Roadmap: »Resource-efficient workplace computer solutions 2020«

Development of a lead market for green office computing

Materialeffizienz & Ressourcenschonung

Written by:

BITKOM

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

Umwelt Bundes Amt
For our Environment

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Imprint

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Content

1 Summary: Development of a lead market for green office computing

The »IT landscape« in companies, authorities and schools/colleges is currently in a fundamental state of change, which particulary affects workplace-related computer solutions. The change in office computing not only opens up new opportunities for IT users, but also for manufacturers and providers of the IT industry. New device types, such as Mini PCs, or server based concepts, such as desktop virtualization, not only offer interesting options from a business viewpoint, they also allow considerable savings potential for energy and resources.

Since the eighties the desktop PC has developed into the dominating form of workplace-related computer solutions. The current number of 26.5 million workplace computers in Germany is made up of desktop PCs (50%), notebooks (41%), thin clients (8%) and Mini PCs (1%) or so-called »nettops«, which have only been available on the market as the new device generation for a few years. Due to their possible mobile applications, notebooks in particular have rapidly gained in significance in the past few years. Moreover, there have also been powerful server based concepts, such as thin client & server based computing, for more than ten years. The latter provide the application software required for a workplace through so-called terminal servers so that a desktop PC is no longer necessary at the workplace. Merely a smaller intelligent »box«, a »thin client« that manages the data transfer between the terminal server and I/O devices, such as display, keyboard and mouse, is still required. Thus the »desktop« only appears to exist – the actual computing and storage performance takes place in the backend infrastructure. This is why we talk of »desktop virtualization« here. Desktop virtualization has for many years been a tried and trusted form of what has recently been discussed as »Cloud Computing«, and is to be specifically furthered through various cloud computing initiatives.

In addition to the potential reduction in pollution due to the use of information and communication technology (ICT), e.g. through smart grids and buildings, the production of ICT devices (PCs, etc.) and infrastructures (data centers, etc.) and their use are associated with large-scale consumption of energy and resources, which in the past has risen continuously. The 26.5 million workplace computers, which were in use in Germany in 2010, consumed about 3.9 TWh of electricity. This is more than a large-scale coal-fired power plant can produce in a year.

Based on this premise the »Material efficiency and resource conservation« project, which was promoted by the Federal Ministry for the Environment, Nature Conservation and Reactor Safety and the Federal Environment Agency (2007 – 2010), tested which computer solutions and technologies have lower energy and material consumption and offer opportunities to specifically develop lead markets for resource efficiency. It has been shown that with a view to workplace-related computer solutions thin client & server based computing in particular has high savings potential for energy and materials. On the basis of the initial scientific analysis the field of thin client & server based computing for stationary workplaces was selected as the field of observation for a dialog process between IT manufacturers, IT users, politics, authorities and science for the development of a roadmap for »Resource-efficient workplace computer solutions 2020«. In order to continuously integrate the different viewpoints and interests in the roadmapping project and involve important key players for the subsequent implementation of the roadmap at an early stage a management committee was set up, which met and exchanged ideas between September 2008 and September 2010 on a regular basis. The management committee accompanied the analysis work, which was performed by the Borderstep Institute for Innovation and Sustainability, with technical and scientific support. The management committee also drafted and adopted the roadmap.

Due to the growing significance of the service sector, the increasing computerization of branches of industry with a previously low level of computer equipment (trade, handicraft, etc.) and the political objective of providing schools and universities with better computer equipment in future, current estimations assume that the number of workplace computers in Germany will grow to about 37.5 million devices by 2020. Despite the continuous increase in the energy efficiency of the devices, the continued usage level of PCs will result in energy consumption through workplace computers continuing to grow in Germany in the next few years.

The desktop PC as an » all-round computer talent« will also be a sensible solution for individual applications in future, and for the majority of office and workplace applications Mini PCs, notebooks and in particular thin client & server based computing (TC&SBC) are from an ecological viewpoint clearly the better alternatives. However, other advantages, such as lower administration expenditure, higher security and lower total cost of ownership can speak for TC&SBC. Based on this premise and a comprehensive analysis as to why the thin client & server based computing approaches have until now only been spreading very slowly in practice despite existing best-practice applications (obstacle analysis), the »Resource-efficient workplace computer solutions 2020« roadmap was drawn up.

The aim of the roadmap is a sustainable structural change in workplace-related computer solutions in Germany by 2020. The roadmap is to be used to develop a lead market for green office computing, which is to contribute to the following economic and ecological goals:

1. Increase in the share of energy and material-efficient workplace computer solutions from 50% today to more than 60% in 2013 and 85% in 2020.[1]

2. Reduction in the average primary energy consumption (PEC) of workplace computers in Germany from 500 kWh per year today (incl. production and terminal server share, without a monitor) to 400 kWh in 2013 and 200 kWh per year in 2020.

3. Reduction in the average product weight per workplace computer (incl. server share) of 5.2 kg today (without a monitor) of 20% by 2013 and at least 50% by 2020.

The 39 measures in the roadmap serve to achieve the stated objectives. The implementation of the roadmap measures would result in savings of 29.4 TWh of primary energy, savings in electricity costs of €2.75 billion as well as a reduction in CO_2 emissions of 5.5 million t and 245,000 t of computer material by 2020. The implementation of the roadmap can also entail the successful development of a rapidly growing market for »green« technologies of the future and the positioning of Germany as a green IT pioneer in terms of international competition.

The wide range of measures and the resources required for their implementation show clearly that the implementation of the roadmap can only succeed in a concerted action of ICT manufacturers, ICT users, politics and science. Thus in order to implement the roadmap the founding of a »Green office computing« initiative in the form of a public/private partnership has been proposed. The initiative - as a network of partners that would like to support and promote resource-efficient computer solutions in companies, authorities and educational establishments – serves as an institutional »platform« that handles the development of the strategic partnership and the coordination of the implementation of the roadmap measures. The initiative should be sponsored by the Federal government, ICT providers, ICT users (committee of IT managers, CIO colloquium, etc.), industry associations like BITKOM and scientific institutions.

1 Computer solutions that consume at least 20% less energy and have at least 20% less terminal weight than an average workplace computer solution in 2010 are referred to here as »energy and material-efficient«.

2 Introduction

In today's information and knowledge society, information and communication technology (ICT) forms the technical basis and makes as a dynamic field of innovation a considerable contribution toward economic development. At the same time, the ICT can make an important contribution toward the saving of natural resources in many economic and social areas, e.g. through the intelligent management of power networks and buildings or through telephone and video conferences.

In addition to the potential reduction in pollution through ICT, the production of ICT devices (PCs, notebooks, TVs, etc.) and infrastructures (data centers, mobile phone networks, etc.) and their use are associated with large-scale consumption of energy and resources, which in the past has risen continuously. If according to Cremer et al. (2003) ICT-related power consumption in Germany was determined to be approx. 38 TWh in 2001, it was already approx. 55 TWh in 2007 according to Fraunhofer IZM/ISI (2009). This corresponds to about 10.5% of German power consumption. The highest growth is to be observed in ICT infrastructures, i.e. in servers and data centers as well as in fixed-line networks and mobile telephones. However, terminals still have the comparatively largest share of ICT-related power consumption. And workplace computers are responsible for a sizeable proportion of this. The approx 26.5 million workplace computers that are currently in use in Germany in companies, authorities and educational establishments (schools and universities) consume about 3.9 TWh of electricity every year (Fichter, Clausen, Hintemann 2010, 21).

Based on this premise the »Material efficiency and resource conservation« project, which was promoted by the Federal Ministry for the Environment, Nature Conservation and Reactor Safety and the Federal Environment Agency (2007 – 2010), tested which computer solutions and technologies have special potential for energy and material efficiency and offer opportunities to specifically develop lead markets for resource efficiency. It has been shown that with a view to workplace-related computer solutions thin client & server based computing in particular has high savings potential for energy and materials (Fichter/Clausen, 2008a; Fraunhofer UMSICHT 2008).

On the basis of the initial scientific analysis and the potential for saving resources found in the ICT sector and particularly in the field of workplace computers, the field of thin client & server based computing for stationary workplaces was selected in consultation with the funding authorities, the Federal Environment Ministry and Federal Environment Agency, as the field of observation for a dialog process between IT manufacturers, IT users, politics, authorities and science for the development of a roadmap for »Workplace-related computer solutions 2020«.

Integrated roadmapping is a proven method of detecting strategic opportunities and risks at an early stage and is used to bundle numerous individual topics, to identify obstacles and action options as well as to specify priorities and measures in a defined field of technology or application. The goals of the roadmapping project »Resource-efficient workplace computer solutions 2020 – Development of a lead market for green office computing« were:

- determine the medium to long-term energy and material efficiency potential of thin client & server based computing (TC & SBC),
- identify the possible uses and obstacles of TC & SBC, particularly in small to medium-sized companies, authorities, educational establishments and private households,
- develop lighthouse projects for the application of thin client & server based computing,
- prepare common scenarios for workplace-related computer solutions,

- prepare an industry roadmap with the time horizon of 2020 and with specific measures and milestones for the development of the lead market for Green office computing.

In order to continuously integrate the different viewpoints and interests of the value-creation chain for workplace-related computer solutions in the roadmapping project and involve key players for the subsequent implementation of the roadmap at an early stage a management committee[2] was set up, which met and exchanged ideas between September 2008 and September 2010 on a regular basis. The management committee accompanied the analysis work, which was performed by the Borderstep Institute for Innovation and Sustainability, with technical support. The management committee also drafted and adopted the roadmap.

The two-year roadmapping process consisted of the following steps:

- Environmental assessment of various options for workplace-related computer solutions

- Selection of relevant branches of industry and sectors for the development of resource-efficient potential in workplace computers

- Analysis of the selected key sectors (small service companies, Federal authorities, schools, home office)

- Use cases and determination of best-practice applications of resource-efficient workplace-related computer solutions (TC&SBC, etc.)

- User surveys (incl. a survey of all Federal authorities) and system houses/resellers on the barriers to using TC&SBC

- Analysis of technological, market and social trends

- Implementation of four Delphi surveys to estimate future trends

- Development of a business-as-usual scenario of »Workplace-related computer solutions 2020«

- Preparation of a roadmap »Resource-efficient workplace computer solutions 2020«, adoption of the roadmap by the management committee in September 2010

- Derivation of a Green IT scenario on the basis of the roadmap and determination of the resource savings potential through the implementation of the roadmap

- Preparation of the results (roadmap, best practice, etc.) for the publication and implementation of transfer workshops.

This document presents the results of the roadmapping process as well as the »Resource-efficient workplace computer solutions 2020« roadmap.

2 The members of the roadmapping management committee are listed in the imprint of this publication.

3 Potential of newer computer solutions for workplaces

The approx. 26.5 million workplace computers that are currently in use in Germany in companies, authorities and educational establishments (schools and universities) consume 3.9 TWh of electricity every year (Fichter, Clausen, Hintemann 2010, 29). This is more electricity than a large-scale coal-fired power plant can produce in a year. The outcome for 2010, together with the energy that is needed to produce the devices, is a primary energy requirement for the production and operation of workplace computers in Germany of 13.2 TWh. The current number of workplace computers is made up of PCs (50%), notebooks (41%), thin clients (8%) and Mini PCs (1%) or so-called »nettops«, which have only been available on the market as the new device generation for a few years.

With a view to stationary computer workplaces all the tests and information that have been available until now indicate that thin client & server based computing has ecological advantages to offer compared with the »classic« desktop PC (Fraunhofer UMSICHT 2008; Clausen et al. 2010). This is clearly and unequivocally substantiated with a view to the better energy efficiency of thin client & server based computing (TC&SBC). Whereas a PC with an average office use per year has accumulated primary energy consumption (PEC) of approx. 700 kWh (without a monitor), notebooks, Mini PCs and thin clients (incl. server share) have just about half the consumption. The average annual primary energy consumption (PEC) of a workplace computer, determined for all device classes, is currently 499 kWh (cf. Table 1). As the table shows, a similar picture also results with regard to material input.

To date there has been hardly any data available concerning the efficiency of raw materials in computer solutions, so a concluding assessment cannot be made here. Nonetheless, the notedly low terminal weights (incl. server share) of the TC&SBC compared with desktop PC solutions show that TC&SBC solutions also have material efficiency advantages to offer[3]. To date there has also been no evidence at all that this miniaturization in the terminals is associated with ecological disadvantages, such as increased pollutant concentrations, increased consumption of especially scarce metals or worse recycling effectiveness.

With an eye to the product service life, all the tests available to date also suggest that the actual use of thin clients is at least not shorter, but very probably clearly longer than with desktop PCs. This is connected with the lower software-related ageing of the devices. Furthermore, the previously known practical examples from the introduction of TC&SBC show that the existing stock of desktop PCs is usually not fully replaced by thin clients all of a sudden, but that the »migration« is successive and any PCs that can still be used are in many cases converted into pseudo TCs (Clausen and Fichter 2009). Fears that the energy efficiency advantages of the TC&SBC are to be counteracted by material efficiency disadvantages due to prematurely decommissioned PCs seem not to be confirmed.

3 Unique ecological advantages can be seen in the avoidance of pollutants as well as in the material input (weight) in the final product. As comprehensive research during the roadmapping project has shown, data on the (accumulated) raw material consumption during the product lifecycle of computer terminals and servers has until now only been very fragmentary. Detailed and scientifically founded figures about electronic components in particular as well as data about the consumption of raw materials in the manufacturing process are missing. Data for younger generations of devices, like Mini PCs, is completely missing. Resource assessment of the computer types analyzed on the basis of the »Accumulated raw material consumption« (ARMC) indicator would be desirable, because with regard to ecological directional safety this indicator is undoubtedly more significant than the material weights and material composition of the final products. However, due to a lack of data a scientifically reliable calculation of ARMC values could not be performed. In agreement with the professional accompaniment provided in the Federal Environment Agency the calculation of ARMC values or comparable indicators was not required and the consideration of material efficiency was concentrated on determining the material weights of the terminals (total weight in kg) as well as their compilation (proportion by weight of electronic components, metals, plastics and power supply units in kg). As far as the (accumulated) raw material consumption was concerned, the roadmapping project revealed a considerable need for research for the future..

Due to the growing significance of the service sector, the increasing computerization of branches of industry with a previously low level of computer equipment (trade, handicraft, etc.) and the political objective of providing schools and universities with better computer equipment in future, current forecasts assume that the number of workplace computers will grow to about 37.5 million devices by 2020 (Fichter, Clausen, Hintemann 2010, 20). Despite the continuous increase in the energy efficiency of the devices, the continued usage level of PCs will result in energy consumption through workplace computers continuing to grow in Germany in the next few years. Greater use of energy-saving device classes, such as notebooks, thin clients and Mini PCs, which as far as performance is concerned are completely adequate for the majority of all office applications, could on the other hand contribute toward considerable savings in energy and material. Therefore, the goal should be a sustainable structural change in workplace-related computer solutions in Germany by 2020 as well as the development of a lead market for »Green office computing«.

Table 1: Comparison of various types of workplace computers

	Workplace computers in Germany 2010				
	PC	Mini PC	Notebook	Thin Client	Total
Stock of computer terminals					
Number of devices	13,000,000	300,000	11,000,000	2,200,000	26,500,000
Structure of stock in percent	49.1	1.1	41.5	8.3	100,0
Energy consumption					
Electric power consumption per computer terminal in kWh p.a. (without display etc.) during utilisation phase	201	74	65	43	
Energy consumption per computer terminal in kWh p.a. during utilisation phase (PEC)	549	202	177	117	
Energy consumption in production phase (PEC) per terminal in kWh	584	285[4]	340	141	
Useful life in years	5	5	4	8	
Energy Consumption in production phase per year of use in kWh (PEC)	117	57	85	18	
Energy consumption in production phase and during utilisation phase per device p.a. in kWh (PEC)	666	259	262	135	
Total energy consumption of using central IT-ressources p.a. in kWh per computer workplace (PEC)	32	32	32	249	
Energy consumption in production phase and during utilisation phase per computer workplace p.a. in kWh (PEC)	698	291	294	384	499
Material usage					
Weight of device in kg	8	2	2.2	1.5	
Weight of notebook dockingstation (use with 50 % of notebooks) in kg			0.2		

4 In the calculation of the accumulated energy consumption (PEC) for Mini PCs the data of a notebook without a monitor was used, because notebook components are usually used here.

	Workplace computers in Germany 2010				
	PC	Mini PC	Note-book	Thin Client	Total
Total product weight in kg	8	2	2.4	1.5	
Proportional weight of terminal server (25kg) per workplace in kg[5]	0.07	0.07	0.07	0.55	
Weight terminal, percentage server and infra-structure per computer workplace in kg[6]	8.07	2.07	2.47	2.05	5.18
Climatic impact					
CO2 emission factor of the German electricity mix in g/kWh	580	580	580	580	580
Global warming potential through power consumption in CO2 equivalent p.a. per computer workplace in kg	122.9	49.4	44.1	75.4	85.4

Source: Calculation and compilation of the data by the Borderstep Institute 2010 (basis: sources in the appendix, market analyses, expert surveys, in particular Delphi surveys).

Economic comparison

At just under 45% administration costs are the highest proportion of total computer costs per workplace (Knermann and Köchling 2007). As administration in server based computing can be carried out more efficiently, Knermann and Köchling (2007, also Knermann 2010) calculate the cost benefits of TC&SBC to be approx. 25% compared with well managed PC workplaces.

Hardware costs and service life are a second cost factor. The hardware costs for notebooks are higher than for simple PCs or even thin clients. On the other hand the service life of notebooks is with approx. 4 years lower. In other words, the functional advantage of mobile use costs money.

Thus, in comparison with other computer solutions TC&SBC clearly has more favorable costs.

Power consumption and power costs in comparison

Even if power costs only account for a smaller part of the total computer costs per workplace, their share has increased constantly in the past few years. In all probability power costs will also continue to grow in future, so an IT decision maker should pay greater attention to this aspect of IT procurement. The following comparative calculation refers to an IT decision maker, who in 2011 has to decide about the new procurement of workplace computers for the start of 2012. In this case, it is assumed that not only PCs but also Mini PCs, notebooks or thin client & server based computing can be used and procured. As far as the power consumption of the computer terminals and the energy efficiency of the central IT (terminal servers, etc.) are concerned, there is a wide range within the various device classes so that the average values of new devices in the respective classes can be used here for a comparison. When it comes to making a procurement decision, there is of course also the option of selecting the most energy-efficient computers in the respective device classes.

5 Since a terminal server manages several workplaces, the weight is only allocated on a pro-rata basis.
6 This means the weight of terminals that are required for an individual workplace. This does not include the weight of the terminal, but the pro-rata weight of the terminal server as well, which is used by this workplace.

In the following comparative calculation average power consumption in idle mode of 63 watts was assumed for a PC, 28 watts for a Mini PC and notebook as well as 11 watts for the thin client. Power consumption in network standby is 8 watts for a PC, 3 watts for a Mini PC and notebook as well as 2 watts for a thin client. A further assumption is that of average office use for the computer (1920 operating hours per year; 3276 hours in network standby for a PC, Mini PC and TC and 728 hours for a notebook; the remaining hours are in »pseudo off« mode (2 watts for a PC, 0.7 watts for a Mini PC and TC) or fully off (notebook)[7]). Average values were also assumed for terminal servers and data center equipment (annual power consumption of terminal servers 1894 kWh, PUE 1.9).

It can on the basis of the described starting point and assumptions be seen that for a review period of 3 years (2012 to 2014) the power consumption of an average computer workplace is 576 kWh if a PC is used. On the other hand, if a functionally comparable Mini PC is used for the same workplace, power consumption is reduced to almost half (303 kWh). The use of an average notebook (276 kWh) and the use of thin client & server based computing (271 kWh) saves even more power. In comparison with an average PC more than 100 kWh per computer workplace can thus be saved per year through thin client & server based computing. About €21 per workplace and per year can be saved with an industry electricity price of €0.20 in 2012 and €0.21 and €0.22 in 2013 and 2014. In addition to the business advantage, an important contribution is at the same time made to climate protection with the power savings.

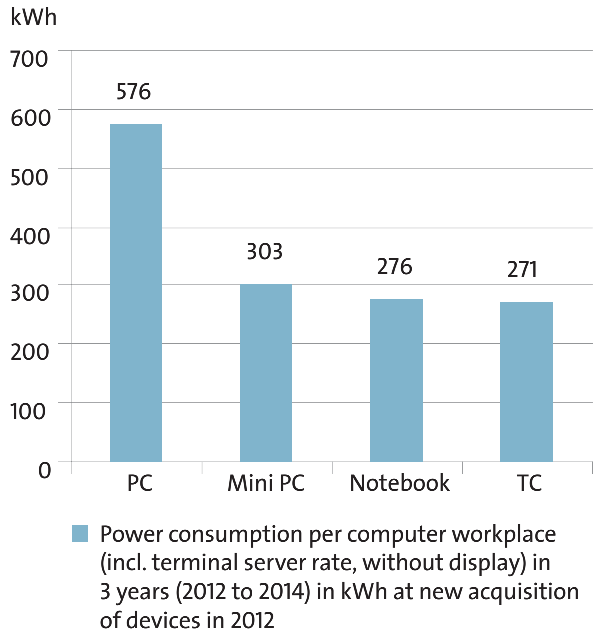


Figure 1: Power consumption of various types of workplace computers in 3 years; Source: Internal calculations.

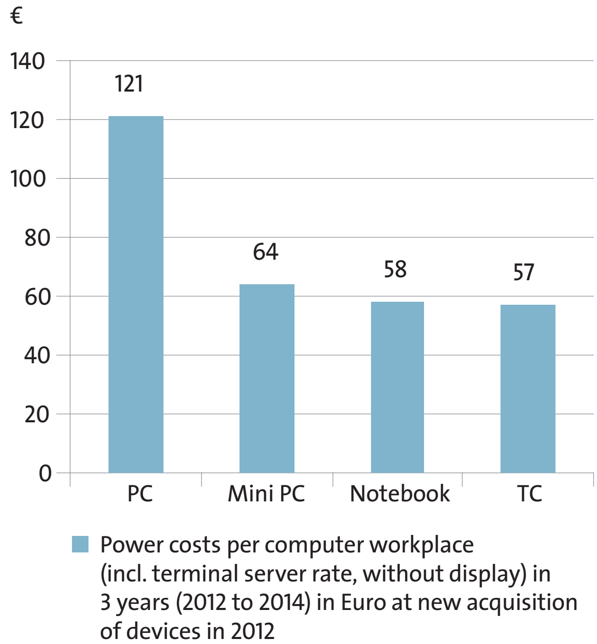


Figure 2: Power costs of various types of workplace computers in 3 years; Source: Internal calculations.

7 The service times were estimated with due regard to the different figures from Fraunhofer IZM and ISI (2009); TCO Development (2007) as well as from Schlomann (2005) and coordinated with the management committee.

Use case: TC&SBC in a small to medium-sized industrial company

In an internationally active, small to medium-sized company with 800 employees IT can be managed by only 5 persons. The reason for this lies in a consequent centralization strategy, which has been pushed forward since 2004. At that time, the IT team transferred most applications from local PCs to a central server farm in head office. Subsequently, 200 of the then 350 PCs could be replaced by thin clients, which also improved the availability of the workplaces. If in the past a PC failed, it had to be put back into operation through support visits and onsite service. Today every branch office has a thin client in reserve, which the users can access themselves if required and immediately continue working.

The desktop environment has in the meantime about 500 thin clients. In addition, there are also 40 notebooks and 60 stationary PCs, the use of which is limited to specific usage scenarios, such as CAD, desktop publishing or individual machine control systems. Thin clients are also to be found in the approximately 50 home workplaces of the small to medium-sized company.

The fan-less thin clients are not only used in the office environment, but also in production. Thanks to their metal casing the devices can themselves survive in severe production environments, such as in welding units. In compact working environments the manufacturing company uses a thin client that is integrated in a TFT monitor. The company uses the high graphic performance of modern thin clients in the preparation in particular of parts lists, in which CAD drawings are simultaneously shown on a second monitor.

The administration costs for the IT infrastructure have been halved in the new desktop environment, because time-consuming activities, such as support visits and onsite service, but also anti-virus measures and software updates incl. patches, are no longer applicable. The energy costs of the desktop environment have also fallen. Energy consumption, including the appropriate server and cooling section in the data center, fell by 52% and the company saves approx. €6,700 annually. Furthermore, the energy costs, which the local servers had caused in the branch offices, as well as fuel consumption for service visits, are no longer applicable.

