

INDUSTRY DEVELOPMENTS AND MODELS

Potential Server and Datacenter CO₂ Savings in Denmark

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IDC OPINION

There is no doubt, that powering IT systems is an interesting part of the overall environment footprint in Denmark. The estimated power consumption by servers and datacenters in Denmark today equals 864 GWh per year. In comparison, this is more than twice the electricity power used in Denmark for street lightning. Compared to all private households' use of electricity, servers and data centers powering constitute 9%.

- ☒ Customers of IT are very aware of the energy use of IT equipment, and by replacing old servers with new servers they often expect a reduction in power consumption. This is also the case, but the need for server capacity is increasing even faster. IDC's calculations show that even with new and more energy efficient servers, the power consumption of servers and data centers will still increase to 2013.
- ☒ There are two key ways of significantly improving the server and data center CO₂ footprint until 2013. The first is to increase virtualization of servers. If all servers in Denmark are virtualized to the extent it makes sense, the total power consumption can be reduced by 33% compared to today – and this even accommodates the increased need for server capacity. In addition to this lower CO₂ footprint, the total cost for power and hardware spending will be reduced by 22% by 2013 equivalent to more than 1/2 billion kr.
- ☒ Another level of reduction can be obtained if all servers are consolidated in large, central datacenters, where the power consumption is reduced to an optimized level documented by some of the most efficient data centers in the world. In this case, the power consumption can be reduced by up to 55% compared to today. This scenario can become reality – at least to some extent – if cloud computing becomes pervasive and IT is delivered as services from large, commercial data centers.
- ☒ The public sector in Denmark (including local, regional and national government) accounts for about 24% of server and datacenter power consumption (including the public sector's use of private datacenters). Although we do assume a slightly different profile with regard to virtualization and datacenter sizes in the public sector, the potential for savings are just as significant in the public sector as in the private sector. This means that even in the public sector, maximum virtualization can reduce total power consumption by 33% compared to today and using cloud computing has the potential of reducing power consumption significantly more.

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IN THIS STUDY

This document has been prepared by IDC for the Danish High Speed Committee and the Danish National IT and Telecom Agency (NITA). It evaluates and estimates the power consumption in Denmark from IT servers and the associated data centers. The study also evaluates a number of future scenarios and the environmental impact from technology developments such as the use of more energy-efficient servers, implementation of virtualized servers and the use of Cloud Computing.

Scope

The research carried out by IDC has not the intent to analyze all aspects of the IT energy consumption. It focuses on servers and the energy overhead by running servers in a data center. This means the following scope for the work:

Included in this study:

- All servers in Denmark whether in the private or in the public sector. Also included are servers running in datacenters servicing Danish customers
- Servers include the systems that are being used by vendors (such as outsourcing vendors' data centers)
- Energy used by data centers for cooling, power for datacenter infrastructure and security

Not included in this study:

- PCs being used as servers
- Energy used by non-server equipment outside the data center such as PCs, printers, network equipment and other peripherals
- Energy used by communication equipment and by communication service providers
- The possible impact from redesigning data centers in Denmark
- The possible impact from changed (higher or lower) energy prices in the future

Summary

This study evaluates and estimates the power consumption in Denmark from IT servers and the associated data centers.

The estimated power consumption by servers and datacenters in Denmark in 2009 equals 864 GWh per year. In cost this equals just above 1b DKK assuming an average price of 1.20 DKK/KWh or a total CO2 emission of 381,000 ton per year.

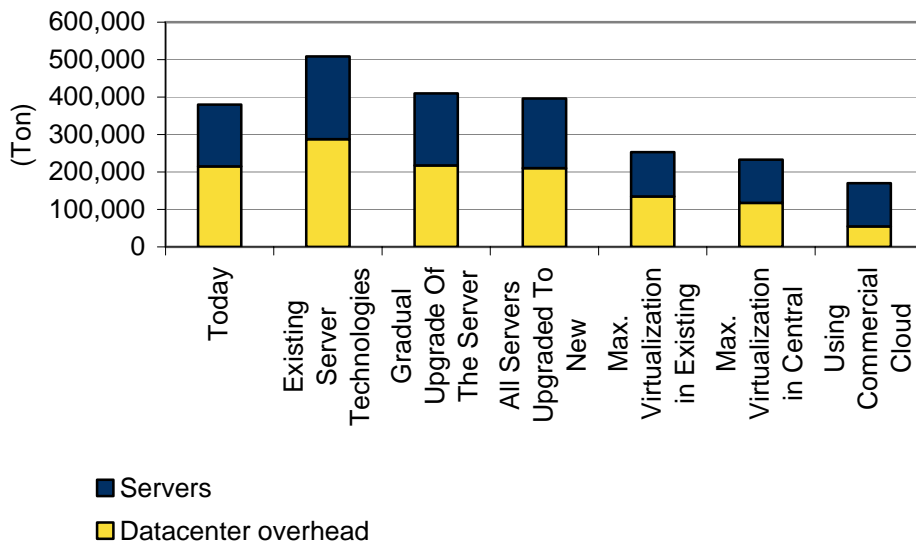
Using these numbers for 2009 as baseline for a number of scenarios, the IDC research shows the following changes through 2013 compared to today:

Scenario 1: Using the existing servers throughout to 2013, e.g. no server replacements

- Server and datacenter power consumption as well as corresponding CO2 emission will increase by 34% by 2013 compared to today
- Yearly capital expenditure by 2013 on servers and related equipment will decline by 66% (only addition of new servers, no replacements)

FIGURE 1

CO2 emission from servers and datacenters today and in 2013 given various scenarios, Denmark (ton/year)



Source: IDC, 2009

Scenario 2: Gradual replacement of old servers with new, more energy efficient servers at normal rate throughout to 2013

- Server and datacenter power consumption as well as corresponding CO2 emission will increase by 8% by 2013 compared to today

