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ISST REPORT

CLOUD TRANSFORMATION
TRENDS & IMPLICATIONS

■ ISST-Report

CLOUD TRANSFORMATION

TRENDS & IMPLICATIONS

Cloud Computing has disruptively changed the global market. At one point or another, companies utilize cloud computing resources to fully exploit the value of their assets. The services provisioned today by global cloud computing providers enable organizations to make use of a vast variety of technologies and trends. Therefore, to maintain competitiveness, it is indispensable for companies to include cloud computing in their strategic digital transformation and operations.

Corporates throughout various industries require the flexibility, scalability, security, and agility provided by cloud computing to meet their strategic business objectives and long-term goals. However, these enterprises often struggle in their endeavor to execute a cloud transformation of their businesses and see themselves faced with organizational, legal, and technological challenges to profoundly define their cloud transformation strategy and make use of new technologies and trends.

The Fraunhofer Institute for Software and Systems Engineering ISST combines long-term scientific and economic experience in the field of cloud transformation and sets high standards for its strategic approach. Our scientists and consultants constantly seek out new trends and set high benchmarks to support organizations in their pursuit of an organization-wide cloud transformation.

This work serves as an overview of what cloud computing inherits and presents the vast variety of cloud enabled and cloud adapted trends and technologies. It presents the current understanding of cloud transformation and shows how the Fraunhofer ISST can assist companies to initiate their journey to a cloud-enabled digital and data-driven company.

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1 CLOUD COMPUTING AS A KEY ENABLER

Cloud Computing is transforming the worldwide digital landscape for decades now. It lays the foundation for an organization's digital transformation, empowers digital business models and enables entire digital and data ecosystems. Exploiting full value from cloud computing services today is indispensable for organizations to obtain sustainable competitiveness and realize strategic goals and visions.

1 Cloud Computing as a key enabler

"I don't think people have really understood how big this opportunity really is. It starts with the premise that the data services and architecture should be on servers. We call it cloud computing – they should be in a "cloud" somewhere.", were the words Google's CEO Eric Schmidt (2001 to 2011), used to introduce cloud computing as the new paradigm of infrastructure and architecture for information systems in 2006. From then until today much has happened. Infrastructure as a Service (IaaS) is an old chestnut already, Platform as a Service (PaaS) has become indispensable for companies and Software as a Service (SaaS) swings up to the standard of providing software.

The above-mentioned concepts of cloud computing are well-known, accepted and used in all domains, areas and company sizes. However, due to innovation potential within the field, new ideas, concepts, and technologies emerge nearly every day, implying two assumptions:

- A big market waits for new trends and solutions and provides interesting and versatile range of topics for research and development, and
- Many challenges remain within the area, which need to be addressed.

In general, the relevance of cloud computing is immense, and it continuously rises over several decades now. Based on several studies, it can be estimated that almost ¾ of businesses with more than 20 employees are looking at / taking into account the newest trends of cloud services. A similar number of institutions and other actors connect the development status of cloud services with the degree of digitization in the company. According to a study led by KPMG in 2020, cloud computing's impact on innovation and new business models is rated as high by 77%, only 17% of the people consulted rated the impact as low. The contribution can be identified primarily in the context of internal processes, communication and structures, aspects that generally have major impacts on the company's overall digital transformation. This is a non-surprising fact since cloud computing abstracts activities from the IT infrastructure and resource discussions and allows to focus on business topics. It can be stated that the use of cloud computing alone does not ensure a direct contribution to digital transformation. However, cloud computing is an enabler that proves to leverage transformation activities within the companies.

One example to display cloud computing's impact on the digital transformation concerns possibilities to scale new ideas, businesses, and business models. In this context, start-ups that possess unique ideas and a working MVP (minimal viable product) can start their business with minimal budget for infrastructure and IT-staff. Under certain conditions, cloud computing makes it possible to bring an application to market with a budget of only 20€ and dynamically grow the IT infrastructure in line with user growth[1].

While politically driven discussions in Europe are ongoing regarding the degree of reliability of companies like Amazon, Microsoft, Google, or Alibaba, with regard to independence of the European digital infrastructure, architects and technicians face an incredible number of available concepts and tools when it comes to transferring their systems into cloud environments. However, even though the cloud market raises large market volumes and the cloud computing technology offers manifold benefits and

1 https://thenewstack.io/how-to-create-infrastructure-for-a-startup-with-only-20-in-your-pocket

Cloud Computing as a key enabler

opportunities, companies in their endeavor of cloud transformation see themselves facing several challenges while migrating their data and processes into the cloud. The process in its entirety requires major organizational effort and change. The multi-user nature of cloud computing raises questions concerning security of data, robustness of processes, legal compliance, service-level-agreements and, of course, monetary benefits. In order to manage the cloud transformation process and exploit optimum value from cloud computing, companies require profound knowledge on what they can expect from today's cloud computing market, what kind of technologies they can rely on and what challenges might occur.

This whitepaper aims to assist organizations in their endeavor of cloud transformation and digital transformation. Therefore, it aims to fulfill three purposes:

- Clarify the wide spectrum of cloud computing to provide a summary of the technological range in order to outline achievable capabilities
- Give an overview on the industries, technologies and trends enabled by the Cloud
- Identify crucial challenges and obstacles in the process of a well-defined cloud transformation

> *„Cloud infrastructures form the foundation of digital innovation and, thus, sustainable competitive advantage. Given the strategic importance of cloud infrastructures for business growth and economic prosperity, sound research is needed to understand fundamental concepts of cloud infrastructures and – even more important – shape them according to our priorities and values. At Fraunhofer ISST, we have identified cloud infrastructures as one of our strategic research topics and, thus, are fully committed to support our partners in their cloud transformation endeavors. We look at this topic of highest practical significance and scientific relevance from both a technological and organizational point of view in order to pave the way for end-to-end strategies and implementations pathways.“*
>
> - Prof. Dr.-Ing. Boris Otto, Managing director Fraunhofer Institute for Software and Systems Engineering, ISST

2

CLOUD COMPUTING OFFERINGS AND MARKET SITUATION

The global cloud market is steadily growing, and more and more services and providers enter the market every day. To make optimal strategic decisions concerning their IT infrastructure and data value generation, it is essential for organizations to understand the offerings and players in the cloud computing market. A firm foundation of knowledge about choice options is crucial to avoid missed opportunities and prevent dependencies through lock-in effects.

2
Cloud computing offerings and market situation

The purpose of this chapter is to give an overview of the most important concepts of cloud computing and, at the same time, provide insights into the current market situation. Based on this, the biggest players on the market are introduced.

2.1
Offering Models

Cloud computing incorporates different fundamental offering models. With the public, private, hybrid, and community cloud, the four most common *deployment models* are presented. Subsequently, we specify with IaaS, PaaS, and SaaS the three fundamental *service models* of the cloud in order to lay the foundation for the following chapters.

2.1.1
Deployment Models

In the **public cloud** resources are obtained via the Internet from a cloud provider that is responsible for managing the resources and making them available to anyone who wants to use or purchase them. Accordingly, the infrastructure is located at the cloud provider[2]. The public cloud offers a wide range of benefits for enterprises, including high availability, scalability, elasticity, and predictive costs. The usage of public cloud computing in Germany has increased significantly in the last 10 years. Whereas in 2011 only 6% of companies used public cloud computing, nowadays this number is more than six times higher.

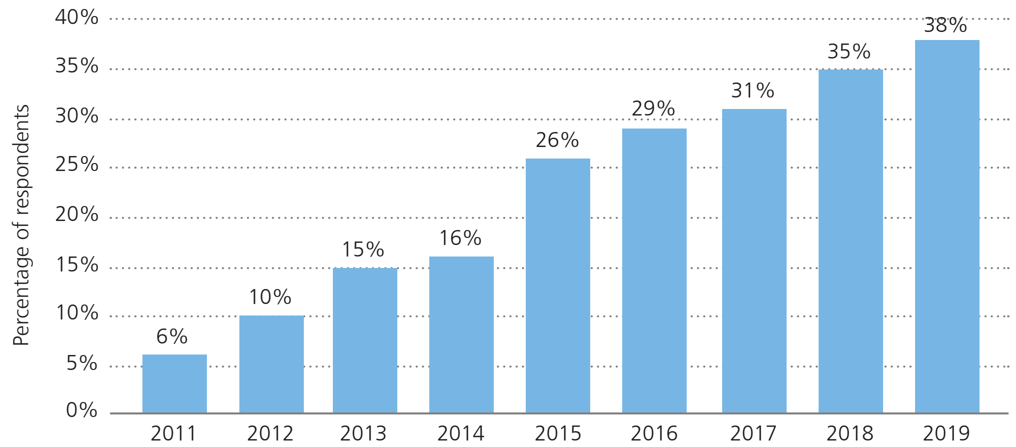

Fig. 1:
Use of public cloud computing in companies in Germany from 2011 to 2019 (KPMG Cloud Monitor 2020)

The **private cloud** is exclusively provisioned for selected organizations only. The infrastructure can be located in the organization's premises or in a third party's premises and can be either managed, owned or operated by that organization or by any third-party company. To organizations, the private cloud offers many of the benefits of a public cloud, while enabling additional control and customization capabilities. Since 2017, more than half of all companies in Germany are using a private cloud, with this trend continuing to rise.

