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CLOUD COMPUTING IN GERMAN HIGHER EDUCATIONAL INSTITUTIONS

Bachelorarbeit

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vorgelegt von

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Abstract

Only little information is available about the diffusion of cloud computing in German higher educational institutions. A better understanding of the state of the art in this field would support the modernization of the higher educational institutions in Germany and allow the development of more adequate cloud products and more appropriate business models for this niche.

For this purpose, a literature research on Cloud Computing and IT-diffusion will be run and an empirical investigation with an online questionnaire addressed to higher educational institutions in Germany will be performed to illustrate the state of the art of Cloud Computing in German higher educational institutions as well as the threats and opportunities perceived by employees of higher educational institutions data centers connected to the usage of the cloud.

In addition to that, different experts from universities and businesses will be interviewed to complete the knowledge and information collected through the online questionnaire and during the research phase. The expected results will serve to create a recommendation for higher educational institutions in Germany about either they should migration to the cloud or not and introduce a list of guiding questions of critical issues to consider before using cloud-computing technologies.

Zusammenfassung (German)

Aktuell stehen nur wenige Informationen über die Verbreitung von Cloud Computing in deutschen Hochschulen zur Verfügung. Ein besseres Verständnis vom Stand der Technik in diesem Bereich würde die Modernisierung der Hochschulen in Deutschland und die Entwicklung von geeigneteren Cloud Produkten und neuen Geschäftsmodellen für diese Nische ermöglichen.

Zu diesem Zweck wird eine Literaturrecherche über Cloud Computing und IT-Verbreitung und eine empirische Untersuchung mit einem Online-Fragebogen an Hochschulen in Deutschland durchgeführt, um den aktuellen Stand von Cloud Computing an deutschen Hochschulen zu untersuchen. Ebenso fragt die Untersuchung nach den Chancen und Risiken, die die Mitarbeiterinnen und Mitarbeiter von Hochschulrechenzentren bei der Nutzung von Cloud Computing sehen.

Im Anschluss daran werden Experten aus Universitäten und Unternehmen interviewt, um die gesammelten Informationen vom Online-Fragebogen und während der Forschung zu erweitern. Die erwarteten Ergebnisse werden dazu dienen, um eine Empfehlung für Hochschulen in Deutschland zu verfassen, ob sie Cloud Technologien schon benutzen sollen oder nicht. Darüber hinaus wird eine Liste mit kritischen Leitfragen vorgestellt, die vor der Migration zum Cloud Computing berücksichtig werden sollte.

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1 Introduction

A simple search using Google Trends[1] confirms that the terms “cloud” and “cloud computing” are one of the buzzwords in the year 2011 in Germany and worldwide. It has gained excitement not only from technologists and CIOs but also caught the attention and consideration of business leaders around the planet.

In the year 2008, during the ‘Emerging Technologies Conference’ of Gartner Inc., analysts Daryl Plummer and Thomas Bittman declared that: “By 2012, 80 percent of Fortune 1000 companies will pay for some cloud computing service, and 30 percent of them will pay for cloud computing infrastructure” (Rhoton, 2010, S. 3).
In 2010, Gartner’s forecasts become even more precise: “By 2012, 20 percent of businesses will own no IT assets” (Gartner, Inc. (B), 2010). Expert predictions ranging from IDC, Forrester, The Yankee Group and Redmonk all paint a similar picture (Simonds, 2009) (Rhoton, 2010, S. 4).

Cloud computing is gaining importance and spreading enthusiasm throughout the IT industry in Germany too. The dedication of the CeBIT 2010 (which is the world's largest and most international computer fair [2]) to “Work and Life with the Cloud” [3] confirms the growing interest in the topic.

Cloud computing is changing business models, cost models, and data centers. Innovative CIOs and other IT managers are freeing up valuable resources for strategic actions by deploying cloud applications that are less complex to manage and maintain and have a better balance between security, cost, and functionality than traditional on-premise software[4].

Higher educational institutions, however, have a clear unique mission and a strategic purpose. Despite these differences, many educational institutions worldwide (especially in the United States) decided to move partially or completely their infrastructure to the cloud. This trend didn’t seem to be followed in German higher educational institutions in early 2011 and justified the inquiring of the following interrogations:
Are German higher educational institutions following this trend or planning to move to the cloud? Is cloud computing currently ready to meet the needs and high expectations and requirements of German higher educational institutions? What are the most important perceived threads and opportunities by university employees? Is it really the right time to switch the IT infrastructure of these institutions to the cloud and If so, what elements should be considered before the migration?

This thesis and work aims to answer these questions.

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[1] http://www.google.com/trends?q=cloud+computing&ctab=0&geo=de&date=all
[2] http://en.wikipedia.org/wiki/CeBIT (Retrieved November 21, 2011)
[3] http://www.cebit.de/en/about-the-trade-show/facts-figures/profile/cebit-2011-review (Retrieved November 21, 2011)
[4] http://decomplexification.com/2011/10/18/can-business-run-on-cloud-applications-alone-i-did-for-year-lessons-learned/ (Retrieved November 21, 2011)

2 Introduction to Cloud Computing

2.1 History of Cloud Computing

The history of computing began with the "Z3" which was an electromechanical computer designed by Konrad Zuse in 1941. It was the world's first working programmable, fully automatic computing machine [5]. Four years after, John Mauchley and J. Presper Eckert built the ENIAC (Electronic Numerical Integrator and Computer). ENIAC was the first general-purpose electronic computer. It was a Turing-complete digital computer capable of being reprogrammed to solve a full range of computing problems (Shurkin, 1996).

The sixties and seventies were the era of mainframe computers. These powerful computers were primarily used by corporate and governmental organizations for critical applications, bulk data processing, industry and consumer statistics, enterprise resource planning, and financial transaction processing [6]. Users could interact with the central computing delivered though the so-called 'Terminals' by delivering Input data and receiving the output. The invention of the transistors in 1947 and the microprocessors in 1969 boosted the evolution of the computers and their miniaturization. The commercial introduction of the personal computer (PC) by IBM in the early 1980s revolutionized organizational data processing and was a commercial success that led other computer manufacturers to develop their own personal computers that were compatible with the IBM PC. One notable exception is Apple Computers, Inc., which developed its own line of non-IBM-compatible computers, namely the *Apple* and *Macintosh* line of computers [7].

The development of the Internet was a major milestone to enable cloud computing. The Advanced Research Projects Agency (ARPA) of the United States Department of Defense originally invented the Internet in 1969 to be a communication network that could survive a nuclear war. The emergence of networking involved a redefinition of the nature and boundaries of the computer. Computer operating systems and applications were modified to include the ability to define and access the resources of other computers on the network, such as peripheral devices, stored information, and the like, as extensions of the resources of an individual computer. Initially these facilities were available primarily to people working in high-tech environments, but the spread of applications like email and the World Wide Web (Freiberger & Swaine , 2000) combined with the development of cheap, fast networking technologies like Ethernet and ADSL saw computer networking become ubiquitous almost everywhere [8]. The high bandwidth and technologies like Java and Ajax or Web Services have allowed the development of highly interactive websites and then around the year 2000 the deployment of whole applications through Internet browsers, which was popular under the name of 'Software-as-a-Service' (Finch, 2006). In analogy with the provision of software through the Internet, computing power was also delivered through a network. Grid Computing [defined later in

[5] http://en.wikipedia.org/wiki/Z3_(computer) (Retrieved November 21, 2011)
[6] http://en.wikipedia.org/wiki/Mainframe_computer (Retrieved November 21, 2011)
[7] http://www.enotes.com/business-finance-encyclopedia/information-systems (Retrieved November 21, 2011)
[8] http://www.networlddirectory.com/general/computers/computer-basics/computer-applications.html (Retrieved November 21, 2011)

Chapter 2.3.3] was well established since the beginning of the nineties in the academic field (Foster & Kesselman, 2003). In the year 2007 another milestone was reached when IBM and Google began building large data centers that students can tap into over the Internet to program and research remote. They called this new model in which "computing chores increasingly move off individual desktops and out of corporate computer centers to be handled as services over the Internet", cloud computing (Lohr, 2007) (Böhm, Herzog, Riedl, Leimeister, & Krcmar, 2010).

Cloud computing represents an evolution and congregation of several trends. The ultimate objective has been on the radar of many IT companies such as Sun, HP and IBM for several years but the first commercially viable offering came unexpectedly from another sector of the industry. It's the fabulous story of Amazon.

Rhoton (2010) explains how Amazon introduced the first public cloud computing service: "Amazon was arguably the first company to offer an extensive and tough set of cloud-based services. This may seem somewhat odd since Amazon was not initially in the business of providing the services. However, they had several other advantages that they were able to leverage effectively.

Amazon started as an on-line bookstore in 1995. Based on its success in the book market it diversified its product portfolio to include CDs, DVDs and other forms of digital media, eventually expending into computer hardware and software, jewelry, grocery, apparel and even automotive parts and accessories.

A major change in business model involved the creation of merchant partner-ships that leveraged Amazon's portal and large customer base. Amazon brokered the transaction for a fee thereby developing a new ecosystem of partners – and even competitors.

As Amazon grew, it had to find ways to minimize its IT cists. Its business model implied a very large online presence (Amazon received 615 million visitors in 2008 according to Wikipedia), which was crucial to its success. Without the bricks-and-mortar retail outlet, its data center investments and operations became a significant portion of its costs structure.

Amazon chose to minimize hardware expenditures by buying only commodity hardware parts and assembling them into a highly standardized framework that was able to guarantee the resilience they needed through extensive replication. In the course of building their infrastructure, their system designers had scrutinized the security required to ensure that the financial transaction and data of their customers and retail partners could not be compromised

The approach met their needs however it was inherently optimized. Amazon and partners shared a common burden or boon, depending on how you look at it, with other retailers in that a very high proportion of their sales are processed in the weeks leading up to Christmas. In order to be able to guarantee computing capacity in December they needed to overprovision for the remainder of the year. This meant that a major share of their data center was idle eleven out of twelve months. The inefficiency contributed to an unacceptable amount of unnecessary costs.

Amazon decided to turn to their weakness into an opportunity. When they launched Amazon Web Services in 2002, they effectively sold some of their idle capacity to other organizations that had computational requirements from January to November. The proposition was attractive to their customers who were able to take advantage of a secure and reliable infrastructure at reasonable prices without making any financial or strategic commitment" (Rhoton, 2010, S. 12).

2.2 Defining Cloud Computing

There is currently no universal definition of cloud computing, but diverse interpretation, probably because the offers in the area of cloud computing are relatively new and constantly evolving (Metzger, Reitz, & Villar, 2011, S. 2). John Rhoton (2010) in his book "Cloud Computing Explained: Implementation Handbook for Enterprises" showcases some of the definitions that have circulated in the blogosphere: (Rhoton, 2010, S. 7)

> The 451 Group: „The cloud is IT as a Service, delivered by the IT re-sources that are independent of location".
>
> Gartner: „Cloud computing is a style of computing where massively scalable IT-related capabilities are provided as a service across the Internet to multiple external customers".
>
> Forrester: „A pool of abstracted highly scalable, and managed infrastructure capable of hosting end-customer applications and billed by consumption".
>
> Wikipedia: „A style of computing in which dynamically scalable and often virtualized resources are provided as a service over the Internet. Users need not have knowledge of, expertise in, or control over the technology infrastructure ‚in the cloud' that supports them".

In „A Break in the Cloud: Toward a Cloud Definition", a White Paper published for the ACM Computer Communication Reviews, the authors found over twenty distinct definitions of cloud computing in their research (Vaquero, Rodero-Merino, Caceres, & Lindner, 2009).
Vaquero, Rodero-Merino, Caceres, & Lindner assembled some of the main notions into: „A large pool of easily usable and accessible virtualized resources (such as hardware, development platforms and/or services). These resources can be dynamically reconfigured to adjust to a variable load (scale), allowing also for an optimum resource utilization. This pool of resources is typically exploited by a pay-per-use model in which guarantees are offered by the Infrastructure Provider by means of customized SLAs (service-level agreements)" (Vaquero, Rodero-Merino, Caceres, & Lindner, 2009).

According to Rhoton (2010), this definition is considered as comprehensive but it hides the primary discovery of the paper that no single theme seemed to permeate all of the definitions. This observation may be somewhat discouraging but we might consider that although the definitions are not identical, or in some cases even very similar, they are still not contradictory. They simply emphasize different aspects of a complex and multi-faceted concept.

He state that, „most definitions of cloud computing include different elements of the complete description and yet they typically do not address every single aspect that anyone has associated with cloud computing“ (Rhoton, 2010, S. 8).

Charles Babcock (2010) highlights that beyond businesses, many consumers and users have shown interest and appetite in consuming new services on the Web. They maintain personal data and information in social network profiles and identity management websites like Facebook and Google+, post pictures in Flickr and disclose professional associations on services like LinkedIn and that the cloud offers a business model where many services, including massive amount of computer server power storage and network bandwidth can be made available at a low price.

Babcock (2010) says „The technology convergence has found expression in a new distribution model for computing. So in addition to technology, the cloud is a business model that makes a new form of computing widely available at prices that heretofore would have been considerate impossible“.

Babcock also adds one important defining characteristic to the technology and business model: “In the deeper example of sending a workload to the cloud and telling it how it’s to be run, the user has assumed a new relationship with the data center that has not been possible for most remote users in the past. The cloud gives the user ‘programmatic control’ over part of the data center, the ability to command a server in the data center to run the program she has selected and sent” (Babcock, 2010).

Another definition of cloud computing is the one published in Barrie Sosinsky’s book “Cloud Computing Bible” (2011): “Cloud computing is an abstraction based on the notion of pooling physical resources and presenting them as a virtual resource. It is a new model for provisioning resources, for staging applications, and for platform-independent user access to services. Clouds can come in many different types, and the services and applications that run on clouds may or may not be delivered by a cloud service provider. These different types and levels of cloud services mean that it is important to define what type of cloud computing system you are working with” (Sosinsky, 2011).

In “Cloud Computing an SOA convergence in your Enterprise” (2009), David S. Linthicum adds another definition for cloud computing: “cloud computing is the ability to provide IT resources over the Internet. These resources are typically provided on a subscription basis that can be expanded or contracted as needed. This includes storage services, database services, information services, testing services, security services, platform services… pretty much anything you can find in the data center today can be found on the Internet and delivered as-a-service” (Linthicum, 2009).

The most widely used and normative definition is that issued by the US National Institute of Standards and Technology (NIST): “Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. This cloud model promotes availability and is composed of five essential characteristics, three service models, and four deployment models" (NIST, 2011). This definition was chosen as a reference for this work and will serve as basis for the rest of this thesis.

The NIST definition provides also the five **essential characteristics** of cloud computing: (NIST, 2011)

- *On-demand self-service:* A consumer can unilaterally provision computing capabilities, such as server time and network storage, as needed automatically without requiring human interaction with each service's provider.

- *Broad network access:* Capabilities are available over the network and accessed through standard mechanisms that promote use by heterogeneous thin or thick client platforms (e.g., mobile phones, laptops, and PDAs).

- *Resource pooling:* The provider's computing resources are pooled to serve multiple consumers using a multi-tenant model, with different physical and virtual resources dynamically assigned and reassigned according to consumer demand. There is a sense of location independence in that the customer generally has no control or knowledge over the exact location of the provided resources but may be able to specify location at a higher level of abstraction (e.g., country, state, or datacenter). Examples of resources include storage, processing, memory, network bandwidth, and virtual machines.

- *Rapid elasticity:* Capabilities can be rapidly and elastically provisioned, in some cases automatically, to quickly scale out, and rapidly released to quickly scale in. To the consumer, the capabilities available for provisioning often appear to be unlimited and can be purchased in any quantity at any time.

- *Measured Service:* Cloud systems automatically control and optimize resource use by leveraging a metering capability at some level of abstraction appropriate to the type of service (e.g., storage, processing, bandwidth, and active user accounts). Resource usage can be monitored, controlled, and reported, providing transparency for both the provider and consumer of the utilized service."

As specified in the definition above, the NIST differentiate between four **deployment models** for cloud services, which are: (NIST, 2011)

- *Private cloud:* The cloud infrastructure is operated solely for an organization. It may be managed by the organization or a third party and may exist on premise or off premise.

- *Community cloud:* The cloud infrastructure is shared by several organizations and supports a specific community that has shared concerns (e.g., mission, security requirements, policy, and compliance considerations). It may be managed by the organizations or a third party and may exist on premise or off premise.

- *Public cloud:* The cloud infrastructure is made available to the general public or a large industry group and is owned by an organization selling cloud services.

- *Hybrid cloud*: The cloud infrastructure is a composition of two or more clouds (private, community, or public) that remain unique entities but are bound together by standardized or proprietary technology that enables data and application portability (e.g., cloud bursting for load balancing between clouds).

The figure below clarifies the deployment models and the different locations that clouds can come in.

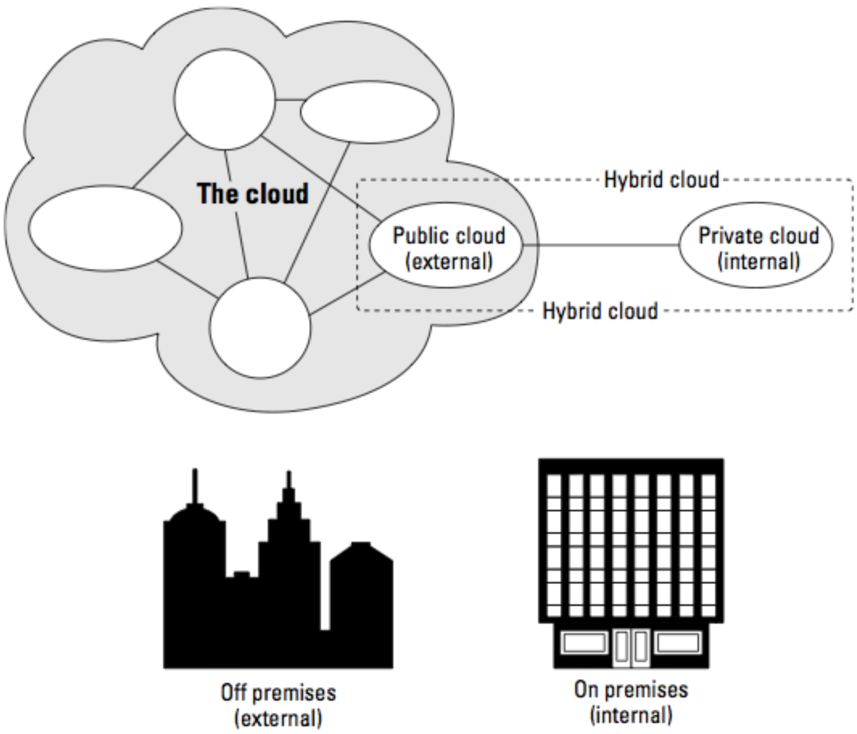

Figure 2-1: Deployment locations for different cloud types (Sosinsky, 2011, S. 8)

One important aspect of cloud computing is the strong focus toward service orientation. Instead of offering only packaged solutions it is necessary to decompose all the functionality that users require into primitives, which can be assembled in packages as required (Rhoton, 2010, S. 19).

In order to easily aggregate premise the cloud functionalities in an optimum manner and get a clear picture of all services available the NIST presented in the same document defining cloud computing, three **service models**: (NIST, 2011)

- *Cloud Software as a Service (SaaS).* The capability provided to the consumer is to use the provider's applications running on a cloud infrastructure[9]. The applications are accessible from various client devices through a thin client interface such as a web browser (e.g., web-based email). The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, storage, or even individual application capabilities, with the possible exception of limited user-specific application configuration settings.

- *Cloud Platform as a Service (PaaS)*: The capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages and tools supported by the provider. The consumer does not manage or control the underlying cloud infrastructure including network, servers, operating systems, or storage, but has control over the deployed applications and possibly application hosting environment configurations.

- *Cloud Infrastructure as a Service (IaaS):* The capability provided to the consumer is to provision processing, storage, networks, and other fundamental computing resources where the consumer is able to deploy and run arbitrary software, which can include operating systems and applications. The consumer does not manage or control the underlying cloud infrastructure but has control over operating systems, storage, deployed applications, and possibly limited control of select networking components (e.g., host firewalls).

Amazon Elastic Compute Cloud (EC2) is a classical example of Infrastructure as a Service, Google App Engine and Microsoft Windows Azure are considerate to be Platform as a Service, and Salesforce.com is probably one of the best-known examples of Software as a Service.

This classification has been universally accepted and it is the most commonly used in the related literature. Nonetheless, some of the authors and vendors add other service models for specific components or categories depending on their understanding or portfolio, all of which take the following form: XaaS, (Everything as a Service). An example of XaaS is 'Business Process as a Service' which is "another widely agreed-upon layer on-top of SaaS where complex business processes that may span multiple applications are provided to consumers" (Breiter, Spatzier, & Behrendt, 2011).

Rhoton (2010) name these three service models "The SPI Model" (Software as a service, Platform as a service, Infrastructure as a service) and distinguish two primary dimensions, which constrain the offerings. In Figure 2-2: SPI Tradeoffs, Rhoton shows that cloud services differ according to their flexibility and degree of optimization.

[9] "A cloud infrastructure is the collection of hardware and software that enables the five essential characteristics of cloud computing. The cloud infrastructure can be viewed as containing both a physical layer and an abstraction layer. The physical layer consists of the hardware resources that are necessary to support the cloud services being provided, and typically includes server, storage and network components. The abstraction layer consists of the software deployed across the physical layer, which manifests the essential cloud characteristics. Conceptually the abstraction layer sits above the physical layer." (NIST, 2011)

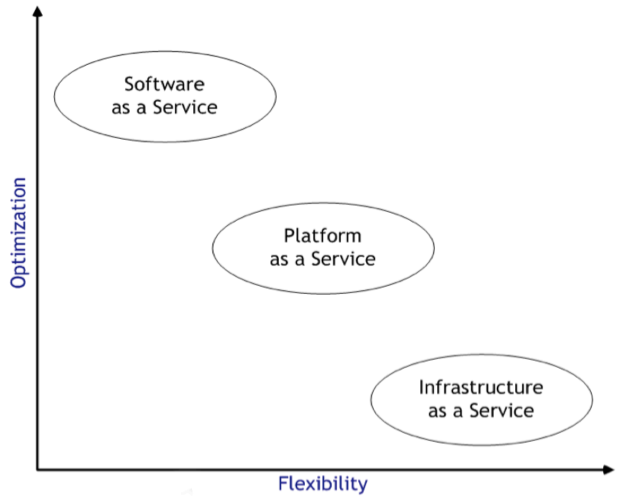

Figure 2-2: SPI Tradeoffs (Rhoton, 2010, S. 20)

2.3 Related Terms

In order to understand the vision, goals and strategy behind cloud computing, it is useful to explain some key concepts that form its foundations and are essential to its development and implementation.