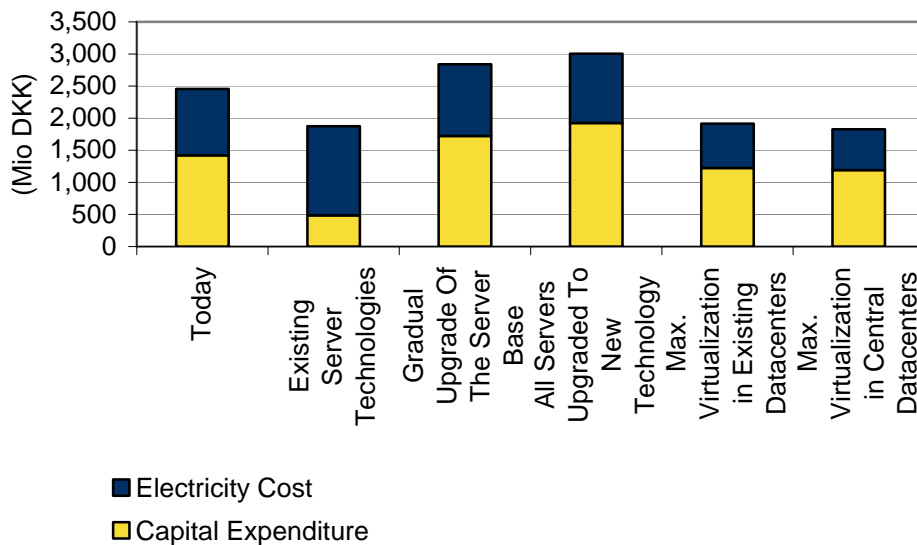
- ☒ Yearly capital expenditure by 2013 on servers and related equipment will increase 21%
- ☒ Total yearly costs (power and hardware) by 2013 will have increased by 16% - or approximately 400m DKK

Scenario 3: Accelerated replacement of old servers with new, more energy efficient servers so that all servers in the installed base are replaced by 2013

- ☒ Server and datacenter power consumption as well as corresponding CO2 emission will increase by 6% by 2013 compared to today
- ☒ Yearly capital expenditure by 2013 on servers and related equipment will increase by 36%
- ☒ Total yearly costs (power and hardware) by 2013 will have increased by 22% - or approximately 550m DKK

FIGURE 2

Server and datacenter hardware cost today and in 2013 given various scenarios, Denmark (Mio DKK)



Source: IDC, 2009

Scenario 4: All servers are virtualized to the extent possible by 2013 in existing data centers

- ☒ Server and datacenter power consumption as well as corresponding CO2 emission will decline by 33% by 2013 compared to today
- ☒ Yearly capital expenditure by 2013 on servers and related equipment will decline by 14%

- ☒ Total yearly costs (power and hardware) by 2013 will have decreased by 22% - or approximately 550m DKK

Scenario 5: All servers are virtualized to the extent possible by 2013 in central data centers

- ☒ Server and datacenter power consumption as well as corresponding CO2 emission will decline by 39% by 2013 compared to today
- ☒ Yearly capital expenditure by 2013 on servers and related equipment will decline by 16%
- ☒ Total yearly costs (power and hardware) by 2013 will have decreased by 26% - or approximately 630m DKK

Scenario 6: Complete Use of Commercially Available Cloud Services

- ☒ Server and datacenter power consumption as well as corresponding CO2 emission will decline by 55% by 2013 compared to today

SITUATION OVERVIEW

Datacenter Power Consumption

The key starting point for assessing the power consumption of servers in Denmark is the number of server installed. IDC's server taxonomy segments the server market into three classes:

- ☒ Volume server market: Consisting of all systems with average sales values (ASVs) less than 150,000 kr.
- ☒ Midrange enterprise server market: Consisting of all systems with ASVs of 150,000 kr. – 350,000 kr.
- ☒ High-end enterprise server market: Consisting of all systems with ASVs of 350,000 kr. or more

Installed base of servers is composite shipments and initial server shipments plus upgrades minus retirements. Volume servers generally have a life expectancy of three to five years, and mainframe type systems typically have a longer life. IDC has been tracking shipments of server in Denmark for decades and therefore is able to provide a detailed picture of servers in use today.

TABLE 1

Server installed base by sector and server class

	Volume servers	Mid-range servers	High-end servers
Central government	12,900	200	15
Regional government	3,500	100	5
Local government	18,900	200	10
Private segment	162,400	2,600	160

Note: Calculated based on actual shipments

Source: IDC, 2009

Based on extensive research, IDC has estimated the typical power consumption for servers as is stated in the following table.

TABLE 2

Typical power consumption by server class

Server Class	Power Consumption
Volume servers	190 W
Mid-range servers	745 W
High-end servers	10,800 W

Source: IDC, 2009

A significant number of the installed servers in Denmark are installed in data centers of various types. For the purpose of this study, IDC has categorized data centers in the following categories:

- Server closet:** A very small room or "closet" often outside of direct IT management control that has little to no security or cooling; usually under 10 m²; usually less than 5 servers installed.
- Server room:** A secondary computer location that usually is under IT control, often 10-100 m² in size and may have some power and cooling as well as security capabilities; usually 5-25 servers installed.
- Localized datacenter:** May be a primary or secondary location that is usually 100-500 m² requiring badge or pin access and has some power and cooling redundancy to ensure constant temperature and humidity settings; usually 25-100 servers installed.
- Central data center** consists of both
 - Mid-tier datacenter:** Is the primary server location for an organization that is a large room, and typically 500 to 2,000 m². It has superior cooling systems that are probably redundant and is usually protected by two levels of physical and digital security; usually 50-500 installed servers.
 - Enterprise class datacenter:** Is the primary server location for an organization. Is a very large room often in excess of 2,000 m² and has advanced cooling systems, redundant power, and is protected by multiple levels of physical and digital security; usually 500-1,000s of installed servers.

For each type of data center, IDC has evaluated the amount of power being used by the data center for cooling, in-house infrastructure, storage and other in-house power consumption. This energy use is best evaluated as a ratio relative to the power consumption of servers that are hosted by the data center. Although this ratio varies significantly between data centers – dependent on how effective the centers are in power consumption – there is still an approximate proportional relationship between power used by servers in a data center and the power overhead used for cooling etc.

IDC research has provided the following average factors by data center type:

- Server closet: 0.90 MWh for each 1.0 MWh used by installed servers
- Server room: 1.45 MWh for each 1.0 MWh used by installed servers
- Local data center: 1.40 MWh for each 1.0 MWh used by installed servers
- Central data center: 1.25 MWh for each 1.0 MWh used by installed servers

Based on these assumptions as well as the estimated number of data centers in Denmark, the total power consumption for servers and data centers in Denmark 2009 can be estimated.

In order to assess the environmental footprint and economic implications, the annual spending on servers and other datacenter hardware (i.e. storage and infrastructure network) are included. The data for this is taken directly from IDC's market research databases, which are based on actual sales figures as reported by vendors.

