”
- Reorganise data storage

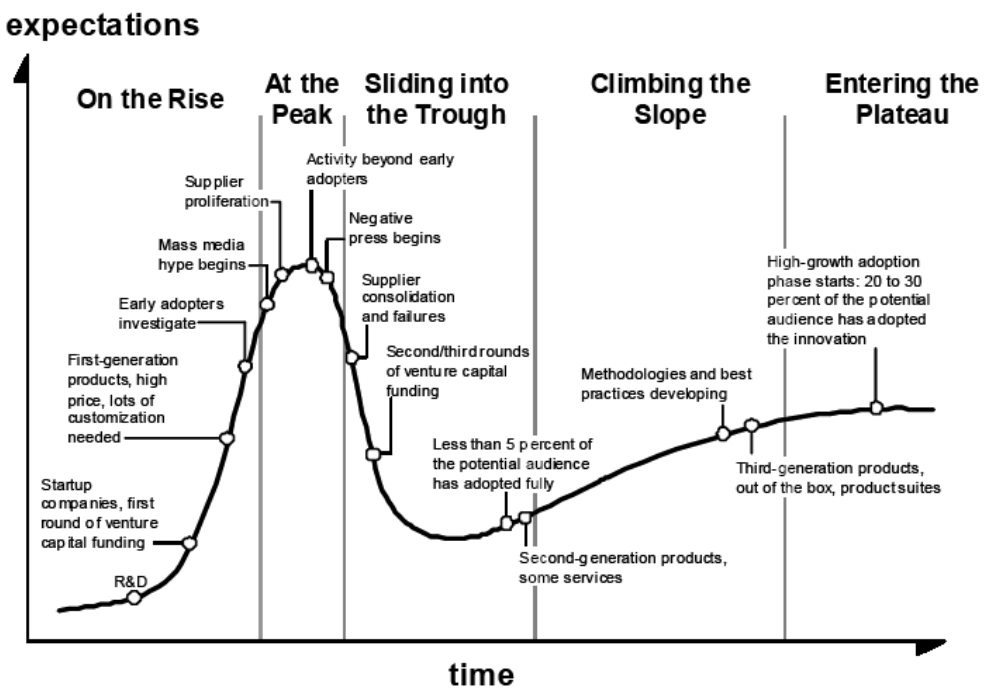
4. Measures to improve energy efficiency (2)

Infrastructure efficiency

- Modularity, flexibility → closer to optimal workload of UPS, transformers, power supplies, cooling system, …
- Accept higher temperatures and more tolerances for humidity (HPC?!)
- Improve energy efficiency of heat evacuation (and use of evacuated heat!)
- Monitoring, controlling and (automatic) managing

→ Best practice guide (Code of Conduct, 2008) and others

Gartner's Hype Cycle



Source: Gartner (July 2009)

Source: Fenn et al., 2009

Gartner's Hype Cycle

A few examples (Gartner, 2009)

- DC distribution and cooling management software have reached the peak of "inflated expectations"
- Free cooling and power monitoring and management software are sliding into the trough between second or third rounds of venture-capital funding and sobering industry adoption statistics.
- Other solutions sliding along into the aforementioned trough are combined heat and power, flywheel UPS systems and in-rack cooling

US different from Europe (engineering culture, relative prices)?

Simulations show potentials

	optimised infrastructure [5])	conventional infrastructure [5])	inefficient infrastructure [5])	(Mitchell-Jackson, 2001)[3])
shares based on:	kWh/a	kWh/a	kWh/a	kW
free-cooling	yes	yes	no	no [4])
computer room temperature	26°C	22°C	20°C	20-21°C [4])
cold water temperature	11/17°C	6/12°C	6/12°C	7-10°C [4])
COP chillers	4.0	2.5	2.5	unknown
supply air temperature	14°C	12°C	12°C	unknown
pressure loss in CRAC	350 Pa	500 Pa	900 Pa	unknown
fan efficiency	65%	60%	55%	unknown
C1 = DCiE = Computers	75.7%	59.2%	47.6%	48.5%
HVAC	13.3%	24.8%	30.4%	36.9% [1])
Light	2.0%	3.0%	4.0%	3.4%
Power distribution unit	2.0%	4.0%	5.0%	[2])
UPS	5.0%	7.0%	10.0%	[2])
Others	2.0%	2.0%	3.0%	11.2%
Total	100.0%	100.0%	100.0%	100.0%