2.3.1 Autonomic Computing

IBM's Senior Vice President Paul Horn initially introduced the term 'Autonomic Computing' to the National Academy of Engineers at Harvard University in 2001 (Chess & Kephart, 2003). In a manifesto named "Autonomic computing: IBM's Perspective on the State of Information Technology" (2001) he describes autonomic computing as the building and designing of "computing systems capable of running themselves, adjusting to varying circumstances, and preparing their resources to handle most efficiently the workloads we put upon them. These autonomic systems must anticipate needs and allow users to concentrate on what they want to accomplish rather than figuring how to rig premise the computing systems to get them there" (IBM, 2001).

In the same manifesto, IBM defines eight key elements and characteristics that such a high-level system should possess: (IBM, 2001)

1. An autonomic computing system needs to "know itself" - its components must also possess a system identity. Since a "system" can exist at many levels, an autonomic system will need detailed knowledge of its components, current status, ultimate capacity, and all connections to other systems to govern itself. It will need to know the extent of its "owned" resources, those it can borrow or lend, and those that can be shared or should be isolated.

2. An autonomic computing system must configure and reconfigure itself under varying (and in the future, even unpredictable) conditions. System configuration or "setup" must occur automatically, as well as dynamic adjustments to that configuration to best handle changing environments.

3. An autonomic computing system never settles for the status quo - it always looks for ways to optimize its workings. It will monitor its constituent parts and fine-tune workflow to achieve predetermined system goals.

4. An autonomic computing system must perform something akin to healing - it must be able to recover from routine and extraordinary events that might cause some of its parts to malfunction. It must be able to discover problems or potential problems, and then find an alternate way of using resources or reconfiguring the system to keep functioning smoothly.

5. A virtual world is no less dangerous than the physical one, so an autonomic computing system must be an expert in self-protection. It must detect, identify and protect itself against various types of attacks to maintain overall system security and integrity.

6. An autonomic computing system must know its environment and the context surrounding its activity, and act accordingly. It will find and generate rules for how best to interact with neighboring systems. It will tap available resources, even negotiate the use by other systems of its underutilized elements, changing both itself and its environment in the process -- in a word, adapting.

7. An autonomic computing system cannot exist in a hermetic environment. While independent in its ability to manage itself, it must function in a heterogeneous world and implement open standards -- in other words, an autonomic computing system cannot, by definition, be a proprietary solution.

8. An autonomic computing system will anticipate the optimized resources needed while keeping its complexity hidden. It must marshal IT resources to shrink the gap between the business and personal goals of the user, and the IT implementation necessary to achieve those goals -- without involving the user in that implementation.

Cloud computing and autonomic computing has different objectives but the development of such self-healing, self-configured, self-protected and self-managed systems has great consequence for Cloud Computing.
In fact, autonomic computing is highly attractive to cloud providers because implementing it in the cloud architecture means “optimizing costs of operating and maintaining infrastructure and business functionality” (Winans & Brown, 2009, S. 5) which will lead to a more efficient data center management. Without such self-regulating system in place, cloud providers could not keep up with the maintenance costs and demands of the features they offer.

2.3.2 Utility Computing

Utility computing is not a new concept, but rather has quite a long history. Among the earliest references is the speech of Professor John McCarthy at the MIT Centennial in 1961, “If computers of the kind I have advocated become the computers of the future, then computing may someday be organized as a public utility just as the telephone system is a public utility... The computer utility could become the basis of a new and important industry" (Abelson, 1999).

Utility computing is "the packaging of computing resources to a customer who pays for these resources as metered service when needed. The objective is to use services effectively while reducing associated costs" (Krutz & Dean Vines, 2010, S. 6). This model has the benefit of a low or no initial cost to acquire computer resources; instead, computational resources are essentially rented - turning what was previously a need to acquire products (hardware, software and network bandwidth) into a service.

One essential practice in this type of services is the problem of negotiation and definition of a Service Level Agreement (SLA) between the provider that promises to deliver a certain service as a utility, i.e. storage, computing power or deploying 'in the cloud', and the client who needs a certain level of Quality of Service (QoS) to be guaranteed, monitored and enforced (Sokolov, 2009). Even more important than SLAs is the QoS measure of guaranteed uptime. Uptime requirements are estimated (necessarily or unnecessarily) to be anchored at 99,99% or higher in the SLAs of most enterprises but cloud providers have not yet been prepared to this match of high quality expectations yet (McKinsey & Company, 2009, S. 26).

2.3.3 Grid Computing

Cloud computing evolves from grid computing and provides on-demand resource provisioning. Grid Computing may or may not be in the cloud depending on what types of users are using it (Myerson, 2009).

It refers to interconnecting many computers to solve a problem through highly parallel computation. "These grids are often based on the loosely coupled and heterogeneous systems, which leverage geographically dispersed volunteer resources. They are usually confined to scientific problems, which require a huge number of computer processing cycles or access to large amount of data" (Rhoton, 2010, S. 11).

In the paper "Grid vs. Cloud – A Technology Comparison" (2011), Brandic and Dustdar from the Vienna University of Technology sees Grid computing as a provider of concepts and tools for the provision of High Performance Computing (HPC) resources and applications as services that may be acceded transparently and on-demand. The main goal of grid computing is to provide on demand access to HPC infrastructure by augmenting standardized protocols and services. One major application area of the Grid is interconnection and transparent use of computational resources for scientific and large-scale application (Brandic & Dustdar, 2011).

Brandic and Dustdar (2011) summarize the major differences between Grids and Clouds in four points:

- Business Models: While in Grid business models are usually based on bilateral arguments between academic institutions, provision of resources in Clouds requires more differentiated business. Several types of business models raging from resource providers who only provide computing resources (e.g., Amazon, Tsunamic Technologies), over SaaS providers who sell their own resources together with their own software services (e.g., Google Apps, Salesforce.com) to companies that attempt to run a mixed approach, i.e., they allow users to create their own services but at the same time offer their own services (Sun N1 Grid, Microsoft Azure).

- Resource Management: Resource management represents another major difference between Grids and Clouds, While Grids rely on batch systems, and use of virtualization and technologies represent the resources management solutions for the Clouds.

- Resource Provision Models: Grid resource provisioning models are based on virtual organizations where the relationships are established offline. In Clouds usage of SLAs, compliance and trust management is essential.

- Resource Availability: In Grids, the resource sharing relies in the best effort manner. Sometimes resources are not available and sometimes there are plenty of resources, which are idle. Clouds rely on massive elasticity in Clouds. Challenging issues in Clouds are to find the balance between wasting resources due to the virtualization overhead and standby modes of devices on the one hand, and pooling of resources to facilitate efficient consumption of resources and reducing energy consumption on the other.

2.3.4 Service-Oriented Architecture

A Service-oriented Architecture (SOA) disaggregates the information technology landscape of an enterprise into unassociated coupled functional primitives called services. In contrast to monolithic applications of the past, these services implement actions and may be used by many different business applications (Rhoton, 2010, S. 10).

Linthicum (2009) presented a coherent definition of Service-oriented Architecture (SOA), “An SOA is a strategic framework of technology that allow all interested systems, inside and outside of an organization, to expose and access well-defined services, and information bound to those services, that may be further abstracted to process layers and composite applications for solution development. In essence, SOA adds the agility aspect to architecture, allowing us to deal with system changes using a configuration layer rather than constantly having to redevelop these systems” (Linthicum, 2009, S. 5).

The relationship between cloud computing and SOA is that the cloud provides IT resources and computing power you can leverage on demand, including resources that host data, services, and process (Linthicum, 2009, S. 7).

2.4 Cloud Computing for Higher Education

2.4.1 The Problem with Legacy Systems in Higher Education

In a recent report published by Deloitte named "Making the grade 2011: A study of the top 10 issues facing higher education institutions" (Deloitte, 2011), Louise Upton, Principal and Canadian Higher Education Lead said that "Higher education institutions are in the midst of a perfect storm. Government funding is declining, market conditions have reduced the value of endowments, private backing is on the wane and costs are going up."

This statement is reinforced by the Gartner Group's survey "The 2011 Higher Education CIO's Agenda: Lean Controlled Growth" (Lowendahl & Auringer, 2011) claim that two of the top priorities facing higher education CIOs today are improving technical infrastructure and reducing enterprise costs. Reduce costs and offer a flexible scalable infrastructure, are two of the most frequent promises and selling arguments of cloud computing vendors. They claim that cloud computing could will enable improvements in these two key areas.

In Table 1: Higher Education Business Priorities 2008-2011, you can see an overview of the top 10 priorities of higher education CIOs measured by Gartner. (Gartner, Inc. (C), 2011).

Ranking	**2011**	**Change**	2010	2009	2008
Increasing enterprise growth	1	↑			
Attracting and retaining new customers (students, partnerships and research)	2	↑	4	5	2
Improving technical infrastructure	3	↑			
Creating new products, services and innovation	4	↑	5	7	5
Reducing enterprise costs	5	↓	3	3	10
Improving business processes	6	↓	1	1	1
Improving business continuity, risk and security	7	↑			
Implementing and updating business applications	8	↑			
Attracting and retaining the workforce	9	↑			
Increasing management control	10	↑			

Table 1: Higher Education Business Priorities 2008-2011 (Gartner, Inc. (C), 2011)

A report by Educause titled “Top-Ten IT Issues Facing Higher Education” (Scrivener Agee & Yang, 2009) provides further evidence that higher education CIOs are interested in optimizing infrastructure and reducing costs as funding IT and administrative/ERP systems concerns took the top two spots. Clearly, many higher education CIOs are feeling the pressure to reduce costs, and standardize systems and resources via shared services initiatives. Both are very difficult to accomplish with legacy technology that is in use on many campuses today (Workday, 2011).

The maintenance for these legacy systems, also called “on- premise” infrastructure, is expensive. At a time when many colleges and higher educational institutions are under significant pressure to cut costs, most can no longer afford to maintain an old, inefficient technology infrastructure that do not have the functionality universities and colleges need to run their institutions. A whitepaper published by Workday Inc. (2011) states that legacy systems typically cannot handle complex payroll requirements or unique financial requirements such as fund accounting and that many institutions badly need to upgrade their legacy systems to take advantage of new functionality, but upgrading on-premise technology is often cost prohibitive (Workday, 2011).

With the explosive growth of mobile and Web 2.0 technologies [10] [11], institutions are in need of more advanced technology solutions that keep pace with the times and evolutions. Legacy administrative systems cannot keep up with the dynamic organizational requirements of modern universities. Not only they limit the efficiency and agility, but also cause a struggling to receive and distribute timely and accurate financial and operational information and provide the necessary reports to funding sources (Workday, 2011).

These inefficient legacy administrative systems force IT staff to spend too much time on tactical activities such as maintaining existing systems and processing transactions and not enough time on more strategic work that supports the mission and goals of the educational institution.

The Figure 2-3: Higher Education in Pain , describes the continuous difficulties, problems and challenges facing higher educational institutions nowadays.

[10] http://www.switchfast.com/switchfast-blog/2009/6/11/rapid-growth-in-mobile-technology-is-changing-the-face-of-business.aspx (Retrieved November 21, 2011)
[11] http://www.web-strategist.com/blog/2008/04/25/forrester-report-global-enterprise-web-20-market-forecast-2007-to-2013/ (Retrieved November 21, 2011)

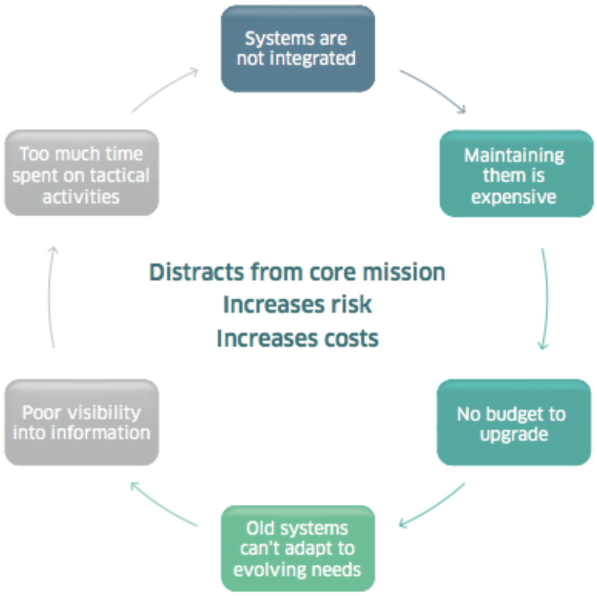

Figure 2-3: Higher Education in Pain (Workday, 2011)

2.4.2 Opportunities of Cloud Computing in Higher Education

Higher education institutions progressively are turning to cloud computing to lower cost and take advantage of the latest technology (Workday, 2011). The benefits of cloud applications or the educational sector are numerous as demonstrated in Table 2: Cloud Applications vs. On-Premise – One-to-One Comparison.

The cloud simplifies and enhances IT, enables IT to discharge non-essential processes, and allows IT to refocus on driving the primary mission and objectives of higher education institutions. Using the cloud greatly rises IT agility and allows institutions to pay for only the IT services they use, enabling better resource tracking, more foreseeable costs, improved budget estimating, and faster return on investment.

	Cloud	On-Premise
Software	Utility subscription model (operational cost)	Perpetual license model (capital cost)
Implementation	Lower cost, faster to deploy	Higher cost, Higher risk
Maintenance	Part of subscription costs	An additional ~22% of license fees per year
Updates/Upgrades	Part of subscription costs	Additional cost and risk
Training	Consumer-Internet user experience; limited training is required	ERP user experience; extensive training is required
Infrastructure: Hardware/ Software	Infrastructure outsourced to cloud provider; built into subscription costs	Customer responsible for infrastructure; significant additional cost and risk
Security/Contingency	Data privacy/security,	Data privacy/security,

Planning	availability, performance, backup, disaster recovery managed by cloud provider; built into subscription costs	availability, performance backup, disaster recovery managed by customer at significant additional cost and risk

Table 2: Cloud Applications vs. On-Premise – One-to-One Comparison (Workday, 2011)

Workday's whitepaper (2011) affirms that educational institutions using cloud technology are able to take advantage of the newest innovations, fast implementations, and immediate updates with the newest functionality. Packaged integrations, lower operating costs, better service levels, and comprehensive security complete the list of added benefits of cloud over on-premise systems.

2.4.3 Issues and Concerns about Cloud Computing in Higher Education

Despite the economic potential and great promises that cloud computing offers to higher educational institutions, valid concerns remain for universities leaders deliberating the particulars of their institution's involvement in the cloud. In a whitepaper published by (Hignite, N. Katz, & Yanosky, 2010) four main issues and concerns for cloud computing in higher education are identified: integration and security, risk and compliance issues, governance questions, and IT staffing implications (Hignite, N. Katz, & Yanosky, 2010):

a. Integration and Security

The integration of services is among the largest challenges and likely takes most of the time and resources at IT departments in the higher educational institutions. The availability of new services in the cloud and the drive to incorporate those services will increase the integration challenge.

Among other key challenges are security issues, such as security of the facility where data is stored, security of data transport, and reliability of the provider. Data integrity is also top of mind, as are data privacy and confidentiality. Issues regarding ownership and access of data and identity management, along with issues of accreditation, certification, and audit, all lead to broader questions about liability and the role of cloud providers versus cloud customers.

b. Risk and Compliance Issues

Not unlike other outsourcing arrangements, cloud computing raises a number of red flags for the risk-averse, including interrogations about privacy protection in connection with outsourcing of e-mail and data security and privacy issues with regard to shared storage. For instance, in a shared services environment, an institution cannot control where its information is stored and how or by whom it is accessed.

Data residing in foreign countries may be subject to seizure or disclosure. If the institution's data resides with that of other customers or clients of the provider, a discovery order aimed at another customer could expose the data to seizure even if you aren't a party to the legal action. How do you manage those risks, especially when you don't necessarily have transparency in the handling of your data? How do you protect against risks to data security, integrity, and availability resulting from service failures, vendor lock-in, and security holes?

- **The need for common standards and third-party risk assessment.** One key benefit of cloud computing within a shared services environment is that it can force a degree of standardization. A service provided using standard forms and solutions would also help minimize duplication of efforts. A best practices approach would improve higher education's approach to third-party risk assessment to ensure that providers are meeting reasonable standards expectations.

  Examples include **EuroCloud Germany_eco** (www.eurocloud.de), which is the association of the German cloud computing industry. They promote acceptance and meet the demand for cloud services in the German market. Some of their goals are to: introduce a seal of approval for cloud services, support the clarification of legal issues and raise provider awareness of user demands.

- **Making the case to state legislatures.** A key concern for public institutions is articulating to state legislatures how moving to the cloud can be a substantial cost- saving measure; a key concern for all institutions is to work with state and federal lawmakers to approach data protection in a manner that serves privacy and security interests while allowing institutions to use cloud sourcing strategically to promote academic missions and drive economic growth. Given the array of broadly worded regulatory standards and reasonable security measures, institutions would benefit from a certification process for cloud services. What might help is the creation of an advisory body that could identify best practices and certify services.

- **Exit strategies and SLAs.** Among the concerns about provider relationships that cloud sourcing raises are corporate transparency, how to manage supplier performance, issues of service portability and vendor lock-in, switching costs, and the structuring of service level agreements. Developing an exit strategy up front can help identify areas of risk and levels of commitment. It can also unearth hidden costs for getting out of a service agreement that could be as expensive as getting in.

  Can standards allow for a higher degree of portability? Can we stipulate that data quality assurance is an entry point for the cloud? What happens if a company is purchased?

c. Governance Questions

One obstacle for many institutions may be convincing key stakeholders on campus of the need to embrace cloud computing as a viable option for running the enterprise. Universities should look at the cloud as an emerging phenomenon that will require some care and feeding of decision makers. Failure to deal with the implications of this move is the number one cause of failure within the cloud.

While in theory many processes could willingly move to the cloud, cloud sourcing certain business functions would require a more complex or long decision-making approach. Institution leaders must also contend with faculty and staff who, for various reasons, make their own decisions about accessing cloud services. Without trying to control those decisions, the university's administration need to at least manage that migration so it have a stake in those relationships and in those agreements.

Governance-related questions include internal issues specific as well as decision-making approaches on behalf of a group of institutions. Critical perspectives include the CIO, the chief business officer, the provost, university counsel, and procurement and risk management. Another key to have on board is the expertise and insight of the institution's HR officer. Having the right HR policies and practices in place to pass this transition in a respectful and positive way will be essential.

d. IT Staffing Implications

While staffs throughout the institution will be affected by changes from cloud computing, the IT personnel will be directly impacted. In this new world of cloud computing, institutional leaders must not only concern themselves with impacts of cloud sourcing on IT staffing levels but also discern the implications of the cloud for the skills and experience required by IT employees going forward.

IT departments of higher educational institutions will be expected to serve as a contract and relationship manager, that requires a different set of skills and training, including more business, communication, and relationship management skills, and have a greater understanding of outsourcing and contractual issues and practices.
In addition to greater focus on the professional development needs of IT staff, certain collaborative efforts could help IT personnel fulfill new job expectations.

One example could be the creation of a consortium of CIOs for sourcing services that could act in a tactical procurement role to facilitate demand for this expertise. In fact, collaboration emerged as not only a worthy goal but also an essential component for taking full advantage of the cloud.

2.5 Technology Diffusion: Hype Cycle & Implementation Gap

Some critical voices say that cloud computing is just temporary hype that will vanish over time [12]. It is indeed difficult to predict the future, so before moving a business to the cloud, it is wise to investigate the relationship between the excitement of some IT-experts about this new technology, facts and actual investment and try to discern the hype from what's commercially viable to see if the bold promises of cloud computing will pay off.

[12] http://www.zdnet.com/blog/service-oriented/is-cloud-computing-hype-or-something-riskier/4038 (Retrieved November 21, 2011)

Industry analysts use a ‘Hype Cycle’ to describe the tendency of new technologies to gain an exaggerated interest before they are really to be deployed in the production and commercial environments. This cycle was first presented by Gartner and described in his information technology research and advisory company’s website as a “graphic representation of the maturity and adoption of technologies and applications, and how they are potentially relevant to solving real business problems and exploiting new opportunities. Gartner Hype Cycle methodology gives you a view of how a technology or application will evolve over time, providing a sound source of insight to manage its deployment within the context of your specific business goals”[13].

Gartner explains that each Hype Cycle drills down into five key phases of a technology’s life cycle as shown in Figure 2-4: Gartner Hype Cycle :

- **Technology Trigger:** A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist and commercial viability is unproven.

- **Peak of Inflated Expectations:** Early publicity produces a number of success stories—often accompanied by scores of failures. Some companies take action; many do not.

- **Trough of Disillusionment:** Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investments continue only if the surviving providers improve their products to the satisfaction of early adopters.

- **Slope of Enlightenment:** More instances of how the technology can benefit the enterprise start to crystallize and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious.

- **Plateau of Productivity:** Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology’s broad market applicability and relevance are clearly paying off.

[13] http://www.gartner.com/technology/research/methodologies/hype-cycle.jsp (Retrieved November 21, 2011)

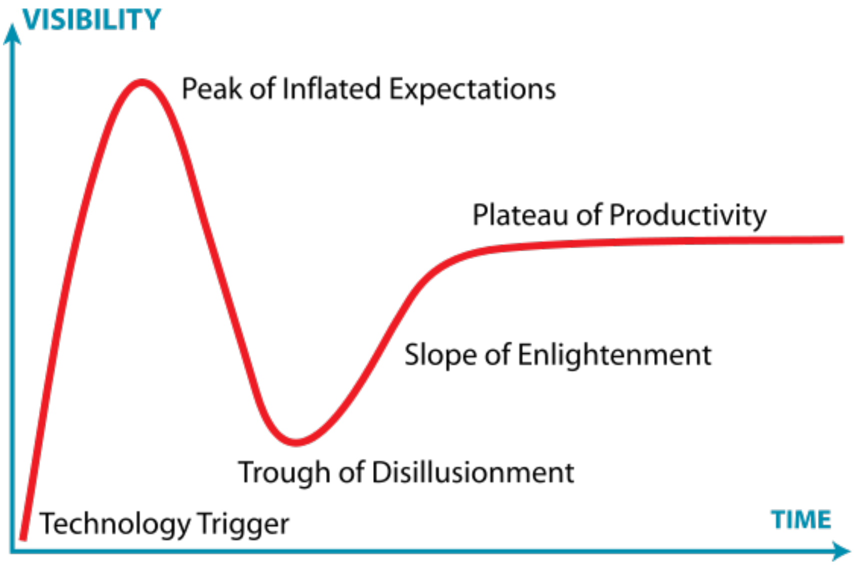

Figure 2-4: Gartner Hype Cycle **(Gartner, Inc. (A), 2010)**

In Gartner's 2010 "Hype Cycle Special Report Evaluates Maturity of 1,800 Technologies", cloud computing was placed at the end of the Peak of Inflated Expectations (See Figure 2-5: Gartner's Hype Cycle for Emerging Technologies) which is a "phase of over enthusiasm and unrealistic projections" (Gartner, Inc. (A), 2010). Although according to Gartner's map, it means that these technologies may be on their way to mainstream, the next stop is one of disillusionment because those technologies failed to live up to expectations but predicted that cloud computing will be mainstream in less than 5 years (Gartner, Inc. (A), 2010).

