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Energy saving at data hotels

Doing more with less

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Acknowledgement/Preface

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Abstract

During the past decade in the Netherlands, the increasing traffic of digital data has resulted in the Information and Communication (ICT) industry becoming one of the most energy-intensive sectors. This report presents ways of reducing energy consumption in the ICT industry. A method for judging the energy efficiency of an ICT company (data hotel) is presented, as is an overview of the impact of various technical concepts and energy-saving measures on energy efficiency. The technical concepts and energy saving measures are explained and, where possible, payback periods indicated. The idea is that local government, in partnership with the ICT industry, can use the findings of this report to reduce energy consumption. There is a lot of technology available to reduce the energy demand of the ICT industry. An important condition for improving energy efficiency is preventing cooled air from being mixed with heated air in computer rooms to allow a higher cooled air temperature, thus avoiding unnecessary running time for compression cooling. A suitable indicator that can be used to judge the energy efficiency of an ICT company (data hotel) is "Energy Usage Effectiveness" (EUE). This is the quotient of the total annual energy consumption and the annual energy consumption of the ICT equipment (core business). Early adapters in the ICT industry have already demonstrated that an EUE of 1.1 is feasible. For existing ICT companies (data hotels) a maximum EUE of 1.4 is achievable with available technologies. New ICT companies (data hotels) can use modern technologies, making a maximum EUE of 1.3 feasible.

Foreword

Around the millennium, realization dawned that the ICT industry had become a major energy user – a realization that was only fuelled by forecasts of colossal growth. This was a wake-up call to the Municipality of Amsterdam, which in 2001 commissioned research from ECN into the situation in the industry and the technical feasibility of energy saving. Those growth forecasts are now a reality; hence energy efficiency in the ICT industry is even more important. The industry has not been idle, however: new technologies have been developed that enable the situation to be changed. It was high time, then, to carry out fresh research. The present report gives readers an up-to-date picture of the technologies available and their energy and economic potential.

Managers of data centres are increasingly concerned about the rising operational cost of the energy they use and the high energy prices. The debate on climate change has also focused attention on the ICT industry, with climate targets being set at national, international and municipal level. Amsterdam has set itself the target of CO_2 emissions that are 40% lower than the 1990 level by 2025. This enormous task can only be achieved if all concerned are willing to take far-reaching measures. The ICT industry is one of the sectors where it is necessary – and feasible – to assist in this task. The Municipality of Amsterdam has therefore set energy efficiency in the ICT industry as one of its priorities.

It is not only the Municipality of Amsterdam that realizes there is room for improvement in the ICT industry: at European level, for instance, a Code of Conduct is being developed to encourage the industry to take action, and at national level the Ministry of Economic Affairs in The Hague is looking at entering into Multi-Annual Agreements on Energy Efficiency with the sector. While these projects are voluntary, they show that the industry cannot escape the obligation to raise the level of its aspirations. The Municipality is trying to contribute to this with a two-pronged policy: partnership and enforcement!

In *partnership* with the ICT industry, the Municipality's Climate Agency is taking the initiative to examine what measures the industry can adopt to reduce its energy consumption. With its Green IT Project the Agency aims to build on the good examples it has encountered: there are 'early adapters' in the private sector that are already doing a lot more than the law requires on their own initiative. A major element in the Green IT Project, therefore, is exchange of knowledge and experience among early adapters, the rest of the industry and experts.

The other prong of policy, of course, is *enforcing* energy performance standards under the Environmental Management Act. This involves forcing companies to implement energy measures that will pay back within five years, so as to create a level playing field, a foundation for the private sector. The present report provides information on the basis of which ICT companies can raise the level of their aspirations. It will also serve as input to the debate on the minimum standards that can be imposed on ICT companies under the Act.

Fortunately there are many enthusiastic ICT companies showing in their day-to-day practice that substantial energy savings can be made without pricing themselves out of the market. These companies have seized the opportunity to reduce their energy costs dramatically while at the same time fulfilling their social responsibility. Let us foster this win-win situation and take it as an inspirational example for the industry to follow.

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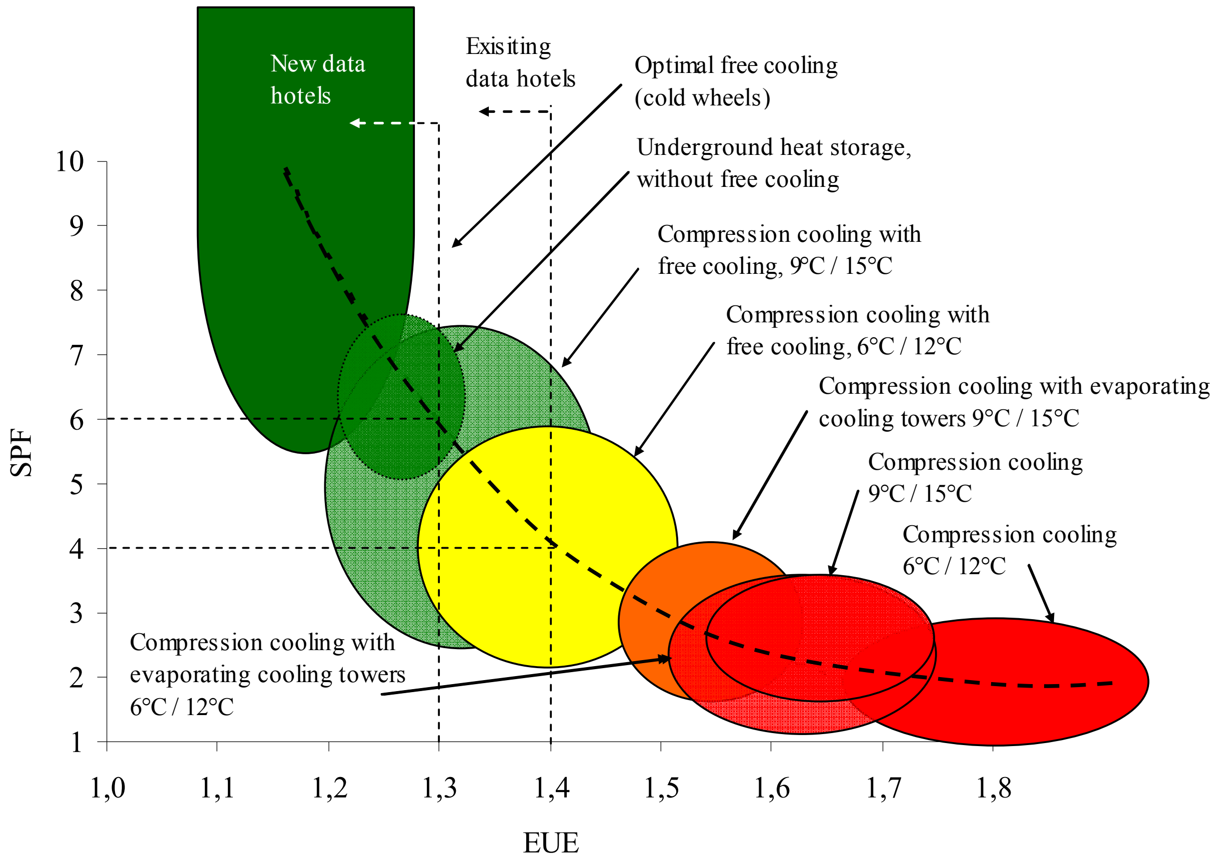
As a result of the growth in digital data traffic, the Information and Communications Technology (ICT) industry has become one of the most energy-intensive sectors during the past decade. This report gives an overview of current ways of using energy efficiently in the industry. Local authorities and the ICT industry can use it to reduce the sector's energy consumption in partnership, instead of achieving this by tough enforcement.

The efficiency of the cooling determines, to a large extend,
the efficincy of a data hotel



Indication of the Seasonal Performance Factor (SPF) and Energy Usage Effectiveness (EUE) that can be achieved using various concepts. Energy-efficient technology is shown in green, energy-wasting technology in red. A maximum EUE of 1.4 is achievable using available technology in existing data hotels. In new data hotels with newer technology a maximum EUE of 1.3 is feasible.

To judge whether something is energy-efficient or not we need a frame of reference. We therefore looked at the available data to see what indicators currently exist that are relevant to ICT. A parameter that provides a good yardstick of the energy consumption of a cooling system is the SPF (Seasonal Performance Factor). EUE (Energy Usage Effectiveness) can be used to judge the energy efficiency of a data hotel: this is the ratio of the data hotel's total annual energy consumption to the annual energy consumption of the ICT equipment.

A high SPF generally results in a low EUE. This relationship is used to indicate what standards can be laid down for SPF and EUE, given the current state of the art. It follows that a minimum SPF of 4 and a maximum EUE of 1.4 are achievable using standard technology in existing data hotels. In new data hotels newer technologies can be used, making a minimum SPF of 5 and a maximum EUE of 1.3 feasible.

To sum up, there is a lot of technology available to improve energy efficiency in the ICT industry. The most important factor when making improvements is preventing cooled and heated air from mixing in computer rooms, so that the air supply can be increased, thus avoiding unnecessary use of compression cooling equipment. Nationwide the potential reduction at data hotels alone is approx. 0.32 TWh a year – comparable to the annual electricity consumption of some 100,000 households. Taking server rooms and ICT equipment in offices into account as well, the potential could be doubled. Early adapters in the industry have demonstrated that an EUE of 1.1 is feasible for a data hotel, but there are still cases where an EUE of 1.8 is not being achieved. This wastage is not necessary nowadays given the technology available, the investment required and the financial savings at current energy prices, which can only be more in the future.

1. Introduction

As a result of the growth in digital data traffic, the Information and Communications Technology (ICT) industry has become one of the most energy-intensive sectors during the past decade. It is estimated that just under 7.5% of total electricity consumption in the Netherlands is accounted for by ICT at present, owing to such things as the increase in Internet use and telecommunication, the number of mobile devices and all sorts of services that can only exist thanks to digital networks. ICT has become indispensable to our society and is still developing rapidly, causing changes in our lives.

1.1 Purpose of this report

The ICT industry, then, uses a lot of energy – energy that is needed to operate computers, servers, routers, printers, iPods, MP3 players, transmission masts, mobile telephones etc. The annual electricity consumption of all ICT in the Netherlands could supply the energy needs of a city like Amsterdam for 2½ years at present. And all that energy is converted into heat in the computer hardware. The cooling systems that extract the heat from the computer hardware also use energy. There are cases where the cooling system consumes half the total energy consumption of a data hotel. There are lots of ways of reducing the cooling energy required dramatically, however, and getting data hotels to use energy more efficiently. The fact that these methods can be used effectively in the ICT industry has been demonstrated by some early adapters in the industry.

The Municipality of Amsterdam's Environmental and Building Department, in partnership with SenterNovem, commissioned the Energy research Centre of the Netherlands (ECN) at the beginning of 2001 to examine the current state of the art as regards energy consumption in the ICT industry. A report[1] indicated what methods and technologies for reducing energy consumption were available at that time. In recent years various fresh initiatives have been taken to improve energy efficiency, some of them by the ICT industry itself.

The ICT that is the subject of this report relates mainly to data hotels and offices. Precisely what data hotels are is explained in Chapter 2. ICT in offices relates mainly to server rooms.