Part of the server capacity in the private segment is hosted by IT outsourcing companies, but utilized by public organizations. Although the overall effect is limited, the energy consumption and CO₂ emission should be counted for in the public sector instead of the private. According to IDC's research, just less than 8% of the total server spending is for hosting services. The public sectors' share of this is just around 20%. It is assumed that there is a strong correlation between spending and server utilization – i.e. 1.6% (8% x 20%) of the server utilization in the private sector is used by public organizations.

Finally, the following assumptions related to CO₂ emission and energy cost, are used:

- CO₂ emission: 440 g/KWh
- Electricity price: 1.20 DKK/KWh

TABLE 3

Server and datacenter characteristics by sector

	Central government	Regional government	Local government	Public utilization of private servers	Private segment
Servers					
Number of Servers	13,100	3,600	19,100		164,900
Energy Consumption (GWh/year)	25	7	34	5	304
CO ₂ emission ('000 ton/year)	11	3	15	2	134
Power Consumption (Mio DKK)	30	8	41		371
Average annual server spending (Mio DKK)	74	21	79		841

TABLE 3

Server and datacenter characteristics by sector

	Central government	Regional government	Local government	Public utilization of private servers	Private segment
Datacenters					
Number of datacenters	3,900	1,200	6,300		51,500
Overhead energy consumption (GWh/year)	33	9	45	6	396
Overhead CO2 emission ('000 ton/year)	15	4	20	3	174
Datacenter total					
Total datacenter energy consumption (GWh/year)	58	16	79	11	700
Total datacenter CO2 emission ('000 ton/year)	26	7	35	5	308
Total datacenter power consumption (Mio DKK)	70	19	95		853
Total annual hardware spending (Mio DKK)	103	29	110		1,178

Source: IDC, 2009

In conclusion, the estimated power consumption by servers and datacenters in Denmark in 2009 equals 864 GWh per year. In cost this equals just above 1b DKK assuming an average price of 1.20 DKK/KWh or a total CO2 emission of 381,000 ton per year.

The public sector accounts for 19% of the total power and CO2 consumption, of which local government has the highest share followed by central government.

Energy Efficient Server Technologies

There are several components in a server, which can be enhanced in terms of energy efficiency, contributing to cut down the overall power requirements.

The first point where power efficiency gains have to be obtained is at the computing hardware level in the servers. This is extremely important, because by reducing the amount of power and thus the amount of heat generated by servers, it is possible to bring down the power needed to cool them as well.

Hardware efficiency can be enhanced at CPU, memory, and disk levels via power management tools working in many different ways. Most advances are expected at CPU level where approximately half the power is consumed. It is estimated that hardware efficiency at best can lead to a 20% improvement in efficiency

Power supply units are also undergoing constant developments in terms of efficiency. On average, the PSU power efficiency has improved from 70% to 75% in recent years and efficiency requirements for PSUs above 80% have been proposed.

Other than lowering the power request from the IT equipment, the electricity bill can also be cut down at rack and room level.

Rack-level optimization requires that racks and servers are designed to work together - i.e. it may be necessary to replace the racks and/or servers. By doing so, cooling and possibly power supply, storage etc, can be moved from the individual server to the entire rack. Power management applications can also help, as - for instance - rack cooling can be varied depending on the total utilization of the servers in the rack.

Optimization at room level includes relatively simple processes like cleaning up in cabling, but much more drastic steps are needed to lower the overhead considerably. Some of the most efficient steps are controlling the airflow in the datacenter and managing the temperature in details. This includes for instance raising the server racks from the floor and cooling only selected areas in the datacenter. Other possibilities include using lighting, which generates less heat or using the surrounding environment - cool weather or nearby water - in the cooling system. This level of redesigning however is often not possible in existing datacenters and is furthermore very costly to establish. Another possibility is to change the temperature level in the room, as a lot of IT equipment can easily operate at higher temperatures than typically used.

The most efficient way of lowering energy consumption however, is to reduce the numbers of physical servers in use and the most effective way to do this is by using server virtualization technologies.

Server Virtualization

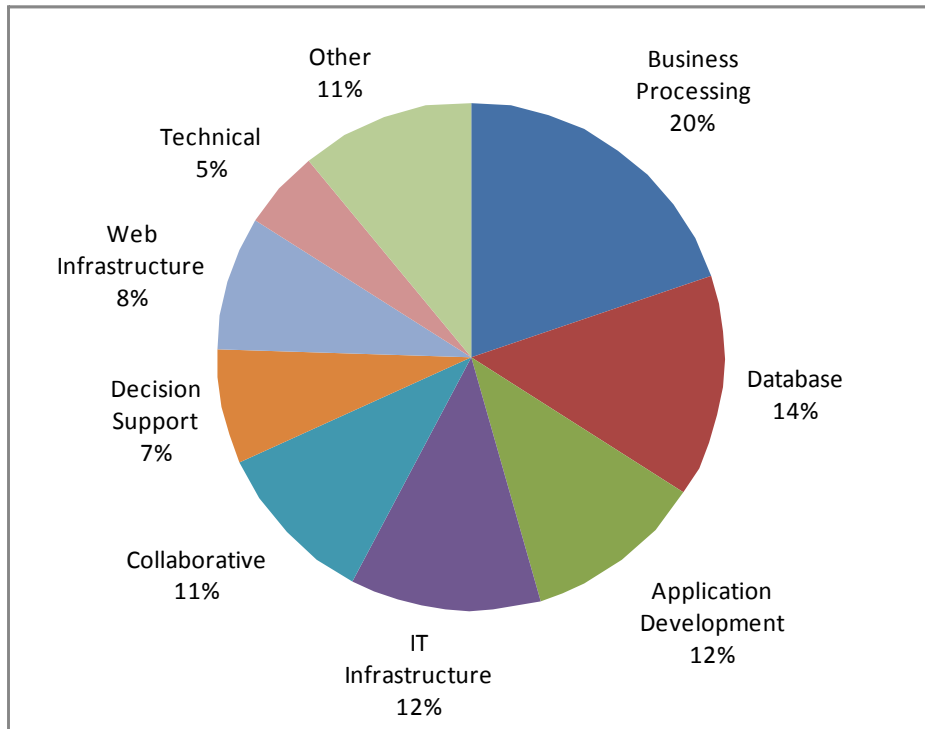
While only a few years ago, server virtualization was predominately used in limited deployments and test environments, today business critical applications rely on virtual servers. Server virtualization is mainly used for isolating applications and workloads on dedicated machines. Surveys show that two thirds run only one operating system – although quite frequently in different versions. This indicates that virtualization is predominately used for creating servers, which are dedicated to specific applications or groups of applications.