Use case: Thin clients in the education network of Bremerhaven

The administrative schools office of Bremerhaven, Germany is responsible for the maintenance and service of the IT infrastructure of Bremerhaven schools. This comprises a total of 60 terminal servers, central software provision and support for the total of 1,500 computer workplaces in the network. These are divided into 700 thin clients and 800 desktop PCs, which are operated as clients in the network. The objective of the conversion to thin clients is to minimize administration costs.

Thin client workplaces in a school in Bremerhaven, Photo: IGEL

The drive-less thin clients do not offer a target for attack by viruses, and unwanted installations are not possible. Indirect savings also result from the fact that the thin clients do not work without their server connection. Since this is known to all pupils, the normal classrooms need not be specially protected against theft. Working with the fan-less devices also benefits the working atmosphere, because the noise levels are in comparison lower and the air in the computer room is better.

The other advantages, such as lower energy consumption and higher security, will considerably increase the proportion of thin clients in schools in future. There could already be more thin clients than PCs in the Bremerhaven education network in a few years. State-of-the-art models are already multimedia-capable and offer an increasingly wide range of uses and highly efficient management solutions that save further costs.

However, the Bremerhaven Schools Administration not only uses thin clients in a pedagogic field, but also in school management. In 39 schools there are between 3 and 4 thin clients in the office and in the headmaster's offices. Maintenance and support of the system is performed centrally by one service provider. Another advantage of the administration is that no data is lost even in the case of theft, because there is no local storage option in the thin clients. Onsite service is no longer necessary thanks to the remote maintenance option. Support costs are about 20% lower than before and energy costs in the schools are falling, because the TCs only have about 25% of the power consumption of PCs. The Schools Administration estimates that the devices, which are less expensive to buy, also amortize in about 3 years despite the additionally operated data center with considerable energy consumption.

Use case: TC&SBC in a tax consultant's office

In 2001 a tax consultant's office converted to server based computing without immediately replacing in this context the PCs with TCs. The reason for the conversion was the constant need to have time-consuming software updates performed on all computers as well as on the other hand the subsequent necessity to continuously purchase more powerful PCs. Both were no longer required due to the fact that the applications were transferred to servers.

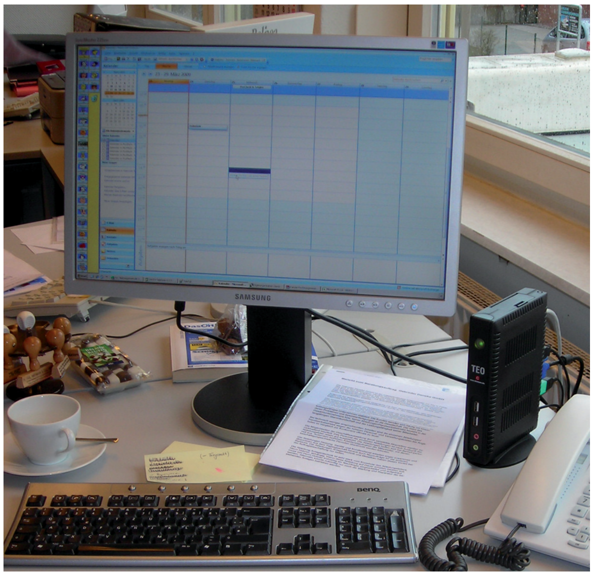


Photo: Borderstep

A network with a central database and data backup as well as a mail server has already been available since the nineties. The new terminal servers are also to be found in an ancillary room on the ground floor of the tax consultant's office. At present the server room fulfills the following functions:

- Server based computing: 2 energy-efficient servers with a consumption of approx. 50 watts each are used as redundant terminal servers.
- E-mail: The mail server is still of conventional design and uses approx. 200 watts of electricity.
- Data storage and data backup: data is stored in a data server with eight highly efficient hard disks.
  This device also organizes backups on six mobile hard disks, which are exchanged on a daily basis.

8 The 10% UPS value corresponds to the normal degree of efficiency of a small UPS system of about 90%. The 30% value for the air conditioning was estimated from the experience of the tax consultant's office and takes into consideration that the air-conditioning device only runs approx. 50% of the time.

The power supply is secured by means of a UPS. Air-conditioning equipment switches on automatically when the temperature is too high. The capacity that currently has to be allocated in the server room to the individual function »server based computing« is about 100 watts of the server capacity plus 10% for UPS and plus approx. 30% for air-conditioning[8], i.e. a total of about 140 watts. Distributed over 25 workplaces, the data center share of server based computing per workplace requires about 50 kWh per year. Thin clients that weigh about 1 kg and have power consumption of approx. 22 kWh/a are gradually replacing the PCs, which have consumed per workplace approx. 140 kWh plus the network share.

Use case: Thin clients for the Federal Institute for Materials Research in Berlin

The Federal Institute for Materials Research and Testing (BAM) has three locations in Berlin and about 1,800 employees. Thin clients have already been in use in division VIII.2 »Non-destructive damage assessment and environmental measurement methods« of the BAM since the mid-1990s. The division started using thin clients (TC) with a Linux server in 1996. The initiative for this originated from the head of division, who had heard of thin client solutions at an event and as a Linux fan was very impressed with this option. The main reasons for the introduction of thin clients were on the one hand the noiselessness of the devices and on the other hand the conviction »that not everyone should be an administrator, because that takes up too much working time«.

The first Windows servers and further thin clients were purchased in 2000. About 40 thin clients as well as 15 PCs and 20 notebooks are currently in use in the division. 23 of the total of 40 TCs are nine years old. The applications for the thin clients and the other terminals are provided on a total of three terminal servers. After initial problems with individual graphics cards were eliminated through replacement, the servers and TCs have according to the thin client manager of the division, who also supports the Windows servers, until now worked without a single failure. The greatest advantages of using TCs are to be seen in the:

- noiselessness due to the lack of fans,
- great flexibility of use of the software that is installed once only on the server (the user infrastructure does not have to be changed),
- variability in the assignment of workplaces (e.g. for students),
- fail-safety and speed, with which the terminals can be exchanged.

Its IT support time has been reduced from about six hours to approx. three hours per week due to the use of TCs. The largest disadvantage is to be seen in the risk of failure of terminal servers, at least when no redundancy is ensured. According to the estimation of the TC manager, the long lifespan of TCs, their low susceptibility to repair and low administration expenditure result in lower costs (total cost of ownership) than in desktop PCs.

Use case: Thin clients in the Sparkasse (savings bank) organization

Only four years after the start of the rollout the system house of the Sparkasse organization has in the meantime installed 142,000 thin clients for its customers, the Sparkassen, and state banks. In 2010 this was the largest installation volume of thin clients in the world. A further 60,000 are to follow by 2011. The offer makes it easier for Sparkassen to convert from expensive and maintenance-intensive PCs to low-priced thin clients, because all applications are provided via terminal servers. Thus, the thin clients themselves manage with minimal CPU performance and only need a flash memory instead of a hard disk. The security level increases, whereas its costs and outlay fall.

An additional plus point is that thin clients hardly create any waste heat. They do not need a fan, are quiet to operate and consume considerably less power. In 450 workplaces the savings in energy costs alone total on average €15,000 per year. Thus the technology is best suited to reduce the cost and work outlay for a complex IT infrastructure:

Photo: Borderstep

On the one hand the existing equipment in the workplaces must be replaced much less frequently, because performance is hardly required of the terminals - application software updates, which generally require higher performance, are only installed on the server. On the other hand the time required of the IT manager is much less, because the manager performs the entire maintenance and administration centrally. If a new application is configured on the server, it is simultaneously available to all users – even users in remote locations can be connected.

4 Obstacles and prejudices

The transition from a desktop PC to server based computing is a fundamental system change in IT with an essential impact on workplaces and work processes. It also requires other competencies in operational IT and calls for the decision makers of IT projects to have the courage to initiate fundamental system changes. In this context, it is also important that the risk of a malfunctioning IT is currently classed by most companies as a life-threatening risk (EIU 2007) and is accordingly handled with caution. The consequence that it is associated with a large variety of obstacles is not least due to the significance of system change. A series of prejudices against server based computing have also been propagated, which mostly originated from experiences with the first device generations, but which also have an impact on opinion making today.

Decision making and organization

In many cases, the decision makers in companies, administration and other organizations are not correctly informed. Not only does the suboptimal information of the manufacturers and providers of thin client & server based computing (TC&SBC) play a role in this regard, the previous marketing for classic PC solutions occasionally also promotes prejudices against TC&SBC. The lack of clarity on the part of decision makers with regard to cost-reducing effects is often particularly crucial in this respect.

The comparatively limited distribution of TC&SBC in many branches of industry results in further uncertainty among the responsible decision makers. In a great many larger organizations, e.g. authorities, there is also a separation of responsibilities in IT management between central IT (data centers, provision of central services, etc.) and local IT tasks, such as the responsibility for terminals or department-specific applications. This complicates the implementation of integrated TC&SBC solutions, because to some extent people fear losing responsibilities and decision-making powers here.

In many workplaces TC&SBC is also associated with change. However, neither advantages nor actual disadvantages are known to the employees ex ante - so for them a feeling of uncertainty may possibly arise. This can be a reason for resistance on the part of the employees against the introduction of TC&SBC.

Hardware

The most common prejudice against TC&SBC is in the poor assessment of the graphics and media performance. The reason for this is the fact that the first generations of TCs did not to some extent have a sound card and could not e.g. be used in languagec lasses in schools, despite there being popular and good software offerings for this purpose. In the current TC&SBC solutions the identical performance for most workplaces as regards both graphics and media is a success.

Despite the expected long service life of between 8 and 10 years, only some manufacturers give a 3-year warranty as well as the option of a 5-year extension. Spare parts supply for 5 years is not guaranteed by all manufacturers. The high potential service life of the devices can therefore not always be used as an argument for customers with long service life expectations (SME). Very long service lives should be supported by as many manufacturers as possible by long warranties and a good concept of upgrade options and spare parts supplies.

Application software

In the particular case of special software with low sales figures there is often a lack of terminal server capability. For this reason a general conversion to server based computing has until now not been feasible in many companies and also e.g. in the field of scientific applications. As a result of desktop virtualization it has since 2009 already been possible to overcome such obstacles.

Operating systems and standardization

In many cases, there is proprietary hardware and very different types of hardware. The operating system (mostly Windows embedded or Linux), but also vendor-specific management software or firmware, does not always support the hardware of several manufacturers, and the customer is thus either bound to the manufacturer or has to run several operating systems in parallel.

Operating systems and management software of various TC manufacturers are disparate. Certain individual functions, which facilitate the operation and administration of large stocks of devices, are to some extent not available (or have only been available for a short time). From the customer's viewpoint this circumstance is partly seen as a problem, especially if device stocks have to be taken over during mergers and acquisitions. However those customers, who require simple (and often especially resource-efficient) systems for special applications, would also not be helped by a standardization of the systems at a high level.

Know-how in the IT sector

Despite a clearly increasing level of competence in this field, a great many system houses are still not familiar with TC&SBC and have little know-how and experience. And they also lack qualified specialists. This considerably intensifies the uncertainty of decision makers in user companies, because in many cases long-standing, stable and good relationships exist between the companies and the system houses that provide support. Many companies would very much like to implement the important and high-risk system change with a partner who is well known to their company. The lack of competence on the part of many system houses is ultimately a significant obstacle.

5 Trends and relevant factors of influence

How will the energy and material input of workplace-related computer solutions develop in Germany by 2020? To answer this question it is first of all necessary to clarify which factors influence the energy and material input of workplace-related computer solutions. A distinction should be made here between direct and indirect factors of influence. On the basis of expert interviews and the analysis work of the roadmapping project it is possible to accept the following direct factors of influence as relevant:

Direct factors of influence

Computer equipment for stationary workplaces

- Number of stationary computer workplaces in Germany.
- Equipment structure of computer workplaces (percentage of the respective computer types)

The result of these two factors is the:

- Number of respective computer types (in units) for stationary workplaces in Germany.

Forms of software provision

It can be approximately assumed for early 2010 that thin clients must still be fully run under server based computing (SBC) and that 90% of PCs, Mini PCs and notebooks will work with local software, i.e. software running on the terminal and that about 10% will work in the cloud, i.e. in the Internet. However, the previous form of software provision will change in the future. Thanks to concepts such as Hosted Virtual Desktop (HVD) and the growing use of Software-as-a-Service (SaaS), additional options of central software provision, which will also be increasingly used on PCs, Mini PCs and notebooks, will be added to the previous form of server based computing. This will have consequences for the calculation of energy consumption and material input of offline-capable devices, such as PCs, Mini PCs and notebooks, because these will also make use of central computing and storage resources to an increasing extent. Thus, one central factor of influence for the environmental use of workplace-related terminals is:

- the usage ratio of local software to centrally provided software (SBC, HVD, SaaS).

Energy and material input of computers and data centers

- Production: Average accumulated primary energy consumption (PEC) for the production of the respective terminal in kWh
- Average service life per terminal in years
- Utilization phase: Energy consumption per terminal p.a. in kWh (for defined usage scenarios: operating hours per year, power consumption in various modes (operation, standby, off) etc.).

The energy consumption of the data center must be taken into consideration for centralized software provision on a pro rata basis. Direct factors of influence here are:

- Average number of clients per terminal server
- Virtualization degree of terminal servers (number of virtual servers per physical server)

- Average energy consumption per terminal server p.a. in kWh (for defined usage scenarios: operating hours per year, power consumption in various modes (full load, idle, off). The fact that unused terminal servers can in future be increasingly used for other applications or automatically shut down is taken into account here
- Average energy consumption required to produce a terminal server
- Average service life per terminal server in years
- Average energy requirement of the data center infrastructure, expressed in DCiE or PUE

As far as material input is concerned, direct factors of influence here are:

- Product weight per terminal and terminal server in kg or g
- Pro rata weight of the most important material classes (electronic components, plastic parts, metal parts, power supply unit) in %.

Indirect factors of influence

The above mentioned direct factors of influence have an immediate influence on energy consumption and the material input of workplace-related computer solutions. However, their characteristics depend in turn on other factors, which indirectly influence the environmental use of computer solutions. Factors of influence, which have a considerable impact on the direct factors of influence presented above, are to be seen and included as indirect factors of influence. The identification of these so-called indirect factors of influence was done in a systematic way. And a distinction was made between the following relevant influencing dimensions:

- Social factors of influence
- Political factors of influence
- Market factors of influence
- Technological factors of influence.

Central factors of influence were identified during research, queries among the management committee of the roadmapping process and during the Delphi surveys (cf. section 6). Below is a list of the identified indirect factors of influence (trends and events) and an estimation of how these affect the direct factors of influence. Only indirect factors of influence, which have a positive or negative impact on the direct factors of influence, were included in Table 2 below. Indirect factors of influence, for which a neutral impact can be assumed, were not included in the table, because they do not cause changes. Particularly relevant factors of influence (key factors) were discussed and chosen in the management committee of the roadmapping project.

Table 2: Overview of the impact of indirect key factors on central indicators (direct factors of influence) of the energy and material requirements of workplace-related computer workplaces

Indirect factors of influence (trends and events)	Impact of trends and events on....			
	Number of computer workplaces and devices	Demand for specific computer type	Energy consumption per computer workplace	Material input per computer workplace
⬆ = increases ⬇ = reduces				
Social factors of influence				
Number of schoolchildren falls from approx. 11 million in 2010 to approx. 10 million in 2020[9]	⬇			
Decrease in the working population by about 1 million.	⬇			
Decrease in the number of employees in public service	⬇			
More fluent changes between working and private life	⬆	⬆ Mobile devices / Location-independent solutions ⬇ PC/Mini PC		
Awareness for climate change and shortness of resources is growing (»Everyone has to do their part!«)			⬇	⬇
Political factors of influence				
Increasing investments in education: Number of school computers: 1.5 million (2010), 2.0 (2013), 2.5 (2020)	⬆			
Tightening-up of the requirements for standby			⬇	
Tightening-up of the requirements for ecological design			⬇	⬇
Computer workplaces (even lower noise levels)		⬇ PCs		
Increase in public R&D resources for »Green IT«		⬆ Notebooks, Mini-PCs, TCs ⬇ PCs	⬇	⬇
Increase in subsidies, spread of »Green IT«		⬆ Notebooks, Mini-PCs, TCs ⬇ PCs	⬇	⬇
Market factors of influence				
Tertiarization: Decline in number of employees in sectors with low computer quota (e.g. construction) in favor of service sector	⬆			
Computerization of sectors like trade and handicraft (equipped to date with few computers)	⬆			

9 Cf. Federal Statistical Office of Germany (2006): population of Germany until 2050, 11th coordinated population projection, p. 19 f.

Indirect factors of influence (trends and events)	Impact of trends and events on....			
	Number of computer workplaces and devices	Demand for specific computer type	Energy consumption per computer workplace	Material input per computer workplace
Trend toward mobile working		↑ Mobile devices / Location-independent solutions ↓ PC/Mini PC		
Increasing substitution of PCs with notebooks, because mobile, powerful, save space and energy		↑ Notebooks ↓ PCs	↓	↓
Mini PCs or nettops increasingly replace PCs		↑ Mini PC, Nettop ↓ PC	↓	↓
Hardware prices continue to fall, but more slowly than before	↑			
Development of the network for mobile computer use		↑ Mobile devices / Location-independent solutions ↓ PC/Mini PC		
Increasing bandwidths in the network infrastructure		↑ Notebook, TC ↓ PC/Mini PC		
Trend toward smaller form factors (»smaller, lighter, thinner«)			↓	↓
»Hunger for computing power« increases with graphics, e.g. through larger, high-resolution monitors, video and 3D applications		↑ PC	↑	↑
Readiness for »external« data storage is growing		↑ TC ↓ PC/Mini PC		
Sensitivity for data protection and security is on the increase		↑ TC		
Increasing demand for use-based computer performance		↑ PC/Mini PC		
Number of available applications on servers is increasing		↑ TC		
Market for Hosted Virtual Desktop is expanding rapidly		↑ TC		
Rapid increase in Software-as-a-Service (SaaS)		↑ TC		
Increase in parallel operation of private notebook and business TC	↓	↑ Notebook ↓ PC/Mini PC		
Increase in new workplace concepts (shared desk, etc.)		↑ Notebook, TC ↓ PC/Mini PC		
Public procurement is becoming a pull factor for Green IT		↑ Notebook, PC/Mini PC ↓ PC	↓	↓

Indirect factors of influence (trends and events)	Impact of trends and events on....			
	Number of computer workplaces and devices	Demand for specific computer type	Energy consumption per computer workplace	Material input per computer workplace
Increase in energy and relevant raw material prices is above the inflation rate			↓	↓
Technological factors of influence				
Increasing miniaturization (semi-conductors, cable connectors, power supply units, etc.)			↓	↓
Increase in the use of notebook components			↓	↓
Components are becoming more efficient, continuously falling power consumption (power supply units, drives, etc.)			↓	
Solid state disks (SSD) are being increasingly used instead of hard disks (HDD)			↓	↓
Increase in the use of intelligent power management			↓	
Percentage of metals in computer terminals is falling, percentage of plastics is growing				↓
Increase in the use of »toughened« TCs (powerful graphics, multimedia capability, etc.)		↑ TC		
Integration of PC computing and terminal services			↑	↑
Extension to the (battery) life of mobile devices		↑ Notebook		
Increase in the use of hardware-accelerated remote protocols in SBC and SaaS (PCoIP, etc.)		↑ TC		
New virtualization concepts			↓	↓

Source: own.

6 Delphi surveys on the development of relevant factors of influence until 2020

Delphi surveys were conducted between December 2009 and March 2010 so as to be able to estimate the development of the direct factors of influence that have been identified as relevant (power consumption of the computer terminals, etc.) until 2020. Here it was assumed that on account of the long-term observation and the specific expertise required to estimate individual factors of influence, industry and technology experts can also only make estimations that are reliable and based on plausible, objective arguments on a limited number of factors of influence. Therefore, the direct factors of influence that were identified as relevant have been split into four topics:

1. Stock and market figures for computer terminals in workplaces in Germany until 2020
2. Power consumption, weight and service life of computer terminals until 2020
3. Forms of software provision for workplace-related computer solutions until 2020
4. Environmentally relevant indicators for servers and data centers in Germany until 2020

A questionnaire was drawn up for each of the four topics and in cooperation with the management committee of the roadmapping project between four and six experts were identified for each of the four topics. The process of the Delphi survey was then as follows:

- In the first round of the survey the experts were asked to answer the questionnaire of their topic and to return it to the Borderstep Institute.

- The Borderstep Institute put the answers (trend statements, estimations, figures) for each topic together in a document and made the details anonymous (statement of expert 1, expert 2, etc.).

- The consolidated and anonymous result document of the 1st round of the survey was then sent to the experts of the respective topics again, and these experts were only informed which expert they themselves were (»Expert 1«, etc.). The people surveyed were then to re-check, and if necessary amend their own estimations in the light of the arguments and figures of the other experts and return them to the Borderstep Institute.

- The Borderstep Institute put the feedback together again and deduced on the basis of the aforesaid trend statements and numerical estimations the figures for the respective trend parameters (cf. Fichter et al. (2010). The results were made available to the experts in anonymous form.

The results of the Delphi surveys are documented in Fichter et al. (2010) in detail. The following scenarios are based on the values of central factors of influence that were determined in the Delphi surveys, whereby not all values were automatically adopted because their occurrence depends on a series of measures and events, which first have to be explicitly addressed in the scenarios. The occurrence or non-occurrence then also represents the difference between the business-as-usual scenario and the Green IT scenario.

7 Objective and function of the scenarios

The objective of the roadmapping project was to determine the resource efficiency potential of thin client & server based computing as well as additional workplace-related computer solutions and to draw up a roadmap for their development. The scenarios developed for this purpose and presented below have two functions:

1. They are used as a basis for the preparation of the roadmap »Resource-efficient workplace computer solutions 2020«.
2. The influence that roadmap measures will have on the energy and material consumption of workplace-related computer solutions in Germany until 2020 is to be calculated and presented on their basis. Thus, the scenarios are used to make the difference clear between »business-as-usual« and additional efforts on the part of politics, the ICT economy and the users. The additional efforts are mapped by the initiatives and measures of the roadmap.

Two scenarios are developed and taken into account:

1. A »business-as-usual« scenario (basic scenario), which continues previous trends (e.g. continuous increase in energy efficiency in terminals, more mobile terminals, etc.) and thus shows the impact of the motto of no change: »Keep it as it is!«
2. A »Green IT« scenario, which assumes additional efforts and initiatives, as defined in the roadmap, on the part of politics, the ICT industry and the users.

In both scenarios development is equated with the number of computer workplaces. The difference between both scenarios results from the additional energy and material efficiency measures in the Green IT scenario, which is expressed in a different computer equipment structure (more Mini PCs, more TC&SBC, etc.) and faster improvement in energy and material efficiency.

Lead question of the scenarios

The following question was formulated as the lead question for the scenarios:

How will the energy and material input of workplace-related computer solutions develop in Germany until 2020?

Definition of the period of observation

The period of observation for the scenarios is defined as follows:

- Time horizon: 2020, with an interim observation for 2013 (reference year of the Federal government for energy-saving targets in the field of Federal IT, and the process of the current legislative period)
- Geographic definition: Germany
- Area of observation for computer solutions: stationary workplaces (companies, authorities, educational establishments (schools, universities), welfare institutions, etc.), i.e. without private households.
- Functional unit: computer use in stationary workplaces.

Types of computer solutions for stationary workplaces under observation:

1. Desktop PC
2. Mini / Compact PC / Nettop
3. Notebook
4. Thin Client & Server Based Computing (incl. hosted virtual desktop (HVD) solutions and Software as a Service (SaaS) as forms of public or private cloud computing as well as incl. server based computing with desktop PCs as »fat« clients)

- System definition of computer solutions: In addition to the terminals themselves, terminal servers on a pro rata basis and the relevant infrastructure (cooling, air conditioning, etc.) are also included for all terminals, whereby thin clients depend almost fully on server-based software, whereas for other terminals a large-scale increase in the use of software from servers and from the Internet is only to be expected in the next few years.