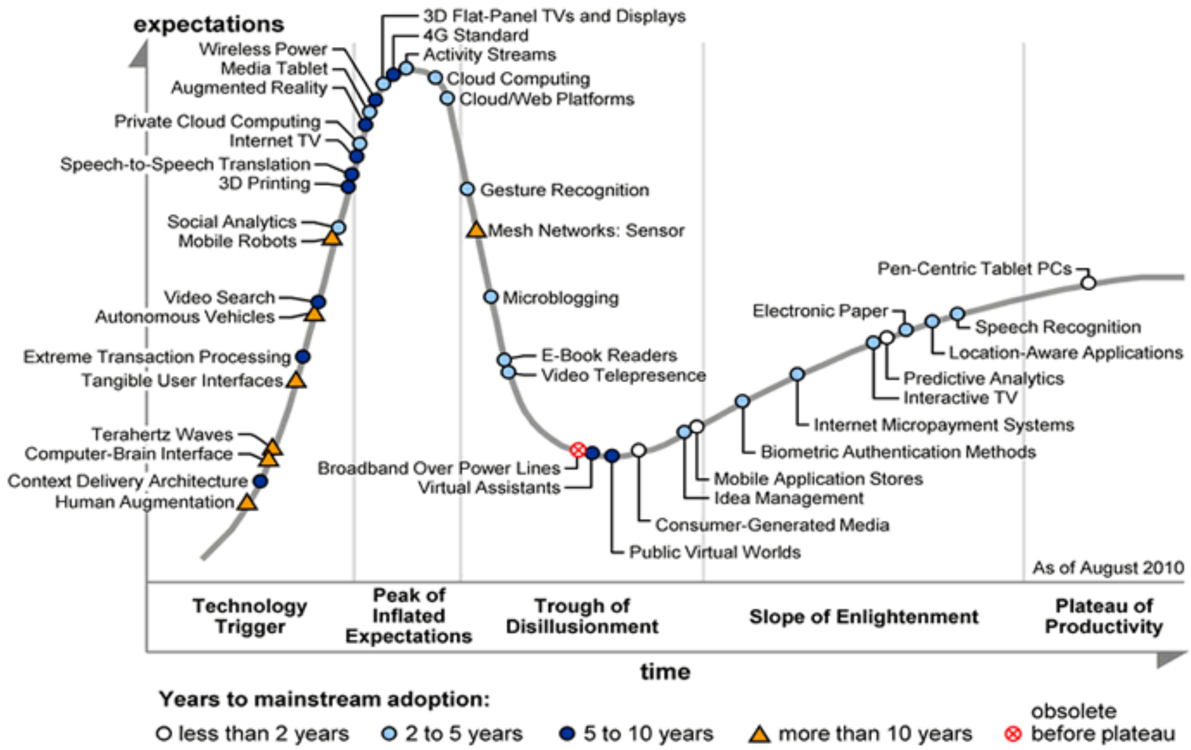

Figure 2-5: Gartner's Hype Cycle for Emerging Technologies **(Gartner, Inc. (A), 2010)**

While it is very interesting to understand the hype around cloud computing, it is also helpful to examine the historical implementation cycle of new technologies.

In this book, 'Crossing the Chasm' (2002), Geoffrey Moore proposes a variation of the original 'Technology adoption lifecycle' theory by Everett Rogers (Rogers , 2003). The theory segments the target market according to the speed with which they adopt new technologies and uses five categories to design these segments as shown in Figure 2-6: Moore's Technology Adoption Curve: (Rogers , 2003)

- Innovators: They are the first individuals to adopt an innovation. Innovators are willing to take risks, youngest in age, have the highest social class, have great financial lucidity, very social and have closest contact to scientific sources and interaction with other innovators.

- Early Adopters: This is the second fastest category of individuals who adopt an innovation. These individuals have the highest degree of opinion leadership among the other adopter categories. Early adopters have an advanced education and are more discrete in adoption choices than innovators.

- Early Majority: Individuals in this category adopt an innovation after a varying degree of time. This time of adoption is significantly longer than the innovators and early adopters. Early Majority tends to be slower in the adoption process.

- Late Majority: Individuals in this category will adopt an innovation after the average member of the society. These individuals approach an innovation with a high degree of skepticism and after the majority of society has adopted the innovation.

- Laggards: Individuals in this category are the last to adopt an innovation. These individuals typically have an aversion to change-agents and typically tend to be focused on "traditions".

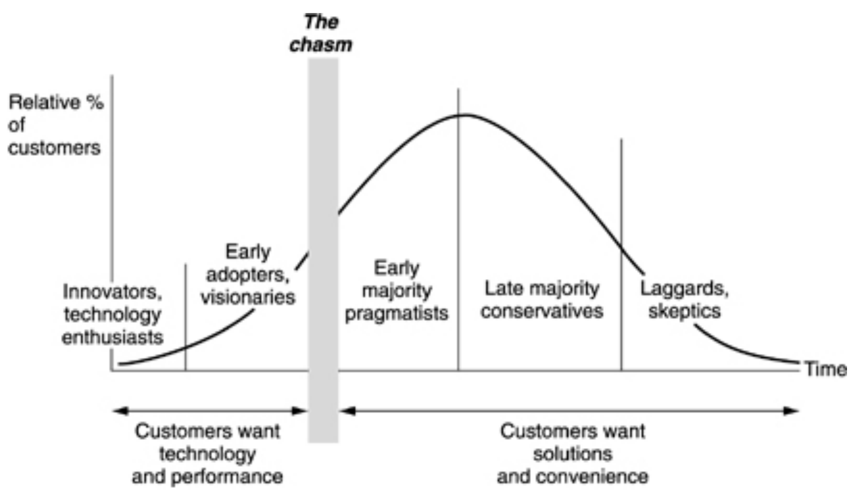

Figure 2-6: Moore's Technology Adoption Curve (Rogers , 2003)

While being at one extreme or the other may give cause for some concern there is not necessarily any value related with being earlier or later in the adoption curve. Some companies can gain competitive advantage by leveraging and showcasing the newest technologies. Others may risk their business if they pursue areas outside their core competency too early (Rhoton, 2010, S. 6).

Moore (2002) also suggest that for discontinuous or disruptive innovations, there is a gap or chasm between the first two adopter categories (innovators/early adopters), and the early majority [14] (See Figure 2-6: Moore's Technology Adoption Curve).

According to Moore, the marketer should concentrate on one group of customers at a time, using each group as a base for marketing to the next category. The most difficult step is making the transition between visionaries (early adopters) and pragmatists (early majority). This is the chasm that he referring to. Technologies or products that cannot cross this chasm will die or remain niche. If successful, a firm can create a ‘bandwagon effect’ in which the momentum builds and the product becomes ubiquitous” [15].

Rhoton (2010) notice a noteworthy twist that cloud computing brings to Moore’s adoption model: in some ways, the propensity to adopt may be reversed from other technologies. Habitually, technologies savvy organizations prefer new developments while those who like to remain distant from technology also like to keep the status quo as long as possible.

In the case of cloud computing, an increased trend to outsourcing and subcontracting moves large portions of the technology systems outside the company control and responsibility. This can be attractive to those who would prefer to focus on non-technical aspects of their business and are pleased to see their fixed IT costs reduced and their computer departments, which they never consider to be contributing to the bottom line, reduced (Rhoton, 2010, S. 6).

[14] http://en.wikipedia.org/wiki/Technology_adoption_lifecycle (Retrieved November 21, 2011)
[15] http://en.wikipedia.org/wiki/Diffusion_(business) (Retrieved November 21, 2011)

3 Methodology

3.1 Research Design

The descriptive method of research was used for this study. To define the descriptive type of research, Creswell (1994) stated that the descriptive method of research is to gather information about the present existing condition. The emphasis is on describing rather than on judging or interpreting. The aim of descriptive research is to verify formulated hypotheses that refer to the present situation in order to elucidate it.

The descriptive approach allows a flexible approach, thus, when important new issues and questions arise during the duration of the study, further investigation may be conducted. The aim of descriptive research is to obtain an accurate profile of the people, events or situations. With this research type, it is essential that the researcher already has a clear view or picture of the phenomena being investigated before the data collection procedure is carried out. The researcher used this kind of research to obtain first hand data from the respondents so as to formulate rational and sound conclusions and recommendations for the study [16].

In this study, the descriptive research method was employed so as to know if cloud computing technologies are being used in German higher educational institutions during the time of research and to identify the role and significance of used cloud services in this field.
Employees of higher educational institutions data centers and cloud experts in Germany were used as respondents in order to gather relevant data; the descriptive method is then appropriate as this can allow the identification of the similarities and differences of the respondent's answers.

The primary data type gathered for this research was derived from the answers the participants gave during the survey process and the phone interviews. Usually descriptive researches also use a secondary type of data from published documents and literatures that are relevant to the topic studied to combine the quantitative and qualitative approach of research. For this purpose a desk research was conducted to gain the essential knowledge needed to write this thesis capitalizing on books and scientific papers and articles to increase the quality of the work.

3.2 Instruments

3.2.1 The Online Questionnaire

This online questionnaire was conducted in order to determine whether German higher educational institutions currently use cloud computing or not. The advantages and disadvantages as well as the reliability of using cloud services in the higher educational environment were also part of the objectives.

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[16] http://www.oppapers.com/essays/COntractual-Employees-On-Both-Public-And/427018 (Retrieved November 21, 2011)

To create the sample that should virtually represent the German higher educational environment, E-Mail(s) with the request to complete the online questionnaire were sent to employees of 50 higher educational institutions data centers in Germany. The criteria to select these 50 universities were to be the first 50 German universities listed the QS World University Rankings® for the year 2010/11 [17].

In addition to that, a request was sent to an association called ‘Zentren für Kommunikation und Informationsverarbeitung in Lehre und Forschung e.V.’ (ZKI), literally translated “Association for communication and information processing centers in teaching and research” to spread the link of the online questionnaire in their internal mailing list. The ZKI was founded in 1993. Since then, the center promotes the processing of information in teaching and research in universities and predominantly publicly funded major research institutions [18]. According to their website, the ZKI supports the computing centers in their tasks by:

- Supporting the exchange of ideas and experiences.
- Stimulating the cooperation between the ZKI and Data Centers.
- Provide consultation and collaborate with educational and scientific institutions.

In the activity diagram below you can see an overview of the online questionnaire’s outline. A more comprehensive version of the diagram is available in Chapter 4: Current State of Cloud Computing in German Higher Educational Institutions.

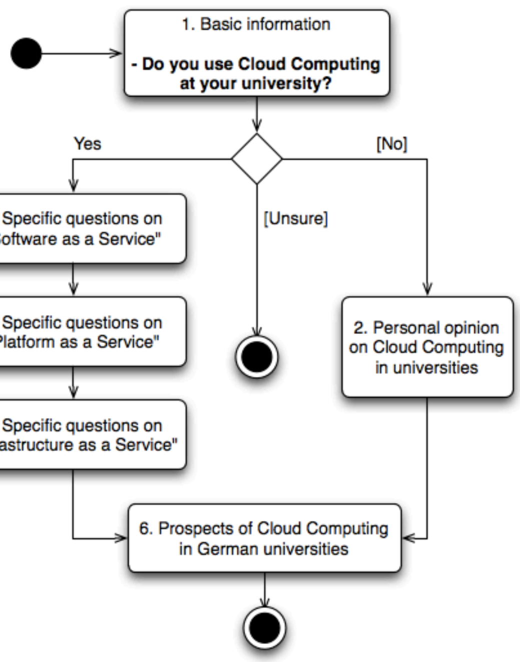

Figure 3-1: The online questionnaire’s outline

[17] http://www.topuniversities.com/university-rankings/world-university-rankings/2010 (Retrieved November 25, 2011)
[18] http://www.zki.de/der-verein/ (Retrieved November 21, 2011)

The contacted sample of higher educational institutions was formed as following: 84% (Count: 42 of 50) universities and 16% (Count: 8 of 50) of universities of applied science. The same sample also represented 12% private institutions (Count: 6 of 50) and 88% public institutions (Count: 44 of 50).

After a runtime of about four weeks, a total of 25 respondents have accomplished the online questionnaire. These participants represented 72% (Count: 18 of 25) universities, 28% (Count: 7 of 25) universities of applied science, 92% (Count: 23 of 25) public institutions and 8% (Count: 6 of 25) private institutions.

The charts below present an overview of the variation between the contacted institutions and those who took part in the online questionnaire categorized by their type ('Universities versus Universities of Applied Science' and then 'Public institutions versus Private institutions').

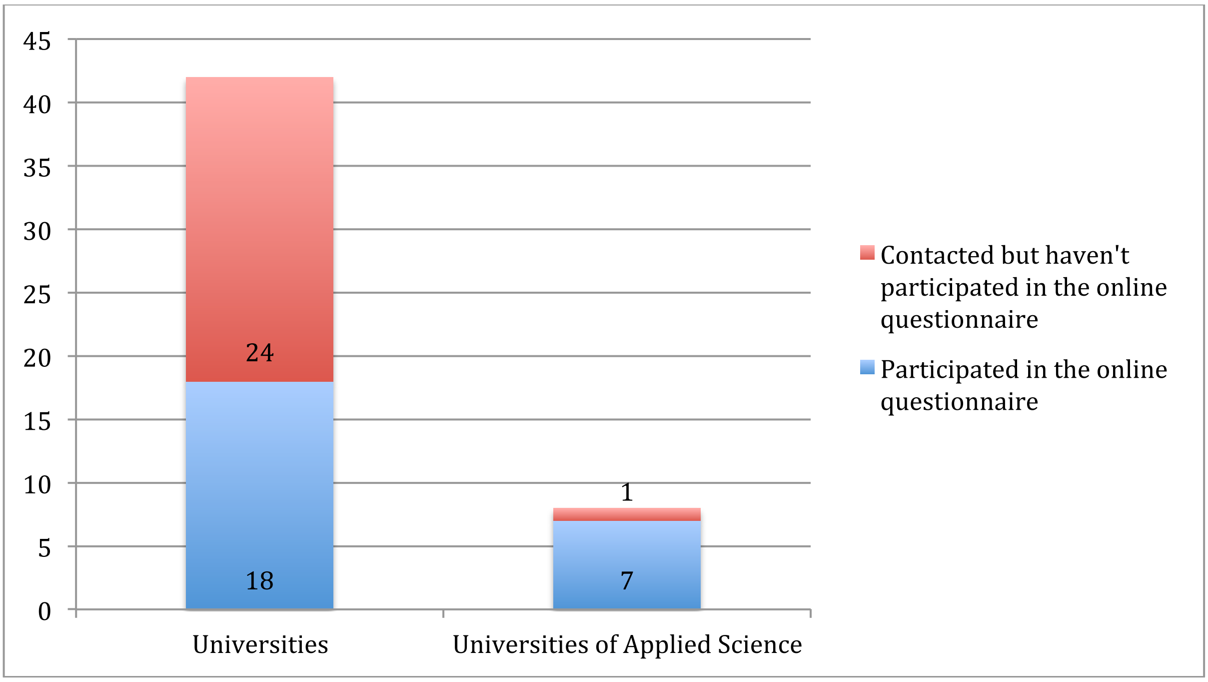

Figure 3-2: Participation in the online questionnaire - Universities vs. Universities of Applied Science

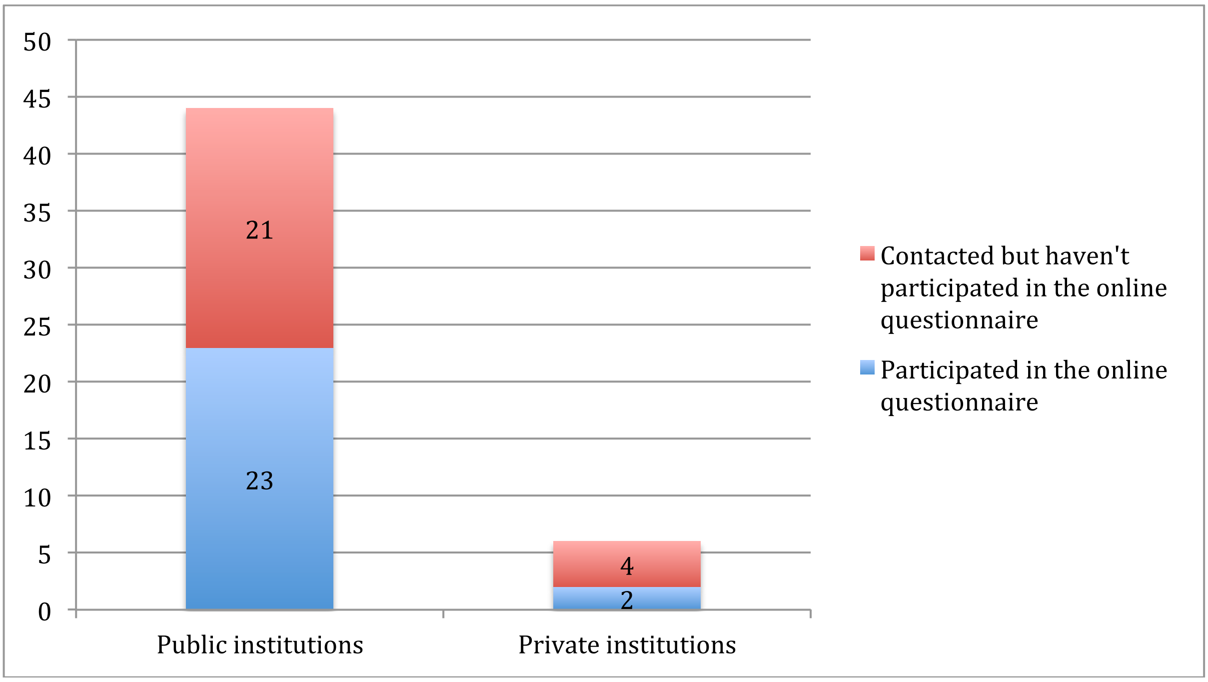

Figure 3-3: Participation in the online questionnaire - Public vs. Private institutions

The Data gathered from this research instrument is then analyzed and interpreted in Chapter 4: Current State of Cloud Computing in German Higher Educational Institutions.

3.2.2 The Interviews

Telephone interview were undertaken as a method for qualitative research to gather a deeper understanding of the point of view of selected cloud experts.

McNamara (1999) describes interviews as “particularly useful for getting the story behind a participant’s experiences. The interviewer can pursue in-depth information around the topic. Interviews may be useful as follow-up to certain respondents to questionnaires, e.g., to further investigate their responses”. This method enables the researcher to gather information rapidly and allows some personal contact and interaction with the respondents.

The interview was designed for two categories of respondents: experts from the academic field and experts from the IT industry. It was conducted with spokespersons from these institutions:

- Microsoft (Live@Edu and Office Academic Division)
- IBM (Cloud Development & Test / R&D Division)

- High Performance Computing Center Stuttgart
- Karlsruhe Institute of Technology (Research Group for Cloud)

In the activity diagram below you can see a simplistic overview of the interview's outline.

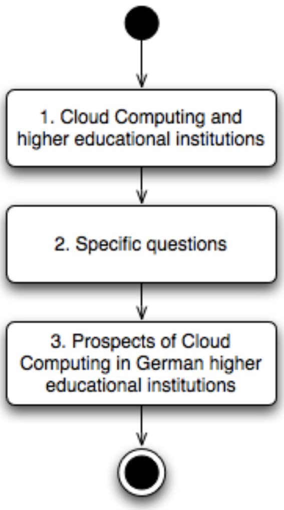

Figure 3-4: The telephone interviews outline

The information gathered from the interviews is presented in Chapter 5: Perspectives of Cloud Computing in German Higher Educational Institutions.

3.3 Ethical Considerations

As this study required the participation of human respondents, specifically employees of 25 higher educational institutions data centers and 4 cloud computing experts, certain ethical issues were addressed. The consideration of these ethical issues was necessary for the purpose of ensuring the privacy of the participants.

Among the significant ethical issues that were considered in the research process include consent and confidentiality. In order to secure the consent of the selected participants, all important details of the study were relayed, including its aim and purpose of the thesis. By explaining these important details, the respondents were able to understand the importance of their role in the completion of the research.

The confidentiality of the participants including universities was also ensured by not disclosing their names, professional title or personal information in the research. Only relevant details that helped in answering the research questions were included.

4 Current State of Cloud Computing in German Higher Educational Institutions

4.1 Preparing the Online Questionnaire

4.1.1 Purpose and Requirements

To define the purpose of the online questionnaire, this null hypothesis was set: "Higher Educational institutions in Germany are not using cloud computing, are not currently studying the possibility of using it and are not aware of its advantages".

The main requirements set for the online questionnaire were:

- It should be completely in German to be sure that every participant would understand it easily.
- It should contain basic explanations on cloud computing and links to external websites for further reading it needed.
- Filling it should last no longer than 20 minutes.

4.1.2 Key Questions of the Survey

The online questionnaire contains a welcoming text at the beginning explaining the aim of the survey, its subject, a quick definition of cloud computing as an introduction and an email address to contact if they need support filling the questionnaire. At the end, the user will receive an acknowledgement thanking them for the participation. The core of the questionnaire is composed by 1 to 5 main blocks of questions depending on the answering scenario. Each block will try to answer one key question.

The table and the activity diagram below explain the main blocks of the online survey and its key questions.