With dedicated servers it is not only possible to optimize the setup to the specific applications – it also makes administration, measuring performance etc. easier thereby enabling workload balancing. There is definitely a need to do this, as many companies run more 100-150 individual applications on their servers and as the figure above illustrates, the server workloads are spread across several applications.

Savings and reducing cost has so far been the most important driver for virtualization projects. Reducing cost is not just about lowering capital expenditure, but rather improving utilization of resources. Interviews reveal that the primary reason for wanting to improve utilization is not due to "do more with the same hardware", but rather use the energy more efficiently and optimize the server capacity of a given amount of square meters.

FIGURE 3

Virtual Server Workloads



Source: IDC, 2009

However cost is not the only driver and improving the quality of the infrastructure – i.e. improve availability and faster response to changes is commonly seen as an additional advantage. Improved management and easier maintenance are other benefits most companies seek.

IDC surveys have shown that more than 80% of those having experience with server virtualization are in general positive – and none are negative. This positive attitude is practically unheard of within IT perception, but it should be noted that there are of course problems with virtualization, which however don't eclipse the positive results.

Currently, the main problem with virtualization projects is that some applications are not suited for virtual environments. Although the applications – in theory – shouldn't "be aware" of the virtualization layer, this is not always the case. Some applications refuse to run in a virtual setup, while others cannot be scaled up and down depending on resource need, as the application won't recognize the additionally allocated capacity. Another problem is the lack of support from application developers. The difficulties are often related to legacy applications and the scope of the problems is likely to diminish in time. A related problem is that support from application vendors is not perceived as good enough.

Other problems have related to the implementation process and several companies have started extensive virtualization implementations as fully internal projects only to find that the needed expertise wasn't available in-house.

Finally it should be noted that although virtualization has proven to be very robust and lead to lower down-time, a system failure will typically have a more significant impact than in a traditional non-virtualized setup. The reason is that more logical servers run on each physical server, so if the physical server breaks down, all logical ones will too. Also, a failure in the virtual machine software will affect the entire virtual infrastructure – bringing down all servers.

Cloud Services

IDC prefers the more general "Cloud Services" over "Cloud Computing", partly because users or buyers of such services do not necessarily think of what is offered as "computing". Cloud services are fundamentally about an emerging delivery/consumption model – one that can be applied to IT industry offerings (e.g., as in software-as-a-service (SaaS), and storage or server capacity as a service), but also much more broadly, to offerings from many other industries, including entertainment, energy, financial services, health, manufacturing, retail and transportation, as well as from government and education sectors.

At a high level, cloud services can be described simply and informally as:

"Consumer and business products, services and solutions delivered and consumed in real-time over the Internet"

This is a useful simplification for discussing cloud services with non-technical business people, but it is obviously too broad a description to capture what's important: how the emerging cloud model dramatically differs from prior online offering models in ways that promise to fundamentally expand and transform markets. After all, online services have been around for a very long time – from the timesharing systems of the 1970s through the first generation of transactional Internet commerce sites. Thus, IDC's formal definition of cloud services includes the following eight key attributes, that – in combination – differentiate cloud services from these other online delivery/consumption models.

The cloud services model, by leveraging all eight of these attributes together, "make business and consumer cloud services easier and cheaper – and often better – to consume than through traditional delivery models. These attributes lower costs (for customers and suppliers), speed and simplify access, speed and fine-tune provisioning (in line with true demand/usage), greatly increase the number and variety of available services (thanks to lower development and deployment costs, and standards), and improve the potential to integrate."

Of the 8 defining characteristics below, some of them may manifest to different degrees, or in different ways, in different cloud service categories (e.g., "self-service" for cloud applications vs. cloud storage), but for all categories of cloud service offering, there is an important common thread: these attributes manifest in ways that offer major customer advantages compared with traditional delivery/consumption models.

FIGURE 4

Defining Cloud Services



Source: IDC, 2009

It’s worth repeating: the reason the cloud services model is worth defining (and researching) is that the combination of these attributes delivers a unique and powerful set of benefits (in bold above) for the industries and organizations that deploy and use these services.

Deployment Models: Public vs. Private Clouds

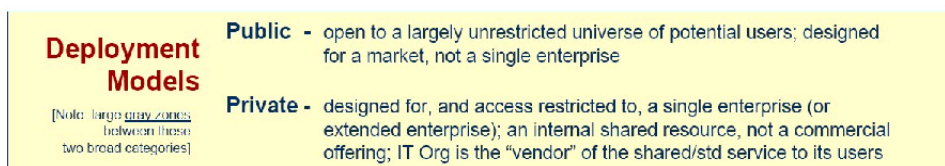
A major market development in the last 12 months has been the emergence of the idea that the very same eight attributes above – which have given public cloud providers like Amazon, Google, Salesforce.com and others great advantages in cost, speed, simplicity and value-creation velocity – can be applied to corporate data centers within a private (single-, or extended-, enterprise) setting. “Private clouds”, by definition, don’t have nearly the same reach and scale as public clouds, but they do offer significant improvements over traditional private deployment models.

And so our definitional framework for Cloud Services is now expanded to include the two deployment models shown in the figure.

As noted in the Cloud Services definition chart below, Public and Private models represent two ends of a deployment continuum, which we expect will frame a growing variety of models that mix aspects of both.

FIGURE 5

Cloud Deployment Models



Source: IDC, 2009

It's important to note that the notion of private clouds didn't just arise suddenly from public clouds, but is really an evolutionary next step in CIOs' decade-long efforts to transform their organizations into service-oriented IT delivery providers – what IDC has referred to for almost ten years as the journey toward “dynamic IT”. Private clouds (and public clouds, for that matter) are built on the key elements of that transformational roadmap – consolidation, standardization, virtualization and automation – and add important new ingredients: turnkey packaging, self-service provisioning and administration, more granular and elastic scaling, granular usage metering and leverage of Internet standards and technologies. For the past ten years, many CIOs have found the journey to dynamic IT, based on conventional offering approaches, very slow, difficult and costly. We believe these new ingredients that private clouds add will help CIOs move much faster down the dynamic IT path.