- System definition for environmental assessment: Both energy consumption during the utilization phase and energy consumption during the device production are included for terminals and servers. Merely the energy consumption during the utilization phase is included for the data center infrastructure (air-conditioning systems, etc.).

- System side effects (e.g. omission of or reduction in office air conditioning in the case of thin clients with almost no waste heat or the reduction in traffic emissions due to mobility costs for maintenance and repair that are no longer applicable) are not taken into account.

- Due to unavailable data on raw material consumption[10] a simplified procedure, which merely includes the product weights of the devices as well as the proportional material classes (electronic components, plastic parts, metal parts, power supply units), is used when looking at material input.

The scenarios cover both qualitative descriptions (of starting conditions, factors of influence, effects of certain measures, etc.) and quantified trend parameters (number of computer workplaces in Germany, energy consumption per computer type, etc.). The energy consumption and material input of workplace-related computer solutions from 2010 to 2020 can be presented on this basis.

10 Cf. the statements in footnote 3 on p. 7.

8 Business-as-usual scenario: »Workplace-related computer solutions 2020«

The following scenario describes the development of workplace-related computer solutions in Germany from the viewpoint of 2020. It also points out the extent to which computer use has changed in companies, public administration and educational establishments (schools, universities), what effects this has on the number of workplace computers, energy consumption and material input and what trends and reasons were crucial to this.

Since 2010 the number of workplace computers in Germany has risen from 26.5 million to 37.5 million devices. This is based on three factors: On the one hand the shift of economic performance and employment figures from the primary and secondary sector to the service sector (tertiarization) has continued. This has brought about a further decline in employment figures in sectors of the economy with a low computer quota (e.g. construction) and an expansion in workplaces in the service sector. The computerization of branches of industry such as trade and handicraft, which until 2010 were still equipped with relatively few workplace computers, also caused an increase in the number of installed workplace computers. A second reason for an increase in the numbers of devices is the considerable political efforts of the past ten years to equip schools and universities in Germany with a better IT infrastructure. When it comes to school computer equipment, success has been achieved in bringing general schools up to the average level of OECD countries. A third main reason for the increase in computer terminals used in companies, authorities and educational establishments (schools, universities) is the fall in hardware prices. Although they did not fall to the extent of the previous decade, the continued »decline in prices« from 2010 to 2020 has on the whole increased sales and the number of devices installed. Contradictory trends during this time, such as the decrease in the working population by about 1 million or the fall in the number of school children from approx. 11 million in 2010 to about 10 million in 2020, could not stop the increase in the number of installed computer terminals in Germany.

Not only has the number of computers used in companies, authorities and educational establishments clearly increased in the past decade, there has also been a fundamental change in the types of computer. The percentage of the »classic« PC of all computer terminals in workplaces has fallen from about 49 % in 2010 to 31 % in 2020. Despite this decline in relative significance, the PC has acquitted itself in competition with Mini PCs, notebooks and thin clients (TCs) better than many experts thought ten years ago. This is based on two factors: On the one hand PC manufacturers with cut-price offers are at an advantage compared with other device types, and on the other hand almost all PC manufacturers offer in the meantime high energy-saving PC devices, which with power consumption in part of less than 40 watts in idle mode (new devices in 2020) already come very close to average Mini PCs (25 watts) and average notebooks (25 watts).

The expansion of telecommunications networks for mobile computer use and substantially increased bandwidths in the network infrastructure have supported the trend toward mobile working as well as »more flowing« transitions between private and working life and made the notebook with its percentage of all stock devices the forerunner as early as 2013. This top position has since been stabilized at just above 45%. The increasing substitution of PCs with notebooks in the workplace is to do with the fact that they permit mobility, save space and energy, plus the fact that they have become more powerful (longer battery lives, etc.) and lower priced in the past ten years.

However, the »structural shift« in the equipment of offices with computer terminals can be seen more clearly in the increase in installed Mini PCs and thin clients. The number of Mini PCs used in companies, authorities and educational establishments has in the meantime increased from 0.3 million devices in 2010 to 2.5 million devices. The main reasons for this are that the devices' performance is fully adequate for most office applications. They also save space, have low noise levels and contribute toward savings in energy and material. Although German providers of Mini PCs were relatively well represented in the marketplace in the first years after their introduction in 2008, Asian and US-American providers have since taken over the major market shares in this segment. This is a little different in the market segment for thin clients. Most devices on the German market are still sold by German providers. The number of installed thin clients in workplaces in Germany has risen from 2.2 million in 2010 to 5.9 million devices in 2020. Thus the thin client percentage of all computer terminals has increased in this period from 8.3 % to 15.7%.

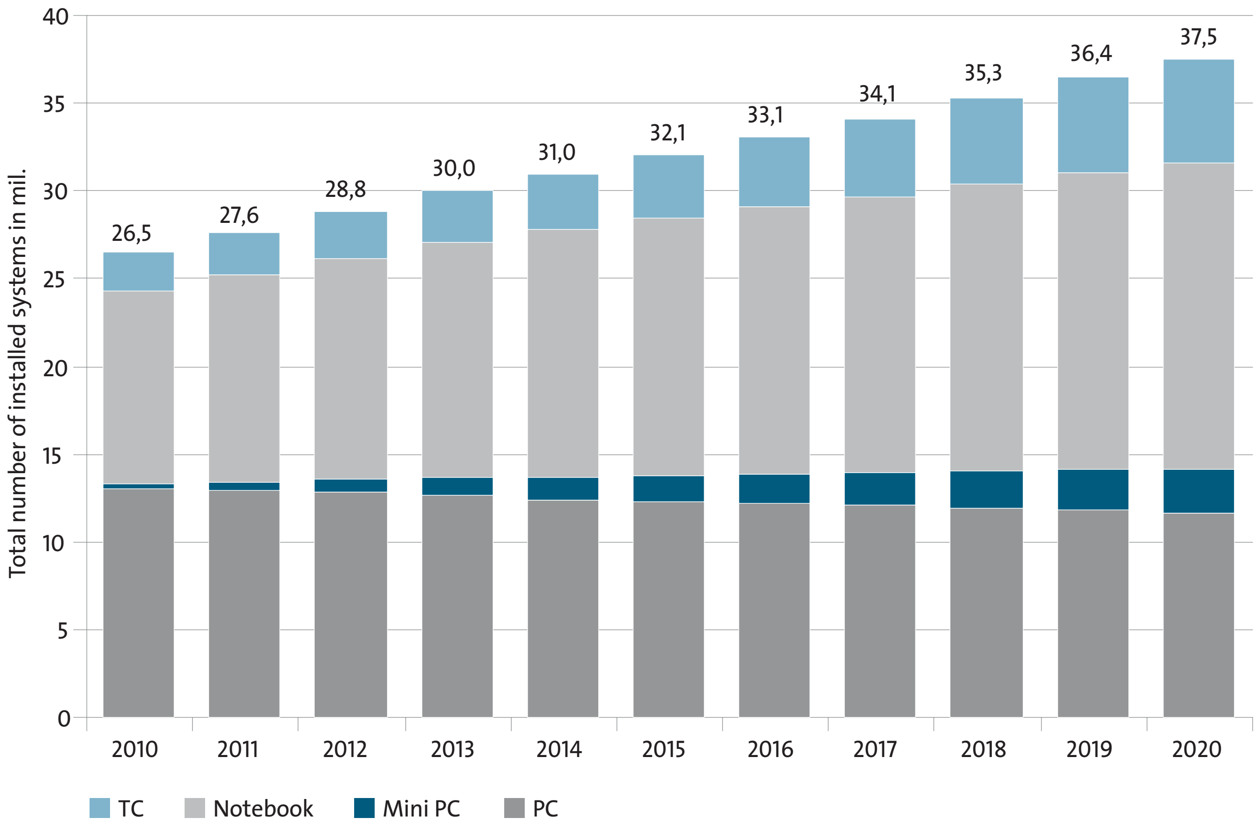


Figure 3: Number of computer terminals in workplaces (companies, authorities, education) in Germany until 2020 in the business-as-usual scenario; Source: Own calculations, Fichter/Clausen/Hintemann (2010).

Although computer terminals and servers have become clearly more energy-efficient since 2010, the total primary energy consumption (PEC) of all computer workplaces in Germany first rose from 13.24 TWh in 2010 to 13.64 TWh in 2013 and only fell to 11.99 TWh afterwards. Compared with 2010, this corresponds to an increase of about 3 % (2013) and a decrease of 9% (2020).

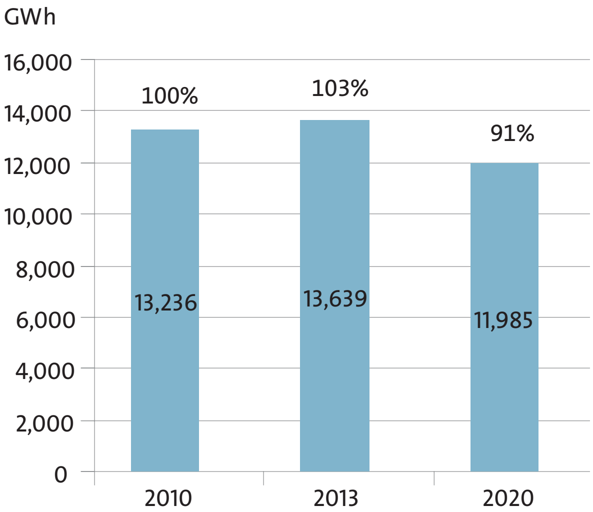


Figure 4: Accumulated energy consumption (PEC) of all workplace computers in Germany p.a. in GWh (incl. production and data center use, without a monitor) in the business-as-usual scenario, Source: Own calculations, Fichter/Clausen/Hintemann (2010).

The calculation of accumulated energy consumption (PEC) includes both the power consumption of the computer terminals and the consumption of servers and data centers (incl. infrastructure like cooling and air conditioning), which were used by computer workplaces. The calculation also includes the energy that was needed to manufacture the terminals and servers. Both the substantially increased number of workplace computers and the fact that PC, Mini PC and notebook users largely work today within the framework of server based computing (SBC) and hosted virtual desktop concepts (HVD) and as part of Software as a Service (SaaS) are responsible for the increase in energy consumption. This means that with PCs, Mini PCs and notebooks only 25% of the application software still runs on the terminal itself today (2020). The remaining 75% of the application programs are provided for these devices by terminal servers. In 2010 90% of the application software for PCs, Mini PCs and notebooks still ran on the terminal itself (cf. Table 3). Due to technology and the concepts almost all of the application software for thin clients always runs on central terminal servers.

Table 3: Percentage of software provision for computer terminals in workplaces in Germany until 2020 in the business-as-usual scenario

	2010				2013				2020			
	Local Software	SBC	HVD	SaaS	Local Software	SBC	HVD	SaaS	Local Software	SBC	HVD	SaaS
Desktop PC, Mini PC, Notebook	90	4	4	2	55	20	20	5	25	20	40	15
Thin Client	0	90	10	0	0	70	20	10	0	50	30	20

Source: Fichter/Clausen/Hintemann (2010).

Since weekly working hours have not fundamentally changed since 2010, the usage times have also essentially remained the same. Based on the values assumed in 2009 by Fraunhofer IZM and ISI, workplace computers are operated for 1,920 hours in idle and active mode (48 weeks x 5 days x 8 hours), but still only have low utilization levels so that somewhat higher consumption in active mode does not have any measureable effects. In addition to the actual usage time (1,920 hours), stationary devices (PC, Mini PC, TC) are also operated for 9 hours on network standby on working days (3,276 hours per year), for the remaining time the devices are in a pseudo-off mode, in which at the end of the decade they still have very low power consumption. Deviating from this, notebooks are only in network standby for two hours per day (728 hours per year), because they are often transported and are then in fact »off«.

If it were only a matter of the hardware, the power consumption values of the devices would have had the potential to fall substantially. However, since increasingly demanding software resulted in further increases in performance on the hardware side, only very small reductions in power consumption became effective. As far as PCs are concerned, this value fell for new devices from 65 watts in 2010 to 60 watts in 2020, for Mini PCs and notebooks from 30 watts in 2010 to 25 watts in 2020 and for TCs from 12 watts in 2010 to 10 watts in 2020. In network standby the power consumption fell from 10 watts to 6 watts (PC), from 3 watts to 2 watts (Mini PC and notebook) and from 2 watts to 1 watt (TC); and in pseudo-off mode to universally 0.5 watts for all devices. Table 4 shows the development of annual power consumption in new devices between 2010 and 2020. Based on this premise, it was possible to determine the average annual power consumption of installed computer terminals in workplaces from 2010 to 2020.

Table 4: Average annual power consumption per new computer terminal in Germany until 2020 in the business-as-usual scenario

	Average annual power consumption per new computer terminal in workplaces (without a monitor, without a server, without central IT, only in the utilization phase) in kWh			
	PC	Mini PC	Notebook	Thin Client
2010	166	71	61	33
2011	162	69	59	32
2012	158	67	58	31
2013	154	66	57	30
2014	152	65	56	29
2015	150	64	55	28
2016	148	64	55	27
2017	145	63	54	26
2018	142	62	53	25
2019	140	61	52	25
2020	137	60	51	24

Source: Own calculations, Fichter/Clausen/Hintemann (2010).

While the average annual power consumption values of workplace computers have continuously fallen since 2010 (cf. Table 4), nothing has changed since then as far as the average service life of the devices is concerned. PCs and Mini PCs are still used for an average of 5 years. Notebooks are still used for an average of 4 years and thin clients for 8 years.

The improvement in the energy efficiency of computer workplaces is also due to a considerable increase in server performance. Despite a massive increase in computer performance (RAM of 24GB in 2010, of 256GB in 2020) and the hard disk capacity (1TB in 2010, 10TB in 2020), the average power consumption of an existing volume server has fallen from 400 watts at full load in 2010 to 369 watts in 2020. The power consumption fell even more in idle mode (from 160 watts in 2010 to 118 watts in 2020) and in shutdown mode (20 watts in 2010, 4 watts in 2020). Together with the possibility of automatically shutting down and re-booting this has resulted since 2010 in continuously falling absolute annual power consumption per installed terminal server of 1984 kWh in 2010 to 1475 kWh in 2020.

Table 5: Average annual power consumption of a terminal server until 2020 in Germany in the business-as-usual scenario

	Average annual power consumption of a terminal server in kWh
2010	1984
2011	1953
2012	1918
2013	1883
2014	1843
2015	1801
2016	1747
2017	1686
2018	1621
2019	1551
2020	1475

Source: Own calculations, Fichter/Clausen/Hintemann (2010).

Within the context of server based computing (SBC) it was possible for a server to »manage« an average of 50 clients in 2010. This number rose to 80 in 2013 and to 150 in 2020. Similar leaps have been recorded for hosted virtual desktop (HVD) and Software-as-a-Service (SaaS). With HVD it was possible in 2010 for a terminal server to take care of 25 terminals, today that number is 50. And with SaaS this number has also doubled from 50 to 100 within a decade.

Improved power management in data centers has also contributed toward the increase in the energy efficiency of computer workplaces in Germany. The energy efficiency of the infrastructure of a data center can be represented by the relationship of the energy consumption of IT and the energy consumption of the infrastructure (cooling, air conditioning, power supply). The infrastructure energy efficiency (PUE) has fallen from 2.0 in 2010 to 1.9 in 2013 and ultimately to 1.7 in 2020.

In the past ten years the aforesaid increases in energy efficiency have caused the average primary energy consumption (PEC) per computer workplace to fall for all device types. This includes all power consumption that arises through the production and use of terminals and servers as well as the use of the data center infrastructure (cooling, air conditioning, etc.). It does not include the power consumption of monitors and the other office infrastructure (printers, telephones, etc.), because the latter can be assumed to be identical for all computer types. The docking station merely had to be taken into account for a notebook, because half of all notebook users use such a device in the workplace. And with a power draw of 1W the additional energy consumption through a docking station can be practically ignored. This is different for material consumption, because the docking station weighs 400g on average.

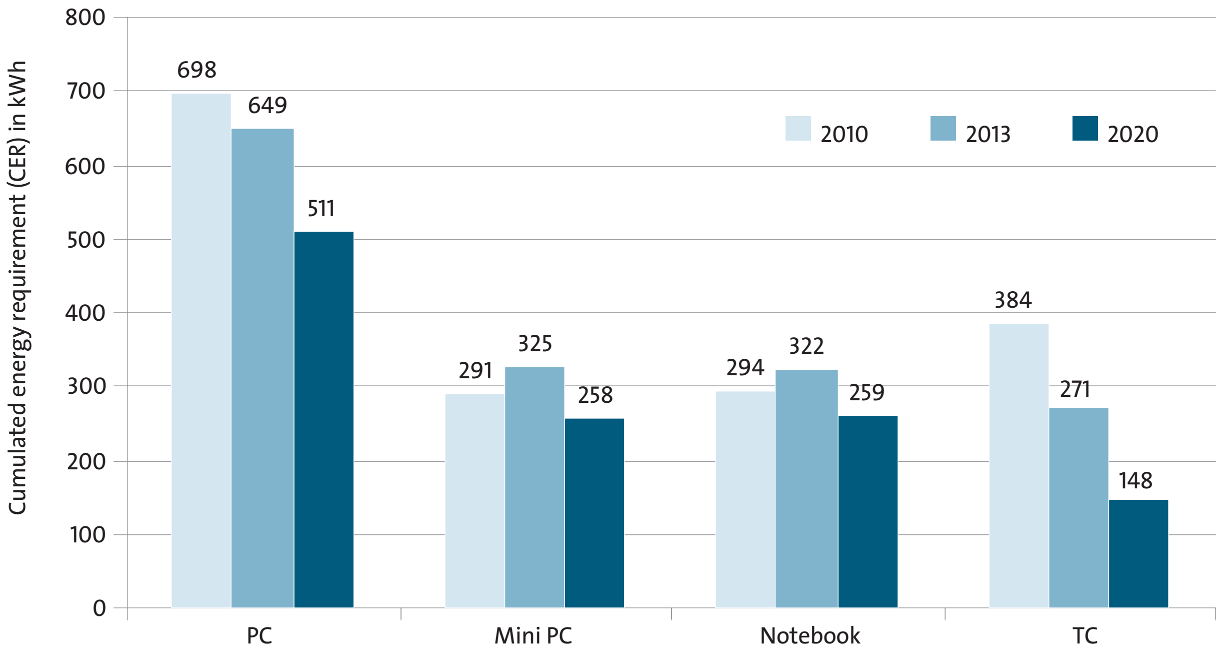


Figure 5: Accumulated energy consumption (PEC) per workplace computer p.a. in kWh in Germany (incl. production and data center use, without a monitor) in the business-as-usual scenario; Source: Own calculations, Fichter/Clausen/Hintemann (2010).

The greatest progress in energy efficiency was made by thin client & server based computing. If a thin client is used, only 148 kWh of primary energy per year are accrued for each workplace today (incl. terminal server). In 2010 this value was still 384 kWh. This sharp fall is less due to the increased efficiency of the terminal than to the clearly improved ratio of the number of thin clients per server (see above). If the Mini PC and notebook were still somewhat more favorable in energy input per workplace in 2010 than the thin client, the thin client was already the clear frontrunner in energy efficiency in 2013. In 2010 it was just under two times more energy-efficient than the PC, today the factor is larger than 3.

If a distinction is made between the energy consumption of the terminal and energy consumption due to the use of central IT resources (terminal servers) through server based computing (SBC), hosted virtual desktop concepts (HVD) and Software as a Service (SaaS), it can be seen that the energy consumption for all terminal types has fallen between 2010 and 2020. Things look different when it comes to the energy input of computer workplaces due to the use of central IT (terminal servers). Input has almost tripled from 32 kWh (PEC) in 2010 to 92 kWh in 2013 for PC, Mini PC and notebook users. This is to do with the fact that during this period greater recourse to the central provision of application software on terminal servers was taken in PC, Mini PC and notebook workplaces (SBC, HVD, SaaS). This trend further intensified between 2013 and 2020, but did not result in an increase in energy consumption for central IT, because considerable improvements could be achieved in energy consumption for terminal servers and data centers and furthermore a terminal server today can »manage« many more clients (terminals) than before (see above).

If you consider material input per workplace instead of the accumulated energy consumption, the result is similar. If you add the product weight of a computer terminal and the proportional weight of the used terminal server, the result is the development of the last ten years, as presented in Figure 7. The thin client workplace also comes off best of all here. Today it still has a weight of approx. 1.4 kg (thin client plus server share). On the other hand, a PC workplace (PC plus server share) has at present a weight of about 7.3 kg and is thus more than 5-times

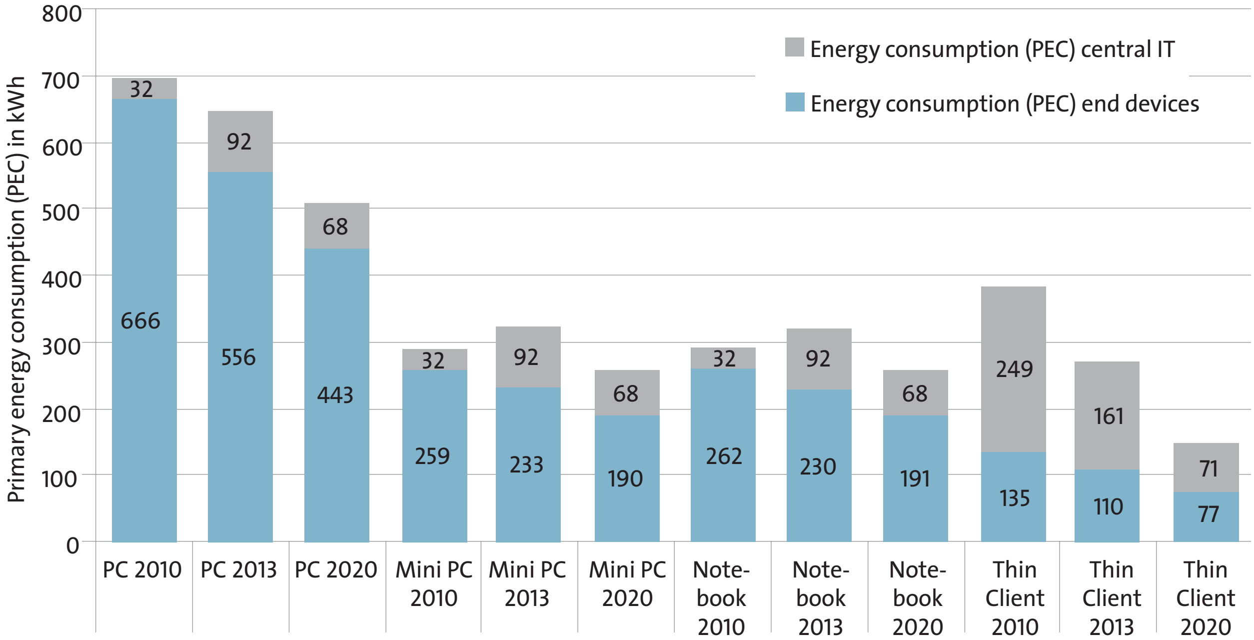


Figure 6: Primary energy consumption (PEC) per workplace computer p.a. in kWh in Germany differentiated according to terminal (without a monitor) and use of central IT (terminal server) in the business-as-usual scenario; Source: Own calculations, Fichter/Clausen/Hintemann (2010).

more material intensive. This is among other things due to the fact that the average weight of a PC has fallen only relatively slightly. In 2010 the average weight of a new PC was 8 kg, today it is still 7 kg. In contrast to energy consumption, the Mini PC with 1.8 kg and not the notebook ranks 2nd when it comes to material input. The weight of the Mini PC itself has fallen from 2 kg in 2010 to 1.5 kg in 2020. The notebook (from 2.2 to 1.7 kg) and the thin client (from 1.5 to 1.1 kg) have also »lost« approximately half a kilo in this time. The weight reduction looks somewhat different if you add the terminal and the proportion of the terminal server together (cf. Figure 7). The server percentage of the material weight is approx. 4% in 2020 for a PC, approx. 15% for a Mini PC, approx. 13% for a notebook and approx. 25% for a thin client[11].

