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Horizon Cloud – The Forum for Strategy Focused Cloud Stakeholders

D1.2: Cloud Computing Portfolio

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Abstract

This deliverable represents the second release of the H-CLOUD European Cloud Computing Portfolio. It explores the European cloud landscape with the objectives of mapping it in all its dimensions, identifying the positive outcomes of work undertaken by the European cloud community and spotting potential gaps, and creating a viable knowledge resource for use by the community.

Keywords:

Cloud computing, the cloud computing landscape, cloud federation, edge computing, green IT

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Dissemination Level		
PU	Public, fully open, e.g. web	√
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CO	Confidential to H-CLOUD project and Commission Services	

EXECUTIVE SUMMARY

This deliverable represents the second release of the H-CLOUD European Cloud Computing Portfolio. It explores the European cloud landscape with the objectives of mapping it in all its dimensions, identifying the positive outcomes of the work undertaken by the European cloud community and spotting potential gaps, and creating a viable knowledge resource for the community. It will be the basis for the development of an easily searchable online catalogue of relevant cloud-related initiatives.

The European Cloud Portfolio encompasses a total of 246 initiatives (111 profiled in the first release and 135 added in this second release) relating to cloud computing, with a specific focus on federated cloud, edge computing, and green computing. In the R&I context, 99 H2020-funded projects were identified; 147 initiatives have resulted from desk research in the deployment area, of which 38 relate to the public sector, 95 come from the private sector, and 14 are from public-private partnerships.

In this updated European cloud landscape, the desk research has identified:

- 74 federated cloud initiatives – 16 from R&I and 58 from deployment
- 60 edge initiatives – 33 from R&I and 27 from deployment
- 12 green IT initiatives – 5 from R&I and 7 from deployment
- 111 initiatives addressing cloud, but with no specific reference to the three H-Cloud key areas above mentioned – 49 from R&I and 62 from deployment[1].

This analysis of the European Cloud Landscape has shown that:

- The European cloud market is maturing across all European industries and adoption has grown across all models (public, private, and, in particular, hybrid).
- To stay ahead of the global competition, European providers need to fill gaps both in terms of service offerings and of go-to-market strategies.
- Federated cloud is the focus of several deployment initiatives, primarily in the public sector, where there are no competitive barriers that hinder collaboration. Some examples are emerging also in the private sector, where ecosystem-centric business models are driving multiple companies to cooperate, even across industries, to innovate products and services, and enhance operational efficiency.
- Several research and innovation projects focus on Platform as a Service and edge computing solutions.
- Green computing outcomes are the by-product of innovations that make cloud and edge architectures efficient, but not the sole focus of projects and initiatives.

There are numerous cloud corporations with European headquarters and SMEs across all layers of the cloud market. They have the opportunity to grow, particularly in PaaS, SaaS and cloud support services, but to do so, they need to achieve technical innovation and overcome go-to-market strategy gaps. If they do not address these gaps, global hyperscalers will extend their dominant position from IaaS to other segments of the cloud market.

Successful federated cloud services with large-scale adoption are still a long way from reality. Several challenges need to be overcome, and considerable work must be done before they become mainstream. At the current stage of maturity, public sector organisations have a better chance of developing and adopting federated cloud services within a region or country because of 20 or more years of history of building shared services. As for the private sector, the emergence of ecosystem centric business models, mostly open and structured B2B

[1] The sum of federated cloud, edge, green IT, and cloud generic initiatives is higher than 246 because some initiatives entailed more than one topic of interest for this analysis.

marketplaces, are creating active demand for cloud federation, but require strong alignment of incentives to be scaled to tighter levels of collaboration; in fact, only a handful have adopted the 'One-stop-shop' or 'Full-Integrator' model.

The edge computing ecosystem is still emerging in Europe and will depend on the timeframe of the roll-out of 5G technologies. The edge ecosystem has many different layers, and a better understanding of the interrelation between cloud and edge is required. In addition, the layer at which federation makes sense in the edge ecosystem needs to be understood.

With European organisations now including requirements for the sustainability of IT equipment into their supplier requirements, green IT and energy efficiency have become design criteria for next-generation IT infrastructure. When building out edge infrastructure, thinking about the lifecycle of the equipment and defining standards and guidelines for lifecycle management are important. The same can be said about procurement of services: many cloud providers focus on the “green” label to attract new customers.

The three dimensions of federation, edge computing, and green IT are interlinked and should be considered at the same time. That is because federation can be an enabler of more efficient usage of computing resources, so that demand for electricity can be tamed. At the same time, edge computing architecture that are now being developed need to be optimised for energy consumption to avoid the proliferation of edge devices result in uncontrollable growth of electricity demand. Federation and edge are related, because edge resources are natively distributed and the ability to federate them securely and efficiently can augment and help realise the benefits of edge.

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1 INTRODUCTION

This section outlines the background, methodological approach, and structure of this document.

1.1 Background

H-CLOUD leads coordination and support activities for the consolidation and growth of the cloud computing research and innovation community in Europe, bringing together innovators, policy makers, cloud computing research, industry stakeholders, and users into a participatory and sustainable open forum. To address the challenges and opportunities arising at the research, technological, policy, standardisation, and organisational levels, H-CLOUD provides the community with a rich set of collaborative content, tools, and actions to overcome fragmentation and increase collaboration in Europe and beyond, while aligning on a common direction to help create a strategic research, innovation, and deployment agenda for cloud computing in Europe.

Cloud is a key pillar of the future of IT infrastructure enabling expansion of digital innovation across industries. In fact:

- By the end of 2021, 80% of enterprises will put a mechanism in place to shift to cloud-centric digital infrastructure twice as fast as before the pandemic.
- By 2023, an emerging digital infrastructure ecosystem will be the underlying platform for all IT and business automation initiatives anywhere and everywhere.
- By 2024, 80% of enterprises will overhaul relationships with infrastructure providers to better execute their digital strategy for ubiquitous deployment of resources and for more autonomous IT operations[2].

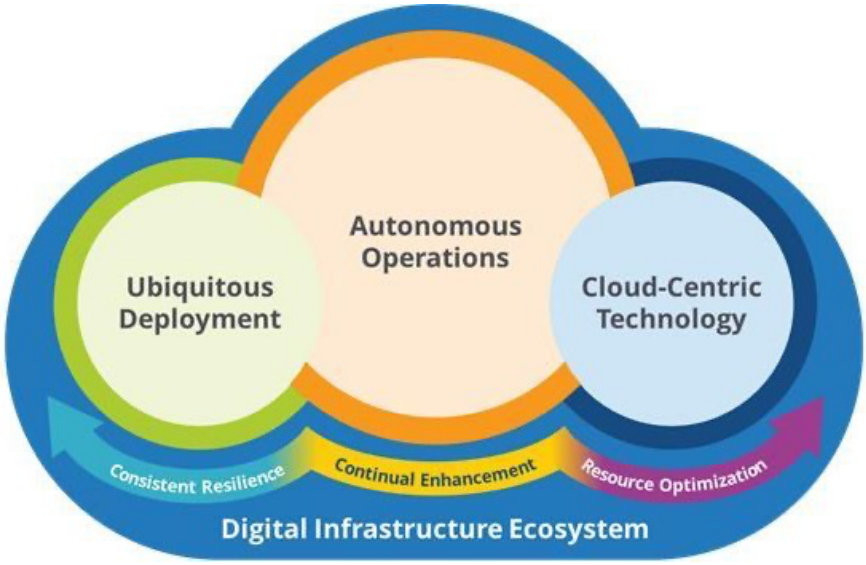

Figure 1: The central role of cloud in the emerging digital infrastructure[3]

[2] IDC Future of Digital Infrastructure, September 2020
[3] Source: Ibidem

However, it must be noted that elements other than technology innovation also play an important role in this context: governance, organisational structure and ultimately business success have a great influence on organisations' choices. All these elements must be investigated in order to build up a comprehensive picture of the European cloud computing landscape.

One of the activities performed by the project in this direction is represented by the collection of the foundational evidence which led to the development of an introductory overview of the European cloud landscape. 246 initiatives[4] have been profiled and analysed from two perspectives: research & innovation (European-funded projects in the field of cloud computing) and deployment (private and public initiatives making cloud computing services available for use).

As in the first release, the goal of this deliverable is:

- To map out the European cloud landscape in all its dimensions.
- To identify the positive outcomes of the work undertaken by the European cloud community and to spot potential gaps.
- To create a viable knowledge resource for use by the European cloud community.

In particular, the information collected will form the basis for the development of D1.4, Second release of the Best Practices Guide, and D1.5, Online Catalogue and Knowledge Transfer.

The second release of the Good Practices Guide (D1.4) will enrich the list of initiatives, providing added value to what is currently considered state of the art, and will present a model for the implementation of future actions in the cloud computing field.

The online catalogue (D1.5) will make the data collected within this deliverable available as an easily searchable collection of relevant cloud-related activities that will be integrated into the H-CLOUD portal. This catalogue will be continuously updated as more information is incorporated in the Cloud Computing Portfolio. Users will be able to filter their search results based on the categories, classifiers, and metadata defined within the portfolio, and their results will be displayed in an intuitive and user-friendly fashion. These search results will provide best-practice indicators that link back directly to their sources and will provide insightful information to the user.

1.2 Methodological Approach

The mapping of European cloud computing initiatives in this deliverable is based on desk research and augmented by interviews conducted to complete the first release of the Best Practices Guide (D1.3). This qualitative research encompasses European initiatives that have taken place or are being developed on a local, national, European, or global level and have been collected from different sources.

To create the second release of the Cloud Computing Portfolio, with specific reference to R&I EU-funded projects, we have further enriched the list of H2020 funded projects adding the following topics:

- **The Industrial Leadership Pillar**
  - Software Technologies (ICT-10-2016, ICT-16-2018)
  - Factories of the Future (FOF-12-2017, "ICT Innovation for Manufacturing SMEs")

[4] In the first release of the Portfolio we analysed 111 initiatives; this second release enriched the Portfolio with 135 more initiatives.