2 Polash et al. 2014

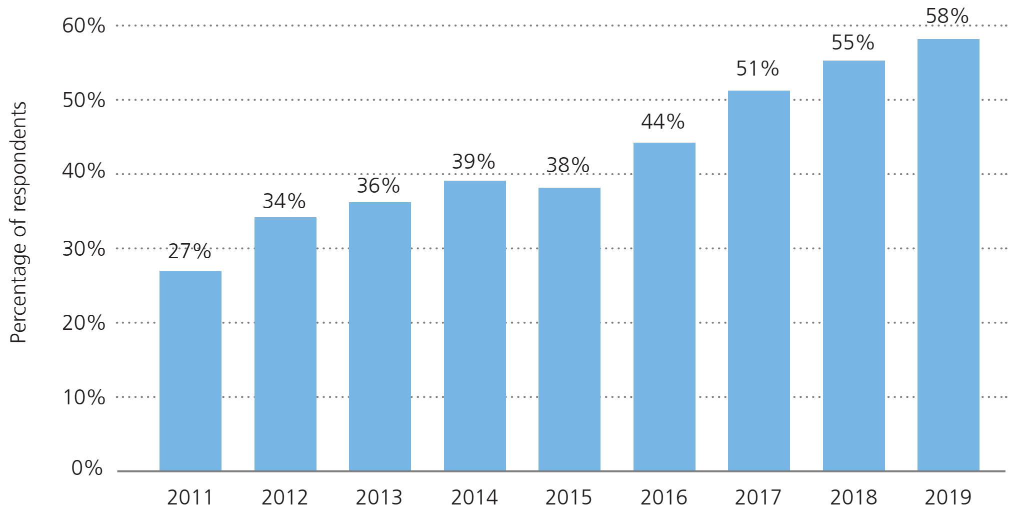

Fig. 2:
Use of private cloud computing in companies in Germany from 2011 to 2019 (KPMG Cloud Monitor 2020)

The **hybrid cloud** is defined as a composition of the before mentioned deployment models, which are bound together by standardized technologies, allowing the cloud user or organization to share data and applications between public and private clouds. In fact, organizations that successfully use the hybrid cloud can get the best of both models. For them, it is possible to deploy many of their own security measures that they use in their existing on-premises infrastructure, while being able to scale up or down to handle excess capacity.

If a community of organizations possess common interests, policies, objectives and missions regarding their cloud strategy, the **community cloud** can be a good choice regarding the deployment model. The infrastructure can be shared among the community and is situated in one of the communities' organizations or in a third party's place. It is noticeable that a community cloud is not explicitly offered by the most popular cloud providers. However, it is possible to configure this deployment model with provider-specific modifications of the other deployment models mentioned before.

2.1.2
Service Models

Infrastructure as a Service (IaaS) defines the provision of computing infrastructure via the internet. Therefore, in general, different cloud providers operate their own data centres for storage, administration and maintenance of hardware and software[3]. Looking at IaaS, cloud users can freely dispose of computing-power (e.g. virtual machines, processors, storage, and databases) as well as complete virtual networking structures, including firewalls, router, and back-up systems directly from a cloud provider.

Like in other service models, responsibilities over infrastructure components are divided into user and provider-based responsibilities, based on a Shared Responsibility Model. As the name suggests, the user and the provider share the responsibility for security in the Shared Responsibility Model. The given transparency when using IaaS in combination with the possibility of flexible resizing infrastructure resources on demand have ensured continuous revenue growth. While in 2010 revenue was at 2.9 billion US-Dollars, it has increased more than 18-fold in the last decade.

3 Bhosale et. al. 2020

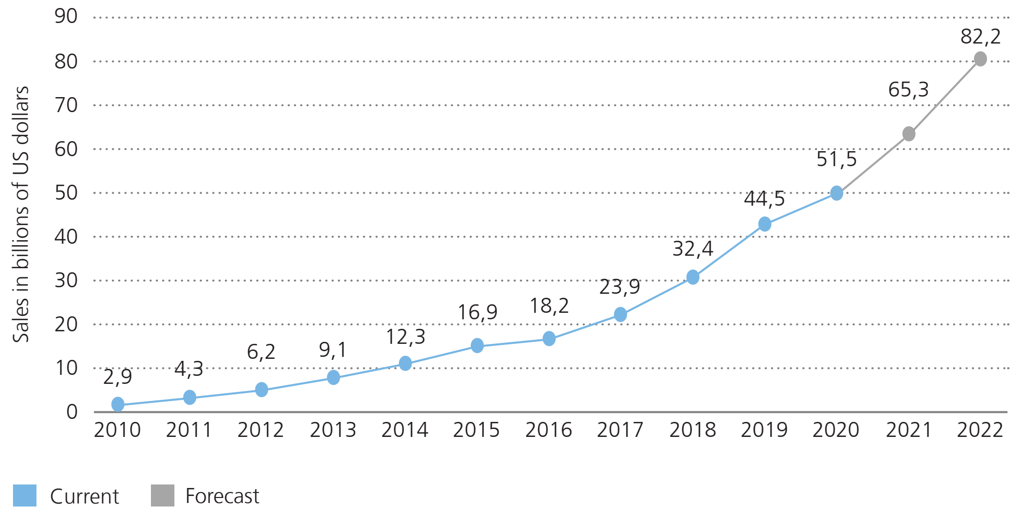

Fig. 3:
Sales of Infrastructure-as-a-Service (IaaS) worldwide from 2010 to 2020 and forecast to 2022 (in billions $) (Gartner, November 2020)

Platform as a Service (PaaS) provides a platform for users to independently develop, launch, and manage applications. The tools required for this, such as a programming environment and configuration management, are provided and managed by the cloud provider themselves. Thereby, with PaaS it becomes possible to support the web application Lifecyle from implication, over management / administration to actualization. Developers can thus focus on their own work, whereas in the background, cloud providers take over administration of other components. Although, PaaS did not play a huge role in the early 2010s, until now, it has developed strongly in terms of revenue. In 2019, for example, the global revenue for PaaS counted 37.5 billion US-Dollars with growing tendency.

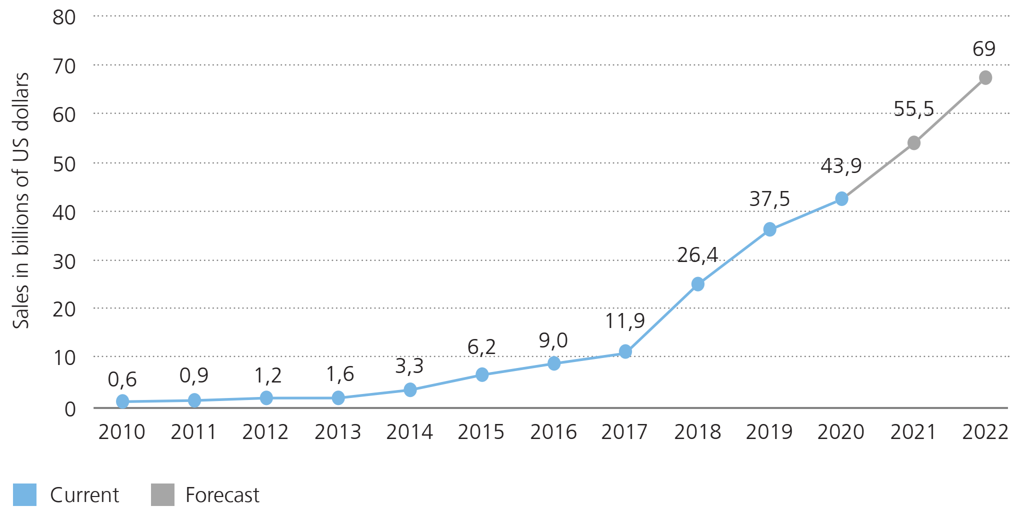

Fig. 4:
Sales of Platform-as-a-Service (PaaS) worldwide from 2010 to 2020 and forecast to 2022 (in billions $) (Gartner, November 2020)

With **Software as a Service (SaaS)** the cloud provider offers complete software or complete applications that run on the cloud and can be accessed via Internet[3]. The underlying infrastructure, middleware, software and data related are located at the cloud provider. Cloud Users can – with SaaS – obtain different services on a flexible basis and with low investment costs. Already 10 years ago, with revenues of 10.7 billion USD, SaaS – until now – has been the most lucrative service model. Global revenues of SaaS accounted for about 102 billion US Dollars.

3 Bhosale et. al. 2020

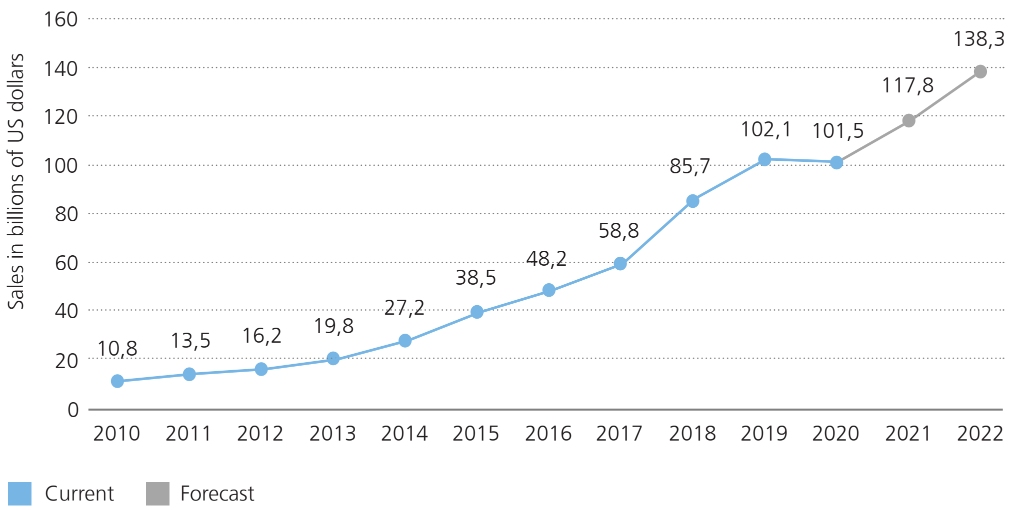

Fig. 5:
Sales of Software-as-a-Service (SaaS) worldwide from 2010 to 2020 and forecast to 2022 (in billions of U.S. dollars) (Gartner, November 2020)

In addition to the offering models presented above, there are others that rise and fall in popularity. Trends worth mentioning are e.g. Serverless Computing, Edge Computing or Multi-Cloud Computing, which will be taken up later in the trends chapter. Other service models like Desktop as a service (DaaS), Data as a Service (DaaS), Container as a Service (CaaS) or Business Process as a Service (BPaaS) are also becoming more common. Overall, this service models are summarized as Anything as a Service (XaaS).