11 At this juncture it should again be pointed out that the observation of product weights only provides an initial idea for the actual environmental impact of the products. Together with the observation of energy consumption (PEC), however, the result here is a consistent image. The Environmental Research Plan project entitled »Indicators / KPIs for raw material consumption within the context of the sustainability discussion«, as promoted by the German Federal Ministry for the Environment, determined that the accumulated primary energy consumption (PEC) represents various environmental impacts very well, in particular in products that stand out for a high level of energy consumption. Thus certain inferences drawn from the PEC value can be applied to accumulated raw material consumption (ARMC).

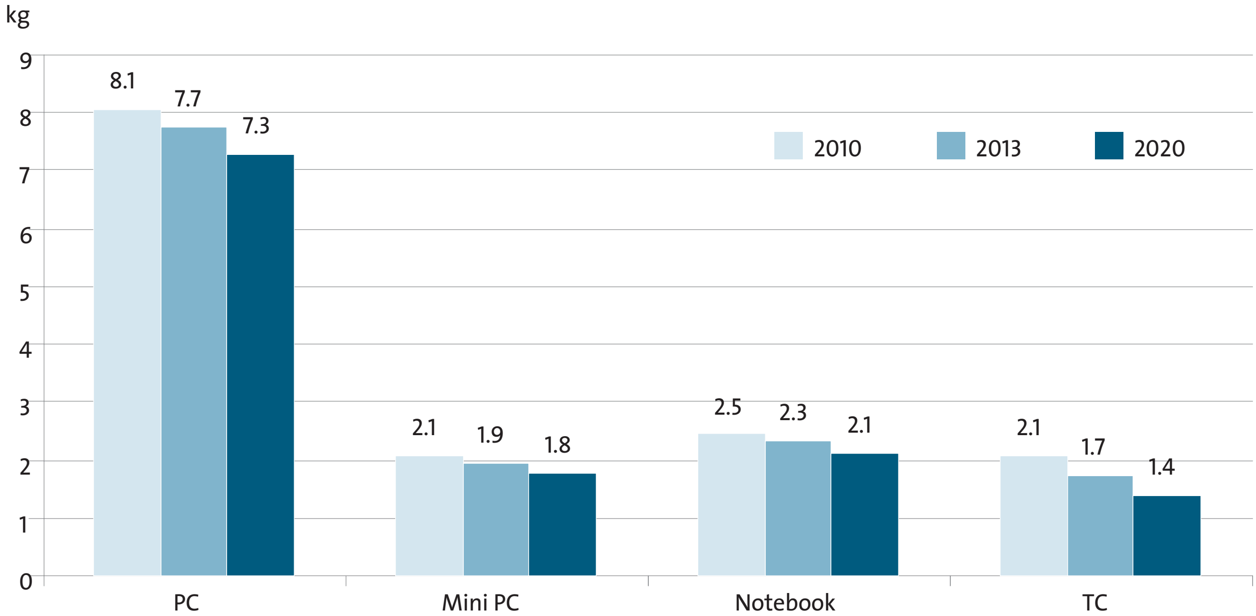


Figure 7: Material input per workplace computer in Germany in kg (incl. server share, without a monitor) in the business-as-usual scenario; Source: Own calculations, Fichter/Clausen/Hintemann (2010).

The environmentally related overall effects of the described development of workplace-related computer solutions in Germany show the following picture:

- The primary energy consumption (PEC) of all computer terminals in workplaces in Germany (production and use, incl. pro rata use of terminal servers and data center infrastructure) has fallen slightly from 13.24 TWh in 2010 to 11.99 TWh in 2020.

- The primary energy consumption (PEC) of terminal servers used by computer workplaces (production and use) and data center capacities rises from 1.32 TWh in 2010 to 2.97 TWh in 2013 and thus increases 2.3-fold within three years only. Since then the energy consumption of central IT (terminal servers), which is used by computer workplaces, has almost remained on this level (2.56 TWh in 2020).

- The weight of all computer terminals used in German workplaces (companies, authorities, schools/universities) falls slightly by just under 8 % to approx. 125,000 t in 2020. However, very different developments can be seen in the various material percentages (electronic components, plastics, metal parts, power supply units). Whereas material input falls very much in the metal parts and slightly in the power supply units, it increases in the electronic and plastic parts (cf. Figure 8).

- The weight of all terminal servers used by computer workplaces rose clearly between 2010 and 2020 by 3.5-fold to more than 10,000 t. This is due to the increased use of central IT infrastructures. The number of installed terminal servers for office workplaces in Germany increased substantially in the last decade from 116,440 to 409,200. On the other hand, the average weight of a terminal server remained the same at 25 kg.

- If you add both figures together, it becomes clear that the terminals and servers used by computer workplaces in Germany lose weight slightly by 2 %. The fall in the tonnage of device weight illustrates the reduction in material input in IT terminals. However, whether in fact less resources are used during the development of the devices, i.e. when extracting raw materials, processing them, during component production and assembly, still cannot be answered conclusively.

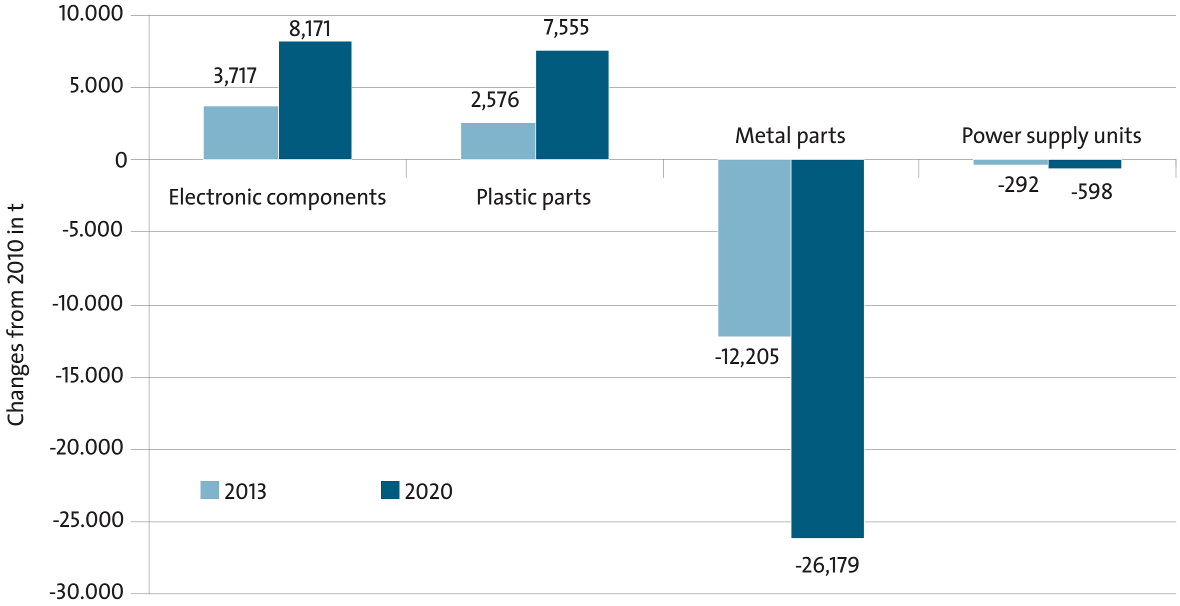


Figure 8: Change in the overall weight of components of workplace computers in Germany in tons (without a server share, without monitors) in the business-as-usual scenario; Source: Own calculations, Fichter/Clausen/Hintemann (2010).

- The developments in workplace-related computer solutions from 2010 to 2020 have not contributed toward climate protection in Germany. Despite the increased energy efficiency of terminals and servers, the total power consumption of all computer workplaces in Germany has risen by 2% due to the increasing number of devices and the increasing use of central server resources. The use of central server resources in particular even resulted in an increase in power consumption of 8% by 2013 and thus also in an increase in CO_2 emissions. By 2020 the CO_2 emissions from the power consumption of workplace computers and their proportional use of data center capacities in Germany fell to 1.90 million t. However, this reduction of 16% can only be explained by the fact that electricity in Germany became considerably cleaner in the past decade due to the increased use of renewable energy sources. Thus, the CO_2 emissions in the German electricity mix fell from 580 g/kWh in 2010 to 480 g/kWh in 2020 . This corresponds to a reduction of about 17%..

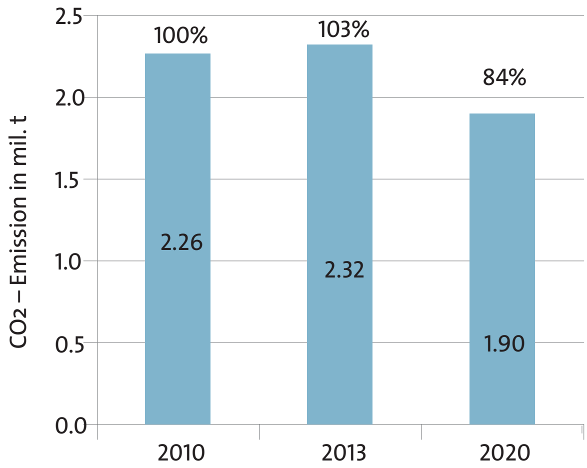


Figure 9: CO_2 emissions due to the power consumption of workplace computers in Germany (incl. data center use, without monitors) in the business-as-usual scenario; Source: Own calculations, Fichter/Clausen/Hintemann (2010).

12 If you assume a fall in CO_2 emissions in the German electricity mix to 480 g/kWh by 2020, this is a continuation of the trend from 1990 to 2009 (Federal Ministry for the Environment 2010). This assumption is the average of the current forecasts (e.g. Nitsch 2008, EWI 2008).

9 The roadmap »Resource-efficient workplace computer solutions 2020«

As can be seen in the Business-as-usual (BAU) scenario, a resource-saving strategy for workplace computers must be started for two points: On the one hand the respective device types and systems must become substantially more efficient as regards energy and material, but on the other hand a »structural change« is also needed in the device types. The desktop PC as an all-round computer talent will also be a sensible solution in future for individual applications, but for the majority of office and workplace applications Mini PCs, notebooks and in particular thin client & server based computing (TC&SBC) are from an ecological viewpoint clearly the better alternatives.[13] However, other advantages, such as lower administration expenditure, higher security and lower total cost of ownership can speak for TC&SBC.

Based on this premise and a comprehensive analysis as to why the thin client & server based computing approaches have until now only been spreading very slowly in practice despite existing best-practice applications (obstacle analysis), the following roadmap »Resource-efficient workplace computer solutions 2020« was prepared in the first half-year of 2010 by the management group of the roadmapping project »Thin Client & Server Based Computing« (cf. list of members in the imprint).

The aim of the roadmap is a sustainable structural change in workplace-related computer solutions in Germany by 2020. The roadmap is to be used to develop a lead market for green office computing, which is to contribute to the following economic and ecological goals:

1. Increase in the share of energy and material-efficient workplace computer solutions from 50% today to more than 60% in 2013 and 85% in 2020.[14]
2. Reduction in the average primary energy consumption (PEC) of workplace computers in Germany from 500 kWh per year today (incl. production and terminal server share, without a monitor) to 400 kWh in 2013 and 200 kWh per year in 2020.
3. Reduction in the average product weight per workplace computer (incl. server share) of 5.2 kg today (without a monitor) of 20% by 2013 and at least 50% by 2020.

The measures of the roadmap serve to achieve the stated objectives. Implementation of the roadmap is highly attractive both from an ecological and economic viewpoint, because consequently a considerable amount of energy, resources and money can be saved and the position of Germany as a green IT pioneer in terms of international competition is enhanced.

The wide range of measures and the comprehensive resources required for their implementation show clearly that the implementation of the roadmap can only succeed in a concerted action of IT manufacturers, IT users, politics and science. Whereas individual measures of the roadmap can be picked up and implemented by individual players, the implementation of the roadmap depends as a whole on a broad network of public and private partners. Thus to implement the roadmap the founding of a »Green office computing« initiative in the form of a public/
private partnership has been proposed. The initiative – as a network of partners that would like to support and promote resource-efficient computer solutions in companies, authorities and educational establishments – serves as an institutional »platform« that handles the development of the strategic partnership and the coordination of the

13 Cf. footnote 3 on p. 7.

14 Computer solutions that consume at least 20% less energy and have at least 20% less terminal weight than an average workplace computer solution in 2010 are referred to here as »energy and material-efficient«.

implementation of the roadmap measures. The »Green office computing« initiative should be sponsored by the Federal government, ICT providers, ICT users (committee of IT managers, CIO colloquium, etc.), industry associations like BITKOM and scientific institutions. Establishment should take place by the end of 2011 and promote and accompany the implementation of the roadmap in the long term.

A total of 39 individual measures were drawn up for the roadmap by the management committee, and both times and time periods as well as responsibilities were defined for their implementation. The fields of measures are presented briefly below. A detailed description of the roadmap measures as well as their assumed impact on the use of different types of computer solutions and on energy consumption and material input is to be found in the appendix (cf. Appendix: Detailed list of the roadmap measures).

Roadmap field of measures: »Business models«

Server based systems of cloud computing endanger established business models, e.g. of PC suppliers and PC service companies, but also create new business opportunities. Opportunities for system houses exist in combined hardware and software offers, IT leasing models and software hosting. Therefore, special importance is attributed to the market-related dialog of manufacturers, trade and IT service providers in the roadmap field of measures »Business model«. Through the market dialog attractive business models are to be prepared and made known for both the entire delivery chain and for users. These can include e.g.:

- Innovative cloud computing offers
- Hardware service bundles
- Lump-sum offers for small companies
- Thin books
- Software and data offers with attractive conditions for the cloud.

It is essential for these new business opportunities to be taken by the IT branch in order to enable the competencies of a resource-efficient IT in Germany to be reinforced and to develop a German lead market for this technology.

Roadmap field of measures: »Green office computing information campaign«

Both IT specialists and decision makers in companies and organizations are to be reached by a wide range of informative materials. The central component of the information campaign is a collection of best practices from many branches and both large and small companies and organizations. In cooperation with the business media decision makers are to be given a better understanding of this information, as are IT specialists in cooperation with the IT trade press and suitable information portals. In Berlin the aim is to set up a permanent Green IT showroom, and to have a Green IT truck nationwide. Central measures of the Green office computing information campaign:

- Best-practice information materials for various target groups (SME, authorities, etc.)
- »Green office computing« information campaign in cooperation with business media (target group: top management) as well as with IT specialist media (target group: corporate IT decision makers and IT specialists)
- Branch-related and professional-group-related information campaign
- Green office computing showroom
- Green IT truck.

The existing best-practice solutions are made known by the Green office computing information campaign and the number of users increases substantially.

Roadmap field of measures: »Lighthouse projects«

As a result of the exemplary implementation of server based IT systems in various user industries and application areas that have until now been hardly accessible for this technology, e.g. engineering or media, and which make very exacting demands of computing power and performance, lighthouse projects are to be created with high level of coverage in the respective branch of industry or the respective field of application.

- Lighthouse project - Small service companies
- Lighthouse project - Engineering
- Lighthouse project - Housing estates
- Lighthouse project - School associations.

The implementation of lighthouse projects also proves the feasibility of server based solutions in application contexts, in which they have hitherto been regarded as infeasible or only difficult to realize. Consequently, the market that is accessible for these solutions is becoming larger.

Roadmap field of measures: »Education and Qualification«

The analyses within the framework of the roadmapping project have shown that smaller system houses and resellers in particular are not yet familiar with TC&SBC or do not sufficiently know the potential of TC&SBC. It is therefore necessary to draw up a concept for a nationwide program of information and training events that is due to last for several years. Cooperation with IT further education organizations and congress organizers is practical here. The target groups are system houses, decision makers and IT specialists. The series of further education is to be supplemented by the attempt to integrate server based IT systems in the university educational canon and school education in an appropriate way. The setting-up of relevant foundation chairs appears to be worthwhile.

- Information and training events for system houses and resellers »Future market: Green office computing«
- Branch-related series of training courses »Simpler, more reliable, lower-cost: Intelligent office computing solutions«, target group: IT decision makers from SMEs and small organizations
- Inclusion of TC&SBC and Green Computing in the university educational canon (informatics, etc.)
- Foundation chairs »Server based computer solutions« and »Green Office and Home Computing«
- Inclusion of TC&SBC and Green Computing in the educational canon (informatics lessons, etc.) in schools
- Information and educational offer »Green Computing Kids« for schools.

The spectrum of impact of the educational and qualification measures is broad based. In the short and medium term the training of system houses and resellers opens up new sales channels for resource-efficient computer solutions. In the long term the educational components in schools and universities create a better knowledge base among junior staff.

Roadmap field of measures »Trade unions, works councils, staff councils«

The advantages and disadvantages as well as the obstacles and pressures of the conversion to server based systems from the viewpoint of the employees are collected in case studies and a sample company agreement is drafted in an initial subproject of the roadmap that is already up and running. The advantages and disadvantages of server based workplace computer solutions and of cloud computing from the viewpoint of the employees are made known in dialog with works and staff councils, technology advice centers and trade unions.

- Study of the impact and acceptance of server based workplace computer solutions

- Development of a sample company agreement for server based workplace computer solutions and distribution of the results of the study

- Dialogs with trade unions, technology advice centers, works and staff councils.

In the medium term the projects from an employee viewpoint and the development of a sample company agreement reduce any objections on the part of the users.

Roadmap field of measures »Technology development and standards«

R&D activities are required both to introduce energy and material-saving components, e.g. through transfer from notebook production, and to increase the performance of server based systems in order e.g. to qualify them for especially computing-intensive engineering workplaces or the media industry. Progress continues to be necessary in the performance and energy efficiency of operating systems, virtualization and management software as well as in applications.

- Research and development (R&D) to increase the energy and material efficiency of TCs
- High-performance servers and high-performance bandwidth for engineering and graphics users
- Development of software solutions to increase the ratio of clients per server in SBC, HVD and SaaS
- Increase the energy and material efficiency of servers.

Due to the further increase in the energy and resource efficiency of the devices progress can in future be achieved in two directions: On the one hand the efficiency of standard applications increases, and on the other hand

it becomes possible to develop especially computing-intensive applications for energy-efficient SBC and HVD.

Roadmap field of measures: »The state as an IT user and sponsor«

The basis for the implementation of Green office computing in public service is the inclusion of the concept in the ICT strategy of the Federal government, the Green IT plan of action and work done by the committee of IT managers of the German Federal Administration as well as the project and work group »Green IT«. The work to publicize resource-efficient IT solutions must be directed at Federal, state and municipal parliaments and authorities and has to address the latter in two different functions: On the one hand, the state as an IT user is encouraged to use resource-efficient IT solutions, and on the other hand the state as sponsor of R&D in all aspects of IT should actively stimulate the further development of resource-efficient IT solutions through suitable funding schemes of the Federal Ministry of Economics and Technology, Federal Ministry of Education and Research and the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

The state as a user:

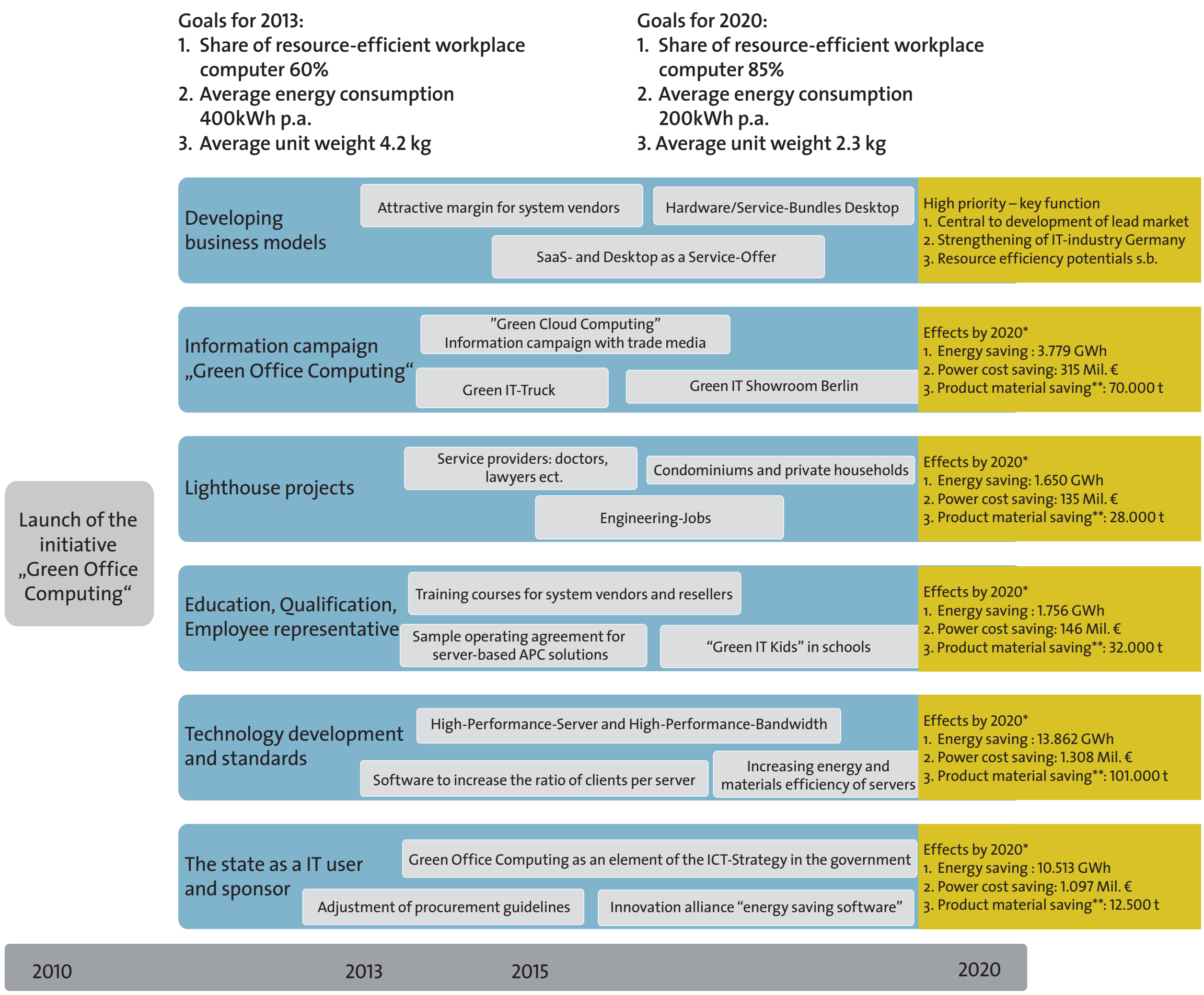
- Green Office Computing solutions as an element of the ICT strategy of the Federal government
- Inclusion of Green office computing solutions in the Green IT plan of action of the Federal government
- Announcement of the roadmap »Resource-efficient workplace computer solutions 2020« to Federal, state and municipal authorities
- Announcement of the roadmap »Resource-efficient workplace computer solutions 2020« to Federal, state and municipal parliaments
- Adaptation of procurement guidelines and general agreements of public procurement

The state as a sponsor:

- Environmental labels for thin clients and Mini PCs
- Fundamental study on the impact of application software on the energy consumption of IT
- Green office computing innovation alliance
- Energy-saving application software« innovation alliance

- Green Office Computing solutions as a continuous keynote in the funding focus »IT goes green« of the Federal Ministry for the Environment
- Development of the diffusion of Mini PCs
- Measures to increase the average hardware efficiency of data centers
- Measures to increase the average PUE of data centers in Germany

The measures that address the state as a user directly increase the number of IT workplaces that are set up as resource efficient. Addressing the state as a sponsor ensures both long-term progress, e.g. through fundamental studies and innovation-oriented activities, and also promotes the diffusion of resource-efficient IT solutions in the medium term.



* The effects were determined based on extensive interviews with experts, analysis and detailed simulation models. These effects and the made assumptions are documented in: Fichter, K.; Clausen, J.; Hintermann, R. (2010): Szenarien Arbeitsplatzbezogene Computerlösungen 2020, Berlin.

** The data on material savings has been calculated solely on the product weight and a gross material consistency. Conclusions about the use of raw materials can not be taken on these rough assumptions.

Figure 10: Roadmap »Resource-efficient workplace computer solutions 2020: Development of a lead market for Green office computing«

10 Green IT scenario: Implementation of the roadmap by 2020

The following scenario describes the development of workplace-related computer solutions in Germany from the viewpoint of 2020. The difference between the BAU scenario and the following »Green IT scenario« is that the latter assumes the implementation of the roadmap »Resource-efficient workplace computer solutions 2020« as presented in the previous section and that the assumed impact of the measures on the type and number of used (installed) computer terminals and the increase in energy and material efficiency have occurred.

