Energy- and Eco-Efficiency of Data Centres

A study commissioned by DIAE[1] / ScanE[2] of the Canton of Geneva

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Contents

Summary

In this study we investigate strategies and technical approaches to fostering more energy-efficient and environmentally sound planning, building and operating of data centres. We then also formulate recommendations on how to integrate the findings in the legal and regulatory framework in order to handle construction permits for large energy consumers and promote energy efficiency in the economic sectors.

1 Context and objective

The starting point of the study is the “accord” negotiated between the Canton of Geneva, operators of data centres and representatives of environmental organisations concerning the energy and environmental aspects to be considered in the new data centres. The government intends to integrate the results of this negotiation process in the regular procedure set up to handle construction permits for large energy consumers and to promote energy efficiency in the economic sectors. The authors had participated in the process leading to the accord and were asked to support the follow-up process by investigating different aspects of the accord:

- Is it feasible and does it make sense to measure energy efficiency in data centres by the Coefficient of Energy Efficiency (CEE)?
- Are voluntary policies approaches adequate in the socio-political situation in Geneva and adapted for data centres and similar activities?
- Can the required “equal treatment” of all companies with activities similar to data centres and of large energy consumers in all other economic sectors be fulfilled?

2 Approach and methodology

Energy-economic and policy aspects of these three issues were studied. The energy analysis was focused on data centres and similar activities in the ICT-sector, but the outcomes relative to the central infrastructure of the buildings are valid for all kinds of high electric load buildings. The policy analysis took a more general approach and the findings can be applied to all large energy consumers.

3 Data Centres: description/function and energy use

A data centre is a building or a fraction of a building (a hall or a room) accommodating servers and other ICT equipment. Until the mid-nineties the large majority of all data centres were corporate data centres – computer centres owned and operated by a company and mainly used for company-internal tasks. Over time, some of these corporate data centres began to be outsourced to “hosting facilities”, which contributed significantly to the observed electricity “savings” in office buildings (Weber, 2002). Liberalisation of the telecom-market, mobile telecommunication and the emerging e-economy were other drivers for the fast growth of hosting facilities. Collocation and managed data centres are two types of hosting facilities.

About half (50% ± 20%) of the electricity consumption of a computer centre is used by the central infrastructure and the other half by the ICT-equipment. 50% of the electricity delivered to the ICT-equipment is lost in the power supply. A detailed questionnaire about energy consumption sent to existing and planned data centres in Geneva got a rather low response and the information was sparse and of doubtful quality.

4 Energy efficiency in data centres

In this chapter we discuss the technical potential including some economic considerations. However, the economic dimension is difficult to integrate – especially in the fast evolving market of data centres and ICT. Policy aspects are considered in chapter 6.

In the absence of an adequate indicator for the service delivered by data centres, we chose to measure the energy efficiency by the coefficient of energy efficiency (CEE), a two-step measure of the fraction of the "useful" energy:

$CEE = C1 * c2 = (U / T) * (u / U)$, with T = total electricity consumption of data centre

U = total el. consumption of ICT-equipment

u = "useful" el. consumption of ICT-equipment

A measurement concept for C1 - the measure of the energy efficiency of the central infrastructure - is proposed. It can be easily implemented with few additional costs in new data centres. Technical problems and relatively high costs cannot be excluded for some existing buildings.

The energy efficiency potentials in ICT-equipment are discussed on the level of the individual equipments and for groups of equipment. Specific energy consumption of processors and other electronic components is decreasing extremely quickly but the increase in ICT-services is even faster. Large unexploited energy savings are possible in the operation of the equipment (particularly by a reduction of standby-losses), in the optimisation of the power supply system (optimised workload of the power supply) and by switching to larger servers (which needs a shift in business philosophy away from collocated to dedicated data centres).

The two most important measures to reduce power loads and electricity consumption of the central infrastructure are

- using free cooling techniques, and
- optimising the cold-water circuit temperature.

Operating the HVAC system with maximum free-cooling capacity, elevated room air temperature (26°C instead of 20°C) and the cold water circuit at elevated temperatures (13/19°C instead of 6/12°C) allows for a reduction in electricity consumption of the HVAC-system on the order of more than 50%. The share of electricity consumption for computers (C1) in optimised data centres may reach more than 70%, whereas it is less than 50% in centres that are equipped with an inadequate (oversized) or inefficient infrastructure.

5 Eco-efficiency in data centres

The most important questions are related to "refrigerants used in cooling equipment", "green electricity" and "emissions from emergency power generators".

The phase-out of partly halogenated hydrocarbons (HCFCs) is discussed in Europe. They may be replaced with partly fluorinated hydrocarbons (HFCs) and so-called natural refrigerants. Because of their considerable global warming potential and their indirect ozone-depleting effect, a careful treatment during filling, maintenance and end of life treatment of HFC chillers is of utmost importance. We therefore recommend making the same high demands on the handling of HFC as on the handling of CFCs and HCFCs.

The value of the commitment of the operators of data centres to buy electricity from hydropower is discussed and a strengthened commitment that contributes to fostering new renewable energy sources is proposed. This scheme, known as "naturemade"-labelled electricity, is marketed in Geneva by SIG as "SIG Vitale Vert".

The emissions of NO_X, CO, hydrocarbons and particulates expected from emergency power generators are orders of magnitude below the emissions from road traffic. But, during emergencies, they could - locally and for a limited time – be rather important. A detailed assessment is recommended.

6 Policies to foster energy efficiency in data centres

The “Energiemodell Zürich” and the “Energiemodell Schweiz” can readily serve as bases for a similar approach in Geneva. In these two models, the data centres are in fact able to negotiate target values, whether as an individual company, a group of data centres, or a group with large consumers from other sectors of the economy. The CEE concept is compatible with the general criteria applied in the Zurich and Swiss models. The data centres’ speed of technical and business cycles nevertheless definitely presents a problem, as it makes it more difficult to get the data centres’ commitment to target values negotiated for the medium and long term.

This approach, “voluntary agreement on target values”, is compared to the actual situation in Geneva that concentrates more on the procedure to be followed. It is also compared to two other scenarios characterised by a higher degree of intervention by the state, that is, by the room for manoeuvring granted to economic and environmental actors in the course of the procedure. In order to facilitate the discussion about advantages/disadvantages of the different scenarios, we compare them systematically by using a set of criteria. Finally, we identify several conditions that need to be changed should the canton of Geneva want to institute one of the scenarios that go beyond the energy concepts and procedures currently being formalized (e.g. adoption of the 'Règlement modifiant le règlement d'application de la loi sur l'énergie", L 2 30.01).

7 Conclusions, recommendations, outlook

The detailed analysis of the technical-economic feasibility showed that C1, the first component of CEE, is a good choice to describe the energy efficiency of a data centres central infrastructure. It can be used in the construction-permission process and in the follow-up monitoring process. The second component of CEE, C2 measuring inefficiencies in the ICT equipment, can be used to monitor the inefficiencies in the ICT equipment. But the uncertainties are still too important to use C2 as an indicator leading to a target value or even a constraining standard.

Voluntary policy is the essence of scenario S2[3]. It fits well in the actual policy “environment” in Switzerland (cf. voluntary agreements for CO_2 reduction) and in the initiated legislative reforms in Geneva, and can be implemented immediately. More constraining policies (S3, S4) are investigated regarding the central infrastructure. A comparison shows an obvious advantage of S3 and S4 regarding effectiveness, but the political obstacles and the time needed to prepare and implement these policies are probably rather important. Furthermore, additional administrative resources as well as a cultural change within the ScanE are pre-conditions for more constraining policies.

The conclusions of the policy analysis are not restricted to ICT companies. The different scenarios can be applied to all important energy consumers in all economic sectors – provided that adequate indicators for energy efficiency can be defined and determined.

Seventeen recommendations grouped in four topics are derived from these conclusions and from more general insights. These topics are:

- Transfer of the accord into an institutionalised legal and regulatory framework

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[3] Today it is partially realised in the new regulation of the Canton of Geneva (appendix 6)

- Energy-efficiency policies for all large energy consumers
- Preconditions, pre-requisites
- Operational design of voluntary energy policies

In the final outlook we recall that the future electricity demand of data centres is uncertain, but it will grow substantially for ICT in general. Nevertheless, electricity for ICT will remain in the coming years a small fraction of total energy and electricity consumption in Geneva. In order to reach the goals set by the energy policy in Geneva, it is most important to involve all economic activities and all energy-consuming processes and equipment in a process aimed at a more energy-efficient economy.

1 Context and Objective

1.1 Context

In spring 2001 after five months of investigation and deliberation an “accord” (Appendix 1) was signed between the government of Geneva, a group of NGOs and the promoters of four data centres planned to be built and operated in 2001/2002. The negotiation process was the government’s answer to the appeal of the NGOs against a factual constructing-permit for large “data centres”. Environmentalists were mainly concerned about the electric power demand of several tens of MW, corresponding to the mean electric power load of several tens of thousands of households.

The main points of the “accord” are:

- The promoters of data centres reduce their demand of electric power substantially,
- At least 70% of the electricity purchased will be produced from renewable energy-resources, particularly hydro-power
- The promoters take measures to encourage customers to optimise their energy consumption
- The promoters measure energy and power consumption of their site in order to set up an indicator of energy efficiency
- The promoters annually deliver their measurements to the Canton of Geneva, including a description of measures realised and planned in order to improve the indicator of energy efficiency
- The Canton of Geneva treats in a similar way all companies active in the same business
- The Canton of Geneva will carefully watch that the obligations are fulfilled by the promoters

The main results were presented by DIAE, representing the government of the Canton of Geneva, at a press conference on March 6, 2001 (appendix 1).

The accord is limited in time to December 31, 2003. But the government has the intention to integrate the results of this negotiation process in the regular procedure to handle construction permits for large energy consumers and promote energy efficiency in the economic sectors. Changes in the legal and regulatory framework and in the formal procedure were adopted very recently (cf. appendix 6). The authors had accompanied the process leading to the accord and were asked to support the follow-up process by investigating different aspects of the accord:

- Feasibility of the CEE-concept (CEE = Coefficient of Energy Efficiency, see section 4.2.1) from the technical-economic point of view[4]: measurement, efficiency potentials, target values and/or standards. Its use in a permit-delivery process or for monitoring purposes

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[4] The CEE-concept was used without empirical or detailed theoretical evidence that it could be applied in real situations.

should be investigated and alternatively other measurement procedure should be investigated.

- Suitability of voluntary policies, e.g. „Grossverbrauchermodell Zürich“ or „Energiemodell Schweiz“[5]. Are these approaches adequate for Geneva? Is this approach still possible regarding the very short business cycles of the ICT–companies (ICT = Information- and Communication-Technologies)?

- Fulfilment of the equity-criteria: equal treatment of all companies with similar activities, but also large energy consumers in all other economic sectors. The authorities of the Canton of Geneva are concerned with energy and environmental issues of important energy consumers, not just in the ICT sector but also in all other economic sectors. In order to maximise the potential impact and to treat all economic actors on an equal basis, the envisaged new energy- and environment-policy approach should be applicable to all important energy consumers.

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[5] Regarding the institutional implementation, a voluntary agreement approach similar to the one used in the “Grossverbrauchermodell” in Zurich or the “Energiemodell Schweiz” in the Program “SwissEnergy”, was considered to be most appropriate in the negotiation process.

2 Approach and methodology

The question of the feasibility of the CEE-concept is divided in two topics: "C1" related to energy efficient layout and monitoring of the infrastructure and "c2" looking at the efficiency of the ICT equipment. Technical, legal and political aspects are considered. Two applications of CEE are considered:

- authorisation of construction
- monitoring of energy efficiency in operation over time

Only Data Centres are considered. Whether a similar coefficient can/should be defined for other economic activities, and whether it is applicable to any of these two domains, is not the topic of this report.

The integration of voluntary agreements in a legal structure is exemplified by the "Grossverbrauchermodell" in Zürich and the "Energiemodell Schweiz", and is further discussed on the basis of a descriptive exposition of several possible alternative concepts (scenarios).

The equity-aspect was looked at from the point of view of whether the CEE-concept and the formal process could be adapted to other large energy consumers.

The investigations regarding policy aspects are not restricted to data centres. The proposed scenarios are applicable to all economic activities and the general conclusions are valid for all sectors. But the analysis was not conducted on the level of the individual sectors and thus sector specific questions are not treated. Furthermore, the policy analysis was concluded before the adoption of the new "Règlement modifiant le règlement d'application de la loi sur l'énergie" (L 2 30.01). Thus, this final report does not take into account this latest policy development, which already integrates some of our previous policy recommendations.

Table 2-1: Domains of investigation

	authorisation of construction	monitoring-process
data centres	technical and political feasibility	technical and political feasibility
all economic activities	political feasibility	political feasibility

2.1 Energy analysis

The energy analysis is conducted in a two-step process. First we investigate what energy is used for in a data centre. As no reliable data was available from the data centres planned or operated in Geneva, we used information from large computer centres in Switzerland (3.2.2) and published data (3.2.1) in national and international literature. In a second step the energy use and energy efficiency potentials are evaluated at the level of the ICT equipment (section 4.3) and infrastructure (section 4.4). For the latter, results of detailed simulations by Altenburger (2001) for different technological solutions and different operation modes could be used.

2.2 Policy analysis

First, we briefly restate the problem created by the power demand of data centres, which was the starting point for this research. We show the main lessons to be learned from this conflict, its origins and the contractual solution that was found in the end. (section 6.1)

We then analyse and discuss energy policy models used in Zurich and in the framework of the federal program EnergieSchweiz.

Taking the current development of laws and regulations into account (scenario S1), we critically discuss the solution that is envisaged now. We make several recommendations for the regulatory texts that have been edited (appendix 6).

We then outline three other possible scenarios for formulating and implementing a new procedure for energy authorization and monitoring of data centres and other large consumers in the canton of Geneva. (Scenarios S2 to S4 call for target or mandatory values and effective energy monitoring.). (section 6.3.1)

Last, we point out some conditions that are necessary to move the procedure currently being reformed towards one of the three other scenarios S2 to S4. Since these are of a more interventionist type, they require a larger involvement of the public sector, especially of ScanE. In order to help with the discussion of which scenario to choose, we compare the scenarios systematically with the help of criteria formulated in the framework of this project.

3 Data Centres

3.1 Description and function of Data Centres

A Data Centre – taken in a wide sense - is a building or parts of a building (a hall or a room) accommodating servers and other ICT equipment (Figure 3-1). The function of the equipment hosted in a data centre is manifold. It may be an element of an intranet, part of the public infrastructure of the Internet and the telecommunication-system or a mixture of these two functions (Figure 3-2). Other classifications of data centres are more suggestive regarding the function of a data centre: computer centre, server farm, point of presence, telecom main switch, ...


source: Tebodin

Figure 3-1: The “internals” of a data centre (Hartkamp, 2002)

There are many ways to classify data centres, e.g. regarding the service provided:

- ISP = internet service provider,
- ASP = application service provider,
- FSP = full service provider,

or with respect to the ownership of the data centre and of the ICT equipment:

- corporate data centres
- collocation data centres
- managed data centres

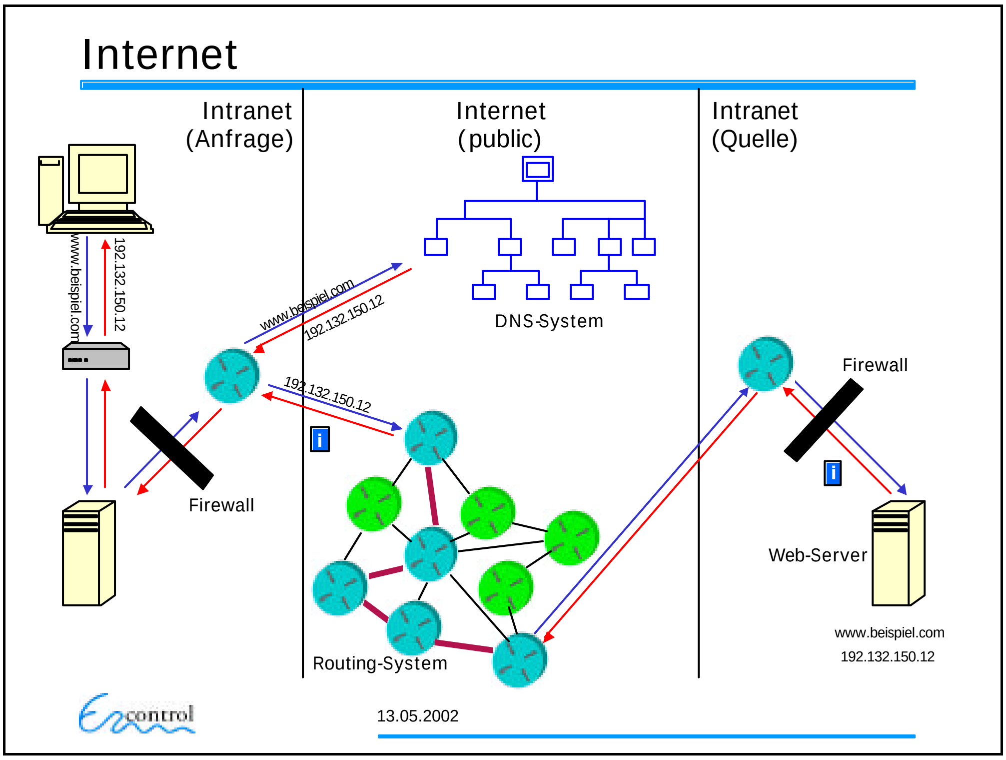


Figure 3-2: Intranet and Internet (DNS = Domain Name System)

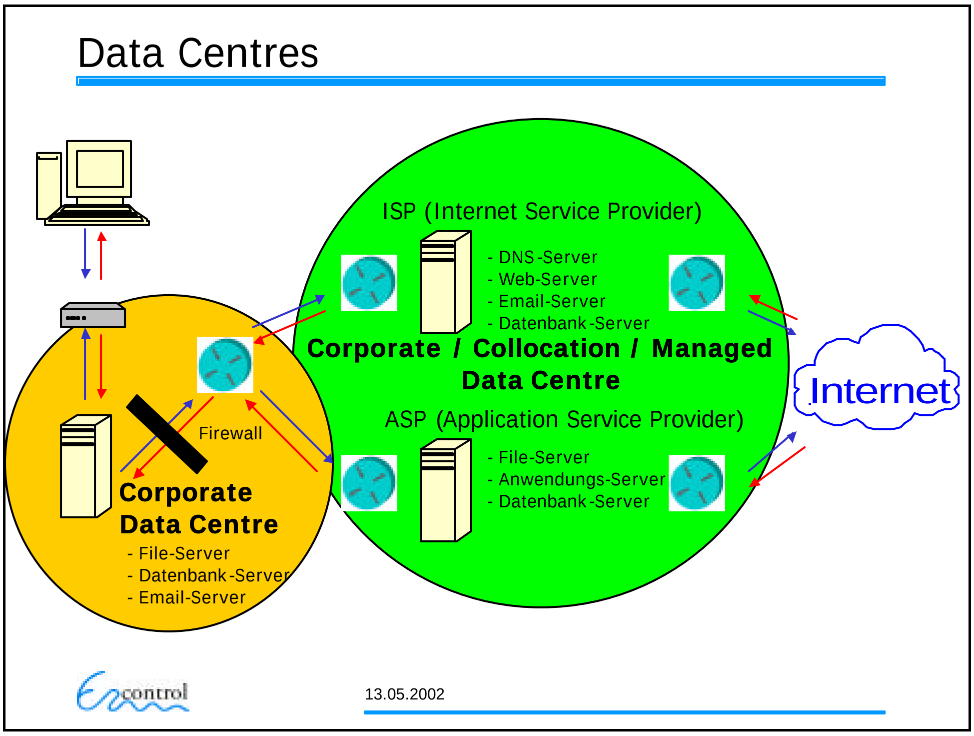


Figure 3-3: Data Centres classified with respect to ownership of equipment (or business-model) and main types of servers hosted in these data centres

Until the mid-nineties the large majority of all data centres were corporate data centres. Typical examples are the computer centres owned and operated by large banks and insurance companies in Switzerland, discussed in section 3.2.2. Over time, some of these corporate data centres began – mainly for economic and possibly for security reasons - to be outsourced to “hosting facilities”, which contributed in a significant way to the observed electricity “savings” in office buildings (Weber, 2002). Liberalisation of the telecom-market, mobile telecommunication and the emerging e-economy were other drivers for the fast growth of hosting facilities.

Collocation and managed data centres are two types of hosting facilities. In collocation centres, the operator owns the building and the central infrastructure, and outside companies rent space and bring in their own computer equipment. Regarding managed data centres, Mitchell-Jackson says: “In managed data centres, the owner of the data centre owns not only the racks but also the computer equipment within the facility. These data centres also provide other services such as software management. From an energy standpoint, the important distinction is that the floor plan and layout for a managed hosting facility can be planned ahead of time while the equipment and actual power demands of a co-location facility are up to the customers that rent the space. The division, of course, is not as clear-cut as it may seem. The exact power needs of a managed hosting facility are not always known in advance since the rate of technological change in this industry is rapid. However, there are more unknown variables in a co-location facility.” (Mitchell-Jackson, 2001, p 6).

Towards the end of the 20th century many dotcom-companies experienced a very fast growth (in terms of stock-exchange indices) and the future of the e-economy was generally considered to be bright. Much of the money earned in that period was invested in the infrastructure needed and generated by this new economy: transmission and processing capacity for the huge information-flow expected to be needed and generated.

Several systems of fibre-connections between continents, countries and major cities were built, (Figures 3.4 and 3.5) and at the interconnection-points of international, national and local networks data centres were planned to handle, redirect and store these flows. The transmission capacity of the fibre networks is extremely high and a fast increase in the demand of data handling capacity was expected, even if the real demand of the economy was unknown.

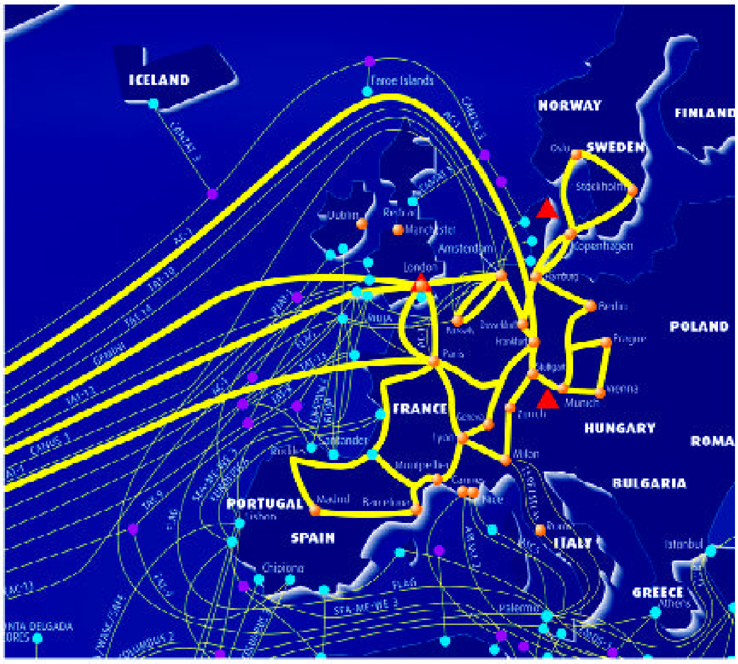


Figure 3-4: Examples of data highways interconnecting European countries and Europe and the USA. (Source: http://www.teleglobe.com/en/our_network/globesystem_europe.pdf)

Figure 3-5: Examples of data highways interconnecting European cities (Source: http://www.kpnqwest.ro/networks/eurorings_map/)

In order to be ready to satisfy any demand, internationally and globally active investors acquired huge areas for data handling facilities, and in all industrialised countries one or several cities experienced a demand of huge additional power loads. In Switzerland Zürich and Geneva were the most promising regions, Zurich mainly because of the important financial- and emerging ICT economy and Geneva–, in addition to these two economic activities , as an important location of international organisation. It is not clear whether the location of CERN was of some importance, but the expected increase of data-flow from future activities at CERN is impressive and will need similar facilities (Courrier, 2002)

Today, after the financial crash of many dotcom-companies and the general financial crises of the ICT industry, the situation looks rather different than expected two/three years ago. Some of the operators of data centres experienced bankruptcy, others did not realise their planned data centre, yet others are in stand-by, waiting for better times. Only a few of them are slowly filling-up their area with clients.