- Development, deployment and operation of ICT-based e-infrastructures (EINFRA-12-2017 “Data and Distributed Computing e-infrastructures for Open Science”)
- SME Instrument
- EU-Brazil, EU-Japan, and EU-Korea – joint calls

- **Societal Challenges Pillar**
  - Inclusive, innovative and reflective societies

For this second round of research, the team has performed a thorough research of relevant initiatives within the private and public sectors, enriching the number of sources used in the first release of the portfolio. The research expanded including the GAIA-X use-case directory[5], the IDS use-case directory[6], and the Cloud28+ directory[7], as well as major EU telecommunications companies’ and governments’ websites.

The methodology used in this report is based on the following steps, implemented between July 2020 and May 2021:

a) Desk research of the main public sources (mainly Cordis database and project websites) to identify more EU-funded projects in the field of cloud computing

b) Desk research on industry clouds and public sector initiatives

c) A first list of initiatives and initiative profiles frozen as of November 2020 to allow for analysis

d) The elaboration of desk research results

e) The production of this deliverable (D1.2 – V1.0), presenting the main results of the analysis taking as reference the preliminary findings outlined in D1.1

f) The update of the report addressing the recommendations formulated by the European Commission, with specific regard to the identification and analysis of the European cloud supply side (the portfolio has been enriched with 36 new profiles).

g) The production of this deliverable (D1.2 – V2.0), presenting the main results of the updated analysis.

1.3 Structure

This deliverable is structured as follows:

- **Section 1** outlines the background, the methodology, and the structure of the deliverable.
- **Section 2** provides an overview of the Cloud Computing Portfolio's structure
- **Section 3** presents the Cloud Computing Portfolio
- **Section 4** provides an analysis of the profiles identified, focusing on the three pillars (Federation, Edge, and Green IT) and describing the European cloud supply landscape.
- **Section 5** concludes the deliverable with main takeaways and next steps.

[5] https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html
[6] https://www.internationaldataspaces.org/get-involved/#usecases
[7] https://cloud28plus.com/EMEA/search?content_type=offerings

2 CLOUD COMPUTING PORTFOLIO STRUCTURE

This chapter describes the Cloud Computing Portfolio structure and the rationale behind it. It explains the main categories used for the profiling of the identified initiatives. The definitions used in this section are further explained in Appendix A – Glossary.

2.1 Portfolio Priority Areas

To map out the European Cloud landscape in all its dimensions, we have selected initiatives across two main contexts:

- **Research & Innovation:** Collaborative R&I projects funded by the European Commission under the H2020 research programme.
- **Deployment:** Private or public initiatives that make cloud computing services available for use; in particular:
  - Public initiatives (cloud initiatives managed and funded by governments, local or regional administrations, or other public sector organisations)
  - Private initiatives (collaborative industry clouds intended as cloud-based platforms through which multiple companies in an industry collaborate in some fashion towards a common goal, such as improving industry insight and/or capability, achieved by aggregating cost reductions, operational benefits, risk mitigation, and/or insight creation from pooled data/information; excludes single vendor commercial offerings)
  - Public-private initiatives (initiatives resulting from partnerships between public and private sector entities aiming to establish a dynamic ecosystem in the field of cloud computing)

Initiatives were selected if they included keywords on which the H-CLOUD project focuses – namely, cloud, federation, green, or edge.

- **Cloud:** As per NIST's definition, we consider cloud as having five essential characteristics – namely, on-demand self-service, broad network access, resource pooling, rapid elasticity or expansion, and measured service. (Appendix A describes this further.)
- **Federation[8]:** Federation is often discussed in the context of multi-cloud integration (federated cloud) and data sharing (federated data). Our analysis refers to both federated cloud and federated data more generally as federated IT service structures, or "federations" for short.

  Federations exhibit several essential characteristics:
  - A federation is an alliance of multiple organisations.
  - Participating organisations are "members" of the federation and collaborate for common goals.
  - Each federation has a "federating entity" at its core -- which can be either virtual or a real organisation separate from any member.
  - Members agree to conform with various technical standards and operating procedures that enable interoperation, collaboration and sharing, appropriate to the type and purposes of the federation.

[8] For a more detailed description, see "The Potential of Cloud Federation", Appendix 14 of the H-CLOUD Green Paper.

- Participation can involve a degree of sharing resources (including services, data, metadata or other assets).

These essential characteristics are reflected in the NIST Cloud Federation Reference Architecture[9] (NIST CFRA).

- **Green IT:** This relates to sustainable energy and materials to build and use computing resources.
- **Edge:** We consider edge computing not just as the pure functionality of supporting computation at the network edge, but through the full cloud-edge continuum – i.e., from cloud data centres, via intermediary edge devices and capabilities, to devices at the network edge.

2.2 Template Structure

Once the main contexts of the research and priority keywords had been identified, we proceeded with the development of a profiling template to include all the relevant information needed for consequent mapping and analysis.

We have built up a structure composed of four macro-areas, described as follows.

Macro-area 1: Identification. This includes an initiative name, acronym, accessible link, and contact person.

Macro-area 2: Description. Besides including an initiative description, duration, geographical scope, specific domain, and technology, this macro-area includes specific details on:

- **Initiative lifecycle stage:**
  - *Research and innovation projects* aimed at designing, engineering, prototyping, piloting, and demonstrating.
  - *Deployment initiatives* aimed at making services available for consumption on the market. For this stage, initiatives have been differentiated at an even more granular level between experimentation and deployment in controlled operational environments and deployment, operations, and support in operational/industrial environments.
- **Cloud delivery model:**
  - *Infrastructure as a Service (IaaS):* IaaS refers to services closely tied to the physical technologies themselves – notably, various types of compute, storage, and file system and networking and typically exposed as virtual machines ("instances") and managed with virtualisation tools such as OpenStack.
  - *Platform as a Service (PaaS):* In PaaS, the capability provided to the consumer is to deploy onto the cloud infrastructure consumer-created or acquired applications created using programming languages, libraries, services, 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 configuration settings for the application-hosting environment.
  - *Software as a Service (SaaS):* SaaS involves fully integrated software suites centred on specific activities. Major examples include customer relationship management (CRM), enterprise resource planning (ERP), and financial accounting, as well as office productivity tools like Google Office and DropBox. Microsoft's Azure offerings are largely SaaS, supported by flexible IaaS capabilities that are also sold to clients.

[9] https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.500-332.pdf

- **Cloud deployment model:**
  - *Public:* Public cloud services are open to a largely unrestricted universe of potential users and designed for a market, not a single enterprise.
  - *Local:* This refers to on-premises private cloud.
  - *Hosted Private:* In the private cloud scenario, third-party commercial cloud service providers offer customers access to private services that the service providers have built and they own and operate.
  - *Enterprise Private:* In the private cloud scenario, an enterprise typically either acquires a pre-integrated cloud services system or integrates component software and hardware elements and operates the cloud service for its own use.
  - *Hybrid:* This is a solution that includes two of more of the above deployment types.

Initiatives have also been categorised by the industries they serve. The main industries covered are:

- Manufacturing
- Agriculture
- Utilities
- Public administration
- Education and skills
- Finance
- Healthcare
- Information and communication industry
- Construction
- Retail
- Transport
- Professional services

Macro-area 3: Organisation. This macro-area includes details on the governance model, operating model, ownership, and control and on the main stakeholders.

Macro-area 4: Impact. This macro-area will capture good practices and aims at collecting information on uptake, customer satisfaction, socioeconomic impacts, and lessons learned.

A full representation of all the dimensions included in the H-CLOUD portfolio can be found in Appendix B. These dimensions will be searchable in an online catalogue by European organisations, policy makers, end users, and other interested parties.

3 THE EUROPEAN CLOUD COMPUTING PORTFOLIO IN NUMBERS

3.1 Description of European Cloud Portfolio

The European Cloud Portfolio encompasses a total of 246 initiatives (111 profiled in the first release and 135 added in this second release) relating to cloud computing, with a specific focus on federated cloud, edge computing, and green computing. In the R&I context, 99 H2020-funded projects were identified; 147 initiatives have resulted from desk research in the deployment area, of which 38 relate to the public sector, 95 come from the private sector (industry collaborative clouds), and 14 are from public-private partnerships.

In this updated European cloud landscape, the desk research has identified:

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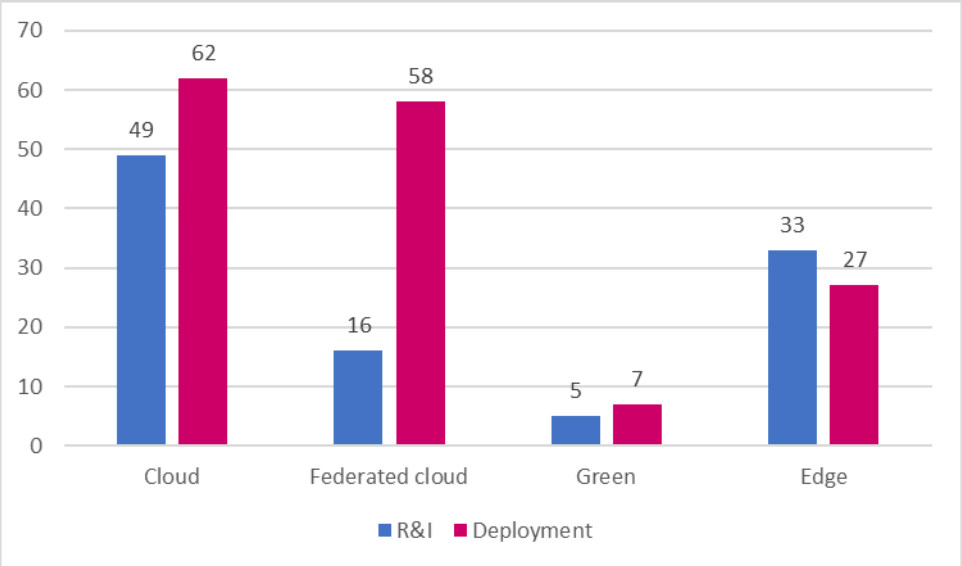

Figure 2: R&I and Deployment Initiatives by H-Cloud Relevant Keywords[10]

Figure 2 shows that:

- Green computing initiatives and projects are very few. Green computing is often a by-product of cloud infrastructure becoming more and more efficient. The EU Green Deal and the EU member states' recovery plans have a strong focus on sustainability. That combined with the growth of investments in edge computing architecture, which are not yet optimised for energy efficiency, are expected to drive more attention towards green in the next 3-5 years.
- The number of edge computing R&I projects is higher than edge deployment initiatives. This is the opposite of federated cloud, thus an indication of early stages of development of the technological capabilities and standards that underpin edge computing architectures.