Since 2010 the number of workplace computers in Germany has risen from 26.5 million to 37.5 million devices. As a result of the »Green office computing« initiative, which was established by the Federal government, the IT industry, IT users and science in 2011, the roadmap »Workplace-related computer solutions 2020« was developed und consequently implemented in the following years. Thanks to this public/private partnership it has been possible to achieve a fundamental structural change in the type of workplace-related computer solutions in less than ten years. The comprehensive information campaign »Green office computing« that was started in 2011, various lighthouse projects as well as specific training and education efforts have enabled IT decision makers, traders and system houses as well as IT users to be better informed about the options of energy and material-efficient computer solutions in the office. The result of this is that today 85% of all workplace-related computer solutions can be regarded as energy and material-efficient, i.e. they consume at least 20% less energy per year and have at least 20% less product weight than the average of all workplace computers in 2010. The average annual energy consumption (PEC) per workplace computer (without a monitor, incl. terminal server use and production) was 499 kWh in 2010, and the average weight (without a monitor, incl. terminal server share) was 5.2 kg.

Whereas the PCs still in use today (2020) on average need 402 kWh p.a. despite comprehensive efficiency measures (without a monitor, incl. terminal server use and production), the average value for Mini PCs in 2020 is 177 kWh, for notebooks 183 kWh and for thin client & server based computing 77 kWh per year and workplace (in each case without a monitor, but incl. terminal server use and production).

Table 6: Average primary energy consumption (PEC) of different computer solutions in workplaces in Germany in the Green IT scenario

	Production and use energy per year (PEC) and workplace in kWh (without a monitor, incl. terminal server use)				
	PC	Mini PC	Notebook	TC	Gesamt
2010	698	291	294	384	499
2013	599	275	273	181	388
2020	402	177	183	77	190

Source: Own calculations, Fichter/Clausen/Hintemann (2010).

Table 7: Average material input of different computer solutions in workplaces in Germany in the Green IT scenario

	Device weight (without a monitor, incl. terminal server share) in kg				
	PC	Mini PC	Notebook	TC	All Clients (average)
2010	8.1	2.1	2.5	2.1	5.2
2013	7.6	1.8	2.2	1.5	4.2
2020	6.1	1.6	1.9	1.0	2.3

Source: Own calculations, Fichter/Clausen/Hintemann (2010)..

The findings that Mini PCs, notebooks and thin clients are for most office applications clearly more energy and material-efficient computer solutions than the classic PC, has resulted in a fundamental structural change in the equipment of companies, authorities and schools/universities in Germany. If the percentage of PCs of all computer terminals in workplaces in 2010 was still just under 50%, it has continuously fallen since then and is currently just about 15%. Ten years ago the PC was still clearly the largest device class among the workplace computers, today it is just holding position 3.

Table 8: Equipment of companies, authorities and schools with workplace computers in Germany in the Green IT scenario

		PC	Mini PC	Notebook	TC	Total
2010	Number of devices in units	13,000,000	300,000	11,000,000	2,200,000	26.500.000
	Equipment structure	49.1%	1.1 %	41.5%	8.3%	100,0%
2013	Number of devices in units	11,552,500	1,317,500	13,647,500	3,482,500	30.000.000
	Equipment structure	38.5%	4.4%	45.5%	11.6%	100,0%
2020	Number of devices in units	5,629,000	4,427,500	18,567,500	8,876,000	37.500.000
	Equipment structure	15.0%	11.8%	49.5%	23.7%	100,0%

Source: Own calculations, Fichter/Clausen/Hintemann (2010).

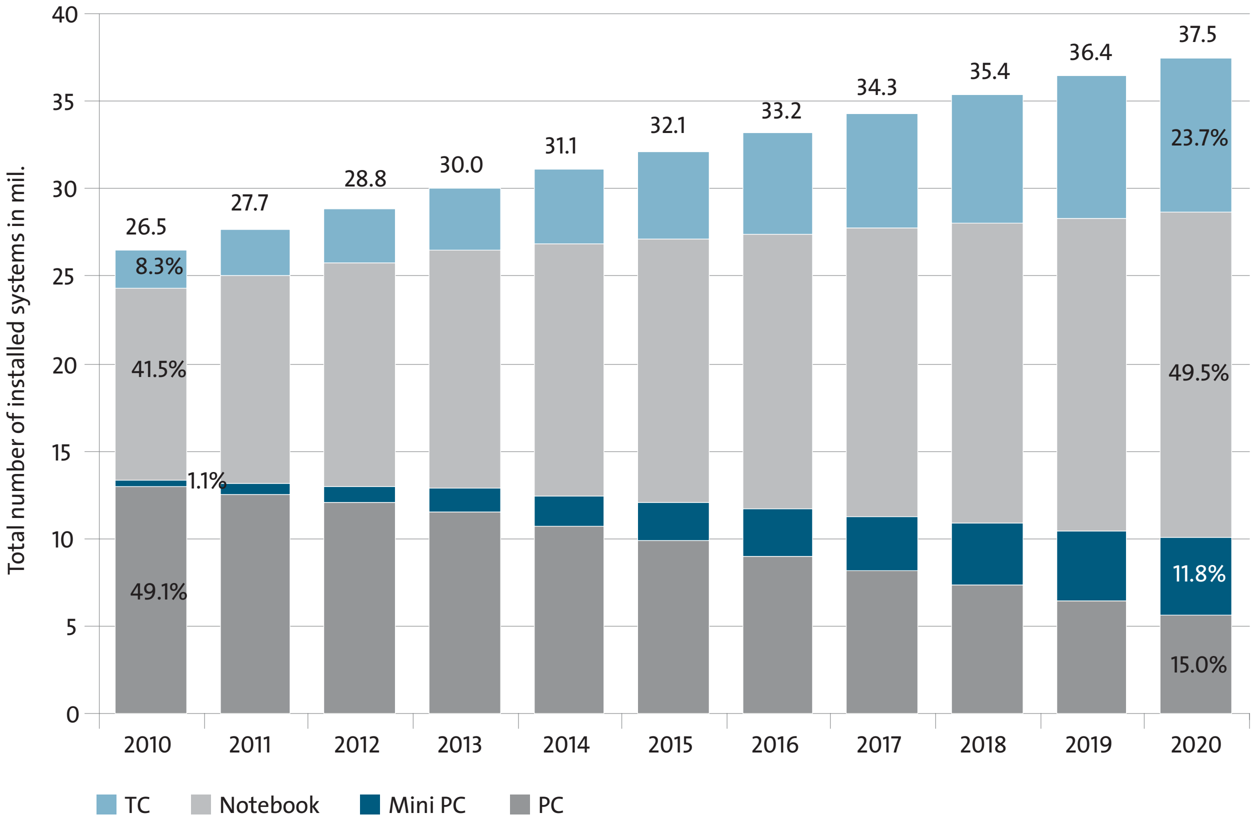


Figure 11: Number of computer terminals in workplaces (companies, authorities, education) in Germany until 2020 in the Green IT scenario; Source: Own calculations, Fichter/Clausen/Hintemann (2010).

The structural change in the equipping of offices with workplace computers and the implementation of further measures of the roadmap »Workplace-related computer solutions 2020«, such as the initiation of the »Green office computing« innovation alliance, the development of software solutions to increase the ratio of clients per terminal server or the successful development of high-performance servers and a high-performance bandwidth for engineering and graphics users, had substantial effects on the overall energy consumption of office computing in Germany. The various measures have resulted in both the efficiency of the terminals and above all the efficiency of central IT (terminal servers, ratio of clients per terminal server, etc.) improving considerably (cf. Figure 12).

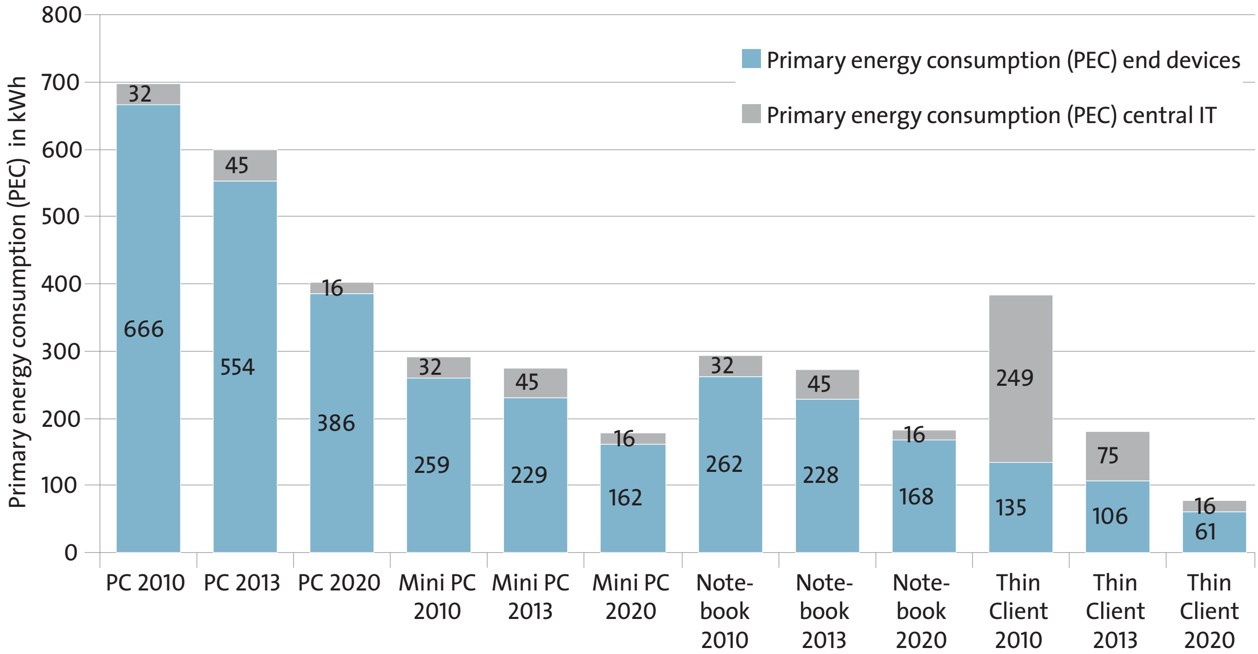


Figure 12: Primary energy consumption (PEC) per workplace computer p.a. in kWh in Germany differentiated according to terminal (without a monitor) and use of central IT (terminal servers) in the Green IT scenario; Source: Own calculations, Fichter/Clausen/Hintemann (2010).

If you consider the overall primary energy consumption (PEC) of all workplace computers in Germany (without a monitor, incl. terminal server use and device production), it can be seen that the implementation of the roadmap »Resource-efficient workplace computer solutions 2020« has resulted in the absolute energy consumption falling from 13.24 TWh in 2010 to 7.13 TWh in 2020. This corresponds to a reduction of 46%.

During the last ten years the public/private partnership »Green office computing« has also contributed to an overall substantial reduction in the material input of workplace computers. Despite the increased number of devices (26.5 million in 2010, 37.5 million in 2020) the weight of all the computer terminals used in German workplaces (companies, authorities, schools/universities) has fallen since 2010 by almost 40 % to just under 83,000 t in 2020.

However, in the development of the material input for workplace-related computer solutions very different trends can be seen in the various material percentages (electronic components, plastics, metal parts, power supply units). Whereas material input for the metal parts and power supply units fell very much and stagnated as regards the »mass« of electronics, it increased for plastics on account of the design (cf. Figure 14).

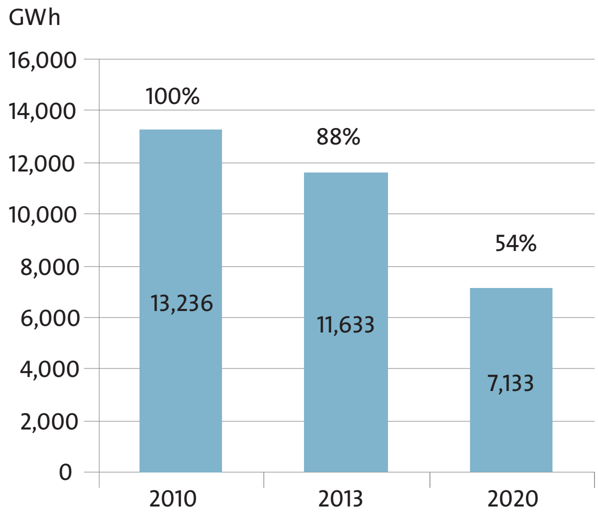


Figure 13: Primary energy consumption of all workplace computers in Germany p.a. in GWh (incl. production and data center use, without a monitor) in the Green IT scenario;
Source: Own calculations, Fichter/Clausen/Hintemann (2010).

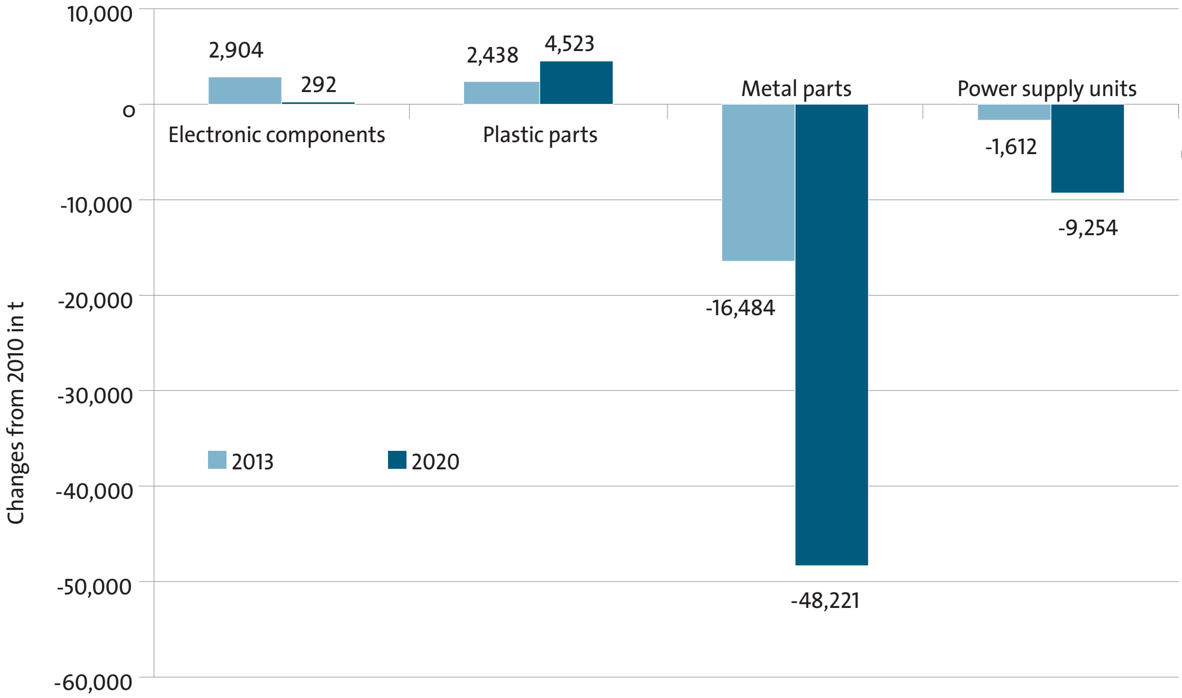


Figure 14: Development of the overall weight of components of workplace computers in Germany in tons (without a server share, without monitors) in the Green IT scenario; Source: Own calculations, Fichter/Clausen/Hintemann (2010).

With a view to climate protection there has also been a considerable change in workplace-related computer solutions during the past decade. Despite an increase in the workplace computers used from 26.5 million in 2010 to 37.5 million in 2020, the overall CO2 emissions from the power consumption of workplace computers (without a monitor) and terminal servers in Germany in the past ten years have more than halved and are today about 1.03 million t CO2 per year. There are two mains reasons for the substantial reduction. Electricity in Germany has on the one hand become cleaner. Thus, the CO2 emissions in the German electricity mix fell from 580 g/kWh in 2010 to 480 g/kWh in 2020. This corresponds to a reduction of about 17%. The second and even more important reason for halving the CO2 emissions through the use of workplace computers lies in the implementation of the total of 39 Green IT measures of the roadmap »Workplace-related computer solutions 2020«. With its promotion and implementation of the roadmap the »Green office computing« initiative has not only contributed toward energy and material efficiency in computer workplaces, but has also made a considerable contribution toward climate protection in Germany.

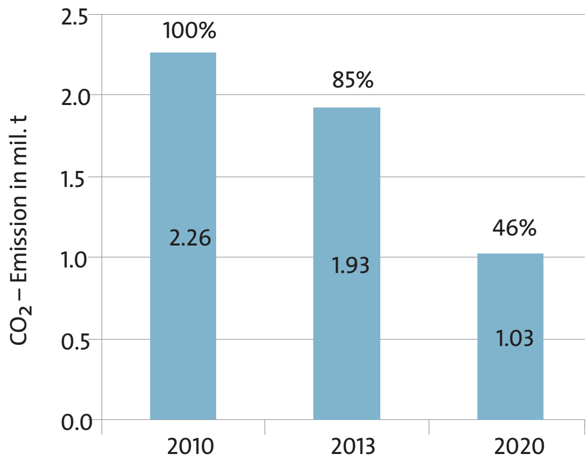


Figure 15: CO_2 emissions due to the power consumption of workplace computers in Germany (without monitors, incl. data center use) in the Green IT scenario; Source: Own calculations, Fichter/Clausen/Hintemann (2010).

11 Benefits of the roadmap: Differences between the BAU and Green IT scenarios

The Green IT scenario presented in the previous section differs from the Business-as-usual (BAU) scenario in that it assumes the implementation of the roadmap as presented in section 7.[15] The impact on the roadmap measures is in other words mapped as the difference between the BAU and the Green IT scenario. Not all impacts of the roadmap measures can be quantified - no quantification is possible for a third of the measures. The measures, whose impact could be estimated sufficiently plausibly and in a well-founded way on the basis of expert opinions and workshops, were included in the estimation of the impact. Additional substitutions of PCs with energy and material-efficient workplace computers were assumed in order to at least approximately include the effect on the non-quantifiable measures. These were estimated in a very »conservative« way with 20% of the sum of the quantifiable impacts.

The differences between the BAU and the Green IT scenario are presented below. They show what benefits the implementation of the roadmap »Resource-efficient workplace computer solutions 2020« has. The fact that the actual impact of a roadmap implementation can be considerably greater than can be expressed here in figures should also be taken into consideration. This is due on the one hand to the fact that not all impacts of the individual roadmap measures can be quantified without further ado, but also due to the fact that the possible mutual enhancement effects from the implementation of individual measures cannot be reliably forecast. In this respect, the following presentations of the benefits of a roadmap implementation are based on »conservative« assumptions and are rather to be understood as the presentation of the minimum effects.

Whereas in a business-as-usual scenario the annual energy requirements (PEC) of workplace computers in use in Germany (incl. production and terminal server use, without a monitor) of 13,236 GWh in 2010 would only fall slightly to 11,985 GWh, the implementation of the roadmap »Resource-efficient workplace computer solutions 2020« enables considerable savings in energy. In the Green IT scenario the annual energy consumption falls by about 45% between 2010 and 2020 (cf. figure 15).

15 Whereas a scenario presents the situation at a defined point in time in the future (e.g. in 2020), the roadmap describes the development path there.

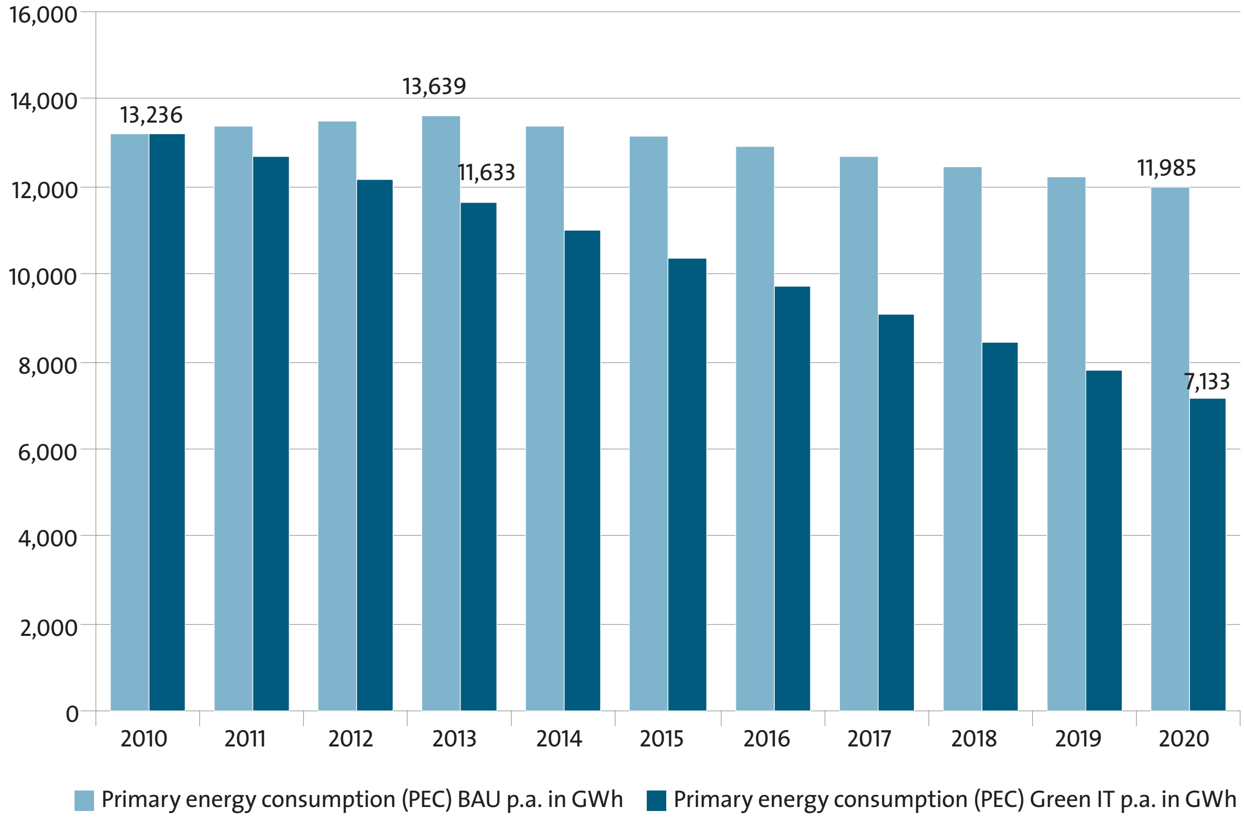


Figure 16: BAU and Green IT scenario in comparison – Primary energy consumption (PEC) of workplace computers in Germany (incl. production and terminal server use, without a monitor); Source: Own calculations, Fichter/Clausen/Hintemann (2010).

The annual savings in primary energy consumption (PEC) through the implementation of the roadmap measures are 2,006 GWh in 2013 and then 4852 GWh in 2020. If you consider the power consumption of terminals and servers in 2020, it is reduced through the implementation of the roadmap measures from 3,967 GWh to 2,137 GWh.

If you add up the annual savings in primary energy consumption (PEC) of the Green IT scenario, it can be seen that a total amount of energy (PEC) of 4 TWh can be saved by 2013 and an amount of 30 TWh by 2020 (cf. Figure 17).

Through using the power savings brought about by implementing the roadmap measures the power costs for workplace computers and central IT (terminal server) also fall considerably. Companies, authorities and educational establishments in Germany would as a result of using more energy-efficient computer solutions (Mini PCs, notebooks, thin clients) save power costs of about €2.75 billion by 2020 (cf. Figure 18).