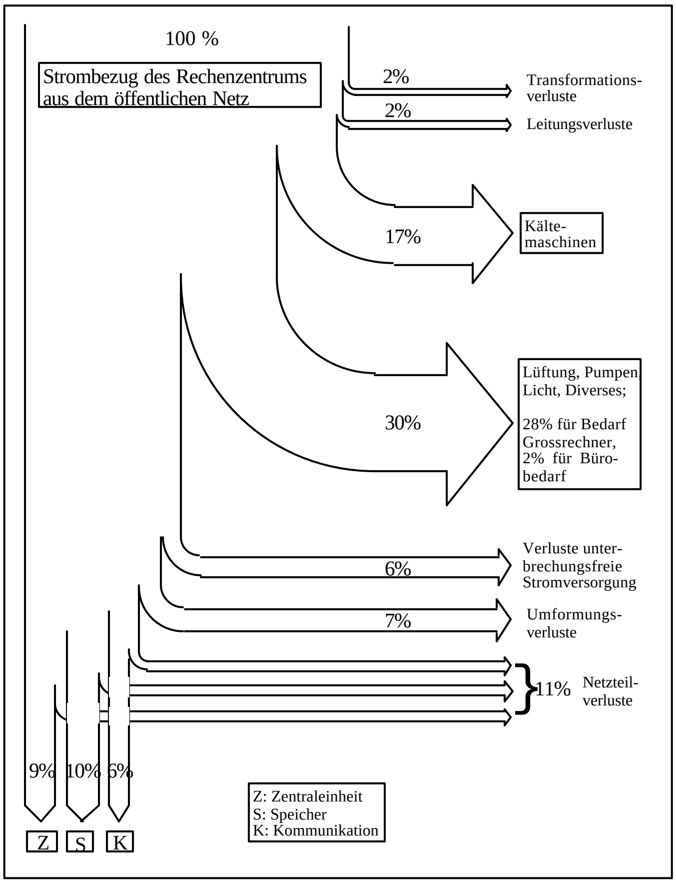
The future is uncertain. Most of the analysts agree that e-economy will play an important role in the future, but most certainly as an integral part of the economy as a whole. Data flow and data processing is increasing fast and will do so in the future. On the other hand, it is uncertain if the full capacity of data centres will ever be needed. This depends not only of the future of the e-economy, but also on technological solutions and the predominant business-model (section 4.3.1). The future electricity demand of data centres is discussed in detail in (Cremer et al., 2003).

3.2 Energy use in Data Centres

3.2.1 Consumption patterns

An overview of energy use in a large computer centre (4 MW) is given by Aebischer (1993):

"Only 25% of the electricity is used for information processing, information transmitting and information storing; the other 75% are used by the infrastructure needed to operate the computers or are lost in the manifold transformation and transmission-steps of the electric current.



The split of the electricity consumption can be determined in a first order approximation by a measurement of the power-flow (see figure):

- *25% central processor unit (Z), storage devices (S) and communication (T)*
- *25% energy-losses in transformation, transmission and other processes, including UPS*
- *50% central infrastructure, mainly chillers (Kältemaschinen), ventilation-systems and pumps*

The order of magnitude of this distribution of power needs should be rather representative of computers. In three smaller systems (between 3 and 9 kW) the fraction used in the HVAV-system is of the order of 30%. In an other computer-room with a mean power load of 30 kW HVAC-applications are responsible for slightly more than 50% of total power. And even when using a single PC between 40% (only lighting) and 70% (lighting and air-conditioning) of the electricity is used for the infrastructure."

Hartkamp (2002) summarises energy consumption of a data centre with an electric peak power of 16.2 MWe in a power flow diagram (figure 3-6). In that example, about 30% of the power is used for cooling purposes (20-25% chillers, 5-10% fans, pumps etc.), 5% for UPS (uninterruptible power supply) and 65% for computers and other ICT equipment.

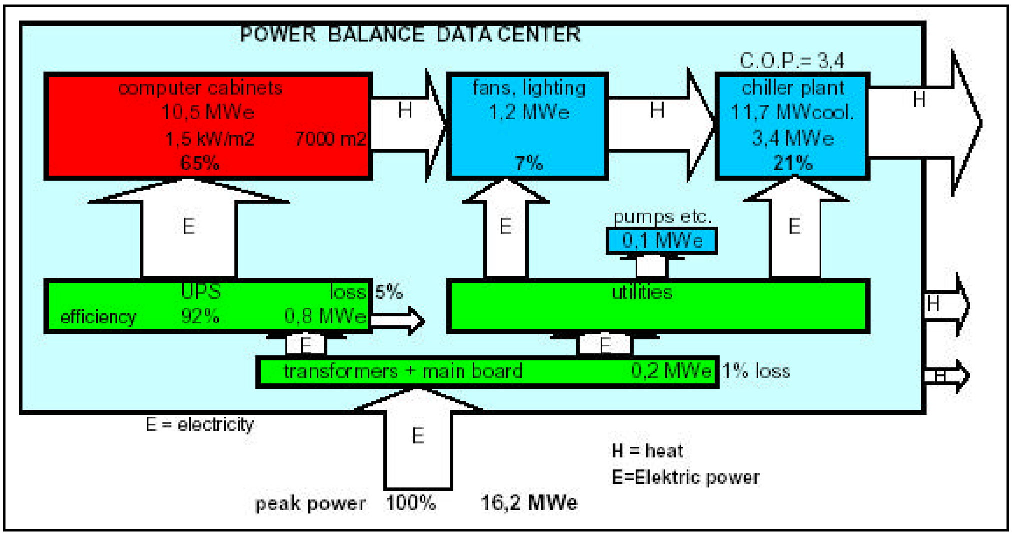


Figure 3-6: Power flow diagram of a data centre (Source: (Hartkamp, 2002) http://www.iea.org/weo/ict/novem.pdf)

Mitchell-Jackson (2001) characterises data centres by the electric power load or energy consumption per unit floor area (W/m2 or kWh/m2). In order to get meaningful figures she defines in detail the different functions of the total area. In a data centre in the USA the following allocation of the gross floor area was found (Mitchell-Jackson, 2001):

- 50 - 60 % computer room floor area where:
    - 20 - 33 % was for equipment[6] cabinets (equipment rack)
    - 50 % was for traffic surface (aisle space or service cleaning area
    - 20 % was for infrastructure (support equipment)
- 50 – 40 % for infrastructure, offices and others

The measured power loads (Figure 3-8) are much below the values used for planning purposes, typically 1000 W/m^2 (= 100 W/ft^2). On the other hand some experts believe that computer power density will increase substantially in the future (Burkart, 2001). In the rack-room (50 m^2) of a data centre in London, a power density of 1218 W/ m^2 was measured; the power density per rack was 1791 W/rack (Zurita, 2001).

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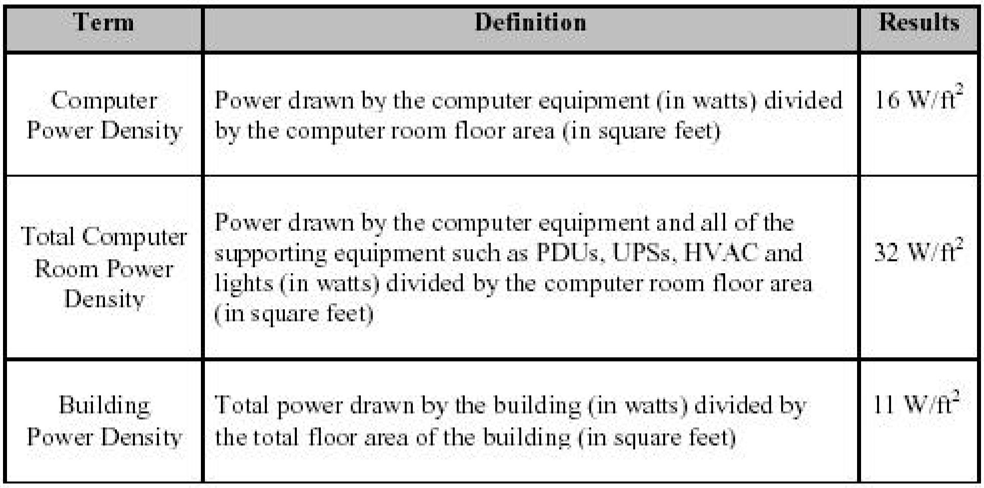
[6] The composition of the equipment in the computer rooms was found to be: 60% servers, 18% switches, 9% disks and 8% routers.



Term	Definition	Results
Computer Power Density	Power drawn by the computer equipment (in watts) divided by the computer room floor area (in square feet)	16 W/ft^2
Total Computer Room Power Density	Power drawn by the computer equipment and all of the supporting equipment such as PDUs, UPSs, HVAC and lights (in watts) divided by the computer room floor area (in square feet)	32 W/ft^2
Building Power Density	Total power drawn by the building (in watts) divided by the total floor area of the building (in square feet)	11 W/ft^2

Figure 3-8: Power densities in a data centre in the USA shown in (Mitchell-Jackson, 2001, Table 10). (1 W/ft^2 = 10 W/m^2)

3.2.2 Energy consumption in large computer centres in Switzerland

For several years, large Swiss banking institutes, insurances and an air line have formed a group which shares experience on operation of their computer centres. In order to compare energy consumption in the different computer centres, they introduced an indicator K, defined as the ratio of the electricity required by the computers divided by the electricity purchased from the utility. K is measured twice a year (on a Wednesday in February and in August) for one hour. Some of the group members take measurements for 24 hours in order to avoid special operation modes like ice storage discharges (with chillers out of operation). If the chillers are not included in the measuring system (i.e., only the amount of purchased cold is measured and known) a (artificial) factor of two is applied to determine the amount of electricity needed to produce the cold.

The values of K vary:

- from one computer centre to another (figure 3-9): Every computer centre has its own characteristics in terms of power density (power load of equipment per m^2 computer room floor space), infrastructure technology (modularity of chillers, uninterruptible power supply, etc., free cooling possibilities), included additional activities (e.g., back office working places, gold safe), and measurement possibilities (inclusion of chillers located in other buildings, exclusion of additional activities located in the same building/ on the same floor).

- over time: Due to the fast development in information technology and in the banking sector in general, the equipment in computer centres and its surrounding conditions are highly variable. Furthermore, weather conditions during the (very short) measurement period may vary considerably. The infrastructure equipment may therefore work at full or optimal load at one period in time, but one year later, it may work only at (inefficient) partial load.

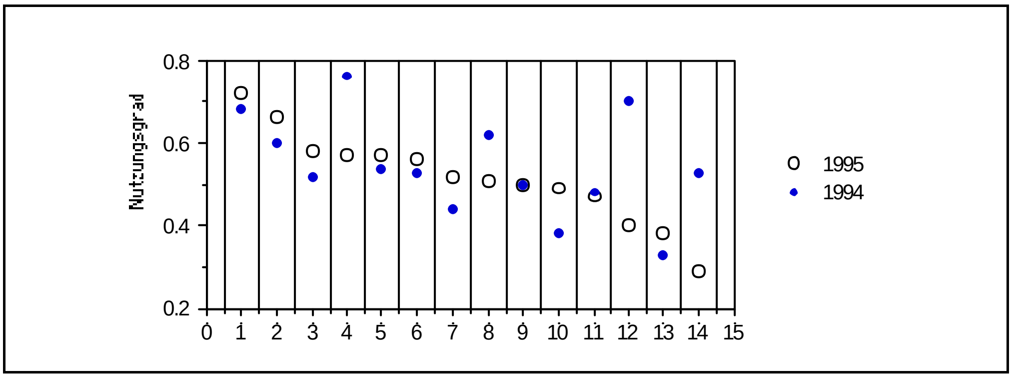


Figure 3-9: Value of K (indicator similar to C1) in 1994 and 1995 in 14 computer centres in Switzerland (source: Bänninger (1996) in Aebischer (1996))

It was not possible to receive detailed measurement data and related information for all of the computer centres, which would be necessary to understand both the variance between different computer centres and between measurement time series of a single computer centre. In particular no information was available on

- the meteorological situation during the measurements
- the operation mode during the measurements (e.g., cooling via ice storage facilities or free cooling, number of UPS in operation etc.)

For a few data centres single measurement results, or even time series for K and its components were available (although confidential). Due to the many influencing parameters (unknown for the particular measurement periods) no particular conclusions can be drawn. However, some tendencies could be observed:

- Between 45 and 65% of total electricity purchased by a computer centre is used by the computer equipment itself.
- Cold production is the dominant consumer of the infrastructure using a share of 20 to 30% of total electricity purchased.
- Electricity consumption for ventilation is highly variable with a range between less than 5 and more than 15% of total electricity purchased. One computer centre with high electricity consumption for ventilation runs a free cooling system operated with air only (in addition to the conventional chillers).
- Electricity transformation and UPS systems require about 10% of the total electricity purchased.
- Lighting and miscellaneous consumers/losses contribute only little to the total electricity consumption (a few percents).

In general, K is higher for the measurements made in February. However, for some computer centres no such seasonal variation can be observed. This is partly due to the fact that some computer centres purchase cold from an external facility and therefore they apply the artificial constant factor mentioned above to convert this energy into electricity consumption.

In order to generate meaningful and reproducible figures for K, the following suggestions are made (partly based on the measurement concept developed by Huser in section 4.2.3):

- K should be based on electricity consumption (and not electricity power load).

- Main power supply (high voltage and low voltage), cooling (including pumps), ventilation, emergency power generator, UPS, miscellaneous (lighting, office equipment, plugs) and power supply for the equipment should be measured separately and on a monthly basis. Furthermore the amount of energy (heat) extracted from the equipment (the computer room floor area) should be measured.

- If free cooling and / or heat recovery is practiced in addition to conventional refrigeration, individual measurements should be made to determine their share in heat extraction and electricity consumption.

- Ambient temperature and ambient moisture should be measured resulting in a monthly average.

- If cold is purchased from a third party or from an external site, the amount of heat extracted and its electricity consumption should be measured.

- If (part of) the infrastructure is shared with other activities (e.g., cooling of banking office working places), an allocation of the total electricity consumption and therefore separate measurements of energy extracted are required.

3.2.3 Energy consumption in existing and planned Data Centres in the Canton of Geneva

In the negotiation-process leading to the “accord”, the participating data centres had to document their demand of electric power with planning values regarding specific electric loads and detailed information describing the technical solutions chosen for production of cold, security of power supply and other domains. But, the information was not always ready available and due to different definition and delimitation the data were hardly comparable between different data centres.

In the “accord” it is stipulated that the operators of the data centres measure power loads and energy consumption of their site in order to set up an indicator of energy efficiency and annually deliver their measurements to the Canton of Geneva, including a description of measures realised and planned in order to improve the indicator of energy efficiency. Furthermore, the “accord” says that the Canton of Geneva should treat all companies active in the same business in a similar way.

In our investigation we also included a number of existing data centres already operational in Geneva and sent a request for data based on a detailed questionnaire (appendix 3) to all these (existing and planned) data centres (appendix 2).

The response was rather mixed. One data centre delivered satisfactory information, showing that it was not impossible to answer the questionnaire. Some others answered partially and others did not respond for different reasons:

- they had become bankrupt

- they declared not to be able to produce the requested data

- they refused to deliver any data

For further data collection the following recommendations can be made:

- The legal base for data collection must be clear and explicitly referred to and documented in the questionnaire or in an appendix of the request; attention to possible sanctions should be called and imposed if necessary
- The data to be delivered must be clearly defined and the measurement procedure has to be described in a measurement concept
- The effort and cost to collect the data should be as low as possible
- But the data has to be detailed enough to perform a scientific analysis
- As the data collection may need technical changes and investments, foresee enough time

4 Energy efficiency in Data Centres

4.1 Definition of energy efficiency potentials (Jochem, 2000)

When considering potentials for efficiency improvement, it is essential to distinguish between several terms of energy efficiency potentials describing future technological achievements with different time horizons and different boundary assumptions, but also on the level of analysis in the case of the economic potential. The report here uses the following definitions:

- *The theoretical potential represents the achievable energy savings in theoretical considerations of thermodynamics where energy services (e.g. room at 20°C, t steel produced) are kept constant, but useful energy demand and energy losses can be minimised by process substitution, heat and material reuse and avoided heat losses. The limitations of theoretical potentials of energy efficiency are the laws of thermodynamics.*

- *The technical potential is the achievable energy savings resulting from implementing the most energy-efficient versions of the commercial and near-commercial technologies available at a given time, regardless of cost considerations and re-investment cycles. This can be expressed as a phased-in potential that reflects the total replacement of the existing energy-converting and -using capital stocks.*

- *The market trend potential – or the expected potential - is the efficiency improvement that can be expected to be realised in practice for a projected year and a given set of boundary conditions (e.g. energy prices, consumer preferences, energy policies in place). This market-trend potential reflects the continued existence of current obstacles and market imperfections hindering profitable efficiency potentials from being fully realised.*

- *The economic potential is the energy saving that would result if each year over the time horizon in question all replacements, retrofits and new investments were shifted to the most energy-efficient technologies that are still cost-effective at given energy market prices. It also includes all organisational measures such as maintenance, sensitive operation and control as well as timely repairs. There are sub-definitions for economic potentials depending on the economic perspective being used: the business or project perspective, the macro-economic perspective, and welfare-based perspective (see below). The economic potential implies a well-functioning market, i.e. competition between investments in energy supply and the demand side. It is also assumed that the various barriers preventing such well-functioning competition in current energy service markets have been corrected by requisite policies. It is assumed that as a result of such policies, end-users in all sectors have easy access to reliable information about the cost-effectiveness and technical performance of both existing and newly emerging energy efficiency options. The transaction costs for individual investors, and the indirect costs of policy programmes associated with implementing these options, are assumed to have been lowered to their irreducible minimum.*

- *The welfare-based – or societal – potential represents the "cost-effective" savings when externalities are taken into consideration. These include damage or avoided damage cost from health impacts, air pollution, global warming and other ecological impacts, as well as energy-related occupational accidents that accrue to society. This wider definition of cost-effectiveness is the most important measure for a holistic energy policy including energy security and environmental quality.*

- *Finally, the policy-based achievable potential represents the energy savings which can be realised with various policy instruments or packages of policy instruments. Here, field data from evaluation research are used to estimate participation rates and per-participant savings in voluntary or standards-based technology programmes. The policy-based achievable potential lies between the market-trend potential and the economic potential (which can also be changed by taxation).*

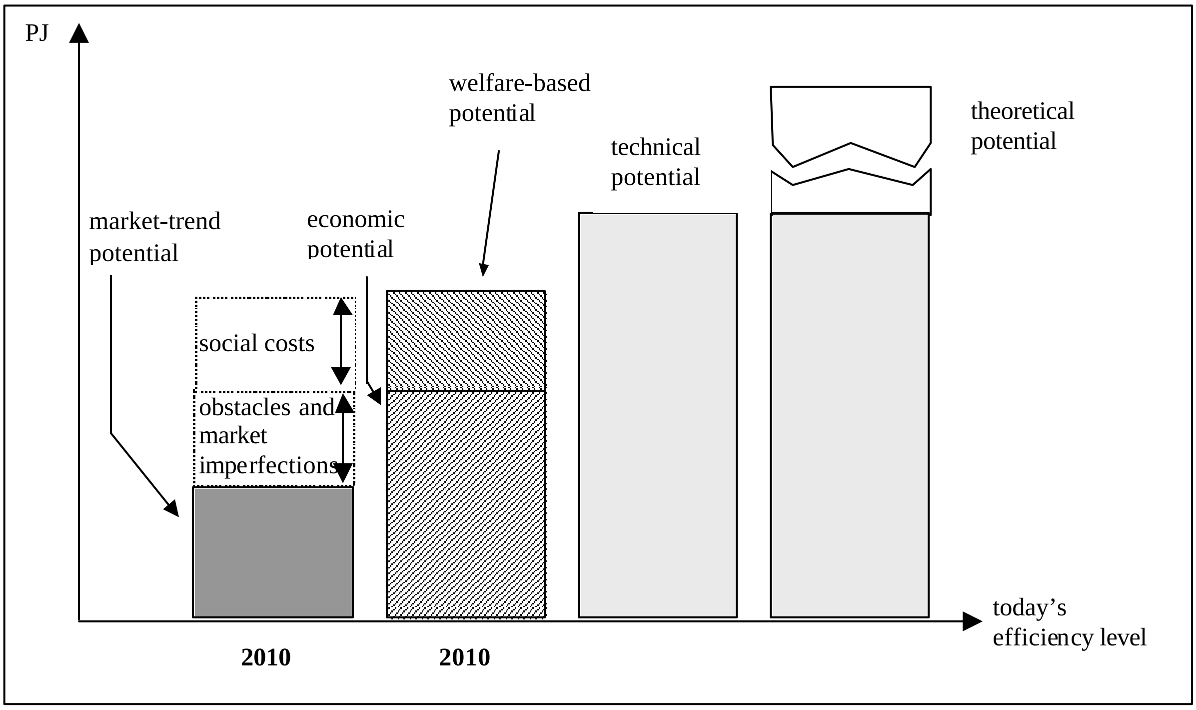


Figure 4-1: Scheme of theoretical, technical, economic and market-trend potentials of energy efficiency"

End of excerpt from (Jochem, 2000).

In this chapter we discuss the technical potential including some economic considerations. But the economic dimension is difficult to integrate – especially in the fast evolving market of data centres and ICT altogether. Policy aspects are considered in chapter 6.

4.2 Measuring energy efficiency

A commonly used measure of the energy efficiency of a commercial building is the annual energy consumption per square meter. In order not to compare apples and oranges one often corrects energy consumption for climate differences and classifies buildings according to their HVAC-equipment (HVAC = heating, ventilation, air-conditioning), e.g. fully air-conditioned building, building with mechanical ventilation, building with no cooling and no mechanical ventilation, and/or according to the economic sector or building type, e.g. office building, hospital, school. For most of these buildings energy and electricity consumption is dominated by HVAC and lighting, and the mean electric load is typically of the order of 10-100 W per square meter.

In parts of some buildings, energy consumption is dominated by specific processes like cooking, washing or data processing (computer rooms). Mean electric loads may locally be of the order of several 100 W per square meter. If these high electric-load zones represent a substantial fraction of the building, then the measure of energy consumption per square meter is no longer a good measure of energy efficiency of the building. One may therefore use an other indicator, such as energy per meal or per guest for a restaurant, or not include this processinduced energy consumption at all in the calculation of energy per square meter, but consider it in a separate approach.

The main processes in a data centre are data/information processing, transferring/transmitting and storing. The energy efficiency of a data centre should then be measured in terms of “energy per standardized data/information service” (e.g. number of instructions per second in a processor such as MIPS or a memory cycle in a RAM). No such indicator exists for data centres. We therefore chose to measure the energy efficiency in terms of a two-step measure of the fraction of the “useful“ energy, called the coefficient of energy efficiency (CEE).

4.2.1 The CEE-concept

The Coefficient of Energy Efficiency (CEE) is a measure of the energy efficiency of a data centre. CEE expresses the ratio of the electricity consumed by processors, hard disks and the like (u, so-called "useful electricity") divided by the electricity purchased from the utility (T) (Figure 4.2).

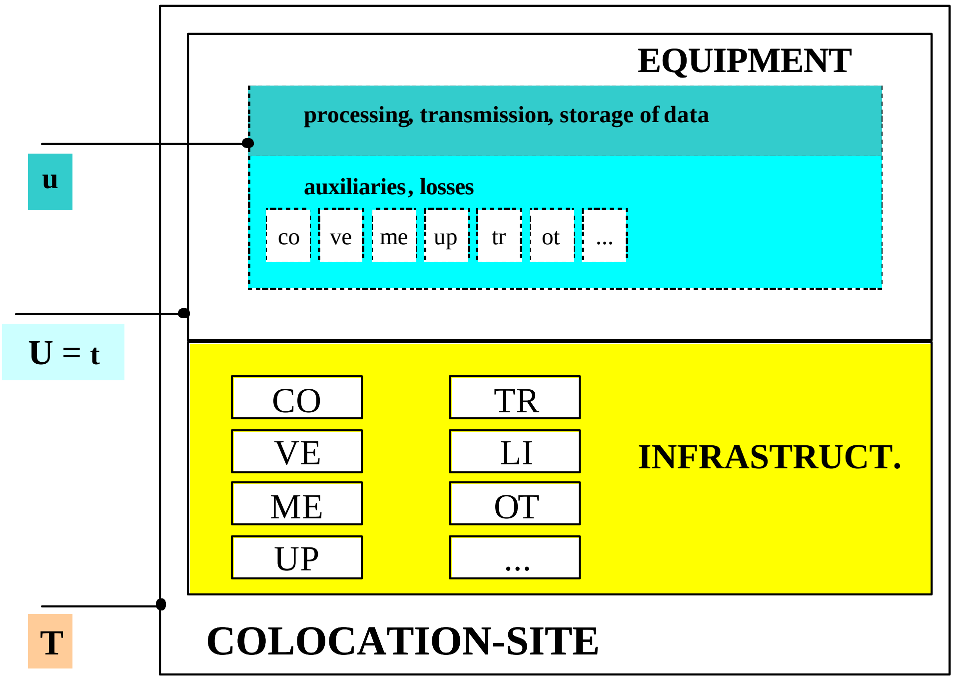


Figure 4-2: Schema of a collocation site and its electricity consuming parts. See text for explanation of the abbreviations.