[10] The sum of federated cloud, edge, green IT, and cloud generic initiatives is higher than 246 because some initiatives entailed more than one topic of interest for this analysis.

When looking at federated cloud initiatives, Figure 2 shows a healthy number of R&I (16) and deployment initiatives (58) active in this kea area. However, to get a complete understanding of these data, the level of integration and the consequent business model must be analysed. H-CLOUD has defined five different levels of federation business model: open marketplace, structured marketplace, reseller, one-stop-shop and full integrator[11]. Figure 3 shows the distribution of the initiative profiled taking into consideration the above-mentioned classification.

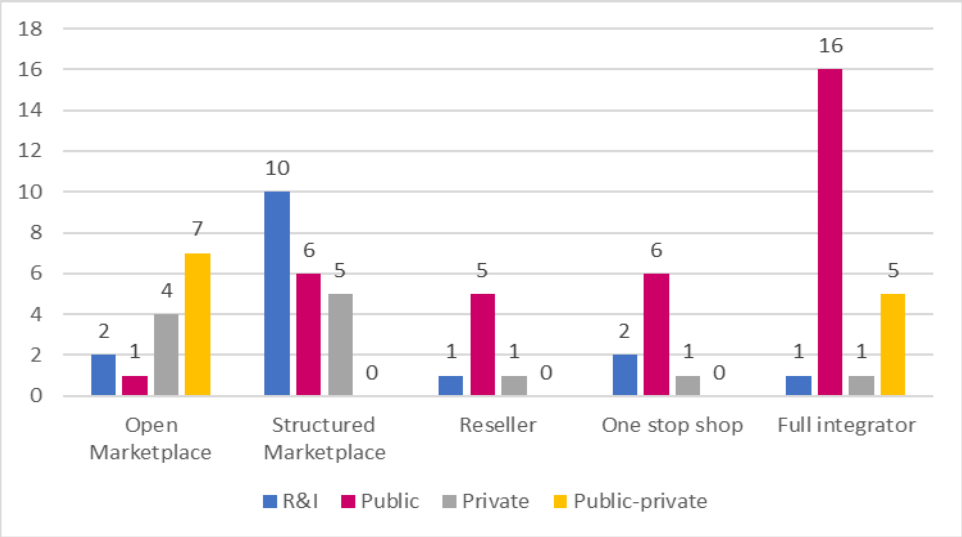

Figure 3: R&I and deployment initiatives on cloud federation

Federated cloud is the focus of several deployment initiatives, primarily in the public sector, where there are no competitive barriers that hinder collaboration. Some examples are emerging also in the private sector, where ecosystem-centric business models are driving multiple companies to cooperate, even across industries, to innovate products and services, and enhance operational efficiency.

At the current stage of maturity, public sector organisations have a better chance of developing and adopting federated cloud services within a region or country because of 20 or more years of history of building shared services. As for the private sector, the emergence of ecosystem centric business models, mostly open and structured B2B marketplaces, are creating active demand for cloud federation, but require strong alignment of incentives to be scaled to tighter levels of collaboration; in fact, only a handful have adopted the 'One-stop-shop' or 'Full-Integrator' model.

[11] For a full description of the five federation business models, see H-CLOUD Appendix 14 of the Green Paper "The Potential of Cloud Federation".

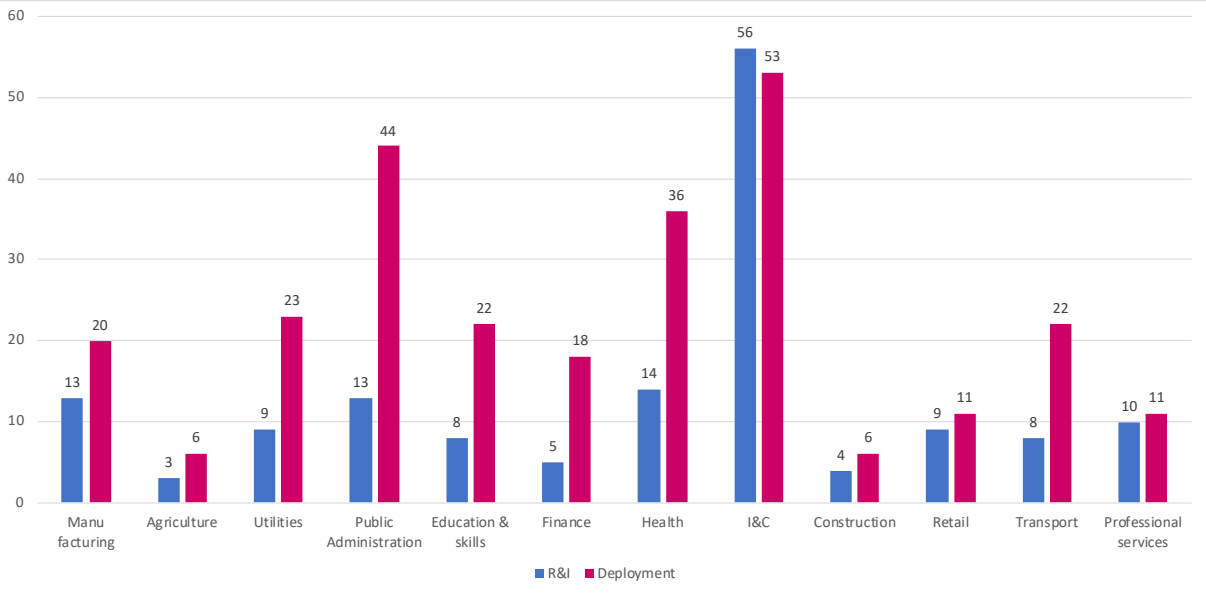

Figure 4: R&I and Deployment Initiatives by Sector[12]

Figure 4 shows the distribution of R&I and deployment initiatives by sector. The analysis has highlighted that:

- The ICT industry is the engine of R&I projects, which indicates a need to continue growing the involvement of end-user industries that can develop and test solutions that address practical business use cases.
- Public sector industries – public administrations, education and research, health – are involved in many deployment initiatives, indicating an appetite for cloud computing and the need to collaborate through federated cloud.
- Other industries primarily involved in cloud computing are manufacturing, utilities and transport, which are strategic industries for the European economy as a whole. And they are well aligned with the European Data Strategy's goal to leverage cloud to create open data spaces, such as "industrial data space", "energy data space" and "mobility data space".

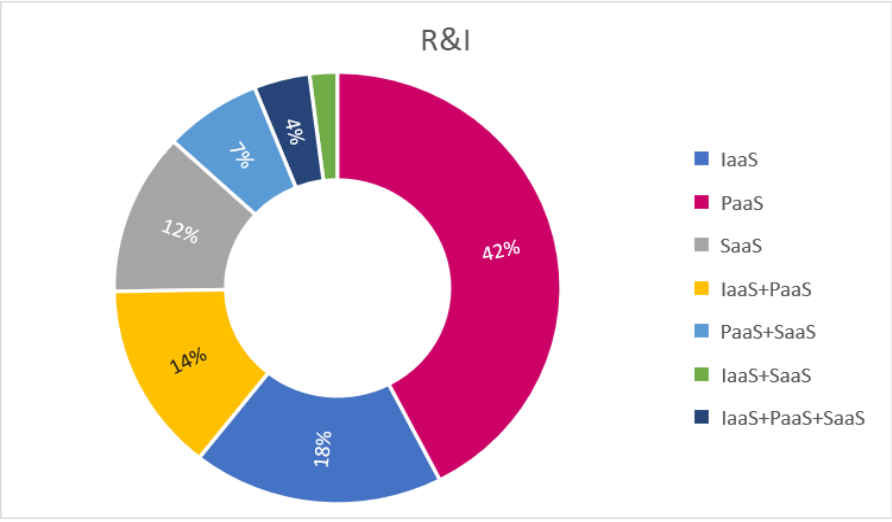

Figure 5: R&I Initiatives by Cloud Delivery Model

[12] Some initiatives involve more than one industry.

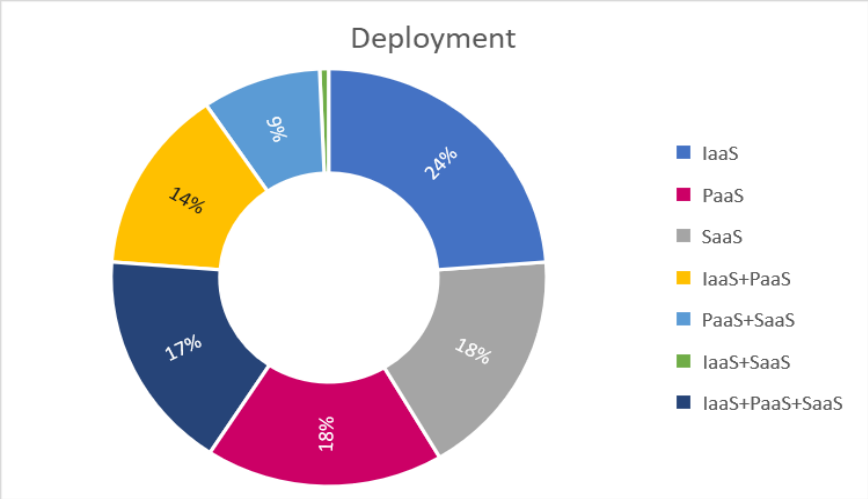

Figure 6: Deployment Initiatives by Cloud Delivery Model

Figure 6 and 6 show an important dichotomy between R&I projects and deployment initiatives. That is 42% of R&I projects are centred on Platform as a Service (PaaS), while 24% of deployment initiatives are centred on Infrastructure as a Service (IaaS). This indicates a high maturity of the IaaS market, both from a supply and demand perspective, while the PaaS market still leaves room for growth for cloud suppliers that will engineer and bring to market innovative solutions and knowledge in areas like data management, analytics, service deployment and service orchestration.