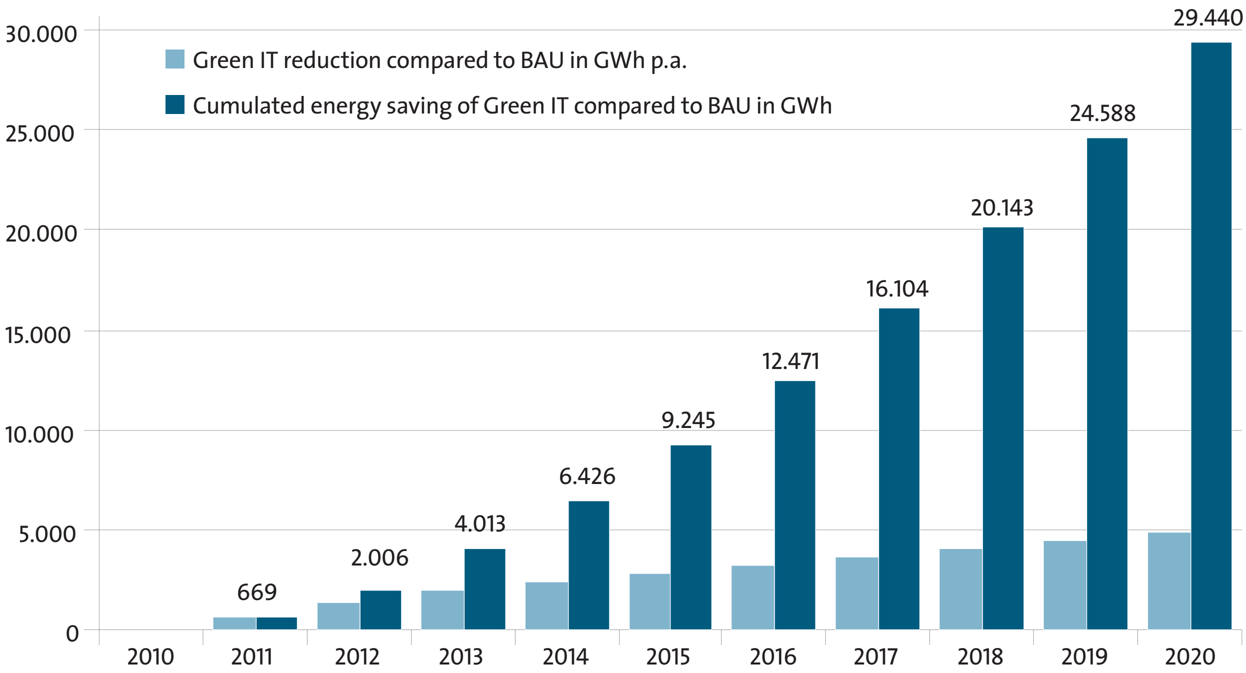


Figure 17: Savings in primary energy consumption (PEC) through the implementation of the roadmap (Green IT scenario);
Source: Own calculations, Fichter/Clausen/Hintemann (2010).

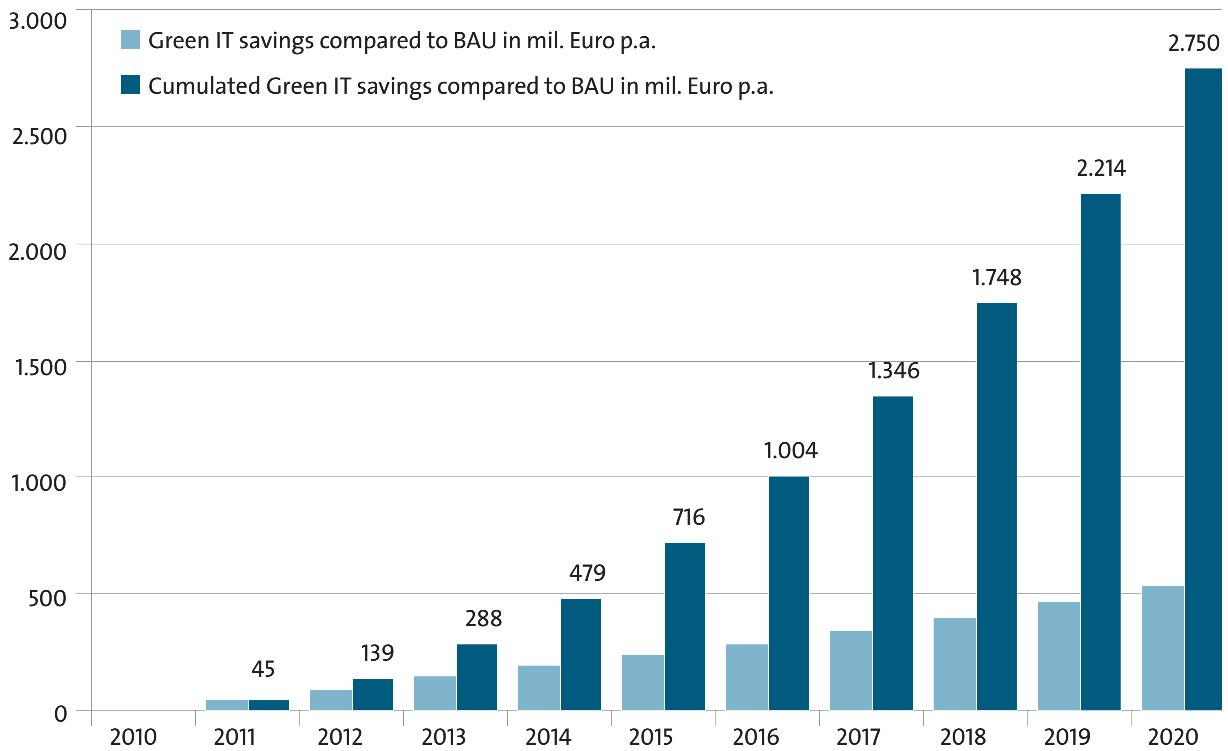


Figure 18: Savings in power costs[16] through the implementation of the roadmap (Green IT scenario); Source: Own calculations, Fichter/Clausen/Hintemann (2010).

16 The calculation of the power costs assumed an average electricity price for commercial customers of €0.18 / kWh in 2010 and a price increase of 5% p.a. in the following years.

The implementation of the roadmap also entails substantial advantages for climate protection. Thus, the calculations of the effects of the roadmap measures show that a total of about 5.5 million t of CO2 can be saved in Germany by 2020 through their implementation.

The roadmap comprises a total of 39 measures in eight fields, whereby only six fields of measures can be quantified in their impact on energy consumption, power costs, CO2 emissions and material input. The field of measures »Founding of a Green office computing initiative« as an institutional platform for the implementation of the roadmap is of fundamental significance for the ecological and economic success of the roadmap, but on account of its indirect impact on savings in energy and material it cannot be quantified. The field of measures »Business models« is also of key significance for the diffusion of energy and material-efficient computer solutions, but can in its present impact also not yet be quantified on a scientific basis. The respective contributions of the remaining six fields of measures of the roadmap toward saving energy, CO2 reduction and saving power costs are presented in table 20. The fields of measures »Education and Qualification« and »Trade unions, works and staff councils« have been summarized in the presentation.

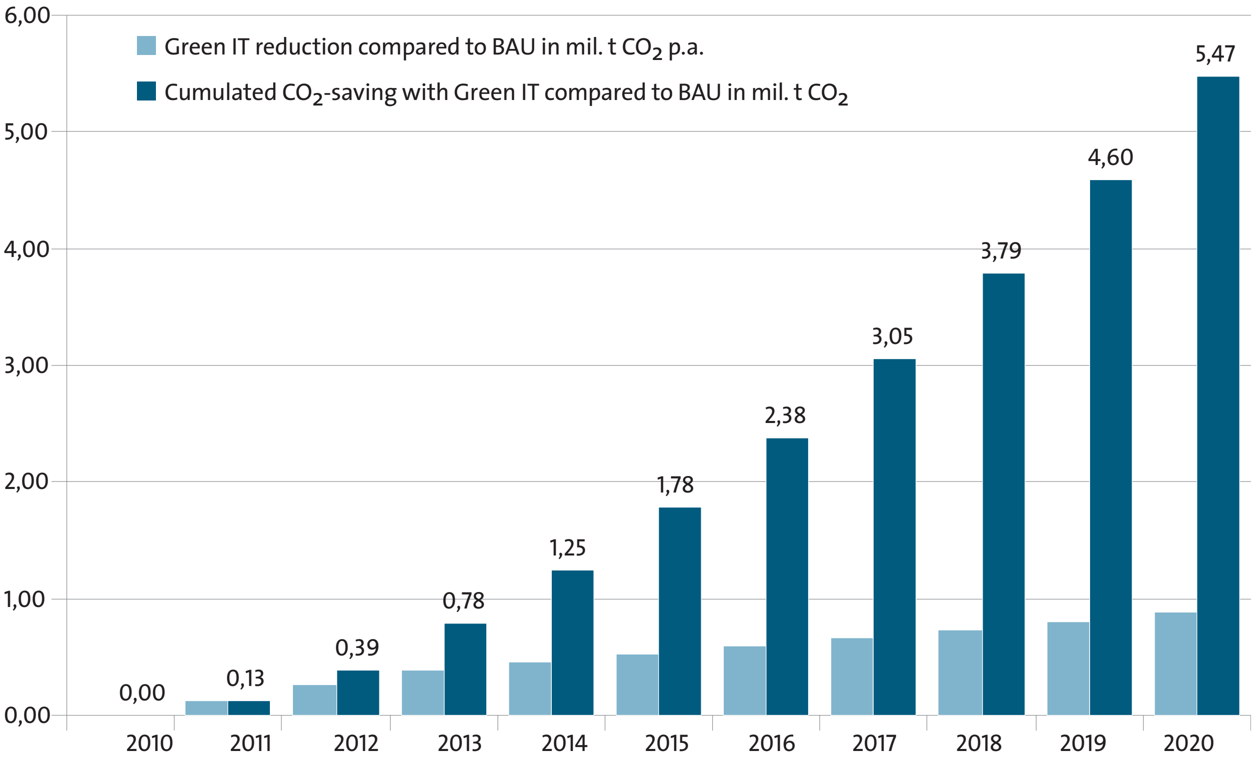


Figure 19: Reduction in CO_2 emissions through the implementation of the roadmap (Green IT scenario);
Source: Own calculations, Fichter/Clausen/Hintemann (2010).

Table 9: Energy, CO2 and power cost reduction through the various roadmap fields of measures

Roadmap field of measures	Savings in Green IT compared with BAU	2013	2020
»Green Office Computing« information campaign	Accumulated savings in energy compared with BAU in GWh	350	3,779
Lighthouse projects	Accumulated savings in energy compared with BAU in GWh	115	1,650
Education, qualification and employee representation	Accumulated savings in energy compared with BAU in GWh	173	1,756
Technology development and standards	Accumulated savings in energy compared with BAU in GWh	2,560	13,862
The state as an IT user and sponsor	Accumulated savings in energy compared with BAU in GWh	1,168	10,513
Total (all roadmap fields of measures)[17]	**Accumulated savings in energy compared with BAU in GWh**	**4,013**	**29,440**
»Green Office Computing« information campaign	Accumulated savings in CO_2 compared with BAU in t	57,960	606,140
Lighthouse projects	Accumulated savings in CO_2 compared with BAU in t	18,329	255,982
Education, qualification and employee representation	Accumulated savings in CO_2 compared with BAU in t	28,626	282,506
Technology development and standards	Accumulated savings in CO_2 compared with BAU in t	512,184	2,697,376
The state as an IT user and sponsor	Accumulated savings in CO_2 compared with BAU in t	242,317	2,135,223
Total (all roadmap fields of measures)[17]	**Accumulated savings in CO_2 compared with BAU in t**	**784,925**	**5,474,801**
»Green Office Computing« information campaign«	Accumulated savings in power costs in € million	21	315
Lighthouse projects	Accumulated savings in power costs in € million	7	135
Education, qualification and employee representation	Accumulated savings in power costs in € million	11	146
Technology development and standards	Accumulated savings in power costs in € million	188	1,308
The state as an IT user and sponsor	Accumulated savings in power costs in € million	89	1,097
Total (all roadmap fields of measures)[17]	**Accumulated savings in power costs in € million**	**288**	**2,750**

Source: Internal calculations.

17 The effects of implementing all fields of measures is not identical with the sum of implementing individual fields of measures, because when implemented simultaneously the individual fields of measures influence each other and reduce their impact in part.

The project »Material efficiency and resource conservation«, in which the roadmapping project »Thin Client & Server Based Computing« was embedded, was not only aimed at increasing energy efficiency, but also improving material efficiency and resource conservation in particular. As Figure 20 shows, implementation of the roadmap makes a considerable contribution toward saving materials. Merely the weight reductions in the end products (workplace computers and terminal servers) were taken into consideration in this calculation. If you were also to take into account the associated changes in material and raw material input during the product lifecycle, the figures would be fundamentally higher. However, a calculation of the change in raw material consumption could not be done due to the lack of available data on accumulated raw material consumption (cf. footnote 3 on p. 1).

As Table 10: shows, all fields of measures of the roadmap make a considerable contribution toward saving materials. The relatively largest impact would originate from the field of measures »Technology development and standards« and thus from a field that is primarily affected by the in-house R&D efforts of IT manufacturers. The fields of measures continue to have a great impact, which primarily result in the use of fewer material-intensive PCs - i.e. a change in user behavior, such as the »Green office computing« information campaign or »Education, qualification and employee representation«.

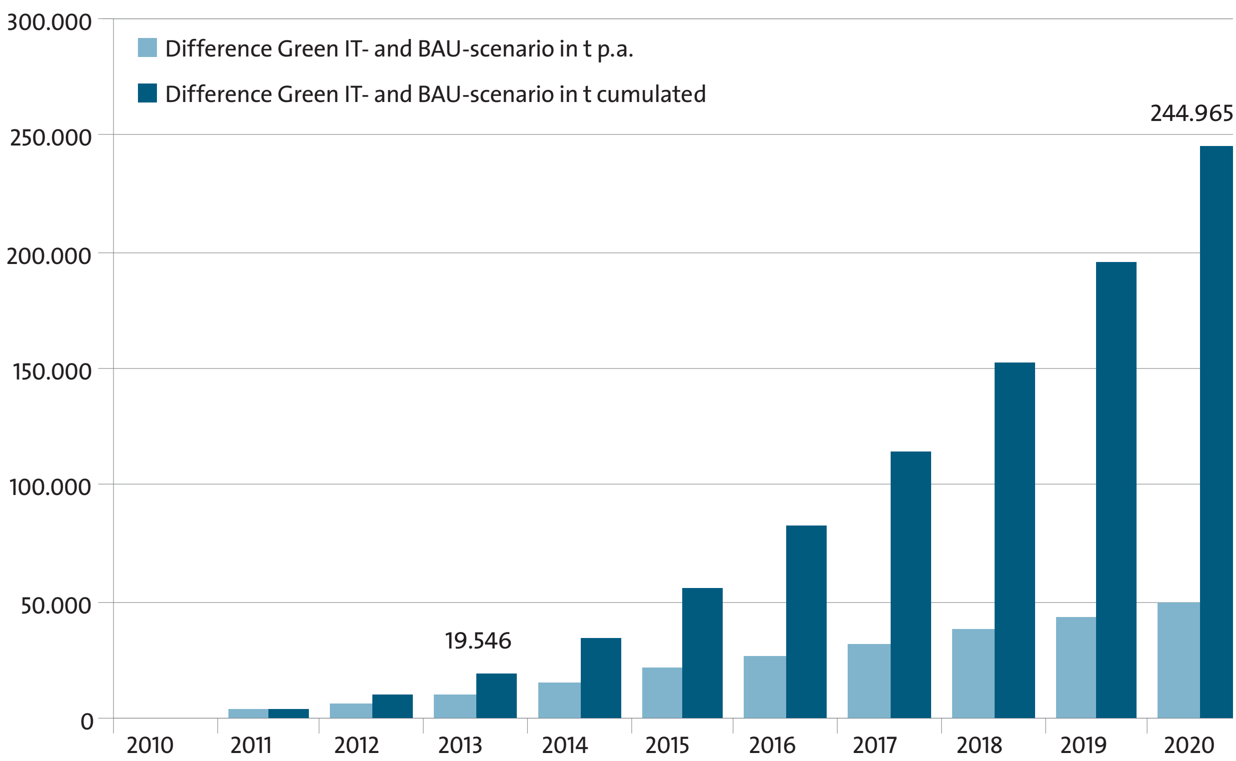


Figure 20: Savings in material in workplace computers in Germany (incl. terminal server shares, without a monitor) through the implementation of the roadmap (Green IT scenario); Source: Own calculations, Fichter/Clausen/Hintemann (2010).

Table 10: Contribution of various roadmap fields of measures toward savings in materials

Roadmap field of measures	Savings in Green IT compared with BAU	2013	2020
"Green office computing" information campaign	Accumulated savings in materials compared with BAU in t	6,057	69,531
Lighthouse projects	Accumulated savings in materials compared with BAU in t	1,919	28,037
Education, qualification and employee representation	Accumulated savings in materials compared with BAU in t	2,971	31,864
Technology development and standards	Accumulated savings in materials compared with BAU in t	7,195	101,393
The state as an IT user and sponsor	Accumulated savings in materials compared with BAU in t	1,239	12,543
Total (all roadmap fields of measures)[17]	Accumulated savings in materials compared with BAU in t	19,546	244,965

Source: Own calculation.

Table 11 below gives you an overview once again of the impacts that emanate from the implementation of the roadmap »Workplace-related computer solutions 2020«.

Table 11: Benefits of the roadmap: Differences between the BAU and Green IT scenarios

Savings in Green IT compared with BAU	2010	2013	2020
Primary energy consumption (PEC) BAU p.a. in GWh	13,236	13,639	11,985
Primary energy consumption (PEC) of Green IT p.a. in GWh	13,236	11,633	7,133
Reduction in Green IT compared with BAU in GWh p.a.	0	2,006	4,852
Accumulated savings in energy of Green IT compared with BAU in GWh		4,013	29,440
Net power costs for commercial customers in € (price increase: 5% p.a.)	0.18	0.21	0.29
Power costs of the BAU scenario in € million	702	879	1,163
Power costs of the Green IT scenario in € million	702	730	627
Savings of Green IT compared with BAU in € million	0	149	536
Accumulated savings of Green IT compared with BAU in € million		288	2,750
BAU scenario: Global warming potential through power consumption in CO_2 equivalent p.a. in t	2,262,888	2,319,490	1,903,978
BAU scenario: Global warming potential through power consumption in CO_2 equivalent p.a. in t	2,262,888	1,927,027	1,025,856
Reduction in Green IT compared with BAU in t CO_2 p.a.	0	392,463	878,122
Accumulated CO2 savings of Green IT compared with BAU in t CO_2		784,925	5,474,801
Material input of BAU scenario in t p.a.	137,211	135,932	134,303
Material input of Green IT scenario in t p.a.	137,211	126,159	85,277
Difference between Green IT and BAU scenario in t p.a.	0	9,773	49,025
Accumulated difference between Green IT and BAU scenario in t		19,546	244,965

12 Lessons learnt: What can cooperative roadmapping provide?

As the roadmapping project »Thin Client & Server Based Computing: Development of a lead market for resource efficiency« has shown, cooperative roadmapping can provide the following:

- Long-term perspectives: Early recognition of opportunities and risks (e.g. ecological and economic opportunities to develop a green office computing lead market).

- Estimation of potential: Determination of the material efficiency and resource conservation potential (e.g. through greater use of »lean« computer types (thin clients) for workplaces).

- Acceleration and funding of the distribution of already existing efficiency technologies: Better understanding of existing obstacles for the implementation of resource-efficient solutions of the future (e.g. system change in IT) and clarification of the question how the potential for material efficiency and resource conservation can best be developed in the short, medium and long term.

- Integration of the perspectives of various players: Resource efficiency from the viewpoint of different players. In the field of workplace computers, e.g. the IT manufacturers, software providers, system houses, IT users (SMEs, major companies, authorities, schools, etc.) and science.

- Innovation timetable: Development of specific measures to tap the potential of energy and material efficiency and resource conservation with specific objectives, timetables, milestones and responsibilities.

- Support and specification of the »Green economy policy«. The offensive on material and energy efficiency and the development of future green markets can be supported by branch-oriented roadmapping processes.

- Identification of challenges: Technology requirements, standardization requirements, research requirements, qualification requirements, user requirements and conditions for the development of especially relevant future markets of resource efficiency are identified during roadmapping.

- Bundling of competencies: Roadmapping bundles specific competencies and know-how from research institutes, companies, associations and groups of society. This cannot be provided by individual companies, particularly SMEs, alone. They acquire direct access to interdisciplinary knowledge and to specific know-how.

- Integration of associations of industry: Integration, sensitization and activation of branch-related and trade associations as a (previously little used) platform for the development of coordinated innovation timetables for resource efficiency and as potential multipliers for the transfer of the result to corporate innovation management (with a pilot character).

- Market opportunities: Indicate opportunities and strategies for the creation and extension of markets for efficiency technologies and identify pilot projects for German companies in central future markets of efficiency technologies.

- Innovation impetuses for companies: Impetuses to link the roadmap with operative activities in corporate innovation policy and management in order to develop the potential of resource efficiency.

The experiences from the roadmapping projects can also be transferred to other fields of technology and used as an essential element of an innovation-oriented environment policy and a sustainability-oriented economic policy. However, when using the methodology of cooperative roadmapping in the future, a series of important aspects must be observed to enable the process to be efficiently and effectively designed and used to activate higher resource-saving potential:

- Integration of independent, market and technologically neutral process facilitators with specialist expertise and competence in migration,
- Selection of search and observation fields with high resource-saving potential and »hidden« opportunities (e.g. cross-section technologies),
- Existence of a political will in ministries and authorities to develop a roadmap in cooperation with industry and science,
- Committed representatives of ministries and authorities, who also actively assist in the process of drawing up the roadmap,
- Involve committed industry experts and high-ranking decision makers,
- Expand the technological viewpoint: user integration,
- Generate knowledge from many different angles (e.g. Delphi surveys),
- Do not hide possible incidental consequences and risks (e.g. rebound effects),
- Involve social stakeholders,
- Transfer results in a target-group-oriented and active way,
- Ensure continuity, e.g. through the institutionalization of alliances.

Glossary

BAU	Busines-as-usual
Cloud Computing	Cloud computing denotes a new approach for IT solutions, in which applications and data are no longer on a local computer, but are provided via the Internet.
Desktop virtualization	This concept entails PC desktop virtualization in the data center. The users can access applications in the data center via terminals, e.g. thin clients. The »desktop« therefore only seems to be available.
Hosted Virtual Desktop (HVD)	A virtual PC, which runs as a virtual machine in the datacenter. The user-specific software runs, is configured on a clearly known server.
ICT	Information and communication technology
Accumulated raw material consumption (ARMC)	Sum of the volume of a raw material used to provide a product along the value-creation chain. Common unit used is tons. The ARMC covers all the raw materials, including energy sources, used to manufacture and transport a product. Materials that are not used economically and mixtures of materials, such as unused extraction, are not taken into account.
Material	1. Material or mixture of materials that is intended for the manufacture of products. This not only covers raw materials but also further processed materials or mixtures of materials. 2. Collective term for materials or mixtures of materials.
Material efficiency	Ratio of an achieved result or of the benefit to the material costs required for that purpose. With regard to production processes material efficiency is used as an indicator that measures the ratio of the material quantity of a product to the material quantity used in its production.
Material intensity	Reciprocal value of material efficiency, i.e. the ratio of material costs to the achieved result or benefit.
Mini PC	»Mini PC« is short for »minimized personal computer« and is also called small form factor PC.
Lifecycle Assessment (LCA)	Compilation and assessment of the input and output flows and the potential environmental impact of a product system during the course of its life. Input and output flows mean all the material and energy flows that go into the product system occur within the product system and flow out of the product system (e.g. energy, raw materials, supplies, waste, emissions, wastewater).
PEC	Primary energy consumption
Primary raw material	Raw material that is won through extraction from its natural environment.