2.2 Cloud usage and market volume

The sales figures for cloud computing services have been showing steady growth for several years. The perception and use of cloud computing services in companies is also growing accordingly. Statistical studies show that cloud usage in Germany is steadily increasing. For example, a survey conducted in Germany shows that the use of cloud computing among companies with more than 20 employees was 76% in 2019, whereas in 2017 it was only 66%. At the same time, the proportion of companies that did not consider cloud computing to be a relevant topic in their strategic considerations diminished. Whereas in 2017 just under one in seven companies did not perceive cloud computing as a relevant topic, in 2019 only one in seventeen companies perceived cloud computing as irrelevant. Thus, the proportion is currently running steadily towards zero, which enables new market and value creation potentials as well as new customers for the cloud market. In addition to the growing use of cloud services in both the private cloud sector and the public cloud sector, there is another interesting develoment: while the proportion of companies for which cloud computing is not an issue is currently falling, there is an ever-increasing number of companies which are planning or currently discussing the use of cloud computing. This shows that getting started with cloud computing is a longer process that takes time and planning.

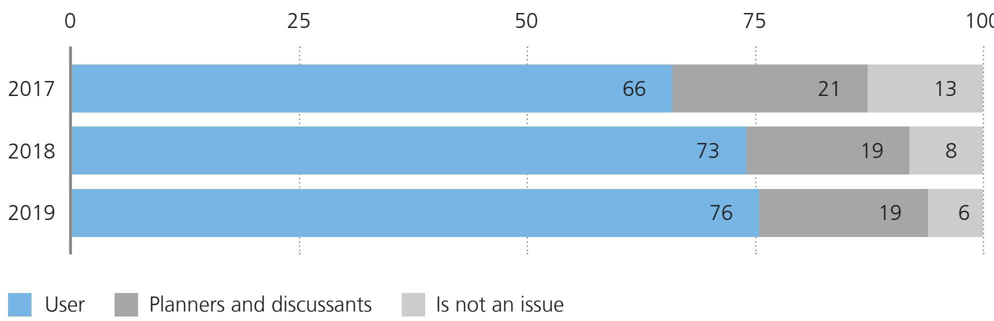

Fig. 6:
Cloud-Computing usage and planning compared over time (KPMG Cloud Monitor 2020)

In that regard, it is noteworthy to mention the usage distribution of various chargeable cloud services in German companies. Most of the expenses regarding cloud computing services in these companies fall on data storage services with a 61% usage and E-Mail services with a 48% usage. Simultaneously, only 19% of chargeable cloud services fall on computing capacity for company owned software and CRM-Software.

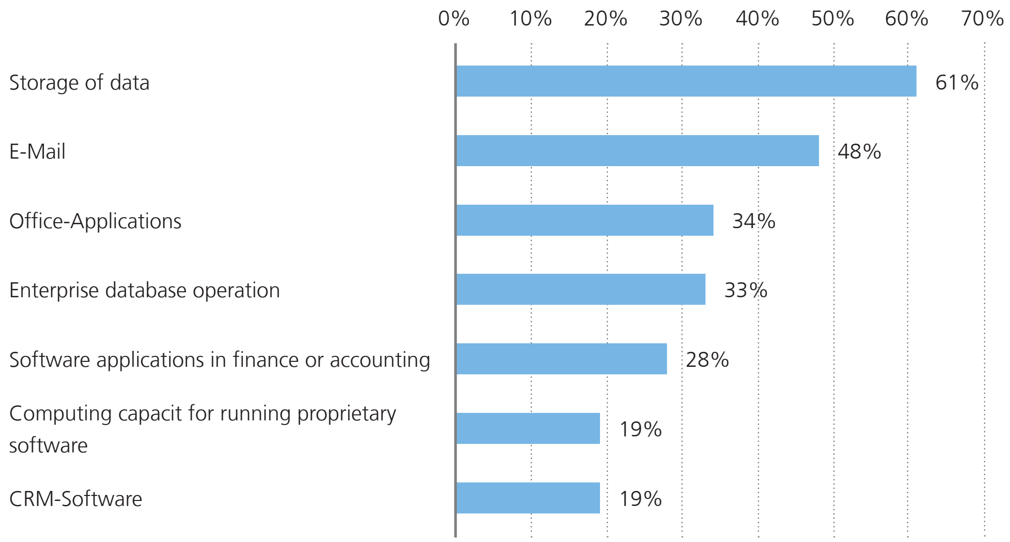

Fig. 7:
Share of cloud-using companies in Germany that use paid cloud services for the following purposes in 2018 (Eurostat Nutzung von Cloud Computing Diensten)

There is a large number of companies in the German area that conceive the migration of information and data systems into the cloud as a key project in their strategic annual planning. Nevertheless, almost three out of four companies only discover during the migration that they lack necessary internal knowledge (WP cloud assessment telecom). This is a major factor, as market volume of cloud-computing-services in Germany are forecasted to surpass 12 billion euro by 2021 after barely reaching 4 billion euro in 2016. This trend can be observed in a global development, as cloud computing revenue is forecasted to reach 326 billion euro worldwide by year 2022 after reaching 42,8 billion euro in 2010. However, this trend does not apply to different cloud computing services equally. While Cloud Business Process Services generated more than two thirds of 2010 worldwide cloud computing revenue, today Cloud Application and Cloud Infrastructure Services constitute the largest part of the worldwide revenue with almost 150 billion euro in 2020.

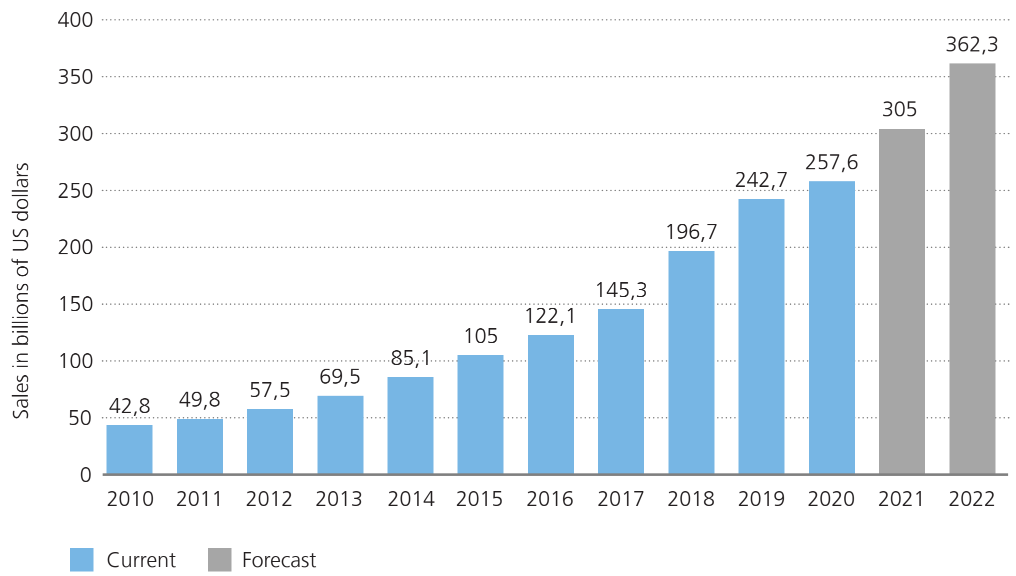

Fig. 8:
Cloud computing revenue worldwide from 2010 to 2020 and forecast to 2022 (in billions of U.S. dollars) (Gartner, November 2020)

2.3
Big players in the cloud market

Since cloud computing is an important factor in maintaining the competitiveness of companies due to its many advantages compared to on-premise solutions, such as high availability, scalability, elasticity and predictive costs, a correspondingly large number of different cloud providers have emerged over time[4]. The pioneers in this area are American companies such as Amazon, Microsoft, and Google. Still, there has been an increase in European companies, which differ from the American cloud providers in terms of firm size and service offer[5]. Within the ultimate 5 years, the cloud divisions of the biggest American cloud providers have increased fivefold from 10 billion (2015) to around 55 billion USD (2020). At the same time, increasing demand has led to tripling investments in cloud computing[6].

When people talk about Amazon, most of them think of the world's largest online marketplace or the movie and music streaming portal. However, the real „cash cow" at Amazon is its subsidiary **Amazon Web Services (AWS)**. Amazon continues to generate the majority of its net revenue from Amazon Marketplace, at approximately $245 billion in 2019 (for comparison, AWS net revenue is approximately $35 billion in 2019). However, Amazon Marketplace 2019 operative profit is „only" $8.7 billion, while it is $9.2 billion for AWS over the same period[7]. This is quite a remarkable figure, considering the large differences in net sales between the two divisions. The importance of AWS for Amazon is also reflected by the recent change in leadership at the company. Andy Jassy, the founder of AWS, will replace Jeff Bezos as the new CEO in the fall of 2021.

AWS's dominance is remarkable when looking at providing IaaS with a global share of 45% in 2019. To serve customers globally and to guarantee high availability, AWS Cloud comprises 77 so-called "Availability zones (with three in Frankfurt). Microsoft Azure and Google Cloud Platform (GCP), who also operate data centres globally, demonstrate continuous growth of their market shares regarding IaaS. However, with a market share of 18% (Azure) and 5% (GCP), market power of AWS is still unmatched. Yet Azure dominates the SaaS sector with a market share of 14% because of products such as Outlook, Hotmail or Microsoft 365.

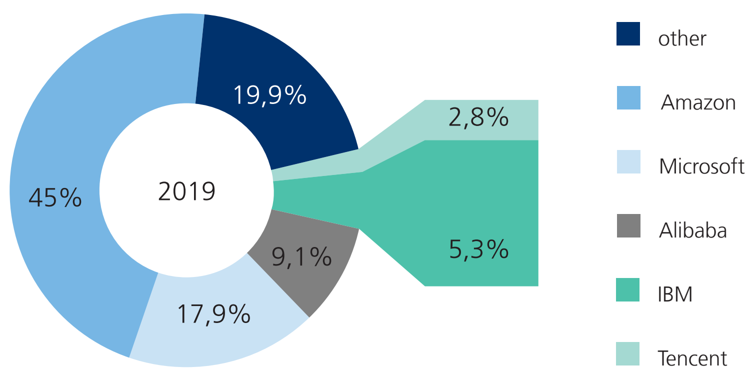

Fig. 9: Market shares of Infrastructure-as-a-Service (IaaS) revenue worldwide in 2019 (Gartner, November 2020)

4 Flexera, "Flexera State of the Cloud Report 2020"
5 Synergy Researchgroup, "European Cloud Providers Struggle to Reverse Market Share Losses"
6 (https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/how-can-we-recognize-the-real-power-of-the-internet-of-things#)
7 Börsenblatt 2020, "Amazon Deutschland macht rund drei Milliarden Euro mehr"

In general, Azure, as well as GCP and AWS, dispose a great product portfolio containing IaaS, PaaS, and SaaS for multiple applications. In addition to that, multiple services of third-party-providers can be obtained via the marketplaces of the cloud provider.