Cloud Deployment Model	Number of Initiatives	%
Public	37	31%
Local	1	0%
Hosted private	16	12%
Enterprise private	27	20%
Hybrid	66	37%
Total	147	100%

Table 1: Deployment Initiatives by Cloud Delivery Model

Hybrid and public cloud represent the majority of deployment initiatives (see *Table 1*). This is true also in the public sector, where many government entities have set up their own private or community cloud programs, but also leverage many public cloud solutions for selected workloads, like website hosting, collaborative tools, storage and back-up, and content management.

The breakdown of R&I projects by cloud deployment model is not represented here, because the vast majority of them are focused on design and development of tools to enable the deployment and operation of cloud services across hybrid, multi-cloud environments.

The European Cloud landscape is maturing quickly across industries and deployment and delivery models. However, more research and innovation and deployment support are needed, particularly focused on platform as a service capabilities and edge computing. Green computing outcomes are expected to be a by-product of innovations that will make cloud and edge architectures efficient, so that the ICT industry can contribute to the EU Green Deal sustainability ambitions; but it is not the sole focus of many projects and initiatives.

4 ANALYSIS OF THE EUROPEAN CLOUD LANDSCAPE

Cloud computing is a key enabler of the European Commission's digital agenda "Shaping Europe's Digital Future"[13]. Cloud can deliver business and technical benefits to both public institutions and private enterprises in Europe. It is also at the nexus of other technology trends, such as edge computing and green IT, which are expected to positively impact the European Data Strategy, the European Industrial Strategy, and the European Green Deal.

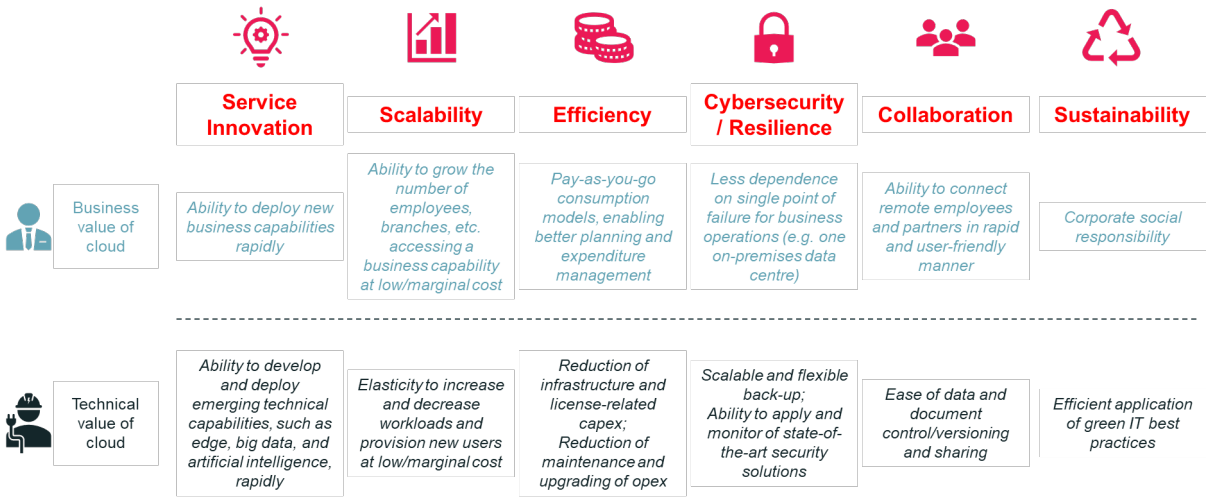

Figure 7: The Potential Business and Technical Value of Cloud Computing

However, to realise the benefits of cloud as an enabler of digital public services, next-generation industries, the data economy and clean and sustainable energy usage; regulatory, organisational, architectural, and data sharing concerns must be investigated to provide evidence to support the creation of enabling policies.

The European cloud landscape is a rapidly changing, collaborative and ecosystem-based landscape with a strong focus on security, data privacy and innovation. European organisations across all sectors see cloud computing services as the engine for their digital innovation. While many users have skills and experience in working with global hyperscalers, European cloud suppliers have engineered and brought to market services that are similar to those of global cloud providers in terms of technical capabilities. Given their regional/local presence and understanding of the local regulations and requirements, they also have the potential to offer value added features in terms of data sovereignty, industry and use case specific capabilities, legacy migration and cloud management skills that respond to the specific requirement of European users.

The analysis has highlighted that there is an evolution in cloud projects in Europe with most recent cloud projects and initiatives being centred on supporting the scalability of innovation accelerators such as AI, blockchain and IoT while the longest running deployment initiatives, for examples those in public sector, were founded to supply more traditional IaaS workloads. The focus of cloud R&I projects is at operator level, meaning that the project encompasses design, development, prototyping and production of technical cloud solutions rather than addressing business or organisational functions of brokering or regulating cloud solutions. Some projects are also at the enabler level, including software design and development to enable the deployment and operation of cloud services across hybrid, multi-cloud environments, while also maximising efficiency of computing infrastructure and complying with data privacy and security regulation.

[13] https://digital-strategy.ec.europa.eu/en

Organisational/business challenges have been successfully identified and will require additional investment to deliver services that are scalable, affordable and compliant.

4.1 Supply side analysis

The European supply side of cloud services is structured around the three main models defined by NIST in 2011[14]: Infrastructure as a Service (IaaS), Platform as a Service (PaaS) and Software as a Service (SaaS). Complementing those public cloud service models, there are ancillary services, such as hosting services and cloud support services.

- **Hosting services** are an evolution of infrastructure outsourcing that European enterprises and public sector have relied upon before cloud services became widely adopted. European organizations outsourced their IT infrastructure and applications or used a third-party provider to host their IT infrastructure and applications. There is still today a substantial market for outsourcing and hosting services in Europe, offered by both European and global suppliers, some that focus primarily on basic server co-location, others that offer system management for dedicated hosting instances. This market has evolved to offer hosted private cloud services, which are dedicated IT infrastructure services operated for a single customer at a time.
- **Cloud support services** are offered by suppliers that help end-users design, configure, implement, migrate to, orchestrate and manage IaaS, PaaS and SaaS. Examples of European cloud support service providers include Atos[15], Capgemini[16], Cloudeon[17], Computacenter[18], Devoteam[19], Nordcloud[20], TietoEVRY[21].

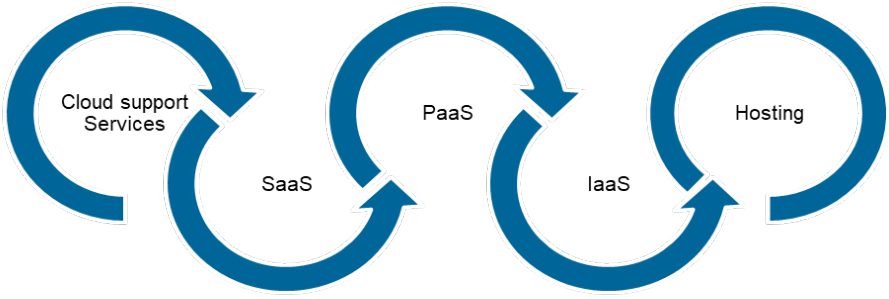

Figure 8: Cloud supply services models

4.1.1 Market overview

US-based vendors strongly dominate the public cloud market in Europe. They have been consistently increasing their market share over the past years, according to IDC's 2020 semi-annual public cloud tracker[22].

[14] https://csrc.nist.gov/publications/detail/sp/800-145/final
[15] https://atos.net/en/solutions/cloud-solutions
[16] https://www.capgemini.com/it-it/service/cloud-services/
[17] https://www.cloudeon.com/
[18] https://www.computacenter.com/us/solutions/cloud
[19] https://devoteamcloud.com/
[20] https://nordcloud.com/
[21] https://www.tietoevry.com/en/services/cloud-and-infrastructure/
[22] It must be noted that although IDC tracks a large number of providers, they may not be the totality of cloud suppliers. https://www.idc.com/tracker/showproductinfo.jsp?containerId=IDC_P29737

Sector	Market size	Concentration	Top 3 EU suppliers
IaaS	$11.6b	Highly concentrated, with the top 3 global suppliers that control almost 70% of the market: • AWS 54.7% • MS 9.3% • Google 5.5%	• OVH 3% • Orange Business Services 1.8% • T-Systems 1.2%
PaaS	$9.6b	Moderately concentrated, with the top 3 global suppliers that control approximately 47% of the market: • Microsoft 22.3% • AWS 15.6% • Salesforce.com 9.1%	• SAP 2.7% • Celonis 1.1% • Siemens 0.5%
SaaS	$44.3b	More fragmented, with top 3 global suppliers that control only 22% of the market: • Microsoft 10.6% • Salesforce.com 6.3% • SAP 4.7%	• SAP 4.7% • Visma 2.1% • Kaspersky 0.9%

Table 2. Public Cloud Services Market in Europe[23]

Public IaaS market. The top 3 vendors control almost 70% of the market, largely because of the massive footprint AWS holds in this space. This market segment has the highest number of European providers ranking within the top 10, i.e. Orange[24], Vodafone[25], T-Systems/Deutsche Telekom[26] and Atos. However, their role and market power are much smaller than that of the so called global hyperscalers.

Public PaaS market. The top 3 vendors (Microsoft, AWS, Salesforce) have 47% market share, and they continue to expand in Europe. In this market the concentration is lower than that of the IaaS market. Despite the slightly lower market concentration relative to Public IaaS, there are only 2 European vendors (i.e. SAP[27] and Siemens[28]) and one (Celonis[29]) that is headquartered both in Germany and the US.

Public SaaS market. The top 3 vendors (Microsoft, Salesforce, SAP) have 22% market share. While the leading vendors are US-based, with only 2 European vendors in top 10 (SAP and Visma[30]), market power is better distributed and because of the massive variety of use cases European vendors are in a better position to compete.