This report gives an overview of current ways of using energy efficiently in the ICT industry. At a time like the present, when the ICT industry is flourishing again and the environment and energy consumption are in the media all the time, it is important to draw the industry's attention to ways of reducing energy consumption. This benefits not only the environment but also the industry itself, as energy costs money and it is only getting more expensive. Energy saving in the industry is worthwhile from the economic as well as the environmental point of view. This report therefore makes a start on developing criteria for comparing the energy efficiency of data hotels. An indicator of this could possibly be used in future by the authorities (municipal or provincial) to judge them.

1.2 Target group

The report can be used by environmental inspectors to assist them in their enforcement work: a checklist is appended for this purpose (which is explained in the body of the report). The ICT industry itself can also use the report to apply the methods described. In addition, it may inspire engineers to develop new and improved concepts that could reduce the industry's energy consumption still further.

1.3 Method

The Municipality of Amsterdam (Environmental and Building Department) and ECN have been working together closely for over ten years. ICT and energy consumption have been a major topic in their work together right from the start: ECN has assessed many different energy reports on ICT companies for the Department, and it has carried out projects for SenterNovem and KPN, among others, including experiments and measurements at system level in ICT companies to see how the amount of energy used for cooling could be reduced. The report is based partly on data from these projects, along with data from energy reports and contacts with early adapters in the ICT industry, including KPN, TeleCity Redbus, UpTime Technology, Pink Roccade-Getronics and Hamer Installatietechniek. Publications and research reports by other researchers outside ECN have also been used.

To produce this report we started by surveying the energy consumption of data hotels based on existing energy reports on ICT companies and projects that ECN has carried out for such companies. We then looked at the methods currently available for assessing and reducing the energy consumption of data hotels, by:

- Visiting data hotels where energy-saving technologies (in some cases new ones) have been used
- Contacting companies that supply and install systems for data hotels
- Surveying the information available on energy-saving technologies
- Carrying out measurements at ICT companies to ascertain the effect of energy-saving measures

Lastly, we drew up a table of the effects of energy-saving measures, giving an indication of payback periods where possible.

2. The ICT industry: the current situation

The fact that the ICT industry uses a lot of energy is no longer news. For a long time the industry was not interested in energy consumption, its main concerns being speed and high availability. In conjunction with the absence of performance standards for data hotels and computer rooms this resulted in a situation where the industry was using unnecessarily large amounts of electricity. To give an impression of what data hotels and computer rooms look like and what components are used in the industry, the ensuing sections describe data hotels and computer rooms (server rooms) in offices and how their energy consumption breaks down.

2.1 Data hotels

The infrastructure that makes mobile telephony and Internet services possible is still growing in size and energy demand. The illustration below from Google Earth shows a data hotel whose electricity consumption causes an annual CO_2 emission of approx. 37 million kilogrammes. At 10 eurocents per kWh the cost of the electricity is over 6 million euros a year. The CO_2 emission caused by just this one building is equivalent to no less than 7% of the total emission from electricity consumption of the city of Groningen. The data hotel in this example was built around 2000.

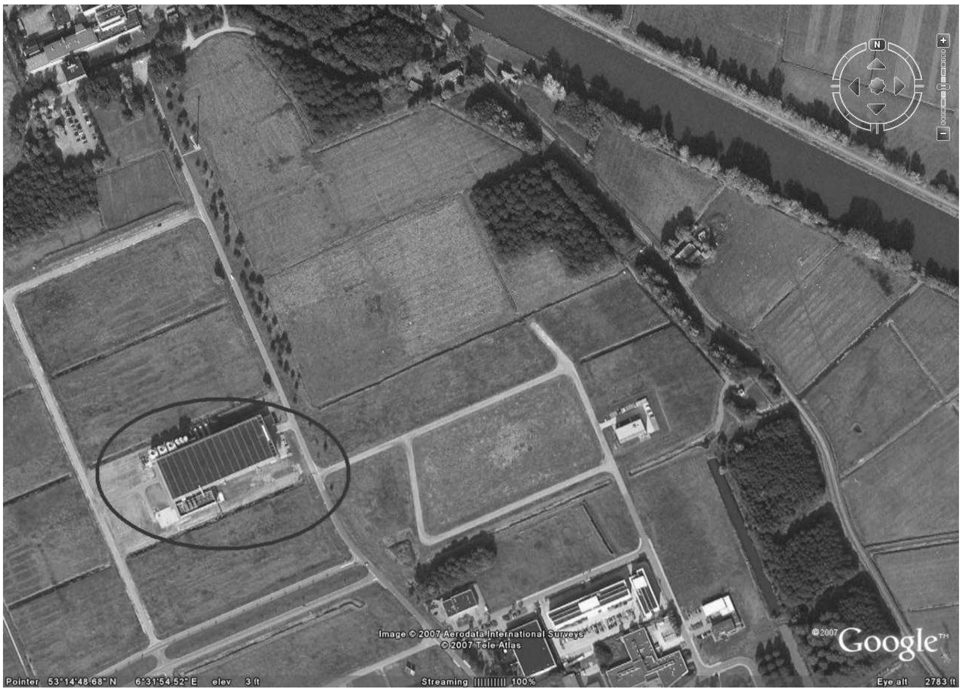


Figure 2.1 *Data hotel in Groningen, built around 2000 (circled). Photo: Google Earth*

In those days 'haste' was the main driving force behind the ICT industry, with the result that not much attention was paid to energy efficiency. What was important was that computer rooms were kept cool, as there was a major fear of equipment becoming overheated. The cooler it was in the computer rooms, the 'safer' it seemed to be. As a result of this fear, computer rooms were often kept unnecessarily cool (as low as 16 °C in some cases) and the cooling equipment wasted a lot of electricity. On top of this, facilities such as cooling and power supplies were wildly oversized, simply to ensure that there was enough cooling and power: these systems were therefore operated under part load, resulting in poor energy efficiency.

2.1.1 Components

Generally speaking, the main components used in data hotels are:
- Cables, both fibre optic and copper
- Devices that convert the optical signal into an electrical signal (multiplexers)
- Devices that send the signals to the right addresses (routers)
- Processors that process commands (CPUs)
- Storage media, e.g. hard drives
- Electronics that enable the devices to communicate with one another

Figure 2.2 *Computer equipment stacked in racks in large spaces where heated and cooled air can mix. Photos: ECN*

The support facilities at data hotels consist of:
- The building
- Fire-fighting facilities
- Security, maintenance and servicing
- Emergency power and uninterruptible power supplies (UPS) which ensure that equipment can be supplied with power of the right quality (even if the power grid fails)
- Climate control (cooling and in some cases humidification)

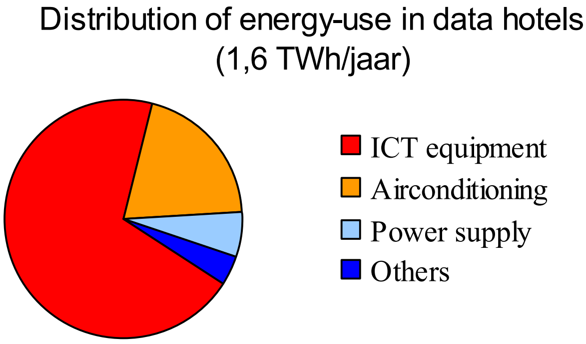
The energy consumption of a data hotel is determined by the following components:
- Computer equipment
- Climate control
- UPS
- Offices, lighting and other spaces

This breakdown is based on the various functions of a data hotel and is shown in the order of the proportion of total energy consumption.

2.1.2 Energy consumption

It is estimated that just under 7.5%[2] of Dutch electricity consumption is accounted for by ICT. ICT in offices and data hotels is responsible for an annual consumption of 2.8 TWh – comparable to the annual consumption of 875,000 households. This report looks only at the electricity consumption of data hotels and office buildings, as these categories fall under the immediate sphere of influence of the Municipality of Amsterdam's Environmental and Building Department.

By way of example, Graph 1 shows the proportion of total energy consumption at an existing data hotel accounted for by each of the components listed above. The values are averages, based on energy reports on a number of companies which applied for environmental permits between 2000 and 2007.



Graph 1 Distribution *of current average energy consumption at existing data hotels*

It should be noted that there are big differences between companies, especially in the amount of energy used for climate control, according to the data available to ECN ranging from 10% to 50% of total energy consumption! Big differences (between 2% and 12% of total energy consumption) have also been found in the amount of electricity used by the UPS. There are cases where the size of the emergency power supply is geared to the full connection capacity of an ICT company, whereas the actual power consumed is lower by a factor of 10, as the computer rooms available are not yet fully utilized. The losses in the emergency power supply equipment (generally in the order of a few percent) then relate to the full connection capacity, not the actual power consumed.

As the chart shows, ICT equipment in existing data hotels accounts for 70% of energy consumption on average. The remaining 30% is used for ancillary functions. On average about 22% of energy consumption is used for climate control and about 6% for the UPS. The energy used by these functions depends directly on the energy consumption of the ICT equipment, as this is what determines the amount of heat that needs to be extracted and the amount of emergency power that needs to be kept in reserve. In practice major savings can be made on the amount of energy used for cooling (climate control) and emergency power.

2.1.3 Development

There were numerous reports in the Dutch media in 2007 that ICT companies spend more on energy than on staff. Also, because of the growth of the industry, ICT companies are increasingly coming close to the maximum power available (connection capacity). Also, ICT equipment is becoming more compact, thus increasing the energy density (W/m²). Existing data centres have an energy density in their computer rooms of 400-1500 W/m². This is growing and is expected to reach some 5000 W/m² within a few years. The increase over the past few years has resulted in situations where the cooling capacity available determined the amount of computer equipment in a computer room. As a lot of companies saw this coming a few years ago, slowly but surely they have been paying more attention to energy saving. Using energy more efficiently in the ICT industry is important not only from the point of view of energy saving, then, it is also necessary in order to take full advantage of the space available in a computer room with today's ICT equipment, as this is what power is needed for above all. Every kWh of power needed for other components (e.g. cooling) means less energy available for the core business. We are also seeing existing data hotels that wish to expand but do not have the cooling capacity to do so modifying their systems to make cooling more efficient, thus making power available for use by additional ICT equipment in computer rooms.

One way of using ICT equipment itself more efficiently is by 'virtualizing' processes. This is a term that is commonly used in ICT but difficult to explain. In essence, virtualizing enables processors and data storage to be used more efficiently. An example of virtualization is running more than one operating system on one PC: this enables two people to use the PC's capacity at the same time, so the second person can switch his PC off. A brief explanation of virtualization can be found on the Internet.[9]

New data hotel projects are above all growing in size. Whereas seven years ago connection capacities in the order of a few megawatts were envisaged, nowadays there are companies budgeting for dozens of megawatts as actual power consumed! This is due among other things to the increased use of 'blade servers': this new generation of ICT equipment has caused an increase in the power density of computer rooms from hundreds of watts per square metre a few years ago to several kilowatts per square metre now. The increased power consumption is due to the fact that the ICT industry has been able to incorporate more processes and functions on a PCB. The increasing load also places increasing demands on cooling concepts to enable computer rooms to be filled with hardware in spite of the problem.

Fortunately, for most of the new data hotels being set up nowadays, using energy efficiently is an important criterion. Smart modular concepts make more efficient use of the power available and avoid unnecessary loading of the power grid. This also yields benefits as regards the financial investment needed in facilities such as emergency power supply and cooling that go hand in hand with modular growth: the investments also grow in a modular fashion.

The question of temperature in computer rooms is also approached differently nowadays. Whereas at the beginning of 2000 the requirement was above all for data hotels to be kept cool, the important thing now is a stable temperature over time, and modern computer rooms are rarely cooled below 25 °C.