FUTURE OUTLOOK

Having analyzed the current situation, the next step is to understand how the energy usage can change over the next 5 years. For this purpose, IDC has build 6 scenarios for the future power consumption of servers and data centers in Denmark. Each of these scenarios is presented in the following sections and both the environmental and financial impact of each scenario is highlighted.

Scenario 1: Existing Server Technology

General Assumptions

This scenario is built on the general assumption that the server installed base by 2013 is expanded with new servers as the need for capacity increases. However, new servers have the same average power consumption as today and no further virtualization or data center improvements are expected.

Of course, this scenario is not realistic, as technology advances are bound to happen, existing servers are being replaced and virtualization is increasing, but the scenario is very useful as a baseline for the following scenarios and serves as a worst case scenario if server and datacenter energy consumption is neglected in the climate debate.

Specific Assumptions

Historically, the need for server capacity has increased on average by 6% yearly. IDC therefore estimates that the need for server capacity will increase by 6% yearly throughout 2013.

Environmental and Financial Impact 2013

The following table shows the environmental and financial impact from using today's technologies and architecture throughout 2013.

TABLE 4

Environmental and financial impact, existing server technologies

	Public (incl. privately hosted)		Private companies	
	Servers	Total datacenter	Servers	Total datacenter
Energy consumption (MWh/year)	95,526	219,869	406,697	936,048
CO2 Emission (ton/year)	42,031	96,743	178,947	411,861
Power Consumption (Mio DKK)	115	264	488	1,123
Hardware spending (Mio DKK/year)	64	90	283	396

Source: IDC, 2009

Conclusion

If no further improvements in the effectiveness of servers and data centers are achieved over the next five years, the environmental footprint of servers and data centers will have increased by 34% by 2013 compared to today.

As the installed base of servers is only expanded to accommodate the need for additional computing performance, the hardware spending is reduced significantly.

The consequence of not replacing servers with new more energy efficient ones also means that the cost related to power consumption increases with the same 34% as the environmental footprint.

Scenario 2: Gradual Upgrade of the Server Base

General Assumption

This scenario is built on the general assumption that the server installed base over the next five years is being replaced by new servers with lower power consumption due to the continued improvement of server technologies. The replacement will be according to the standard replacement rates experienced in the market. It is also an assumption that general data center power effectiveness is gradually improved to 2013 – but applied to existing data centers without any major redesign of data centers. No further virtualization is expected compared to what is the case today.

Specific Assumptions

Based on IDC research, the average typical power consumption will change from 2009 to 2013 as follows:

	2009	2013
Volume servers	190 W	165 W
Midrange servers	745 W	650 W
High end servers	10,800 W	9,500 W

Another assumption is the improved power effectiveness of data centers. IDC has the following estimates of the average power consumption by data center type (including in-house infrastructure power). All data is power consumption per 1 W of server power consumption of the installed servers:

	2009	2013
Server closet	0.90 W	0.85 W
Server room	1.45 W	1.31 W
Local data center	1.40 W	1.20 W
Central data center	1.25 W	1.02 W

Environmental and Financial Impact 2013

The following table shows the environmental and financial impact from the already expected gradual upgrade of the installed server base with new low-energy products throughout 2013.

TABLE 5

Environmental and financial impact, gradual upgrade of the base

	Public (incl. privately hosted)		Private companies	
	Servers	Total datacenter	Servers	Total datacenter
Energy consumption (MWh/year)	83,020	177,164	353,483	754,095
CO2 Emission (ton/year)	36,529	77,952	155,532	331,802
Power Consumption (Mio DKK)	100	213	424	905
Hardware spending (Mio DKK/year)	226	317	1,004	1,405

Source: IDC, 2009

Conclusion

This scenario is estimating the environmental impact if no specific changes such as virtualization or major redesign of data centers is implemented. Only the improvements in terms of the natural replacement of the server base with more energy efficient servers and equipment is included. The gains thus come from the general technology development.

This scenario will result in the environmental footprint of server and data centers will have increased by 8% by 2013 compared to today.

In this scenario, the installed base of servers needs to expand by approximately a third, resulting in a significant increase in hardware spending and a total datacenter spending 16% higher than today..

Scenario 3: All Servers Upgraded to New Technology***General Assumption***

This scenario is built on the general assumption that *all* the server installed base over the next five years is being replaced by new servers with lower power consumption due to the continued improvement of server technologies. It is also an assumption that general data center power effectiveness is gradually improved to 2013 – but for existing data centers without any major redesign of data centers. No further server virtualization is expected compared to the level of server virtualization today.

Specific Assumptions

The specific assumptions are identical to scenario 2. The only additional assumption is that the replacement of the entire installed base of servers is completed by 2013.

Environmental and Financial Impact 2013

The following table shows the environmental and financial impact from a total upgrade of the installed server base with new low-energy products throughout 2013.

TABLE 6

Environmental and financial impact, all servers upgraded to new technology

	Public (incl. privately hosted)		Private companies	
	Servers	Total datacenter	Servers	Total datacenter
Energy consumption (MWh/year)	80,238	171,227	341,655	728,860
CO2 Emission (ton/year)	35,305	75,340	150,328	320,698
Power Consumption (Mio DKK)	96	205	410	875
Hardware spending (Mio DKK/year)	254	356	1,120	1,569

Source: IDC, 2009

Conclusion

This scenario is estimating the environment impact if no specific changes such as virtualization or major redesign of data centers is implemented. But pushing the replacement of equipment with new equipment with lower power consumption and having that process finished by 2013 will result in a lower environmental footprint than the previous scenario.

This scenario will result in the environmental footprint of server and data centers will have increased by 4% by 2013 compared to today. The reason this number is very close to the previous scenario is that already with the natural replacement of servers, almost the entire installed base will have been replaced by 2013 already.

Evidently, as the entire installed base of servers is upgraded, the hardware spending will be even higher than in the previous scenario and consequently the total spending will be 22% higher than today.

Scenario 4: Maximum Virtualization in Existing Data Centers

General Assumption

This scenario is built on the general assumption that virtualization of servers in Denmark is accelerated to an assumed maximum degree of virtualization until 2013 as well as the technology development assumed in the previous scenarios. We assume that the data center structure remains basically unchanged and no major redesign of data centers is carried out.

Specific Assumptions

In addition to the specific assumptions mentioned in the previous scenarios, this scenario adds the effect of increased virtualization of servers in Denmark. Virtualization of servers are already started, and IDC surveys of Danish companies show that the current degree of virtualization is between 25% and 35% (share of servers being virtual as opposed to physical) dependent on segment.