[23] This includes both Western Europe and Central and Eastern Europe, so it is a larger number of countries than EU-27.
[24] https://www.orange-business.com/en/solutions/cloud-computing
[25] https://www.vodafone.com/business/cloud-and-hosting
[26] https://www.t-systems.com/de/en/cloud-and-infrastructure
[27] https://www.sap.com/products/cloud-platform.html
[28] https://new.siemens.com/global/en/products/buildings/automation/cloud-solutions.html
[29] https://www.celonis.com/intelligent-business-cloud/the-cloud-platform
[30] https://www.visma.com/cloud-technology/

The global cloud hyperscalers have customers across Europe, but they only have data centers in select European countries, as it requires a high level of capital investment to open up a cloud datacenter. They are planning to broaden their network of datacenters in Europe, but will likely not cover every single European country, as the market potential especially in smaller countries does not warrant the capital expenditure. Global public cloud suppliers also play a prominent role or are the initiators of open source initiatives, such as Openstack, Docker, Kubernetes, Tensorflow, etc. As a result, they have become vendors of choice also among developers. Country level differences exist in terms of the appetite for cloud adoption. The UK and Netherlands have embraced public cloud services early on, whereas Germany and France have been slower to adopt and have favored working with European suppliers. However, the COVID-19 crisis, accelerated demand for hyperscaler services, hence US suppliers captured large part of the growth, particularly in the IaaS market.

- The hosting service provider market is divided into:
    - The hosted application management market, which grew 7% in 2020 in Europe reaching 4 Billion USD, led by TietoEvry, IBM, Equinix, Bechtle and Oracle, who together generate 47% of the market revenue. Examples of European providers in this space are Cegeka[31], Almaviva[32], CGI[33], Ordina[34], Telefonica[35], Nordcloud, and the telco service providers like T-systems, OBS[36], OVH[37], Telefonica, Ionos 1x1[38], BT[39], and Swisscom[40].
    - The hosting infrastructure services market , which grew 5% in 2020 in Europe becoming a 21 billion USD market, led by IBM, T-Systems, Equinix, Rackspace, and Telefonica, who together make up 18% of the market. In the hosting infrastructure market, there is a much higher fragmentation and variety of European local providers, like Orange, Inetum[41], TietoEvry, CGI, Almaviva, Indra sistemas[42], Ordina, Vodafone, Cegeka, etc.
- The cloud support services market - The provision of public cloud services (i.e. Public IaaS, Public PaaS and Public SaaS) cascades into a wide range of opportunities for IT services providers to deliver their services ranging from advisory and consulting to system integration and deployment services to managed and support services. Most public cloud services vendors maintain ecosystems of partners to deliver their services to the end customer. Fragmentation in the IT services provider landscape pertaining to professional and managed services associated with cloud is high, mapping largely the fragmentation found in the traditional IT services domain. This market segment includes:
    - The large systems integrators that are building internal competence centers or communities of practice for the major global cloud providers, starting where they are experiencing most customers' demand, which is for AWS, Microsoft Azure, Google Cloud platform and Alibaba. They are also investing in platform capabilities around Salesforce and ServiceNow. In building out their "practices", the systems integrators are investing in certifications for their employees to

[31] https://www.cegeka.com/en/ro/cloud-solutions
[32] https://www.almaviva.it/it_IT/Digital-Change/Cloud
[33] https://www.cgi.com/en
[34] https://www.ordina.nl/
[35] https://www.telefonica.com/en/
[36] https://obsproject.com/
[37] https://www.ovh.com/europe
[38] https://www.ionos.com/
[39] https://www.bt.com/
[40] https://www.swisscom.ch/en/about.html
[41] https://gfi.world/fr-en/
[42] https://www.indracompany.com/en

acquire favourable partner status rankings with the global cloud providers and fill the cloud skill shortage in Europe.

- Highly specialised cloud-native consultancy firms emerging, who focus on targeted market segments, such as cloud-native DevSecOps skills to help accelerate customer's development of cloud-native applications and capabilities. These fast-growing companies are often the target of acquisitions because the skills of their employees are scarce and sought after. For instance, the Danish Telco TDC acquired a 40% stake in Cloudeon in 2018 and IBM acquired Nordcloud in 2021.

There are European cloud suppliers in all layers of the cloud market. These include both large corporations that, as described above, hold significant market shares, and SMEs, as show in the table below.

Layer	Examples of large EU corporations	Examples of EU SMEs
Cloud support services	Atos, Capgemini, Computacenter, TietoEVRY	Devoteam, Nordcloud
SaaS	Visma, SAP	Talentsoft, Comarch
PaaS	Siemens, SAP, Celonis	A1 Digital, Scaleway, Citynetworks
IaaS	OVH, T-Systems, Orange Business Services	A1 Digital, Scaleway, Citynetworks
Hosting	Ionos 1x1, OVH, T-Systems, Orange Business Services, Telefonica	

Table 3. Examples of European large corporations and SMEs in the cloud market

4.1.2 Identified gaps and areas for improvement

The analysis has identified a number of gaps European providers need to address both in terms of service offerings and in terms of go-to-market.

In terms of service offerings:

- European IaaS suppliers are less advanced than global suppliers in the development of cloud-native offerings (e.g. server-less architectures based on containers and microservices). This is the result of a legacy offering focused on hosting and co-location, which have been complemented by virtual server offerings and are only slowly moving to cloud native environments.
- European PaaS suppliers are less advanced than global suppliers in the development of cloud-native emerging technologies, such as machine learning and artificial intelligence, IoT platforms and blockchain. They are either hosting their PaaS software in their own datacenter and offer it as a service, or more often are working with a global IaaS supplier to re-architect their software onto one platform, such as Siemens working with Microsoft for their IoT platform capabilities.
- European SaaS suppliers, including large companies like SAP, are still undergoing a transition from selling their software through a perpetual license model for on-premise

use to offering their software through a subscription model. As in the case of PaaS providers, many software vendors are transitioning to the SaaS model.

European cloud suppliers across all three areas, when they own their datacenter, operate at a smaller scale compared to global providers. Hence, they can afford smaller investments in efficient and resilient data center capabilities, in terms of systems management, energy efficiency, cybersecurity, and physical security.

European cloud suppliers across all layers of the cloud market – with the exception of few large cloud support services companies, like Atos and Capgemini – have less capacity to invest in go-to-market activities than their global counterparts. This results in:

- Marketing messaging limited to service features, functions and pricing, instead of thought leadership business value by industry,
- Lower influence on press and analyst firms,
- Fewer, less paid and less well-trained salespeople, pre-sales solution architects and after sales technicians,
- Less variety of pricing,
- Weaker onboarding, less attractive incentives and less appealing training programs for partners and developers,
- More limited capacity to contribute to open-source communities,
- Less investment available to fund pre-competitive proof-of-concept projects that show the value to the customer, before committing to long-term engagement.

In the case of European software vendors, there is an additional layer of transformation that they need to go through. They need to become platform as a service (PaaS) and software as a service (SaaS) providers, who offer their software solutions as a service, instead of through a perpetual license and installed on-premise. They are either hosting their software in their own datacenter and offer it as a service, or they are looking for a public cloud services partner to host the software and offer it as a service based on the IaaS service. SaaS vendors used to choose a single IaaS provider initially, to move their software onto one platform. In the next wave of evolution, they want to be able to run on multiple IaaS platforms, to offer their customers choice of IaaS provider. This opens new opportunities for European IaaS & PaaS providers to become part of the multicloud strategy of SaaS providers. There are hundreds of software companies in Europe, they all need to become SaaS providers and need IaaS and PaaS providers as partners.

4.2 A focus on H-CLOUD key areas

4.2.1 Cloud Federation

The analysis has highlighted that federated cloud services are still at the early stages of maturity but progressing well. Most private sector deployment initiatives and R&I projects have adopted open or structured marketplace models of federation. Whereas the public sector has embraced more integrated federation models, like 'One-Stop-Shop' and 'Full-Integrator'.

There is still no common approach or description for cloud federation, but one thing is clear – the objective is to bring cost efficiency, scale and speed to the complex IT tasks that European organisations need to implement. Federated models are common in the public sector, such as APIS IT[43] in Croatia, STATENS IT[44] in Denmark, or BRZ[45] and eGIZ[46] in Austria, building on

[43] https://www.euritas.eu/2017/01/30/apis-it-croatia/
[44] https://statens-it.dk/
[45] https://www.brz.gv.at/en/
[46] https://www.a-sit.at/egiz/e-government-innovationszentrum-egiz/

the public sector's long history of collaborative delivery of IT services across government departments and agencies. By contrast in the private sector, competitive pressures have historically represented a barrier; nevertheless, federated approaches are being increasingly explored in the private sector, as a way to develop and scale ecosystem-centric business models that span multiple organisations.

A good number of cloud federation projects are also about bringing together data from different sources to create information sharing platforms and reusability of tools, to empower people with knowledge. This is particularly true in knowledge intensive industries, such as life-sciences, where the huge upfront investments in R&D can be reduced through collaboration and healthcare services, where bringing together patient information – in a secure manner – can improve personalisation of care and outcomes.

Bringing clarity to the different layers of cloud federation (such as data, security, network, infrastructure, applications, platform services, testing and development, optimisation tool sets) and the value each layer adds can speed the adoption of cloud federation projects. The European cloud federation initiatives are multi-dimensional and have multiple delivery models including IaaS, PaaS, and SaaS. Given the scale as well as ecosystem-nature of cloud federation programs, the most frequent deployment model is public cloud. There is a strong preference to capitalise on open-source OpenStack public cloud platforms to enable this.

The cloud federation initiatives covered in this European Cloud Portfolio continue to be very siloed, and the geographic scope also varies -- ranging from national to European to global scope.

If cloud federation is to span cloud providers (both private and public) from all European countries, the following elements need to be put in place:

- Amplification of the business value,
- Clear definition of cloud federation,
- Deeper visibility and transparency into all projects to avoid repetitive services,
- Support and incentives to forge synergies between right technology layers,
- The technology architecture to bring together all providers,
- The cloud-based operating model to manage the federation,
- Technology standards for consistency,
- Support for cultural and attitude shift.

Currently, these components do not seem to be put into practice at scale.