2.2 Offices

Nowadays almost all offices have a small server room in the building, often not much more than a large broom cupboard containing a few racks of computer equipment. As the power consumed in these relatively small rooms is almost all converted into heat, cooling is generally used to prevent the equipment overheating. This can be provided by various types of device: 'split units' are generally used, but also 'computer air conditioners'.

Cooling is provided by recirculating air through an air treatment unit, which cools the air in a heat exchanger. In many cases lack of space dictates a small unit, where the hot air drawn in is only exposed to a relatively small heat exchange area. In order to provide sufficient cooling a small heat exchange area needs to be colder than a larger one, but the lower the temperature of the area the more power is needed for cooling. Also, at such low temperatures the air is dehumidified, using an unnecessarily large amount of energy: this can account for as much as 30% of the energy used for cooling. If the computer room is completely internal to the building (i.e. it has no external walls) it is often poorly ventilated; rooms on the perimeter of a building are often fitted with ventilation, but the apertures are often blocked to guard against break-ins.

Figure 2.3 *Server room in an office building. At the back on the left is an air treatment unit to provide cooling. On the right are the racks of computer equipment. Photo: ECN*

PCs and monitors account for the vast majority of power consumed at office workstations. As already indicated, the power consumed by these devices contributes to the heating of offices. In winter this reduces the demand for space heating, but in spring, summer and autumn it increases the risk of overheating, requiring additional cooling to keep the indoor climate comfortable.

In large offices the cooling required is generally provided centrally, as part of the air conditioning system. In smaller offices small air conditioners known as 'split units' are often installed. These small systems are particularly likely to use a lot more power for cooling, as they are generally of lesser quality, in energy terms, than larger central systems.

3. Indicators

To judge whether something is energy-efficient or not we need a frame of reference. We therefore looked at the data available at ECN to see what indicators currently exist that are relevant to ICT, looking at cooling in data hotels and data hotels as a whole. We also looked at the values that can be achieved for the various indicators given the current state of the art. This is discussed in a subsequent chapter when looking at the technologies individually.

3.1 Existing labels and energy-saving initiatives

For ICT equipment designed for personal and office use (printers, monitors, photocopiers, scanners, PCs, etc.) there is already a label that has been in existence for a few years that indicates how much energy they consume. Equipment with this 'Energy Star' label complies with certain energy efficiency standards. The label has been developed by the US Environmental Protection Agency and the US Department of Energy. The standards it lays down are constantly being raised. The expectation is that equipment installed in data hotels will soon also be able to be awarded an Energy Star label. The Dutch government is encouraging municipal agencies to invest only in equipment with an Energy Star label. In addition, a Code of Conduct for Data Centres[11] is currently in preparation: this is an EU initiative, which is expected to be finalized in spring 2008. The Code is being developed in response to rising energy consumption in the ICT industry and the need to reduce the impact on the environment, the economy and energy supply security. The purpose of the Code is to reduce energy consumption in a cost-effective manner without hampering the running of data hotels, by coordinating the activities of manufacturers, sellers, consultants, users and data hotel owners. The Code tries to achieve this by improving knowledge on the energy demands of data centres, raising awareness and recommending best energy practice. It is a voluntary scheme designed to bring interested parties together. The NNI (the Dutch standards institution) has also begun work on a 'practice guideline' for computer rooms. The plan is for the initial draft text to be complete at the end of 2008. The guideline will set out what form systems can take in practice. Practice guidelines do not generally have statutory status, they merely serve as a guide to design and implementation.

A term commonly used in the ICT industry, sometimes used in connection with efficiency and labelling, is 'Tier'. This is a classification and has nothing to do with energy consumption. The Tier classification indicates the availability of a data hotel's services, in other words what percentage of the time it is on line. Tier I means lower availability (off-line approx. 1.2 days a year) than Tier IV (off-line approx. 4.5 hours a year). There are hardly any Tier IV data hotels. The Tier chosen has consequences for the systems, of course. Most data hotels fall into Tier III. Tier classification might be used in future to classify energy efficiency as well.

3.2 Cooling equipment

Cold can be generated using a cooling unit in various ways. The most common method is still compression cooling. Low-pressure evaporation is used to extract heat from a cooling medium and transmit it to a coolant. The coolant is compressed in a compressor, where its temperature rises. The hot compressed coolant is condensed in a condenser, where it gives off the heat to the air. The coolant is allowed to expand and therefore cools, and the cycle is ready to start again. Figure 3.1 is a schematic representation of the cycle.

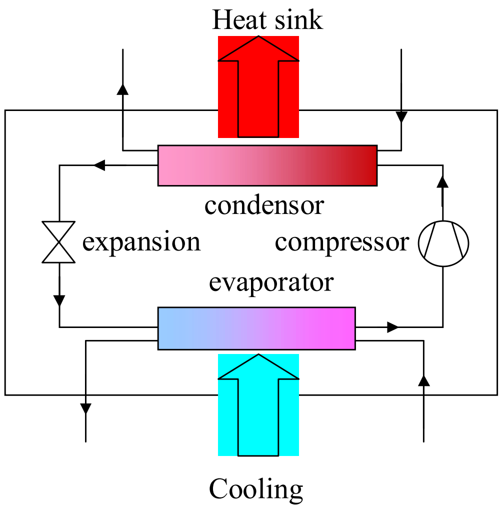


Figure 3.1 *Schematic representation of compression cooling*

Various indicators of energy efficiency are used in the cooling industry. These are explained below. The values they can have, given the current state of the art, are discussed in a subsequent chapter.

3.2.1 CoP (Coefficient of Performance)

Many parameters can be used to express the efficiency of cold generation. One that is commonly used is the Coefficient of Performance or CoP: this is the ratio of the cooling power to the compressor power used in a particular operating situation. The equation below shows how to calculate the CoP.

$$COP = \frac{P_{cooling}}{P_{compressor}}$$

$$Where:$$

$$P_{cooling} = Cooling\ power\ [kW]$$

$$P_{compressor} = Electrical\ power\ compressor\ [kW]$$

Equation 1: CoP, indicator for compression cooling

In general, then, a high CoP means ‘the ability to achieve high energy efficiency’. Compression cooling equipment used to cool data hotels with a CoP of 3 has poor energy performance; a CoP of over 4.5 is easy to achieve.

3.2.2 Carnot factor

Another way of calculating the CoP is by using what is known as the ‘Carnot efficiency’ and the evaporator and condenser temperature. The Carnot efficiency is the ratio of the theoretical maximum output of the entire cooling cycle to the actual output, excluding ancillary power. It is calculated using the following equation.

$$COP = \eta_{carnot} \cdot \frac{T_{evaporator}}{T_{condensor} - T_{evaporator}}$$

$$Waarin:$$

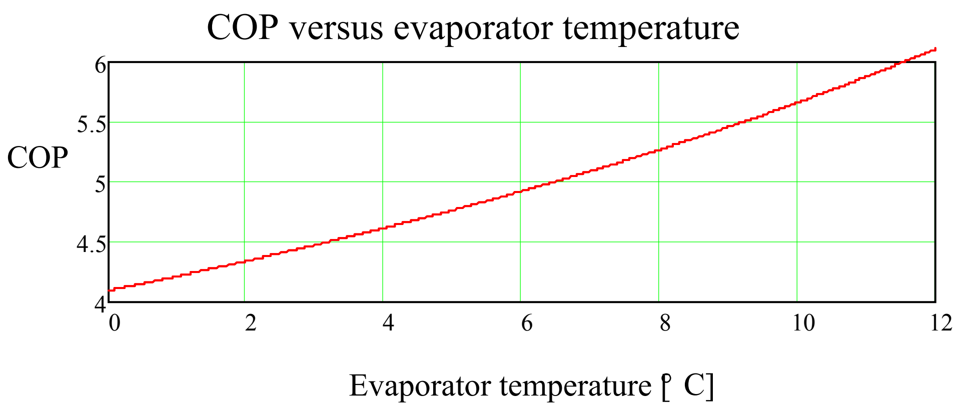
$$\eta_{carnot} = Carnot\ efficiency\,[-]$$

$$T_{verdamper} = evaporator\ temperature\,[K]$$

$$T_{condensor} = Condensor\ temperature\,[K]$$

Equation 2: Calculating the CoP using the Carnot factor

A higher evaporator temperature (indoor air) results in a higher CoP. A smaller temperature difference between the condenser and the evaporator also results in a higher CoP. Graph 2 shows CoP as a function of evaporator temperature, assuming condenser temperature to be constant. The Carnot efficiency of large cooling units is between 0.5 and 0.6[10] and is in effect a characteristic property of a compressor, which can be found in the technical specifications. Compressors with poor energy performance have a low Carnot efficiency.



Graph 2 *CoP as a function of evaporator temperature (Carnot efficiency = 0.6, condenser temperature = 40 ºC)*

3.2.3 SPF (Seasonal Performance Factor)

The CoP can vary a lot in different part-load situations, and it does not take the energy used by ancillary equipment such as condenser fans and pumps into account. The CoP is a power ratio, i.e. not a direct measure of the energy (kilowatt hours) used by a cooling system: even if a compression cooling unit in a system has a high CoP, the system may have poor energy performance if it uses a lot of ancillary power or does not make use of free cooling. On its own, then, a high CoP is no indication of energy efficiency.

A parameter that provides a good yardstick of the energy consumption of a cooling system is the SPF (Seasonal Performance Factor). This is the ratio of annual cold generation to the total energy required to generate this cold, including ancillary power.

$$SPF = \frac{Q_{produced}}{Q_{necessary}}$$

$$Where:$$

$$Q_{produced} = Amount\ of\ produced\ cooling\,[kWh]$$

$$Q_{necessary} = Necessary\ amount\ of\ energy\,[kWh]$$

Equation 3: Calculating the SPF

3.3 Data hotels, PUE and EUE

Various indicators have been devised to indicate how efficiently the electricity consumed by an ICT company is actually used. For the purposes of this report we have adopted the indicator used in the 'Green Grid Initiative'.[1][8] Green Grid refers to 'Power Usage Effectiveness' or PUE. If this ratio is 1, all the power is used solely by the ICT equipment – the ideal case, but one that cannot be achieved in practice. The actual value will therefore always be greater than 1.

$$PUE = \frac{P_{total}}{P_{ICT\ equipment}}$$

$$Waarin:$$

$$P_{totaal} = Total\ electrical\ power\ [MW]$$

$$P_{ICT\ equipment} = Electrical\ power\ ICT\ equipment\ [MW]$$

Equation 4: Power Usage Effectiveness (PUE) of a data hotel

As the power used in practice varies over a year, however, e.g. as a result of changing loads on the cooling equipment, it is better to express data hotel efficiency with a unit that relates to annual energy consumption. PUE is then replaced by EUE (Energy Usage Effectiveness), the total annual energy consumption divided by the annual energy consumption of the ICT equipment.

$$EUE = \frac{E_{total}}{E_{ICT\ equipment}}$$

$$Where:$$

$$E_{total} = Total\ annual\ energy - use\ [MWh]$$

$$E_{ICT\ equipment} = Annual\ energy - use\ ICT\ equipment\ [MWh]$$

Equation 5: Energy Usage Effectiveness (EUE) of a data hotel

[1] This initiative involves a worldwide ICT consortium set up to develop and promote energy-efficient data hotels and information services.