Electricity consumption and losses can be grouped into two levels, namely the infrastructure and the ICT equipment.

Infrastructure: The infrastructure is needed to maintain a safe operation of the entire computer centre. For that purpose, chillers, ventilation systems, UPS (uninterruptible power supply), etc. are required.

Equipment: Similarly, but on a much lower power level, computer devices comprise ventilation, UPS, transformation, sometimes even individual small cooling equipment.

In the CEE concept, the attribution of equipment is done on a functional (and not physical) basis. Electricity consumption for the ventilation system for instance, which transports cold air from the heat exchangers of the cooling system to the equipment and which is located in the computer room, is nevertheless classified under electricity consumption of the infrastructure and therefore part of consumption T (but not U).

CEE is defined as

$$CEE = u / T = C1 * c2$$

with

$$C1 = U / T = U / (U + CO+VE+ME+UP+TR+LI+OT)$$ [7]

and

$$c2 = u / t = u / (u + co+ve+me+up+tr+ot)$$

Abbreviations:

T	total electricity consumption of data centre
U = t	total el. consumption of equipment
CO	electricity used for production of cold, refrigeration
VE	electricity used for ventilation, evacuation of heat by air
ME	electricity used for other mechanical work, e.g. pumps
UP	electricity used for uninterruptible power supply
TR	electricity used for transformation and correction of electr. power
LI	electricity used for lighting
OT	electricity used for others (miscellaneous consumers and losses)

Depending on the measurement concept, and due to its inferior relevance, "lighting" (LI) is often included in "others" (OT).

T	total electricity consumption of equipment
u	“useful” el. consumption of equipment
co	electricity used for production of cold, refrigeration not included in C1
ve	electricity used for ventilation, evacuation of heat by air not included in C1
me	electricity used for other mechanical work, e.g. pumps not included in C1
up	electricity used for uninterruptible power supply not included in C1
tr	electricity used for transformation and correction of electr. power not included in C1
ot	electricity used for others not included in C1

4.2.2 Arguments to use CEE as an indicator of rational use of energy in Data Centres

Ideally, energy efficiency of a data centre should be measured in terms of energy consumption per unit of service delivered to the customer. However, there exists no commonly agreed method to measure the service provided by a data centre. Some manufacturers even use measures of services, which are specific to a given model of equipment (Huser, 2001). Even if a standardised method of measuring the service would exist, its value would vary so fast due to technological progress that it would not be possible to define any reference value necessary to evaluate the efficiency of a data centre.

Using the floor area as a reference for the energy consumption does not make much sense in a data centre. Indeed, the same electricity consuming equipment may either be dispersed over a large area – leading to a low value of electricity per unit of floor area – or densely packed together in fully equipped racks resulting in a high value of energy per m2, with no difference in the specific electricity consumption per unit of energy-service.

The coefficient CEE, on the other hand, is a significant and stable indicator of an efficient layout of the central infrastructure (C1) and of an energy-efficient configuration of the IT-equipment (c2). The choice of CEE as the indicator for a rational use of energy is substantiated by the following arguments:

- CEE is independent of the economic development (increase in internet and application services provided by a particular data centre) and the technological development of the

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[7] C1 is a measure of the energy-efficient layout of the infrastructure, similar to the coefficient K used by the group of computer centres described in section 3.2.2

equipment (amount of internet and application services provided by one single server for instance). Hence, CEE does not limit the amount of services that an operator of a data centre can provide.

- C1 can be measured at reasonable costs.
- Data centre operators can influence C1, when deciding on (infrastructure) investments and in some limits during operation.
- Other approaches are possible within c2, which would not be possible in an approach where the indicator is W/m2 and thus does not differentiate between the infrastructure and the production apparatus.

4.2.3 Measuring concept of C1[8] in Data Centres

The target is to measure C1, the first component of the “Coefficient of Energy Efficiency” (CEE). The measurement concept for C1 specifies the measurements needed to determine the values of the components[9] of C1. The concept should be ready at the beginning of the planning phase. In particular the electrical distribution should be implemented in such a way that the measurement concept can be easily applied.

We assume that the airflow and cold water used for heat-evacuation in the data centre are supplied by a plant, which supports only this data centre. If the air or the chilled water comes from a third party supplier, these media must be measured separately at the input. The chilled water can be measured easily ; the air however can be measured only with high expenditures.

The efficiency of the cooling system, particularly the use of free cooling but also the coefficient of performance (COP) of the compressors, depends among other things on the outside temperature. The efficiency must therefore be measured over a period of one year. A continuous data recording aids the technical optimisation of the systems. Once the system is running smoothly a monthly analysis of the data should be adequate. As the minimal data recording frequency we recommend one month.

The measurement points are defined in Table 4-1 and in Figure 4-3. The proposed specifications for the accuracy of measurements are presented in appendix 3. The relation between the components defining C1 and the measurement points in Table 4-1 is the following:

- T[10]: measurement No. 1.1
- U: measurement No. 8.1
- CO + ME: measurement No. 4.1
- VE: measurement No. 5.1

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[8] The indicator K, used by the large computer centres in Switzerland (section 3.2.2), is in fact very similar to C1, but its loose definition and the absence of a detailed measurement concept make it difficult to use.

[9] C1 itself is defined very easily by two measurements: T and U, but in order to understand differences between data centres and variations over time the various components defining C1 must be known. This information is also needed in order to identify possible measures to improve the energy efficiency.

[10] See section 4.2.1 for explanations of this and the following terms.

- UP: measurement No. 8.1 minus measurement No. 7.1
- TR: measurement No. 2.1. minus measurement No. 1.1
- OT + LI: measurement 6.1

The measurement of the outside temperature (9.1) and humidity (10.1) is needed for the evaluation of the value “CO”.

Table 4-1: Definition of measuring points (see Figure 4-3)

No.	medium	measuring point	measured value	minimum function
1.1	electricity	main entrance high tension	kWh	total/month
2.1	electricity	main entrance low tension	kWh	total/month
2.2	electricity	main entrance low tension	kVar	total/month
3.1	electricity	emergency power generator	kWh	total/month
3.2	electricity	emergency power generator	kVar	total/month
4.1	electricity	refrigerant plant and pumps	kWh	total/month
5.1	electricity	ventilation	kWh	total/month
6.1	electricity	office equipment, light, plug sockets	kWh	total/month
7.1	electricity	input USP-system	kWh	total/month
8.1	electricity	output USP-system	kWh	total/month
9.1	ambient temperature	external area	°C	average value/month
10.1	ambient humidity	external area	% r.H.	average value/month

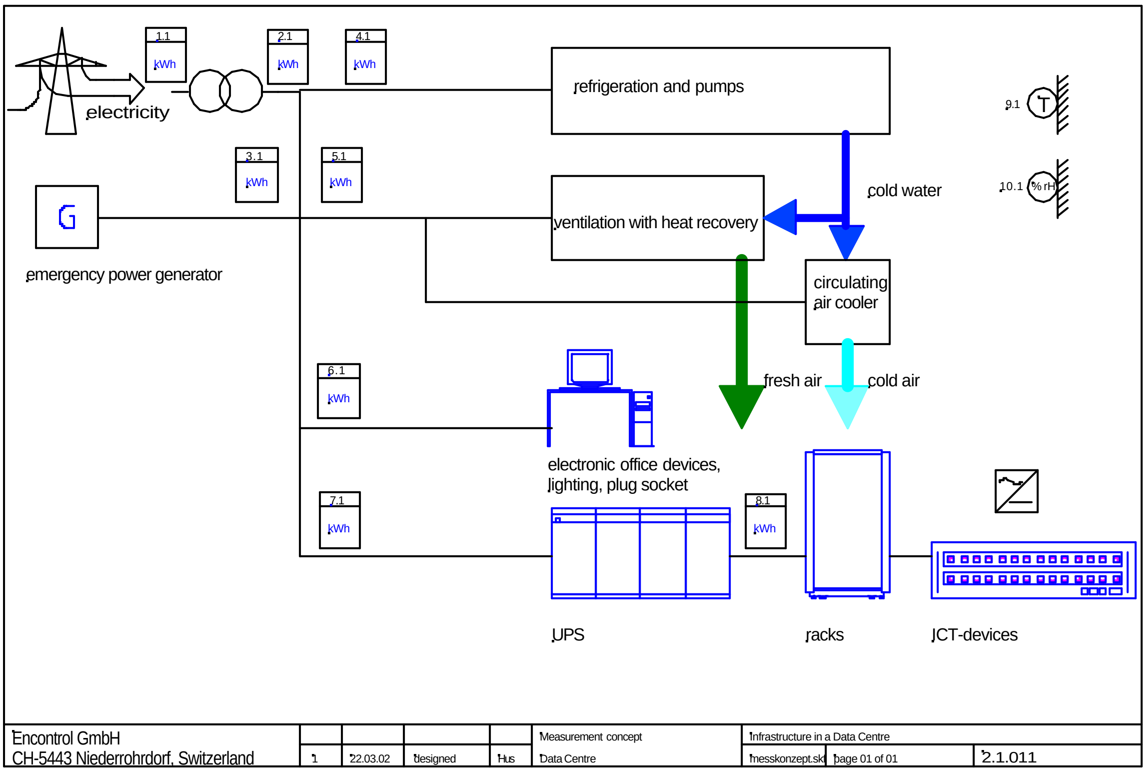

Figure 4-3: Measurement concept for data centres (see Table 4-1)

4.2.4 Measuring c2 in Data Centres

C2, the component of the Coefficient of Energy Efficiency (CEE) on the level of the ICT equipment, expresses the ratio of the electricity consumed by processors, storage devices and the like (u, so-called "useful electricity") divided by the total electricity consumption of all the servers, routers, switches and other electronic equipment (t):

$$c2 = u / t = u / (u + co+ve+me+up+tr+ot)$$

The electricity consumption of the ICT equipment (t) is measured at the output of the UPS-system (point 8.1 in the scheme in Figure 4-3). The mean power-load of the ICT equipment (= t divided by the observation period) is in general much lower, for example by a factor 3, than the sum of the nominal power loads of all the equipment[11]. This is well known for PCs and was confirmed by Mitchell-Jackson (2001) for data centres.

The useful electricity u cannot be measured directly. We therefore investigated the possibility of evaluating the different energy-losses, and derive u by the difference between t, the total electricity entering the equipment rooms, and these losses. We then get:

$$c2 = u/t = (t– co-ve-me-up-tr-ot) / t$$

The assortment of equipment in a typical data centre is given by Mitchell-Jackson (2001): 60 % server, 18 % switches, 9 % disks, and 8 % routers. In all these equipments, the most important energy losses (> 80%) occur at the following stages:

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[11] This was the main reason, recognised in the negotiation process by the operators, of the overestimation of the needed electric power for the data centre.

- transformation and correction of the electrical power in the power supply (tr)
- evacuation of the heat by fans (ve)
- reliability of the power supply, e.g. by uninterruptible power supplies and/or redundant layout of power supplies (up)

The question remains as to how to evaluate these losses tr, ve and up. In a typical data centre the number of equipments is of the order of several thousands. It is therefore not conceivable to measure the losses in all these equipments individually. But it does not seem impossible to define a limited number of classes of equipment, characterised by the type of power supplies, the use of UPS and geometrical criteria representing the fraction of electricity used to evacuate the heat, where most of the equipment would fit in. In order to determine the losses in the power supplies we need to know the efficiency curves (efficiency in function of workload) of the different classes of power supplies and the distribution of the workload of the equipment. Efficiency curves can be measured relatively easily (Aebischer and Huser, 2002). In order to determine the distribution of the workload the following information is needed:

- nominal or rated load of all equipment in the data centre
- measurement of the actual load by class of equipment, by rack or by groups of racks
- typical distribution of the ratio of the actual load to rated load for different classes of equipment

The first two points define the mean value of the ratio of actual load to rated load for groups of equipment. The third piece of information is important, because of the non-linearity of the efficiency curves.

In addition, we need more information about the use of power supplies and ups:

- fraction of the different classes of equipment that use redundant power supplies
- fraction of the different classes of equipment that use individual (not central) UPS.

Finally, information is needed about the packing of racks: how many servers of which size in a rack.

The losses in stand-alone equipment and the question of whether the characteristics of the equipment located in a data centre and information about their layout can be gathered by the operator of the data centre is discussed in the next section 4.3.

4.3 Energy consumption pattern and energy efficiency potentials of ICT equipment (c2)

The energy efficiency potential in ICT equipment is first investigated in single (stand alone) equipment (sections 4.3.1-4.3.4) and then followed by some reflections on energy efficiency in groups of equipment (section 4.3.5).

For stand-alone equipment, we look at servers as the typical equipment located in data centres. The use of automated power management and switching off of equipment when not used are two energy saving measures widely applied in personal computers. Are these measures transferable to servers? What about energy efficient chip technologies? Can the losses occurring in power transformation, heat evacuation and power security measures be reduced?

And finally the crucial question: are the conclusions for stand alone equipment still valid for servers and similar equipment in data centres?

4.3.1 Servers: the typical ICT equipment in Data Centres

A Server is a computer, which is not manipulated directly and continuously by a person. Servers supply functions and services to a group of users or process data, which are transmitted or required by other computers, in the background of the user. Servers are also characterised by high standards with respect to security and availability.

Until the mid-eighties, large computers (mainframes) in computer centres fulfilled the tasks of today's servers; downwards minicomputers (e.g. DEC VAX family) were used. Today, these segments are usually called high-end and midrange servers. For some years low-end servers execute functions such as file management, printing, communication, and web serving. Besides functional differences, the most important segmentation criterion is security or redundancy. A frequently used market segmentation defines three categories of servers:

- Entry, low-end, value, entrance or PC server: lower price segment (< 20'000 US$); used in non-critical applications and often by small businesses. In this category, components such as processors, power supplies and disks are not redundantly executed. They usually provide file management, printing, communication and web-server functionality.

- Mid rank, mid sized or enterprise server: middle price segment (20'000 US$ to 200.000 US$); critical components in redundant execution: dual processors, redundant power supply, hot plug ability of disks, exhausts and memories; used particularly for file and application servers with mid-range volume of data and mid-range availability.

- High end, enterprise or mission critical server: upper price segment (> 200'000 US$). The devices are provided with all possible security characteristics: redundant components, hot plug ability of all critical items and scaling of the performances. These devices usually execute traditional batch processes with high volume of data, e.g. mass calculation processing, applications for databases or reservation systems of airlines.

The typical range of power drawn by a server lies between 30 and 1000 W (Table 4-2). High-end servers may need several tens of kW of electric power.

Table 4-2: Measured (and nominal) power load of servers (Sources: own measurements, measurements of manufacturers and Roth (2002))

manufacturer	model	electrical power (* own measurements) [W]	nominal power [W]
IBM	xSeries230	115*	250
IBM	xSeries240	145	-
IBM	xSeries330	110*	200
IBM	xSeries350	135	-
IBM	xSeries370	1000	-
Hewlett-Packard	Netserver E800	80*	250
Hewlett-Packard	LH Pro	130*	-
Compaq	Proliant 1600	137*	250
Compaq	Proliant 370	80*	250
Compaq	DL320	76	-
Sun	Cobalt 41	34	-
Sun	Cobalt 4R/XTR	72	-

Routers, switches and repeaters are other equipments frequently used in data centres. The same or similar chips to the one used in severs are the main component of all these equipments. The other main energy consuming components are the power supplies and ventilators, which are also very similar to the ones used in servers. We therefore concentrate in the next sections on servers, but the results and conclusions are also valid for these other ICT equipments.

Servers are used in two configurations:

- stand alone devices (comparable to a personal computer in tower form)
- in housing which is built into a rack with standardized dimensions. 14 servers (height 13.4 cm) or 42 servers (height 4.45 cm) can be integrated in a rack. Designers try to build servers smaller and smaller. The newest generation is called the blade server and has the dimension of an ordinary electronic board. It is built vertically in the rack. 168 blade servers can be implemented in an ordinary rack. This means a reduction in costs due to reduction of used area, but it also means an increase in heat dissipation per square meter. Several blade servers (typically 6 to 12) are connected to one common power supply. Whether the reduction of the number of individual power supplies leads to a reduction of losses in power supplies depends mainly on the workloads and cannot be answered without further investigation.

With a few exceptions, servers run 24 hours a day 7 days a week, and electricity consumption is independent of the data processed. There is no automatic power management as in personal computers and servers are hardly ever switched off, even if they are not used for several days. Energy saving potential by switching off servers is high and several initiatives favouring switching off servers at night and developing and introducing a power management were recently taken on the national and international level (Huser, 2002; Ademe, 2002).

Huser (2002) evaluates the energy saving potential by switching off servers in small and medium companies in Switzerland to 40%-50% of the total energy used by these servers. In order to estimate possible savings by an automatic power management we would need to know the typical usage patterns (load distribution and load factors) of servers. Such data do not exist, but it is evident that the workload varies with the kind of server (a bigger one , for economic reasons, is more often working at full capacity than a small one) and its function.

4.3.2 Chip technology

On the level of the computer-chips extremely fast technological changes were observed in the past: a reduction of energy demand by a factor of hundred for the same activity every ten years (Aebischer et al., 2000). For the coming ten years no substantial slowdown in efficiency improvements is expected. Further energy efficiency gains will result from different development:

- ultra-low-voltage operation.
- more and more functions directly integrated on chips
- shutting off portions of chips, when not in use, improving power efficiency in both active and standby modes
- use of copper wiring
- use of silicon-on-insulator
- use of low-k dielectrics
- and possibly more innovative technologies...

Energy efficiency improvements are generally a by-product of R&D in faster and more powerful processors. For mobile equipment on the other hand, energy efficiency is an important topic because of the limited energy in (storage) batteries. Energy optimised chips are used, consuming substantially less energy (typically 1/10 of ordinary processors or even less) at the cost of reduced performance and higher price. Neither of these two implications is widely accepted by the market until now, despite lower investments for the infrastructure (cooling and ventilation), substantial cost savings in the longer term (lower electricity bills) and increased reliability due to lower operating temperatures.

But, in recent years, with ongoing miniaturisation and integration power loads per unit of chip-surface became an increasing problem. The heat to be evacuated is even more a problem in densely packed racks in data centres. Power optimised chips and new software/hardware interaction concepts are proposed as an alternative (IBM, 2001; Transmeta, 2002)

It remains a question whether these savings would be permanent or whether they would be resorbed after a couple of years by faster increase in computing capacity (rebound effect), in no way different from the increase in energy demands of ICT equipment, despite the tremendous energy efficiency improvements mentioned at the beginning of this section.

4.3.3 Reduction of energy-losses in power transformation, heat evacuation and measures for a reliable power supply

In ICT equipment the largest energy-losses are:

- electricity used in power supplies for transformation and correction of electrical power
- electricity used by fans for evacuation of heat by air
- electricity used in UPS for a reliable power supply, and additional losses in power supplies due to their redundant layout.

The efficiency of power supplies varies between different models (Table 4-3) and is strongly dependent on the workload (actual electric load divided by the nominal or rated load) and how the workload is distributed over the different DC-outputs (Figure 4-4-1).

Table 4-3: Distribution of energy efficiency for 14 computer power supplies with a nominal load of 300 W (c't, 2001)

Power output [W]	efficiency min. [%]	efficiency max. [%]	efficiency average value [%]
2,5 W (0,8 % load)	27	53	38
185 W (62 % load)	70	77	72,5

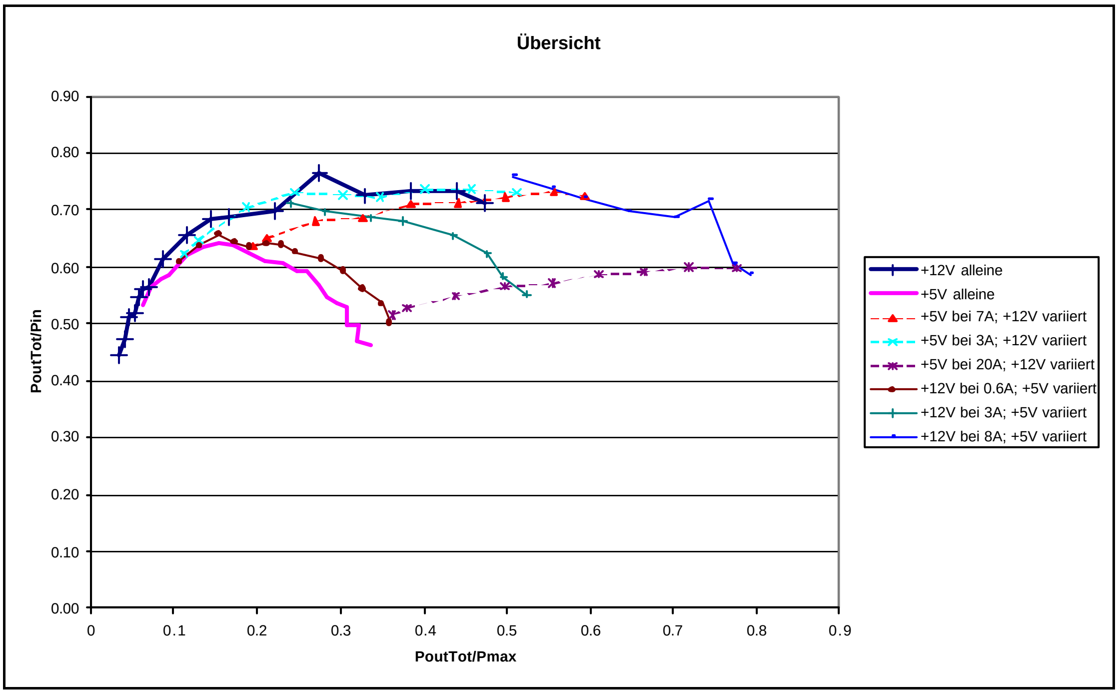

Figure 4-4-1 Efficiency (power out / power in) of a 200-Watt power supply in function of the workload (power out / Pmax) (Aebischer and Huser, 2002)

A 400-Watt power supply has only one 12 V DC output with a rather high efficiency for a workload above 20% (Figure 4-4-2). Aebischer and Huser (2002) report on this general tendency in modern power supplies to produce only one or two DC-outputs inside the power supply with subsequent DC-DC transformations on the main board and even on the processors. The efficiency of one DC-DC transformation lies between 60% and 95%, with typical values between 80% and 90% (Aebischer and Huser, 2002). But, a DC-DC transformation at the level of the processor is substantially less efficient than 80% (Kaeslin, 2002; in Aebischer und Huser, 2002). The consequence of this new trend for the overall energy efficiency of supplying power to the electronic components is not known yet. But it means that an optimisation of the energy losses in the power transformation stage may become even more complex than it is today.