<table>
<tr><td colspan="3">1. Welcome Text and explanations</td></tr>
<tr><td colspan="3">2. Basic information about the participants and their knowledge of cloud computing.
Filter question: Does the institution you are working for use cloud computing?</td></tr>
<tr><th>Filter question answered with “Yes”</th><th>Filter question answered with “No”</th><th>Filter question answered with “Unsure”</th></tr>
<tr><td>3a. Does your institution provides or use Software as a Service (SaaS)? If yes, what exactly? What pros and cons do you see in using SaaS at higher educational institutions?</td><td rowspan="3">3. Personal opinion about cloud computing, pros and cons of its use in higher educational institutions and important criteria to choose a cloud provider</td><td rowspan="4"></td></tr>
<tr><td>3b. Does your institution provides or use Platform as a Service (PaaS)? If yes, what exactly? What pros and cons do you see in using PaaS at higher educational institutions?</td></tr>
<tr><td>3c. Does your institution provides or use Infrastructure as a Service (IaaS)? If yes, what exactly? What pros and cons do you see in using IaaS at higher educational institutions?</td></tr>
<tr><td colspan="2">4. What prospects do you see for the use of cloud computing in The German higher educational institutions?</td></tr>
<tr><td colspan="3">5. Thanking message</td></tr>
</table>

Table 3: Key questions of the online questionnaire

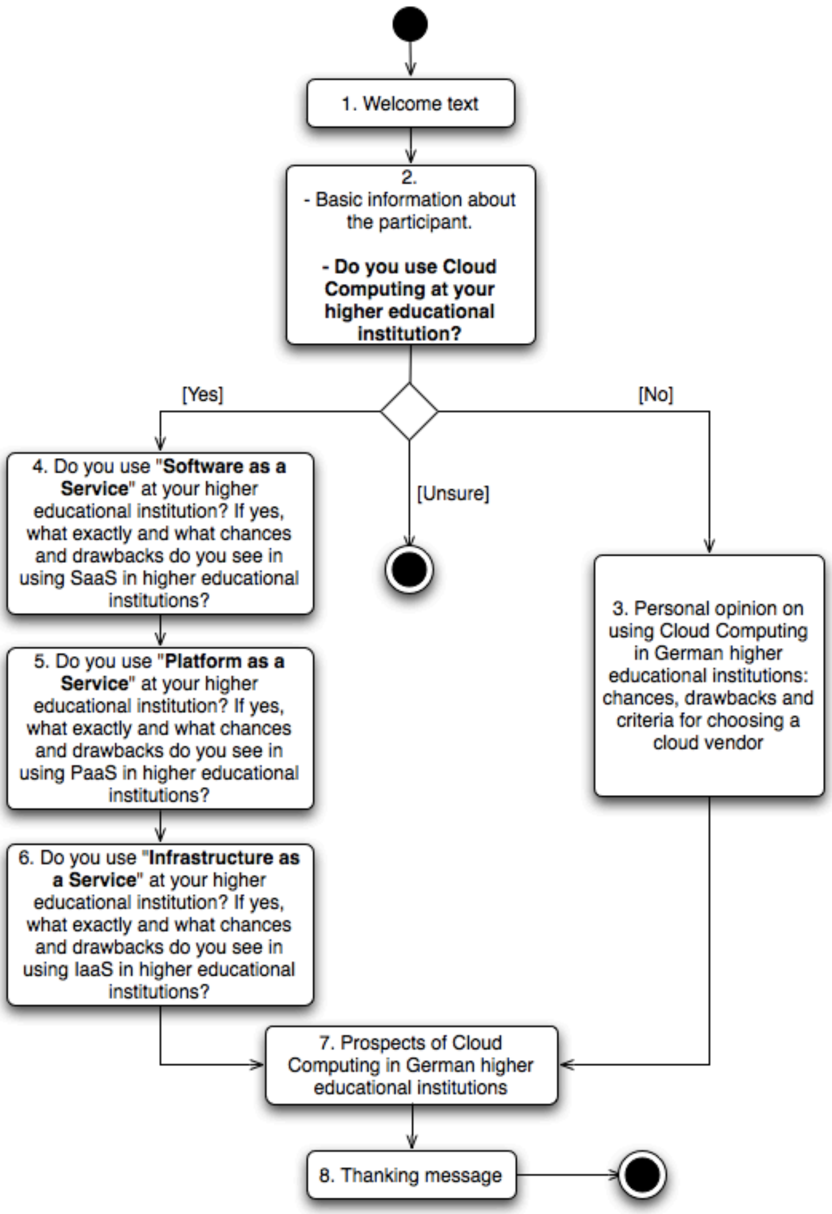

Figure 4-1: Activity diagram presenting the main structure and key questions of the online questionnaire

4.1.3 Designing the Survey

The online questionnaire was created and designed at SurveyGizmo <http://students.sgizmo.com/> using a free student license that enables most of the enterprise features. The survey was activated from Mai 15th, 2011 to June 15th, 2011 and reachable under this address:

http://www.surveygizmo.com/s3/523463/Cloud-Computing-in-deutsche-Hochschulen

4.2 Results and analysis of the online questionnaire

To present the main results of the online questionnaire, the answers collected are structured as presented in Table 3: Key questions of the online questionnaire.
The detailed answers of the online questionnaire are attached in the Annex.

4.2.1 Opinion of Higher Educational Institutions Data Center's Employees about Cloud Computing

The majority of the higher educational institutions data center's employees affirmed that that cloud computing could be beneficial to higher educational institutions in Germany (70%, Count: 7 of 10). They stated that the most attractive cloud computing service model for higher educational institutions is Infrastructure as a Service (71,4%, Count: 5 of 7), than Software as Service (57,1%, Count: 4 of 7) and in the last place Platform as a Service (42,9%, Count: 3 of 7).

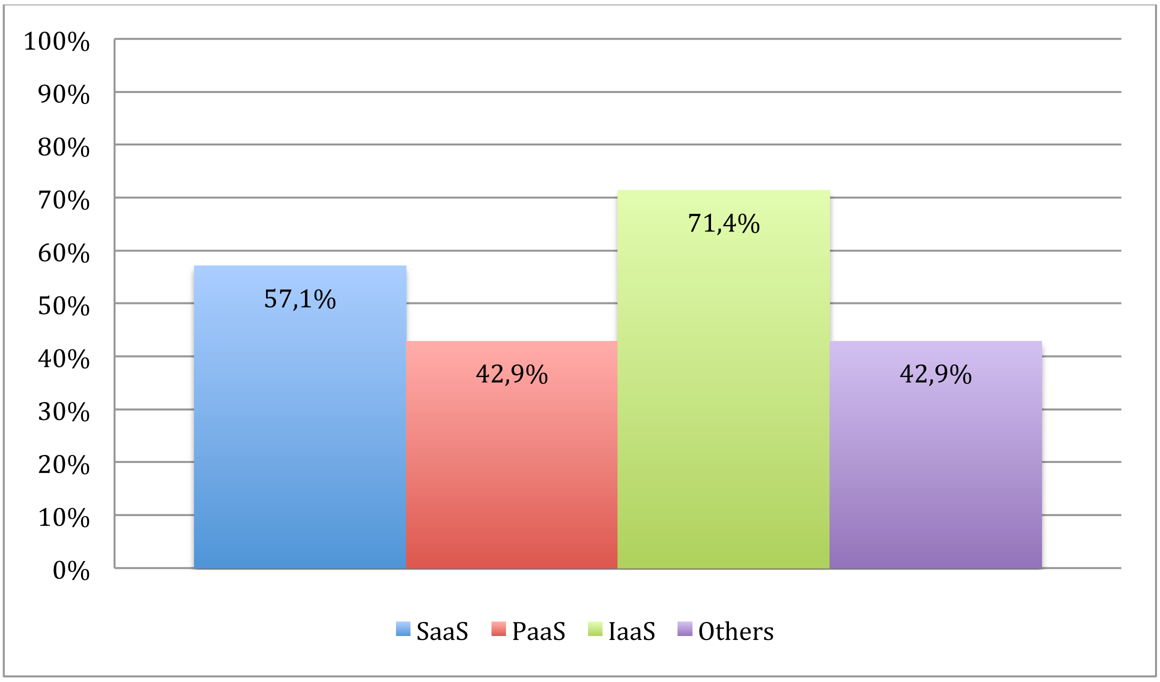

Figure 4-2: Most attractive cloud computing service model for German higher educational institutions

University data center staffs expect these top strengths from using cloud computing:

- High scalability of the offered services (90%, Count: 9 of 10)
- High availability of the services (70%, Count: 7 of 10)
- Greater performance (60%, Count: 6 of 10)
- Secure data storage trough redundancy (50%, Count: 5 of 10)
- Increase mobility by accessing data from everywhere (50%, Count: 5 of 10)
- Easy collaboration (30%, Count: 3 of 10)
- Outsourcing of Maintenance (20%, Count: 2 of 10)
- Outsourcing of support (10%, Count: 1 of 10)

It’s also interesting to notice that none of the participants in this question block have checked “Higher security of the services and infrastructure” or “cost saving”.

The top perceived threads of cloud computing were:

- The security of the services and the infrastructure (90%, Count: 9 of 10)
- Data security (80%, Count: 8 of 10)
- Data privacy (80%, Count: 8 of 10)
- Dependency to the provider (70%, Count: 7 of 10)
- Difficulties in the integration and data migration (70%, Count: 7 of 10)
- The need for a stable and fast Internet connection (70%, Count: 7 of 10)
- Employees’ dependency for external in support (50%, Count: 5 of 10)
- Employees’ dependency for externals in maintenance (40%, Count: 4 of 10)
- Costs (40%, Count: 4 of 10)
- Limited functionalities and options (40%, Count: 4 of 10)
- Risk of the unavailability of the services (30%, Count: 3 of 10)

4.2.2 Usage of Cloud Computing in Higher Education in General

52% from a total number of 25 responses answered with “Yes” (Count: 13 of 25), 44% with “No” (Count: 11 of 25), and 4% answered with “Unsure” (Count: 1 of 25).

More than the half of the German higher educational institutions, which participated in the questionnaire are currently using cloud computing. A detailed description of this usage is explained in following questions.

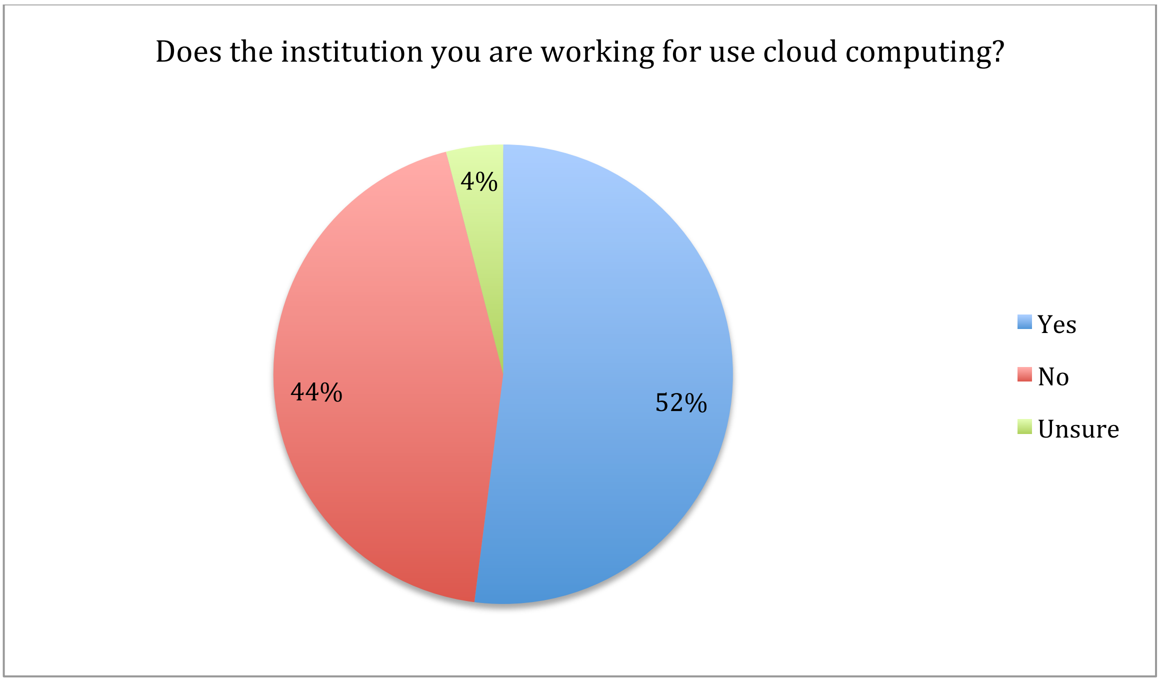

Figure 4-3: Usage of cloud computing in German Higher Educational Institutions - Overview

The institutions currently operating cloud computing are divided as following: 85% of them are universities (Count: 11 of 13) and 15% are universities of applied science

(Count: 2 of 13). And from a different perspective, 100% of these institutions that use cloud computing are public institutions (Count: 13 of 13).

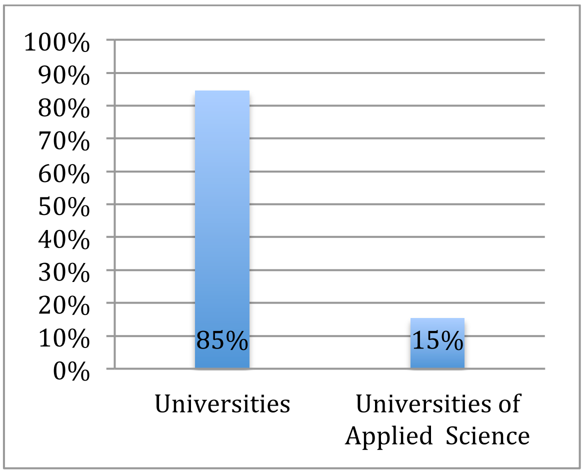

Figure 4-4: Usage of cloud computing in German Higher Educational Institutions - Universities vs. Universities of Applied Science

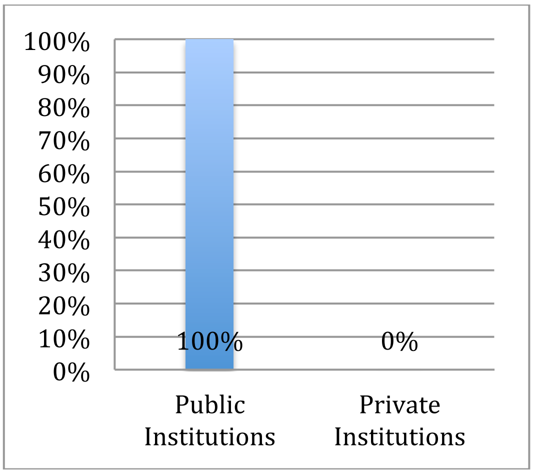

Figure 4-5: Usage of cloud computing in German Higher Educational Institutions - Public vs. Private Institutions

Another interesting fact is that 46% of the participants who don't use cloud computing yet (Count: 5 of 11), stated that they are currently studying the possibility of using it and only one institution stated that they deliberately decided against it.
This relatively high percentage prove that universities are indeed interested in the topic and allow a positive prognosis of the development of the numbers of higher educational institutions that use cloud computing in the next years.

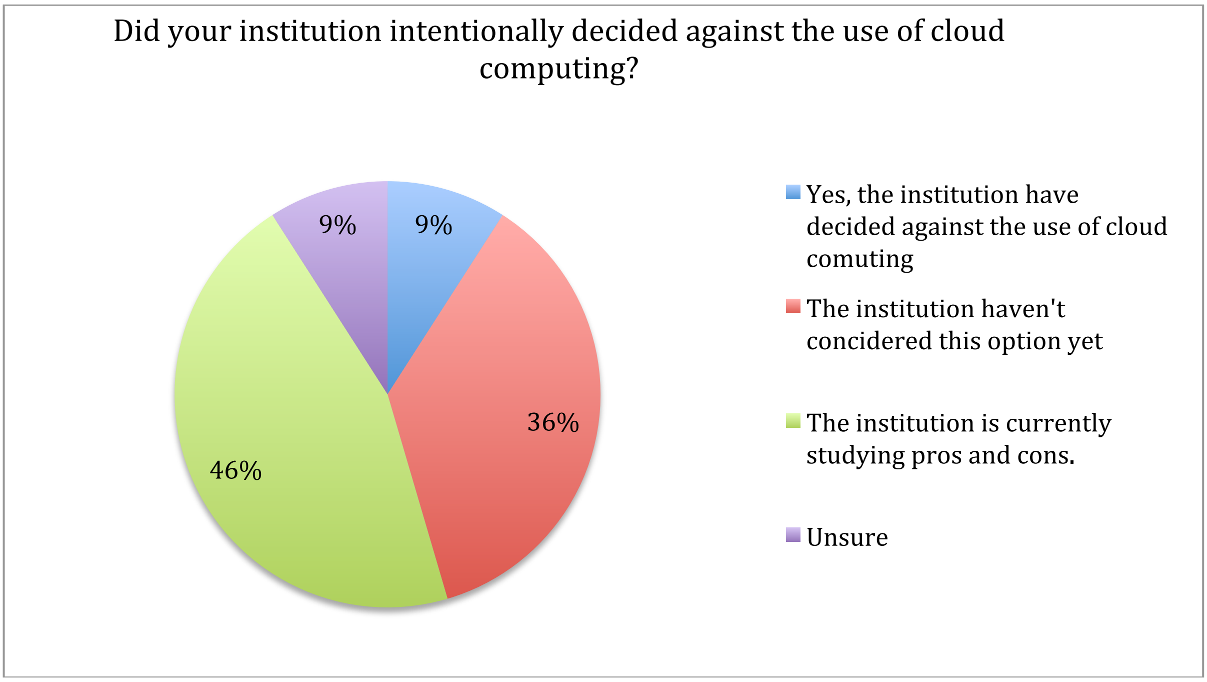

Figure 4-6: Deliberate decision against the use of cloud computing in higher educational institutions

4.2.3 Usage of Software as a Service (SaaS) in Higher education

The online questionnaire shows that 61,5% of the participants in the survey are using Software as a Service (Count: 8 of 13). These universities use Software as a Service mainly for teaching and research reasons (both options answered with 75%, Count: 6 of 8) but also for administrative operations (37,5%, Count: 3 of 8).
The online survey asked the participants using SaaS also what specific kind of service do they use it for. The top three answers were respectively: E-Mail with 75% (Count: 6 of 8), Calendar and university management programs both with 62,5% (Count: 5 of 8) and conferencing programs with 50% (Count: 4 of 4).

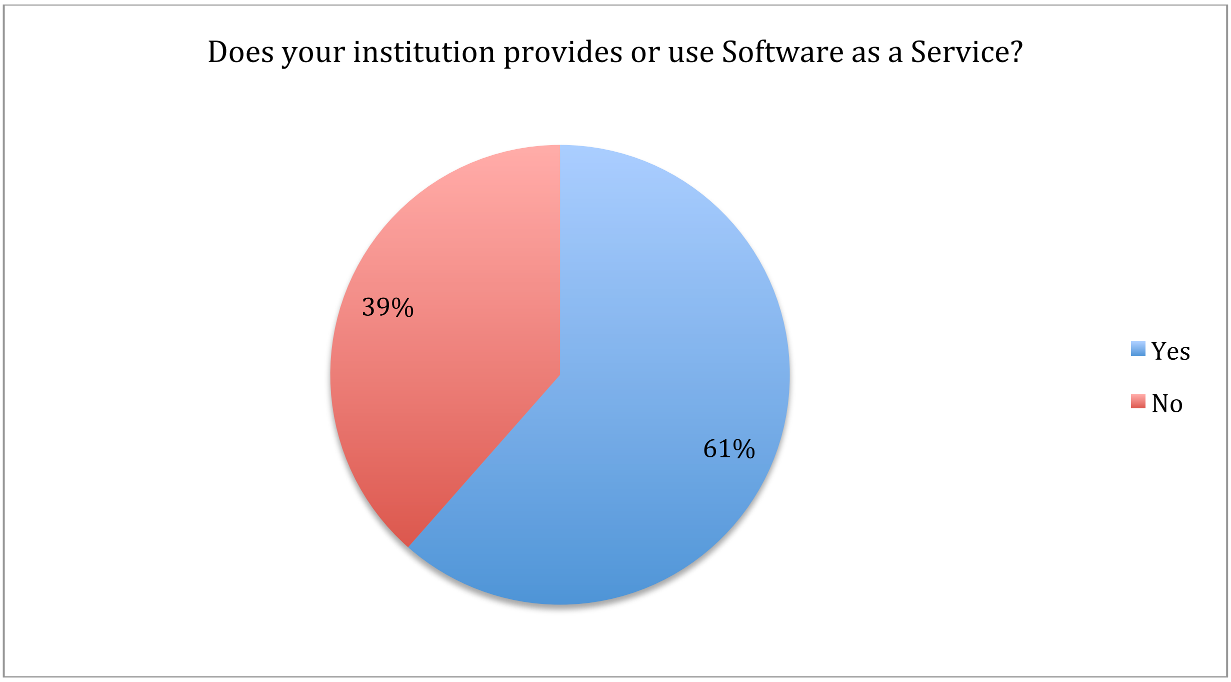

Figure 4-7: Usage of Software as a Service in German higher educational institutions

Asked about the top chances and arguments for the use of Software as a Service in higher education, 100% of the participants (Count: 8 of 8) indicated that high and constant availability of the services is considered as a pro argument for SaaS. 62% of the participants (Count: 6 of 8) said that the high security, data privacy and cost saving are next major arguments and 50% of the contributors (Count: 4 of 8) see the opportunity of outsourcing of maintenance and support as a reason for using SaaS in higher educational institutions.

Some of participants added in the comments other arguments for the use of Software as Service in higher education. Here are the most interesting ones (a complete list is provided in the Annex):

- Elasticity, the easiness of moving and switching services
- Flexibility in the deployment of services
- Reduction of the operation's costs
- Bonding and engaging students to the university
- Simplification of the Backend in the university data center through process optimization

The participants chose also the most relevant disadvantages of Software as Service. 62,5% (Count: 5 of 8) of them affirmed that security and data privacy risks constituted the most important drawbacks, 25% (Count: 2 of 8) thought that risks in availability of the services and the dependency to externals in the support and maintenance are the most important weaknesses, and 12,5% (Count: 1 of 8) perceived the cost factor as a risk in implementing Software as a Service.

Other proposed drawbacks and argument against using SaaS are:

- Problems during network unavailability
- Possible problems and complications in restoring data
- Unknown storing place of the data (technical and legal aspect)

4.2.4 Usage of Platform as a Service (PaaS) in Higher Education

54% (Count: 7 of 13) of the participants confirmed they use of Platform as a Service in their university. All of them are using PaaS for teaching purposes, 85,7% (Count: 6 of 7) are using it for research and 28,6% (Count: 2 of 8) for administrative and management motives.
Most of the German higher educational institutions using PaaS are also self-providing it (85,7%, Count: 6 of 7). Indeed only 42,9% (Count: 3 of 7) of the participants indicated using PaaS offered by externals.