R&I initiatives

The R&I cloud federation projects analysed[47] are initiatives aimed at bringing to the market codes, data exchange platforms, and tools to help developers focus on building customer solutions (such as smart contracts, or faster software development). These projects are also European in scope indicating the value of R&I collaboration and synergies to make cloud federation successful. The R&I cloud federation projects depend on the ecosystem to combine technologies, infrastructure layers and data sources to create business value for users.

Most R&I projects are not focused on a specific deployment model (public, private or hybrid). They are rather aimed at designing and developing software tools that enable the deployment and operation of cloud services across hybrid, multi-cloud environments, while maximising efficiency of computing infrastructure and complying with data privacy and security regulation.

[47] For the complete list of initiatives with the related federation categories, see Appendix C.

Public/public-private initiatives

These are projects and cloud service providers partly funded by governments and partly by the private sector.

One of the most notable cloud federation projects is GAIA-X[48]. The vision of the initiative is to create a connected and open data infrastructure layer to create an open, digital ecosystem to collect, share and analyse data without compromising on European privacy regulation requirements. GAIA X plans to connect decentralised infrastructure services such cloud and edge, and it is not intended to be competitive to global hyperscalers — it will be a layer on top of their services.

There are several other cloud federation projects, such as International Data Spaces[49] at the EU level, but also others at national level such as CODE-DE[50] (Germany) or Estfeed[51] (Estonia), are public-private initiatives. These projects create a common platform to connect ideas and outcomes, so more organisations can adopt the practices and scale the benefits.

To ensure success for this type of joint project, there needs to be active encouragement and funding of these initiatives. To prompt this active engagement, evidence shows that the collaboration between private and public sector needs to be focused on pre-competitive initiatives that support a broad community that has a higher societal purpose, such as Helix-Nebula in the scientific research space. Highlighting the success factors and benefits funded cloud federation projects can help boost more initiatives in this area.

Private initiatives

Although the federated cloud model is mostly present in the public sector, there is a growing number of private initiative-based cloud federations in Europe (Cloud28+[52], AquaCloud[53] among others). Most of the private initiatives related to federation aim at building cloud capabilities uniquely required in Europe – such as services that comply with specific regulations around data and security including GDPR.

4.2.2 Edge Computing

The Edge Computing market remains in its infancy in Europe. The analysis of the initiatives collected reveals that most of them are connected to private-sector deployment or research and innovation projects, with limited public involvement including Public Private partnerships. The market is still fragmented, with many independent initiatives using different standards, that are unconnected, ad provide limited guidance for a future consolidated ecosystem. Today, most initiatives focus on enabling infrastructure and platform (e.g. K3S[54]) for distributed services, maintaining a cloud-native approach.

Most European edge stakeholders are operators and enablers of solutions with a clear lack of regulators and brokers. This may be an indication of the overall low maturity of the market. The scale of the initiatives is often global, even if some European-only initiatives have been identified. This is in line with the expectations, as one of the driving forces of Edge Computing is the ability to enable cloud-like capabilities on a distributed footprint at large scale.

The technologies that are most interested in relation to Edge Computing are the Internet of Things and Big Data, with a component of artificial intelligence that IDC expects to be of

[48] https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html
[49] https://www.internationaldataspaces.org/
[50] https://code-de.org/de/
[51] https://eu-sysflex.com/estfeed-data-exchange-platform-by-elering/
[52] https://cloud28plus.com/EMEA
[53] https://aquacloud.ai/

[54] K3S is a lightweight version of the orchestration tool Kubernetes [“K8S”] now being increasingly adopted in the cloud.

increasing interest in the future[55], as soon as the infrastructure and platform technology stacks become more standard and commonly adopted.

R&I projects

R&I initiatives are starting to target the creation of a common ground for different players to build on top of the infrastructure and platforms that are available and distributed, targeting the developer environment. Two key aspects are at the centre of many projects: (1) the creation of a continuum from edge devices to networks and cloud, and (2) the development of toolsets for application development. For example[56], the RADON[57] project aims to establish a European DevOps framework for creating and managing microservices-based applications, running on edge at platform layer. UNICORE[58], is creating tools helping EU players to lead the next generation of cloud computing services and technology. Federation is targeted as well by R&I projects that aim to develop standards, as is the case of UNICORE, securing the data, as is the case of DECODE[59] activity, or industry specific applications, as is the case of Fed4IoT[60].

Private initiatives

Private-sector deployment initiatives are more popular, both from a provider standpoint and a user standpoint, very often already at the operational deployment stage of the project lifecycle. From a provider standpoint, the focus is largely on distributing capabilities, especially infrastructure capabilities, near to the customer premises in a hybrid approach. This is behind the value proposition of recent, locally focused initiatives as Edge Infra[61] as well as of established and global ones like Threefold[62]. Hybrid is one of the keywords for edge as IDC European research reveal that European buyers prefer to run edge workloads on-premise or in hybrid environments[63].

This approach raises sustainability considerations since broader distribution of less optimised infrastructure (compared to a cloud central data centre) may result in a higher consumption of resources. Some of the initiatives that have been analysed address this topic: Threefold has the reduction of the global internet consumption as one of its core values. The Green Edge Cloud[64] initiative, beyond using green energy to run the data centre facilities, re-uses the waste-heat to substitute the use of fossil-fuel.

The analysis also highlights that the overall edge market, particularly for the private initiatives, is skewed towards heavy asset industries, such as manufacturing, transportation or utilities and energy. For these industries, digital transformation requires the addition of instrumentation and intelligence to critical operating assets (such as presses, cutting machines, generators, pipelines, locomotives) so that they can be connected to the IT backbone to access the large amount of data generated and more efficiently manage the equipment. Examples are iXworld[65], Mindsphere[66], Wordsensing[67].

[55] IDC, Worldwide Edge Spending Guide
[56] Examples resulted from the analysis performed by the project team; see Appendix C for the complete list.
[57] https://radon-h2020.eu/
[58] http://unicore-project.eu/
[59] https://decodeproject.eu/
[60] https://fed4iot.org/
[61] https://www.edgeinfra.net/
[62] https://threefold.io/
[63] IDC, "Are Digital Leaders Deploying Edge Workloads in the Cloud?", October 2020, https://www.idc.com/getdoc.jsp?containerId=EUR146952120
[64] https://www.greenedge.cloud/
[65] https://www.index-traub.it/en/ixworld/
[66] https://siemens.mindsphere.io/en
[67] https://www.worldsensing.com/

4.2.3 Green IT

Sustainability is a key tenant of the European recovery plan. The IT industry, and in particular the cloud sector, can contribute in several ways. First, by federating cloud resources to increase utilisation that can compensate for the increase in computing capacity demand. Second, by switching to alternative energy sources to lower the carbon footprint of computing. This analysis shows that these strategic goals are not yet reflected in many deployment initiatives and R&I projects. But examples like Green Edge Cloud and Threefold are early signs of a changing attitude towards sustainability. Edge computing in particular is expected to require green technology innovation, because edge computing architectures will have to be optimised for energy efficiency so they help in achieving long-term carbon emission targets.

The key to make European green IT initiatives successful is to clearly define the KPIs and impact assessment to determine success. Clear definition, measurable outcomes, and continuous audits by independent bodies can help avoid "greenwashing" of technologies and approaches. This is important to make sure that the funding and research is directed to projects or initiatives that yield true benefits.

Large scale datacentres delivering cloud services have the potential to maximise server utilisation because of economies of scale. The green IT projects identified are working on reducing energy consumption by facilitating resource sharing, or bringing compute closer to the user, or even providing data-driven insights to take meaningful action and optimising energy usage. Green IT projects are leveraging modern or next-generation infrastructure such as serverless technologies, lightweight edge, or low-energy IoT infrastructure which are designed to be less resource-intensive, efficient, and scalable to minimise energy waste.

Working quickly to define the metrics and outcomes at pan-European level is important to eliminate the complexities for providers to work on unified standard guidelines to deliver services across Europe and eventually globally.

5 CONCLUSIONS

5.1 The Current European Cloud Landscape

This analysis of the European Cloud Landscape, including 246 R&I projects and deployment initiatives, shows that:

- The European cloud market is maturing across all European industries and adoption has grown across all models (public, private, and, in particular, hybrid).
- Federated cloud is the focus of several deployment initiatives, not only in the public sector, where there are no competitive barriers that hinder collaboration, but also in the private sector, where the growth of ecosystem-based business models are driving multiple companies to cooperate, even across industries, to innovate products and services, and enhance operational efficiency.
- Several research and innovation projects are focused on Platform as a Service and edge computing solutions.
- Green computing outcomes are the by-product of innovations that make cloud and edge architectures efficient, but not the sole focus of projects and initiatives.

The innovative solutions that are the subject of R&I projects and the governance models that are being scaled in deployment initiatives must be brought together to make federated cloud mainstream. They should focus on maximising:

- The efficiency of the European computing infrastructure – including the energy efficiency that aligns with the ambitions of the EU green deal
- Fostering data-driven innovation by focusing on specific use cases where technology can make an impact on priority European industries, like public sector, manufacturing, utilities, transportation and agriculture
- Ensuring trusted use of data in compliance with data privacy and security regulations and ethical guidelines.

Successful federated cloud services with large-scale adoption are still a long way from reality. Several challenges need to be overcome, and considerable work must be done before they become mainstream. At the current stage of maturity, public sector organisations have a better chance of developing and adopting federated cloud services within a region or country because of a long tradition of building shared services. As for the private sector, the emergence of ecosystem centric business models, such as B2B marketplaces, and innovation communities are creating active demand for cloud federation but require strong alignment of incentives to . be scaled.

The European cloud supplier landscape is characterized by strong concentration of market shares in the hands of global hyperscalers for Infrastructure as a Service, while more opportunities exist in other layers of the cloud market, such as PaaS, SaaS and cloud support services, for European cloud corporations and SMEs. To harness the opportunity offered by dynamic market evolution in PaaS, SaaS and Cloud Support services, European cloud suppliers need to fill technical innovation gaps, such as faster adoption of server-less architectures based on containers and development of cloud-native emerging technologies, such as machine learning and artificial intelligence, IoT platforms and blockchain. They also need to execute more compelling go-to-market strategies, including for instance thought leadership on the business value of cloud for specific industries and business processes, nurturing a partner and developer ecosystem through pricing incentives and training programs. The edge computing ecosystem is still emerging in Europe and will depend a lot on the timeframe of the roll-out of 5G technologies. The edge ecosystem has many different layers, and a better understanding of the interrelation between cloud and edge is required. In addition, the layer at which federation makes sense in the edge ecosystem needs to be understood.