In theory all servers can be virtualized, but in reality this is not going to be the case. There will always be a relatively small share of servers where it does not make sense to make virtual – they can be a single server at a remote site or a server dedicated to a single application that does not lent itself to virtualization.

IDC is making the following assumptions about share of servers being virtualized today and in 2013:

	2009	2013
Central government	35%	80%
Regional government	30%	80%
Local government	25%	75%
Private segment	30%	80%

In addition to these assumptions, there will be a maximum number of virtual server per physical server. These numbers are well documented:

	Average number of virtual servers
Volume servers	5
Midrange servers	6
High end servers	10

TABLE 7

Example: Topdanmark Forsikring

Project	In 2008, 61 physical servers were virtualized to 10 new servers. The project also includes replacement of PCs to more efficient products.
Environmental footprint	Already in 2008, the project of server virtualization reduced power consumption with 336 MWh yearly.
Future	Another 123 physical servers to be replaced by virtual servers. This will bring the savings of power consumption up to 754 MWh yearly. Also optimization of data center cooling is considered.

Source: IDC, 2009

The average price for servers used for virtualization is higher than for servers, which are used in a "traditional" non-virtualized environment as the configuration is typically

more extensive. Moreover virtualization leads to increased higher spending on system infrastructure software as more licenses are needed.

Environmental and Financial Impact 2013

The following table shows the environmental and financial impact from a change to maximum virtualization of servers in Denmark to 2013 (in addition to the technology development assumed in the previous scenarios).

TABLE 8

Environmental and financial impact, maximum virtualization in existing data centers

	Public (incl. privately hosted)		Private companies	
	Servers	Total datacenter	Servers	Total datacenter
Energy consumption (MWh/year)	51,644	110,232	217,770	464,713
CO2 Emission (ton/year)	22,723	48,502	95,819	204,474
Power Consumption (Mio DKK)	62	132	261	558
Hardware spending (Mio DKK/year)	163	229	711	995

Source: IDC, 2009

Conclusion

This scenario is estimating the environment impact if all servers are virtualized to the assumed maximum virtualization degree as well as the other changes in replacement of equipment with new equipment with lower power consumption. This is the first of the scenarios where the absolute environmental footprint will be reduced in 2013 compared to today.

This scenario will result in the environmental footprint of server and data centers will have been reduced by 33% 2013 compared to today in spite of server capacity has increased.

The reduced number of servers needed and the improved server utilization, which virtualization allows for, the overall spending on hardware will be reduced by 16% compared to today. This means that total cost of power and hardware is reduced with 22% compared to today.

Scenario 5: Maximum Virtualization in Central Data Centers

General Assumption

This scenario is built on the general assumption that virtualization of servers in Denmark is accelerated to an assumed maximum degree of virtualization until 2013 as well as the technology development assumed in the previous scenarios.

In addition to this, we assume a centralization of servers in large data centers where a more efficient power usage can be obtained. However, we do not assume any major redesign of data centers with new technologies.

Specific Assumptions

No further specific assumptions are needed apart from stated above.

TABLE 9

Example: Region Hovedstaden

Project	Region Hovedstaden is one of the biggest regions in Denmark with a total of 11 data centers today. This makes it a very large IT installation. The objective is to reduce the number of data centers from 11 to 2 high technology centers by 2013 together with a number of additional initiatives to consolidate and virtualization of the servers. Also, existing data centers are used and the possibility of using free cooling is explored.
Environmental footprint	Today the power consumption is almost 4m KWh per year.
Future objective	To reduce power consumption with 50% by 2013 and by using Co2 neutral energy to eliminate the environmental footprint

Source: IDC, 2009

Environmental and Financial Impact 2013

The following table shows the environmental and financial impact from a change to maximum virtualization of servers in Denmark to 2013 as well as a centralization in central data centers (in addition to the technology development assumed in the previous scenarios).

TABLE 10

Environmental and financial impact, maximum virtualization in central data centers

	Public (incl. privately hosted)		Private companies	
	Servers	Total datacenter	Servers	Total datacenter
Energy consumption (MWh/year)	50,129	101,260	211,806	427,849
CO2 Emission (ton/year)	22,057	44,555	93,195	188,253
Power Consumption (Mio DKK)	60	122	254	513
Hardware spending (Mio DKK/year)	163	228	689	964

Source: IDC, 2009

Conclusion

This scenario is estimating the environment impact if all servers are virtualized to the assumed maximum virtualization degree as well as the other changes in replacement of equipment with new equipment with lower power consumption. Furthermore, we assume that servers are consolidated in central data centers – which for instance would be the case if IT is provided as services from central data centers.

This scenario will result in the environmental footprint of server and data centers will have been reduced by 39% 2013 compared to today in spite of server capacity has increased.

Centralizing the servers in fewer larger datacenters allows for a consolidation of servers – i.e. more high-end servers are used instead of volume servers. The consequence is that hardware spending is slightly reduced compared to the previous scenario. Moreover, central datacenters are more power efficient than local centers, resulting in a decrease in power consumption compared to the previous scenario. Totally, this means that overall spending on servers and datacenter spending just 1% above today's level.

Scenario 6: Complete Use of Commercially Available Cloud Services

General Assumption

This scenario is completely different from the previous in that the current servers are not replaced or upgraded, but discarded as all applications are delivered as services from a large cloud data center.

Unlike scenario 5, in which all servers were centralized in existing datacenters in Denmark, this scenario assumes very few extremely large and highly optimized centers hosts the needed server capacity.

This scenario is highly theoretical, as it not possible to rely solely on cloud services, as several applications will not be available and user reluctance will not be overcome. Nonetheless, it illustrates the possibilities of cloud computing and emphasize the need to think differently in order to leap forward instead of baby stepping.

Specific Assumptions

Although cloud computing data centers should be able to utilize the server capacity better than smaller datacenters, this is only marginally and not accounted for in this model. The real benefit is in the overhead savings, as these datacenters are built from scratch and optimized for reducing power consumption and cooling cost.

Cloud computing data centers are assumed to utilize the energy significantly better than "central datacenters". While a few highly optimized datacenters reportedly (e.g. by Google and Microsoft) have PUE (Power Utilization Effectiveness) below 1.2, the average score for cloud datacenters is significantly higher.