Quelle: Altenburger, 2001 in Aebischer et al., 2003

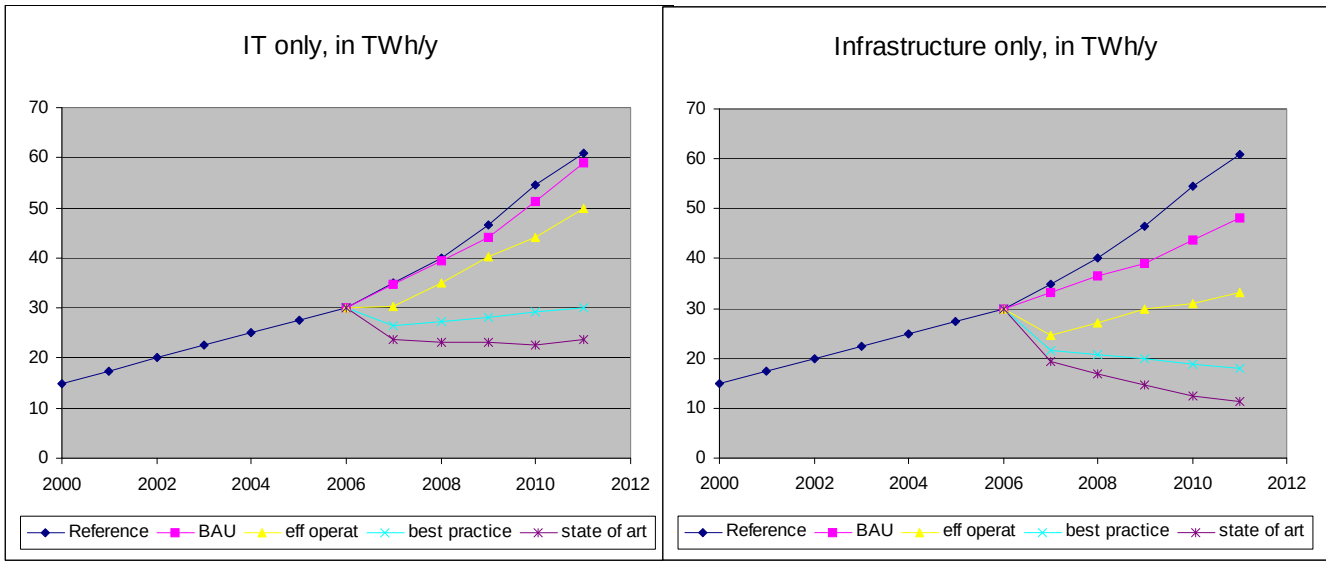
Examples demonstrate feasibility

- Strom rationell nutzen. Umfassendes Grundlagewissen und praktischen Leitfaden zur rationellen Verwendung von Elektrizität. (RAVEL, 1992)
- Erneuerung der Wärmeabfuhr in einem existierenden Rechen-zentrum in Basel mit Stromeinsparungen von 50 bis 75% für die Kühlung (Altenburger, 2004, Auftrag BFE)
- 100% Aussenluftkühlung von Telefonzentralen bei Swisscom (Singy/ Többen, 2005)
- Energy-Efficient Data Centres. Best-Practice Examples from Europe, the USA and Asia (Fichter K. et al., 2008)
- ENERGY AND COST SAVINGS BY ENERGY EFFICIENT SERVERS – CASE STUDIES (E-server consortium, 2009)

What's new in best practice?

- Consolidation, virtualisation (DCiE may decrease!)
- Air flow control
  - measurements thanks to sensors and simulations thanks to faster computers
  - cold/warm aisles
  - cold aisle containment
- Higher temperatures and larger tolerances regarding moisture
- Better documentation

Energy savings in IT and in central infrastructure



In 2011 only 30% of optimised infrastructure!

Source: EPA, 2007, Figure ES-1; own calculations

Contribution of more efficient infrastructure is relevant!

DCiE 50% → 62.5% best practice scenario (30% of all DC have DCiE = 80%)
→ 67.5% state of the art scenario (30% of all DC have DCiE = 85%)

In CH (with 2.8% of US-servers) electricity savings of 200-300 USD/year in 2011

DCiE						Savings Infrastruct in CH, Mio.CHF/y					
	Reference	BAU	eff operat	best practice	state of art		Reference	BAU	eff operat	best practice	state of art
2000	50.0%					2000	0				
2001	50.0%					2001	0				
2002	50.0%					2002	0				
2003	50.0%					2003	0				
2004	50.0%					2004	0				
2005	50.0%					2005	0				
2006	50.0%	50.0%	50.0%	50.0%	50.0%	2006	0	0	0	0	0
2007	50.0%	51.0%	55.0%	55.0%	55.0%	2007	0	9	57	75	88
2008	50.0%	52.0%	56.3%	56.9%	58.1%	2008	0	20	72	108	130
2009	50.0%	53.0%	57.5%	58.8%	61.3%	2009	0	42	94	150	178
2010	50.0%	54.0%	58.8%	60.6%	64.4%	2010	0	61	132	199	236
2011	50.0%	55.0%	60.0%	62.5%	67.5%	2011	0	72	156	241	278

Source: EPA, 2007; own calculations

Obstacles to improve DCiE

- Life time of infrastructure >> IT-equipment
- Little cooperation between IT- and infrastructure-people
- Separate budgets for IT and infrastructure
- TCO hardly considered
- HPC?