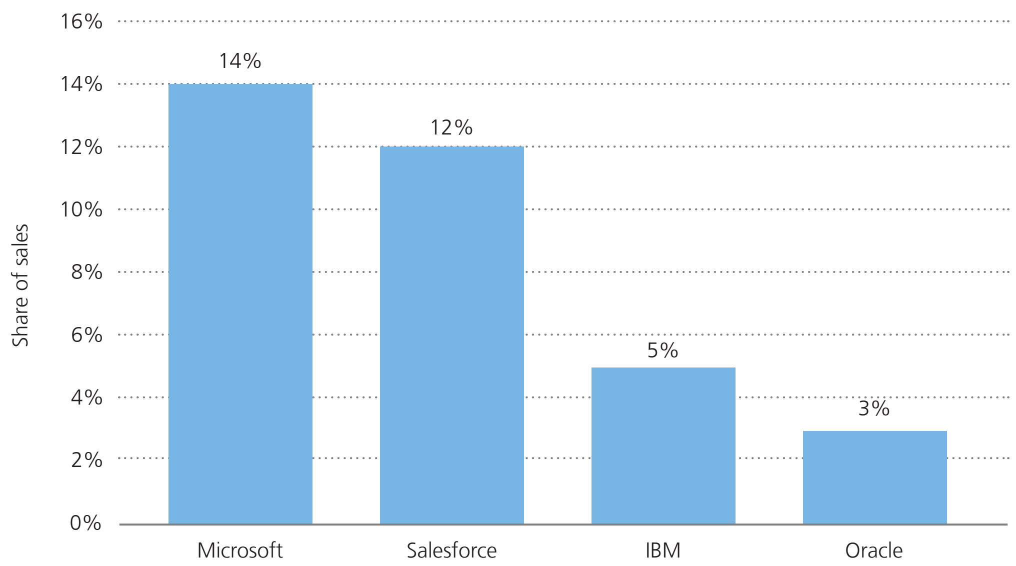

Fig. 10: Market shares of leading companies in software-as-a-service (SaaS) revenue worldwide in 2019 (statista.de)

> To get a better overview of the services offered by the three providers, we will point out specific services in the upcoming chapter for each trend presented.

3 CLOUD-ENABLED AND ADAPTED TRENDS

To make optimal strategic decisions it is indispensable for organizations to understand and react to environmental and technological changes and trends. Cloud computing for decades now presented itself as an enabler for crucial and disruptive technological innovations. Many industries could not have been realized in their current form without cloud computing services that empower a variety of technologies and solutions. Hence, it is essential for organizations to realize the trends and technologies that can be realized and exploited on a cloud computing basis.

3 Cloud-Enabled and adapted trends

This chapter introduces into cloud-enabled and adapted trends. **Adapted trends** include the most important emerging and existing technology trends enhanced by the cloud. While these trends have emerged apart from the cloud and can be used without the cloud, the cloud lowers the entry barrier in dealing with these trends and empowers the user to use them more efficiently and purposefully. In contrast to the adapted trends, the **cloud trends** chapter addresses trends that have emerged directly in the Cloud Computing environment.

3.1 Adapted trends

3.1.1 Internet of Things

One of the main drivers of the digital era and the volume and variety of data is the rise of Internet of Things (IoT) connected devices. Today, connected devices continuously define entire industries, change modern value creation processes and human interaction. Amazon, Microsoft, Google and other cloud providers offer a variety of IoT-Services in order to make use of an IoT-Cloud and exploit full value of smart and connected devices. An IoT-Cloud can serve as a ready-made technology stack that supports the communication of back-end components with each other. The technologies in the IoT-Cloud are tightly integrated and enable efficient operations for device management, interface design, integration and big data analytics. According to McKinsey, there is an estimated economic value of 11,1 trillion $ generated from IoT by 2025[8]. The reason is obvious: The IoT Analytics Group estimated about 9.5 billion connected IoT devices at the end of 2019, expecting it to grow to 28 billion by 2025. The huge potential of IoT is rapidly changing markets and businesses as displayed by one of the largest start-up funding of the last years by the IoT Hardware and Software Company Samsara. Founded in 2015, Samsara has risen to 1500 employees in less than 5 years, raising 300 million $ in 2019, with a portfolio including, among other, cloud-based machine vision systems, industrial controllers, and environmental sensors.

In order to exploit full value from IoT, more and more companies fall back on public cloud solutions to scope their IoT initiatives. According to research from Crisp Research AG, the workloads in public clouds generated by IoT are continuously rising and have become the largest factor in public cloud workload breakdowns. While in 2015 an estimated 3% of public cloud workload referred to IoT, in 2020 it was already 23%. The IoT-Cloud-Market is growing and can be compared to the IaaS Market, leading public cloud hyper-scalers to offer more and more IoT services for big data management in a complaint manner, secure cloud integration, and IoT data analytics. For example, AWS IoT Analytics offers companies services to automatically perform IoT-Data-Analysis tasks, including filtering and processing of data. AWS IoT core services in the AWS-IoT-Suite, as it processes and transfers messages and data between devices and edges, supporting the communication via HTTP, WebSockets and MQTT. Azure, for example, offers with Azure IoT Central a SaaS to outsource infrastructure management into to public cloud. Users can thereby monitor devices, manage IoT applications and develop process rules via a Web UI. The

8 (https://www.mckinsey.com/business-functions/mckinsey-digital/our-insights/how-can-we-recognize-the-real-power-of-the-internet-of-things#)

Azure IoT Hub offers, like AWS, centralized communication backend while the Azure Sphere offers services to improve provision security. Google's Cloud IoT Core offers services to load, store and manage data generated from end devices and combines different dataflows, which can be analyzed via Cloud Dataflow, BigQuery, and Cloud Bigtable. It supports MQTT- and HTTP communication and scales automatically, depending on data demand and data flow. The cloud IoT Core confirms device identity and authenticates devices when they are connected.

The growth of IoT usage has not lost any momentum. More and more smart and connected devices are in operation. New technologies can thus become a decisive driver of the digital transformation. Public cloud services therefore offer an increasing number of opportunities to exploit IoT to its full potential.

> IoT services in **MS Azure** are categorized into connectivity and analytics services, as well as into edge and device support services. For the former, Azure IoT Hub and Azure Iot Central, and for the latter, Azure IoT Edge and Azure Sphere are crucial services for connecting and accelerating IoT solutions. **AWS** offers, among others, AWS IoT Greengrass, a device software service, AWS IoT Core, a connectivity and control service, and AWS IoT Analytics, an analytics service. Whithin **GCP**, devices can be connected and managed using Iot Core. In addition, with Edge TPU, it is possible to execute machine learning inferences on edge devices.

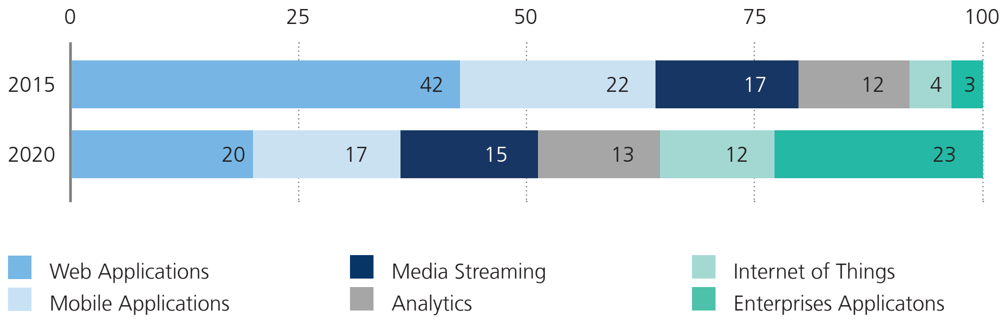

Fig. 11: Public Cloud Workloads breakdown by 2015 and 2020 (Crisp Research AG, 2015)

> *"Depending on the domain, the demand for edge computing is moving in different ways – what we do see is people asking for cloud and edge. There are some capabilities that are handled better in a cloud - centrally, because of scaling effects, and some are better handled at the edge, close to sensors."*
>
> - Michael Hanisch, Head of Technology, Amazon Web Services (German Branch)

3.1.2
Artificial intelligence and machine learning

Artificial Intelligence (AI) is one of the biggest technological trends in our time advancing the digital era. It is a key enabler to adapt technology to social and economic needs. Digital assistants like Apple Siri and Amazon Alexa change the way we interact with technology and consume digital services. Smarter algorithms expand the possibilities in a variety of research fields like smart mobility, smart city or - currently in the worldwide attention – pandemic response planning. In 2020 Scientists in Google's Deepmind designed the AlphaFold 2, an artificial intelligence program to perform revolutionary predictions of protein structure, creating groundbreaking advancements in the medical field. OpenAI's GPT-3 uses deep learning to create an autogressive language model, which enables AI to read and write human text, changing the way we interact with digital entities and services. Machine learning (ML) and AI enable high-tech logistic processes by monitoring crucial networks of hardware and optimizing efficiency of smart products and services. Today organizations need a strong AI engineering strategy to ensure competitiveness of businesses and exploit data to its fullest potential.

But these endeavors sometimes require expensive and critical skills and tools to be implemented in the ongoing processes of a company. Cloud computing services in form of IaaS, PaaS or Saas enable developers to utilize the full potential of AI even with a low budget. Cloud computing offers businesses to scale processes in an efficient and effective manner. Corresponding services pre-trained and ready to use ML, DL and AI models and services, that companies can use in their data analytics initiatives. Cloud computing can lay the environment required for AI execution by offering direct pipelines from data bases to AI services, while securing a high level of reliability, scalability and flexibility. A survey conducted in Germany shows that an increasing number of companies make use of AI technologies made possible by cloud computing. The rise of AI usage in the cloud is in accordance with the rise of cloud computing usage. The ability to utilize AI services even with a low budget creates more and more start-ups that make use of Cloud based services to get started quickly without making major business investments.