For this scenario, a PUE of 1.25 has been used. This value is in between the value in the "Best practice" and "State of the Art" scenarios defined by the U.S. Environmental Protection Agency and The Green Grid - a global consortium dedicated to developing and promoting energy efficiency for data centers. The assumption of a PUE of 1.25 means that compared to the previous scenarios, we assume that the data center

power overhead is 0.25 W for every 1 W consumed by the servers (in the previous scenarios this value was 1.02 W for every 1 W consumed by the servers).

These scenarios are summarized by:

Best practice

- Eliminate unused servers
- Enable power management on 100% of servers
- Moderate consolidation of servers and storage
- Aggressively adopt “energy-efficient” servers

State of the Art

- Eliminate unused servers
- Aggressively adopt “energy-efficient” servers
- Aggressively consolidate servers & storage
- Enable power management at data center level

Environmental and Financial Impact 2013

The following table shows the environmental and financial impact from a change to supplying all IT as cloud services from large central data centers.

TABLE 11				
Environmental and financial impact, existing server technologies				
	Public (incl. privately hosted)		Private companies	
	Servers	Total datacenter	Servers	Total datacenter
Energy consumption (MWh/year)	50,206	74,054	211,729	312,301
CO2 Emission (ton/year)	22,091	32,584	93,161	137,412

Source: IDC, 2009

Conclusion

Using available cloud services drastically cuts the energy consumption and CO₂ emissions to a level 55% below today's use. It should be noted that even the CO₂ emission may change significantly compared to the values in the table above, as the datacenters could be placed anywhere in world and have a significantly different CO₂/KWh ration than in Denmark depending on the share of CO₂ neutral energy sources in the power supply.

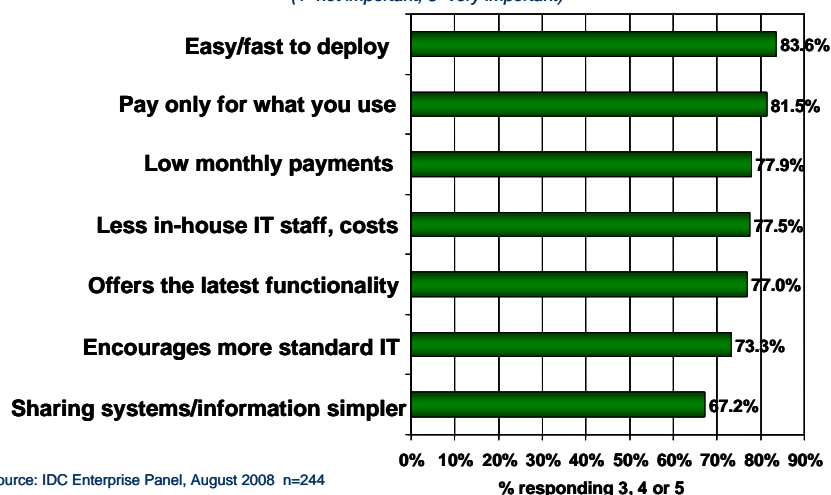
As can be seen above, we have not quantified the financial impact of moving from traditional computing and datacenters to cloud computing. Although most people assume there are significant cost savings gained through cloud services, this is not very easy to quantify. First of all because a cost comparison must take into account that the same type of service is compared and secondly because the cost structure changes significantly when using external services versus an in-house solution.

Still, IDC research has shown, that the promise of lower costs is very central in organizations view of cloud services as can be seen from the figure below. In addition to the flexibility of using cloud services, the economic incentives seem to be two: By using the cloud model, customers are only paying for what they are using, and the total monthly payments are considered lower by almost 80% of companies when rating the benefits of cloud services.

FIGURE 6

Key Advantages of Cloud Services

Q: Rate the *benefits* commonly ascribed to the 'cloud'/on-demand model
(1=not important, 5=very important)



Source: IDC, 2009

In assessing the cost of cloud services further, we refer to a study presented by Intel Corporation (Presented in April 2009 at IDC Virtualization Forum, USA). In this, the TCO (total cost of ownership) of cloud services is presented, and the biggest part of the cost is hardware which is found to account for more than 50% of the costs. This translates into a total cost factor of maximum 2 times the cost of the hardware, even taking into account that the provider needs a margin on top of the cost.

IDC research shows, that for a traditional IT budget in an organization, approximately 15-20% of the costs are hardware. So in this type of environment, the total cost of IT is about 5 times the cost of the hardware (which can even be considered to be more expensive because of the lower buying power individual organizations have versus large scale computing centers).

While the use of cloud services does not entirely eliminate the need for in-house IT resources, we can assume that the amount of in-house IT resource will drop significantly when moving to cloud services.

Taking these factors into account we can derive at a conservative estimate of the cost of cloud services being half the cost of running IT as an in-house solution. Of course, we would need more empirical data to making a more solid conclusion about the cost of cloud services.

ESSENTIAL GUIDANCE

There is no doubt, that powering IT systems is an interesting part of the overall environment footprint in Denmark. The estimated power consumption by servers and datacenters in Denmark in 2009 equals 864 GWh per year. In cost this equals just above 1b DKK assuming an average price of 1.20 DKK/KWh or a total CO2 emission of 381,000 ton per year.

In comparison, the amount of power used by servers and data centers (not including all PCs, peripherals and network equipment) is more than twice the electricity power used in Denmark for road lightning and 70% more than electricity power used by railways and other electrical transport in Denmark. Compared to all private households' use of electricity, servers and data centers powering constitute 9%.

The public sector accounts for 24% of the total power and CO2 consumption, of which local government has the highest share followed by central government (this includes the public sector's use of private data centers). So, even within the public sector it is very important to address the environmental impact of IT.

The importance of this area in the overall environmental debate is even more important as the use of IT is expected to grow in the coming years. IDC expects the need for server capacity to increase by an average of 6% yearly over the 5 years to 2013 that is IDC's forecast time frame.

However, the advancement of technology is going to improve the power effectiveness of IT equipment. Still, with the natural replacement of servers with new, more energy effective servers that will happen over the next 5 years will not improve the total power consumption. Totally, our calculations show that the power consumption (and therefore CO2 emission) will have increased by a total of 8% by 2013. Even if this process is pushed – for instance with incentives – so that the entire installed base of servers is replaced by 2013, the total power consumption will still have increased by 4% compared to today.

If the total use of power by servers and data centers should be significantly reduced compared to today, other means are necessary than the basic improvements in server power consumption.