4. Energy-saving measures in ICT

The EUE of an average data hotel, as shown in Graph 1 on p. 12, is 1.4: in other words, 70% (1/1.4 x 100%) of the power consumed is used by the ICT equipment. There are data hotels, however, which have an EUE of 1.8 or more. Improving the EUE of existing data hotels involves clearing number of hurdles, but it is certainly not impossible. The fact that ICT equipment needs to be kept running constantly often makes it difficult to improve data hotels that are up and running, but a good deal can be done using temporary power supply and cooling systems. Advantage can also be taken of various natural change points – e.g. when systems are being replaced, refurbished or expanded – to make improvements in efficiency. At the time of writing there are a number of companies that have overcome the hurdles and refurbished their existing buildings and systems so as to use the energy available more efficiently. A good example is a Pink-Roccade/Getronics building in Amsterdam, where, following a radical refurbishment, the EUE has been improved from approx. 1.7 to approx. 1.3 (77% of the energy is now used by the ICT equipment, instead of only 59%). How this has been achieved is discussed later on in this report. When building new data hotels there are various options available for using energy efficiently.

Energy saving in the ICT industry starts with the computer hardware itself. Efficient hardware can do more with less, so less power is needed for facilities such as climate control and emergency power supply. Also, the temperature and relative humidity requirements in rooms where servers are running determine the energy consumed for climate control. Lastly, it is important to select the right size of systems and use efficient technology. Various energy-saving technologies that have been used in practice are discussed below, focusing on cooling and emergency power supply in data hotels, then looking lastly at server rooms.

4.1 Cooling

The air in server rooms in offices and data hotels is generally cooled by cooling units. The cooled air is blown into the computer rooms to cool the ICT equipment. The heated air is drawn in and cooled by the cooling unit, then the cycle is repeated. A number of factors, as explained below, substantially simplify the extraction of heat from computer rooms, enabling a lot of energy to be saved.

4.1.1 Temperature and relative humidity

If we consult manufacturers' specifications for ICT equipment we find that the maximum ambient temperature at which service life and quality are guaranteed is about 40 °C on average.[4] In other words, cooling computer rooms to temperatures well below 30 °C is unnecessary and results in energy being wasted. A study by Pinheiro et al. (2007)[5] shows that temperature has much less effect on 'disk errors' on hard drives than was previously thought. What is important is that temperatures should not fluctuate too much over time. The American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) recommends an air supply temperature of 20-25 °C.

The humidity requirements in manufacturers' specifications are also much more wide-ranging than those that used to be implemented in computer rooms. It is not necessary to regulate relative humidity within a bandwidth of a few percent: many device specifications indicate that it should be between 90% and 10% (non-condensing). Relative humidity and temperature are related: if the air is cooled too much, condensation forms on the heat exchangers that cool the air, which adversely affects cooling capacity. Condensation also makes the air in the computer room drier, with the result that it needs to be specially humidified to avoid problems with static electricity. It is important, then, that the cold water or coolant in the cooling unit should not be so cold as to cause condensation: in practice this means that the evaporator temperature should not be allowed to fall below 9 °C.

In theory, raising the air supply temperature by 1 °C increases the efficiency (CoP) of cold generation in compression cooling equipment by over 3%, as Graph 2 on p. 17 shows. Raising the air supply temperature by, say, 3 °C could even make cold generation 35% more efficient – again in theory –, as it reduces dehumidification.

A saving of this magnitude could be achieved by raising the evaporator temperature in the cooling unit from e.g. 6 °C to 9 °C (many types of cooling equipment have an adjustable evaporator temperature). If the 9 °C temperature results in an ambient temperature that is too high for the computer equipment, however, increasing the heat exchange area in the computer room between the air and the coolant may be the solution. The evaporator temperature can be changed by adjusting a control. The investment required (a few hours' labour) is quickly recouped from the saving: in the case of the Groningen data hotel in Figure 2.1 the work is paid for in under a week. Installing additional heat exchange area is more expensive, of course, but the simple payback period (investment divided by annual saving) can be under five years.[2] The cabling system and the way the floor area is used (rental or owner occupation) affect the cost of increasing the heat exchange area.

4.1.2 Separating hot and cold air

Physically separating the heated and cooled air so that they cannot mix is in fact one of the first measures to be taken to enable a cooling system to work more efficiently.

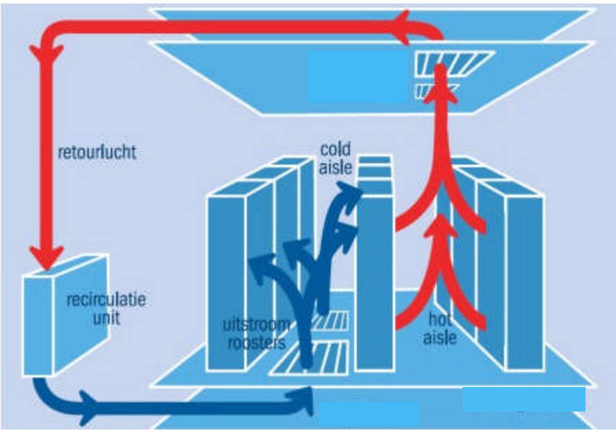


Figure 4.1 *In practice the air does not flow as shown by the designers' arrows; turbulence can cause heated air to mix with cooled air, resulting in higher energy consumption. Photo: Computable*

[2] This does not take account of the loss of floor area where ICT equipment could be sited, which could be examined on a case-by-case basis.

Figure 4.2 *Situation where cold and hot air are kept separate. Photo: UpTime Technology*

Separating hot and cold air in computer rooms in this way is achieved by creating cold and hot aisles. The cold air then flows through the ICT equipment horizontally. In Figure 4.1 the top of the aisles is left open, so hot and cold air can still mix. If the aisle is enclosed, this short circuit can be prevented, so as to use cold even more efficiently, as shown in the photo: this has a major effect on the temperatures in the aisles. Measurements carried out by ECN show that the difference in temperature between the hot and cold aisle in a case such as that shown in Figure 4.1 is only 0.5-1 °C, whereas with a covered aisle it can be as much 8 °C. In practice this means that a cooled air temperature of 25 °C provides sufficient cold to extract the heat in a computer room with covered aisles. The temperature could be even higher if the computer equipment is allowed to run at its maximum operating temperature. In spaces that are not covered the air supply may well have to be below 21 °C. Separating hot and cold air makes for a substantial improvement in efficiency, especially in existing systems using compression cooling equipment: the size of the improvement is discussed later on in this chapter.

An additional advantage of physically separating hot and cold air is that the air treatment units need to move far less air, as the cold available is being used much more efficiently. This means that fewer units are needed in computer rooms if the aisles are covered, releasing more floor area for computer hardware – unlike the case in the previous section, where raising the evaporator temperature can result in the need for a larger heat exchange area, hence more floor area for extra units. Keeping hot and cold air separate generally affects the control of cooling in computer rooms.

Physically separating hot and cold air, then, not only enables the intake temperature to be raised e.g. from 21 °C to 24 °C; also, less air is needed to extract the heat, so air treatment units can be switched off. Raising the air temperature by 3 °C as described in the previous section makes a cooling unit almost 10% more efficient. The cost of covering aisles is around 180 euros per m². In cases where cooling is provided solely by compression cooling equipment (no free cooling, an SPF of 3.5) separating hot and cold air has a simple payback period of under five years.[3]

[3] 180 [€/m²]/(8760 hours x 1.5 kW/m² x 1/3.5 x 10% x 0.1 €/kWh) = 4.8 years.

Even in cases where compression cooling equipment is used for less than the whole year and the ICT equipment consumes more than 1.5 kW/m² the payback period can be under five years.

4.1.3 Part-load control systems

The way a cooling system is controlled has a major influence on the SPF and the CoP. One example is a condenser pressure control system: this involves using an electronically controlled expansion valve to regulate the pressure and temperature in the condenser, thus reducing the power used by the compressor. When the temperature drops outside but compression cooling is needed the condenser temperature can be lowered. The payback period of electronic expansion valves when combined with free cooling is currently too long to make this a compulsory requirement, as using free cooling reduces the operating time of the cooling unit. Consequently controlled expansion valves do not pay back so quickly at current prices and energy prices. If direct expansion is used, instead of a fluid system with free cooling, electronic expansion valves currently have a payback period of under seven years.

If a cooling unit often operates under part load this will adversely affect its SPF, as the proportion of ancillary power (for pumps, control system etc.) is not generally reduced under part load: this, after all, is not the situation for which the system was designed. A 'cascade control' system as shown schematically in Figure 4.3 overcomes this problem to some extent.

A cascade consists of a number of cooling units connected together but controllable separately. In the example, say 68% of the maximum cooling capacity is required, cooling units 2 and 4 operate under full load and unit 6 under part load: consequently only a very small proportion of the capacity being used is operating under part load. As two units (Nos. 1 and 2) are each able to supply 50% of the maximum cooling demand, this also provides 100% redundancy: if any unit breaks down, 100% of the maximum cooling demand can still be supplied.

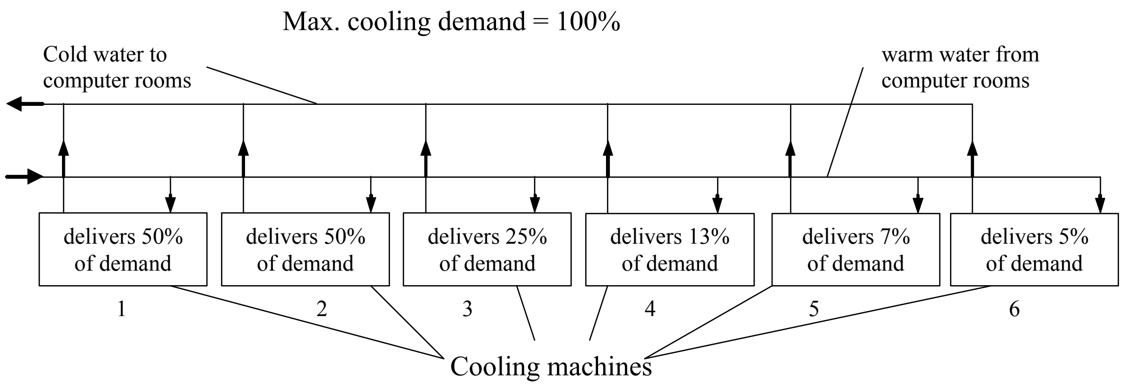


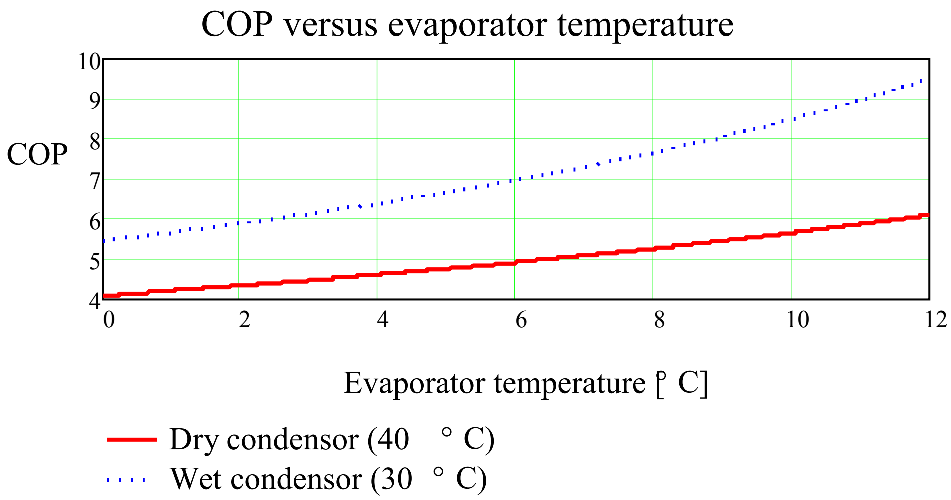
Figure 4.3 *Cascade control of cooling units*

In addition to a good part-load control system for the cooling units, a good part-load control system for the fans is also important, as the power required for these can be over half the total required for cooling. If the cooling system is running under part load, a lot of power can also be saved by switching off condenser fans and air treatment unit fans – in fact this applies to all the ancillary power for the system.