With European organisations now including requirements for the sustainability of IT equipment into their supplier requirements, green IT and energy efficiency have become design criteria for next-generation IT infrastructure. When building out edge infrastructure, thinking about the lifecycle of the equipment and defining standards and guidelines for lifecycle management are important.

5.2 Next Steps

The information collected in the European Cloud Portfolio will represent the main content of the online catalogue available to all relevant stakeholders interested in obtaining deeper knowledge of what is being developed within the European cloud computing arena. The first version of the catalogue has been released in in February 2021 and will be further enriched with new profiles.

In addition, some of the initiatives profiled within this Portfolio will be further analysed through executive interviews aimed at assessing whether they could be considered success stories and good practices based on five identified criteria: business impact, technology innovation, organisational structure, data governance, and environmental and sustainability performance. The second release of the related deliverable is planned for May 2021.

Finally, the insights gathered in this landscaping exercise will inform the challenges and recommendations identified in the H-CLOUD Green Paper and subsequently captured in the Strategic Research, Innovation and Deployment Agenda, whose release is planned in 2021.

APPENDIX A - GLOSSARY

Cloud Computing

The original meaning of cloud computing related to having characteristics such as elasticity of resource supply and the automated provision of services, rather than any specific IT technologies. NIST's definition[68] of the five essential characteristics of the "cloud" is widely accepted:

- On-demand self-service
- Broad network access
- Resource pooling
- Rapid elasticity or expansion
- Measured service

In this definition, ICT services can be provided in a "cloud-like" way, without specifying the technology or business model to be used.

Cloud Federation

Federated cloud allows cloud-based services to be delivered to clients using a federated organisational structure. "Federation" more generally allows various services and/or assets provided by individual federation partners to be planned, deployed, and delivered seamlessly to clients in an integrated manner. Federation is one kind of coordinated organisational structure.

Federations are currently receiving extra attention as mechanisms to increase service capacity and capabilities in a multi-supply environment to augment each individual federation member's ability to serve a wider user base. In October 2019 the governments of Germany and France announced the Gaia-X federated cloud initiative, with a strong focus on creating a federated cloud and data capability. The EU discusses both cloud federation and data spaces (related to federated data) in its communication "A European Strategy for Data" (EUSD). There is also ongoing research on "federated cloud technology", much of it EC-funded and adopted by digital infrastructures to address challenging data processing requirements of research communities.

Federation is often discussed in the context of multi-cloud integration (federated cloud) and data sharing (federated data). Our analysis refers to both federated cloud and federated data more generally as federated IT service structures, or "federations" for short.

Federations exhibit several essential characteristics:

- A federation is an alliance of multiple organisations.
- Participating organisations are "members" of the federation and collaborate for common goals.
- Each federation has a "federating entity" at its core -- which can be either virtual or a real organisation separate from any member.
- Members agree to conform with various technical standards and operating procedures that enable interoperation, collaboration and sharing, appropriate to the type and purposes of the federation.
- Participation can involve a degree of sharing resources (including services, data, metadata or other assets).

[68] https://nvlpubs.nist.gov/nistpubs/Legacy/SP/nistspecialpublication800-145.pdf

These essential characteristics are reflected in the NIST Cloud Federation Reference Architecture (NIST CFRA).

The H-CLOUD project has published the paper “The Potential of Cloud Federation” in which organizational principles and best practices of federations are described, as well as mechanisms for technical and service organization and coordination[69].

Edge Computing

Edge computing is a distributed computing paradigm that brings computation and data storage closer to the location in which it is needed to improve response times and save bandwidth. It refers to the “edge” of the network, where a network connects with specific devices, such as smartphones, wearable devices, and Internet-of-Things (IoT) devices.

Green IT

Green cloud refers to the adoption of green principles across the cloud computing ecosystem and throughout all related equipment lifecycles.

[69] https://zenodo.org/record/4733566#.YJOoRrUzY2x

APPENDIX B – PORTFOLIO STRUCTURE

Macro-area 1: Identification	
Project Acronym	This database column should report the project's acronym.
Full name	This database column should report the project's full name.
URL link	This database column should include a URL link to an active webpage.
Contact	This database column should name the individual responsible for project leadership, including the organisations to which s/he belongs and his/her phone number and email address.

Macro-area 2: Description		
Project description	*This database column should include a short paragraph or a maximum of three bullets describing the strategic goals (WHY) of the project and the solutions developed/used (WHAT).*	**WHY**
		WHAT
Project type – actual cloud services	*Research & innovation collaborative projects (European, national, ...)*	**Research & innovation**
	Public initiatives (cloud providers funded by governments)	**Public initiative**
	Private initiatives for profit/ not for profit (industry cloud; no single-vendor commercial offering)	**Private initiative**
	Public-private initiative (i.e. Helix Nebula)	**Public-private initiative**
Duration	*This database column should indicate start and end dates – or no end date if the duration is indefinite.*	**Start date**
		End date
Object	*This database column should explain the focus of the project in terms of the deliverable(s).*	**Enabler** This includes the design and development of a technology that enables the operation of a cloud solution, such as a piece of hardware or software.

Macro-area 2: Description		
		Operator This includes the design, development, prototyping, and production of cloud solutions.
		Broker This entails the orchestration of third-party solutions through a marketplace, a catalogue, framework procurement agreements, an identity and access management portal, etc.
		Regulator This entails the definition, dissemination, and auditing of standards, certifications, and toolkits that help with the procurement, development, deployment, and management of cloud solutions.
Geographic scope	*Local, regional, national, multinational: within the EU, the whole of the EU, other world regions, or global*	**Local/Regional**
		National
		European
		Global
		Named area
Cloud delivery model	*This database column should outline whether this relates to:* • *Infrastructure as a service* • *Platform as a service* • *Software as a service* *as per NIST definitions.*	**IaaS**
		PaaS
		SaaS
Cloud deployment model	*This database column should outline whether this relates to:* • *Public cloud* • *Local cloud as a service* • *Hosted private cloud* • *Enterprise private cloud* • *Hybrid cloud* *as per IDC definitions.*	**Public**
		Local
		Hosted private
		Enterprise private
		Hybrid

Macro-area 2: Description		
Project lifecycle stage	*This database column should explain the stage of cloud solution development and delivery on which the project focuses:* • ***Research and development, including design and engineering**, prototyping, and pilot demonstration* • ***Experimentation and deployment** in a controlled but operational environment* • ***Deployment, operations, and support** in an operational/industrial environment*	**Research & development** **Small-scale deployment** **Operational deployment**
Industry	*This database column should reflect the industry as per IDC classification:* • *Construction* • *Education* • *Finance* • *Health* • *Information & communication* • *Manufacturing* • *Professional services* • *Public administration* • *Retail and wholesale* • *Transport* • *Utilities*	**Manufacturing** **Agriculture** **Utilities** **Public administration** **Education & skills** **Finance** **Health** **Information & communication** **Construction** **Retail** **Transport** **Professional services**
Specific domains targeted	*This database column should indicate the specific domains that the project targets:* • *Green deal*	**Green deal** **Science & research** **Mobility**

Macro-area 2: Description		
	• *Science and research* • *Mobility* • *Smart cities* • *Small and medium-size enterprises (SMEs)*	**Smart cities** **Small & medium-size enterprises**
Technology	*This database column should provide a qualitative description of the innovative technologies on which the project focuses beyond cloud. These could include, but are not be limited to:* • *Big data and analytics (BDA)* • *Social media* • *Internet of Things (IoT)* • *Artificial intelligence/ Machine learning (AI/ML)* • *Augmented reality/ Virtual reality* • *Blockchain* • *Edge computing* • *Next-gen connectivity: 5G/6G/wi-fi 6* • *Quantum computing*	**Big data** **Social media** **Internet of Things** **Artificial intelligence/Machine learning** **Augment reality** **Blockchain** **Edge** **Next generation connectivity** **Quantum**

Macro-area 3: Organisation		
Governance model	*This database column should describe the governance model of the initiative*	
Operating model	*This database column should explain how resources are organised to develop/ deliver cloud service:* • ***Centralised**: One legal entity is entirely accountable for organising resources to develop/deliver the service.* • ***Federated**: Service development/delivery responsibilities are distributed across a network but coordinated by an orchestration entity.* • ***Consortium**: Temporary collaboration is set up for the time of the project.*	**Centralised** **Federated** **Consortium**
Ownership and control		**Centralised** **Collaborative**
Business model	*nly for R&D projects, this database column should report the amount of investment in the project. It should also, where relevant, report the share of investment funded by the EU.* *or initiatives other than R&D, this database column should describe the models used to exploit the solutions designed and developed in the project:* • *Typology (licensing, subscription, corporate funding, support services, and government grant)* • *Distribution of annual revenues by category (% share)*	**Funding** **Typology** **Distribution revenues by category**

Macro-area 3: Organisation		
Stakeholders	*This database column should describe the mix of contributors to the project:* 1. *Public sector* 2. *Academia/Research organisation* 3. *Industry – to include R&D units of commercial enterprises* 4. *Community organisations (associations, PPPs, etc.)* *For each four categories, the names, roles, and countries of origin of the participants should be reported.* *R&D projects – a list of coordinators and partners – names and categories* *All other projects – the leader (name and type) and other participants (overall number + % distribution by category)*	**Public sector** **Academia/Research organisations** **Industry** **Community organisations** **Other participants (nr and %)**

Macro-area 4: Impact		
Uptake	*Target users (government, academia, industry, associations, and individual consumers)* *Number of users (most recent data)* *Growth rate (% increase from previous year)* *Revenues (previous year)* *Revenue increase (% from previous year)*	**Target users** **Number of users** **Growth rate** **Revenues** **Revenues increase**
Customer satisfaction	*Improvement of experience, quality of services, no lock in*	
Socioeconomic impact	*Impact on SMEs' industry competitiveness (not a target, low, medium, high)*	**Not a target** **Low** **Medium** **High**
Socioeconomic impact	This database column should describe the socioeconomic impacts of the project.	
Lessons learned	This database column should analyse what went well in the project and what could have been done differently with the benefit of hindsight.	