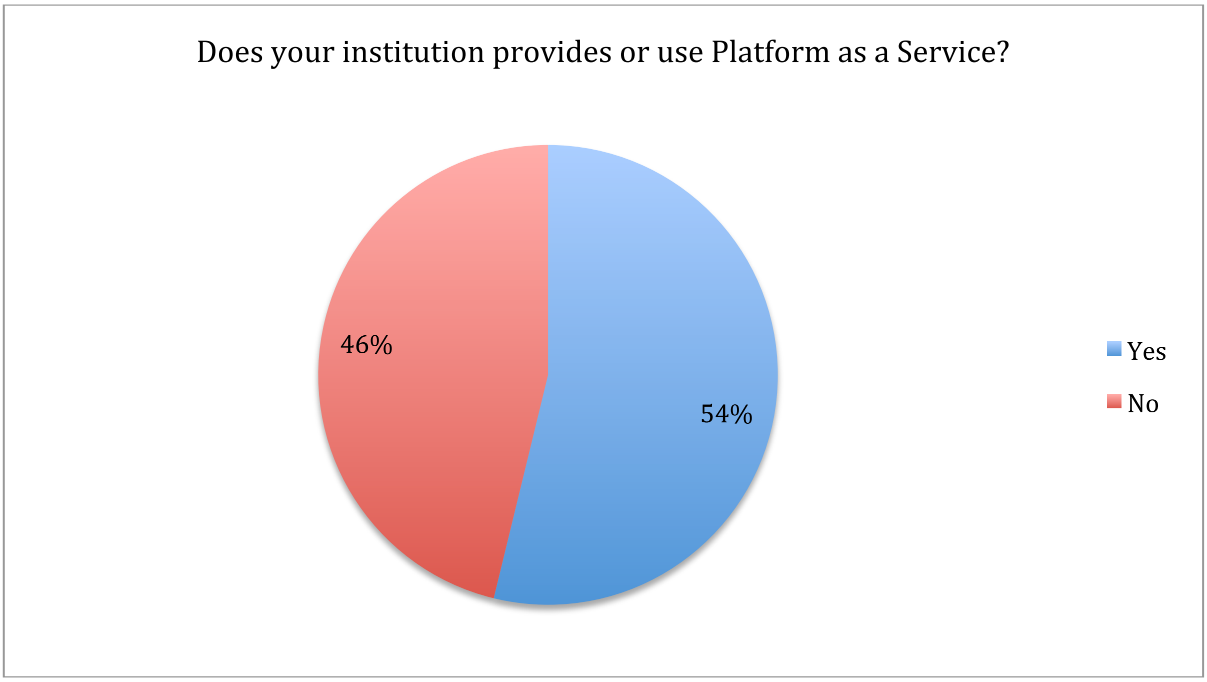

Figure 4-8: Usage of Platform as a Service in German higher educational institutions

PaaS users ordered properties and arguments for the use of Platform as a Service in higher education as following: 87,5% (Count: 7 of 8) for the availability, Security and cost saving with 62,5% (Count: 5 of 8), 50% (Count: 4 of 8) for the data privacy and 35,5% (Count: 3 of 8) for the outsourcing of maintenance and support.

Furthermore, contributors of the questionnaire added few other benefits for using Platform as a Service in higher educational institutions:

- Flexibility in the deployment of services
- Homogeneous IT Landscape / High level of Virtualization
- High grade of capacity utilization

On the other hand, the principal drawbacks of using Platform as a Service were: the security and data privacy risks (both 62,5%, Count: 5 of 8), risks of unavailability and dependency to externals (both 25%, Count: 2 of 8) and the cost factor (12,5%, Count: 1 of 8). Another disadvantage of using PaaS suggested by the participants is the need of new competencies to handle and manage such contracts, which is of course valid for SaaS and IaaS too.

4.2.5 Usage of Infrastructure as a Service (IaaS) in Higher Education

With 69% (Count: 9 of 13), Infrastructure as a Service is by far the most used service model of cloud computing in German higher educational institutions.
All of the universities and universities of applied science using IaaS are using it for research purposes (100%, Count: 9 of 9). 66,7% (Count: 6 of 9) of the German higher educational institutions are using IaaS for teaching and 44,4% (Count: 4 of 9) for management and organizational causes.

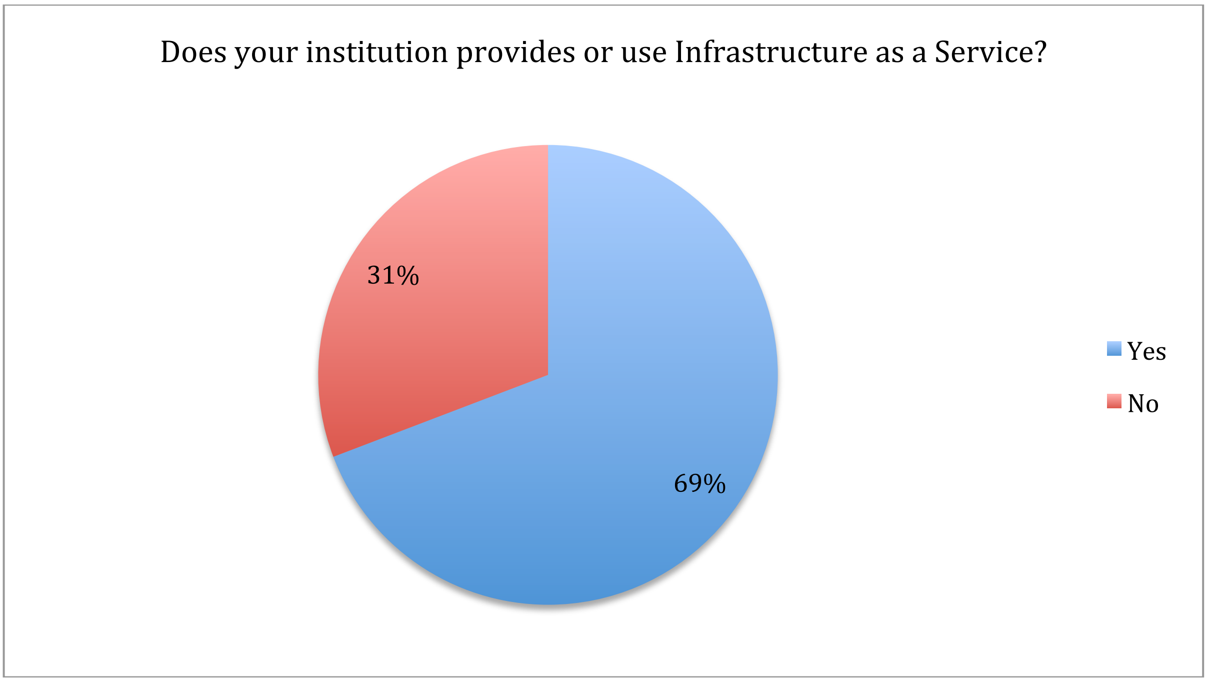

Figure 4-9: Usage of Software as a Infrastructure in German higher educational institutions

The most widely spread deployment model of 'Infrastructure as a Service' are private clouds (77%, Count: 9 of 9), hybrid cloud (44,4%, Count: 4 of 9) and finally public clouds (11,1%, Count: 1 of 9).

All of the institutions participating in the survey and using ‘Infrastructure as a Service’ are relying on their own data center to offer this service, and 33,3 of them (Count: 3 of 9) are trusting externals to provide IaaS. One of the institution even acknowledged being a client of Amazon Web Services.

The institutions using Infrastructure as a Service perceived these factors as the most significant ones to encourage the use of IaaS:

- High availability and cost saving with 88,9% (Count: 8 of 9)
- High security and data privacy with 66,7 (Count: 6 of 9)
- Outsourcing of maintenance and support with 44,4% (Count: 4 of 9)

Furthermore, participants indicated these points being a chance and opportunity if using IaaS in a higher educational environment:

- Consolidation of the expensive and energy inefficient data centers
- Scalability of the computing power depending on the growth of the institution.
- Create synergy through the common use of the hardware
- Standardization of the IT infrastructure resulting in freeing human resources for other activities.

The biggest threats of IaaS in the participants’ opinion were:

- Risks in the availability, security risks and data privacy risks with 55,5% (Count: 5 of 9)
- Dependency risks due to the outsourcing of maintenance and support with 44,4% (Count: 4 of 9)
- High costs with 22,2% (Count: 2 of 9)

Other mentioned threats were:

- Loss of competencies in the data center
- Difficulty to meet the flexible requirements of the universities research facilities
- Education of the data center personals to be able to manage the service

The online questionnaire showed that all of the participants own and rely on a university data center that they use to offer traditional services for students and educational stuff like providing computing power and software, e-learning platforms and even offer cloud services for some of them.

5 Perspectives of Cloud Computing in German Higher Educational Institutions

5.1 Completing the Online Questionnaire with Experts Interviews

The next goal of this thesis which was to formulate a recommendation for higher educational institutions about the usage of cloud computing. The qualitative research technique of online questionnaire showed some limitations here. This part of the investigation was more interested in the depth of the data rather than breadth and required a higher flexibility and playing an active role in the data collection process. The technique of telephone interviews was selected because it gives the respondents a marge of freedom to answer the questions how they wish to and maybe present a completely different perspective on the topic of the thesis that haven't been previously considered. Another considerable advantage of this method was that it allowed a marge of interaction with the experts that enabled increasing the understanding of the Status Quo of cloud computing in the Germany in general and in the higher educational landscape specifically.

Since these interviews were designed to complete the main qualitative research technique, a last section was embedded in the online questionnaire that was sent to higher educational institutions (described in Chapter 4: Current State of Cloud Computing in German Higher Educational Institutions). In this extra part, the participants were asked if they want to take part in a telephone interview.
At the end, five contributors took the offer into consideration and two of them reaffirmed their interest when they were asked personally via e-mail. Two of these institutions were selected based on their research activities in the field of cloud computing as showcased in their respective websites. Both of these institutions were public universities (already using cloud computing in one of it's forms) as no university of applied science and no private institution were willing to cooperate further after the online questionnaire.
The corporate participating in the interviews were selected based on their cloud product portfolio, weight on the market and reputation in the IT scene. In total, four companies were contacted and two of them refused to take part in the interview or couldn't find an appropriate spokesman to support the research.

The Tables below presents an overview of the structure of the conducted interviews and some of key questions asked. Table 4 is dedicated to the interview with employees of higher educational institutions and Table 5 to the interview run with spokespersons from cloud solutions vendors. These phone interviews were designed to take between 30 and 40 minutes each and all the questions were asked in German language.

#	Question block's title	Sample of the questions asked
1	Cloud computing in higher education	– Should cloud computing for higher education be differently defined? What disparities can be identified between the two notions? – Why should higher educational institutions use cloud computing? – What are the requirements of higher educational institutions toward cloud computing?
2	Specific questions about the use of cloud computing in this institution	– Complementary questions about the use of Software-as-a-Service, Platform-as-a-Service and Infrastructure-as-a-Service based on the answers entered in the online questionnaire.
3	Prospects of cloud computing diffusion in German higher educational institutions	– How realistic is it that German higher educational institutions completely switch their IT to the cloud? – What should be done to reach the vision of a cloud supported higher education? – Personal opinion about what kind of cloud deployment model is the more suitable for higher educational institutions.

Table 4: Structure overview of the interviews run with academics

#	Question block's title	Sample of the questions asked
1	Cloud computing in higher education	– On your company's website, cloud computing is defined as following "…", would you like to add something to this definition? – Should cloud computing for higher education be differently defined? What disparities can be identified between the two notions? – What are the requirements of higher educational institutions toward cloud computing?
2	Specific questions about cloud products offered by the company interviewed	– Questions about the company's offered cloud solutions, and statistics of their use in the higher education in Germany.
3	Prospects of cloud computing diffusion in German higher educational institutions	– How realistic is it that German higher educational institutions completely switch their IT to the cloud? – What should be done to reach the vision of a cloud supported higher education? – Personal opinion about what kind of cloud deployment model is the more suitable for higher educational institutions.

Table 5: Structure overview of the interviews run with the corporate

5.2 Results and Analysis of the Interviews

The conducted telephone interviews helped the gathering of a deeper understanding of the Status Quo of cloud computing in Germany and facilitated the creation of a recommendation for higher educational institutions that will be presented and argued in Chapter 6: Recommendations and Critical Issues to Check for German Higher Educational Institutions.

To present the results of the interviews, the answers to two key questions from the third question block 'prospects of cloud computing diffusion in German higher educational institutions' will be showcased. The answers are presented in tables with columns representing two distinct perspectives corresponding to the categories of interviewed participants: higher educational institutions on one side and cloud-computing vendors on the other side. The information presented in the tables is not a literal transcription of the interviews, but rather the gist and essence of the statements acknowledged by the interviewed persons and organisations.

	Perspective of higher educational institutions	Perspective of cloud computing vendors
How realistic is it that German higher educational institutions completely switch their IT to the cloud?	There are special universities services that can be provided better and cheaper by a classical legacy system (Especially the IT infrastructure used for research). These activities will be less affected by the adoption of cloud solutions. However, in the future higher educational institutions will not be able to keep operating the commodity services and will probably assimilate them in a cloud.	There is a significant "shift mind" felt. More and more customers and clients are getting interested in the topic and are already starting dealing with cloud services. Most of the small and medium-sized universities will indisputably adopt cloud computing in one of its forms. The larger universities with over 20,000 students are expected to move only limited parts of their IT systems to the cloud (for example, the student or alumni email system).

Table 6: Probability of a total adoption of cloud computing in higher educational institutions

All of the interview partners agreed that the time of completely migrating the IT at higher educational institutions in Germany hasn't arrived yet. Some of the interviewed experts predict the change to begin within specific categories of organisations (for example: small and medium-sized universities) and then spread within other organisations when the first universities will succeed in adopting it. Other interviewed spokespersons forecast that the change will be based on the service model of cloud computing offered. They estimate that Infrastructure as a Service is one model of cloud computing that will be most rapidly implemented due to the great cost savings it promises and Software as a Service more slowly because of the fear of compliance issues with the German Federal Data Protection Act (Bundesdatenschutzgesetz, BDSG) and the lake of ‘best case practises’ in this field.

	Perspective of higher educational institutions	Perspective of cloud computing vendors
What kind of cloud computing deployment model is the more suitable for higher educational institutions?	A community cloud fits best to higher educational institutions in the long term. The development of the educational cloud will go in this direction. In the community model, a group of educational institutions are bound together by the common purpose of providing IT services to students and a set mutual of compliance requirements like privacy and security. The biggest advantage of this deployment model is that organizations can share costs between them and dynamically allocate the computing power where it is needed.	• The hybrid deployment model is an optimal solution for higher educational institutions. It combines the best of the private and public cloud. Educational institutions could have the security and high privacy standards needed within sensitive components but also profit from the advantages of world-known public cloud providers such as innovative technologies, flexibility and high cooperativeness. • Universities should invest in building a private cloud because it provides the highest level of security and control, despite the relatively high costs of building and managing it in comparison to other cloud deployment models.

Table 7: Most suitable cloud computing deployment model for higher educational institutions

The opinions of the interviewed experts diverge when it comes to chose the optimal deployment model of cloud computing. On one hand, the higher educational institutions’ employees praise the benefits of the community cloud on the long term and see the private cloud as a suitable alternative until a common organisation or entity start building this envisioned community cloud. On the other hand, the interviewed spokespersons of corporates promote the adoption of a private cloud solution even for the long term as it offer the highest level of security and control over the data. Other corporates advice to consider moving to a hybrid cloud that combines public and private cloud elements depending on the functionality needed, requirements requested and the sensitivity of the data processed.
One common vision identified in most of the interviews is that higher educational institutions’ data centres will not disappear over time, but will rather progressively change their core work and role into an IT Service & Support Center.

6 Recommendations and Critical Issues to Check for German Higher Educational Institutions

6.1 Recommendations for Higher Educational Institutions

After an extensive desk research about cloud computing, the conducted interviews with different experts from the industry and the academic field and the interpretation of the result of the online questionnaire fulfilled by higher educational institutions employees, the following recommendation was created and addressed to German higher educational institutions:

- **Adoption of Software as a Service:**

  It is wiser to wait. The industry needs to prepare solutions that fit more to the high requirements and expectations of higher education in Germany.
  Only a small number of cloud providers currently guarantee the storage and processing place of personal data within the European Economic Area (EEA), which is a major legal issue that can't be ignored because of the strict German Federal Data Protection Act (Bundesdatenschutzgesetz, BDSG §9). German educational institutions should select a cloud computing provider that understands the issue with the BDSG and has invested in their cloud architecture and organization to be compliant with it [19].
  To get a deeper insight in the requirements regarding data security and privacy in the cloud in Germany, I advise the reading of the 4th Chapter "Cloud Computing und Datensicherheit" in the book "Cloud Computing: Chancen und Risiken aus technisher und unternehmerischer Sicht" by C. Metzger, T. Reitz & J. Villar (2010) that explains the problematic in detail.

  Cloud providers need to prove the promised cost efficiency in comparison to the current software-licensing model of universities with concrete and credible case studies. At the time of writing this thesis none of the major SaaS providers advertising directly for universities and the public sector have published studies proving their cost effectiveness or demonstrating the security of their architecture. Indeed most of the cloud providers addressing educational institutions just published quotes from clients worldwide praising the general cloud model or the company directly.

  German higher educational institutions will need more than just citations to get more confidence and trust in the cloud model. I believe that the independent advise of specialized cloud associations and auditing groups would be of great help to build more confidence in this area and call for associations like EuroCloud Deutschland_eco e.V.[20] which is the Association of the German Cloud Computing to put more effort in continually monitoring, evaluating and assessing the cloud solutions for the higher educational sector to make the decision process, choice and general offers overview easier and clearer for institutions willing to use or test cloud services.

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[19] http://cloudcomputing.sys-con.com/node/1416444 (Retrieved November 21, 2011)
[20] http://www.eurocloud.de/ (Retrieved November 21, 2011)

- **Adoption of Platform as a Service:**

  The building of web applications and services entirely from the Internet don't need the storage of people's personal data and is less critical than adopting SaaS or IaaS. From the teaching perspective, higher educational institutions and particularly computer science departments are encouraged to use PaaS in parallel to the classical development and programming software, since they need to educate students and train them to use and master state-of-the-art technologies. Platform a as a Service might also be used internally to develop applications for the management and administration of the educational institutions, since it handles the whole life-cycle of the software.

- **Adoption of Infrastructure as a Service:**

  You probably shouldn't dissolve your data center and exclusively rely on an IaaS provider yet. The reasons for my relative skepticism resemble the ones mentioned for SaaS, namely a lack for convincing and independent case studies proving the cost efficiency of the cloud model over the classical one, the data privacy and BDSG issue, an absence of transparency regarding the security regulations of the server farms and data encryption procedures in most of the cloud providers directly targeting the educational and/or public sector in their solution's portfolio.

  It is important not to forget that there is an alternative to the well-known global companies. In fact, some new national and regional hosts are immerging, tying to serve this exact niche and differentiate themselves from the mainstream cloud providers by capitalizing on their understanding of the German privacy laws, and their high flexibility as small and medium enterprises which allow them to satisfy the specific requirements of their customers.
  This is probably the most attractive solution if you are planning to use a public cloud infrastructure for teaching, university administration or replace some of the servers you physically own and manage. If you are rather using Infrastructure as a Service for research purposes then you should consider making a leap and start experimenting with private and/or hybrid cloud infrastructures to get familiarized with it and test deploying some instances depending on your goals and needs before making a decision if this is the right solution for your institution. Keep in mind that creating a private cloud could secure you from the privacy (and maybe security) issues, but it's cost efficiency over the traditional data center model has not have been proven yet.

  Unfortunately, there is no universal advise to offer about the using of IaaS, The experts interviewed in this work shared their experience and gave an encouraging feedback using Infrastructure as a Service in the educational field. More surprisingly, some institutions confessed experimenting with the products of a famous world-known public cloud provider. Nevertheless, I believe that higher educational institutions should decide by themselves what kind of deployment model is more appropriated for their needs and intensely test and exanimate the offers of the vendors they are interested in without falling in a systematic blind resistance to IaaS.

6.2 List of critical issues that Higher Educational Institutions should check before selecting a public cloud computing vendor

It is evident that introducing cloud-computing services in higher educational institutions will present many challenges. The performed online questionnaire sowed that the security perspective in the move to the cloud is the most critical one since much of the computing system infrastructure will be under the control and/or supervision of a third-party provider.

The task of assessing and pre-selecting the portfolios of the cloud vendors isn't an easy mission. It's a period full of doubt and incertitude and where the internal Task Force that has the responsibility to choose the provider, needs the ability to look behind the promotional speech used by the companies to advertise their products. All the weaknesses and strengths of the competing companies need to be discovered then analysed and their risks evaluated.

In order to help identifying and assessing these risks, I created a list of critical issues that Higher Educational Institutions should check before selecting a public cloud computing vendor. Since all the experts interviewed agreed that there are no major differences between cloud computing in general and cloud computing for higher education beside the higher security and privacy requirements, this list could also be used by any enterprise willing to move it's infrastructure to the cloud.

The created list merged two different documents found in the performed desk research: The main points form "What questions should your cloud ask your cloud provider?" published in "Cloud Security: A Comprehensive Guide to Secure the Cloud" by Krutz and Dean Vines (Krutz & Dean Vines, 2010, S. 261) were combined with the content and the structure of another list published in the book "Cloud Computing: Implementation, Management and Security" by Rittinghouse and Ransome (Rittinghouse & Ransome, 2010, S. 163). The result is a modest try to guide the decision process by asking open questions that need to be asked by the institutions management to each cloud vendor.

1. **Privileged user access:**
    a. Who has specialized access to the data? (Rittinghouse & Ransome, 2010)
    b. How are such privileged administrators hired and managed? (Rittinghouse & Ransome, 2010)
    c. What will be your relationship and contact channels with these administrators?