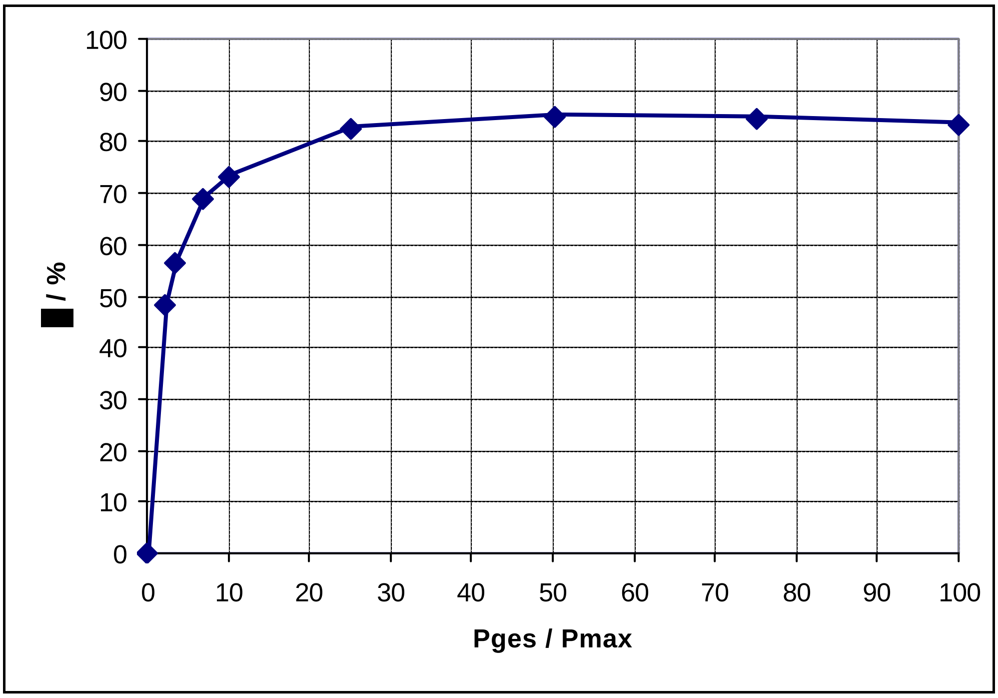

Figure 4-4-2 Efficiency (power out / power in, in %) of a 400-Watt power supply in function of the workload (Pges / Pmax) (Aebischer and Huser, 2002)

The workload of several servers, routers and switches were measured and lies typically between 50% and 30%. If several power supplies are used in parallel for security reasons the workload is substantially lower. The workload of PCs in the on-mode was measured to lie between 14% and 25% with efficiencies of the power supplies between 57% and 78% (Figure 4-4-3)

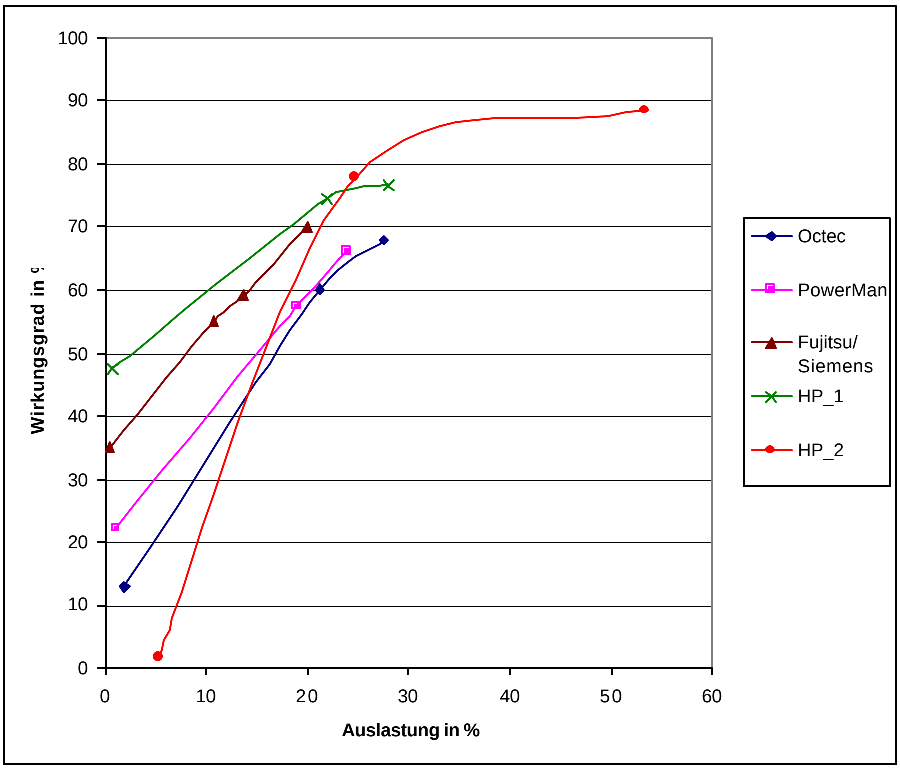

Figure 4-4-3 Efficiency (Wirkungsgrad, in %) of power supplies in 4 PCs for different workloads (Aebischer and Huser, 2002)

The mean efficiency of a power supply in actual use is the result of decisions taken by several actors: the manufacturer of the power supply, the manufacturer or assembler of the equipment (server or similar equipment) and the configuration and end-user of the equipment.

Power supplies are mass products, manufactured in large series of standardised sizes. For personal computers or low-end servers standard sizes are 200 W, 250 W and 300 W of nominal power. The various DC-output levels and the maximum power output for each of the outputs is to some extent specified by the manufacturer/assembler of the equipment, and is usually chosen high enough to supply the necessary electric current to all the extension boards of the device. The developer of a power supply can choose within certain limits, at which workload the maximum efficiency is reached. Considering the low average load of the majority of the equipment in use, defining the efficiency-maximum at a lower load-level could reduce a certain fraction of the losses. Such an improvement was realised in recent years for personal computers. An extra DC-output level of 5 V was introduced in order to reduce energy losses in the standby-mode with a typical power load of less than 1% of the nominal power. The efficiency is thus increased in this way from a very poor <10% to >50% (Figure 4-4-4) (Aebischer and Huser, 2002).

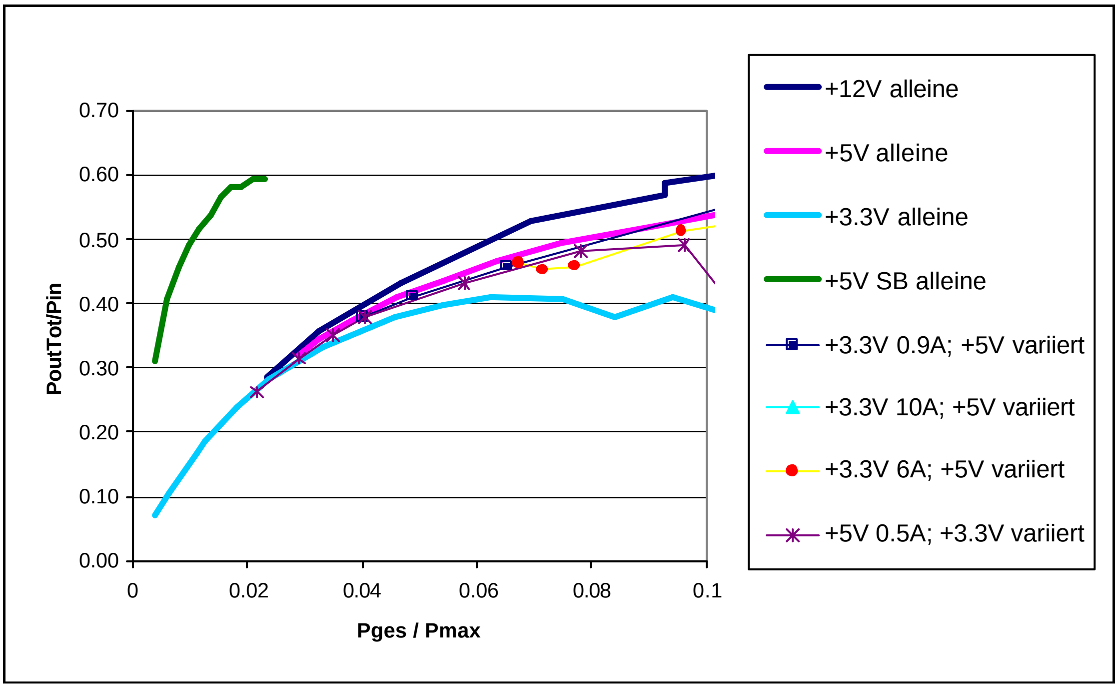

Figure 4-4-4 Efficiency (power out / power in) of a modern power supply with a special DC-output (+5V SB) for very low workloads (power out / Pmax) in the standby-mode (Aebischer and Huser, 2002)

The person/institution in charge of the final configuration of the ICT equipment and the end-user hardly ever bother about power supplies. Power supplies are usually bought together with the chassis (and the motherboard). Most of the time, no technical specifications regarding power supplies are delivered and it is almost impossible to get any information about energy efficiencies. The pre-request to chose and use a power supply in an energy efficient way is an energy declaration, which does not exist or is not accessible for the end-user.

A few years ago, power transformation in ICT equipment meant power distortion. The typical power factor of a personal computer in 1993 was 0.6 (Roturier et al., 1994). Today, practically all modern power supplies, which are implemented in servers or high end communication devices, have integrated the function "Power Factor Correction" (PFC) (Aebischer and Huser, 2002). The power factor of four power supplies for servers and routers showed rather high values of 0.95

at reasonable workloads, but rapidly decreasing values below 20% workload (Aebischer and Huser, 2002). A negative consequence of PFC is a reduction in the maximal energy efficiency by a few percent.

Energy saving potentials in power supplies are high, but for all actors/players involved the opportunities are limited. A first important step to improve the situation is a detailed energy declaration.

The electric load of a server is of the order of several tens to several hundreds of Watts (Table 4-2) and all this electric energy has to be evacuated eventually in the form of heat. The main heat sources in a server are the processors and the power supply. For a Pentium-processor the power density is approximately 33 Watts per square centimetre. This heat must be transported away. The internal temperature in the device may not rise over 42 to 45 °C. The processor fans (fan radius about 2,5 cm) have an electrical power of about 1,5 W (own measurements and Windeck, 2001). Larger fans (fan radius about 4 cm) for device ventilation or power supplies have an electrical power of approximately 3 W (own measurements).

A typical standalone low-end server normally has several fans. They are built in the power supply and on the main processors. In the HP Netserver E800 model these fans have a total electrical power of 9.8 W (own measurements: 1 x 3 W, 1 x 4,4 W and 1 x 2,4 W). The power consumption corresponds to about 10 % of the total power consumption of the Server.

In flat built rack servers the air for heat evacuation flows usually from the front to the rear. Highly loaded sections (processors) are often ventilated by air ducts. Several small fans (up to 10 pieces or more) are used for heat transport. For example, in a rack-optimised server (model IBM of xSeries 330) there are 9 small fans with an electrical power of 2.5 W each. This results in a total electrical power of 22 W, which corresponds to about 25 per cent of the power consumption of the server. The higher proportion of the rack-optimised server is due to the flat and compact construction of the device with only small air ducts.

The fans in modern personal computers are often speed controlled (the processor temperature determines the speed of the fan). This reduces the noise level of the computer and the power of the fan. This technique could be introduced in servers.

Recommendations and specifications for the development of computers with optimal waste heat transport can be found on the Intel-Internet page (Intel, 2002). Saving potentials in heat evacuation by air are difficult to estimate. 20% savings in electricity use for driving the ventilators is certainly a lower limit. Much higher saving potentials using water-cooling are discussed in the next section.

Most of the stand-alone servers are equipped with an uninterruptible power supply (UPS). The efficiency of this equipment depends, as in power supplies, on the workload (Figure 4-5). And for the same reason as in the power supply, the workload is typically of the order of 50%-30%. Typical losses are therefore of the order of 15%. Another measure to increase the reliability of the power supply is redundant layout of the power supplies. The consequence is an even lower workload on the power supplies. These additional losses have been discussed earlier.

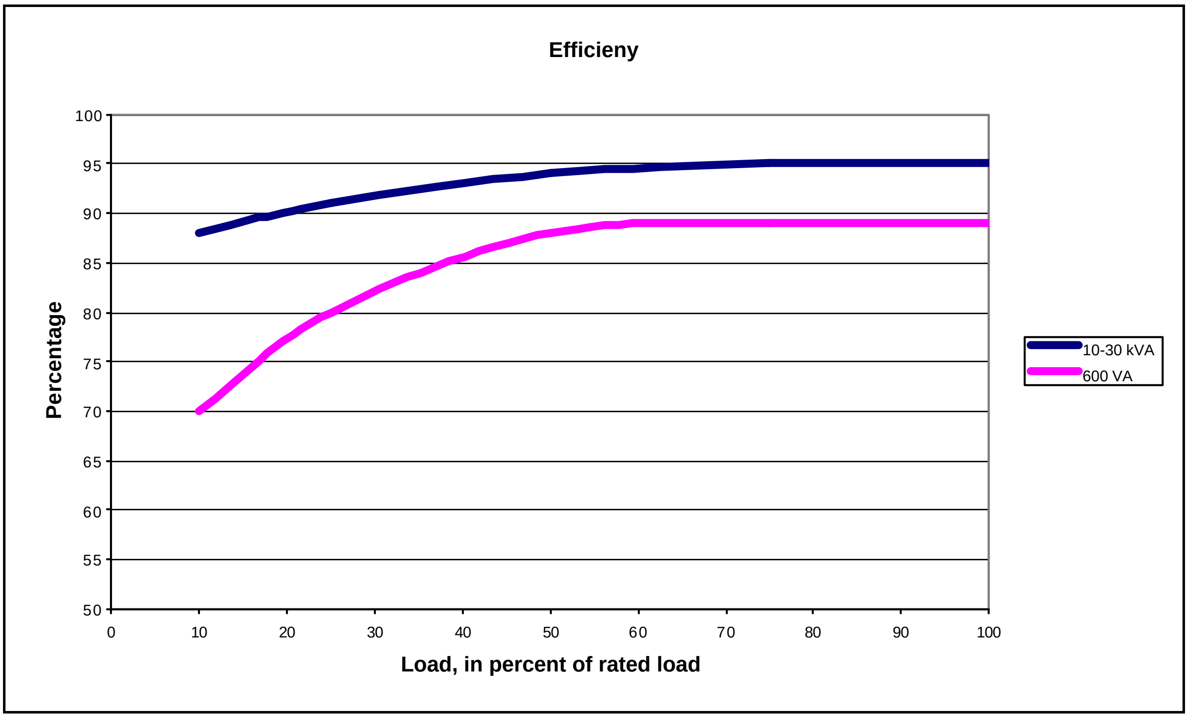

Figure 4-5 Efficiency of two UPS as a function of the workload

Technical measures to reduce energy-losses in UPS in the planning phase are discussed by Mauchle and Schnyder (2001 and 1999) and Bruhin and Geisser (1998).

A summary of energy use pattern and energy saving potentials in servers are presented in Table 4-4.

Table 4-4: Energy use patterns in a server before and after energy use optimisation

	before optimisation %	before optimisation W	after optimisation W	after optimisation %
processors, storage devices, input/output	(20-30)%	40-60.	40-60.	(30-40)%
power supply, including power factor correction	(30-60)%	60-120.	60.	40%
fans: heat evacuation by fans	(10-30)%	20-60.	20.	13%
uninterruptible power supply, UPS	(5-20)%	10-40.	10.	6%
other losses	(0-10)%	0-20.	10.	6%
total	100%	200	140-160.	100%

4.3.4 Energy efficiency in groups of ICT equipment in Data Centres

For economic reasons, it is not currently feasible to measure the energy consumption of all the equipment in a data centre individually[12]. We therefore proposed a procedure to evaluate the

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[12] Two categories of costs have to be considered: hardware (a once-only investment) and software including analysis and reporting. Using standard hardware could require investments of the order of 600 CHF per measurement-point. If a large scale measurement (several hundred thousand measuring points) is conside-

losses using an approach, which relies on typical configurations of equipment, typical efficiency curves of power supplies (and UPS, if used) and geometrical characteristics important for heat evacuation (section 4.2.4). Power supplies and UPS show efficiency curves, which are strongly dependent on the workload. If the efficiency curves are known, the configuration of the equipment (servers, routers) - including the number of power supplies operated in parallel for security reason - define the losses occurring in the power supplies and in the UPS.

The question of whether the equipment installed in a data centre can be characterised with respect to the degree of utilisation of the power supplies and the UPS was discussed with operators of data centres in Geneva (Ldcom, Digiplex and SafeHost). The operator of a data centre of the **collocation**-type does not usually know what equipment the client is using and how it is configured. The client is the owner of the ICT equipment and responsible for the layout. But, the operator can/does require/dictate some technical characteristics/specifications, for example, concerning security aspects and limitations of the power load of groups of equipment, such as equipment put into a rack. Some of the operators do not exclude the possibility of establishing a database of all the ICT equipment brought into the data centre, including their rated/nominal power and information about redundant layout of power supplies. Neither do they exclude the possibility of measuring power loads and energy consumption of groups of equipment, for example by rack or by groups of racks. The concept of a database of all equipment is supported by (Facinelli, 2001). A similar approach was used for office equipment by UBS (Becker, 1998). It is an open question, whether political authority could impose the establishment of such a database by the operators – even if they are not the owners of the equipment - by enacting a legally binding regulation.

Neither do these operators exclude the possibility of measuring power loads and energy consumption of groups of equipment, e.g. by rack or by groups of racks. In fact, some of the operators do use this kind of information for billing purposes by including an estimation of the electricity consumption in the tariff of the rented area. If this estimation would be based on actual consumption it could be an interesting incentive[13] for the client to use more energy-efficient equipment and optimise the layout/configuration of the equipment with respect to energy consumption. But, to do so, the client has to be educated/trained and motivated. The operators of data centres – possibly in collaboration with the political authority – can contribute to this by diffusing information and instruction notes. But the ICT industry has to deliver the basic technical information, in particular, a detailed energy declaration of power supplies and UPS'.

Assuming that the database and the energy consumption measurement exist (and representative efficiency curves of power supplies and UPS are available) it is possible to estimate the main energy losses (tr, ve and up) occurring in the ICT equipment of a data centre, and quantify c1, the first component of CEE (section 4.2.4). This value of c1 is an approximation with variable uncertainties in the different data centres. It is therefore hardly useable for benchmarking purposes and cannot – like C2 for the infrastructure part – be used as a target value or a constraining minimal value (standard) in a construction or operating permission process. But it could be a good enough indicator for purposes of monitoring energy efficiency of the ICT equipment. The biggest impact on energy consumption is expected from the procedure itself. Information collection and data analysis draw attention to imperfections and possible improvements, and may as a result encourage the different parties involved to take further initiatives.

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red, then the development of a special chip requiring an investment of the order of a million CHFs is probably a more economic solution. Cost for one measuring point could then be reduced by a factor of hundred. The situation is similar on the software-side . The development and configuration requires high investments. The cost per measurement point drops rapidly with the increase of number of measurement point.

[13] For the operator of a data centre energy costs represent some 10-20% of total costs ????????????????

Today, collocation is the dominant form of “hosting” (Mitchell-Jackson, 2001). This is also the case for the majority of the new data centres in Geneva. But, experts believe that managed data centres will become more important in coming years (Pittrof, 2001; Morosoli, 2001) with the evident advantage of a higher value-added activity and the possibility for the operator of the data centre to select the ICT equipment with the best cost/benefit characteristics. This could mean that in the near future larger computers with a much reduced electricity demand[14] per unit of service output may be used.

The operator of a **managed** and **corporate** data centre has different additional opportunities to optimise the energy demand of the ICT equipment:

1. reducing the number of servers running in standby for security reason (redundant servers)
2. reduce energy losses by optimising the configuration and the layout of the individual equipment
3. apply innovative solutions, like water cooling and possibly centralised AC/DC-transformation and DC-distribution

The typical electric load of a data centre (equipment rooms only) is of the order of 400 W/m2 for internet applications and 200 W/m2 only for telco applications[15] (Operators, 2001). Aside from different ICT equipment, an other big difference is the way that the electric power is distributed among the individual ICT equipment. In a typical telco environment we find a central AC/DC transformation and DC-distribution, whereas in an internet environment most of the individual equipment have its own AC/DC transformer. This may be one of the reasons why telcos have a lower power load. Following Kolar (2002) there is no straightforward answer to the question of whether losses in power transformation could be substantially reduced by systematically using central AC/DC transformation. Further research is needed to evaluate the advantage of central AC/DC transformation and the disadvantage of higher transmission losses of DC-distribution.

Customers of collocation data centres tend to use compact rack servers in order to reduce costs for rented floor area. In these flat built rack servers, electricity to drive fans for heat evacuation becomes more important, e.g. 25 per cent of the power consumption of the server. This higher percentage of power consumption for fans of the rack-optimised server is due to the flat and compact construction of the device with only small air ducts. Operators of managed data centres could think about using water for heat evacuation. Indeed, with increasing power density of processors, manufacturers of servers and racks envisage direct water-cooling. A leading rack producer has developed a bus system for cooling water, which feeds coolers of different processors (c’t, 2002). With this direct water-cooling system it is possible to dissipate much more heat with less auxiliary transport energy than by air ventilation. But using water in an electronic system is critical in terms of security, and therefore will be avoided as long as possible.

4.4 Energy efficiency potentials by optimising the layout and the operating of the infrastructure (C1)

Mitchell-Jackson (2001) analysed the power loads of a typical data centre in the USA. The analysis showed that slightly more than 50% of the electricity purchased is used for chillers,

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[14] IBM requests electricity savings of 95% by replacing thousands of servers with one central computer: the IBM eServer z900 (IBM, 2001)

[15] telco = telecommunication

computer room air conditioning units, auxiliary equipment and lights. The remaining part is fed into the computer rooms.

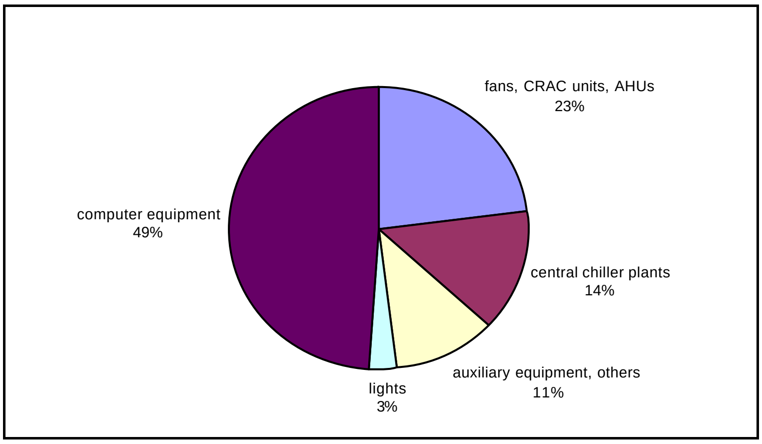

Figure 4-6: Breakdown of computer room power by end use (Mitchell-Jackson, 2001)

The question is now whether a ratio of computer room electricity consumption versus total electricity consumption of 0.5 is good practice, or whether higher values may be achieved with smart concepts and efficient technologies.

4.4.1 Cooling equipment

A substantial part of the electricity consumption is required for cooling. The consumption can mainly be influenced by

- the temperature level of the cold water circuit and the cooling water,
- free cooling possibilities (which depends again on the temperature level of the cold water circuit),
- the air temperature level in computer rooms, and
- modularity of the infrastructure.

The exact saving effect is hard to determine in general because of highly variable surrounding conditions under which data centres are operated. Nevertheless, we give it a try based on the extensive experience of Amstein + Walthert (2001) in planning and building data centres. The following sections are based on personal information provided by Altenburger (2001). He modelled the electricity consumption of HVAC equipment for various operation modes of a model data centre with variable heat load.

The modelling is based on climatic parameters of the Swiss lowlands. Free cooling benefits vary according to climate (e.g., higher share of free cooling in Nordic countries). The results shown are therefore not generally applicable irrespective of the geographic location of the computer centre.

a) Influence of cold water and computer room air temperature:

In a given computer room with air temperature of 26°C, a change in temperature in the cold-water inlet temperature from 6°C to 11 and 13°C reduces the electricity demand by about 44% and more than 50%, respectively (Figure 4-7). This is mainly due to better energy efficiency of the chillers (COP 4 and 3.5 instead of 2.5). However, at lower computer room air temperatures (below 22°C) these efficiency gains are over compensated by the larger increase in ventilation electricity consumption (much more air is required to cool the equipment due to the smaller temperature difference).

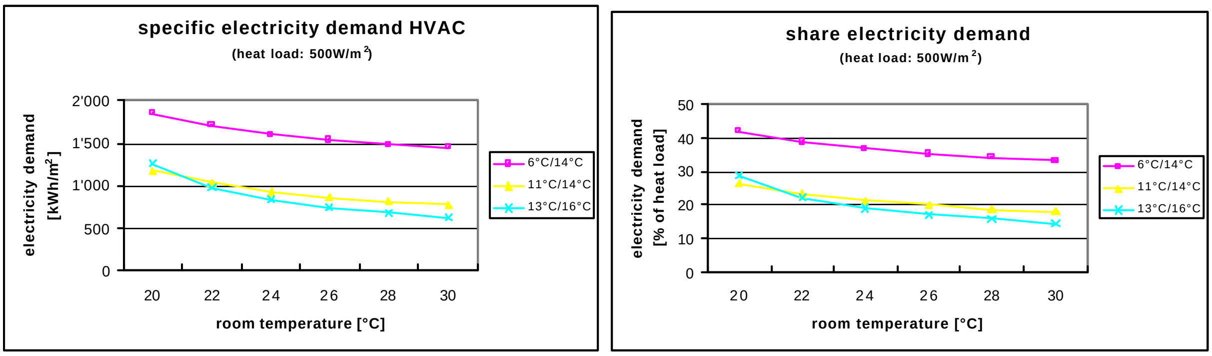

Figure 4-7: Specific electricity demand (kWh per m^2 and year and percentage of heat load) for cooling and ventilation, depending on computer room air temperature and cold-water inlet and cooling air temperature (Altenburger, 2001). Air velocity: 2m/s, fan efficiency: 60%.