Part-load control systems of this kind have been standard in the cooling industry for years and can thus be regarded as the current state of the art.

4.1.4 Dry condensers and wet condensers

Compression cooling units use less power when the difference in temperature between the evaporator and the condenser is small, as shown in Equation 2 on p. 17. This can be achieved as described above: the evaporator temperature can be raised by taking the equipment to its specification limits and separating cooled and heated air. The difference in temperature between the evaporator and the condenser can be reduced still further by lowering the condenser temperature. Normally speaking, doing this reduces the amount of heat that can be given off, but allowing water to flow along the condenser overcomes this restriction, as part of the water evaporates, thus extracting more heat from the condenser.



Graph 3: CoP as a function of evaporator temperature at various condenser temperatures (Carnot factor = 0.6)

A 'wet condenser' of this kind, or wet cooling tower, can extract the same amount of heat at a lower condenser temperature than a dry condenser, or dry cooling tower. A wet cooling tower, however, uses water, which has to be treated to prevent algal growth and scale formation. Steps also need to be taken to prevent the growth of legionella bacteria: there are guidelines on the subject and methods of reducing this. Disposing of the water used is often problematic, as it is frequently contaminated with chemicals. For this and other reasons wet condensers or wet cooling towers often require a lot of ancillary power. Wet condensers or cooling towers can cause condensation clouds at certain times of the year, so this needs to be taken into consideration when choosing a location (Schiphol Airport, motorway, residential area etc.).

Besides wet and dry condensers there is an intermediate type known as a 'hybrid condenser'. As the name suggests, this is a combination of a dry and wet condenser. Generally this cools in winter just with air (dry); in summer the air is humidified (wet). The characteristics of dry and wet condensers described above also apply to hybrid condensers, depending on the operating situation (wet or dry).

Depending on the evaporator temperature, using wet condensers or wet cooling towers yields an improvement in the CoP of 35-60% over dry condensers. An eye needs to be kept on the amount of ancillary power required, however, and preventing the growth of legionella bacteria is still a concern in the case of wet cooling towers: this can cancel out the energy saving from the cooling unit's improved CoP, as is often the case in practice.

4.1.5 Free cooling

The climate in the Netherlands is such that a lot of 'free' (and sustainable) cold is available from the outside air. The figure below shows the number of hours in a year that the temperature is below a particular value (1 year = 8760 hours).

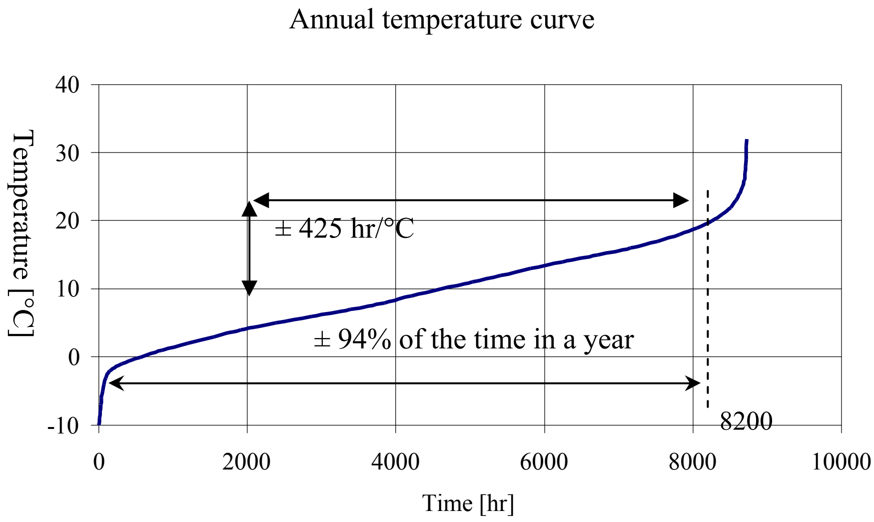


Figure 4.4 *Number of hours that the outside temperature is below a particular value*

As Figure 4.4 shows, it is cooler than 20 ºC outside for some 8200 hours a year (94% of the time!). A substantial amount of power for compression cooling can be saved by using systems that are able to take advantage of the sustainable cold available (‘free cooling’). If the ICT equipment is taken to its temperature limits and the cooled air is used efficiently, compression cooling is even unnecessary.

Figure 4.5 is a schematic representation of free cooling in a system using cooled water. The thick black lines represent the fluid system. The red and blue arrows represent the hot and cold air. There are two heat exchangers on the roof: one serves as the cooling unit’s condenser, the other is used for free cooling. The heated fluid can be pumped direct from the heat exchanger in the air treatment unit to the heat exchanger on the roof, where it gives off the heat to the outside air. The unit switches on when it is too hot outside to cool the fluid solely with the outside air. If the climatic requirements in computer rooms are made more wide-ranging and higher temperatures allowed, more cold from the environment can be used and considerable savings made on cooling energy.

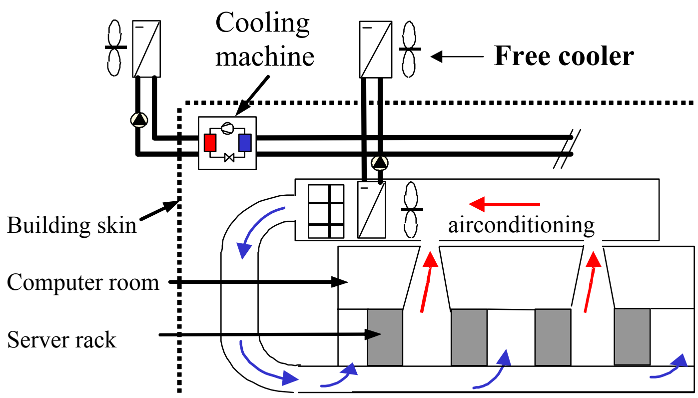


Figure 4.5 *Schematic representation of the use of free cooling*

There are many suppliers that supply cooling systems which use free cooling as standard products. Free cooling also has advantages as regards the power needed for emergency power supply and reliability: if a compression cooling unit breaks down, cold from the environment can still be used. In practice free cooling as used in Figure 4.5 saves some 30% of energy consumption for cooling compared with systems without free cooling. It pays back within a few years. Systems with a free cooling facility of this kind can be regarded as the current state of the art. Buildings where free cooling cannot be employed for structural reasons, e.g. because the roof is not strong enough, are generally not suitable for data hotels.

4.1.6 Cold wheels

Another way of using cold from the outside is to transfer cold from the outside air to recirculated air from a computer room using a hot or cold wheel. The diagram below shows the principle of cooling using a cold wheel. In essence, cold outside air continuously cools half of the wheel. As the wheel turns slowly, the cooled part of it rotates in the hot air flow that needs to be cooled.

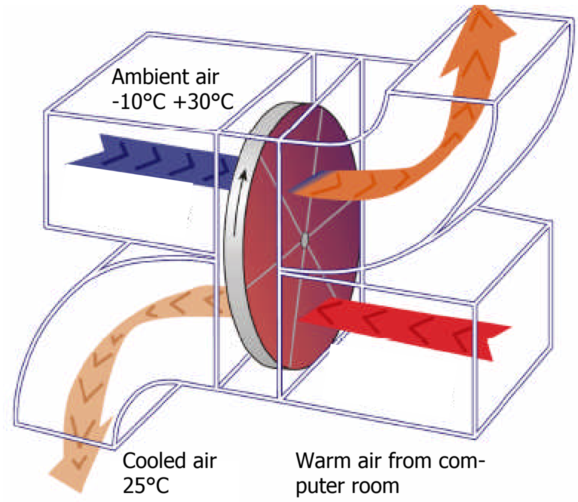


Figure 4.6 *Cooling recirculated air from computer rooms with outside air using a cold wheel. Photo: UpTime Technology*

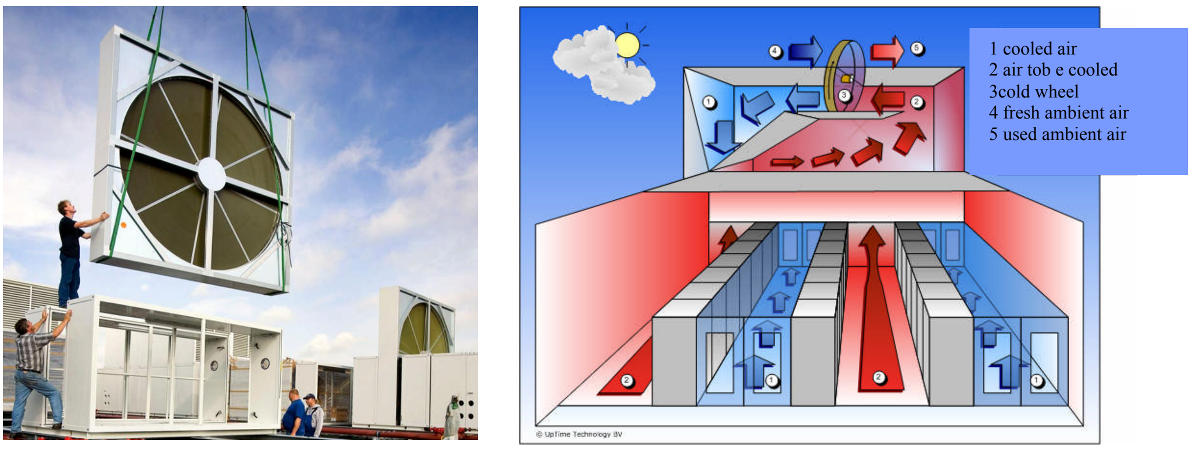


Figure 4.7 *Photo and diagram of the principle of using vertical cold wheels on the roof of an existing data hotel. Photo: Hamer installatietechniek, PinkRoccade Geotronics, KPN and UpTime Technology*

Vertical wheels enable the system to be sited on the roof. Horizontal wheels enable the system to be sited on the perimeter of a data hotel and to grow in modular fashion (see also 4.6). The building must of course have large air ducts to transport the hot and cold air to and from the wheels.

Compared with the average situation as shown in Graph 1, cooling using cold wheels can yield a substantial improvement in the EUE. The energy saving – the reduction in total energy consumption from applying this principle as against that average situation – can be as much as around 20%. Compared with data hotels that do not take advantage of free cooling, cooling using cold wheels can even halve the total energy consumption. Again, the additional investment in these systems, compared with systems without free cooling, is recouped within a few years.