2. **Regulatory compliance:**
    a. Is the cloud vendor willing to undergo external audits and/or security certifications? (Rittinghouse & Ransome, 2010) If yes, how often and how will he prove it?
    b. Are the cloud operations available for physical inspection? (Krutz & Dean Vines, 2010)
    c. What are the privacy policies and policies addressing ownership of client data? (Krutz & Dean Vines, 2010)

3. **Data location:**
    a. Does the provider allow for any control over the location of the data? (Rittinghouse & Ransome, 2010)
    b. Where will the data be stored and processed and what are the security and privacy laws in effect in those locations? (Krutz & Dean Vines, 2010)

4. **Data segregation:**
    a. Is there a data encryption available at all levels? (Rittinghouse & Ransome, 2010)
    b. Were these encryption structures and algorithms designed and tested by experienced and certified professionals? (Rittinghouse & Ransome, 2010)

5. **Recovery:**
    a. What will happen to the data in case of a disaster? (Rittinghouse & Ransome, 2010)
    b. Does the cloud vendor offer a complete restoration? If so, how long would it take to restore your data? (Rittinghouse & Ransome, 2010)

6. **Investigate support:**
    a. Does the cloud vendor have the ability to investigate any inappropriate or illegal activity? (Rittinghouse & Ransome, 2010)
    b. Will the vendor provide a sample or total access to the log files so that the types of data being recorded are available for review? (Krutz & Dean Vines, 2010)
    c. Could the vendor provide an estimation of historical downtimes at your operations? (Krutz & Dean Vines, 2010)

7. **Long-term viability:**
    a. Are there any exit charges or penalties for migrating from your cloud to another vendor? (Krutz & Dean Vines, 2010)
    b. What will happen to your data if the cloud vendor goes out of business? (Rittinghouse & Ransome, 2010)
    c. How will the data be returned, and in what format? (Rittinghouse & Ransome, 2010)
    d. How will your vendor prove to you that he completely deleted all your data in case you quit? (Krutz & Dean Vines, 2010)

As explained, this list of guiding questions is addressed to IT managers and leaders of the higher educational institutions that are interested in adopting cloud services and are having troubles in choosing the appropriate provider from the multitude of companies getting specialized in this field. It is supposed to help them by providing a generic questionnaire that they need to go through with their potential hosts to verify their compliance and the regulations in the Service Licence Agreement (SLA) with the cloud vendor.

It is also wise to hire external consultants and audit group to assess the offers on the market and propose the most suitable cloud solutions depending on the type, size, characteristics and needs of the higher educational organisation and then monitor and demonstrate on-going compliance with the strict regulatory requirements needed in the educational (and particularly public) sector.

7 Conclusion and Outlook

This work studied the status quo of cloud computing in German higher educational institutions as well as the threats and opportunities perceived by employees of higher educational institutions data centers connected to the use of the cloud.

Chapter 1 presented a general introduction and the motivation behind the thesis.
Chapter 2 introduced to the topic of IT-diffusion and cloud computing in general and then defined some related terms like automatic computing, utility computing, grid computing and service oriented architecture. The specific usage of cloud computing in the higher educational environment was also explained in the same chapter where the main problems with the legacy systems in higher education were presented and furthermore the opportunities and issues using cloud computing in higher education.

Chapter 3 described the methodology used in the desk research, online questionnaire and expert's interviews. Chapter 4 was dedicated to the current state of cloud computing in German higher educational institutions. First, the purpose and special requirements of the survey were explained and then its design and structure. Later in the same chapter, the results of the online questionnaire were showcased and analyzed. The online questionnaire revealed that 52% (Count: 13 of 25) of the interviewed institutions are currently using cloud computing in one of its forms, that 20% (Count: 5 of 25) of these institutions are considering the usage of cloud computing and that Infrastructure as a Service is the most used and attractive deployment model in the field of higher education in Germany. The research also has confirmed a widely held assumption about the top drawbacks of using the cloud: data security, data privacy and dependency to the provider.

In chapter 5, the preparation and planning of the experts' interviews were explained and some of its key outcomes presented. These interviews severed with the desk research to elaborate the recommendation to German higher educational institutions regarding the adoption of cloud computing presented in chapter 6. In this last chapter, higher educational organizations were advised to wait for more secure and adopted for their specific needs Software-as-a-Service products, to use Platform-as-a-Service for teaching and finally to carefully start experimenting with Infrastructure-as-a-Service solutions if a compliant provider is found.

This bachelor thesis has some evident weaknesses that limit the significance of its results: First, despite the online questionnaire was sent to over 50 institutions in Germany, only 25 of them answered it. Second, the choice of the QS World University Rankings® as a selection criteria and the choice of the interview partner work were subjective decisions, open to contest and dispute. In addition to that, all the investigations and desk research done in this work are subject to change within a short period of time as the topic of cloud computing is remaining trendy and the data, researches and information available about it are evolving every month and week.

These weaknesses hinder the formulation of a clear statement describing the Status Quo of the diffusion of cloud computing in German higher educational institutions.

One of the most anticipated projects that could answer most of the worries of higher educational institutions willing to move to the cloud is “Cloud Cycle” (www.cloudcycle.org), which is one of the projects that won the German Federal Ministry of Economics and Technology’s "Trusted Cloud" Competition at CeBIT 2011. “Cloud Cycle” is created by a consortium composed by The Fraunhofer Institute for Secure Information Technology, The Institute of Architecture of Application Systems of the University of Stuttgart, IBM Germany, The Urban Data Processing Center Baden-Franken and regio iT Aachen. The project will benefit of the funding of the Trusted Cloud programs by the federal ministry with approximately 50 million euros over the next three years [21] and aims to create cost effective and scalable services with guaranteed security and compliance with laws, policies and data protection customers of SMEs and the public sector [22]. For the moment, the website of the Cloud Cycle only talks about providing standard solutions to schools, but it is supposable that once the project is successfully finished and implemented in schools, there will be no difficulty in applying it to higher educational institutions.

In the 3rd of August 1984, the University of Karlsruhe received the first e-mail in Germany and started a new Era of digital communication in the whole country. Higher educational institutions were always pioneers in adopting new innovative technologies and this shouldn’t change with cloud computing.
Cloud technologies open the door to a wide range of possibilities that weren’t imaginable before. It is literally a paradigm shift from the computing we used to know in last decade and its opportunities and application field will inevitably grow through the time. Even if the challenges regarding data security and privacy seem to be huge, universities need to overcome them and play again a major role in diffusing them. The first step to reach this goal would be by adopting theses innovations internally.

From another perspective, Universities in the United States are again leading the path in this field and it is only a matter of time until the usage of cloud computing in universities spread across Europe and become a standard. It is useless to wait and react to the environmental changes. German higher educational institutions need to dare to make a leap of faith toward new technologies such as cloud computing if they want to play any role in the international educational scene and this is a golden opportunity to do it. At the end, the ones who will adapt fast will win the race.

[21] http://www.bmwi.de/English/Navigation/Press/press-releases,did=383292.html (Retrieved November 21, 2011)
[22] http://www.cloudcycle.org/uber-cloudcycle/ (Retrieved November 21, 2011)

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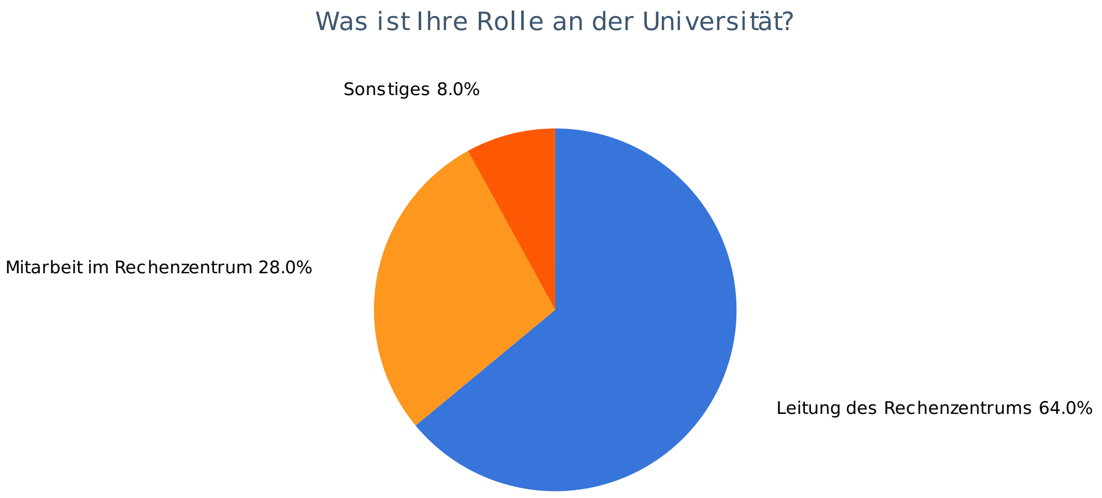
Annex

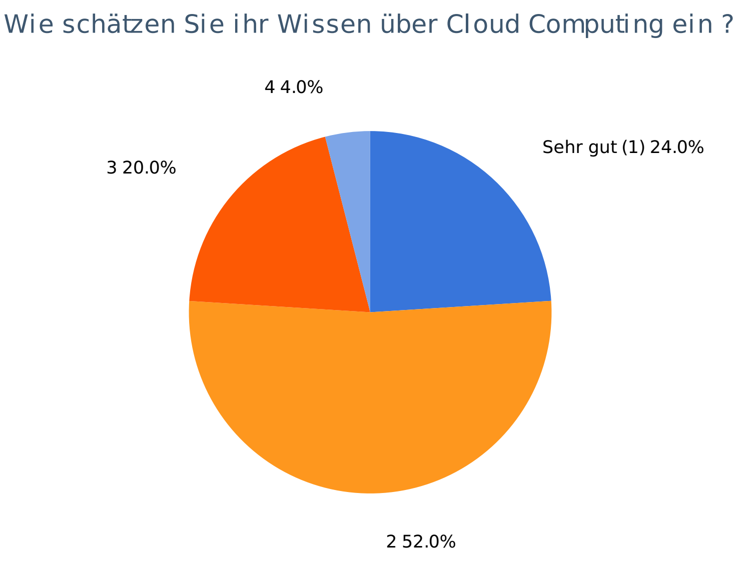
I. Results of the online questionnaire



Was ist Ihre Rolle an der Universität?

Value	Count	Percent %
Leitung des Rechenzentrums	16	64%
Mitarbeit im Rechenzentrum	7	28%
Sonstiges	2	8%

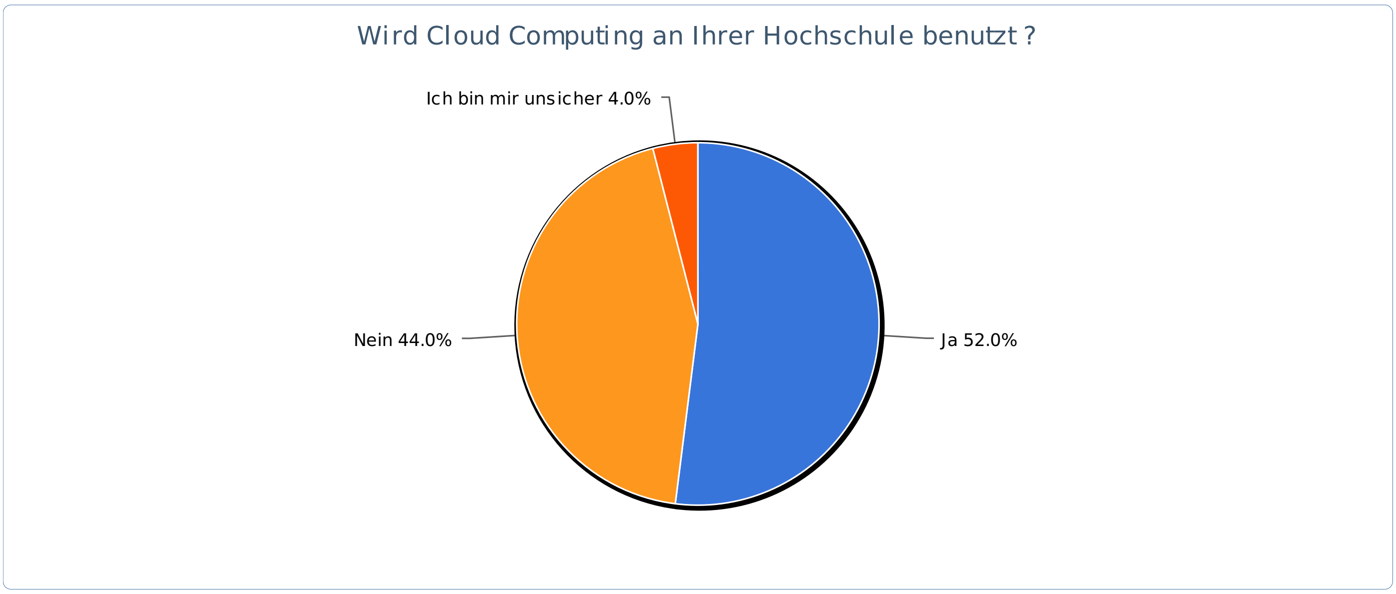
Statistics	
Total Responses	25



Wie schätzen Sie ihr Wissen über Cloud Computing ein ?

Value	Count	Percent %
Sehr gut (1)	6	24%
2	13	52%
3	5	20%
4	1	4%

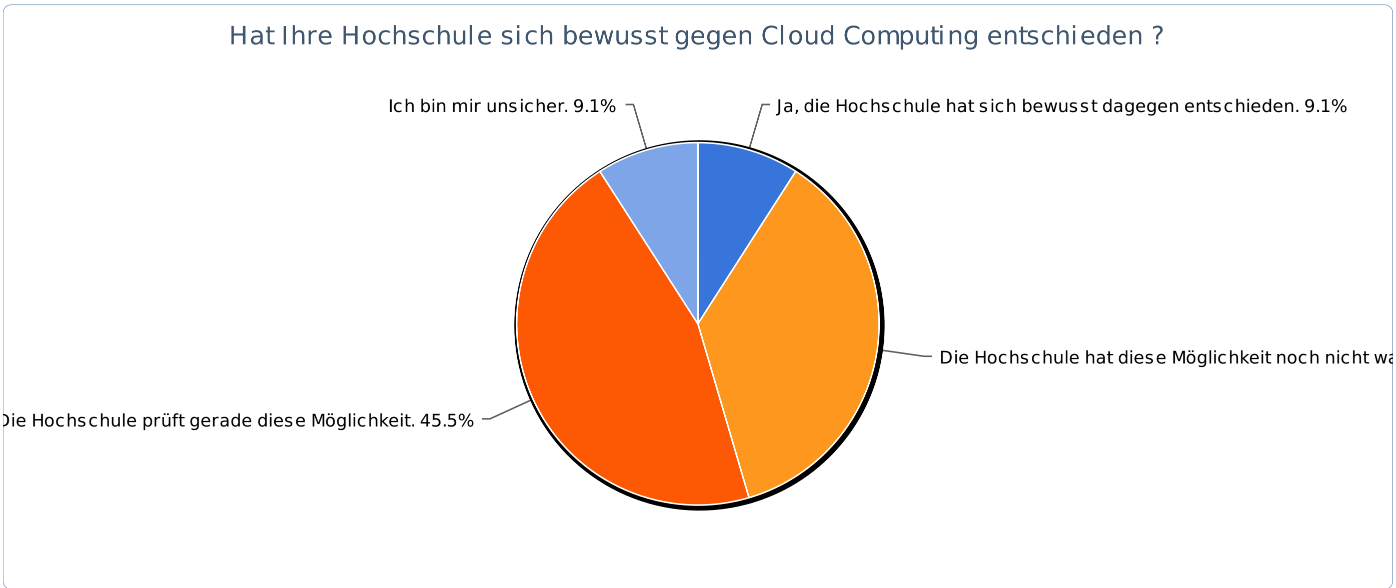
Statistics	
Total Responses	25
Sum	45.0
Average	2.4
StdDev	0.58
Max	4.0



Wird Cloud Computing an Ihrer Hochschule benutzt ?

Value	Count	Percent %
Ja	13	52%
Nein	11	44%
Ich bin mir unsicher	1	4%

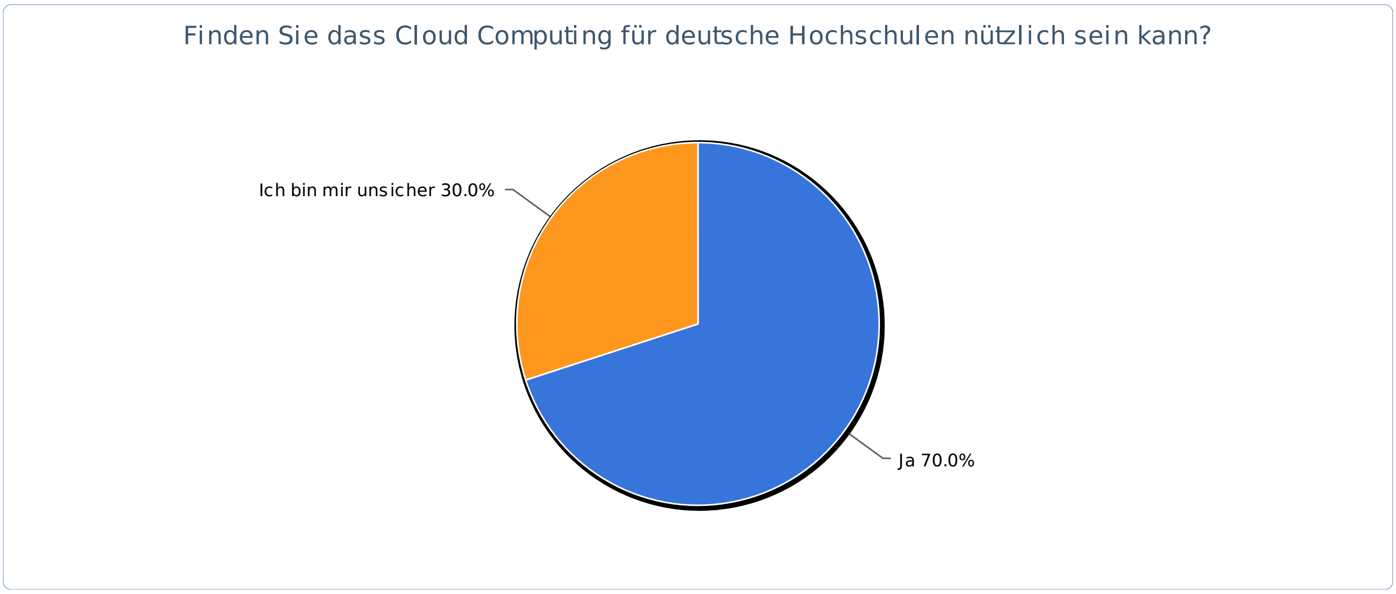
Statistics	
Total Responses	25



Hat Ihre Hochschule sich bewusst gegen Cloud Computing entschieden ?

Value	Count	Percent %
Ja, die Hochschule hat sich bewusst dagegen entschieden.	1	9.1%
Die Hochschule hat diese Möglichkeit noch nicht wahrgenommen.	4	36.4%
Die Hochschule prüft gerade diese Möglichkeit.	5	45.5%
Ich bin mir unsicher.	1	9.1%

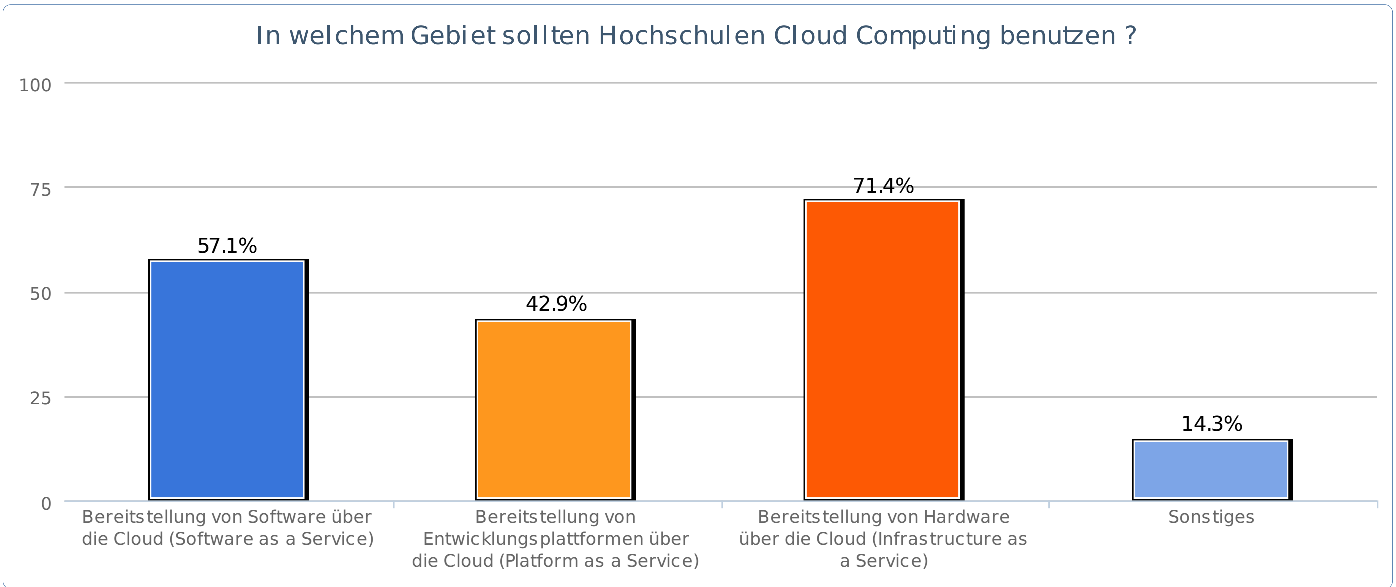
Statistics	
Total Responses	11



Finden Sie dass Cloud Computing für deutsche Hochschulen nützlich sein kann?

Value	Count	Percent %
Ja	7	70%
Ich bin mir unsicher	3	30%

Statistics	
Total Responses	10



In welchem Gebiet sollten Hochschulen Cloud Computing benutzen ?

Value	Count	Percent %
Bereitstellung von Software über die Cloud (Software as a Service)	4	57.1%
Bereitstellung von Entwicklungsplattformen über die Cloud (Platform as a Service)	3	42.9%
Bereitstellung von Hardware über die Cloud (Infrastructure as a Service)	5	71.4%
Sonstiges	1	14.3%

Statistics	
Total Responses	7

Welche Vorteile und Chancen sehen Sie für die Nutzung von Cloud Computing in Hochschulen? Bitte ordnen Sie die folgenden Begriffe nach Wichtigkeit.

	Sehr wichtig	Eher wichtig	Teils, teils	Eher unwichtig	Überhaupt nicht wichtig	keine Antwort	Totals

Skalierbarkeit der Dienste	3 30.0%	6 60.0%	0 0.0%	1 10.0%	0 0.0%	0 0.0%	10 100%
Verfügbarkeit der Dienste	2 20.0%	5 50.0%	2 20.0%	0 0.0%	1 10.0%	0 0.0%	10 100%
Redundante bzw. sichere Datenspeicherung	4 40.0%	1 10.0%	2 20.0%	2 20.0%	1 10.0%	0 0.0%	10 100%
Größere Sicherheit der Dienste und Infrastruktur	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 0.0%	0 100%
Ortsunabhängigkeit bzw. Mobilität	1 10.0%	4 40.0%	2 20.0%	2 20.0%	1 10.0%	0 0.0%	10 100%
Einfachere Zusammenarbeit	0 0.0%	3 30.0%	3 30.0%	3 30.0%	1 10.0%	0 0.0%	10 100%
Kosteneinsparung	0 0.0%	0 0.0%	6 60.0%	3 30.0%	1 10.0%	0 0.0%	10 100%
Outsourcing von Wartung	1 10.0%	1 10.0%	2 20.0%	4 40.0%	2 20.0%	0 0.0%	10 100%
Outsourcing von Support	1 10.0%	0 0.0%	3 30.0%	3 30.0%	3 30.0%	0 0.0%	10 100%
Leistungssteigerung	1 10.0%	5 50.0%	3 30.0%	1 10.0%	0 0.0%	0 0.0%	10 100%

Welche Nachteile und Risiken sehen Sie für die Nutzung von Cloud Computing in Hochschulen?Bitte ordnen Sie die folgenden Begriffe nach Wichtigkeit.