The share of electricity required for HVAC relative to the computer electricity consumption is more or less independent of the heat load (currently observed in Swiss data centres with heat loads between 250 and 1000W/m2).

b) *Influence of air velocity and fan efficiency:*

The energy consumption of ventilation (moving the cold air from the air conditioning units to the racks) is highly dependent on the air velocity. Optimised systems run at low velocities of about 1.5m/s, whereas velocities of 3m/s and more[16] cause a substantial increase in electricity demand. Besides the reduction in energy consumption, low velocities lead to better distribution of the cold air and thus reduce the risk of hot spots[17].

Fan efficiencies vary between 55 and 65%. Figure 4-8 shows the variation in electricity demand for cooling and ventilation (heat load 500W/m2) using optimised and inefficient circulating air coolers. At low computer room air temperatures (<22°C) the electricity demand for cooling and ventilation differs by a factor of 1.7 between an optimised and an inefficient layout. At 26°C, the inefficient layout still requires 45% more electricity than the optimised solution.

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[16] Current systems are running with even higher velocities of 5m/s and more.

[17] Private communication by A. Altenburger, Amstein + Walthert, Zürich, 28.11.01

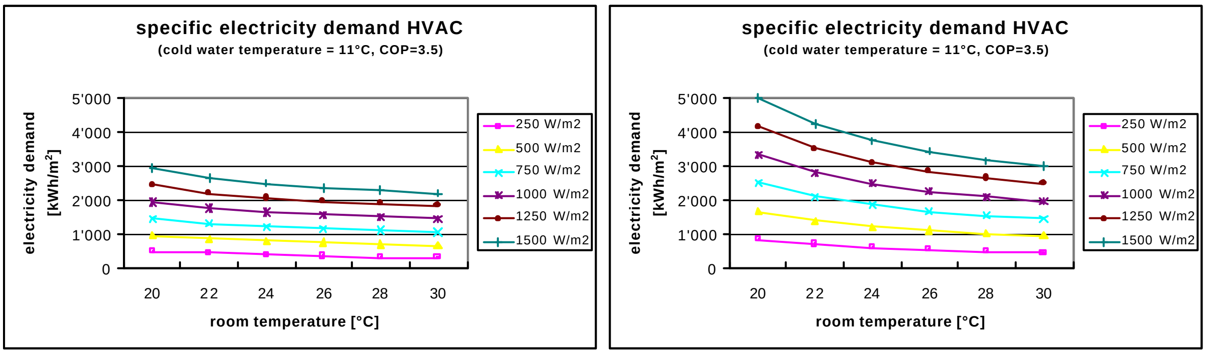


Figure 4-8: Specific electricity demand (kWh per m^2) for cooling and ventilation depending on the computer room air temperature, air flow velocity and fan efficiency (Altenburger, 2001). Left: Air velocity 1.5m/s, fan efficiency 65%. Right: Air velocity 3m/s, fan efficiency 55%.

c) *Influence of free cooling and cold water pumping:*

While the data shown above are valid for systems using free cooling as much as possible, we now turn to the situation where free cooling is excluded (Figure 4-9).

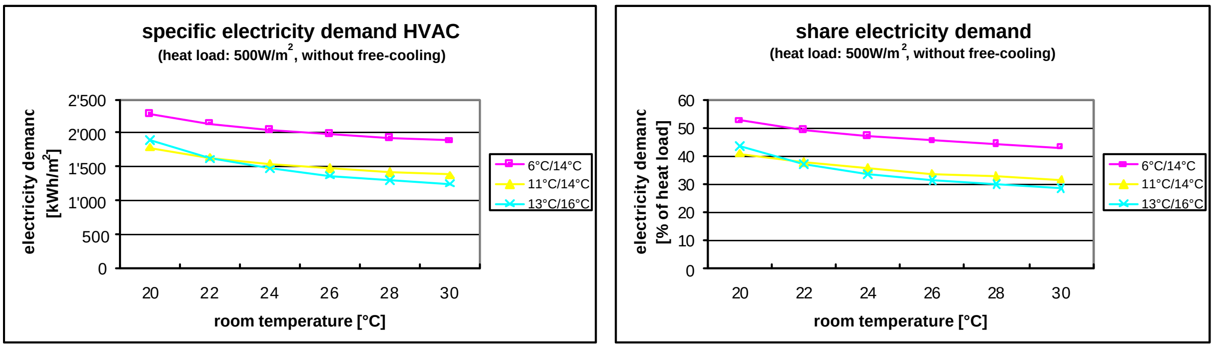


Figure 4-9: Specific electricity demand (kWh per m^2 and per year, and percentage of heat load) for cooling and ventilation without free cooling depending on the computer room air temperature and the cold water and cooling air temperature (Altenburger, 2001).

We recognise that the electricity demand increases by 24% - 30% (6°C cold water inlet temperature, 14°C cooling supply air temperature), 53% - 72% (11°C cold water inlet temperature, 14°C cooling supply air temperature) and 50% - 86% (13°C cold water inlet temperature, 16°C cooling supply air temperature) for computer room air temperatures between 20°C and 26°C. The share of HVAC electricity consumption related to electricity consumption of the computers rises about 10 - 15%-points.

The electricity savings due to free cooling increase with increasing cold-water inlet temperature levels. A rise in cold-water inlet temperature level of 5K (from 6°C to 11°C) allows for an additional reduction in electricity demand by about 40% compared to the free-cooling savings at 6°C (Figure 4-10). A further increase to 13°C is much less effective due to the relatively small amount of additional days during which free-cooling is possible at this higher temperature level.

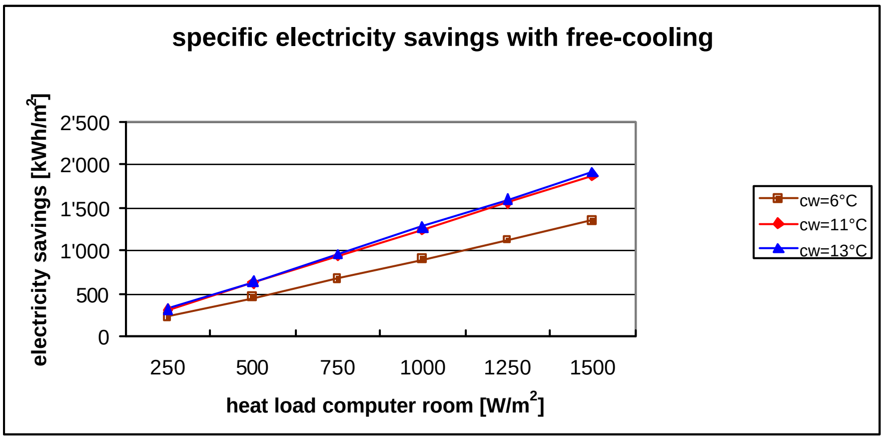


Figure 4-10: Electricity savings with free cooling depending on the cold-water inlet temperature and the heat load (Altenburger, 2001).

The energy used for cold water pumping depends on the amount of water circulated and therefore on the temperature gradient in the heat exchangers. A temperature difference of 2K requires much more water compared to a difference of 6K (Figure 4-11). However, the share of pumping electricity consumption compared to the electricity consumption of the computers is rather low and lies between 0.25% (6K) and 0.75% (2K).

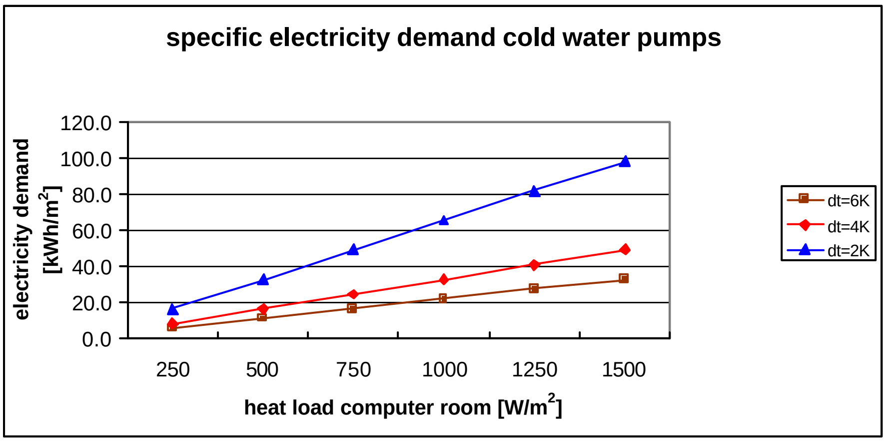


Figure 4-11: Electricity demand of cold water pumps depending on the cold water temperature difference and heat load (Altenburger, 2001).

Besides the increased electricity consumption, a smaller temperature gap between the computer room temperature and the cold-water circuit requires larger heat exchangers and thus larger units of circulating air coolers.

d) Synthesis: design parameters influencing energy efficiency of the cooling equipment

The configuration of the HVAC-equipment and the computer room conditions determine by large the energy efficiency of the infrastructure. A system without free cooling, a cold water temperature of 6/12°C, a computer room temperature of 20°C and an inefficient ventilation system adds 64% to the electricity demand of the computers (irrespective of the specific heat load). By using free cooling the increase is reduced by 10%-points to 54%. An increase in the cold water circuit temperature from 6/12°C to 11/1/°C contributes 16%-points, reducing the share to 38% of the electricity demand of the computers. The use of an optimised ventilation system helps to reduce the share by nearly 16%-points to 22.5%. Finally, a rise in computer room air temperature from 20°C to 26°C reduces the increase by another 5%-points. This leads us to a minimum electricity demand for cooling and ventilation of 17.5% with respect to the yearly electricity consumption for the computers.

Hence, a reduction in the electricity demand of cooling and ventilation by a factor of more than two is achievable in a moderate Swiss climate simply by making use of free-cooling, raising the cold water circuit and the room air temperature, without changing other computer room conditions.

4.4.2 Uninterruptible power supply (UPS)

Different technologies and configurations for uninterruptible power supplies are available for data centres. On one hand, rotary and static UPS systems may be discerned. While the former converts electric energy into kinetic energy and vice versa, the latter makes use of lead acid batteries.

On the other hand the embedding of the UPS in the system may differ. Passive-standby (also called off-line), line interactive and double conversion technologies are available. Standby UPS have a transfer time of as much as 10 milliseconds and deliver a square wave or a stepped square wave, whereas line interactive technologies provide a sine wave and have a transfer time of 1 to 2 milliseconds. Online (or double conversion) technologies deliver a sine wave 100% of the time; as electricity is always passing through the UPS system, there is no transfer time.

(Mitchell-Jackson, 2001, p. 34) assumes that 5 to 7% of the incoming power is lost in the UPS. Rotary systems usually show higher energy efficiencies at full load, about 2 to 3% higher than static double conversion systems. According to the specification of a supplier of UPS systems, maximum efficiencies of 93 and 94.5% for battery-type UPS (60 and 400kVA, respectively), and 95 to 97.5% for rotary UPS (150kVA to 40MVA) can be reached. However, 10% energy losses are not unusual for static UPS systems operated in data centres.

Additionally, efficiency may decrease when operated at partial load. However, there are static UPS systems on the market, which show an equal or even slightly better efficiency at 50% load as compared to full load.

4.4.3 Power distribution unit (PDU) and other auxiliary equipment

The losses in the power distribution unit may amount to 2 to 5%, depending on the load factor. Other auxiliary equipment such as building controls, fire alarms, security systems, telephone systems and emergency power supply units (diesel, natural gas or propane) require additional power, roughly estimated by (Mitchell-Jackson, 2001, p. 34) at 2%. According to her, line losses amount to additional losses of 1% assuming a light load.

The losses caused by the PDU and the other auxiliary equipment is mainly influenced by the power load factor and may vary between 5 and 8% of the total load.

4.4.4 Summary: design parameters influencing C1

The electricity consumption of the entire infrastructure required for data centres is not a given fact. Choosing smart technical solutions allows for a substantial reduction in power load and consequently in electricity demand and investment and operation costs. Because of the interaction of many components and parameters it is hardly possible to quantify possible energy gains by adding the effects of each of the measures. That is why an inquiry among existing and planned data centres in Geneva has been launched. Based on HVAC-models, the electricity consumption of the infrastructure has been determined for various technical outlines. Based on the results a classification of optimised, conventional and inefficient infrastructures is proposed (Table 4-5). Fully optimised systems may use more than 70% of the total electricity consumption for IT equipment, whereas inefficient systems need more than half of the demand for the HVAC equipment.

Table 4-5: Infrastructure electricity consumption in relation to the total yearly electricity consumption for an optimised, a conventional and an inefficient data centre.
[1]): 13.6% for central chiller plant, 23.3% for fans, CRAC (computer room air conditioning) units, AHUs (air handling units).
[2]): Included in "Others".
[3]): Equipment running at 30 to 40% of capacity.
[4]): (Mitchell-Jackson, 2002); this data centre is described in section 3.3.1 [5]): Simulations by Altenburger (2001)

	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	350Pa	500Pa	900Pa	unknown
fan efficiency	65%	60%	55%	unknown
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%

Modularity of the equipment

Due to a generally lower efficiency at partial loads, we expect to have an increase in C1 with an increase in modularity of the infrastructure. However, it is not possible to quantify the effects on C1 of a higher or lower degree of modularity in all the components of the system. Therefore no estimates can be made for this aspect.

4.4.5 Integration of C1 in the permission procedure

The two most important measures to reduce power loads and electricity consumption of the infrastructure are

- Free cooling, and
- cold-water circuit temperature.

Operating the HVAC system with maximum free-cooling capacity, elevated room air temperature (26°C instead of 20°C) and the cold water circuit at elevated temperatures (13/19°C instead of 6/12°C) allows for a reduction in electricity consumption of the HVAC-system in the order of more than 50%. The share of electricity consumption for computers in optimised data centres may reach more than 70% whereas it is less than 50% in centres that are equipped with an inadequate (oversized) or inefficient infrastructure.

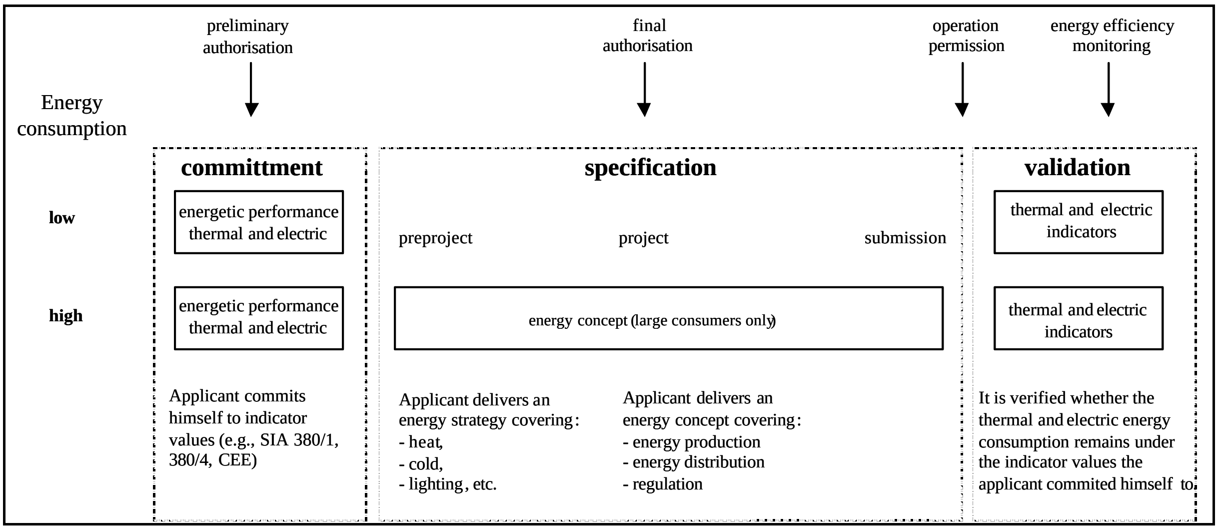
The CEE concept fits into the permission procedure as planned at the DAEL (Département de l'aménagement de l'équipement et du logement) for the Canton of Geneva (Figure 4-12).

In the preliminary authorisation phase, the applicants commit themselves to certain indicators such as target values of SIA 380/4 or a (not yet defined) value for CEE. Maybe even power load figures for computer rooms for a certain application (e.g., 400W per m2 application server rooms) could be used at this stage.

During the final authorisation phase the applicants deliver an energy strategy, and later, an energy concept which allows them to show compliance with the indicators agreed upon during the preliminary authorisation phase.

After the authorisation permission, compliance with the indicators is validated with the system in operation and the actual use of the site. The latter is especially important with regards to power load figures, which may differ substantially between different kinds of applications (application service provider versus information service provider).

The validation of a site ideally takes place a little less than two years after it is in operation because it is the last opportunity for owners to plead improvements under the two year warranty, normally given by suppliers.



Applicant commits himself to indicator values (e.g., SIA 380/1, 380/4, CEE)

Applicant delivers an energy strategy covering:
- heat,
- cold,
- lighting, etc.

Applicant delivers an energy concept covering:
- energy production
- energy distribution
- regulation

It is verified whether the thermal and electric energy consumption remains under the indicator values the applicant commited himself to.

Figure 4-12: Constructing- and operating-permission procedure proposed for the Canton of Geneva (Ouzilou, 2002).

5 Eco-efficiency in Data Centres

This chapter deals with environmental aspects of refrigerants used in chillers, characteristics of certified green electricity (naturemade star) and emissions of emergency power generators.

5.1 Refrigerants used in cooling equipments

5.1.1 Results of life cycle assessment (LCA)

In the past decades, the refrigeration industry has been sensitised due to the discussions about ozone depleting and climate-changing properties of fully and partly halogenated hydrocarbons (CFCs and HCFCs). Today the fade-out of partly halogenated hydrocarbons (HCFCs) is discussed in Europe. They may be replaced with partly fluorinated hydrocarbons (HFCs) and so-called natural refrigerants such as propane, ammonia, CO2 and water. Life Cycle Assessment is used to assess the environmental relevance of these different alternatives from a comprehensive perspective.

The life cycle based environmental impacts of air conditioning systems using ammonia, water, various HFCs and HFC blends as well as HCFC 22 are quantified and compared on the level of a certain amount of heat extracted by a 6/12°C cold water cycle. Besides commonly known environmental impacts of refrigerants such as global warming or ozone depletion, the environmental relevance of trifluoroacetic acid (a persistent and ecotoxic decomposition product of HFC 134a) has been taken into account. The following sections are based on (Frischknecht, 1999) and (Jungbluth und Frischknecht, 2001).

The LCA-inventory of the equipment producing a 6/12°C cold water cycle is composed of:

- Manufacturing of the equipment (incl. heat collection system and heat sink),
- Manufacturing of refrigerants and coolants,
- Electricity production for the operation of the refrigeration system (electricity consumption based on the coefficients of performance shown in Table 5-2).
- Refrigerant losses during first filling (0.5% for NH_3, 2% for HFC and HCFC) and during operation (5% per year for NH_3, 10% per year for HFC and HCFC, including accidental releases).
- Dismantling and disposal of the equipment with partial refrigerant loss (5% for NH_3 and 15% for HFC and HCFC).

The following steps are included: extraction of mineral and fossil resources, manufacturing of materials, working materials, energy carriers and intermediate goods as wells as all transports and waste treatment services for production wastes. Refrigerant losses due to improper work and leakages are included in the loss rates mentioned above. However, data availability on losses shows large potential for improvement.

The by-products, such as hydrochloric acid and water, that are produced along with partly halogenated hydrocarbons are not taken into account. All requirements and emissions are completely allocated to the refrigerants or their intermediate substances.

During production of partly halogenated hydrocarbons, ozone-depleting substances such as CFCs and HCFCs are still emitted as the Montreal Protocol does not cover these emission sources. For the production of HFC 134a for instance, about 0.01 kg CFC11-eq and 77 kg CO2-eq are emitted in a worldwide average.

In the following, results are shown applying the average Swiss electricity mix including electricity trade with France, Germany and other European countries. Table 5-1 shows key figures of the power plant portfolio of Swiss domestic production and Swiss electricity supply mix including electricity trade.

Table 5-1: Electricity mix "Domestic production" and "Domestic production including trade". The electricity model used in this paper assumes that about 35% of electricity imported is directly exported to foreign clients (real transit). [1]): Includes power plants using natural gas, blast furnace and coke oven gas. [2]): Comprises geothermal power plants, electricity from waste incineration plants et cetera.

Average 1990-1994	Domestic electricity production	Domestic production including electricity trade
Hard coal		3.0%
Lignite		1.5%
Fuel Oil	1.0%	1.8%
Natural and other gases [1])		1.3%
Total fossil thermal	*1.0%*	*7.6%*
Hydropower	58.8%	46.0%
Pumping storage	0.9%	0.9%
Nuclear Power	38.2%	44.7%
Others [2])	1.1%	0.8%
Total Production	100.0%	100.0%

According to comparable specifications, chillers using water as refrigerant[18] require less non-renewable energy resources, and show considerably lower impacts on climate change, ozone depletion and terrestrial ecotoxicity. This is, on one hand, due to a much better energy performance (cumulative energy demand, acidification, aquatic ecotoxicity, radioactivity). On the other hand, a switch from HCFC or HFC to water helps to reduce impacts on global warming, ozone depletion and terrestrial ecotoxicity (the latter due to avoiding the creation of trifluoroacetic acid from HFC 134a).

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[18] See http://st-div.web.cern.ch/st-div/st98ws/technology/JacekK.pdf for more information

Table 5-2: Selected environmental impacts of 1TJ cold 6/12°C produced by chillers using H_2O, NH_3, R134a, R404A, and R22 refrigerants.

Chillers 6/12°C using the following refrigerant:		H2O	NH3	R134a	R404A	R22
	Unit	TJ	TJ	TJ	TJ	TJ
Cumulative energy demand	MJ-eq	403'000	541'000	599'000	671'000	577'000
Global warming	kg CO2-equiv.	6'910	8'470	13'900	21'600	14'300
Ozone depletion	R11-equiv.	0.0144	0.0186	0.0566	0.0589	0.211
Acidification	kg SOx-equiv.	48.1	62.1	67.4	73.3	65.6
Summer smog	kg Ethylen-equiv.	10.4	11.7	13	14.4	12.5
Aquatic ecotoxicity	kg 1,4-DCB-equiv.	1'670'000	1'990'000	2'220'000	2'430'000	2'100'000
Terrestrial ecotoxicity	kg 1,4-DCB-equiv.	22.5	26.5	36.5	32.9	28.2
Radioactivity	kBq U-235-equiv.	7000	9690	10700	12000	10300
Coefficient of performance	-	6	4.3	3.9	3.45	4.04

A variation of the coefficient of performance shows that the water-based chiller must have a minimum COP of about 4.5 to match the performance of the NH3 system. In comparison with HFC and HCFC systems, a COP as low as 3.0 is sufficient for the water-based system to show a better performance in terms of global warming or ozone depletion.

Table 5-3: Sensitivity analysis for the chiller using H_2O refrigerant: Influence of variation in the coefficient of performance on selected environmental impacts. Figures are given per 1TJ cold 6/12°C.

Coefficient of performance	**Cumulative energy demand**	**Global warming**	**Acidification**	**Summer smog**	**Ozone depletion**	**Aquatic ecotoxicity**	**Terrestrial ecotoxicity**	**Radioactivity**
	MJ-eq	kg CO2-equiv.	kg SOx-equiv.	kg Ethylen-equiv.	R11-equiv.	kg 1,4-DCB-equiv.	kg 1,4-DCB-equiv.	kBq U-235-equiv.
3.0	783'000	12'477	85	17.9	0.026	2'960'000	40	13'917
3.5	674'429	10'886	75	15.7	0.023	2'591'429	35	11'940
4.0	593'000	9'693	67	14.1	0.020	2'315'000	31	10'458
4.5	529'667	8'766	60	12.9	0.018	2'100'000	28	9'306
5.0	479'000	8'023	56	11.9	0.017	1'928'000	26	8'383
5.5	437'545	7'416	51	11.1	0.015	1'787'273	24	7'629
6.0	**403'000**	**6'910**	**48**	**10.4**	**0.014**	**1'670'000**	**23**	**7'000**
6.5	373'769	6'482	45	9.8	0.013	1'570'769	21	6'468
7.0	348'714	6'115	43	9.3	0.013	1'485'714	20	6'012

5.1.2 Current regulation for the handling of HFCs

In the current version of the "Ordonnance sur les substances dangereuses pour l'environnement (Stoffverordnung)" only production, sale, import, use and end of life treatment of ozone depleting refrigerants are regulated. The handling of Fluorohydrocarbons (HFCs such as R134a) is not covered by Swiss regulation yet.