> In the area of AI and ML, **MS Azure** offers intelligent API functions for contextual interactions with Azure Cognitive Services. Azure Machine Learning is available for creating, training, and deploying AI models. **AWS** offers Amazon SageMaker for building and training large-scale ML models, but also many other artificial intelligence services. **GCP** also provides cloud users with a platform for training and hosting ML models, in addition to varous AI building blocks that focus on speech recognition (cloud translation, speech-to-text, etc.)

3.1.3
Blockchain

Blockchain technology is an online ledger technology that can be deceived as a digital database containing data that can be used and shared within a decentralized and publicly accessible network. The ledger is encrypted and secured, as data can be added into the peer-to-peer network only when it is verified. The verification is performed by multiple parties and no data within the ledger can be altered in a later stage, as the technology protocol prevents falsification of the entire chain of instances, which is why the technology is usually recognized as incorruptible. Blockchain uses decentralized computing, hence all data is stored in multi-agent network instead of a single central entity. The immutability and encryption of the data in a decentralized network adds a security layer to the blockchain, which is why interest is growing in nearly every major industry.

Due to the rapid development of this technological trend, big cloud providers launched blockchain cloud services themselves. Both, blockchain technology and cloud computing services have security protection systems, thus are more resistant and secure. The services are built on the infrastructure of the providers and make use of open-source distributed ledger technology frameworks like Quorum, Ethereum or Hyperledger Fabric. The usage of blockchain technology in a cloud computing environment is associated with different benefits for the user. For example, the geo-independent decentralization and security through private keys offers enhanced data security. The innovative method of blockchain to collect data, perform transactions or smart contracts and execute functions, can build trust in an open public cloud environment. It provides an additional layer of safety to store sensitive data in public clouds, as the decentralized approach prevents unauthorized access and impedes external threats on centralized cloud platforms. Furthermore, continuous ledger control increases efficiency in ownership tracking. The technology offers enhanced accountability through immutability and incorruptibility. Cloud-computing platforms today offer code extensions for developers to build, debug and test custom smart contracts on a blockchain utilizing public cloud resources. In addition, the Hyperscaler offer tools and services to build centralized ledger databases to maintain a cryptographically verifiable and immutable record of transactions or to create fully managed multi-party blockchain networks to eliminate intermediaries.

Even though blockchain-based decentralized cloud computing offers new value propositions and benefits, the solutions come with costs that needs to be considered in the strategic choices of a company. The benefits of blockchain put more weight on security. But having blockchain ledgers globally distributed at a wide scale raises performance costs. This in a way contradicts with the benefits of cloud computing. The current state of blockchain technology requires high effort to provide scalability considering the scalability limitations. Nevertheless, although blockchain cloud computing is in its infancy, it is a technology to be observed and considered in a strategic cloud transformation process.

With Azure Blockchain Service, **MS Azure** support their customers in building, deploying, and managing blockchain networks. Futhermore, Azure Blockchain Workbench enables users to easily prototype blockchain apps in the cloud with prebuilt networks and infrastructure and Azure Blockchain Development Kit connects and integrates blockchain apps with existing apps and databases. Amazon Managed Blockchain as the couterpart of **AWS** is also a fully managed service for joining, creating, and managing scalable networks using the popular open source blockchain technologies Hyperledger Fabric and Ethereum. Futhermore, the AWS Marketplace offers over 70 validated blockchain and distributed ledger technology solution from other partners. While **GCP** does not offer its own explicit blockchain service, it does support interoperability of its own enterprise cloud data warehouse (Big Query) with technologies like Ethereum.

> *"Cloud Computing is the norm, going to the cloud is what we do for many years, now we're moving towards a decentralized notion."*
>
> - Hartmut U. Müller, VP IT Technology & Cross Functions, Daimler AG

3.1.4 Open Source

Open source is a well-known phenomenon related with the idea of using the wisdom of the crowd or empowering the masses since the 1990s. But its' meaning and character fundamentally changed: It changed its role from just being free software or even called "a cancer" to big companies offering proprietary software to an important driver for innovation and is the backbone of most essential software services and devices. Nearly 99% of all codebases reviewed in 2019 use open source technologies according to a Synapsis report and it already transformed software development around the world. Today it drives emerging technology trends and plays an important role in the cloud business landscape. Prominent examples are the acquisitions of GitHub by Microsoft for $7.5 billion in stock and Red Hat by IBM for a total equity value of approximately $34 billion.

Open source enables cloud-based innovation and fosters cloud-based data sharing by being a fundamental aspect of cloud infrastructure technologies. While most of traditional servers run on proprietary technologies, most cloud servers base on the open source technology Linux. Especially for private and hybrid clouds as well as cloud-native technologies, open source offers the flexibility to design an own cloud infrastructure. Jim Whitehurst, president and CEO of Red Hat calls the relationship between open source and hybrid cloud as follows:

> *"As organizations seek to increase their pace of innovation to stay competitive, they are looking to open source and a distributed cloud environment to enable a new wave of digital innovation that wasn't possible before."*
>
> - Frank Gens, Senior Vice President and Chief Analyst, IDC

By easing the availability of hybrid or multi-cloud infrastructure, open source lowers the hurdle for companies to create cloud-based innovations and speeds-up cloud-based data sharing. Following on from this, open source also suggests a reduction in lock-in risk. But the impact on lock-in situation is complex and controverse as, for example, open source code can be wrapped in proprietary technologies. .

100%
of supercomputers use Linux.

~95%
of public cloud providers use Kubernetes

70%
of global mobile subscribers use devices tun on networks built using ONAP

50%
of global auto shipments supported by OEMs using Automotive Grade Linux

50%
of the Fortune Top 50 enterprises blockchain deployments use Hyperledger

1 Billion
security certificates issued by the largest certificate authority in the world: Let's Encypt

Fig. 12: The World runs on open source (The Linux Foundation)

1.15 Billion
lines of code supporting the most business critical and groundbreaking innovations

235K+
developers from the most innovative companies building the future of open technology

19K+
contributing companies across industries bringing open technology into the enterprise

Fig. 13: Helping open technology projects build world class open source software, communities and companies (The Linux Foundation)

One aspect of open source infrastructure technology in the cloud context is their licensing costs. The open or free available infrastructure software code enables rapid scaling without dramatically increasing licensing fees. But the strategic benefits of open source that go beyond operational savings in licensing costs are as follows:

- Access to a Larger User and Developer Ecosystem
- Create Technical and Political Leadership
- Improved Code Quality and Stability
- Collaboration
- Faster Innovation
- Faster Time to Market

To leverage full open source potential, companies have to move from only using open source to contributing or providing open source projects. McKinsey and the Linux Foundation describe the switch from only using to contributing to open source software as the "biggest differentiator" for top-quartile companies in industry-verticals. While traditional software and business practices are proprietary and closed, open source development focuses and collaboration and implies a fundamental shift in philosophy and open source governance expertise. This gains relevance for cloud-based data sharing when considering that 40% of the cloud native technologies are open source and the open source paradigm drives the cloud native community.

> When it comes to open source, **all three Hyperscaler** offer a wide range of open source projects and software with different partners. Highlighting individual open source projects or technologies at this point would not do justice to the wide range of services offered by all three providers. To concretize the extent: AWS alone is currently working on more than 1200 open source projects on GitHub, while GCP is a leading contributor to CNCF open source projects.

3.2 Cloud trends

3.2.1 Cloud Native Computing

To leverage cloud computing and the transformation of software and services there is the requirement to rethink the concepts of engineering, deployment and integration. This is defined as cloud native computing, which can be summarized as „the architecture for assembling software-components in a way that is optimized for the cloud environment". It's not about the servers, to refer to the opening quote of Eric Schmidt, but the services. The Cloud Native Computing Foundation (CNCF) gathered Technologies that follow the cloud native spirit and placed them in a so called "Cloud Native Landscape". With this Landscape the CNCF provides a framework with 6 categories of technologies and tools that address needs emerging from cloud environments. These are Platform, Provisioning, Runtime, Orchestration & Management, App Definition & Development and Observability & Analysis. Each category is itself split into subcategories which envelop different approaches on how the needs are addressed. The landscape describes more than 905 technologies and tools. A significant portion of them is Open Source, 41% as of March 2021. Open Source solutions require a different approach regarding topics like technical support or necessary Know-How. For this reason, if interested in cloud native, one should also familiarize him- or herself with the topic of Open Source.

Cloud-Enabled and adapted trends

Many capabilities of the technologies and tools are adapted and integrated by the different cloud providers and offered as managed services. Further growth of services in this area is expected due to the increasing need to mi-grate more and more systems to the cloud, adapting individual components and capabilities. It will be exciting to see which capabilities stand out from the crowd and are offered as managed services by the cloud providers, as this corresponds to the general needs of the market.

If composed correctly the interplay between the technologies and tools leads to resilient, loosely coupled systemsthat are manageable and observable[9]. They also are a basis for robust automation to iterate quickly and with minimal toil[9]. The cloud native approach is only possible because of key concepts that emerged over the years, concepts which enable a more efficient utilization of cloud resources.

An important Concept for the cloud native approach is the concept of **Microservices**. Microservices can be understood as a specific manifestation of Service Oriented Architecture (SOA)[10]. The idea behind Microservices is simple: Split Monolithic Applications into smaller parts (called services) to better make use of the benefits cloud environments have to offer. Scaling becomes easier because only those services are scaled that actually have to scale, not like in monolithic systems where all components must be scaled col-lectively[10]. A change on one component in a monolithic system means that the monolith in its entirety must be deployed. With microservices each service can be deployed independently[10]. This makes the development process much smoother because the service teams can iterate independently and don't have to wait for the other Teams to make their changes. Teams can be smaller and more focused[10]. Microservices also enable system environments to contain heterogenous Parts[10]. So, for example instead of being chained to the database solution of the monolith, each service can choose a solution that is most suitable to achieve its goal. Nevertheless, it must be weighed up whether it is worth using specialized technologies for every service or whether it is better to build up competencies in just a few specialized technologies[10].