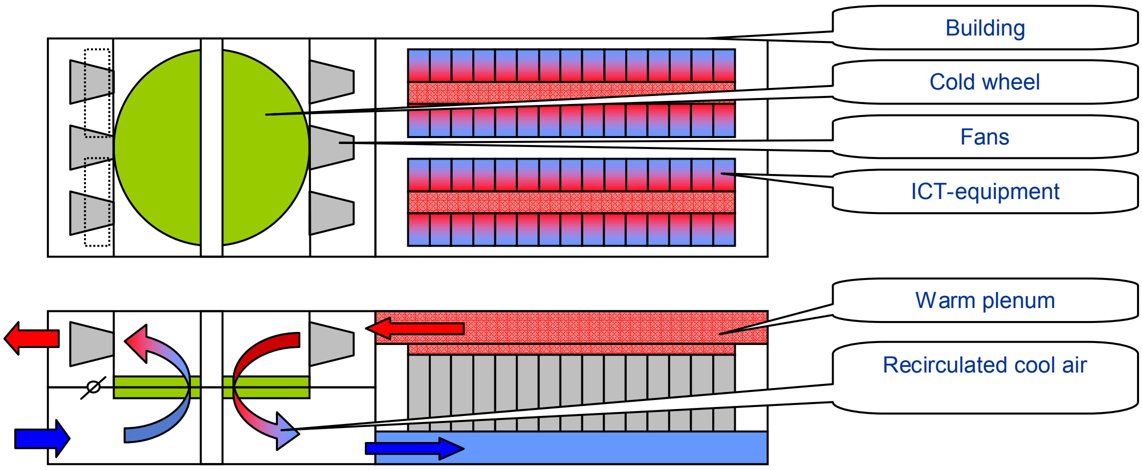


Figure 4.8 *Using horizontal cold wheels. Above: plan view. Below: side view. Illustration: UpTime Technology and KPN*

4.1.7 Heat and cold storage in the ground

Heat/cold storage (or TES, thermal energy storage) in the ground is far from new in the Netherlands: there were just under 600 projects[6] here employing this technology in 2005. TES in the ground is used for cooling in the ICT industry, although it ought really to be referred to solely as 'cold storage' in the ground. The idea behind CS in the ground in the ICT industry is that cold (taken from the air in winter, or from cooling equipment) is used to cool the ground and groundwater; this cold is used to cool water, which in turn is used to cool the air in the computer rooms. An issue here is the enormous quantity of cold needed throughout the year to cool the ICT equipment when cooling solely with a CS system. How much energy a system of this kind saves is difficult to say, as it depends very much on the systems that generate the cold and how this is done.

An ICT company currently has an initiative under way which involves cooling the computer rooms without compressors. By using TES when it is too hot outside for free cooling, compression cooling can be avoided. The planning procedure for TES was found to be a problem during the preparatory phase of the project, however. With initiatives of this kind it is useful to be able to deal with the underground spatial planning – in other words, there need to be clear rules for companies wanting to use the ground for energy storage.

The conclusion from information on TES available at ECN is that a TES system for cooling data hotels requires a substantial investment, for one thing because of the size of the system. A CoP of 10-20 can be achieved in practice, but because of the large quantity of ancillary power required the SPF is generally lower, up to around 6. In spite of the energy saving, systems of this kind do not pay back quickly at present (it takes over 20 years). This is not likely to change much in the coming years, even with rising energy prices.

4.1.8 Cold networks or central cold supply

Cold networks are being developed, or are even operational, at various locations in the Netherlands. Examples can be found in Amsterdam on the South Axis and in the south east area, where two lakes (the Nieuwe Meer and the Oudekerkerplas) are being used as cold sources. These supply cold water from a central location to buildings in the surrounding area (within a radius of a few kilometres) for use in cooling.

The cold networks can be seen as a backup facility if on-site cold generation fails. Where a cold network is used as the basic facility an ICT company will often decide to have its own emergency cooling facility, above all because of the major need for security of supply.

4.2 Absorption cooling

Another way of generating cold is to use absorption cooling. This is not much used in the ICT industry at present, and it is rare in offices too. One of the main reasons is the relatively high temperature needed to run absorption cooling, as it uses high-temperature heat (around 80ºC) to generate cold. Fig. 13 is a schematic representation of the principle.

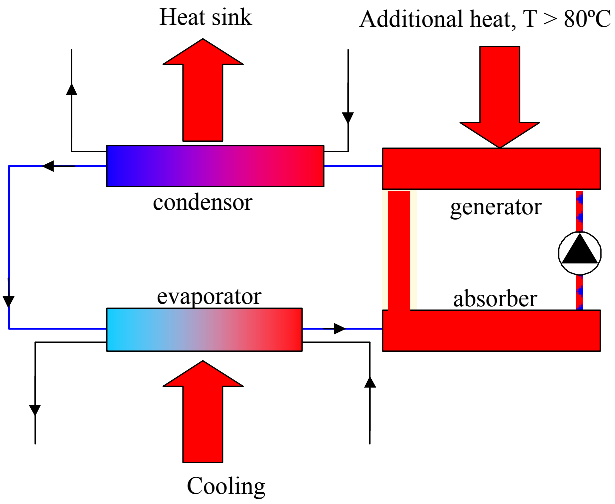


Figure 4.9 *Schematic representation of absorption cooling*

The compressor in a compression cooling unit is replaced by a generator and an absorber in the case of absorption cooling. Absorption cooling units are generally much larger in size and require a larger investment than compression cooling systems. In large systems such as those used in the ICT industry an absorption cooling unit can achieve a maximum CoP of approx. 0.8. In the case of absorption cooling the CoP is the ratio of cooling power to power supplied to the generator.

When absorption cooling is a feasible proposition, an important factor is where the required heat comes from. Taking heat from a modern power plant (such as the one in Diemen) for district heating, for instance, reduces the efficiency of electricity generation at the plant. This is also generally the case with the efficiency of other industrial processes from which heat could be taken. The efficiency of heat production needs to be included when calculating the savings. It is also important that the supply of and demand for absorption cooling occur at the same time. Lastly, the temperature at which heat is available is an important factor: absorption cooling can only be employed if the temperature in the heating network is high enough all year round (approx. 80 °C). If the network has to be kept at a higher temperature for part of the year for absorption cooling, this causes more efficiency losses at the plant and more heat losses in the network.

4.3 Supplying heat from the ICT industry to third parties

This would seem to be an obvious option, but in practice it is no simple matter. The heat from the ICT industry is released at a fairly low temperature (maximum 45 °C), and this is reduced somewhat during transmission to the user. If this heat is to be used effectively, a heat pump is required. Also, an ICT company will want to dispose of its heat all the time, not just when there is a user demand, though heat storage in the ground can be a solution in such cases. Nevertheless, supplying heat to third parties can be feasible, especially if systems are replaced or refurbished in the surrounding plants and buildings when new ICT buildings are being built or existing ones refurbished. A project to supply heat from the ICT company TeleCity Redbus to the AMC/De Meren psychiatric centre in Amsterdam is in preparation at the time of writing.

4.4 Electricity supply

A UPS (uninterruptible power supply) converts the voltage from the power grid from AC to DC and vice versa several times, resulting in an energy loss that can average around 6% of total energy consumption. There are cases where the loss has been found to be much higher: it can rise substantially, to as much as 20%, especially where a data hotel actually uses only a small proportion of the power supply capacity. Unnecessary losses can be avoided by selecting the right size of power supply and emergency power supply, so that only critical equipment that is actually being used is fed from the UPS. This generally means having UPS systems that can grow along with the ICT equipment, known as 'modular' UPS systems. This spreads the investment cost as demand arises.

A lot of ICT equipment is connected to the AC supply from a UPS. This involves converting the voltage three times:

1. from AC to DC (in the UPS)
2. from DC to AC (in the UPS)
3. from AC to DC (in the computer power supply)

Each time it is converted, power is lost as a result of 'iron losses' in the transformers. Many of the systems used convert the full amount of power used from AC to DC several times, causing multiple losses. There are systems available that only convert the power required to charge the batteries in the UPS, sending the remainder direct to the computer equipment: systems of this kind can reduce the energy lost in the power supply to a few percent of the total energy consumption. APC is one of the suppliers of this technology, known as 'delta conversion', for which it claims over 97% efficiency. This can also be achieved with systems that employ flywheels.

4.5 Other spaces and lighting

Despite the fact that these components account for a relatively small proportion of the total energy consumption, it makes sense to try to make savings here too. Energy-saving lighting with high-efficiency luminaires and presence detectors is worthwhile, especially for computer rooms, and perfectly feasible given the relatively small investment compared with the other hardware required. In the case of offices measures such as sun-blinds, energy-saving lighting and luminaires, presence detectors and energy-saving ventilation are suitable. Investments in energy-saving lighting generally pay back within a few years.

4.6 Modular systems

As it usually takes time to fill a data hotel with computer equipment, it is advisable to let the facilities grow as the actual power used increases. Cooling concepts and emergency power supplies can grow with the amount of ICT equipment. Below is a diagram of a storey of a data hotel, where more or fewer cold wheels and air treatment units can be sited along the outside wall, depending on the amount of ICT equipment in the hot and cold aisles (and the actual power used). This enables the facilities to grow in tandem with the ICT equipment and the investment to be spread over time.

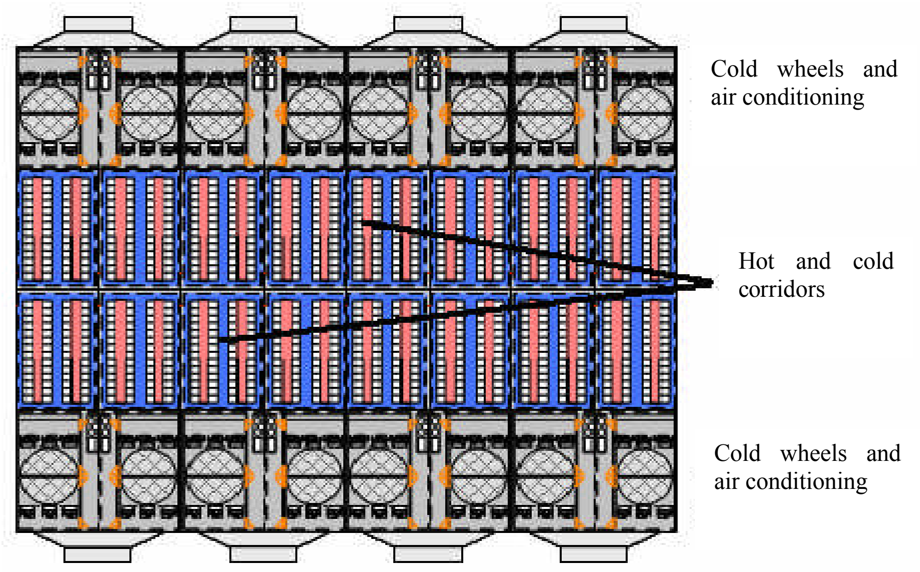


Figure 4.10 *Example of a modular system for a data hotel. Illustration: UpTime Technology*

4.7 Offices

Ways of reducing energy consumption in existing small computer rooms in office buildings would seem to be limited at first sight, but there are a number of methods that can be used to reduce the energy consumed by ICT in offices and the cooling this requires.

4.7.1 Cooling server rooms

In small computer rooms, preventing cold and hot air from mixing (as practised in large rooms) is likely to result in unworkable situations. Also, older cooling systems often have very limited adjustability, apart from the usual thermostat. Nevertheless, it is worthwhile to look at the effect the thermostat setting has on energy consumption. Selecting a higher (warmer) setting makes cooling more efficient and may reduce or eliminate dehumidification. This requires the cooling unit's evaporator temperature to be adjustable, however.