5.1.3 Recommendations

In particular, chillers using water as refrigerant show a better environmental performance as compared to conventional chillers. We therefore recommend actively informing facility managers and HVAC planners about this innovative technology which helps reduce global warming and ozone depleting effects without causing additional other environmental impacts.

However, HFC chillers cannot always be avoided. Because of their considerable global warming potential (comparable or even higher than the one of HCFC R22) and their indirect ozone depleting effect, a careful treatment during filling, maintenance and end of life treatment of

HFC chillers is of utmost importance. We therefore recommend making the same high demands on the handling of HFC as on the handling of CFCs and HCFCs.

5.2 Green electricity

5.2.1 The “naturemade star” certification scheme

As a result of the mediation process, data centre operators committed themselves to purchasing electricity produced from renewable sources. SIG is able to deliver hydropower to data centre customers. However, without explicit promotion of new renewable energy sources, the electricity production mix of SIG would remain the same (hydro and nuclear) and less hydroelectric power would be available for all other SIG clients. A commitment of data centre operators to conventional hydroelectricity – without a promotion of new renewable sources - is therefore a requirement that does not help improve the environment.

But there are possibilities to promote the use of environmentally benign and certified electricity from renewable energy sources such as hydro, photovoltaic, wind and biomass. The label naturemade star developed and supported by several utilities (besides SIG in Geneva., for instance EOS, EWZ in Zürich, BKW in Berne, IWB in Basel), EnergieSchweiz, NGOs (Konsumentenforum, WWF Schweiz and Pro Natura) and the Swiss associations of renewable energies (Biogas Forum, Suisse-Eole, Swissolar) is a stringent certification scheme (see Figure 5-1) and includes a promotional model for new renewable energies (Naturemade, 2000). The certification scheme helps to increase the capacity of new renewable energies such as wind power, biogas or photovoltaic. Additional demand for naturemade star electricity increases the number of (hydroelectric) power plants that go for naturemade star certification. In Geneva naturemade-labelled electricity is marketed as “SIG Vitale Vert” http://www.sig-ge.ch/fr/vitale/entr-vert.asp . The incremental costs are of the order of 0.08 CHF/kWh.

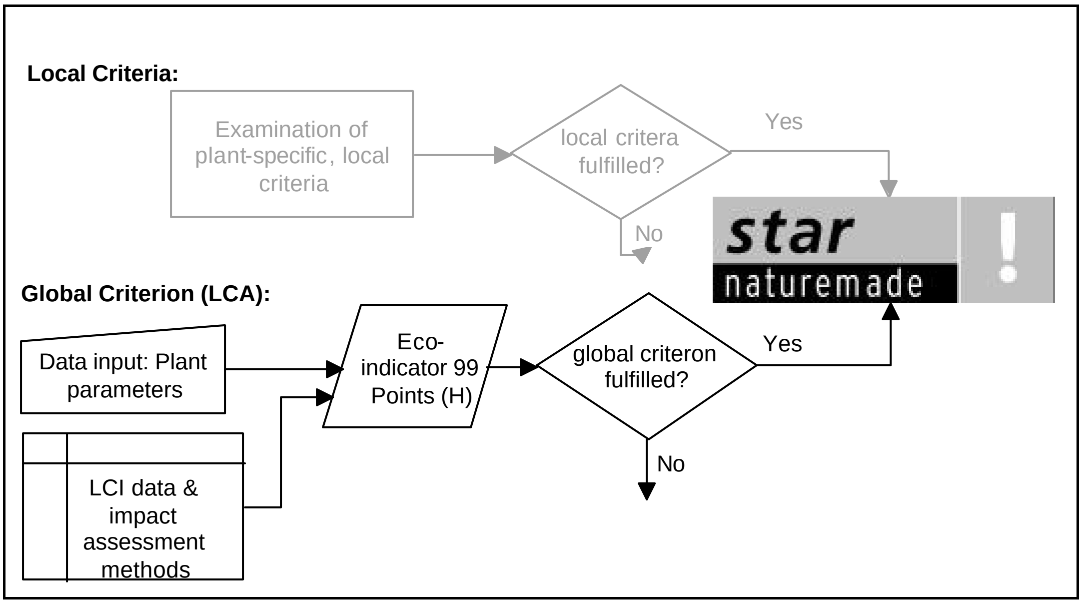

Figure 5-1 Local and global criteria for the labelling of electricity with the *naturemade star* label.

The label naturemade star requires accordance with a set of technology-specific local criteria such as fish ladders and bypass water for hydroelectric power plants and an LCA result per kWh that remains below a threshold limit. The threshold is defined as 50% of the environmental impacts of a modern gas-fired gas combined cycle power plant. Most technologies have no problems remaining under this limit. However, certain photovoltaic power plants and small wind power plants surpass the threshold when they have low specific yield.

Table 5-4: Life Cycle Assessment results using the Eco-indicator 99 method (hierarchical perspective) for systems based on renewable energies and for conventional power plants. The threshold value equals 50% of the environmental impact of a gas-fired gas combined cycle power plant. Plants with lower values are admitted to the certification process.

	mPoints	Certified Systems for Renewable Energy				Conventional Reference Systems				
	Threshold Limit	Hydro Power	Wind Energy1)	Biogas2)	Photovoltaic3)	Gas Combined Cycle - Natural Gas	Nuclear Power	Fuel Oil	Hard Coal	UCTE-Electricity-Mix
Min		367	1'160	< 0	6'730	27'900	6'260	61'600	28'000	24'600
Max	**13'950**	637	9'680	< 0	14'900					

1) Figures for plants with more than 30 kW capacity.
2) Fermenting plants have a lower environmental impact than composting plants. Therefore the overall score of environmental impacts is negative.
3) Plants built before 1995.

5.2.2 Trade-off between energy efficiency and green electricity supply

It could be questioned at which point additional energy efficiency measures cause higher environmental impacts per kWh saved compared to the impacts of an additional kWh of green power. This kind of question would best be answered with the help of life cycle assessment (LCA) if major additional investments were required (e.g., free cooling yes or no). In these cases, the environmental impacts of such investments required for reducing the electricity consumption might be assessed in a comprehensive way (from cradle to grave). Ideally, data centres should consume as little electricity as possible and certified green electricity only.

5.3 Emissions from emergency power generators

Large emergency power generators emit considerable amounts of NO_X, CO, hydrocarbons and particulates (a major cause for respiratory effects and cancer). A diesel engine of 2000kW power capacity for instance emits about 12kg NO_X, 400g of hydrocarbons and 300g of particulates per hour. Do these emissions pose severe air quality problems in Geneva if several emergency power units operate at the same time? For that purpose we use road-traffic related emissions for a comparison.

In Geneva, about 24'000 tons of diesel have been sold in 1999. With average emission factors of 30g N NO_X, 5g HC and 2.5g particulates per kg diesel, daily emissions are 2'000kg, 330kg, and 160kg for NO_X, HC and particulates respectively. In addition, about 210'000 ton of gasoline is sold yearly. With average emission factors of 7.5g NO_X, 5g/kg HC and 0.1g/kg particulates per kg gasoline, total daily emissions amount to 4'300kg, 2'900kg and 60kg NO_X, HC and particulates, respectively. Daily road-traffic related emissions in Geneva are estimated to 6'300kg NO_X, 3'200kg HC and 220kg particulates.

Hence more than 20 2'000kW emergency power units (i.e., 40MWe) are required running 24h each to equal the daily NO_X-emissions of lorry traffic. More than 30 units (i.e., 60MWe) operated during 24h are required to equal the amount of particulates emissions. We expect that emergency cases only occur in limited areas during limited time. Nevertheless we recommend to assess the air quality changes that could occur in areas with a high density of emergency power units and/or with high background concentrations of NO_X and particulates.

Because of the severe health effects of particulates (cancer and respiratory effects) that correlate very well with the increase of particulate concentration in ambient air, we additionally recommend to prescribe particulate filters for emergency diesel units.

6 Policies to foster energy efficiency in Data Centres

6.1 What is the problem with data centres?

Data Centres are huge electricity consumers. Increases of potentially a few 10% in electricity consumption in the Canton of Geneva are not compatible with the declared energy policy aiming at electricity consumption in 2010, which is not higher than in 1990. This conflict was not recognised by the authority, and the legal apparatus did or could not handle it in a way, which was adequate to the question. The first point, regarding targets and new drivers of electricity consumption, is not discussed further in this chapter.

6.1.1 Illogical distribution of competence

The formal administrative decision on air conditioning was made by a service which was “not competent” in a substantial way. In effect the "Service cantonal de l’Energie" (ScanE), part of the “Département de l’intérieur, de l’agriculture et de l’environnement” (DIAE), through the intermediary of its "Commission cantonale de Climatisation", only drew up a preliminary notification for the "Service Sécurité Salubrité" of the "Direction de la Police des Constructions" , an organisation of the “Département de l’aménagement de l’équipement et du logement” (DAEL), which then granted formal authorization to the applicant. Moreover, in the case of an appeal or if the decision was contested, the authority that gave the preliminary notification (ScanE/DIAE) had to deal with the case, rather than the authority that had formally granted the authorization (DAEL).

6.1.2 Procedure became politicised

In the course of the administrative authorization procedure for data centres in June 2000, ScanE alerted the members of the "Commission de l’Energie du Grand Conseil" who, in September 2000, planned to have a hearing of members of the "Commission cantonale de Climatisation". The construction permit was granted on 23 October 2000, before any hearing by the Grand Conseil had taken place. After this elicited opposition by environmental groups, the DIAE chaired negotiations between all the involved actors that ended in March 2001. Such a process (intervention of the legislative branch and contractual solution achieved by negotiating with third parties) is highly unusual for a normal administrative procedure. Its results are sometimes difficult to foresee and raise doubts about the equal treatment of different applicants. A legal and/or regulatory clarification of the procedure would allow for more predictable procedures and results for the applicant as well as for third parties. It would also ensure that the involved agencies follow the general principles of administrative law (in particular legality, equity and proportionality).

6.1.3 Lack of legal and/or administrative framework

As they now read, articles 117 LCI and 117A ARALCI do not establish objective criteria that would allow an application to be refused based on the objectives of cantonal energy policy.

6.1.4 Lack of controlling mechanisms

Article 8 LCI allowed installations to be checked and, if necessary, made it possible to enforce adherence to the demanded standards. In reality, however, such practices were never adopted for air conditioning. This can be partly explained by lack of personnel, technical know-how, and criteria for reference (indexes for appropriateness, for performance, etc.).

6.2 Voluntary approaches in Zürich (Energiemodell Zürich) and in the framework of EnergieSchweiz (Energiemodell Schweiz)

The Canton of Geneva wants to integrate the content of the “accord” between GE and DC into a legal framework. Two interesting models are discussed and evaluated as to whether they are appropriate to be used in the context of Geneva and in the case of data centres.

6.2.1 The "Energiemodell Zürich"

The "Energiemodell Zürich" has been introduced in paragraph 13 in the Energiegesetz (energy law) of Kanton Zürich. Large energy and electricity consumers (more than 5 GWh thermal energy and 0.5 GWh electricity consumption per year, respectively) may be obliged to analyse their energy consumption and to realise reasonable reduction measures. Large consumers can escape this obligation if they commit themselves (individually or in groups) to achieve reduction goals set by the government. This led to a group of 13 enterprises, which together form the so-called "Energiemodell Zürich".

The companies that committed themselves to jointly achieve energy reduction targets in Zürich stem from very different sectors. The "Energiemodell Zürich" comprises 3 insurance companies, 2 banking institutes, 3 retailers and 5 industrial companies. For each of these subgroups of companies the parameter with which energy efficiency gains are quantified has been defined separately (Bürki 2001).

Insurance companies relate their electricity consumption to the amount of floor space (Table 1), banking institutes must reduce their overall electricity consumption (initially within the borders of Canton Zürich, now within Switzerland). Retailers also need to reduce their overall electricity consumption, although in this case after correction for variation in opening hours and amount of freezer meters. Finally, industrial companies calculate the (hypothetical) electricity consumption without considering any saving measures realised since the reference year ($E_{tot} + E_{saved}$) and relating it to the actual consumption (E_{tot}).

Hence, targets are in most cases quantified in relative terms which helps to offset variations in economic development (i.e., increase or decrease in product output). Banking institutes for instance, which (still) use the absolute electricity consumption, have been facing the problem of an increasing number of working places in Zürich (due to the fusion of the former Schweizerische Bankgesellschaft and the Schweizerische Bankverein). For this reason they had to change their balancing area from Canton Zürich to all of Switzerland.

Table 6-1: Different indicators of energy efficiency used in the Energiemodell Zürich

branch	efficiency parameter	comment
insurances	kWh_{el}/m^2	no monitoring of total consumption
banking institutes	kWh_{el}	initially activities in Kt. Zürich, now in entire Switzerland
retailers	kWh_{el}	corrected by the amount of freezer meters and opening hours
industrial companies	$(E_{tot}+E_{saved})/E_{tot}$	no monitoring of total consumption

6.2.2 The "Energiemodell Schweiz"

The "Energiemodell Schweiz" (BUWAL/BFE 2001) is modelled after the "Energiemodell Zürich". It is targeted to medium and large enterprises from the industrial, service and retailer sectors.

The "Energiemodell Schweiz" is focused on total energy rather than electricity consumption. Companies with a large thermal energy demand have priority, whereas (almost) pure electricity consumers are not the focus of this voluntary program.

Energy efficiency is expressed on a relative basis. The parameter is very similar to the one used for industrial companies in the "Energiemodell Zürich" (total energy consumption plus cumulative energy savings due to all saving measures since the starting year, divided by total energy consumption). However, it does not only comprise electricity but quantifies total energy consumption by a relative weighting of the different energy carriers[19].

The impact (the effectiveness) of these two approaches is not (yet) well documented. An early evaluation of the Energiemodell Schweiz (Kristof et al., 1999) did look at strategic and organisational aspects instead of impacts. An ongoing study (Konersmann, 2002) will look at the impact from the point of view of the individual company. Impacts will have to be evaluated in the coming years in the regular evaluation-framework of the EnergieSchweiz programme and the CO2-law. In the “Energiemodell Zürich” the stipulated impacts do not differentiate clearly between energy savings due to structural changes , savings due to long-term autonomous technological progress and savings due to activities in the framework of the Zurich model.

6.2.3 Data Centres within an "Energiemodell"

Data centres would principally fit into an "Energiemodell"-concept as the ones described above. They are equivalent to other companies that joined the "Energiemodell Zürich" and would be allowed to negotiate with Canton Zürich as individual companies (consuming usually more than 0.5 GWh electricity per year), as a group of data centres, and also together with companies from other economic sectors.

The operators of data centres agree that energy aspects can be openly discussed and successful energy saving measures transferred among different data centres. Though energy costs are rather high – between 15% and 20% of the total costs of a data centre - and saving potentials are not negligible, the main differentiation between competing data centres lies in their ICT services. But the question of whether the data centres would be ready to organise themselves in a group that would represent their members in discussions with the authorities, remains unanswered.

As we learn from the "Energiemodell Zürich" and the "Energiemodell Schweiz", it is not necessary and sometimes not even useful to monitor the absolute amount of energy/electricity consumption. The economic development of a company may exercise much more influence on the amount of energy/electricity consumed than saving measures, and may even over-compensate reduction efforts. Because data centres are in their initial stage of market penetration and are working in a sector of fast economic and technological developments, a parameter which expresses relative improvements is much more suited than one which considers the total amount of electricity consumed.

A main obstacle that data centres experience entering any kind of "Energiemodell" is the short business cycle of this kind of activity. With economic payback times of less than two years it is not obvious that such companies will commit themselves for a voluntary but long-term (e.g.,

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[19] The mode of aggregation is disputable. For electricity a weighting factor of 2 is used. According to Mr. Bürki this factor has been derived from the fact that UCTE electricity shows two times higher CO_2-emissions as compared to oil and gas. However, for monitoring of CO_2-emissions, electricity is weighted with 0. For quantifying total energy consumption, a pollution or primary energy based factor (which is then much closer to or above 3) seems more adequate.

ten years) commitment for electricity saving measures. Options should therefore be envisioned which enable one data centre to transfer the commitment to a successor (new owner of the facility(ies)).

6.2.4 The CEE concept and the "Energiemodell"

The Coefficient of Energy Efficiency (CEE) expresses the quality of the infrastructure (cooling, ventilation, UPS) of a data centre relative to the amount of electricity required for the ICT equipment. Similar to some of the energy efficiency parameters used in the "Energiemodell Zürich" and "Energiemodell Schweiz", the CEE is a relative parameter, which does not limit the total amount of electricity consumed. Thus, the economic development of this new and future-oriented activity is not limited as such. However, the CEE concept helps to guarantee a minimum electric efficiency of ISP and ASP activities.

The basic idea of the CEE is therefore compatible with a free market economy and also comparable to other parameters used in the "Energiemodell" concepts.

In contrast to the energy efficiency formula used in the "Energiemodell Schweiz", which is partly based on hypothetical figures, the CEE as outlined above is calculated with measured values only.

6.2.5 Conclusions

The “Energiemodell Zürich” and the “Energiemodell Schweiz” can readily serve as bases for designing one of the Geneva scenarios. In these two models, the data centres are in fact able to negotiate target values, whether as an individual company that consumes more that 0.5 GWh per year, a group of data centres, or a group with large consumers from other sectors of the economy (e.g. banks, insurance companies, industry). The CEE concept we are developing for Geneva could prove compatible with the general criteria applied in the Zurich and Swiss models. The data centres’ speed of technical and business cycles (e.g. short business cycle, economic payback time of less than two years) nevertheless definitely presents a problem, as it makes it more difficult to get the data centres’ commitment to target values negotiated for the medium and long term (for example 5 to 10 years).

From a legal point of view, the CEE is principally suited for expressing the energy efficiency of computer and data centres within an "Energiemodell" concept such as the one for Zürich and for Switzerland. We even judge it superior to the one used in the "Energiemodell Schweiz" because of its close relation to real (measured) electricity consumption figures. In the "Energiemodell Schweiz" the temptation exists to influence the result by changing figures in the hypothetical part of the formula. Using CEE based on monthly measurements, possibilities for data centre operators to manipulate their results are very limited.

6.3 Scenarios for the future

Based on the current reform of the legal framework in Geneva (but without taking into account the latest policy developments), and with to the aim of embedding it in a larger perspective, we sketch out three large scenarios, which differ primarily in the degree of intervention by the state, that is, by the room for manoeuvring granted to economic and environmental actors in the course of the procedure.

In order to facilitate the discussion about advantages/disadvantages of the different scenarios, we compare them in a systematic way by using a set of criteria.

Finally, we identify several conditions that need to be changed should the canton of Geneva want to institute one of the scenarios that go beyond the energy concepts and procedures currently being formalized (e.g. adoption of the 'Règlement modifiant le règlement d'application de la loi sur l'énergie" (L 2 30.01)).

6.3.1 Three scenarios

We draw attention to the fact that all three scenarios focus on energy values (in the sense of objectives to be reached and/or thresholds to be respected in order to receive authorization), in contradiction to scenario S1 (last policy reform, that was not adopted by the time of our final policy analysis report) which concentrates more on the procedure to be followed. In our opinion, the three scenarios therefore represent a qualitative leap forward compared to the reform now under way in the canton of Geneva.

The three scenarios are working propositions that would have to be submitted to the main actors involved (ScanE, DIAE, environmental NGOs, data centres, other large consumers, SIG, chamber of commerce) for consultation and discussion before a final decision could be reached in favour of one of them.

- The scenario "voluntary agreement on target values (S2)" takes its inspiration from the two Zurich and Swiss models described in chapter 6.2. This scenario basically envisions an energy self-regulation. Both decision and control are de facto delegated to data centres or to other large consumers.

- The scenario "formal authorization based on mandatory values (S3)" corresponds to a rather traditional understanding of authorization procedures, such as building permits. It proposes to make energy decisions according to the procedures already in place for construction regulation. In other words, formal authorization increases the public sector's power, while it is only sporadically wielded by it or delegated to private actors (for example the Data Centres themselves, indirect control by environmental NGOs).

- The scenario "integrated control (S4)" goes a step further in the direction of strict legal and administrative monitoring of the conditions for authorization. It increases the role of the state, as it implies rigorous state control and sanctions to ensure that conditionally authorized installations and equipment actually conform to set standards. Here, private economic and/or environmental actors no longer play a role.

Table 6-2: Scenario overview (including scenario 1, the current reform) grouped by activities and responsibilities of different actors

Scenarios grouped by stages of procedure	Prior consultation	Formal decision	Possible appeals	Monitoring	Sanctions / regulatory instruments
Procedure for energy concept (S1)	- Four-step procedure for the energy concept	- Authorization granted by ScanE if the procedure is followed	- Right to appeal based on current legislation	- Checked 36 months after request for operating permit	- Procedure to attain compliance
Voluntary agreement on target values (S2)	- Participation of NGOs, SIG and experts in establishing energy indexes and target values	-Authorization granted/ refused by ScanE - *Target values* negotiated between the ScanE and an individual Data Center, a group of Data Centers or a group of large consumers	- Right to appeal based on current legislation - Right to appeal based on the negotiated agreement	- Periodic *voluntary* statement given by Data Centers on the development of their energy indexes and the degree of success in reaching the target values - *Optional* establishment of a database	- Procedure to attain compliance - Fines
Authorization based on mandatory values (S3)	- Participation of Data Centers, NGOs, SIG and experts in establishing energy indexes and threshold values - Mandatory value set in the regulatory framework	- Authorization granted/ refused by ScanE based on a predefined index *(threshold value)*	- Right to appeal based on current legislation	- Periodic *compulsory* statement given by Data Centers on the development of their energy indexes and the adherence to threshold values - *Optional* establishment of a database	- Procedure to attain compliance - Fines
Integrated control (S4)	- Participation of Data Centers, NGOs and experts in establishing energy indexes and threshold values - Mandatory value set in the regulatory framework	- Authorization granted/refused by ScanE/DIAE based on a predefined index *(threshold value)*	- Right to appeal based on current legislation	- Checks *(on the ground*, in the Data Centers) by ScanE on the development of energy indexes and the adherence to threshold values - *Compulsory* establishment of a database	- Procedure to attain compliance - Fines

Naturally, these are not the only scenarios possible, and hybrid cases may be developed by combining the contents of different phases of the four scenarios.

We emphasize that the CEE index can be used in all the scenarios as an indicator of the target value and/or as a monitoring index.[20] Its status and its usefulness, however, vary from case to case. In the second scenario, its final value can be negotiated before it becomes a target value. In scenarios 3 and 4, its value is measured for each case and is then compared to the target value set in the regulations. It becomes a criterion for granting authorization, and afterwards, monitoring the CEE provides an index of how well the fixed objectives are attained.

The described scenarios in their present state do not contain any instruments for economic incentives (e.g. incentive tax or subsidy, a system of financial reward and punishment according to the energy efficiency of the Data Centres, electricity tax). It is however perfectly possible to include such instruments and to combine them with the authorization procedure which lies at the heart of the proposed scenarios. Two (complementary) categories of incentive instruments in particular could be considered here.

- First, those incentives that come into play before the authorization is granted. The state intervenes here by supporting the purchase and installation of more energy-efficient material, for example through subsidies, advantageous prices, etc.

- The second category of incentives is used during or after authorization is granted, and is closely linked with the energy monitoring, which is to be set up in the new procedure. These incentive tools can take mainly two forms. On one hand, an incentive tax of the reward and punishment type penalizes actors who do not reach the target value (negotiated or set by the state), while rewarding those who surpass the target. This can be done by a direct tax levied on the consumer or by an indirect tax collected by raising energy tariffs. On the other hand, the incentive can be a multi-faceted financial relief package for those actors whose Data Centres are more energy-efficient than the target demands.

No matter which instrument is used, it will eventually become necessary to create a *financial fund* in order to collect, distribute or allocate the sums necessary for such incentives.

6.3.2 Criteria for evaluating scenarios and the need for new conditions

While we do not propose to present an exhaustive analysis of all the implications of the different scenarios, we do evaluate them with the help of some criteria. We identify several conditions that need to be changed should the canton of Geneva want to institute (for example in the course of its expected second legal and administrative reform) one of the scenarios that go beyond the energy concepts and procedures currently being formalized.

The strong and weak points of each of the scenarios outlined above can be identified and analysed. In order to ensure transparency and a fair comparison of the scenarios, the criteria used for evaluation need to be spelled out, among which are the following:

- Appropriateness of energy and economic objectives (overall relevance of the procedure)

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[20] Nevertheless, different definitions of the CEE index – limiting it to C1 or expanding it to include C2 – can change the scenarios. We have defined the CEE index here as containing both components.