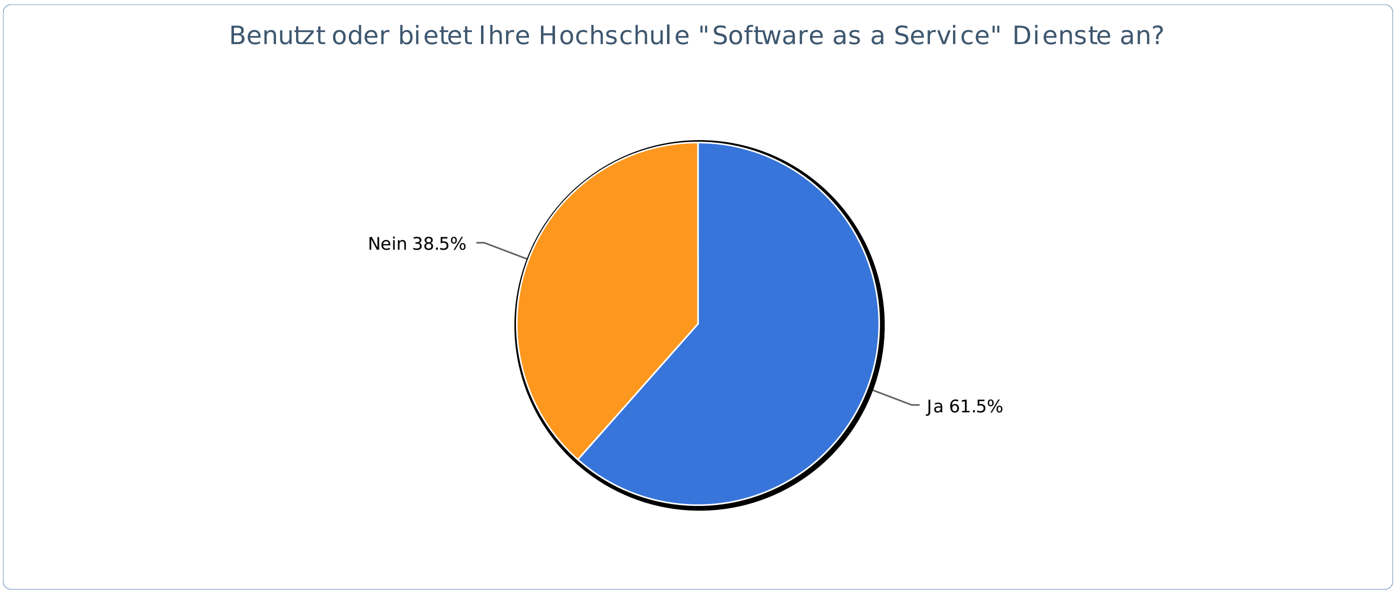
	Sehr wichtig	Eher wichtig	Teils, teils	Eher unwichtig	Überhaupt nicht wichtig	keine Antwort	Totals
Ausfallrisiko der Dienste	0 0.0%	3 30.0%	4 40.0%	2 20.0%	1 10.0%	0 0.0%	10 100%
Eingeschränkte Funktionalität	1 10.0%	3 30.0%	3 30.0%	2 20.0%	1 10.0%	0 0.0%	10 100%
Schwierigkeiten bei Integration und Datenmigration	4 40.0%	3 30.0%	3 30.0%	0 0.0%	0 0.0%	0 0.0%	10 100%
Abhängigkeit bei der Wartung	2 20.0%	2 20.0%	3 30.0%	2 20.0%	1 10.0%	0 0.0%	10 100%
Abhängigkeit beim Mitarbeitersupport	3 30.0%	2 20.0%	1 10.0%	3 30.0%	1 10.0%	0 0.0%	10 100%
Sicherheit der Dienste und Infrastruktur	5 50.0%	4 40.0%	0 0.0%	1 10.0%	0 0.0%	0 0.0%	10 100%
Datensicherheit	6 60.0%	2 20.0%	1 10.0%	1 10.0%	0 0.0%	0 0.0%	10 100%
Datenschutzrisiken	5 50.0%	3 30.0%	1 10.0%	1 10.0%	0 0.0%	0 0.0%	10 100%
Kosten	0 0.0%	4 40.0%	4 40.0%	2 20.0%	0 0.0%	0 0.0%	10 100%
Abhängigkeit vom Anbieter	5 50.0%	2 20.0%	1 10.0%	1 10.0%	1 10.0%	0 0.0%	10 100%
Notwendigkeit einer schnellen und konstanten Internetverbindung	3 30.0%	4 40.0%	0 0.0%	2 20.0%	1 10.0%	0 0.0%	10 100%

Stellen Sie sich folgendes Szenario vor: Ihre Hochschule hat sich für Cloud Computing entschieden und Ihnen die Verantwortung gegeben einen Anbieter auszuwählen. Welche Kriterien sind für die Auswahl der Anbieter entscheidend? Ordnen Sie diese Krieterien nach Wichtigkeit und Relevanz.

Item	Total Score[1]	Overall Rank
Hohe Sicherheit	76	1
Verfügbarkeit der Cloud-Dienste	74	2
Strenge Datenschutz-Richtlinien	71	3
Anpassungsfähigkeit der Cloud-Dienste	63	4
Einfachheit der Bedienung	60	5
Skalierbarkeit der Cloud-Dienste	54	6
Niedrige Kosten	46	7
Hilfe bei der Integration und Migration	41	8
Bekanntheit der Anbieter	30	9
Support und Mitarbeiterschulungen	29	10

Total Respondents: 10

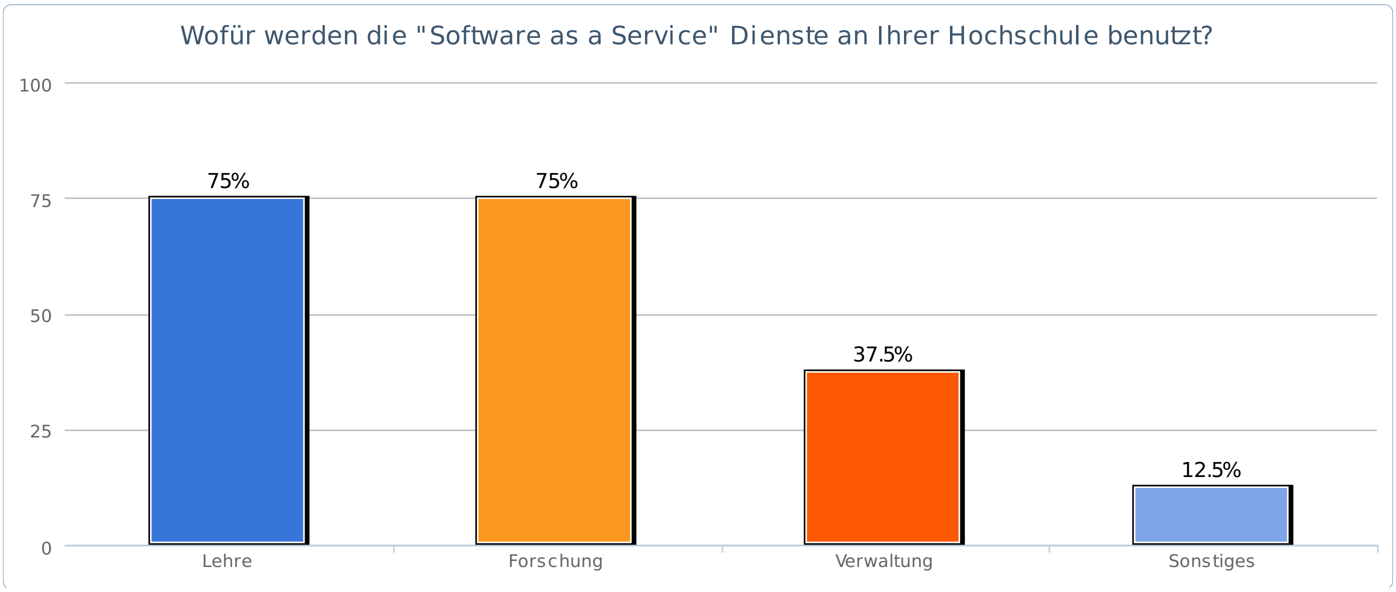
[1] **Score is a weighted calculation. Items ranked first are valued higher than the following ranks, the score is the sum of all weighted rank counts.**

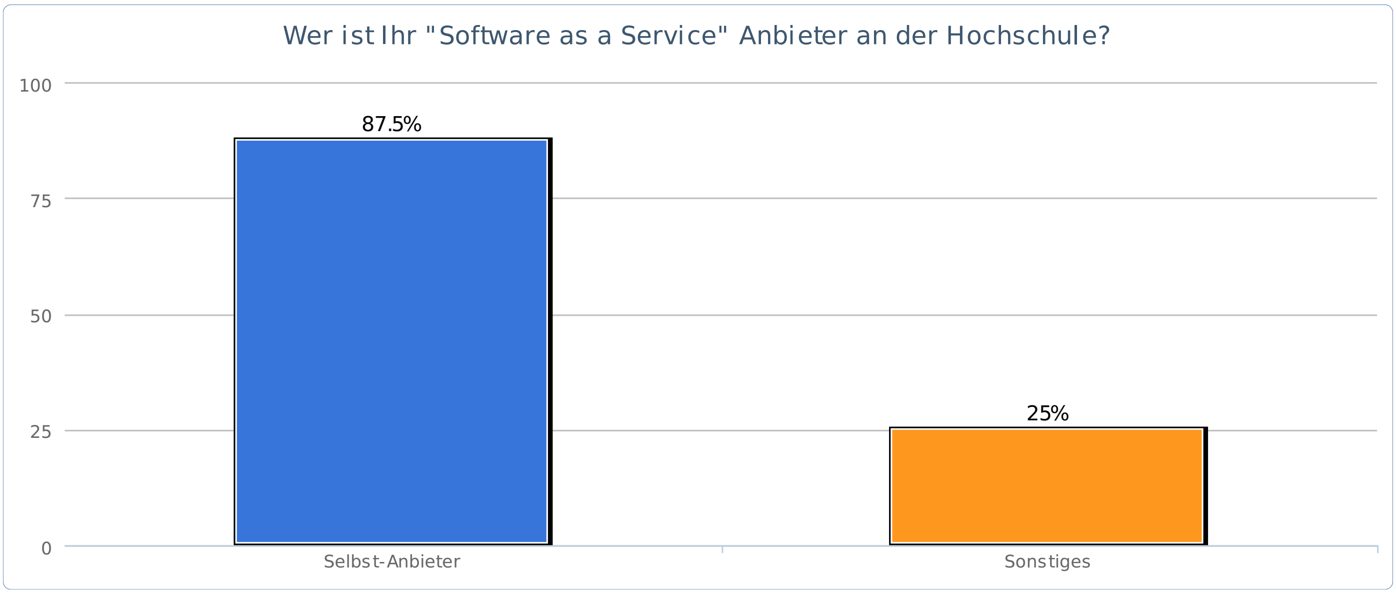


Benutzt oder bietet Ihre Hochschule "Software as a Service" Dienste an?

Value	Count	Percent %
Ja	8	61.5%
Nein	5	38.5%

Statistics	
Total Responses	13





Wer ist Ihr "Software as a Service" Anbieter an der Hochschule?

Value	Count	Percent %
Selbst-Anbieter	7	87.5%
Sonstiges	2	25%

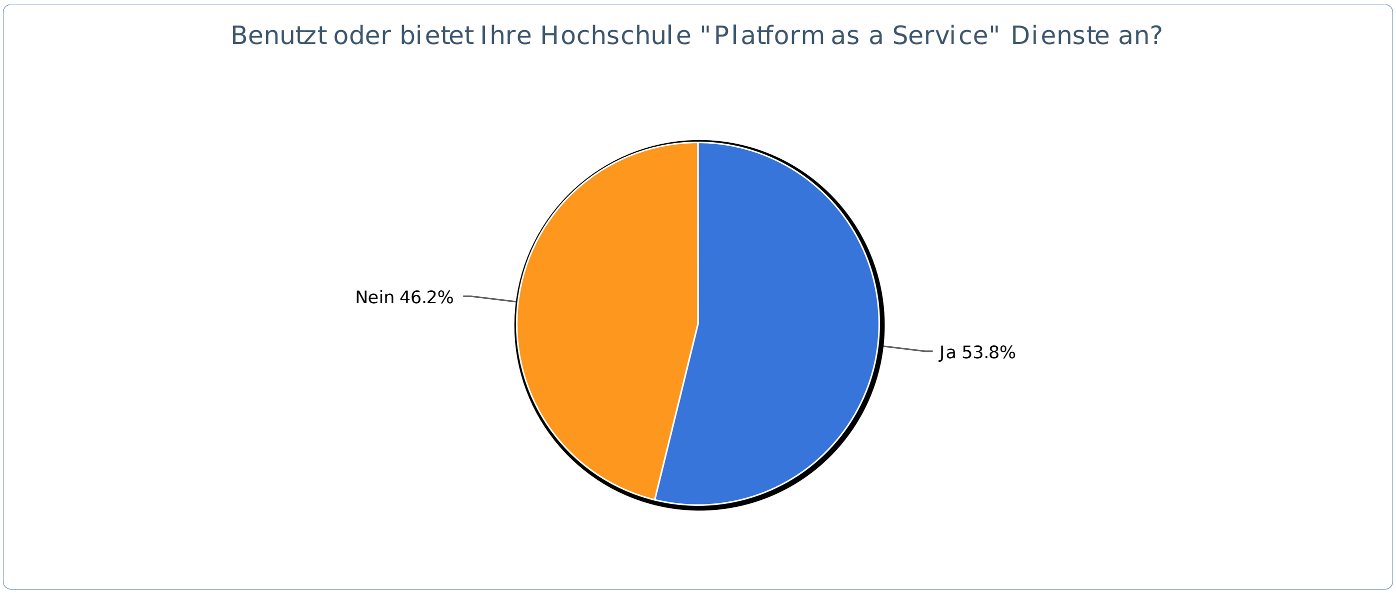
Statistics	
Total Responses	8

Welche Vorteile und Chancen sehen Sie für die Nutzung von "Software as a Service" in Hochschulen? Bitte ordnen Sie die folgenden Begriffe nach Wichtigkeit.

	Sehr wichtig		Eher wichtig		Teils, teils		Eher unwichtig		Überhaupt nicht wichtig		Totals	
Verfügbarkeit	7	87.5%	1	12.5%	0	0.0%	0	0.0%	0	0.0%	8	100%
Sicherheit	2	25.0%	3	37.5%	1	12.5%	2	25.0%	0	0.0%	8	100%
Datenschutz	3	37.5%	2	25.0%	1	12.5%	1	12.5%	1	12.5%	8	100%
Kosteneinsparung	3	37.5%	2	25.0%	2	25.0%	1	12.5%	0	0.0%	8	100%
Outsourcing von Wartung und Support	1	12.5%	3	37.5%	2	25.0%	2	25.0%	0	0.0%	8	100%

Welche Nachteile und Risiken sehen Sie für die Nutzung von "Software as a Service" in Hochschulen? Bitte ordnen Sie die folgenden Begriffe nach Wichtigkeit.

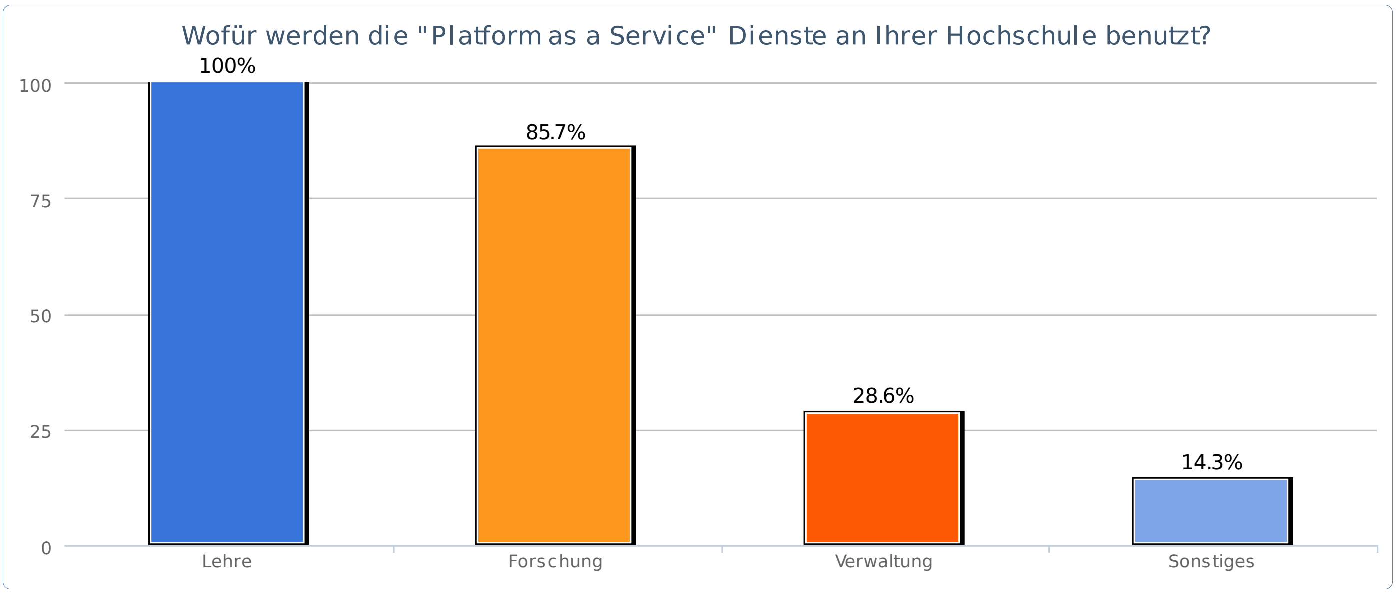
	Sehr wichtig		Eher wichtig		Teils, teils		Eher unwichtig		Überhaupt nicht wichtig		Totals	
Risiken bei der Verfügbarkeit	2	25.0%	0	0.0%	4	50.0%	2	25.0%	0	0.0%	8	100%
Risiken bei de Sicherheit	4	50.0%	1	12.5%	1	12.5%	2	25.0%	0	0.0%	8	100%
Risiken dei Datenschutz	4	50.0%	1	12.5%	2	25.0%	1	12.5%	0	0.0%	8	100%
Kosten	0	0.0%	1	12.5%	4	50.0%	3	37.5%	0	0.0%	8	100%
Abhängigkeit bei Support und Wartung	2	25.0%	0	0.0%	3	37.5%	3	37.5%	0	0.0%	8	100%



Benutzt oder bietet Ihre Hochschule "Platform as a Service" Dienste an?

Value	Count	Percent %
Ja	7	53.8%
Nein	6	46.2%

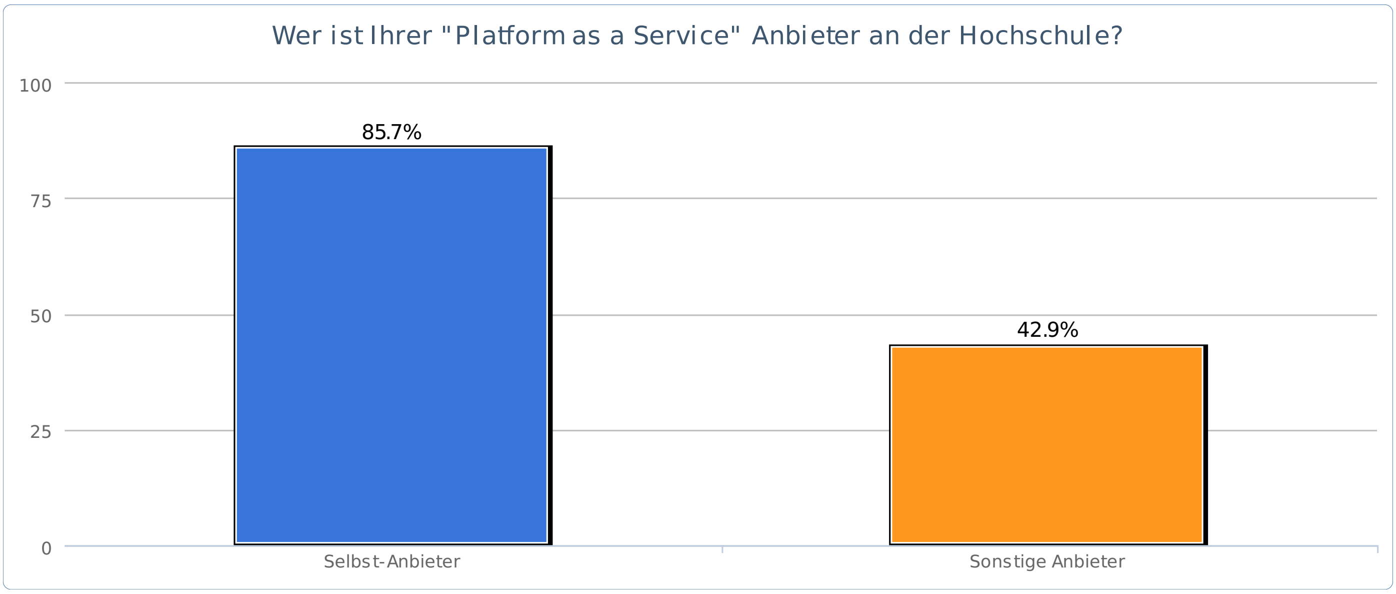
Statistics	
Total Responses	13



Wofür werden die "Platform as a Service" Dienste an Ihrer Hochschule benutzt?

Value	Count	Percent %
Lehre	7	100%
Forschung	6	85.7%
Verwaltung	2	28.6%
Sonstiges	1	14.3%

Statistics	
Total Responses	7



Wer ist Ihrer "Platform as a Service" Anbieter an der Hochschule?