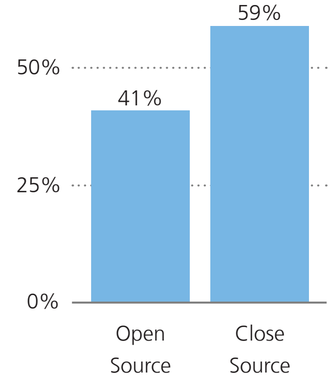

Fig. 14: Open Source Software in the CNCF Landscape, March 2021 (Cloud Native Computing Foundation)

To build functioning microservice architectures, concepts like lose coupling, high cohesion and bounded contexts should be considered[10]. Lose Coupling means, that a change of one service should not lead to a change in another Service. This can be achieved if service to service communication is stripped down to the bare minimum[10]. This leads to the next concept: high cohesion. To get to the bare minimum of inter service communication, behaviors that are related need to be in the same service[10]. A change in a behavior will then only influence one service at a time[10]. The third concept is Bounded Contexts. A domain can consist of many Bounded Contexts each with things the context needs internally and things it shares with other bounded contexts[10].

As can be seen, the realization of such microservices is not straightforward and requires good planning to execute. This applies to microservices developed from scratch as well as to microservices that are elaborated from monolithic systems. Even though the services are standalone, in the end they must work together in a harmonic way[10].

But what are the technical means by which microservice architectures can be implemented? For a long time, Virtual Machines (VM) where the Goto solution for operating services in cloud environments[11]. VMs allow multiple applications to run on the same hardware[11]. But even though VMs where a step in the right direction of utilizing the

9 https://github.com/cncf/toc/blob/main/DEFINITION.md
10 Newman, Sam „Building Microservices"

potential of cloud environments, the technology still had its disadvantages. VMs are large and need a long time to boot up[11]. VMs are hard to manage and it's hard to implement concepts like continuous integration and delivery with them[11].

To address these challenges a process named containerization emerged[11]. Instead of virtualization happening at the hardware level, containerization brings the virtualization to the Operating System layer[11]. This makes containers more lightweight than VMs because each container, does not have its own operating system[11]. Instead, there is a host Operating System, that enables sharing of resources and libraries between containers[11]. Containers are self-contained and as such are easily deployable in different environments[12]. A usual way to use them is to retrieve Container Images from a repository[12].

To be able to organize dependencies between containers an orchestration entity is needed. Managing it all manually would become impossible at a certain stage. To address this problem different **container orchestration** solutions emerged. One of them is Kubernetes. Kubernetes enables effective automated control of cloud resources[13]. It was thought up when Docker started to change the cloud native approach to application packaging and maintenance away from Virtual Machines towards containers[14]. It is not the only Container orchestration solution, but it can be seen as the de-facto standard in this area.

In *Kubernetes* the resources of a cluster are described in simple YAML-Files. The descriptions follow a simple text format and describe the desired state the user wants the cluster to be in. For example, how many containers of a specific service should run at any time and over which communication channels they can be reached. Kubernetes applies these files and makes sure, that the cluster stays in this desired state. Containers get spun up with the desired container Images. Services get set up automatically. When Kubernetes detects the crash of one of the containers it can immediately spin up a replacement container to reach the desired state again. This leads to a robust Architecture that is able to handle outages of parts of the system well. Kubernetes is with its characteristics a critical component in the development of cloud native infrastructure[14].

In terms of the Cloud-Native trend, all three Hyperscaler provide a corresponding Kubernetes service as part of the microservice approach to flexibly manage the scaling of cluster rescources. Code development at **MS Azure** is supported by the Azure Boards and Azure Pipeline services. DevOps tools at **AWS**, such as AWS Code-Pipeline, CodeBuild and CodeDeploy, are also located in the continuous Integration & Deploxment section. **GCP** offers the possibility to participate in the Dev Ops movement with Cloud Build, Spinnaker, Tekton and other services.

10 Newman, Sam „Building Microservices"
11 Potdar, Amit M., et al. „Performance evaluation of docker container and virtual machine." Procedia Computer Science 171 (2020): 1419-1428.
12 Pahl, Claus, et al. „Cloud container technologies: a state-of-the-art review." IEEE Transactions on Cloud Computing 7.3 (2017): 677-692.
13 Medel, Víctor, et al. „Characterising resource management performance in Kubernetes." Computers & Electrical Engineering 68 (2018): 286-297.
14 https://kubernetes.io/blog/2018/07/20/the-history-of-kubernetes-the-community-behind-it/

3.2.2 Multi-Cloud Computing

When a company uses public or private cloud services from more than one cloud provider, in addition to its on-premises infrastructure, this scenario is known as *Multi-Cloud Computing*. Multi-Cloud Computing is a much-discussed trend, not only due to its complexity but also due to possible potentials for organizations and businesses. Furthermore, the relevance of Multi-Cloud Computing can be reinforced by the example of the promise of high availability of cloud providers: Although high availability is an attribute that every cloud provider advertises, which is to be realized by a sophisticated and networked infrastructure and guaranteed by meaningful SLAs, in 2019 approximately every second company is still affected by cloud outages due to technical problems with their cloud provider[15]. Multi-Cloud Computing can provide a solution for this. Due to collaboration with many, independent acting cloud providers, redundance is increasing and breakdowns are prevented – with these two facts being the main reasons for companies to operate Multi-Cloud Computing. Further, it is attractive for companies to obtain specific cloud services from certain cloud providers through multi-cloud computing, to achieve a better distribution of resources at full capacity and ultimately also to reduce costs. However, on average, cost reduction is a relevant reason for using multi-cloud computing for only 1 in 10 companies[15].

Potentials of multi-cloud computing appeal primarily in large companies (> 2000 employees), where in 2020, 9 out of 10 German companies are using multi-cloud computing. In comparison, the usage rate of German companies of all sizes is „only" 32%, whereas 18% at least planning or discussing the use of multi-cloud computing. Reasons therefore cloud be that large companies have to rely on a wide range of specific services on the one hand and want to avoid cloud failures by all means possible on the other.

	Total	20 to 99 employees	100 to 1.999 employees	2000 employees and more
Increased redundancy or avoidance of failures	43%	46%	37%	69%
Use of specific services with specific cloud providers	38%	36%	44%	39%
Better distribution of resources with full utilization	31%	33%	26%	37%
Economic reasons or cost reduction	10%	9%	13%	18%
There is no specific reason	4%	3%	8%	1%
Don't Know/No data	2%	1%	3%	10%

Fig. 15: Reasons for multi-cloud usage (KPMG Cloud Monitor 2020)

As with other trends, multi-cloud computing also poses a number of challenges that companies need to master. First and foremost, the use of various cloud services from different providers must be managed in a targeted manner. To support this, some providers offer higher-level orchestration, cost management and deployment tools. In addition, there are several third-party tools and vendors for multi-cloud management that can help with these challenges. A dynamic and highly elastic multi-cloud environment also requires an enhanced security strategy that goes beyond traditional cloud security measures. Security solutions deployed across multiple providers must be able to share information and automatically correlate threat data to respond to threats across

15 KPMG 2020

the entire network. This requires a special focus on factors such as centralized transparency, orchestration, and control over the entire network. Finally, the lack of expertise is another key challenge when it comes to multi-cloud computing - especially in terms of finding qualified personnel.

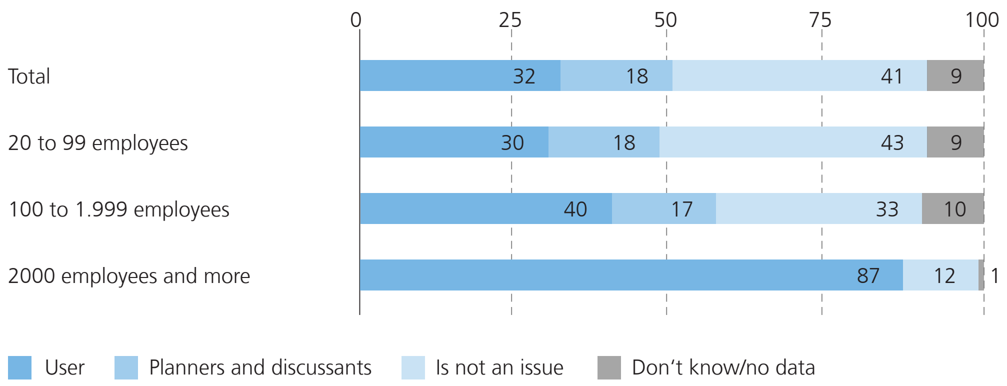

Fig. 16: Use and planning of multi-cloud computing (KPMG Cloud Monitor 2020)

> When using cloud services from different providers, orchestration ist essential for a successfull Multi-Cloud strategy. Fot the setup and management of distributed environments, **MS Azure** provides a corresponding platform with Azure Arc. With the hybrid and multi-cloud applicaiton platform Anthos, **GCP** also offers the ability to orchestrate distributed cloud services. This option does not exist with **AWS**. However, the AWS marketplace offers similar solutions, such as mPlat Suit, which fulfill a multi-cloud conductor's function.

3.2.3 Edge Computing

In the age of IoT and the increasing importance of real-time data processing, the relevance of edge computing as a new computing paradigm based on a distributed approach is increasingly relevant. Unlike traditional cloud computing, edge computing uses infra-structure components such as computing, storage, or networking in the immediate vicinity of the data source or the data-generating device, virtually at the „edge" of the network. A data-generating device can be almost anything these days, from machines in production factories to your own refrigerator or car. Those edge devices or edge computing environments can in turn be connected to a private or public cloud. The key point is that time-critical tasks can be executed in real time and thus without latency through data analysis and evaluation. In this way, costs can also be saved when using cloud computing, since cloud providers charge according to bandwidth, which can be significantly reduced through edge computing. Ultimately, companies can also become more independent in terms of the extent to which they work with cloud providers.