- Contribution to realizing objectives of cantonal energy policy (effectiveness of the procedure from an energy perspective)
- Simplicity and administrative costs of implementation (efficiency of the procedure)
- Implications for the regulatory framework (altering laws, setting rules for procedures and target values, etc.)
- Equal treatment of Data Centres and other large consumers (equity of the procedure)
- Possibility for affected private actors to participate, for example by prior consultation or appeal (openness of the procedure)
- Financial neutrality of the instruments used in implementation (e.g. a financial fund for redistributing any money raised by a tax in the energy sector)
- Etc.

The criteria used for evaluation should be selected and formulated with general administrative principles in mind, while the particular political situation in the canton of Geneva should also be respected.

Moreover, limiting the CEE index to C1, or extending it to include C2, affects which scenario is the best choice. For example, the complete index (C1+C2) would be likely to reduce the flexibility of the involved actors, raise the administrative costs of monitoring and managing the authorization cases, and affect the types of regulatory instruments that could be used.

The following table aims to help in the discussion and in the eventual choice of a scenario by comparing the four scenarios according to the main criteria agreed upon in the meeting of November 30th, 2001. Our valuation is based on information gathered in interviews, analysis of the available documents and data, and on evaluation of identical solutions used in other energy sectors (e.g. target value and threshold value for the energy use of household and office appliances).

Table 6 -3: Scenarios grouped by main criteria for evaluation

Criteria for evaluation	Procedure for energy concept (S1)	Voluntary agreement on target values (S2)	Authorization based on mandatory values (S3)	Integrated control (S4)
1. Energy efficiency	-	+	++	++
2. Simplicity and reproducibility of the procedure	--	-	+	-
3. Equal treatment of large consumers	-	+	++	++
4. Acceptability to large consumers	++	+	-	-
5. Overall relevance	-	+	+	-

Explanation: ++ criterion fully met, + criterion met,
- Criterion not met, - - criterion not met at all

This comparative (albeit not all-encompassing) table shows that the S3 scenario presents the best solution, mainly for the following reasons: setting threshold values, first of all, makes implementation, monitoring, and the authorization process more efficient, predictable and easier to evaluate. It reduces the risk of unfair treatment that might result from a process focused purely on procedure. While this scenario does require important administrative resources for monitoring, overall it engenders less regulation than scenario S4. Furthermore, threshold values reduce the administrative costs of a procedure based on presenting and evaluating concepts without stable, formal norms. In the absence of thresholds, target values could be set or negotiated with the involved actors. It is nevertheless clear that such a solution could not entirely replace a type S3-scenario in terms of energy efficiency.

Moreover, the reforms under way (for example regulations for applying article 6A) should provide for founding a structure that can be built upon as time goes by, and whose construction and architecture could vary depending on the sector in question (e.g. data centre, public buildings, etc.), on technological progress and on advances in scientific research, notably to create performance indicators that could measure the energy efficiency in a specific sector of activity. In order to achieve this, the following elements must be taken into account for translating the concept into a procedure and into a regulatory or legal text.

- The **areas of competence** of the administrative agencies must be clearly identified for the entire authorization procedure,
- The **nature of the decisions** (definite or provisional authorization, etc.) during each step of the procedure has to be described and determined,
- The **criteria for decision-making** and evaluation must be clearly established.

- The **instruments for monitoring**, as well as the way they are used, must be foreseen as delineated,

- The **possibilities for appeal** have to be delineated,

- **Transitional measures** (for example, using target values until indicators for threshold values are established) could be envisioned.

6.3.3 The need for new conditions

To conclude, we identify several changes that are, in our opinion (in spring 2002, before the last policy reform) preconditions for implementing any one of the scenarios S2 to S4. These modifications are diverse in type and are not all the responsibility of ScanE. Anticipating them should nonetheless make it easier to understand and adopt the (possibly) coming reforms.

a) Legal and/or regulatory modifications

Articles 6A and 22B of the projected law very likely provide a sufficient legal basis for introducing target values as the main elements of the energy concept and authorization procedure. On the other hand, a threshold value (as condition for granting authorization) and incentive instruments would have to be based on a new article of the law. In any case, modifications in the regulatory framework are necessary. If the current reform does not already make progress in this direction, then the second legal revision should be used as an opportunity to effect these changes

b) Administrative resources

New administrative resources are clearly required to evaluate the energy concept, and to formulate and monitor the target values or the regulatory implementation of threshold values. Moreover, additional costs would accrue by applying a serious strategy for energy monitoring. These new tasks could either be undertaken within ScanE or delegated to outside actors (private consulting firms or others). In any event, the costs will be directly linked to the complexity of the procedure and the authorization criteria (for example know-how in matters of exergy), as well as to the degree to which those criteria are formalized (for example negotiation and updating of target values).

c) Cultural change within ScanE

Now that the formal competence for granting energy authorizations has been returned to it, ScanE must assume all the resulting responsibilities. This means that ScanE needs to develop a (partially new) culture and to make administrative decisions (including negative ones). ScanE has to move beyond the pure management of procedure and prior notification to become the central deciding authority. It is our opinion that the procedure envisioned to develop a new energy concept does not yet follow these guidelines sufficiently.

7 Conclusions, recommendations, outlook

7.1 Conclusions

The detailed analysis of the technical-economic feasibility showed that C1, the first component of CEE, is a good choice to describe energy efficiency of the central infrastructure of a data centre. It can be used in the construction-permission process and in the follow-up monitoring process. The second component of CEE, C2 measuring inefficiencies in the ICT equipment, can be estimated if the operator of the data centre collects information about the ICT equipment and their use. C2 can then be used to monitor the inefficiencies in the ICT equipment. But the uncertainties in C2 are still too important to be used for benchmarking purposes (between data centres), and C2 can therefore not be used as an indicator leading to a target value or even a constraining standard.

Voluntary policy is the essence of scenario S2[21]. It fits well in the actual policy “environment” in Switzerland (cf. voluntary agreements for CO_2 reduction) and the initiated legislative reforms in Geneva, and can be implemented immediately, whereas a more constraining policy would need more preparatory work. Despite some apparent difficulties – fast technical changes and short business cycles - data centres can well be treated. The first component C1 can easily be used in the “Energiemodelle” used in Zurich and in the framework of EnergieSchweiz. Voluntary agreements with operators to establish databases and promote efficiency improvements by their clients are – on the level of Canton Geneva - the most realistic way to make progress in the complex field of energy-efficiency in the global ICT equipment business. More constraining policies (S3, S4) are investigated regarding the central infrastructure. A comparison shows an obvious advantage regarding effectiveness, but the political obstacles and the time needed to prepare and implement these policies are probably rather important. Furthermore, additional administrative resources as well as a cultural change within the ScanE are pre-conditions for a next policy step towards the scenarios S3 and S4.

It is technically absolutely possible to extend the main elements of the “accord” to all large companies with similar activities, e.g. already existing data centres or corporate computer centres. But, the costs of measuring C1 may, in certain cases, be rather high. The conclusions of the policy analysis are not restricted to ICT companies. The different scenarios can be applied to all important energy consumers in all economic sectors – provided that adequate indicators for energy efficiency can be defined and determined.

7.1.1 Technical feasibility of the CEE-concept

Measuring CEE

A measurement concept is presented for the first term C1 (appendix 3). Measuring costs are low for new data centres. No general estimate of costs to perform these measurements in existing data centres can be given. If the HVAC infrastructure is used by different companies it may be rather complicated and costly to measure the electricity consumption for HVAC purposes of a single company.

The second term C2 cannot be measured, but reasonably accurate estimates of the energy losses at the equipment level can be given, provided a database of the equipment is established by the operator of the data centre.

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[21] Today it is partially realised in the new regulation of the Canton of Geneva (appendix 6)

Energy efficiency potentials

Efficiency potentials were mainly studied for the infrastructure and for power transformation and heat evacuation in ICT equipment. Improvements at the level of the electronic components, processors, storage media and the like, can hardly be influenced by political measures taken at the regional, national and even international level. But this does not mean that there is no scope/room for manoeuvre (Handlungsspielraum). The use of energy optimised processors available on the market (more costly and possibly with slightly lower performance) and larger computers (possibly in a different business context such as dedicated data centres replacing collocation sites) could drastically reduce energy demand for the same service. Savings at the level of the useful energy (energy used in electronic components for processing, storing and transmitting data) lead to savings in the energy losses in power transformation and heat evacuation at the level of ICT equipment and in energy losses at the level of the infrastructure. They are therefore most effective. But the history of energy use by ICT has shown that the extremely fast improvements in the energy efficiency of ICT was, in the long term, always overcompensated by an even faster increase in the quantity of information needed to be treated, transmitted and stored.

Reduction of energy losses at the level of the equipment (C2) and at the level of the central infrastructure (C1) both led to similarly significant savings in the overall energy consumption: a reduction by 50% of the energy **losses** at either level leads to a reduction of total electricity consumption of roughly 25% (assuming that the value of C1 and of C2 are of the order of 0.5 before any improvement is made). On the other hand, efficiency improvements at the level of the useful energy (electricity used by the processors, storing devices etc.) of 50% would lead to savings which are – at first approximation- directly proportional, i.e. 50%.

Indicators used as target values and for monitoring purposes

There is no adequate and generally accepted measure of the service provided by a data centre and therefore no measure of the specific energy consumption usually used to define targets for energy efficiency. CEE, or its components C1 and C2 were proposed instead, because their values are not affected by technical progress at the level of the electronic components and variation in activity of the data centre.

For C1, a target value of 0.65 is proposed for new data centres and 0.55 for existing centres. These values will have to be evaluated with data to be produced by the data centres. Monitoring over a few years, of several data centres or similar buildings (computer centres, switching centre) is needed to learn more about the feasibility of compulsory standards to be reached .

The second term C2 cannot be measured, but reasonably accurate estimates of the energy losses occurring at the equipment level can be given. These estimates are in fact not adequate for benchmarking and setting target values, but they are suited to monitoring energy efficiency at the equipment level in individual data centres. Alternative approaches are proposed to foster energy efficiency of the equipment used in data centres.

7.1.2 Suitability of voluntary policies

Data centres fit into voluntary policy process

Data centres fit well into voluntary policy processes like the “Energiemodell Zürich” and the “Energiemodell Schweiz”. Large data centres with an electricity consumption over 0.5 GWh per year can participate as individual companies. Smaller ones can participate as a group of data centres or by forming a group with large consumers from other economic sectors (e.g. banks, insurance companies, industry). Operators of data centres confirmed that energy aspects can be discussed and openly documented within a group of competing/rival companies, even if the economic advantage of energy efficient layout and operation is not negligible: energy costs represent some 15% to 20% of total costs.

The problem of defining target values in the context of extremely fast technological evolution is overcome by using the CEE concept, which focuses on the efficiency of the central infrastructure and energy losses in the power-supplies and heat evacuation, and is therefore not affected by the fast changes in chip-technology. The short business cycles of data centres aiming at economic payback periods of less than two years are definitely a problem when discussing commitments about target values to be reached usually in 5 to 10 years. But short-term commitments may partially be possible, and in the new context of financial difficulties of the e-economy in the last years more reasonable business cycles will probably be the rule.

C1, the first component of CEE, can be used straightforwardly as the indicator to define target values for energy efficiency of central infrastructures in data and computer centres. C2, on the other hand, is well suited for monitoring purposes in individual data centres. But it is not adequate for defining target values for groups of companies. As an alternative, we propose commitments by operators to take initiatives to improve energy efficiency in the ICT equipment used in data centres.

Voluntary policies fit in the initiated reforms and longer-term strategies in Geneva

Among the four policy scenarios discussed in section 6.3, S2 is a translation of the voluntary policy approach of the “Energiemodelle” in Zurich and in EnergieSchweiz into the context of Geneva. The comparative evaluation in Table 6-3 shows clear advantages of S2 over the scenario S1, which has been already partially integrated in the new regulation in Geneva.

More constraining scenarios, in particular S3, with mandatory values, present advantages in terms of expected energy savings and equal treatment of all consumers, but as any legally binding procedure it can not be started on a “trial and error” basis as is the case with many voluntary processes, and therefore needs more preparation; this also implies more administrative personnel within the ScanE and/or more financial resources for mandate given to private consultants (bureau d'ingénieurs spécialisés).

7.1.3 Fulfilment of the equity-criteria

Existing data centres, computer centres, telco-switches

The use of the CEE –concept, and in particular the first component C1, is not restricted to new data centres. It is well suited to measuring the energy efficiency of the central infrastructure of all kinds of activities with high internal heat loads. One restriction may come from high measurement costs in existing buildings, where the cooling is produced by a central plant used by multiple customers.

Other economic sectors

The investigations regarding policy aspects are not restricted to data centres. The proposed scenarios are applicable to all economic activities (for large energy consumers), and the general conclusions are valid for all sectors. But the analysis was not conducted on the level of the individual sectors and thus sector specific questions (e.g. speed of technological development, number of private operators, geographical mobility of firms, etc.) are not treated.

7.2 Recommendations

Most of the recommendations follow directly from the conclusions in the last section (7.1). Others are of a more general nature. We first focus on the transfer of the “accord” with the new data centres into an institutionalised legal and regulatory framework. Equity with respect to other companies active in the ICT business is considered. A second group of recommendations is related to the application of energy efficiency policies to large energy consumers in other economic sectors. Final recommendations concern preconditions (prerequisites) for successful implementation of the proposed activities, and specific recommendations regarding the operational design of voluntary policies.

But first of all, we strongly recommend to the ScanE to present and to discuss theses recommendations (or at least some of them, that the SCanE considers as relevant/acceptable, even after amendments through the SCanE) with the different policy partners (e.g. SIG, large energy consumers and environmental NGO's) in order to avoid a new clash and to "legitimate"/enlarge the political support of the new policy reform.

7.2.1 Transfer of the “accord” into an institutionalised legal and regulatory framework

R1: Develop and implement a policy framework (including construction permission and follow-up energy efficiency policies), which is open to voluntary agreements between large energy consumers and the cantonal authorities. This framework must include possible sanctions to be applied in the case that a partner does “retire” from the voluntary policy process or that the targets are not reached (R14).

R2: Use C1, the first component of CEE, to measure the energy efficiency of the central infrastructure of data centres. A detailed measurement concept, e.g. the one presented in appendix 3, has to be specified.

R3: Use the value of C1 ≥ 0.65 which must be reached by a new data centre in the construction-permission procedure and in the follow-up monitoring process. For existing data centres the value of C1 ≥ 0.55 is recommended.

R4: The policy framework (R1) is such that all large energy-consuming companies (in the planning phase and in operation) with activities similar to data centres (e.g. same code in the classification of the economic activities[22]) have to deliver the detailed measurements described in the measurement concept at least once a year. This data is analysed and the results used to validate or alter the proposed values of C1.

R5: Negotiate with operators of data centres the establishment of a database of ICT equipment, particularly including the nominal/rated power used in the data centre, and of the configuration/use of the equipment, particularly redundancy of power supplies and use of UPS. Negotiate with the operators the measurement of power loads and energy consumption of groups of ICT equipment or groups of racks. Define together with the operators of data centres initiatives to foster energy efficient behaviour in their clients when procuring and configuring their ICT equipment.

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[22] From the point of view of energy-efficiency it would be preferably to include all large computer centres, e.g. the ones operated at the University, in the hospital, in the cantonal administration or in the financial sector.

R6: Consider using the technology procurement procedure– starting with the organisation of a buyer group with significant purchasing power - in order to emphasise the intention to promote the most energy efficient equipments and components.

R7: Regarding eco-efficiency: inform the operators about the advantages of chillers using water as a refrigerant; treat HFC the same way as CFC and HCFC; prescribe particulate filters for emergency diesel units; assess the air quality in areas with high density of emergency power units; require that the renewable electricity used by data centres is certified with a label like *naturemade star* that includes a promotion-model for new renewable energies.

R8: Consider financial measures against careless overestimation of future needs in public infrastructure[23] and other resources that burden the public budget. Consider measures in spatial planning in order to concentrate energy- (and other infrastructure-) intensive activities in specific zones with existing overcapacities and/or potential for waste heat utilisation.

R9: Consider the development and implementation (costs) of more constraining policies with mandatory values (standards) and integrated control (scenarios S3 and S4).

R10: Take initiatives and support international activities for the establishment of a detailed energy-declaration of power supplies and UPS.

7.2.2 Energy-efficiency policies for all large energy consumers

R11: Apply the construction permission and monitoring process recommended for data centres (7.2.1) to all other large energy consumers. To do so, perform an energy analysis of these other large energy consumers in order to determine suitable indicators of energy efficiency. Consider using C1, the first component of CEE, as indicator for energy efficiency of the central infrastructure for activities with high heat loads to be evacuated. Do not neglect the production equipment (process energy), even if no direct intervention is possible at that level.

7.2.3 Preconditions, pre-requisites

R12: Verify, and if needed reinforce, the legal base forcing companies to measure their energy consumption following a pre-defined measurement concept and deliver it together with other relevant information to the authorities.

R13: Plan enough financial and intellectual resources for the rather long and resource-intensive process of initiating, performing and evaluating a voluntary policy process. Consider seriously the problem of “cultural change” within ScanE and other services and organisations.

7.2.4 Operational design of voluntary energy policies

R14: Verify, and if needed (eventually) reinforce, the legal base of possible sanctions that can be applied in the case that a partner does “retire” from the voluntary policy process or that a target is not reached.

R15: Conceive a comprehensive evaluation of the voluntary policy process – best done by some organisation not involved actively in the process but participating as an observer.

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[23] Short term discounting – in order to reduce the risk of stranded investments - of the utility’s investments in infrastructure (e.g. power-switches) could possibly lead to a significant increase of electricity price. The concerned industry could either look for an other site (possibly with existing overcapacity of power-infrastructure) or produce the power on-site.

R16: Prepare the voluntary activity by taking measures to build-up mutual trust between the involved partners. One pre-condition is common information level. Start with a meeting of the partners, where the findings of the present report are discussed.

R17: Favour the exchange of experience with other cantons and organisations in other countries active in this field. Consider an international workshop at the ITU TELECOM WORLD 2003 http://www.itu.int/WORLD2003/, which takes place in Geneva, October 12-18, 2003. Aim at national and international harmonisation of energy efficiency policies.

7.3 Outlook

The sudden appearance of data centres had several salutary effects:

- realisation that ICT is potentially an important electricity consuming technology (data centres are only the tip of the iceberg!)
- visible conflict between energy policy programmes and economic growth
- recognition of the deficiency of the construction permission procedure

Changes in the legal and procedural framework – with some inputs from this study – will improve the handling of similar situations. The reinforced role of ScanE may have a positive effect on the implementation of energy policy.

The conflict between economic growth and energy policy can be attenuated by a more differentiated view on both sides: an efficient (high capacity) and reliable internet infrastructure is needed for a modern economy, but activities which deliver infrastructure are not particularly interesting by themselves. Research activities and activities producing high added value should be favoured, and ICT companies involved in such activities are usually less energy intensive.

It is uncertain whether electricity demand of data centres will be an issue in the coming years (Cremer et al. 2003). But ICT will be an important issue and increasing energy consumption of ICT equipment will contribute to making it difficult to reach energy policy targets. More aggressive energy efficiency policies are needed if the declared energy policy aiming at electricity consumption in 2010, which is not higher than in 1990, is taken seriously.

To show significant results, it is most important that all economic activities are involved and that efficiency improvements in the use of process/production energy are not neglected.

Literature, References

Ademe: Energy Efficiency Assessment for Entertainment, Information and Communication Appliances [EEA-EICA], SAVE / Altener project proposal, Sophia Antipolis, 2002

Aebischer, B. and A. Huser: Energy Efficiency of Power Supplies. Study co-financed by the Swiss Federal Office of Energy and the Canton of Geneva, November 2002 (short English abstract shown in appendix 7; main report in German http://www.electricity-research.ch/sb/sb_power_supply.pdf ; appendices with detailed measurements in German can be downloaded from http://www.electricity-research.ch/PL/kommunli.htm)

Aebischer, B. et al. : Energie und Informationstechnologie. Energiesparer oder Energiefresser. Bulletin ETH Zürich Nr. 276 Januar 2000

Aebischer, B.: Rationellere Energieverwendung beim Einsatz von Computern. Proceedings der Fachtagung SIWORK '96 "*Workstations und ihre Anwendungen*". Zürich 14.-15. Mai 1996. vdf-Verlag, 1996 (ISBN: 3 7281 2342 0)

Aebischer, B.: Consommation d'électricité dans les centres de calcul. *L'électricité à bon escient. Manuel RAVEL.* Office federal des questions conjoncturelles, Berne, 1993 (ISBN 3-905233)

Altenburger, A.: Electricity consumption of HVAC equipment in data centres, communication. Amstein + Walthert, Zürich, 12.12.2001

Amstein + Walthert: Datencentre. z.B. No. 18, Zürich, 2001

Bänninger, M. : Communication, UBS, Zurich, 1996

Barthel, C., et al.: GHG Emission Trends of the Internet in Germany. Discussion paper for the Japanese-German Workshop *International Climate Policy and the IT-Sector*. Wuppertal, November 2000 (preliminary version)

Becker, K.-H.: Gerätedatenbank, UBS, Zurich, 1998

Brown, E. et al.: An ACEEE White Paper: Overview of Data Ceners and Their Implications for Energy Demand, Washington DC, September 2001

Bruhin, H. and R. Geisser: USV-Anlagen zentral oder dezentral, SEV-Bulletin 1, Zürich, 1998

Burkart, U.H.: Communication, Winterthur Insurance, Corporate IT, Winterthur, 2.4.2001

Bürki, Th.: Communication, Bürki GmbH, Fällanden, 18.7.2001

BUWAL/BFE: Anhang zur Richtlinie über freiwillige Massnahmen zur Reduktion von Energieverbrauch und CO_2-Emissionen (Bereich Industrie, Gewerbe, Dienstleistungen), Bundesamt für Umwelt, Wald und Landschaft, Bundesamt für Energie, Bern, 2. Juli 2001

Conference : Modèle de prescriptions énergétiques des cantons (MoPEC). Edition 2000. Conférence des directeurs cantonaux de l'énergie et conférence des services cantonaux de l'énergie. OFEN/Section OG, Berne, 2000

Courrier: Nouvelle liaison de données à haut débit entre le CERN et les Etats-Unis. Courrier CERN, Mars 2002. La Grille de calcul au banc d'essai. Courrier CERN, Mai 2002

Cremer, C. et al.: Der Einfluss moderner Gerätegenerationen der Informations- und Kommunikationstechnik auf den Energieverbrauch in Deutschland bis zum Jahr 2010 – Möglichkeiten zur Erhöhung der Energieeffizienz und zur Energieeinsparung in diesen Bereichen. Fraunhofer Institut für Systemtechnik und Innovationsforschung (ISI) und Centre for Energy Policy and Economics (CEPE) im Auftrag des Bundesministeriums für Wirtschaft und Technologie, Bonn, 2003

c't: Wasserkühlung für Server. c't 10/2002

c't: Power für den Vierer, 14 ATX-Netzteile im Vergleich, in c't 10/2002

Facinelli, K.: Cooling and Power Requirements for Colocated Hardware. http://www.crystalpc.com/pdf/coolingandpower.pdf

Frischknecht, R.: Umweltrelevanz natürlicher Kältemittel: Ökobilanzen für Wärmepumpen und Kälteanlagen. Schlussbericht ENET No. 9933303, ESU-services, Uster, im Auftrag des Bundesamtes für Energie (BfE), Bern, CH, 1999

Hartkamp, F.: Energy consumption of ICT in the Netherlands. Perspective to the year 2010. Presentation at *Impact of ICT on the energy system*. Workshop of the International Energy Agency, 20/21 February, Paris, 2002 http://www.iea.org/weo/ict/novem.pdf

Huiberts, E.J.T.: Mobiliteit van Data tegen (w)elke prijs? Verkennende studie naar het energiegebruik van ICT infrastructuur voor 2000-2009. Den Haag, Netherlands, 2 maart 2001

Huser, A.: Potential for reducing electricity consumption by switching off servers. Federal Office of Energy, Utility of the city of Zurich, Canton of Basel-Stadt Environment and Energy Office, Berne/Zurich/Basel, May 2002

Huser, A.: Energie in Data Centres. Teilbereiche Geräte und Messkonzept. Zwischenbericht, 18. Juli 2001

IBM: ECP-News, Vol. 5, Nr. 2, May 2001

IBM: IBM PowerPC processor news, October 2001 http://www-3.ibm.com/chips/products/powerpc/newsletter/oct2001/new-prod2.html

Intel: Intel's Developer Site, http://developer.intel.com , with many downloads, e.g. Intel 840 Chipset Thermal Design Considerations, Application Note, July 2002 http://www.intel.com/design/chipsets/applnots/29802702.pdf

Jochem, E.: Energy *End-Use Efficiency*. In *World Energy Assessment*, UNDP, UN-DESA, WEC (edts.), New York, 2000. (www.undp.org/seed/eap/activities/wea)

Jungbluth, N. and Frischknecht, R..: Ökobilanz des R718 Aqua Turbo Kaltwassersatzes: Ergänzung der Studie "Umweltrelevanz natürlicher Kältemittel". ESU-services, www.esu-services.ch, Uster, 2001

Kolar, J.: Communication, Power Electronic Systems Laboratory, Swiss Federal Institute of Technology, Zurich, November 2001 and February 2002.