Value	Count	Percent %
Selbst-Anbieter	6	85.7%
Sonstige Anbieter	3	42.9%

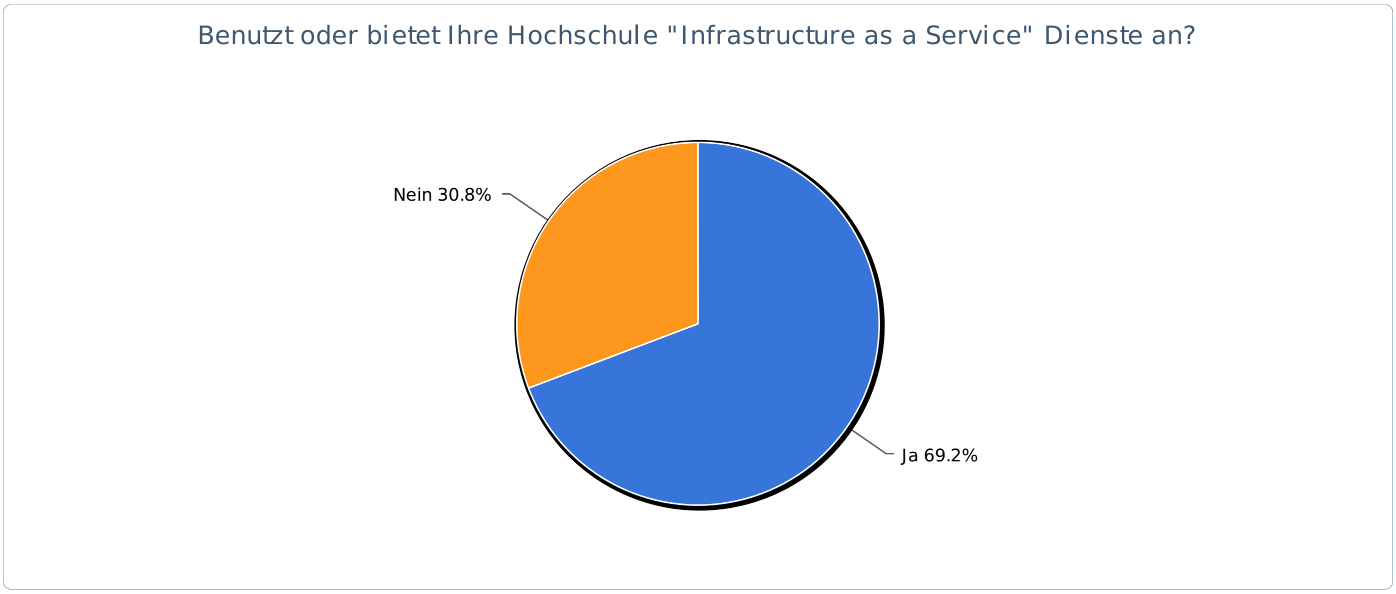
Statistics	
Total Responses	7

Welche Vorteile und Chancen sehen Sie für die Nutzung von "Platform as a Service" in Hochschulen? Bitte ordnen Sie die folgenden Begriffe nach Wichtigkeit.

	Sehr wichtig		Eher wichtig		Teils, teils		Eher unwichtig		Überhaupt nicht wichtig		Totals	
Verfügbarkeit	6	75.0%	1	12.5%	0	0.0%	1	12.5%	0	0.0%	8	100%
Sicherheit	3	37.5%	2	25.0%	1	12.5%	2	25.0%	0	0.0%	8	100%
Datenschutz	2	25.0%	2	25.0%	1	12.5%	2	25.0%	1	12.5%	8	100%
Kosteneinsparung	4	50.0%	1	12.5%	2	25.0%	1	12.5%	0	0.0%	8	100%
Outsourcing von Wartung und Support	1	12.5%	2	25.0%	1	12.5%	4	50.0%	0	0.0%	8	100%

Welche Nachteile und Risiken sehen Sie für die Nutzung von "Platform as a Service" in Hochschulen?Bitte ordnen Sie die folgenden Begriffe nach Wichtigkeit.

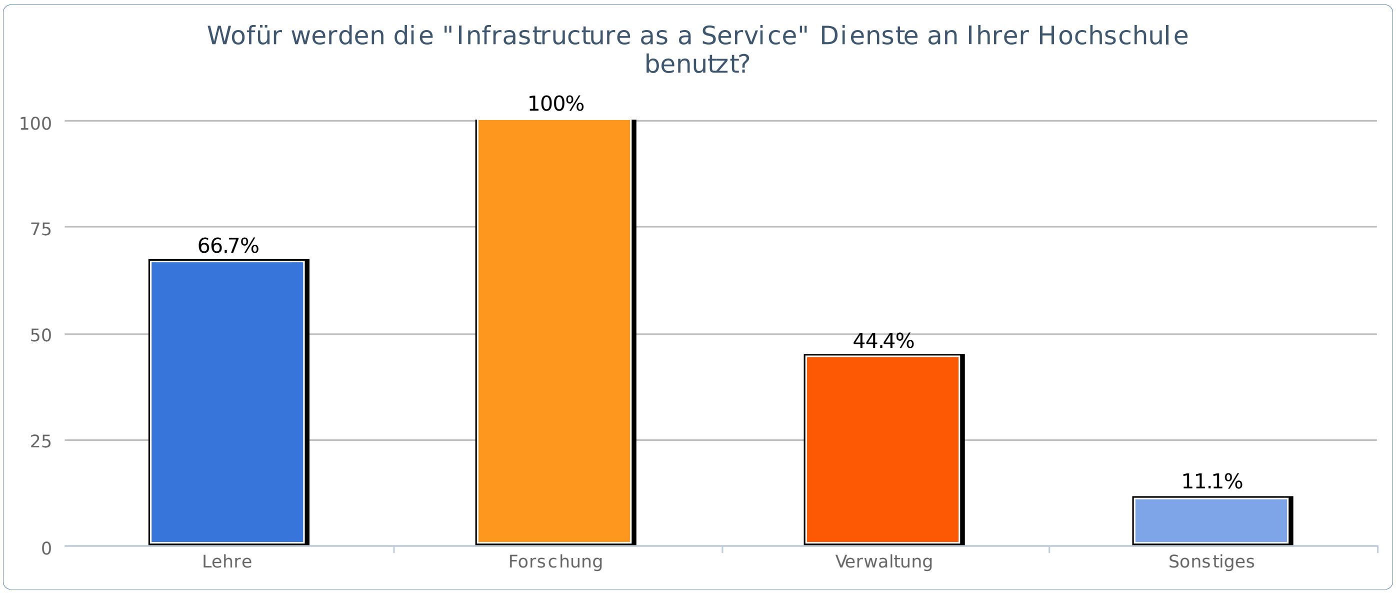
	Sehr wichtig		Eher wichtig		Teils, teils		Eher unwichtig		Überhaupt nicht wichtig		Totals	
Risiken bei der Verfügbarkeit	1	12.5%	1	12.5%	0	0.0%	6	75.0%	0	0.0%	8	100%
Risiken bei de Sicherheit	3	37.5%	2	25.0%	1	12.5%	2	25.0%	0	0.0%	8	100%
Risiken dei Datenschutz	4	50.0%	1	12.5%	1	12.5%	2	25.0%	0	0.0%	8	100%
Kosten	0	0.0%	1	12.5%	3	37.5%	4	50.0%	0	0.0%	8	100%
Abhängigkeit bei Support und Wartung	1	12.5%	1	12.5%	2	25.0%	4	50.0%	0	0.0%	8	100%



Benutzt oder bietet Ihre Hochschule "Infrastructure as a Service" Dienste an?

Value	Count	Percent %
Ja	9	69.2%
Nein	4	30.8%

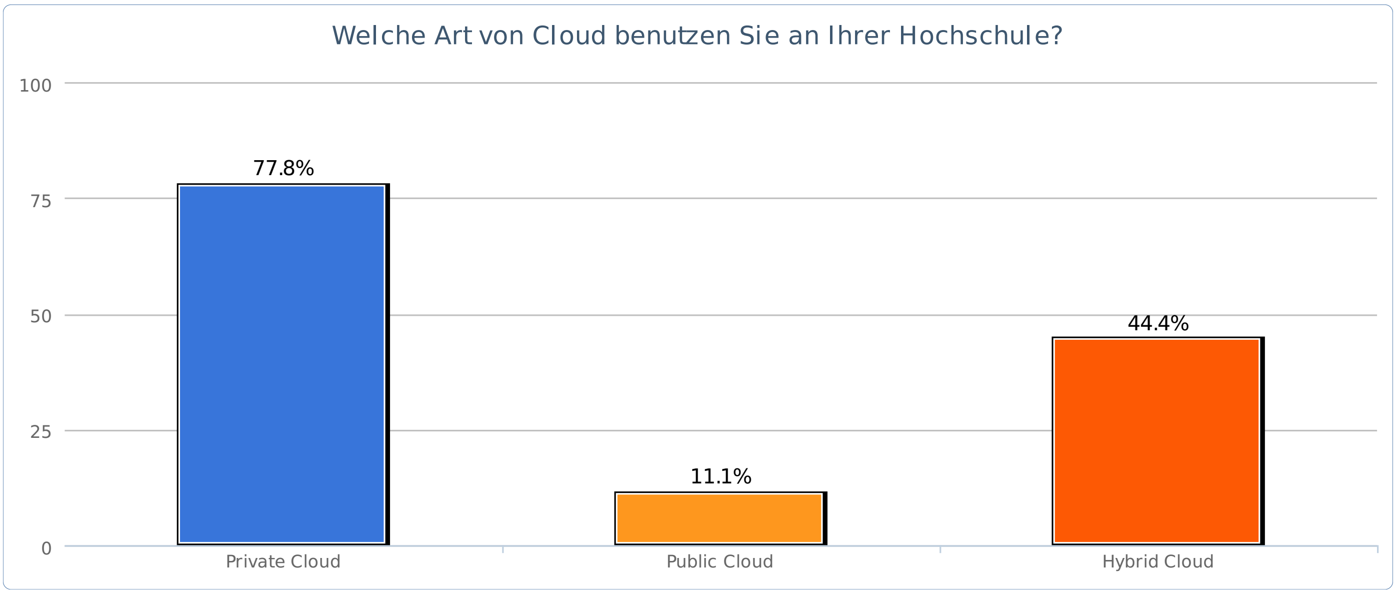
Statistics	
Total Responses	13



Wofür werden die "Infrastructure as a Service" Dienste an Ihrer Hochschule benutzt?

Value	Count	Percent %
Lehre	6	66.7%
Forschung	9	100%
Verwaltung	4	44.4%
Sonstiges	1	11.1%

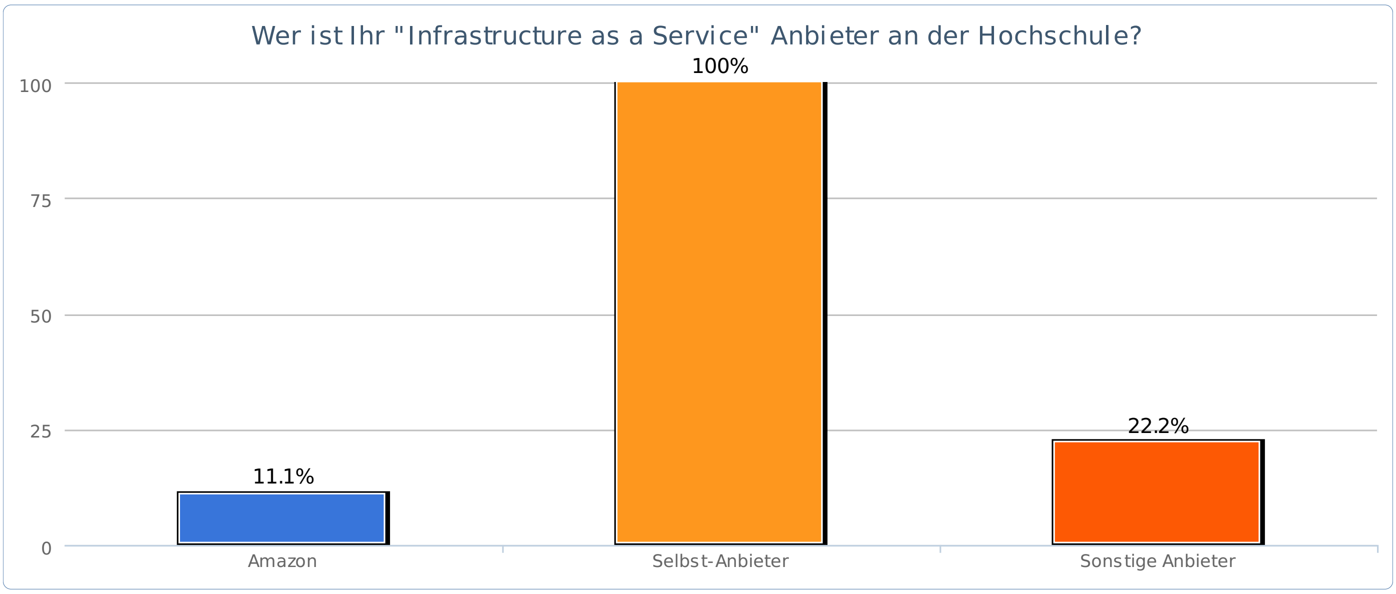
Statistics	
Total Responses	9



Welche Art von Cloud benutzen Sie an Ihrer Hochschule?

Value	Count	Percent %
Private Cloud	7	77.8%
Public Cloud	1	11.1%
Hybrid Cloud	4	44.4%

Statistics	
Total Responses	9



Wer ist Ihr "Infrastructure as a Service" Anbieter an der Hochschule?

Value	Count	Percent %
Amazon	1	11.1%
Selbst-Anbieter	9	100%
Sonstige Anbieter	2	22.2%

Statistics	
Total Responses	9

Welche Vorteile und Chancen sehen Sie für die Nutzung von "Infrastructure as a Service" in Hochschulen? Bitte ordnen Sie die folgenden Begriffe nach Wichtigkeit.

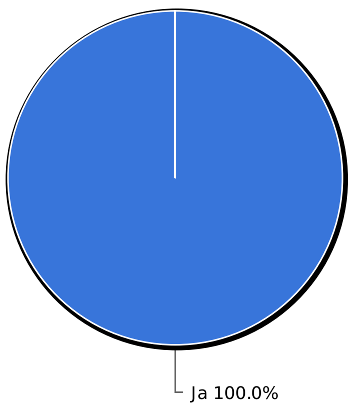
	Sehr wichtig	Eher wichtig	Teils, teils	Eher unwichtig	Überhaupt nicht wichtig	Totals
Verfügbarkeit	6 66.7%	2 22.2%	1 11.1%	0 0.0%	0 0.0%	9 100%
						9 100%

Sicherheit	5 55.6%	1 11.1%	3 33.3%	0 0.0%	0 0.0%	9 100%
Datenschutz	5 55.6%	1 11.1%	2 22.2%	1 11.1%	0 0.0%	9 100%
Kosteneinsparung	4 44.4%	4 44.4%	1 11.1%	0 0.0%	0 0.0%	9 100%
Outsourcing von Wartung und Support	2 22.2%	2 22.2%	3 33.3%	2 22.2%	0 0.0%	9 100%

Welche Nachteile und Risiken sehen Sie für die Nutzung von "Infrastructure as a Service" in Hochschulen? Bitte ordnen Sie die folgenden Begriffe nach Wichtigkeit.

	Sehr wichtig	Eher wichtig	Teils, teils	Eher unwichtig	Überhaupt nicht wichtig	Totals
Risiken bei der Verfügbarkeit	2 22.2%	3 33.3%	1 11.1%	3 33.3%	0 0.0%	9 100%
Risiken bei der Sicherheit	3 33.3%	2 22.2%	3 33.3%	1 11.1%	0 0.0%	9 100%
Risiken beim Datenschutz	3 33.3%	2 22.2%	3 33.3%	1 11.1%	0 0.0%	9 100%
Kosten	0 0.0%	2 22.2%	5 55.6%	2 22.2%	0 0.0%	9 100%
Abhängigkeit bei Wartung und Support	2 22.2%	2 22.2%	1 11.1%	4 44.4%	0 0.0%	9 100%

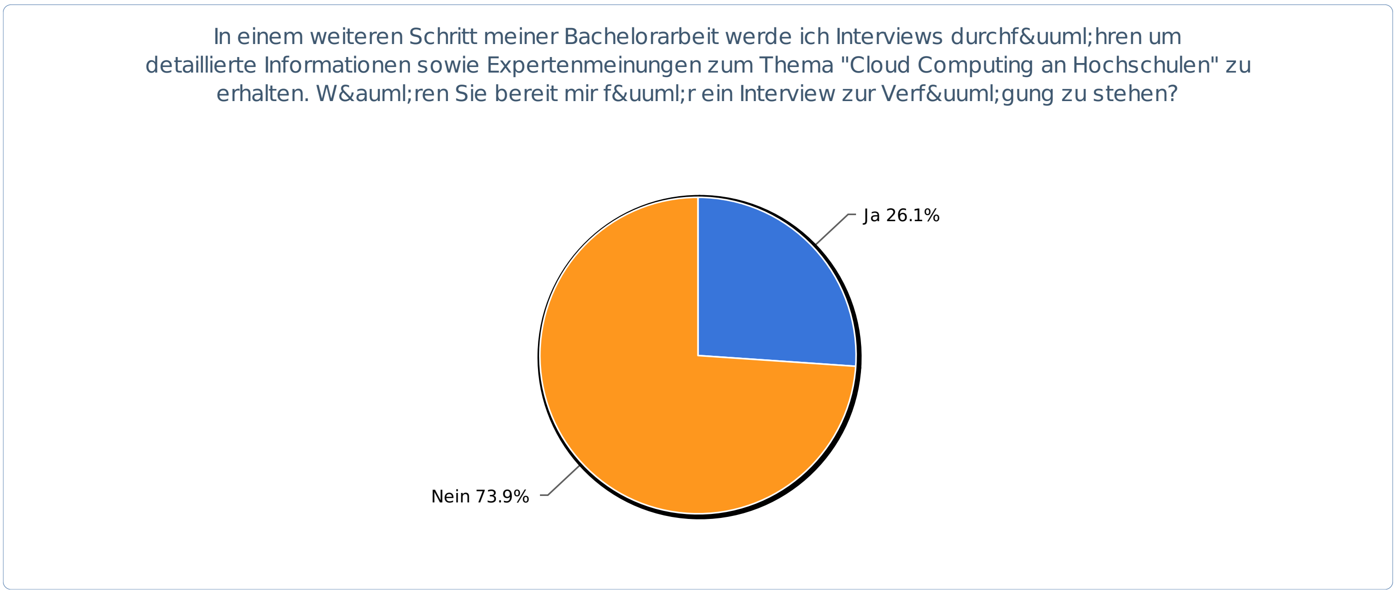
Hat Ihrer Hochschule trotz Nutzung von "Infrastructure as a Service" noch ein Rechenzentrum ?



Hat Ihrer Hochschule trotz Nutzung von "Infrastructure as a Service" noch ein Rechenzentrum ?

Value	Count	Percent %
Ja	9	100%

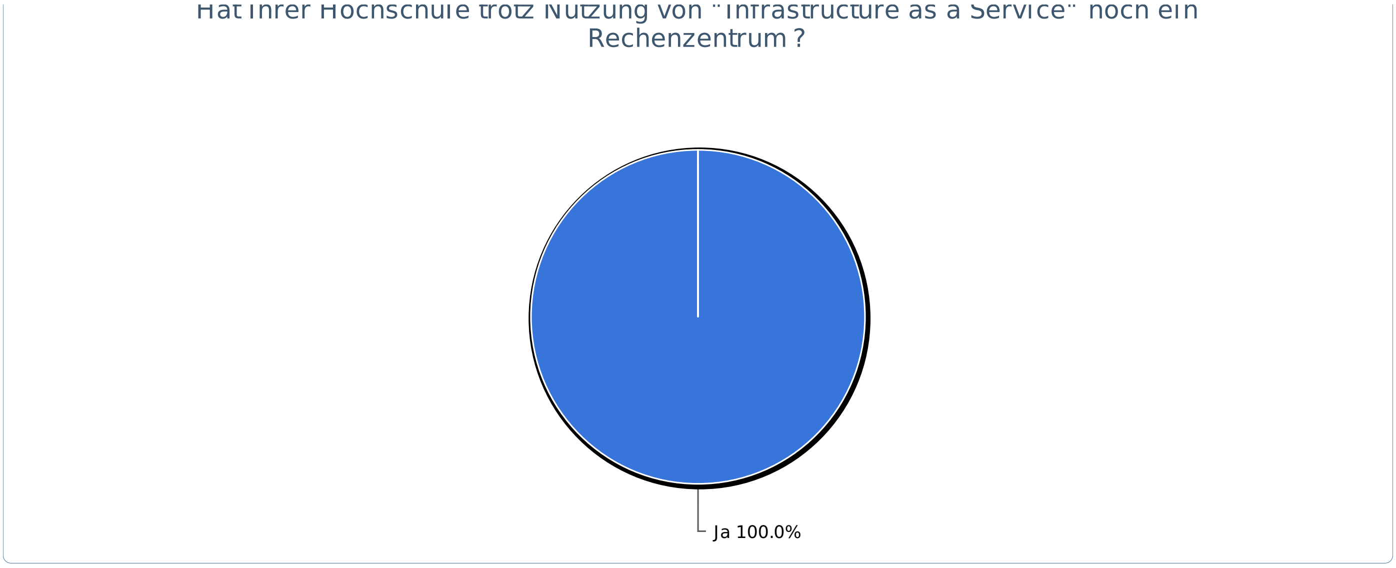
Statistics	
Total Responses	9



In einem weiteren Schritt meiner Bachelorarbeit werde ich Interviews durchführen um detaillierte Informationen sowie Expertenmeinungen zum Thema "Cloud Computing an Hochschulen" zu erhalten. Wären Sie bereit mir für ein Interview zur Verfügung zu stehen?

Value	Count	Percent %
Ja	6	26.1%
Nein	17	73.9%

Statistics	
Total Responses	23



Hat Ihrer Hochschule trotz Nutzung von "Infrastructure as a Service" noch ein Rechenzentrum ?

Value	Count	Percent %
Ja	9	100%

Statistics	
Total Responses	9

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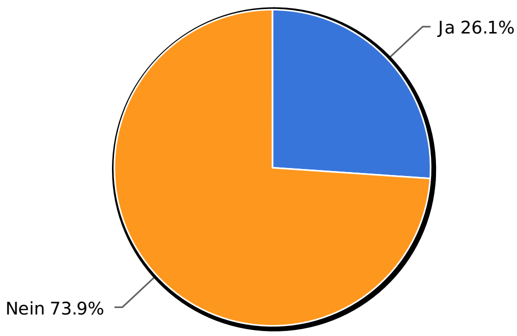

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Value	Count	Percent %
Ja	6	26.1%
Nein	17	73.9%

Statistics	
Total Responses	23