As with all other trends before, there are also challenges with edge computing that need to be considered. Since both the data-generating devices and the edge devices are located at the premises of the companies and not at a provider's data center, the companies are once again entirely responsible for security aspects such as the physical protection of the devices and the network protection. Logically, the cloud providers' shared responsibility model no longer applies to edge computing. It is also important to ensure that the edge devices do not become a single point of failure and companies must also ensure sufficient bandwidth - not only at the data center - but now also at the "edge" of the network. The last thing to mention, similar to multi-cloud computing, is that sufficient trained personnel must be available, since with edge computing maintenance and monitoring of the Devices is the sole responsibility of the companies.

> *"When you look at today, the ratio between processing on the cloud vs. the edge is 80% to 20%. We would expect that this reverses in 5 years, not that cloud processing will become less but that there will be more processing needed and it will grow quicker on the edge."*
>
> - Dr. Max Lemke: Head of Unit Internet of Things, European Commission

> With Azure IoT Edge **MS Azure** offers a fully managed service built on Azure IoT Hub to deploy workloads and services to IoT edge devices cia standard containers. AWS IoT Greengrass seamlessly extends **AWS** to edge devices so they can act locally on the data they generate, while still using th cloud for management, analytics, and durable storadge. With Anthos at the Edge you can extend **GCPs** managed application platform Anthos beyond your data center and public cloud to the edge of your network.

> *"Edge is the focus – decision making on the spot where the data is makes great benefits. From power plants, to houses, to smart phones, there are many use cases."*
>
> - Klaus Ottradovetz, Cloud and IoT Expert, Atos International Germany GmbH

3.2.4 Serverless Computing

Serverless Computing (also known as **Functions as a Service** or **FAAS**) means that cloud user do not have to deal with infrastructure components if they want to use the cloud or work with the cloud. Whereas with IaaS or PaaS solutions cloud users are still responsible for tasks like scaling the number of servers needed or the design of APIs. With Serverless Computing, the cloud user's task is to only deliver the code – all other services are automated and customized through the provider. However, this does not mean that servers are no longer needed when using serverless computing. The code is still executed via servers. The term „serverless" refers to the above-mentioned abstraction of the provision and management of the infrastructure for the user by the provider.

Serverless Computing allows developers to focus on business logic, which increases their productivity and shortens the time-to-market for products and services.

> The hyperscalers each offer individual FaaS solutions with *Azure Functions* (**MS Azure**), *AWS Lambda* (**AWS**) and *Cloud Functions* (**GCP**).

4 HOW FRAUNHOFER ISST CAN SUPPORT

The Fraunhofer ISST is a scientific institute experienced in the field of cloud transformation throughout the entire digital journey of organizations. We serve as a neutral partner and excellent supporter to make strategic choices for the digital landscape of companies. Our experience ranges from scientific publications to a variety of industry projects. We offer guidance to overcome challenges and obstacles in the process of digital transformation and consult our partners on projects to exploit it full value of cloud computing technologies.

4
How Fraunhofer ISST can support

4.1
Challenges in Cloud Transformation

The following chapter will give room for the challenges that occur today in companies' endeavour of a cloud transformation. For that, we will elaborate strategic, technological and compliance challenges and obstacles that companies face in the cloud transformation journey. Furthermore, we want to elaborate how the Fraunhofer ISST supports their partners with its scientific background and economic expertise.

4.1.1
Strategic and organizational challenges

The opportunities offered by the advancement of cloud computing are manifold. By granting advantages through flexibility, scalability, cost-reduction and enabling technological trends, companies perceive numerous chances to enhance their current business or create new business opportunities. However, the current trend in the economy for companies to increasingly utilize cloud services also shows that many companies still only plan or discuss this manner as mentioned in earlier sections. This indicates that the cloud migration process requires time, strategy and effort. There are possible challenges

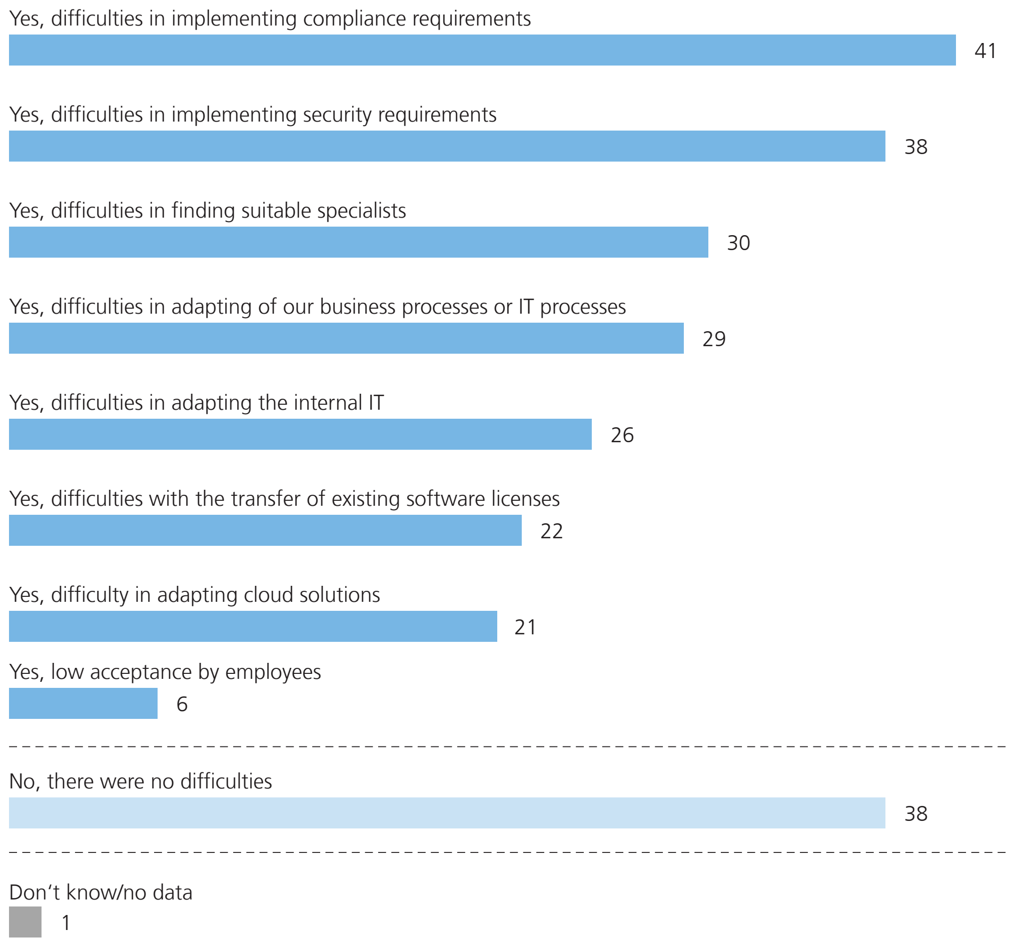

Fig. 17:
Difficulties with the integration of public cloud solutions (KPMG Cloud Monitor 2020)

that need to be considered and addressed in the cloud strategy making procedure, as most challenges cannot be prevented but can be minimized. Surveys show that in 2018 43% of companies had little to no problems, whereas in 2019 close to every third company faced challenges during the cloud migration. One of the reasons for this development is the increase in compliance requirements for companies, which are discussed in the following section. While in 2018 29% of surveyed companies remarked difficulties in the realization of compliance requirements, in 2019 41% remarked this challenge. With that, implementation of compliance regulations surpassed the realization of security requirements and the alignment of Business and IT processes as the biggest challenges for companies. Other surveys indicate that challenges occur with the re-architecting and remediation of legacy applications and technologies. On that regard, companies worry hardly assessable costs or the danger for different lines of business using different cloud services providers.

These challenges sometimes display urgent obstacles for companies to use a public-cloud service. In 2019 almost half of the surveyed companies stated the fear of unauthorized access on company data as the main obstacle for the public-cloud usage. Furthermore, nearly every third organization saw ambiguities regarding the legal situation as a major factor not to use public-cloud services. Some answers even indicated that existing legal and regulatory provisions completely prohibited the cloud migration. Simultaneously, the challenge that public cloud solutions showed difficulties in the integration into inhouse-solutions formed the smallest obstacles in the process. These challenges often times form the main obstacles for companies to define and execute a profound data strategy. A successful data strategy is a common reference of methods, services, technologies, skills, patterns and architectures for managing, sharing, and analyzing data. Empirical data from surveys conducted on companies across different industries show that companies with advanced data strategies regularly outperform competitors. These companies inherit better market positions than competitors and produce significantly higher revenues[16]. In that regard, the usage of cloud services commonly forms a crucial part in data strategies. A survey conducted by and published in the Harvard Business Review shows that more than half of respondents plan to leverage multiple cloud providers as part of their data strategy. The opportunities offered by cloud services support companies to overcome the biggest challenges in their data strategies. For example, 30% of surveyed companies name poor or outdated IT systems as a major factor for unsuccessful data initiatives. The offerings of cloud providers provide flexible and scalable solutions for different levels of IT-infrastructure. The manifold offerings of infrastructure-, platform-, or software-as-a-service support companies in their endeavor to scale their own IT forces, either with cloud solutions or by purchasing IT internally. The offered services broaden the strategic opportunities and enable strategic data initiatives suited to the company goals and budget.

However, the challenges and obstacles faced during the cloud migration are often insignificant compared to the opportunities and advantages that are granted by the flexible and scalable usage of public-cloud services but need to be considered in that making of a long-term organization wide cloud and data strategy.