Product	Directly intended result of a process. This includes raw materials, semi-finished and finished goods, energy and services
Product lifecycle	Successive and interconnected stages of a product system from raw material production to substance reuse or energy recovery or the final disposal of the product.
PUE	Power Usage Effectiveness. PUE states the ratio of the overall energy consumption of a data center to the IT energy consumption in the data center.
Resource, geological	In a geological context the quantities of a raw material that have been geologically proven, but currently cannot be economically won and the quantities that have not been proven, but can for geological reasons be expected in the region concerned. Internationally, different definitions are used, e.g. in English for »resources«, »reserves«, »reserve base«.
Resource, natural (natural capital)	Resource, integral part of nature. This includes renewable and non-renewable primary raw materials, physical space (area), environmental media (water, soil, air), flowing resources (e.g. geothermal, wind, tidal and solar energy) as well as biodiversity. Here it is not essential whether the resources are used as sources for the manufacture of products or as sinks for the absorption of emissions (water, soil, air).
Resource, non-renewable	Resource that does not have the potential to renew itself within a human time-scale. In addition to non-renewable raw materials, these include the resource biodiversity and eroded soil.
Resource requirements	The quantity of resources that is required to satisfy a need.
Resource efficiency	Ratio of a specific benefit or result to the use of resources required for that purpose. Put in environmental science terms, resource use means the use of natural resources. Not to be confused with raw material efficiency. (See also resource productivity)
Resource use	Use of resources in economic processes.
Raw material	Materials or mixtures of materials in an unprocessed or slightly processed condition, which can enter the production process. A distinction is made between primary and secondary raw materials. Other differences, as in renewable and non-renewable, biotic and abiotic raw materials, are common.
Raw material efficiency	Ratio of a specific benefit or result to the raw material costs required for that purpose. Is frequently used in the sense of raw material productivity.
Raw material consumption	Form of raw material use, in which the raw materials are converted in such a way that re-use is no longer available (e.g. combustion or dissipative losses). The term energy consumption is also used in this sense.

Server Based Computing/ Server Centric Computing (SBC/SCC)	Central provision of applications on powerful servers. Using thin clients or other terminals SBC makes it possible to use applications that run in a central application server. The thin clients/PCs are used as terminals, which are fundamentally used for data input and output (via keyboard, mouse and monitor).
Software as a Service (SaaS)	Software as a Service is a software distribution model, in which the software is provided as a service based on Internet technologies. In contrast to »classic« software provision, the users no longer run the software themselves on their terminals or servers, the software is run at a service provider's.
Thin Client (TC)	Computer terminal, whose hardware equipment is consciously reduced in comparison to a PC and which is fundamentally used for data input and output. The actual data processing takes place on a central server, which the thin client accesses.
Thin Client & Server Based Computing (TC&SBC)	Central provision of applications on a powerful server and the use of a thin client as a terminal.
Virtualization	Virtualization can be used to combine or share computer resources. Virtualization abstracts from the actually existing hardware and provides logical systems. A typical application is server virtualization, in which a hardware server is split up in such a way that several logical servers, on which e.g. various operating systems can be installed, are made available to the user.

Appendix: List of the roadmap measures

Roadmapping measure	Description of the measure	Period / Time of implementation
Business models		
Development of new business models	New business models can be started at the following points in particular: ■ Attractive margins for system houses ■ Further development of SaaS and Desktop as service offers ■ Offers of hardware/service bundles (e.g. as with mobile telephones) through service providers ■ Offers invoiced on a monthly basis for private households ■ and small companies ■ TC-compatible license models for software and, if necessary, data (e.g. electronic books) ■ Improvement in the availability of thin books	2010-2015
»Green Office Computing« initiative		
Founding of a »Green Office Computing« initiative as a public/private partnership	The »Green Office Computing« initiative should be sponsored by the Federal government, ICT providers, ICT users (committee of IT managers, CIO colloquium, etc.), industry associations like BITKOM and scientific institutions. Establishment should take place by the end of 2011 and fund and accompany the implementation of the roadmap in the long term. Purpose: Funding of resource efficiency and climate protection through user-friendly and cost-efficient Green IT solutions in companies, administrations and educational establishments.	Foundation 2010 – 2011 Continuation 2011 – 2020
»Green Office Computing« information campaign		
Best-practice information materials for various target groups (SME, authorities, etc.)	Preparation of a concept for best-practice materials; selection of relevant target groups; if necessary, search for separate (co-)financing sources (other than the basic financing from the »Green Office Computing« initiative); preparation of vendor/provider-independent best-practice materials (brochures, case descriptions, etc. on energy and material-efficient office computing solutions)	2010 – 2012 Revisions / Updates on an annual / biennial basis (2013 – 2020)
»Green Office Computing« information campaign in cooperation with business media: Target group is top management (no IT specialists)	Selection of relevant business and management journals; development of a campaign concept; acquisition of budget resources; winning over of media partners for a joint information campaign; agreement of a series of articles, key issues, supplements and the like; provision of basic information (New »green« workplace-related computer solutions; best-practice examples; scientific data on savings potential; scenarios »Workplace-related computer solutions, etc.)	Main focus 2010 – 2013 Continuation 2014 – 2020
»Green Cloud Computing« information campaign with specialist IT media: Target group - company decision makers and IT specialists	Selection of central IT media companies, e.g. Heise-Verlag; development of a concept for a three-year campaign in specialist IT media (e.g. regular editorial contributions in iX, regular supplement »Green Cloud Computing« and the like.) Cooperation with important multipliers (CIO colloquium, etc.) Road show through the Federal states (one event per Federal state per year = 15 events; e.g. half-day events with presentations of best practices by users, manufacturers, possibly accompanied by science)	2010 – 2013

Responsible for implementation	On which factors does the measure impact?	To what extent does the measure impact? Change compared with BAU scenario	Explanation of impact assumption
Hardware and software manufacturers, content providers, mobile network operators, system houses	Market share / stock share of TCs	Increase in the existing number of TCs compared with BAU is difficult to quantify, the impact of the measures very much depends on the specific business model. The costs today for a managed workplace are approx. €35 to €70/month. If you can succeed in developing Desktop as a service offer that is considerably lower priced (e.g. €19.95 per month), the potential can be considerable.	Attractive business models can increase the distribution of TCs substantially, right up to almost completely replacing the PC. The market will decide whether the business models prove to be acceptable.
Federal government, BITKOM (study group: Thin Client & Server Based Computing), IT users, science	Indirect impact	Indirect impact. The impact results from the fact that the initiative supports and coordinates the implementation of the roadmap. It is the institutional basis for the implementation of this roadmap.	
»Green Office Computing« initiative	Indirect impact	No quantification possible	Basis material for the following sections of the information campaign
»Green Office Computing« initiative	Market share / Stock share of TCs, Mini PCs, notebooks	Increases the number of installed Mini PCs, notebooks and TCs and decreases to the same extent the number of installed PCs compared with the BAU scenario: Mini PCs: in 2013 by 30,000 devices and in 2020 by 150,000 devices Notebooks: in 2013 by 30,000 devices and in 2020 by 150,000 devices TCs: in 2013 by 60,000 devices and in 2020 by 187,500 devices	To achieve the said impact a yearly budget for advertisements, etc. of € 0.25 million is assumed.
»Green Office Computing« initiative	Market share / Stock share of TCs, Mini PCs, notebooks	Increases the number of installed Mini PCs, notebooks and TCs and decreases to the same extent the number of installed PCs compared with the BAU scenario: Mini PC: in 2013 by 30,000 devices and in 2020 by 150,000 devices Notebooks: in 2013 by 30,000 devices and in 2020 by 150,000 devices TC: in 2013 by 60,000 devices and in 2020 by 187,500 devices	To achieve the said impact a yearly budget of € 0.3 million is assumed (€ 0.15 million each for advertisements and road show).

Roadmapping measure	Description of the measure	Period / Time of implementation
Branch-related and professional-group-related information campaign	Selection of branches of industry and professional groups with a small share of thin client & server based computing solutions (e.g. small service companies (tax consultants, lawyers, notaries, etc.), doctors' surgeries, handicraft, etc.); preparation of a concept for target-group-related provision of information; use of best-practice materials (see above); cooperation with associations of industry and professional associations; cooperation with system houses; distribution of information materials (brochures, flyers. etc.); holding of target-group-specific events	Planning 2010 – 2011 Implementation 2011 – 2012 Operation 2012 – 2015 (Phase 1, if necessary prolongation)
Green IT Truck	Continuous road show with a presentation of energy-efficient workplace solutions, regional appearances, appearances at trade shows, etc. Duration: 2011 to 2020. Assumptions: approx. 40 appearances per year, at which an average of about 40 decision makers are reached (=1,600 decision makers). Average number of devices per decision maker: 100. Persuasion quota 25 %: In other words, approx. 40,000 devices (TCs and Mini PCs per year). Start in 2012 and 2014 still a little slow. (in comparison: estimated cost of the action: approx. € 500,000 per year, i.e. € 12.50 per device.)	2011 – 2017
»Green office computing« showroom	Preparation of a concept for a »Green office computing« showroom as a national and international »shop window« for IT decision makers from companies, authorities, schools, etc. as well as persons interested in IT (junior IT staff, etc.); preparation of a financing concept; acquisition of resources (e.g. 50% / 50% financing with public resources and private resources); implementation e.g. in Berlin; the organization is to inform private and above all public facilities in a neutral way and answer questions in a competent manner as well as allow an opportunity to test the devices and solutions.	Planning 2010 – 2011 Implementation 2011 – 2012 Operation 2012 – 2015 (Phase 1, if necessary prolongation)
Presence at trade shows (e.g. CeBIT) and important large-scale events		Planning 2010 – 2011 Implementation 2011 – 2012 Operation 2012 – 2015 (Phase 1, if necessary prolongation)
Lighthouse projects		
Lighthouse project e.g. within the scope of small service companies, doctors' surgeries, handicraft, etc.	Preparation of a concept for the provision of »Desktop as a Service« offers for small companies, if necessary, raising funds. Implementation of pilot projects, broad-based communication, presentation at trade shows and congresses.	2010 – 2014

Responsible for implementation	On which factors does the measure impact?	To what extent does the measure impact? Change compared with BAU scenario	Explanation of impact assumption
»Green Office Computing« initiative	Market share / Stock share of TCs, Mini PCs, notebooks	Increases the number of installed Mini PCs, notebooks and TCs and decreases to the same extent the number of installed PCs compared with the BAU scenario: Mini PC: in 2013 by 30,000 devices and in 2020 by 150,000 devices Notebooks: in 2013 by 30,000 devices and in 2020 by 150,000 devices TC: in 2013 by 60,000 devices and in 2020 by 187,500 devices	To achieve the said impact a yearly budget of € 0.3 million is assumed.
»Green Office Computing« initiative, Chambers of Industry and Commerce, manufacturers,	Market share / Stock share of TCs, Mini PCs	Increases the number of installed Mini PCs and TCs and decreases to the same extent the number of installed PCs compared with the BAU scenario: TC: in 2013 by 30,000 devices and in 2020 by 200,000 devices Mini PC: in 2013 by 30,000 devices and in 2020 by 200,000 devices	See »Measures«
»Green Office Computing« initiative	Market share / Stock share of TCs, Mini PCs, notebooks	Increases the number of installed Mini PCs, notebooks and TCs and decreases to the same extent the number of installed PCs compared with the BAU scenario: Mini PC: in 2013 by 15,000 devices and in 2020 by 150,000 devices Notebooks: in 2013 by 15,000 devices and in 2020 by 75,000 devices TC: in 2013 by 30,000 devices and in 2020 by 187,500 devices	
»Green Office Computing« initiative	Market share / Stock share of TCs, Mini PCs, notebooks	Increases the number of installed Mini PCs, notebooks and TCs and decreases to the same extent the number of installed PCs compared with the BAU scenario: Mini PC: in 2013 by 10,000 devices and in 2020 by 50,000 devices Notebooks: in 2013 by 10,000 devices and in 2020 by 50,000 devices TC: in 2013 by 20,000 devices and in 2020 by 62,500 devices	Budget: approx. € 0.1 million p.a.
Manufacturers, system houses, communication: »Green Office Computing« initiative, BITKOM study group Thin Client & Server Based Computing	Market share / Stock share of TCs, Mini PCs	Increases the number of installed Mini PCs and TCs and decreases to the same extent the number of installed PCs compared with the BAU scenario: TC: in 2013 by 10,000 devices and in 2020 by 100,000 devices Mini PC: in 2013 by 10,000 devices and in 2020 by 50,000 devices	

Roadmapping measure	Description of the measure	Period / Time of implementation
Lighthouse project: Engineering workplaces	Engineering workplaces with high demands (e.g. of graphics performance) can be implemented with modern desktop virtualization solutions via TCs. Lighthouse projects could achieve an additional multiplier effect here especially in large industrial companies, because TC solutions are then also used in other workplaces. Server-centralized solutions without direct data exchange provide great data security advantages when in industrial cooperation with suppliers so that very broad-based use would be possible here (TC solutions are the exception here). Feasibility in engineering workplaces provides great leverage in all other office workplaces. The first lighthouse projects are already underway. Assumptions: approx. 3,000,000 computer workplaces in the industry (manufacturing industry). 2013: 5,000 engineering workplaces, 2020: 15,000 engineering workplaces, (leverage in each case 20).	2011 – 2012
Lighthouse project – Housing estates	Preparation of a concept for the use of TCs in housing estates, raising funds, implementation of a pilot project, widespread communication of the results	2011 – 2014
Lighthouse project – Finance	Update of the existing data for the use of TCs in financial institutes, editorial processing, holding of specialist events and appearance at finance trade shows/congresses	2010/2011
Lighthouse project – School associations	Preparation of a concept for cross-school use (school associations) of server based computing, if necessary, raising funds, implementation of a pilot project, widespread communication of the results	2011 – 2012
Education and Qualification		
Information and training events for system houses and resellers »Future market: Green Office Computing«	The analyses within the framework of the roadmapping project have shown that many, smaller system houses and resellers in particular are not yet familiar with TC&SBC or do not sufficiently know the potential of TC&SBC: ■ Preparation of a concept for a nationwide program of information and training events lasting for several years; in cooperation with IT event agencies ■ Possible title of the program or the events »Future market – Green Office Computing: Added value for system houses and resellers« ■ Implementation substantial as regional events, e.g. in cooperation with regional IT initiatives and agencies, such as »Digital Lower Saxony« or »IT Hannover«	Planning 2010 – 2011 Implementation 2011 – 2013

Responsible for implementation	On which factors does the measure impact?	To what extent does the measure impact? Change compared with BAU scenario	Explanation of impact assumption
Manufacturers, system houses, industrial companies	Market share / Stock share of TCs	Increases the number of installed TCs and decreases to the same extent the number of installed PCs compared with the BAU scenario: TCs: in 2013 by 100,000 devices and in 2020 by 300,000 devices	See »Measures«
Manufacturers, system houses, science, housing estate operators, communication	Indirect impact	No quantification possible	Since private apartments are not classed as the subject of the »workplace-related computer solutions« study, the impact is only indirect.
»Green Office Computing« initiative	Market share / Stock share of TCs	Increases the number of installed TCs and decreases to the same extent the number of installed PCs compared with the BAU scenario: TCs: in 2013 by 20,000 devices and in 2020 by 100,000 devices	At present an important German financial institute has approx. 150,000 TCs in use. Even if the spread of TCs in the finance sector is already of a high degree, potential can still be increased here through appropriate communication .
School authorities, manufacturers, system houses, communication: Green Office Computing initiative	Market share / Stock share of TCs / Mini PCs in schools	Increases the number of installed Mini PCs and TCs and decreases to the same extent the number of installed PCs compared with the BAU scenario: TCs: by 10,000 devices in 2013 and in 2020 by 300,000 devices Mini PCs: in 2013 by 10,000 devices and in 2020 by 150,000 devices	Assumption: The number of workplace devices in schools increases by 2020 to a total of approx. 2 million. By copying the lighthouse projects the percentage of TCs and Mini PCs increases significantly, i.e. approx. 50 % of the workplaces to be newly created are TCs or Mini PCs.
»Green Office Computing« initiative Leadership: selected manufacturers like Igel, Fujitsu, Oracle	Market share and stock share of Mini PCs, notebooks, TCs	Increases the number of installed Mini PCs, notebooks and TCs and decreases to the same extent the number of installed PCs compared with the BAU scenario: Mini PCs: in 2013 by 30,000 devices and by 150,000 devices in 2020 Notebooks: in 2013 by 30,000 devices and in 2020 by 150,000 devices TCs: in 2013 by 60,000 devices and in 2020 by 187,500 devices	50% of the quantifiable impact in the field of »Education and Qualification«. – Approx. 5 events p.a. are assumed with in each case 80 participants (400 participants p.a.). Assumption: Half of the participants (= 200) subsequently sells (instead of PCs) 200 Mini PCs, notebooks or TCs p.a.

Roadmapping measure	Description of the measure	Period / Time of implementation
Branch-related series of training courses »Simpler, more reliable, lower-cost: Intelligent office computing solutions«, target group: IT decision makers from SMEs and small organizations	In small companies and organizations there are usually no official IT managers, but decision makers, who have to make IT decisions on a »part-time« basis and without any professional IT know-how: ■ Preparation of a concept for a nationwide program of information and training events lasting for several years; in cooperation with IT event agencies ■ Possible title of the program or the events »Simpler, more reliable, lower-cost: Intelligent office computing solutions«, ■ Implementation as regional events, e.g. in cooperation with regional IT initiatives and agencies, such as »Digital Lower Saxony« or »IT Hannover« as well as in cooperation with regional system houses and resellers	Planning 2010 – 2011 Implementation 2011 – 2013
Inclusion of TC&SBC and Green Computing in the university educational canon (informatics, etc.)	Concepts and opportunities of server based office and home computing solutions (TC&SBC, etc.) have until now scarcely been anchored in the university educational canon or not at all. Therefore, it is imperative to close this loophole in the coming years: ■ Initiation of one or more pilot projects »Server based computer solutions« and/or »Green Office Computing« to prepare concepts and materials for the anchoring of the topics in informatics and other relevant courses of studies ■ Talks with the Federal Ministry of Education and Research and relevant institutions for the development of university curricula ■ Possible establishment of a funding focus »Education initiative: Server Based Computer Solutions / Green Computing« in the Federal Ministry of Education and Research	Initiation of the funding focus (2010 – 2011) Implementation of the pilot project (2011 – 2014) Transfer (2014 – 2020)
Foundation chairs »Server based computer solutions« and »Green Office and Home Computing«	Put the content-related orientation of the foundation chairs (unique selling point) into precise terms and clarify disciplinary integration; sounding out and looking for founders; sounding out and looking for universities and faculties that are interested in having a foundation chair (incl. co-financing and long-term safeguards).	Sounding out 2011 – 2012 Establishment as of 2013
Inclusion of TC&SBC and Green Computing in the educational canon (informatics lessons, etc.) in schools	Concepts and opportunities of server based office and home computing solutions (TC&SBC, etc.) have until now scarcely been anchored in the school educational canon or not at all. Therefore, it is imperative to close this loophole in the coming years: ■ Initiation of one or more pilot projects »Server based computer solutions« and/or »Green office computing« to prepare concepts and materials for the anchoring of the topics in informatics lessons and other relevant courses of general schools as well as vocational and technical schools ■ Talks with the Federal Ministry of Education and Research and relevant institutions of the Federal states for the development of curricula ■ Possible establishment of a funding focus »Education initiative: Server Based Computer Solutions / Green Computing« in the Federal Ministry of Education and Research and/or state ministries	Initiation of the funding focus (2010 – 2011) Implementation of the pilot project (2011 – 2014) Transfer (2014 – 2020)
Information and educational offer »Green Computing Kids« for schools	In addition to anchoring topics such as server based computer solutions and Green Computing in informatics lessons, an information offering is to be created for schools, in which the schools can invite IT/Green IT experts to come into the schools free of charge for individual lessons or half-day/day events. The experts lecture about the latest solutions, demonstrate them and let the children try them out .	Concept preparation (2011) Implementation as of 2011

Responsible for implementation	On which factors does the measure impact?	To what extent does the measure impact? Change compared with BAU scenario	Explanation of impact assumption
»Green Office Computing« initiative Leadership: selected manufacturers like Igel, Fujitsu, Oracle	Market share and stock share of Mini PCs, notebooks, TCs	Increases the stock share compare with BAU for: Mini PCs: in 2013 by 30,000 devices and in 2020 by 150,000 devices Notebooks: in 2013 by 30,000 devices and in 2020 by 150,000 devices TCs: in 2013 by 60,000 devices and in 2020 by 187,500 devices	50% of the quantifiable impact in the field of »Education and Qualification« – Approx. 15 events are assumed p.a. with in each case 50 participants (750 participants p.a.). Assumption: Two thirds of the participants (= 500) subsequently buy (instead of 20 PCs) Mini PCs, notebooks or TCs (plus the multiplier effect, mouth-to-mouth propaganda: x 3)
»Green Office Computing« initiative Federal Ministry of Education and Research	Indirect, long-term impact (as of approx. 2015)	No quantification possible	
»Green Office Computing« initiative Federal Ministry of Education and Research	Indirect, long-term impact (as of approx. 2015)	No quantification possible	
»Green Office Computing« initiative Federal Ministry of Education and Research	Indirect, long-term impact (as of approx. 2015)	No quantification possible	
»Green Office Computing« initiative Federal Ministry of Education and Research	Indirect, long-term impact (as of approx. 2012)	No quantification possible	

Roadmapping measure	Description of the measure	Period / Time of implementation
Trade unions, works and staff councils – Goal: Increase acceptance among the employees		
Study of the impact and acceptance of server based workplace computer solutions	Research in literature on the technological acceptance of IT in general, case studies in 10 companies that among other things are introducing or have introduced TC&SBC, surveys among IT managers and employee representatives	2011
Development of a sample company agreement for server based workplace computer solutions and distribution of the results of the study	Consequences of technology design and migration organization are derived on the basis of the study, documentation in the form of a sample company agreement, transfer Due to the publication of such a sample company agreement the topic is a) supported by a whole new side in the company and b) potential obstacles among the employees are removed	2011
Dialogs with trade unions, technology advice centers, works and staff councils	Consequences of technology design and migration organization are derived on the basis of the study, documentation in the form of a sample company agreement, transfer Due to the publication of such a sample company agreement the topic is a) supported by a whole new side in the company and b) potential obstacles among the employees are removed	As of 2012
Technology development and standards		
Research and development (R&D) to increase the energy and material efficiency of TCs	Acceleration of the introduction of a series of new energy and material-saving components in new TC generations	As of 2010
High-performance servers and high-performance bandwidth for engineering and graphics users	Attainment of series-production readiness for high-performance overall solutions for TC engineering and media applications, etc. on SBC or HVD basis There continues to be a high demand for the central provision of engineering workplaces. Only now is this possible in an efficient way. This workplace type in appropriate branches of industry is the significant IT driver. Inasmuch as the latter can be and is provided centrally, the centralization of all office IT workplaces is only a matter of time. Thus, these measures have an effect on an additional SBC field of application.	As of 2011
Development of software solutions to increase the ratio of clients per server in SBC, HVD and SaaS	Improvement in the performance of operating systems and virtualization software Extension and improvement of management software for capacity management and for the dynamic provision of resources	As of 2011
Increase the energy and material efficiency of servers	Increased transfer of components and experiences from the notebook construction to servers, modeled on Mini PCs The role model of Mini PCs (25 watts) and servers from notebook components (Christmann 35 watts, Apple 18 watts) leads the way and shows the relationship of weight and power consumption..	As of 2010

Responsible for implementation	On which factors does the measure impact?	To what extent does the measure impact? Change compared with BAU scenario	Explanation of impact assumption
Borderstep in cooperation with the Foundation for Labor and the Environment, funding through the Hans Böckler Foundation	Indirect, long-term impact (as of approx. 2012)	No quantification possible	
Borderstep in cooperation with the Foundation for Labor and the Environment, funding through the Hans Böckler Foundation	Market share of SBC and HVD / Stock share of TCs	Increases the number of TCs in 2013 by 15,000 and in 2020 by 60,000. The number of installed PCs is reduced by the same extent.	See »Measures«
Green IT Alliance Federal Ministry for Labor and Social Affairs Federal Ministry of Economics and Technology	Market share of SBC and HVD / Stock share of TCs	Increases the number of TCs in 2020 by 60,000. The number of installed PCs is reduced by the same extent.	See »Measures«
Manufacturers and importers	Reduction in the power consumption and weight of the new TCs	Reduction in the power consumption of the new TCs by 0.2 W per year and in the weight by 20 g per year	The product cycles depend on external factors. Manufacturers have scarcely any influence on various component-related factors
Server manufacturers, TC manufacturers, system houses	Market share of SBC and HVD / Stock share of TCs	Increases the number of TCs in 2013 by 15,000 and in 2020 by 60,000 (replace PCs)	However, in this issue bandwidth is in fact still a topic for small to medium-sized engineering companies and in rural regions.
Manufacturers of operating systems and virtualization software, Open-Source communities, universities	Increase in the ratio of clients per server	Increase in the ratio of clients per server in SBC, HVD and SaaS of an average at present from 50 (SBC), 50 (SaaS) and 25 (HVD) to 450 (SBC), 150 (HVD) and 300 (SaaS) in 2020. Thus, the ratio of clients to servers is three times better than in the BAU scenario in 2020.	This significantly improves the total cost of ownership (TCO) and helps the company with the introduction
Server manufacturers	Reduction in power consumption and in the weight of new servers	Server: Reduction in the annual power consumption of servers by 4% p.a. and in weight by 3% p.a.	