Based on the scenarios in this study, it is evident that virtualization of servers has a much more positive and significant impact on the total power consumption. Assuming a maximum degree of server virtualization in Denmark, the reduction in power consumption by servers and data centers will be 33-39%, the higher number being if the virtualized servers are consolidated in large data centers. Note, that we have not assumed any major redesign of data centers, and the majority of the power efficiency gains come from the virtualization in any case.

Reduction of power consumption with 33-39% will result in a similar reduction of the CO2 footprint as we have assumed a constant ratio between kWh and CO2 emission.

At constant prices, the reduction in power consumption through virtualization equals a saving of 400m DKK on a yearly basis compared to today (assuming a fixed price of DKK 1.20/KWh). Due to the reduced number of servers needed in a virtualization setup, there is potentially an additional 230m DKK savings on hardware yearly.

In order for a further optimization of the power consumption, the next level can be achieved through the consolidation of servers in large central data centers that are designed from scratch and therefore very power effective. This will be the case if IT is delivered as cloud services instead of organizations having their own servers in their own data centers.

Using the best practices described in the references, an achievable level of power efficiency in such highly optimized data centers are 1.25 (0.25 W overhead for every 1 W used by servers). If all IT is delivered using such data centers, the total server and data center power consumption will be reduced by 55% compared to today.

Of course, a scenario with a 100% cloud computing usage is not possible in reality, but the level of power consumption and CO2 emission in this scenario can be considered the "best possible" scenario for the environmental footprint in 2013.

LEARN MORE

Sources Used

The following are key sources used in this research project:

- IDC EMEA Quarterly Server Tracker, Q2 2009
- Nordic Virtualization Opportunities, December 2008, IDC # 610802
- Denmark, Vertical Markets 2007 Analysis and 2008–2012 Forecast, January 2009, IDC # DK520810Q
- Denmark IT Services 2008 Vendor Shares and 2009–2013 Forecast, July 2009, IDC #DK560950R9
- Energy Footprint of the European Server Infrastructure, 2008, and 2009–2013 Forecast, August 2009, IDC #GE11R9
- Worldwide Datacenter 2008-2012 Forecast, November 2008, IDC #215189
- The Economic Meltdown and Its Chilling Effect on the Cost to Power, Cool, and Manage Enterprise Storage, March 2009, IDC #217158
- 2Ways IT. 2Ways IT is a Danish consulting company that has extensive real-life experience with datacenter consolidation and virtualization projects. Data from their database from projects for Danish customers has been used to support and verify a number of the energy assumptions used.
- Elsparefonden. Various publications including:
 - Projekteringsvejledning for energieffektive serverrum
 - Vejledning til drift og vedligehold af energieffektive serverrum
 - Opsummering af data fra undersøgelse af 10 serverrum
- Dansk Elforsyning Statistik 2005. Dansk Energi, 2006
- EPA Report to Congress on Server and Data Center Energy Efficiency
http://www.energystar.gov/index.cfm?c=prod_development.server_efficiency#ndceeip
- Power Usage Effectiveness (PUE) & Data Center Infrastructure Efficiency (DCiE) Progress
<http://www.thegreengrid.org/~media/2009TechForumPresentations/How%20to%20Measure%20and%20Report%20PUE%20and%20DCiE.ashx?lang=en>
- PUE Scalability metric and statistical analyses
<http://www.thegreengrid.org/en/Global/Content/TechnicalForumPresentation/PUE%20Scalability%20Metric%20and%20Statistical%20Analysis>
- Intel: Intel internal analysis of 3 year TCO (cloud computing)
http://www.idc.com/getdoc.jsp?sessionId=4W3XZF1VBB41CCQJAFDCFFAKBEAVAIWD&containerId=VIRF2009_02

- ☒ In addition various vendor Whitepapers and a number of interviews with industry experts have been used

Methodology

The essential calculation is the average energy use per server times the installed base of servers.

The installed base is calculated from actual server shipments using a replacement and retirement model as illustrated in the table below.

TABLE 12

Server Replacement Rates

	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7	Year 8	Year 9
Volume	0%	0%	5%	10%	19%	26%	25%	13%	2%
Mid-range	0%	0%	2%	8%	20%	26%	24%	15%	5%
Hi-end	0%	0%	0%	5%	15%	30%	25%	15%	10%

Source: IDC, 2009

The current average energy use is based on estimated TPC values, which represent the most probable power consumption generated by a certain server model. It is a somewhat abstract value, as the very same server can be configured in a number of ways, which noticeably increase or decrease the power consumption values of the same server models. Nonetheless TPC is the best – if not only – way to draw estimates on server energy consumption.

The TPC has been identified for each of the six most popular server models in the different server classes and the average of these was used as descriptive for all servers in the class. The TPC is identified by either:

- ☒ as indicated by the vendor in the technical specifications or in online configuration tools
- ☒ the maximum power consumption, then multiply it for a 40% factor in case of volume and for 66% in the case of midrange machines and high-end products
- ☒ the maximum input power generated by the highest configuration of PSUs and multiply it by a use factor of 25% (volume servers), 30% (midrange servers), or 40% (high-end servers)
- ☒ the maximum output power generated by the highest configuration of PSUs and divide it by the efficiency rate reported on the specifications sheet

Based on this determined energy use, the environmental and economic effects are calculated by multiplying with CO₂ emission per KWh and price per KWh

The differences between the scenarios are:

- ☒ **Scenario 1:** The required server performance grows 6% annually and there are no technological developments. Consequently, the installed base of servers grows to approximately 268,000. TPC the same as today.
- ☒ **Scenario 2:** Like scenario 1, but as the new servers are more efficient, resulting in both lower TPC and lower growth in the installed base – approximately 233,000.
- ☒ **Scenario 3:** Like scenario 2, but with an accelerated replacement rate, the installed base will only grow to 225,000 and the TPC is reduced even further.
- ☒ **Scenario 4:** Like scenario 1, but assuming that the maximum number of servers is virtualized to the extent possible. The consequence is a substantial reduction in the installed base to just 159,000.
- ☒ **Scenario 5:** Like scenario 4, but with the servers centralized in a large datacenter. As large datacenters are more prone to use higher performing servers, the installed base reaches just 155,000 and the TPC drops marginally.
- ☒ **Scenario 6:** A completely different scenario, assuming that all servers are located in a large cloud data center. The installed base of servers drops to 0, while the energy consumption is reduced significantly due to the more efficient power and cooling structure.

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