4.1.2
Technological challenges

Alongside the organizational aspect of cloud transformation including the structural change, the effort and the stakeholder management, there are also technological aspects and challenges that need to be taken into consideration. For a company to implement cloud technologies, a substantial amount of know-how in this area is needed. It requires a skillset either by training existing workforce or hiring new employees and talents, in order to, e.g., turn an existing monolithic system into efficient mircoservices. Additionally, as described in our multi-cloud section, organizations need to address the interoperability of different services. Relying on one cloud service providers and its technological offerings can cause a lock-in effect, in which a company might become dependent on one single cloud provider and higher shadow costs erise. Hence, semantic interoperability is required throughout the entire technological landscape, to enable multi-cloud environments and reliable performance. In order to avoid vendor lock-in effects and create utilize a functioning multi-cloud environment, the user needs to ensure interoperability and portability by choosing cloud services that have the capability to integrate with ease to the on-premise IT. This heterogeneity of systems and their respective requirements create a significant amount of complexity in the decision making process. The process of cloud migration involves a number of risks concerning data integrity, application portability, process disruption and security issues, which arise from the multi-user nature of cloud computing and the remote access. There is still a lot of movement in the cloud market, and companies need to be careful on which technologies and tools they rely. One opportunity to overcome these challenges is the trialability of cloud computing. Cloud computing providers offer companies to test virtual hardware. They can use them for a period of time and test the environment as well as turn them off. This serves as an opportunity to overcome certain challenges, as this process is hardly replicable, as companies rarely afford 10 spare servers and leave them unused after a short test period.

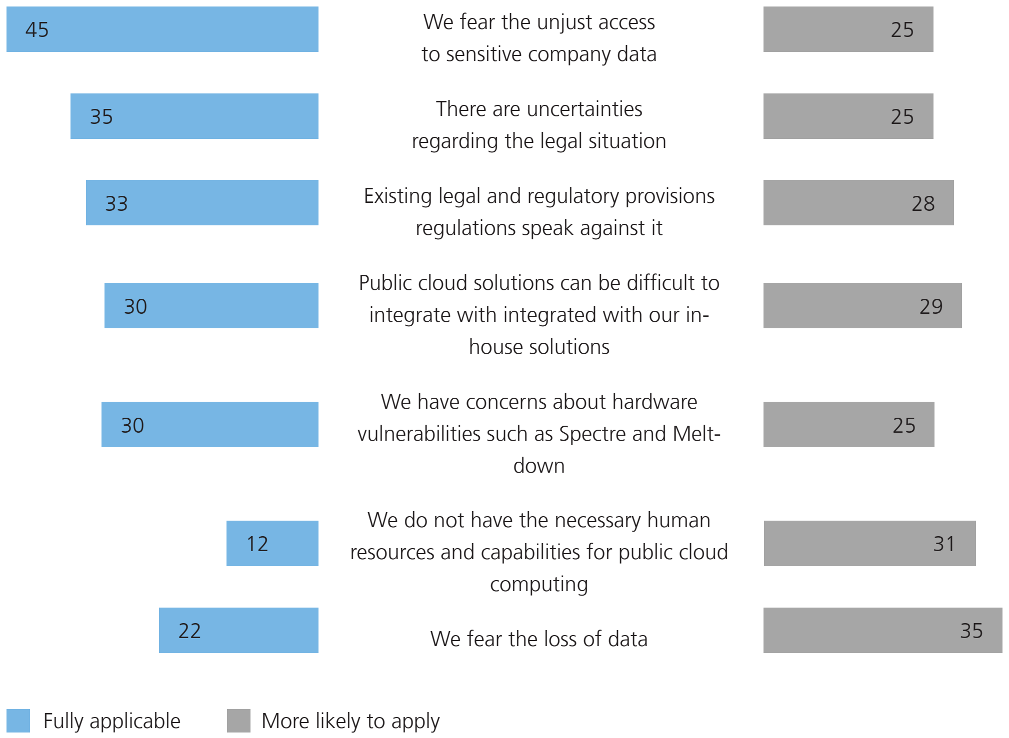

Fig. 18:
Hurdles for companies not using, planning or discussing public cloud solutions in 2019 (KPMG Cloud Monitor 2020)

4.1.3
Compliant data management challenges

In addition to organizational and technological challenges in the cloud transformation process, companies need to consider environmental challenges, namely compliance issues. Since the storage locations of data may shift or remain unknown to the user, the problem of the applicable jurisdiction arises and impede the adoption and management of Cloud Computing Services. Therefore, companies need new methods to avoid being fined for compliance violations, to manage risk factors as well as to manage processes and decision rights. In this context, it is crucial to be informed about current regulations such as GDPR and its relation to the US Cloud Act.

The EU's General Data Protection Regulation (GDPR) intends to protect and strengthen the integrity of the individual and to give people power over their data. GDPR affects both personal data and corporate data - from economic information to trade secrets and intellectual property. However, according to a study of Bitkom, more than every second innovative projects have failed because of GDPR. Four out of ten companies explain that they are not able to build datapools or to share data with their business partners, leading to a reduced use of Big Data or Artificial Intelligence, harming innovation especially when regarding the application of data analysis[16].

The CLOUD Act demands data by placing U.S. interests above foreign laws. All companies in Europe are subject to the CLOUD Act if they are part of a US company or exchange data with US companies. The CLOUD Act requires companies to release not only their own data, but all data in their possession, custody, or control, such as customer data held by a cloud service provider. Therefore, European Cloud providers with headquarters and data centers in Europe offer maximum protection against access by US authorities and are GDPR-compliant. The CLOUD Act is in irresolvable conflict with GDPR. It requires U.S. companies to disclose data stored or processed outside the U.S, which is why currently, companies in Europe run the risk of violating either the US CLOUD Act or the GDPR[17].

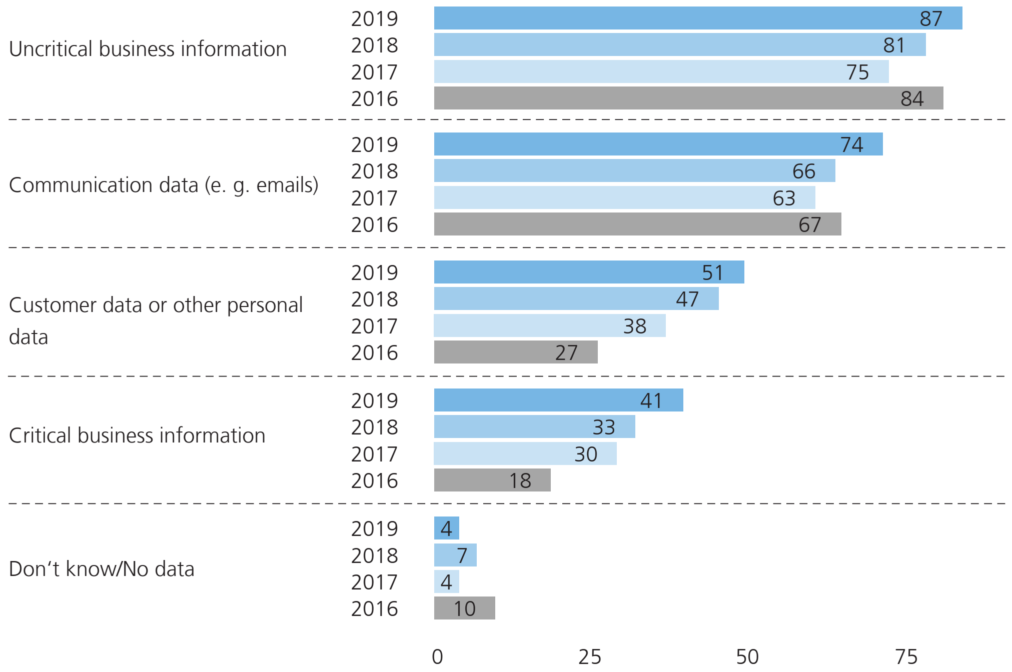

Fig. 19: Data Storage in the public cloud (KPMG Cloud Monitor 2020)

4.2 Our Promise

Cloud Infrastructures are the core of innovative ecosystems and service platforms that ensure innovation and growth of businesses. Fraunhofer ISST is your neutral, trustworthy and reliable partner from the initial scoping all the way down to implementation.

16 Bitkom 2020
17 1&1 Ionos SE 2020

Our methods are grounded by scientific research and have delivered tangible results in more than 150 projects. Due to their research background, our scientists bring in enormous innovative spirit, drive and motivation. Leading companies as well as hidden champions – all around the world – are relying on our expertise and independence.

Whether you are still at the beginning of your journey or have already take part of the way. We support you in the next steps and ensure that the path is straight together.

With our expertise, models and technologies, we build the systems and software that will determine the future. We leverage the drive of cloud transformation to scale digital products and, through our reference to data sharing, enable the creation of smart ecosystems, matching existing requirements and future needs.

We understand your requirements, know what's next, speak the language of both business and tech, and bring ideas into application. We believe, that only by combining both worlds from the very beginning can really drive innovations.

This is our promise and Fraunhofer ISST stands for:

- We know how to get things done in complex organizations and how to transfer research results into practice and thus speed up your data strategy initiatives
- „What's next" is our passion and we work with the latest findings and methods to generate sustainable solutions for your data strategy
- We don't just design frameworks, KPIs or processes, we also support you implementation and deploy them

4.3 GAIA-X and IDSA

The European and German digitization and data strategy is based on the establishment of data spaces for trustworthy, interoperable, and secure data exchange. The establishment of precisely these data spaces is being driven and shaped to a large extent at ISST. Therefore, The Fraunhofer-Gesellschaft is one of the 22 Founding Members of the Gaia-X AISBL. The initiative Gaia-X that is part of the EU data strategy and has the mission to create a sovereign digital infrastructure, by following European values and building upon existing technologies and standards, strives to create a next generation of data infrastructure to proliferate innovation and strengthen the European single market. In this context, open-source technology and open standards are facilitated to create an ecosystem contributing to interoperability, sovereignty, transparency, and security for all participants. The Gaia-X ecosystem comprises the free trading and free market flow of the entire cloud offering spectrum and data. Especially regarding the sovereign data exchange, existing solutions benefit Gaia-X. Among these, IDSA (International Data Spaces Association) contributes the IDS Reference Architecture Model (IDS RAM) as a blueprint for the European Data Space to speed up innovation.

Fraunhofer ISST can guarantee a close collaboration with the different Working Groups of Gaia-X as well as the initiatives of IDSA. We make sure that we develop software-offerings that are Gaia-X compliant. Furthermore, Fraunhofer ISST can offer IDS-ready certified Software and the experienced competences and consulting.

4.4
Contacts

We would be pleased to give you an understanding of our offer with regard to the endeavour of cloud transformation and to cooperate with you. Together we will take this important step in the digital transformation and make your company fit for the future.

Contact us without obligation for a first conversation!

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