Roadmapping measure	Description of the measure	Period / Time of implementation
The state as an IT user and sponsor		
Green Office Computing solutions as an element of the ICT strategy of the Federal government	Inclusion of the targeted funding of energy and material-efficient office computing solutions (Mini PCs, TC&SBC, notebooks) in the ICT strategy of the Federal government	2010
Inclusion of Green Office Computing solutions in the Green IT plan of action of the Federal government	Inclusion of the targeted funding of energy and material-efficient office computing solutions (Mini PCs, TC&SBC, notebooks) in the Green IT plan of action of the Federal government (under the leadership of the Federal Ministry of Economics and Technology)	2010
Announcement of the roadmap »Resource-efficient workplace computer solutions 2020« to Federal, state and municipal authorities	Preparation of a series of lectures and informative events to present the roadmap »Workplace-related computer solutions 2020« in cooperation with the relevant IT committees (committee of IT managers, etc.) at Federal, state and municipal level, implementation of the series of lectures and informative events	2010 – 2011
Announcement of the roadmap »Resource-efficient workplace computer solutions 2020« to Federal, state and municipal parliaments	Distribution of the roadmap »Workplace-related computer solutions 2020« to members and committees of the German Bundestag and state parliaments with responsibility for IT matters as well as to the persons responsible at municipal level	2010 – 2011
Adaptation of procurement guidelines and general agreements of public procurement	e.g. change in the APC framework agreement with the Center for Data Processing and Information Technology (ZIVIT), etc.	2010 – 2012
Blue Angel for thin clients and Mini PCs	Development of award criteria for »thin clients« and »Mini PCs«, inclusion of these product groups in the award of the environmental label	2011 – 2012

Responsible for implementation	On which factors does the measure impact?	To what extent does the measure impact? Change compared with BAU scenario	Explanation of impact assumption
Federal Ministry of Economics and Technology, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and Federal Environmental Agency	Indirect impact	Not quantifiable	Agenda setting and improvement in the general conditions regarding Green office computing
Federal Ministry of Economics and Technology, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and Federal Environmental Agency	Indirect impact	Not quantifiable	Agenda setting and improvement in the general conditions regarding Green office computing
Federal Environmental Agency und Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	Stock share of TCs, Mini PCs, notebooks Annual power consumption per computer terminal in the utilization phase	Increases the number of installed Mini PCs, notebooks and TCs and decreases to the same extent the number of installed PCs compared with the BAU scenario for authorities: Mini PCs: in 2013 by 7,500 devices (for authorities) and in 2020 by 18,750 devices Notebooks: in 2013 by 7,500 devices (for authorities) and in 2020 by18,750 devices TCs: in 2013 by 7,500 devices (for authorities) and in 2020 by 37,500 devices	The impact (greater readiness among IT decision makers to decide in favor of Mini PCs, TCs and notebooks) unfolds between 2011 – 2013; then (2014 – 2020) impact through the resulting learning effects
Federal Environmental Agency und Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	Indirect impact, agenda setting and improvement in the level of awareness regarding Green office computing	Not quantifiable	
Project group »Green IT« of the committee of IT managers, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Federal Environmental Agency	Stock share of TCs, Mini PCs, notebooks	Increases the number of installed Mini PCs, notebooks and TCs and decreases to the same extent the number of installed PCs compared with the BAU scenario for authorities: Mini PCs: in 2013 by 15,000 and in 2020 by 37,500 devices Notebooks: in 2013 by 15,000 and in 2020 by 37,500 devices TCs: in 2013 by 15,000 devices and in 2020 by 75,000 devices	Relatively large impact; the creation of suitable framework agreements for APCs were named as a central prerequisite for the use of TCs in a survey of the Federal authorities in 2009.
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Federal Environmental Agency, Environmental Label Jury, RAL	Indirect, rather minor impact	Not quantifiable	Improved the visibility of energy and material efficiency of Mini PCs and TCs

Roadmapping measure	Description of the measure	Period / Time of implementation
Fundamental study on the impact of application software on the energy consumption of IT	Commissioning and carrying out of a study that proves the relationship between software architecture, energy-saving programming and energy consumption of the application	As of 2011
Green Office Computing innovation alliance	Initiation of an innovation alliance and a new funding focus »Green Office Computing« with the Federal Ministry of Education and Research	Initiation 2011 Implementation 2012 – 2015
»Energy-saving application software« innovation alliance	Initiation of an innovation alliance and a new funding focus »Energy-saving software« with the Federal Ministry of Education and Research to promote the development and diffusion of energy-saving application software; dialog and stakeholder process with leading software providers, transfer of the results of the study: conferences, magazine articles, etc. depending on the result of the study.	Initiation 2011 Implementation 2012 – 2015
Green Office Computing solutions as a continuous principal point in the funding focus »IT goes green« of the Federal Ministry for the Environment	Green Office Computing solutions should become a principal point in the funding focus »IT goes green« in the environmental innovation program of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and remain as such in the long term	2010 – 2020
Development of the diffusion of Mini PCs	Transfer activities to promote the high profile and availability of Mini PCs for office applications	As of 2010
Measures to increase the average hardware efficiency of data centers	Measures to increase the average hardware efficiency of data centers	As of 2010
Measures to increase the average PUE of data centers in Germany	Preparation of a roadmap of efficient infrastructure technologies in data centers	As of 2010

Responsible for implementation	On which factors does the measure impact?	To what extent does the measure impact? Change compared with BAU scenario	Explanation of impact assumption
Federal Environmental Agency	Indirect impact	Not quantifiable	
Green IT Alliance Science forum – Green IT Federal Ministry of Education and Research	Annual power consumption of computer terminals	Reduction in the average annual energy consumption of computer terminals in 2020 by 5 kWh (PCs), 3 kWh (Mini PCs), 2 kWh (notebooks) and 1 kWh (thin clients)	Impact only as of 2016, because the developed energy and material-efficient solutions are only to be launched as of 2016.
Green IT Alliance Science forum – Green IT Federal Ministry of Education and Research	Reduction in resource requirements (energy and material) of computer terminals of every kind	Increase in energy efficiency of computer terminals as of 2012 by 2% every year until 2020.	The work carried out by working group 3 »Software« of the Green IT alliance should be taken into consideration.
Federal Ministry for the Environment, Nature Conservation and Nuclear Safety and Federal Environmental Agency	Indirect impact	Not quantifiable	Lighthouse projects increase the visibility of innovative Green office computing solutions
Manufacturers of Mini PCs, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety	Market share / Stock share of Mini PCs	Increases the stock share of Mini PCs in 2013 by 40,000 and in 2020 by 200,000 to the detriment of the PC	
Manufacturers, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Federal Ministry of Economics and Technology, BITKOM study group Data Center & Infrastructure	Energy and material requirements of data centers	Not yet foreseeable.	
Manufacturers, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Federal Ministry of Economics and Technology, BITKOM study group Data Center & Infrastructure	Energy and material requirements of data centers	Increase in the average PUE of data centers in Germany from 1.9 today to 1,6 in 2013 and to 1.3 in 2020	

Appendix: Calculation table of the BAU scenario

	Year 2010				
	PC	Mini PC	Note-book	TC	Total
Stock of computer terminals					
Number of devices in 1000	13,000	300	11,000	2,200	26,500
Structure of stock in percent	49.1	1.1	41.5	8.3	100.0
Form of software deployment					
Percentage use of local software	90%	90%	90%	0%	
Percentage SBC	4%	4%	4%	90%	
Percentage HVD	4%	4%	4%	10%	
Percentage SaaS	2%	2%	2%	0%	
Energy consumption					
Electric power consumption per computer terminal in kWh p.a. (without display etc.) during utilisation phase	201	74	65	43	
In percent of 2010					
Energy consumption per computer terminal in kWh p.a. during utilisation phase (PEC)	549	202	177	117	
Electric Power consumption of all terminals p.a. in GWh	2,610	22	713	94	3,439
Energy consumption in production phase (PEC) per terminal in kWh	584	285	340	141	
Useful life in years	5	5	4	8	
Energy Consumption in production phase per year of use in kWh (PEC)	117	57	85	18	
Energy consumption in production phase and during utilisation phase per device p.a. in kWh (PEC)	666	259	262	135	
Energy consumption in production phase and during utilisation phase for all devices in GWh (PEC)	8,659	78	2,886	296	11,918
Number of clients per physical terminal server at SBC	50	50	50	50	
Number of clients per physical terminal server at HVD	25	25	25	25	
Number of clients per physical terminal server at SaaS	50	50	50	50	
Electric Power consumption of terminal server p.a. in kWh	1984	1984	1984	1984	
PUE server room / data center	2	2	2	2	
Electric power consumption per terminal server plus infrastructure p.a. in kWh	3,968	3,968	3,968	3,968	
Total electric power consumption of using central IT-ressources p.a. in kWh per computer workplace	11.11	11.11	11.11	87.31	
Total electric power consumption of using central IT-ressources of all devices in GWh	144	3	122	192	
Energy consumption per server in kWh p.a. during utilisation phase (PEC)	10,858	10,858	10,858	10,858	
Energy consumption in production phase (PEC) per terminal server in kWh	1,825	1,825	1,825	1,825	
Useful live of terminal server in years	4	4	4	4	
Energy consumption in production phase per terminal server p.a. in kWh (PEC)	456	456	456	456	

BAU 2013					BAU 2030				
PC	Mini PC	Note-book	TC	Total	PC	Mini PC	Note-book	TC	Total
12,610	1,030	13,450	2,910	30,000	11,650	2,500	17,450	5,900	37,500
42.0	3.4	44.8	9.7	100.00	31.07	6.67	46.53	15.73	100,00
55%	55%	55%	0%		25%	25%	25%	0%	
20%	20%	20%	70%		20%	20%	20%	50%	
20%	20%	20%	20%		40%	40%	40%	30%	
5%	5%	5%	10%		15%	15%	15%	20%	
171	70	60	36		145	63	53	27	
85%	95%	92%	85%		72%	85%	82%	64%	
447	184	157	95		341	147	126	64	
2,151	72	805	105	3,133	1,691	157	933	160	2,940
548	242	293	122		511	213	262	103	
5	5	4	8		5	5	4	8	
110	48	73	15		102	43	66	13	
556	233	230	110		443	190	191	77	
7,016	240	3,094	320	10,670	5,162	475	3,336	453	9,425
80	80	80	80		150	150	150	150	
32,5	32,5	32,5	32,5		50	50	50	50	
65	65	65	65		100	100	100	100	
1883	1883	1883	1883		1475	1475	1475	1475	
1.9	1.9	1.9	1.9		1.7	1.7	1.7	1.7	
3,577	3,577	3,577	3,577		2,508	2,508	2,508	2,508	
33.71	33.71	33.71	58.81		27.17	27.17	27.17	28.42	
425	35	453	171		316	68	474	168	
9,372	9,372	9,372	9,372		5,891	5,891	5,891	5,891	
1,825	1.825	1.825	1.825		1,825	1,825	1,825	1,825	
4.3	4.3	4.3	4.3		5	5	5	5	
424	424	424	424		365	365	365	365	

	Year 2010				
	PC	Mini PC	Note-book	TC	Total
Energy consumption in production phase and during utilisation phase per terminal server p.a. in kWh (PEC)	11,314	11,314	11,314	11,314	
Total energy consumption of using central IT-ressources p.a. in kWh per computer workplace (PEC)	32	32	32	249	
Total energy consumption of using central IT-ressources of all devices in GWh (PEC)	412	10	348	548	1.317
Energy consumption in production phase and during utilisation phase per computer workplace p.a. in kWh (PEC)	698	291	294	384	499
Energy consumption in production phase and during utilisation phase for all devices p.a. in GWh	9,071	87	3,234	844	13,236
Total electric power consumption per computer workplace p.a. in kWh	212	85	76	130	147
Electric power consumption for all devices p.a. in GWh	2,754	26	836	286	3,902
Comparison 2010 and 2013 resp. 2020 in percent					
Material usage					
Weight of device in kg	8	2	2.2	1.5	
Weight of notebook dockingstation (use with 50% of notebooks) in kg			0.4		
Total product weight in kg	8	2	2.4	1.5	
Percentage electronic components	11%	30%	28%	22%	
Percentage plastics	4%	30%	28%	10%	
Percentage metal parts	67%	25%	22%	55%	
Percentage power supply	18%	15%	8%	13%	
Weight of all terminals in metric tons (mt)	104,000	600	26,400	3,300	134,300
Weight of electronic components in mt	11,440	180	7,392	726	19,738
Weight of plastics in mt	4,160	180	7,392	330	12,062
Weight of metal parts in mt	69,680	150	5,808	1,815	77,453
Weight of power supplies in mt	18,720	90	2,112	429	21,351
Weight of server in kg	25	25	25	25	
Percentage electronic components server	30%	30%	30%	30%	
Number of all required terminal server p.a.	36,400	840	30,800	48,400	116,440
Weight of all required terminal server p.a. in mt	910	21	770	1,210	2,911
Weight of electronic components of all required terminal server in mt	273	6	231	363	
Weight of all terminals and server in mt	104,910	621	27,170	4,510	137,211
Comparison 2010 and 2013 resp. 2010 in percent					
Weight terminal, percentage server and infrastructure per computer workplace in kg	8.07	2.07	2.47	2.05	5.18
Climatic impact					
CO_2-emission factor german power mix in g/kWh	580	580	580	580	580
Global warming potential through power consumption in CO_2 eq. p.a. per computer workplace in kg	122.9	49.4	44.1	75.4	85.4
Greenhouse gas potential by energy consumption in CO_2 eq. p.a. in 1000 mt	1,597	15	485	166	2,263
Comparison 2010 and 2013 resp. 2020 in percent					

BAU 2013					BAU 2030				
PC	Mini PC	Note-book	TC	Total	PC	Mini PC	Note-book	TC	Total
9,796	9,796	9,796	9,796		6,256	6,256	6,256	6,256	
92	92	92	161		68	68	68	71	
1,164	95	1,242	469	2,969	790	169	1,183	418	2,560
649	325	322	271	455	511	258	259	148	320
8,180	335	4,336	789	13,639	5,951	644	4,519	871	11,985
204	104	94	95	141	172	90	81	56	106
2,576	107	1,258	276	4,217	2,007	225	1,407	328	3,967
				108.09%					101.67%
7.5	1.7	1.9	1.3		7	1.5	1.7	1.1	
		0.4					0.3		
7.5	1.7	2.1	1.3		7	1.5	1.85	1.1	
15%	28%	28%	23%		20%	25%	28%	25%	
6%	30%	28%	14%		10%	30%	28%	20%	
60%	27%	22%	48%		50%	30%	22%	35%	
19%	15%	8%	15%		20%	15%	8%	20%	
94,575	1,751	28,245	3,783	128,354	81,550	3,750	32,283	6,490	124,073
14,186	490	7,909	870	23,455	16,310	938	9,039	1,623	27,909
5,675	525	7,909	530	14,638	8,155	1,125	9,039	1,298	19,617
56,745	473	6,214	1,816	65,248	40,775	1,125	7,102	2,272	51,274
17,969	263	2,260	567	21,059	16,310	563	2,583	1,298	20,753
25	25	25	25		25	25	25	25	
35%	35%	35%	35%		40%	40%	40%	40%	
118,825	9,706	126,740	47,847	303,118	126,208	27,083	189,042	66,867	409,200
2,971	243	3,169	1,196	7,578	3,155	677	4,726	1,672	10,230
1,040	85	1,109	419		1,262	271	1,890	669	
97,546	1,994	31,414	4,79	135,932	84,705	4,427	37,009	8,162	134,303
				99,1%					97.9%
7.74	1.94	2.34	1.71	4.53	7.27	1.77	2.12	1.38	3.58
550	550	550	550	550	480	480	480	480	480
112.3	57.2	51.4	52.2	77.3	82.7	43.1	38.7	26.7	50.8
1,417	59	692	152	2,319	963	108	675	157	1,904
				102.5%					84.1%

Appendix: Calculation table of the Green IT scenario

	Year 2010				
	PC	Mini PC	Note-book	TC	Total
Stock of computer terminals					
Number of devices in 1000	13,000	300	11,000	2,200	26,500
Structure of stock in percent	49.1	1.1	41.5	8.3	100.0
Form of software provision					
Percentage use of local software	90%	90%	90%	0%	
Percentage SBC	4%	4%	4%	90%	
Percentage HVD	4%	4%	4%	10%	
Percentage SaaS	2%	2%	2%	0%	
Energy consumption					
Electric power consumption per computer terminal in kWh p.a. (without display etc.) during utilisation phase	201	74	65	43	
In percent of 2010					
Energy consumption per computer terminal in kWh p.a. during utilisation phase (PEC)	549	202	177	117	
Electric Power consumption of all terminals p.a. in GWh	2,610	22	713	94	3,439
Energy consumption in production phase (PEC) per terminal in kWh	584	285	340	141	
Useful life in years	5	5	4	8	
Energy Consumption in production phase per year of use in kWh (PEC)	117	57	85	18	
Energy consumption in production phase and during utilisation phase per device p.a. in kWh (PEC)	666	259	262	135	
Energy consumption in production phase and during utilisation phase for all devices in GWh (PEC)	8,659	78	2,886	296	11918
Number of Clients per physical terminal server at SBC	50	50	50	50	
Number of Clients per physical terminal server at HVD	25	25	25	25	
Number of clients per physical terminal server at SaaS	50	50	50	50	
Electric Power consumption of terminal server p.a. in kWh	1984	1984	1984	1984	
PUE server room / data center	2	2	2	2	
Electric power consumption per terminal server plus infrastructure p.a. in kWh	3,968	3,968	3,968	3,968	
Total electric power consumption of using central IT-ressources p.a. in kWh per computer workplace	11.11	11.11	11.11	87.31	
Total electric power consumption of using central IT-ressources of all devices in GWh	144	3	122	192	
Energy consumption per server in kWh p.a. during utilisation phase (PEC)	10,858	10,858	10,858	10,858	
Energy consumption in production phase (PEC) per terminal server in kWh	1,825	1,825	1,825	1,825	
Useful live of terminal server in years	4	4	4	4	
Energy consumption in production phase per terminal server p.a. in kWh (PEC)	456	456	456	456	

Green IT 2013					Green IT 2020				
PC	Mini PC	Note-book	TC	Total	PC	Mini PC	Note-book	TC	Total
11,553	1,318	13,648	3,483	30,000	5,629	4,428	18,568	8,876	37,500
38.5	4.4	45.5	11.6	100.00	15.01	11.81	49.51	23.67	100.00
55%	55%	55%	0%		25%	25%	25%	0%	
20%	20%	20%	70%		20%	20%	20%	50%	
20%	20%	20%	20%		40%	40%	40%	30%	
5%	5%	5%	10%		15%	15%	15%	20%	
169	69	59	35		121	51	43	22	
84%	93%	91%	82%		60%	69%	67%	50%	
444	181	154	92		284	119	102	51	
1,958	91	804	122	2,975	681	224	806	191	1,902
548	242	293	116		511	213	262	84	
5	5	4	8		5	5	4	8	
110	48	73	15		102	43	66	11	
554	229	228	106		386	162	168	61	
6,395	302	3,106	370	10,174	2,175	716	3,110	543	6,545
150	150	150	150		450	450	450	450	
50	50	50	50		150	150	150	150	
100	100	100	100		300	300	300	300	
1756	1756	1756	1756		1319	1319	1319	1319	
1.6	1.6	1.6	1.6		1.3	1.3	1.3	1.3	
2,809	2,809	2,809	2,809		1,715	1,715	1,715	1,715	
16.38	16.38	16.38	27.15		6.19	6.19	6.19	6.48	
189	22	224	95		35	27	115	58	
7,359	7,359	7,359	7,359		4,028	4,028	4,028	4,028	
1,666	1,666	1,666	1,666		1,346	1,346	1,346	1,346	
4.3	4.3	4.3	4.3		5	5	5	5	
387	387	387	387		269	269	269	269	

	Year 2010				
	PC	Mini PC	Note-book	TC	Total
Energy consumption in production phase and during utilisation phase per terminal server p.a. in kWh (PEC)	11,314	11,314	11,314	11,314	
Total energy consumption of using central IT-ressources p.a. in kWh per computer workplace (PEC)	32	32	32	249	
Total energy consumption of using central IT-ressources of all devices in GWh (PEC)	412	10	348	548	1,317
Energy consumption in production phase and during utilisation phase per computer workplace p.a. in kWh (PEC)	698	291	294	384	499
Energy consumption in production phase and during utilisation phase for all devices p.a. in GWh	9,071	87	3,234	844	13,236
Total electric power consumption per computer workplace p.a. in kWh	212	85	76	130	147
Electric power consumption for all devices p.a. in GWh	2,754	26	836	286	3,902
Comparison 2010 and 2013 resp. 2020 in percent					
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Weight of device in kg	8	2	2.2	1.5	
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Weight of electronic components in mt	11,440	180	7,392	726	19,738
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Weight of server in kg	25	25	25	25	
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Weight terminal, percentage server and infrastructure per computer workplace in kg	8.07	2.07	2.47	2.05	5.18
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CO_2-emission factor german power mix in g/kWh	580	580	580	580	580
Global warming potential through power consumption in CO2 eq. p.a. per computer workplace in kg	122.9	49.4	44.1	75.4	85.4
Greenhouse gas potential by energy consumption in CO2 eq. p.a. in 1000 mt	1,597	15	485	166	2,263
Comparison 2010 and 2013 resp. 2020 in percent					

Green IT 2013					Green IT 2020				
PC	Mini PC	Note-book	TC	Total	PC	Mini PC	Note-book	TC	Total
7,747	7,747	7,747	7,747		4,298	4,298	4,298	4,298	
45	45	45	75		16	16	16	16	
522	60	617	261		87	69	288	144	
599	275	273	181	388	402	177	183	77	190
6,917	362	3,723	631	11,633	2,262	785	3,399	687	7,133
186	85	75	62	117	127	57	50	28	57
2,147	113	1,027	216	3,504	716	252	921	249	2,137
				87.89%					53.89%
7.5	1.7	1.9	1.24		6	1.5	1.7	0.9	
		0.4					0.3		
7.5	1.7	2.1	1.4		6	1.5	1.85	0.9	
15%	28%	28%	23%		20%	25%	28%	25%	
6%	30%	28%	14%		10%	30%	28%	20%	
60%	27%	22%	48%		50%	30%	22%	35%	
19%	15%	8%	15%		20%	15%	8%	20%	
86,644	2,240	28,660	4,318	121,862	33,774	6,641	34,350	7,988	82,754
12,997	627	8,025	993	22,642	6,755	1,660	9,618	1,997	20,030
5,199	672	8,025	605	14,500	3,377	1,992	9,618	1,598	16,585
51,986	605	6,305	2,073	60,969	16,887	1,992	7,557	2,796	29,232
16,462	336	2,293	648	19,739	6,755	996	2,748	1,598	12,097
22.82	22.82	22.82	22.82		18.44	18.44	18.44	18.44	
35%	35%	35%	35%		40%	40%	40%	40%	
67,390	7,685	79,610	33,664	188,350	20,327	15,988	67,049	33,532	136,896
1,538	175	1,816	768	4,298	375	295	1,236	618	2,524
538	61	636	269		150	118	494	247	
88,181	2,415	30,476	5,086	126,159	34,149	6,936	35,586	8,607	85,277
				91.9%					62.2%
7.63	1.83	2.23	1.46	4.21	6.07	1.57	1.92	0.97	2.27
550	550	550	550	550	480	480	480	480	480
102.2	47.0	41.4	34.2	64.2	61.0	27.3	23.8	13.5	27.4
1,181	62	565	119	1,927	344	121	442	119	1,026
				85.2%					45.3%

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