On top of this, in computer rooms with one or more outside walls, cooling systems can be installed that draw in air direct from the outside, thus providing free cooling. Such systems also require grilles in the walls so that this air can be returned to the open air (exhaust grilles). The apertures in the walls must not compromise building security. With free cooling these cooling systems, referred to as 'split units', pay back within a few years, compared with systems without free cooling, and they are readily obtainable.

If the air supply temperature is raised from 21 °C to 24 °C the average temperature in the room will also rise by about 3 °C. Changing the thermostat setting needs to be done in close consultation with the owner of the computer room. It is highly advisable to adjust the thermostat setting gradually, by no more than 0.2 °C per hour.

In theory, changing the thermostat setting to the point where it takes full advantage of the equipment specifications can save up to 45% of cooling energy. In practice this is difficult to achieve, and the maximum saving will generally be around 30%. This can be improved by using ventilation apertures and free cooling, provided the evaporator temperature can be raised. In modern cooling units this is often possible because the speed of the compressors is adjustable.

4.7.2 ICT equipment in offices

As regards ICT equipment in offices, the principle of only using equipment that has an Energy Star label can be adopted. Such equipment complies with certain energy efficiency standards. For the sake of sustainable procurement it is advisable only to purchase equipment bearing this label.

Switching off equipment that is not being used is another obvious way of saving energy, but in practice it is more difficult than it sounds. Software maintenance on company PCs is sometimes carried out at night, which means that employees have to leave their systems on at night. If this maintenance is simply done during the daytime, for instance, systems do not need to be left on unnecessarily at night. PCs can also be switched off remotely.

A modern desktop computer with a 19” TFT monitor when switched on (Windows standby) can easily consume a minimum of 100 watts,[4] 40W of which is accounted for by the TFT monitor. In Windows the computer can be switched to the standby setting automatically under ‘Power Options’. This reduces the power used to a mere 2.7 W, and an even lower 2.1 W can be achieved in Hibernation. The best thing, of course, is to switch off equipment that you are not using. Under Windows XP, however, the standby setting can be interrupted by processes such as virus scanners running in the background. This problem appears to have been solved in Vista.

[4] Data obtained from measurements on a PC: Intel Core 2 Duo 6300 CPU at 1.86 GHz (Fujitsu Siemens Esprimo) with 19” TFT monitor (Fujitsu Siemens ScenicView P19-2 P).

5. An approach to reducing energy consumption

The sections that follow describe a general approach to energy saving in the ICT industry. First we discuss existing and new data hotels, in effect summarizing the measures discussed in the previous chapter. We then explain how concepts for data hotels can be judged in terms of energy efficiency. We conclude by discussing what energy efficiency standards could be set for existing and new data hotels.

5.1 Practice

Substantial energy savings can be achieved in existing data hotels by taking a critical look at factors such as air supply temperature, humidification and whether hot and cold air are mixing. When building new data hotels it is important to consider energy efficiency at an early stage. Below we look at existing and new data hotels separately.

5.1.1 Existing data hotels

In existing data hotels there are often many options available for reducing energy consumption, starting in the computer rooms, where hot and cold air flows are often able to mix and air at well below 30 °C is blown through the computer floor. A substantial energy saving can often be achieved in practice in spaces that need to be humidified: here the evaporator temperature is too low (< 9 °C), causing unnecessary dehumidification. Improving the air flows with the aim of preventing hot and cold air from mixing and raising the air supply temperature is an efficient first step towards:

1. Increasing the efficiency of the cooling unit by raising the evaporation temperature
2. Requiring less energy for cooling as a result of not dehumidifying
3. Requiring less energy as a result of not having to humidify
4. Making more cooling capacity available as a result of not dehumidifying

Apart from the above advantages, systems that use free cooling can achieve even greater savings. As free cooling can be used for longer at a higher evaporator temperature, the compressors in the cooling equipment do not have to run for so long. If the outside temperature limit at which free cooling can be used is raised, some 425 hours per °C of running hours a year can be avoided, as illustrated in Figure 4.4. Thus the ability to take advantage of free cooling at an outside temperature of 17 °C instead of 12 °C yields a reduction of some 2125 running hours a year!

The evaporator temperature can also be raised by increasing the heat exchange area between the cooled water or coolant and the air in the computer rooms. In practice this often involves installing more air treatment units in existing computer rooms, and therefore sacrificing floor space for ICT equipment.

If the emergency power supply is fitted with batteries, it is worthwhile to prevent the full power available passing through the transformers, since this causes unnecessarily large losses (6% on average, but they can be as much as 12%), as described at 4.4. Modern systems (delta conversion) that only convert the charging power required can reduce these losses to a few percent. This can also be achieved with systems using flywheels.

It is also worthwhile to look at cooling concepts using cold wheels in existing data hotels where refurbishment and/or system replacement is on the agenda. These generally require a substantial investment, but this is offset by low energy consumption, with all the advantages that entails (more power available for ICT, low energy costs).

5.1.2 New data hotels

As energy efficiency is becoming an important item in the ICT industry, various fresh initiatives have been taken in recent years to make data hotels more efficient. As regards cooling, maximum use of free cooling has become the standard, and there are even concepts being developed (but not yet operational at the time of writing) that require no additional compression cooling. This is related to separating cooled and heated air by creating hot and cold 'aisles', enabling the air supply temperature to be raised so as to take maximum advantage of the cold available in the outside air. Solutions are also available that can reduce the losses caused by emergency power supplies to a few percent. As regards both cooling and power supply, it is worthwhile to design new data hotels so that they can grow in a modular fashion, i.e. cooling and emergency power supply grow gradually as the available square metres of computer space are taken into use. Early adapters have demonstrated that an EUE of 1.1 is feasible for a data hotel: this represents an improvement of about 30% on the normal situation about seven years ago, and an improvement of 20% on the average situation at present.

5.2 Assessing concepts

Figure 5.1 on p. 33 gives an overview of some of the technologies and concepts described above and what effect they can have on energy consumed for cooling and by a data hotel as a whole. Two indicators are used, the SPF (for cooling) and the EUE (for the data hotel): these are explained in Chapter 3. The curve is the average of the data available at ECN from energy reports on data hotels. Where the energy reports do not provide information on energy consumption for emergency power supply and other facilities, averages of 6% and 4% have been assumed respectively. This is in line with the values shown in Graph 1 on p 12[?]. The relationship between the SPF and the EUE (the broken line in the graph) is due to the fact that a high SPF results in a low EUE. The coloured areas indicate what SPF and EUE can reasonably be expected from the concepts described. If we know the SPF and EUE for a data hotel we can mark them on the graph: if the mark is above the broken line, the energy items for emergency power supply and other facilities are together above the average; if it is below the broken line, the items are below the average.

Based on the overview in Figure 5.1 on p. 33, a minimum SPF of 4 and a maximum EUE of 1.4 are achievable using standard technology in existing data hotels. In new data hotels newer technologies can be used, making a minimum SPF of 6 and a maximum EUE of 1.3 feasible. These values are shown by the thin broken lines.

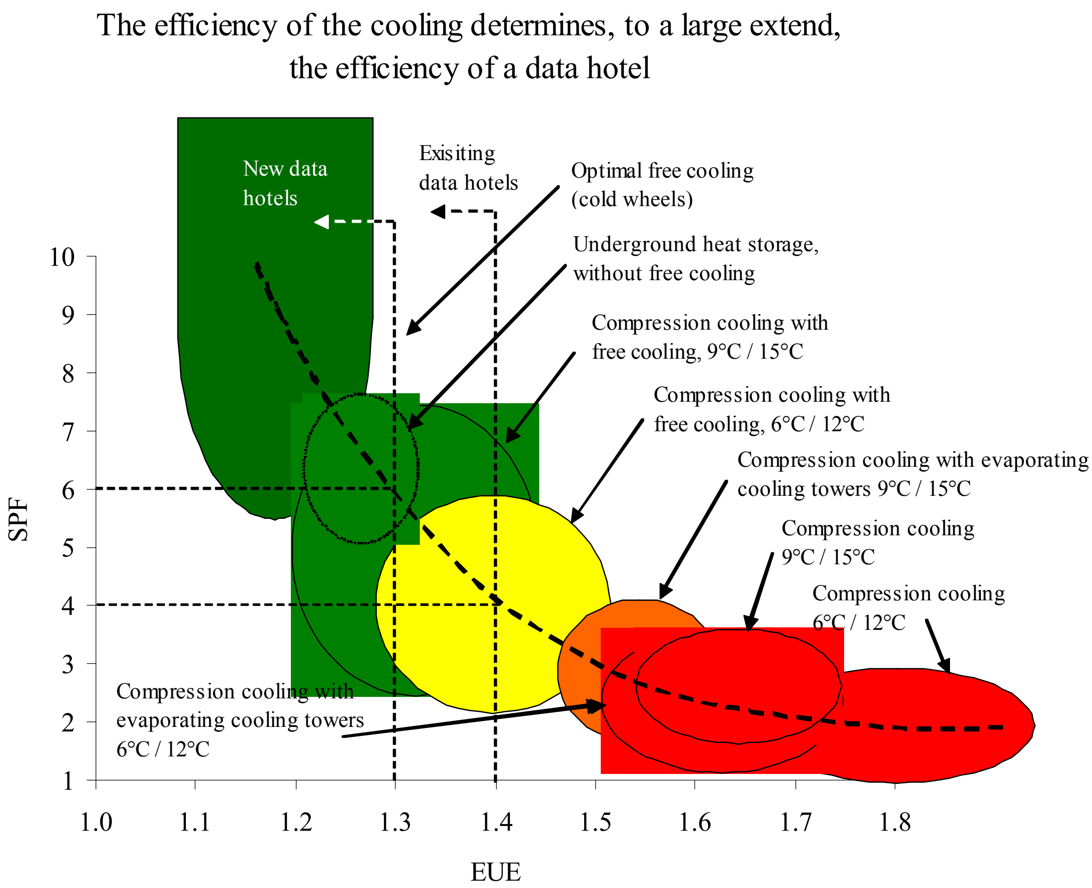


Figure 5.1 *Performance factor (SPF) and feasible energy usage effectiveness (EUE) of various concepts: green denotes energy-efficient technology, red energy-wasting technology. A maximum EUE of 1.4 is achievable using available technology in existing data hotels. In new data hotels with newer technology a maximum EUE of 1.3 is feasible.*

5.3 Checklist

A checklist (in the Appendices) has been compiled to assist environmental inspectors in their work. It gives an overview of economy measures, almost all of which can now be regarded as best available technologies. Energy consumption can be reduced by implementing measures on the list. For good results it is advisable to use the checklist at an early stage in the design. Once the design has been optimized in this way the checklist can serve as an aid to writing an energy report. Lastly, it can also be used while running the data hotel and when regularly evaluating energy consumption.

6. Conclusion and recommendation

The ICT industry has grown into one of the most energy-intensive sectors in the Netherlands, and it is expected to grow in size and energy consumption in the years to come. Also, energy and the environment are hot topics that are highlighting the need to save energy. Given the rise in energy costs, using energy efficiently is even beginning to be a precondition for financial survival in the ICT industry.

The energy efficiency of data hotels can be judged using various indicators. By applying these to various concepts used in the ICT industry we have seen what energy efficiency requirements can be applied to data hotels. EUE (Energy Usage Effectiveness) can be used to judge the energy efficiency of a data hotel: this is the ratio of the data hotel's total annual energy consumption to the annual energy consumption of the ICT equipment. In existing situations an EUE 1.4 or lower can be achieved using existing technologies. In new data hotels newer technologies can be used, achieving an EUE of 1.3 or lower.