Konersmann, L.: Das Energiemodell Schweiz aus der Sicht der beteiligten Unternehmungen. Diplomarbeit. CEPE/ETH, Zürich, 2002

Kristof, K., et al.: Evaluation der Wirkung des Energiemodells Schweiz auf die Umsetzung von Massnahmen zur Steigerung der Energieeffizienz in der Industrie und seiner strategischen, energiepolitischen Bedeutung. Bundesamt für Energie, Bern, 1999

LRV: Luftreinhalte-Verordnung vom 16. Dezember 1985 (LRV): (Stand am 28. März 2000). No. 814.318.142.1, Schweizerischer Bundesrat, Bern 2000 www.admin.ch/ch/d/sr/c814_318_142_1.html

Mauchle, P. and G. Schnyder: Planung und Betrieb von unterbrechungsfreien Stromversorgungsanlagen, SEV-Bulletin 11, Zürich, 2001

Mauchle, P. and G. Schnyder: Kenngrössen für die Wahl von USV-Anlagen – Betrachtungen unter dem Aspekt von Qualtiät und Energieverlusten, SEV-Bulletin 17, Zürich, 1999

Mitchell-Jackson, J.D.: Energy Needs in an Internet Economy: a Closer Look at Data Centers. University of California, Berkeley, U.S., July 10, 2001

Morosoli, B.P.: Die Full-Service-Provider kommen. Vom einfachen Internetzugang zur komplexen Dienstleistung. NZZ, 6. Februar 2001, Nr. 30, B12

Naturemade: Naturemade bringt Strom aus der Natur. Naturemade, www.naturemade.org, Zürich, 2002

Operators: Communication of operators of data centres during the negotiation process leading to the “accord” (appendix 1), Geneva, 2001

Ouzilou, O. : Communication, ScanE, Genève, 15. 2. 2002

Pittrof, Ch.: Web Hosting allein hat keine Zukunft. Nachfrage nach Gesamtlösungen zwingt zur Differenzierung. NZZ, 6. Februar 2001, Nr. 30, B27

RMI: Powering the Digital Economy. Draft Proposal for a Data Center Energy_Design Charrette. Rocky Mountain Institute and D&R International Ltd. Draft June 15, 2001

Roth, Kurt W. et al.: Energy Consumption by Office and Telecommunications Equipment in Commercial Buildings, Arthur D. Little, Inc, Cambridge, USA, 2002

Roturier, J. et al.: Energy-efficient office technologies in Europe (OT3E), Commission of the European Communities, Brussels, 1994

SIG, 2002: Promotion campagne of green power "SIG vitale vert", retrieved from http://www.sig-ge.ch/fr/vitale/entr-vert.asp , 27.05.02

Transmeta: Code Morphing software, Santa Clara, US, 2002 http://www.transmeta.com/technology/architecture/code_morphing.html

Varone, F., Ch. Genoud: Energy- and Eco-efficiency in Data Centres. Rapport intermédiaire, août 2001

Weber, L.: Energie in Bürogebäuden. Verbrauch und energierelevante Entscheidungen. Dissertation ETH, vdf-Verlag, Zürich, 2002 (ISBN 3-7281-2819-8)

Windeck, Ch. und H. Gieselmann: 24 leise Kühler für Sockel-A- und Sockel-370-CPUs, in c't Nr. 17, 2001

Zurita, E.: Communication, Weinmann-Energie SA, Echallens, 18.6.2001

Appendices

Appendix 1: Accord and press-communication of DIAE

ACCORD

Entre

(ci-après»)

et

L'Etat de Genève

et

World Wide Fund for Nature Suisse, 14, chemin de Poussy, 1224 Vernier
World Wide Fund for Nature Genève, 10, rue de Villereuse, 1207 Genève
SSES Suisse, p.a. F. Hiltbrand, 26, rue William-Favre, 1207 Genève
SSES Genève, 8, rue Saint-Ours, 1205 Genève
Contratom, case postale 65, 1211 Genève 8

(ci-après « **les Associations** »)

Préambule

En date du x y 2000, le Département de l'aménagement de l'équipement et du logement a octroyé à entreprise une autorisation de construire DD abc, se fondant sur un préavis relatif à la climatisation délivré par la commission cantonale de climatisation No 00/ab le x y 2000.

En date du x y 2000, les Associations ont recouru à la Commission cantonale de recours en matière de constructions (ci-après «**la Commission de recours**») contre l'autorisation susmentionnée.

Parallèlement à la procédure devant la Commission de recours, entreprise et les Associations ont entamé une procédure de concertation diligentée par l'État de Genève.

Lors de ce processus de concertation, entreprise a apporté des réponses satisfaisantes aux questions posées par l'État de Genève, les experts commis par l'État de Genève et les Associations. Ces questions et les réponses y afférentes sont consignées en **annexe 1** du présent document.

L'évaluation initiale de l'appel de puissance des composants du site de Meyrin sont décrits en **annexe 2** du présent document.

Enfin, l'État de Genève a l'intention de remplacer les dispositions stipulées dans le présent accord par des dispositions légales.

Cela étant précisé, les parties conviennent ce qui suit :

1. Obligations de entreprise

1.1. entreprise réduit sa demande en électricité de xx MVA à yy MVA pour l'ensemble de son site de abc, étant précisé que la demande totale de yy MVA ne sera atteinte qu'à terme, soit probablement en 2004.

1.2. entreprise recourra à une alimentation énergétique d'origine renouvelable (notamment de l'énergie hydroélectrique) pour 70 % au moins de sa consommation dès le début de son exploitation, ceci pour ce qui concerne les installations alimentées au moyen d'énergie électrique. Cet engagement est subordonné à la capacité de son fournisseur d'électricité d'honorer cette prestation. Entreprise s'engage à recourir à une alimentation énergétique d'origine renouvelable pour les 30% restants lorsque le centre de Meyrin sera en exploitation complète, au plus tard le 1er juin 2003, pour autant que entreprisepuisse rester économiquement compétitive par rapport à ses concurrents.

1.3. entreprise prend des mesures propres à inciter ses clients à optimaliser leur consommation énergétique, notamment :

- fixation d'une limite maximale de la demande de puissance par m^2 en fonction de la nature des installations.
- répercussion totale sur ses clients des frais relatifs à la consommation énergétique, de sorte à encourager ces derniers à utiliser un équipement qui optimisera la consommation d'énergie et la puissance.

1.4. entreprise effectuera sur son site des mesures de consommation d'énergie et de puissance conformément aux indications figurant en **annexe 3** du présent document. Ces mesures sont destinées à établir un "indice de performance énergétique".

1.5. entreprise fournit à l'État de Genève un relevé annuel des mesures effectuées, assorti de la description des dispositions prises et envisagées pour améliorer l'indice de performance.

1.6. entreprise autorisera l'État de Genève à effectuer, à ses propres coûts, des mesures de contrôle si ce dernier le juge nécessaire. Les personnes habilitées à effectuer ces mesures devront être agréées par entreprise , elles seront assermentées par le Conseil d'État et soumises au devoir de réserve et de discrétion régissant les fonctionnaires de l'État.

1.7. entreprise s'engage à collaborer avec l'État de Genève à la recherche de solutions permettant d'améliorer l'indice de performance énergétique. Elle appliquera les mesures suggérées dans la mesure où elles sont économiquement performantes.

1.8. entreprise s'efforcera de faire reprendre le présent accord par toute personne physique ou morale à qui l'exploitation du centre serait cédée ou transférée.

2. Droits et obligations de l'État de Genève

2.1. L'État de Genève s'engage à mettre à disposition de entreprise des compétences pour conseiller la société dans ses démarches visant à réaliser les étapes non encore autorisées de son installation, et ce moyennant couverture de ses frais.

2.2. L'État de Genève traitera toutes les sociétés sur le point de s'installer dans le canton de Genève, actives sur le même marché ou exerçant la même activité, de manière égale quant à ses exigences et aux tarifs qu'il pourrait être appelé à pratiquer. Dans ce sens, il s'engage à faire signer à ces sociétés, en particulier aux concurrents de entreprise , un document prévoyant les mêmes obligations que celles prises par entreprise dans le présent accord. L'État de Genève s'efforcera de faire également accepter ces obligations aux concurrents de entreprise déjà installés dans le canton de Genève. L'État de Genève fera en sorte que entreprise puisse vérifier l'effectivité de cette égalité de traitement.

2.3. L'État de Genève s'engage à traiter de manière confidentielle toute information dont la diffusion serait susceptible de porter un préjudice commercial ou d'image à la sociétéentreprise, exception faite du cas où il serait jugé, dans le cadre d'une procédure telle celle visée à l'article 7 du présent document, que entreprise n'honorerait pas des engagements pris, ou si l'État de Genève était publiquement pris à partie par entreprise. Dans le cadre d'une procédure judiciaire, l'État de Genève pourra faire valoir devant le juge toutes les informations en sa possession.

2.4. L'État de Genève peut relever entreprise de tout ou partie de ses obligations relevant du présent accord s'il adopte des dispositions légales ou réglementaires qu'il juge aptes à remplacer les présentes dispositions contractuelles.

2.5. L'État de Genève veille scrupuleusement à la bonne exécution du présent accord par entreprise . Il permettra à un représentant des Associations de vérifier le respect des obligations prises par entreprise dans le cadre du présent accord, pour autant que ledit représentant signe l' engagement de confidentialité annexé au présent accord (cf **annexe 4**). Une copie de chaque engagement de confidentialité sera systématiquement communiquée à entreprise.

3. Obligations des Associations

3.1. Les Associations retirent sans délai le recours déposé le x y 2000 à la Commission de recours. A cet effet, elles remettent à la signature des présentes une lettre de retrait dûment signée par leur conseil (cf. **annexe 5**).

3.2. Les Associations s'engagent à ne pas intervenir dans le cadre des demandes d'autorisations concernant les étapes futures d'installation du site de abc (cf périmètre du site décrit dans l'**annexe 6**), dans la mesure où entreprise satisfait aux obligations contenues dans le présent accord .

3.3. Les Associations désigneront un représentant afin de vérifier le respect des obligations prises par entreprise dans le cadre du présent accord conformément aux modalités prévues à l'art. 2.5 ci-dessus.

4. Durée de l'accord

Le présent accord prendra fin au plus tard le 31 décembre 2003. L'application de l'art. 2.4 du présent accord demeure réservée.

5. Résiliation

Toute violation du présent accord doit être dénoncée par une partie à l'autre au moyen d'une communication écrite. La partie qui se prévaut de la violation aura le droit de résilier avec effet immédiat le présent accord si, dans un délai de trente jours, l'autre partie n'a pas mis un terme à la violation dénoncée.

6. Confidentialité

6.1. Les annexes produites à l'appui du présent accord sont confidentielles à l'exception de **l'annexe 3**.

6.2. Toutes les parties et leurs membres restent tenus par les engagements de confidentialité pris dans le cadre de la procédure de concertation (**annexe 7**).

7. Droit applicable et for

7.1. Tous litiges relatifs à l'interprétation et l'exécution du présent accord sont soumis au droit suisse.

7.2. Les litiges sus évoqués seront tranchés exclusivement et définitivement par un ou plusieurs arbitres suivant le règlement d'arbitrage de la Chambre de Commerce et d'Industrie de Genève.

Annexes

1. Questions des associations et réponses de entreprise
2. Evaluation initiale de l'appel de puissance
3. Support au calcul d'indice de performance énergétique
4. Engagement de confidentialité
5. Lettre de retrait du recours
6. Plan du site entreprise
7. convention de concertation et accords de confidentialité y relatifs

Fait à Genève le x y 2001 en 7 exemplaires

Pour entreprise : Pour l'État de Genève :

_________________________ _________________________

Pour les Associations :

____

COMMUNIQUE DE PRESSE

Un accord de progrès pour la maîtrise de la consommation d'énergie.

Digiplex et LDCOM sont des sociétés internationales actives dans le domaine des télécommunications et de la fourniture de services informatiques.

Installant chacune un centre dans le canton de Genève, ces sociétés ont presenté des demandes de puissance énergétique particulièrement importantes, plusieurs fois supérieures a celle des plus grands consommateurs actuellement installés dans le canton.

Ces demandes, par leur ampleur, ont suscité la très vive inquiétude des associations de protection de l'environnement, les incitant à recourir contre une autorisation de construire délivrée par l'Etat de Genève a Digiplex.

Suite à ce recours, considérant le caractère exceptionnel de la situation et l'intérêt pour Genève de s'inscrire dans un développement économique lié à l'information et aux télécommunications, un processus d'échange d'informations et de concertation a été engagé entre les deux sociétés et les associations, sous l'égide de l'Etat de Genève et avec la participation des SIG.

L'accord signé permet:

- de réduire de manière significative (environ 30%) l'appel de puissance total de chacun des centres,
- d'assurer un suivi dans le temps de la performance des installations en matière de consommation énergétique,
- d'ouvrir la voie d'un développement important de l'économie genevoise dans le domaine en pleine expansion des télécommunications et des services informatiques, en assurant une consommation rationnelle de l'énergie,
- d'assurer un très large recours à l'énergie renouvelable.

Au cours de la concertation, les deux sociétés ont démontré leur capacité et leur volonté de contribuer très concrètement à la protection de l'environnement dans ce canton en donnant à ce paramètre un poids important dans la conception technique de leurs installations et en collaborant tres directement à un suivi de leur consommation énergétique, ce qui constitue une approche novatrice en la matière.

Les associations de protection de l'environnement ont démontré quant à elles leur capacité à mettre en oeuvre les principes de développement durable en incluant dans leur action citoyenne, non seulement des moyens d'opposition, mais surtout la recherche de solutions concrètes concertées, assurant un bon équilibre entre les exigences du développement économique et celles de la protection de l'environnement.

L 'Etat de Genève retire de ce processus des voies nouvelles à envisager pour les rapports d'autorité qu'il exerce dans le domaine de la maîtrise de l'énergie, qui devraient améliorer la rapidité dans le traitement des dossiers, tout en garantissant une meilleure maîtrise de la consommation énergétique, tant en quantité qu'en qualité.

DIAE -Claude Convers / 6 mars 2001

Appendix 2: Data Centres in Geneva

Name
Digiplex Genève Sàrl
LDCOM Louis Dreyfuss Communications SA
SAFE -HOST S.A.
GC Pan European Crossing Switzerland GmbH Global Crossing
COLT Telecom SA
PSINet Geneva
T-Systems Multilink SA
Telehouse (Suisse) SA

Appendix 3: Questionnaire sent to operators/planners of data centres

Information and data of the central infrastructure (coefficient C1 of CEE)

Preamble

The following questions form the basis to get additional knowledge about the energy efficiency in data centres. We kindly ask you to fill in the attached spreadsheet. The following text explains the entries listed in the spreadsheet.

Besides actual operation data, planning data and information should be provided for various alternatives. The alternatives should differ in (change only one parameter per alternative):

- modularity of chillers, (two concepts of modularity)
- share of free cooling (low and highest possible share),
- air temperature level in computer rooms (22°C and 26°C, measured two meters from floor level),
- water temperature level in cold water circuit (6/12°C and 12/18°C).

Data (measurements) and/or simulation results (planning data):

i. Monthly and yearly electricity consumption (or losses respectively) of
   a. main power supply before (measuring point 1.1, see Figure 1) and after **(2.1)** transformation (medium voltage/ low voltage)
   b. cooling (includes production and supply of cold to the heat exchangers in (or close to) the computer rooms and electricity consumption of pumps in the cold water circuits) **(4.1)**
   c. ventilation (mechanical energy to move cold air from the heat exchangers of the cold water circuits to the computer equipment) **(5.1)**
   d. UPS (losses rather than "consumption"; expressed as the difference between electricity into and electricity out from UPS) (**7.1** and **8.1**, respectively)
   e. miscellaneous (lighting, office equipment, plugs) **(6.1)**

ii. Monthly and yearly diesel/natural gas consumption of emergency power generators

iii. Monthly and yearly electricity production by emergency power generators **(3.1/3.2)**

iv. Monthly and yearly amount of energy extracted (cold produced) with
   a. chillers
   b. free cooling
   c. cold uncoupling (from cold sinks, e.g. cold extracted from another cooling circuit on a lower temperature level)

v. Monthly and yearly amount of waste heat recovered (e.g., heat delivered to a district heating network).

vi. Monthly and yearly amount of water required for wet recooling towers (if any)

vii. Total installed capacity for
   a. UPS
   b. emergency power generators
   c. ventilation

d. main power supply
e. chillers
f. free cooling
g. lighting

viii. Average ambient relative moisture **(10.1)** and ambient temperature **(9.1)** (averages on a monthly basis).

ix. Average temperature level of cold water circuit (e.g., 6/12°C) (averages on a monthly basis).

x. Average temperature in the computer rooms, 2m from floor level and at the ceiling (averages on a monthly basis).

xi. Total amount of computer room floor area (footprint of a central computer room including aisles but excluding exterior mechanical rooms and office space).

xii. Total heat load of equipment operated in the computer room floor area.

Additional remarks:

Data for 1.b. (electricity consumption for chillers and pumps) should also be provided when purchasing cold from a third party. Data from this external producer should then be purchased and filled in the questionnaire.

Data for 4. (total cold produced) should specify the share required for cooling for computer room floor area and other activities, respectively, in case these activities are substantial and exceed the ones required to run the site.

Additional Information (technical specification):

In order to be able to interprete your data correctly, we kindly ask you to provide us with additional information about the technical specification of the infrastructure of your data centre. These information comprise the following topics:

i. General layout of infrastructure (concept, sketches)

ii. Modularity (how many units installed) of
a. UPS
b. emergency power generators
c. main power supply
d. chillers
e. recooling towers

iii. Technical specification of
a. UPS (technology, capacity, losses, operation mode (online/offline))
b. emergency power generators (electric capacity, kind of fuel, net efficiency, filters (if any), emission factors for airborne pollutants)
c. chillers (cooling capacity, COPs, kind and amount of refrigerant needed)
d. recooling towers (air, water, combined)

iv. Control and operation concept for cooling

v. Kind of electricity purchased from utility (green labelled electricity, hydroelectric power, utility's mix, other, please specify)

vi. Clients and uses of waste heat recovered (if any).

Measurement concept

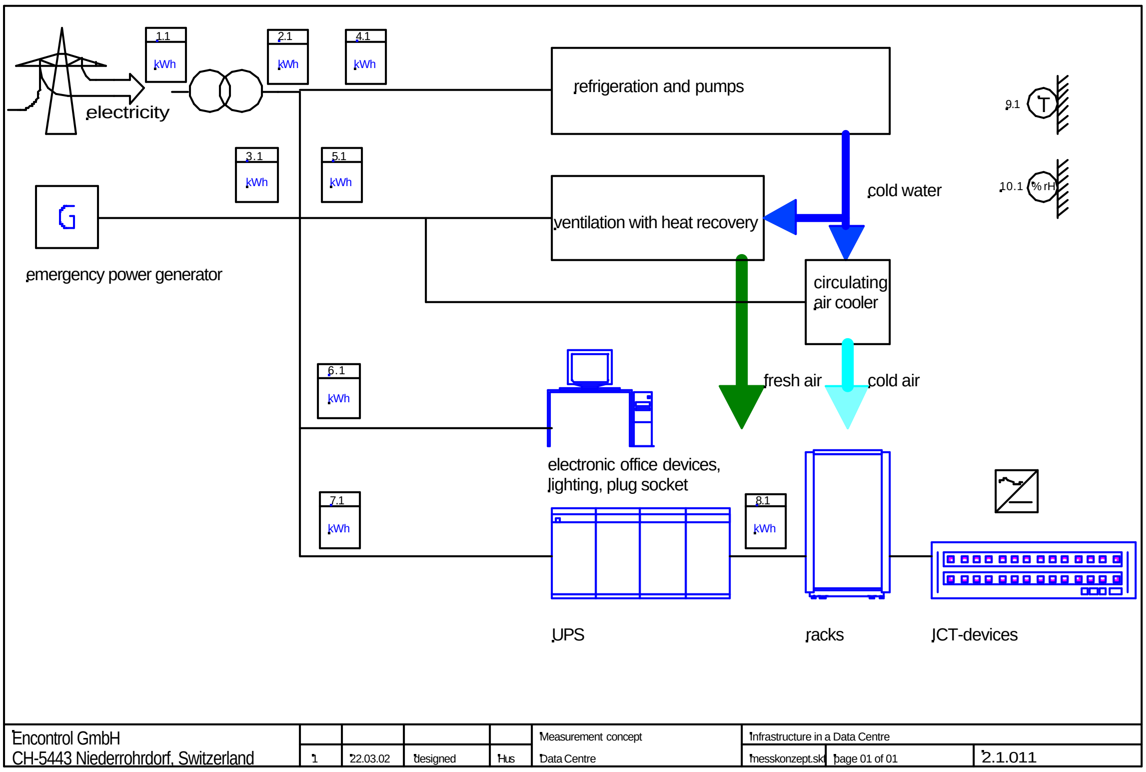

Figure 1: Measurement concept for data centres, developed by A. Huser, encontrol.

Table 1: Specifications regarding accuracy of measurements

Medium	Specifications and regulations in Switzerland	input measurement	sub measurement
Electrical power and energy	regulation 4.8.1986 recommodations 1.3.1993	<= class 0.5	class 1
heat and cold	recommodations 1.3.1991	class 4	class 5

Appendix 4: Liste des personnes interrogées (section 6.2)

M. Emile Spierer : membre de la Commission cantonale de la Climatisation

M. François Brutsch : Secrétaire adjoint du DIAE

M. Rémy Beck: Adjoint au directeur du ScanE

M. Olivier Epelly : Responsable des concepts énergétiques au sein du ScanE

M. Olivier Ouzilou : Directeur du ScanE

M. Christian Gottschall: Direction commerciale des SIG

Appendix 5: Gesetzestexte und Reglemente im Kanton Zürich (Energiemodell Zürich)

Energiegesetz

Paragraph 13 a. FN 10

http://www.kanton.zh.ch/appl/zhlex.nsf/4ae6e4ab7adb6f58c125602f004d07a8/277902f622b59cffc1256036003cdb9c?OpenDocument&Highlight=0,Energiegesetz

Verordnung über die ordentlichen technischen und übrigen Anforderungen an bauten, Anlagen, Ausstattungen und Ausrüstungen (Besondere Bauverordnung I)

Paragraph 48 a. FN37 und 48 b. FN37

http://www.kanton.zh.ch/appl/zhlex.nsf/4ae6e4ab7adb6f58c125602f004d07a8/37962c2e479b6189c1256036003aed1e?OpenDocument&Highlight=0,technische,Anlagen,Bauten

Appendix 6: New legal framework in Geneva

Available on the intranet of the cantonal administration. Contact M. Rémy Beck, Adjoint au directeur, ScanE, cp 3918, CH-1211 Genève 3; ph.: +41-22-3272317, e-mail: remy.beck@etat.ge.ch .

Appendix 7: Energy-efficiency of power supplies.

Abstract (Aebischer and Huser, 2003)

The efficiency of computer power supplies operated at least at 20% of their nominal power lies between 60% and 80%. At lower operating points the efficiency is decreasing rapidly. For PCs in actual use ("On-mode – but low processor activity") we measured operating points of the power supplies between 14% and 25% and a mean efficiency of the power supply units of 66%.

The voltage level of modern processors is as low as 1.5 V and will even decrease in the near future. The DC-output levels of a power supply unit lie usually between 12 V and 3.3 V and a secondary (or even third) power-transformation is needed at the electronic component itself in order to reach the 1.5 V level. The resulting overall efficiency of the power supply systems is therefore of the order of 50%.

The most important technical measures to increase the energy efficiency of the power supply system for ICT equipment are:

- using power supply units with an adequate nominal power in order to reach operating points of 50% or more;
- setting-up a separate power supply system from 230 V AC to 1.5 V DC for low power modes of the ICT equipments.

The technical saving potential of these two measures is for PCs of the order of 30% of today's electricity consumption.

At the policy level we recommend to pursue two strategies:

- introduction of an energy declaration for power supplies;
- reinforcement of the requirements of maximal power loads for ICT-equipments in low-power modes and elaboration of similar requirements for the power loads in the on-mode.