Start to overcome/avoid obstacles - create incentives

- Change business structure to allow and to foster cooperation between IT- and infrastructure-people
- Substantial budget over several years; incentives/awards!
- Exchange of experience → user groups

User Groups

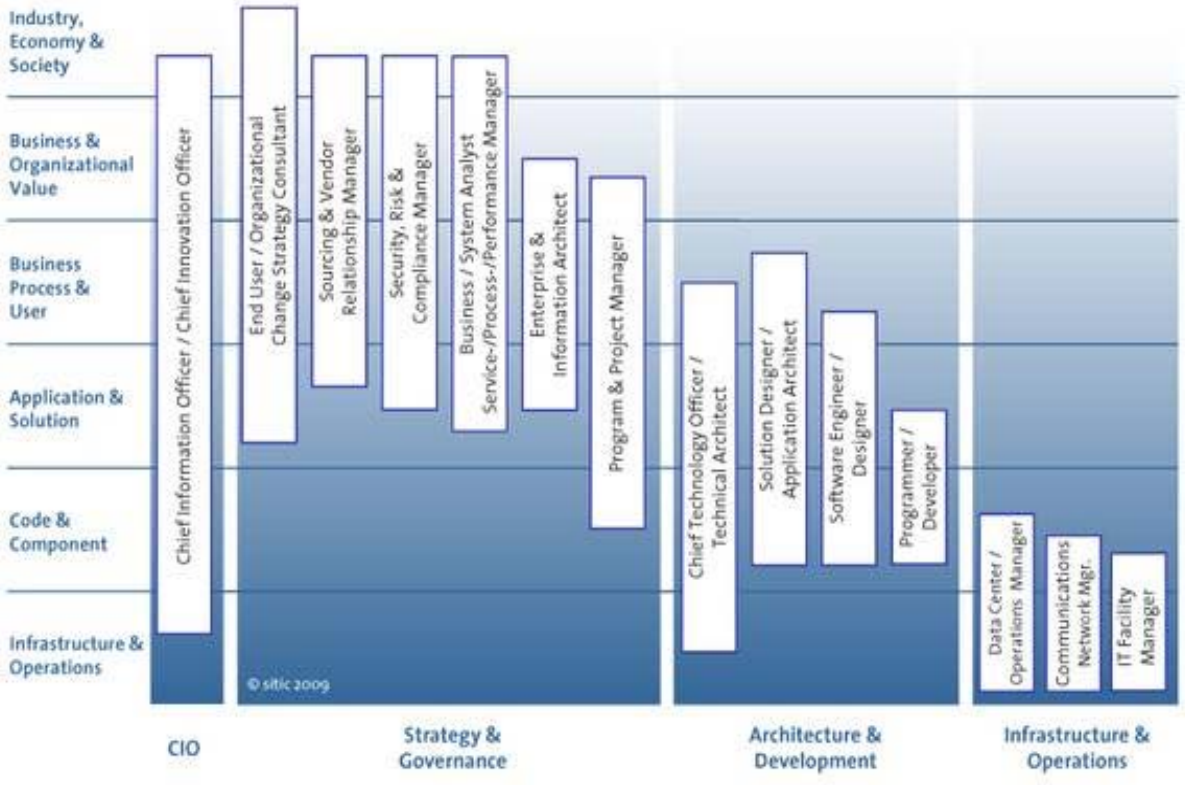
Switzerland

- Traditional: ERFA RZ since 1980s
  - Benchmarking of energy efficiency: K (= DCiE)
  - Today integrated in the local and federal energy policy activities
- Innovative: Infrastructure & Operations Community c/o Swiss IT Intelligence Community www.sitic.ch

US and EU

- Green grid, EPA/DOE, Uptime Institute, …
- Code of Conduct

Sitic-"Communities"



Summary and recommendations

Long term energy demand of ICT determined mainly by IT-technology and IT-services

Large energy saving potentials in infrastructure

Start with measuring and monitoring DCiE

Temperature- and humidity-tolerances are crucial factors

TCO is a good instrument to bring closer together IT- and infrastructure-people

Join a user group or launch a user group

This 1st workshop on HPC Centre Infrastructure is a very promising start!

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