To sum up, there is a lot of technology available to improve energy efficiency in the ICT industry. The most important factor when making improvements is preventing cooled and heated air from mixing in computer rooms, so that the air supply can be increased, thus avoiding unnecessary use of compression cooling equipment. Nationwide the potential reduction at data hotels alone is approx. 0.32 TWh a year – comparable to the annual electricity consumption of some 100,000 households. Taking server rooms and ICT equipment in offices into account as well, the potential could be doubled. Early adapters in the industry have demonstrated that an EUE of 1.1 is feasible for a data hotel, but there are still cases where an EUE of 1.8 is not being achieved. This wastage is not necessary nowadays given the technology available, the investment required and the financial savings at current energy prices, which can only be more in the future.

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Appendix A Checklist: data hotel energy consumption

Instruction for completion

- Fill in your particulars and your expected energy consumption below.
- Provide information on the energy-saving measures you are taking in your company on subsequent pages.
- Once you have completed the checklist, please sign the form.

Name and address	
Name of company:	
Address:	
Postcode/town	
Contact person:	
Postal address:	
Postcode/town	
Telephone	
Fax:	
E-mail	

Company particulars	
Net floor area of ICT rooms (m²):	
Number of staff (FTE)	
Total energy consumption (kWh)	
Electrical connection capacity (kW)	
Date taken into service:	
Design of business activities:	

Energy consumption	kWh per year	%
ICT equipment		
climate control		
power supply		
office		
lighting		
Total		100
PUE (total/ICT equipment)		

Signature		
Place, date:	Name, post, company:	Signature

POINTS FOR CONSIDERATION IN ENERGY-SAVING REPORTS				
ICT-EQUIPMENT				
no	**comments**	**tip**	**question**	**Indication of payback period**
1.1	Energy-efficient equipment ICT equipment differs substantially in terms of capacity and energy consumption. The biggest saving can be achieved by using energy-efficient equipment.	Opting for energy-efficient equipment also enables more equipment to be installed per m².	Has energy-efficient equipment been adopted? If possible, attach a specification of energy consumption (kWh per day), the connection capacity (kW), I/O capacity (Mbit/s), storage capacity (GByte) and computing speed (MIPS) of the equipment selected.	
1.2	Equipment with wide-ranging climatic requirements Using equipment with wide-ranging climatic requirements reduces the energy consumption for climate control. There is equipment on the market that works well at an air temperature of 40 °C, with brief periods of 50 °C. The relative humidity required is usually between 10% and 90%. An important requirement is that condensation must not be able to form in the equipment.		What is the maximum air temperature of the air drawn in from the equipment? What is the minimum humidity of the air drawn in from the equipment? What is the maximum humidity of the air drawn in from the equipment?	
1.3	Power management If the data traffic does not use the full capacity of the equipment 24 hours a day, some of the equipment can be switched to low capacity or standby temporarily without affecting the required reaction speed, thus saving a lot of energy for a small investment. On desktop PCs and laptop PCs power management options of this kind are already standard practice.	To take full advantage of this it is important to design the system configuration in such a way that the data traffic is distributed over a number of servers connected in parallel, so that they can take over one another's functions. This also benefits reliability and simplifies capacity management. Technologies such as cluster technology and SAN (virtualization) apply this principle. There are also various new processors on the market that use less energy by switching to low capacity when the load is low.	Does the ICT equipment use power management, and if so, how?	

CLIMATE				
No	**Comments**	**tip**	**question**	**indication of payback period**
2.1	Creating hot and cold aisles A few general principles that help to reduce energy consumption for cooling: Reduce the cooling demand. Cool at the highest possible temperature. Prevent hot and cold air flows from mixing by creating hot and cold aisles. Use free cooling as far as possible.	Separating hot and cold air, enabling the air supply temperature to be raised, is a measure that generally pays back within a few years.	What principles is the cooling design based on? What is: $T_{\text{air in the computer room}}$ $T_{\text{coolant evaporator in}}$ $T_{\text{coolant evaporator out}}$ $T_{\text{coolant condenser in}}$ $T_{\text{coolant condenser out}}$ Installed cooling capacity	Under five years.
2.2	Using wet cooling towers or wet condensers Reducing the condenser temperature improves cooling equipment performance, but an eye needs to be kept on the amount of ancillary power used, which can cancel out the improvement in performance. Condensation plumes can also form (consider the location!) and legionella growth must be prevented.		What performance improvement does the wet cooling tower provide? How much additional ancillary power does it require? What is the water consumption?	
2.3	Using free cooling A saving on energy consumption for cooling of 20-50% can be achieved by using free cooling. The payback period for the additional investment is generally under five years. The energy saving depends on the proportion of the cooling demand supplied by free cooling. The principle is: the higher the temperature in the computer room, the higher the proportion of free cooling. 40%-95% free cooling can be achieved in practice.	The higher the air temperature setting in the ICT rooms, with the temperature range of the cooled water e.g. at 13 °C … 18 °C, the higher the proportion of free cooling.	What proportion of the cooling demand is supplied by free cooling?	Under five years.
2.4	Using speed control and/or cascade control The cooling system runs under part load a lot of the time. A good part-load control system prevents losses. This can make use of a speed control for screw compressors, in combination with a cascade control system for cooling systems which are unsuitable for use with a speed control. A cascade control system is sometimes incorporated in the units themselves. If the cooling load is less than 100%, some of the fans in the air treatment system can be switched off.		Is there a part load control system using speed control and/or cascade control? Are fans and pumps switched off when the cooling load is less than 100%?	

no	comments	tip	question	indication of payback period
2.5	Using the right cooling medium To transport cold efficiently and flexibly to the places where the heat is generated, the right cooling medium needs to be selected. Whereas water/glycol used to be an obvious and efficient option, nowadays there are also highly efficient air/air systems with cold wheels available.		What is the cooling medium: water, water/glycol or air?	
2.6	Correct air temperature setting The higher the air temperature setting, the larger the proportion of free cooling can be. At present a setting of 25 °C is standard, but settings of 28 °C and over are also found. To save energy, the air temperature setting should be geared to the equipment specifications. This does not require any additional investment. If the proportion of free cooling is increased in this way, a saving on energy consumption for climate control of 10% or more can be achieved.	If the cooling is based largely on free cooling, the climate control system is also less vulnerable to malfunctions in compression cooling equipment.	What is the air temperature setting in the ICT rooms?	The payback period is minimal because of the small investment.
2.7	Wide humidity range The larger the humidity range allowed, the less energy is needed for humidification or dehumidification. To save energy, the humidity range should therefore be geared to the equipment specifications. This does not require any additional investment, and it can yield a saving on energy consumption for climate control of a few dozen percent.	An evaporator temperature of 9 °C is advisable to prevent dehumidification.	What is the humidity range allowed?	
2.8	Placing cooling equipment outside the cooled space If the cooling equipment is sited inside the space it cools, the heat it produces also has to be cooled, thus raising the cooling load by a few percent. Wherever possible, therefore, place the cooling equipment outside the cooled space. This does not require any additional investment.		Where is the cooling equipment sited? Indicate the location on a ground plan.	

no	comments	tip	question	indication of payback period
2.9	Compartmentalizing the space into separate climate zones If the space is divided into compartments, each with its own climate control and cooling unit, this avoids a situation where the most sensitive units determine the climatic requirements for the entire space. This enables the climate and cold generation to be geared more closely to the equipment specifications, thus saving energy.		Is the available space in the building divided into compartments and the equipment sited in accordance with the climatic requirements? Is cooling applied solely to the places where the racks are? What facilities are provided to achieve this?	
2.10	SPF (Seasonal Performance Factor) The overall efficiency of a cooling system can be expressed in terms of the Seasonal Performance Factor. To calculate this, divide the total amount of heat cooled in a year (in kWh of cold) by the power consumed by the cooling system as a whole, including pumps and fans (in kWh).	The performance of a cooling unit can also be expressed as its CoP. When used in the ICT industry a CoP of 4.5 can be achieved. If the CoP is less than 3, the energy efficiency of the unit is poor.	What is the Seasonal Performance Factor of the cooling system as a whole?	

POWER SUPPLY				
no	**comments**	**tip**	**question**	**indication of payback period**
3.1	Selecting the right size of power supply Unnecessary energy consumption can be avoided by selecting the right size of power supply and emergency power supply. This involves only powering critical equipment from the UPS and basing the size of the UPS on the maximum simultaneous power consumption of this equipment. This also saves investment costs.	Selecting the right size of UPS also saves on expensive investments.	What is the UPS capacity? What is this based on? How does it relate to the actual power consumed by the ICT equipment?	
3.2	Efficient UPS The energy loss of various UPS (uninterruptible power supply) systems in practice is between 6% and 12%. Some 5% of the total energy consumption can be saved by selecting an efficient model.		What is the energy loss of the UPS system, and what has been done to reduce it?	
3.3	Central DC supply A lot of ICT equipment is connected to the AC supply from a UPS. This involves converting the voltage three times: 1. from AC to DC (in the UPS) 2. from DC to AC (in the UPS) 3. from AC to DC (in the computer power supply) Each time it is converted electrical power is lost. Integrating the UPS and the computer power supply in a central DC supply avoids two of the three conversions. The ICT equipment is then connected direct to the DC supply.	The facilities for this can be provided when fitting out the data hotel or telecom switch.	Is there a central DC supply? If so, how much of the equipment is connected to it?	

OTHER POINTS				
no	**comments**	**tip**	**question**	**indication of payback period**
4.1	Correct choice of location ICT companies typically have a large demand for power and produce a lot of heat, and this needs to be taken into account when choosing the location.	Ensure that there are enough square metres that can be utilized, and minimize the noise nuisance from the systems. Examples of a wrong choice of location for wet cooling towers are under the approach path to Schiphol Airport or near a motorway.	Does the location selected make for an adequate power supply and efficient cooling, and can equipment be satisfactorily sited inside and outside the building?	
4.2	Power management systems with regular monitoring Energy efficiency can only be improved in a targeted manner if energy consumption and output are periodically compared. This can be achieved by installing a power management system that monitors each customer and each system or room. The corresponding production figures also need to be able to be incorporated in the reports produced by this system. A power management system is needed to control energy consumption.	The reports from it can be included in management reports in the same way as reports on system availability and available and used capacity.	What power management system is being used, and what does it monitor? What kind of reporting is provided to customers and management?	
4.3	Contracts with customers Data hotels and telecom switches can influence the energy efficiency of their ancillary functions (climate control, power supply, office and lighting) themselves. In a data hotel, however, the energy efficiency of the ICT equipment – the main factor in the overall energy consumption – is determined by its customers. In order to be able to influence the energy efficiency of the ICT equipment, data hotels need to reach agreement on the matter with their customers.		What arrangements does the contract between the data hotel and the customer include concerning the energy efficiency of the equipment to be used and the use of power management?	
4.4	Energy consumption by offices and service rooms The Building Decree lays down requirements for the building-related energy consumption of occupancy areas such as offices and service rooms. For this purpose the building-related energy consumption is expressed as the Energy Performance Coefficient (EPC).		What is the EPC for the occupancy areas? Attach the computation.	

no	comments	tip	question	indication of payback period
4.5	Feasibility study of residual heat utilization The heat produced can be used for space heating using a low-temperature heating system. Whether it is feasible to supply residual heat to third parties depends on the temperature at which heat is required, the annual load duration curve of heat demand and heat production, and the additional investment required.		Has the feasibility of using residual heat in the building and/or supplying it to third parties been examined? What was the result?	