APPENDIX C – LIST OF INITIATIVES PROFILED IN THE EUROPEAN CLOUD COMPUTING PORTFOLIO

Appendix C shows the initiatives that have been included in the Portfolio and address federation, edge, and green IT.

The initiatives listed below will be consultable in the H-CLOUD online catalogue, which will include detailed descriptions, information on related stakeholders, and links to official websites.

R&I Initiatives Related to Cloud Federation

Name	Federation business model	Short Description
BEACON	Structured marketplace	An effective, agile, and secure federation of cloud networking resources
MUSA	Structured marketplace	A security framework to support the security-intelligent lifecycle management of distributed applications over heterogeneous cloud resources
CYCLONE	Structured marketplace	The management of multi-cloud application deployment, software defined networks, and federated entities
ENTICE	Reseller	Enables the integration, interoperability, and federation of storage providers
M-Sec	Open marketplace	A collaborative project between the EU and Japan, strengthening connections in the technological spheres of big data, IoT, blockchain, and cloud computing
SSICLOPS	Structured marketplace	Focuses on techniques for the management of federated private cloud infrastructures – in particular, cloud networking techniques
CHOReVOLUTION	Open marketplace	Provides an environment to enable interactions between various services currently provided by local authorities and to deliver advanced applications based on, for example, traffic conditions and local weather information
ACCORDION	One-stop-shop	Opportunistically brings together edge resources/infrastructures (public clouds, on-premises infrastructures, telecom resources, and even end

		devices) in pools, defined in terms of latency, that can support next-gen application requirements
ATMOSPERE	Structured marketplace	Considers a broad spectrum of properties and their measures, and supports the building, deployment, measurement, and evolution of trustworthy cloud resources, data networks, and data services
MELODIC	One-stop-shop	Enables data-intensive applications to run seamlessly within defined security, cost, and performance boundaries on geographically distributed and federated cloud infrastructures
SUNFISH	Structured marketplace	Provides infrastructure and technology to enable public sector players to integrate their computing clouds
Fed4FIRE+	Structured marketplace	Federation of experimental Internet facilities in Next Generation Internet (NGI) area supporting and offering testbeds based on technologies ranging from wireless, wired, 5G, IoT, big data, cloud services, and open flow.
Fed4IoT	Full integrator	Offers virtual silos as-a-service: isolated and secure IoT environments made of Virtual Things whose data can be accesses through standard IoT brokers (oneM2M, NGSI, NGSI-LD etc.).
EOSCpilot	Structured marketplace	Supported the first phase in the development of the European Open Science Cloud (EOSC).
BigDataStack	Structured marketplace	Delivers an infrastructure management system for the holistic management of computing, storage and networking resources, encompassing techniques for runtime adaptations of all BigDataStack operations.
ARTICONF	Structured marketplace	Researches and develops a novel set of trustworthy, resilient, and globally sustainable decentralised social media services.

R&I Initiatives Related to Edge Computing

Name	Focus
Pledger	A new architectural paradigm and a toolset that will pave the way for next-generation edge computing infrastructures
DECENTER	Delivers a robust fog computing platform covering the whole cloud-to-things continuum to provide the AI application-aware orchestration and provisioning of resources
ACCORDION	Opportunistically brings together edge resources/infrastructures in pools, defined in terms of latency, that can support next-gen application requirements
SELFNET	Designed and implemented an autonomic network management framework to achieve self-organising capabilities in managing network infrastructures by automatically detecting and mitigating a range of network problems still being manually addressed by network operators
RAPID	A secure unified model whereby almost any device or infrastructure – ranging from smartphone, notebook, laptop, and desktop to private and public cloud – can operate as an accelerated entity and/or as an accelerator serving other, less-powerful, devices in a secure way
CLARUS	Enhances trust in cloud computing services by developing a secure framework for the storage and processing of data outsourced to the cloud, allowing end users to monitor, audit, and retain control of the stored data without impairing the functionality or cost-saving benefits of cloud services
CLASS	Aims to develop a novel software architecture to help big data developers combine data-in-motion and data-at-rest analysis by efficiently distributing data and process mining along the compute continuum (from edge to cloud) in a complete and transparent way, while providing sound real-time guarantees
DITAS	Provides a framework, composed of an SDK and an execution environment, that aims to overcome barriers now hampering the adoption of cloud computing and aims to increase the adoption of fog computing by exploiting the full potential of these two paradigms in a synergic way
FogProtect	Delivers new and advanced architectures, technologies, and methodologies to ensure end-to-end data protection across the computing continuum, from cloud data centres through fog nodes to end devices
LightKone	Provides a scientifically sound and industrially validated model for doing general-purpose computation in edge networks

mF2C	Designing an open, secure, and decentralised multi-stakeholder management framework, including novel programming models, privacy and security, data storage techniques, service creation, brokerage solutions, SLA policies, and resource orchestration methods
NECOS	Addresses the limitations of current cloud computing infrastructures to respond to the demands of new services, as presented in two use cases that will drive the whole execution of the project
PrEstoCloud	Makes substantial research contributions in the cloud computing and real-time data intensive applications domains to provide a dynamic, distributed, self-adaptive, and proactively configurable architecture for processing big data streams
RECAP	Developing the next generation of cloud/edge/fog computing capacity provisioning via targeted research advances in cloud infrastructure optimisation, simulation, and automation
SESAME	Targets innovations around three central elements in 5G: the placement of network intelligence and applications at the network edge through network functions virtualisation and edge cloud computing; the substantial evolution of the small cell concept; and the consolidation of multi-tenancy in communications infrastructures, enabling several service providers to engage in new edge-computing sharing models
RAINBOW	Designing and developing an open and trusted fog computing platform that facilitates the deployment and management of scalable, heterogeneous, and secure IoT services and cross-cloud applications (i.e. microservices)
FITOPTIVIS	Developing an integral approach to the smart integration of image- and video-processing pipelines for CPS, covering a reference architecture supported by low-power, high-performance smart devices and by methods and tools for combined design-time and run-time multi-objective optimisation within system and environment constraints
FAR-EDGE	A joint effort to lead experts towards the smooth and broad adoption of virtualised factory automation solutions based on Future Internet technologies
Amable DIS	Enables the uptake of Advanced Manufacturing (AM) technologies by SMEs/mid-caps leading to the development of innovative business and service models and new value-chain models through an open-sourced-based, living and adapting AM eco-system which can offer required assistance.
RADON	Integrated methodology and an open-source toolchain aiming to define, evolve, and operate event-centric applications that consume serverless functions, allowing a high-degree of reuse and automation of functions, services and associated data pipelines.
SODALITE	Provides application developers and infrastructure operators with tools that abstract their application and infrastructure requirements to enable

	simpler and faster development, deployment, operation, and execution of heterogeneous applications reflecting diverse circumstances over heterogeneous, software-defined, high-performance, cloud infrastructures, with a particular focus on performance, quality, manageability, and reliability.
UNICORE	Develops tools to enable lightweight VM development to be as easy as compiling an app for an existing OS, thus unleashing the use of next generation of cloud computing services and technologies.
DECODE	Modular privacy-aware IoT hub with a free and open source operating system backed by a state of the art blockchain infrastructure supporting smart-contracts and privacy protections.
Fed4Fire+	Federation of experimental Internet facilities in Next Generation Internet (NGI) area supporting and offering testbeds based on technologies ranging from wireless, wired, 5G, IoT, big data, cloud services, and open flow.
Fed4IoT	Offers virtual silos as-a-service: isolated and secure IoT environments made of Virtual Things whose data can be accesses through standard IoT brokers (oneM2M, NGSI, NGSI-LD etc.).
Bright Beyond HPC	Aimed to solve the cluster management problem in HPC, big data/Hadoop and OpenStack cloud computing by developing and bringing Bright Beyond HPC to market readiness.
VISUM	IR spectroscopy cloud-enabled platform for the rapid, easy integration and customisation of real-time monitoring systems for improved process control, product quality and safety in the food and pharmaceutical industries.
Smartscope-X	Eye screening device uses artificial intelligence and cloud computing to automatically diagnose eye diseases.
PREDISMART	Develops an AI and Big Data platform for the smart efficient use of facility managements, energy and waste management in cities.
Wonderlogic STUDIO	End-to-end environment for industrial process design, simulation and PLC programming
Ida	Combines sensor technology, machine learning & cloud computing to translate raw data (behaviour of cows) from the field into meaningful information that can be used to support decisions made by farmers every day.
Cloud Diagnosis	Development of low-cost cloud monitoring for the diagnosis and prognostic of the wind turbines.
INPUT	Novel edge computing framework specifically designed to enable Personal Cloud Services in 5G-ready softwarised network infrastructures.

ONEEdge	OpenNebula's ONEedge is a distributed cloud management platform that aggregates on-demand cloud resources across multiple edge locations to enable innovative and low-latency next-generation services.

R&I Initiatives Related to Green IT

Name	Focus
COMMUNITY CLOUD	Developing a cloud service to replace centralised server farms with a distributed data centre based on a peer-to-peer network free of infrastructural costs
CLOUDWATCH2	Supporting EU R&D on cloud computing, software, and services across the full innovation lifecycle and move to market, promoting technology advancements and supporting OS software reusability
AFarCloud	Providing a distributed platform for autonomous farming to enable the integration and cooperation of agriculture cyber-physical systems in real-time to increase efficiency, productivity, animal health, and food quality and to reduce farm labour costs
FNS-Cloud	Aiming to overcome fragmentation problems by integrating existing FNS data – which is essential for high-end pan-European FNS research – and by addressing FNS, diet, health, and consumer behaviours, as well as by promoting the exploitation of sustainable agriculture and organic farming
Catalyst	CATALYST aspires to turn data centres into flexible multi-energy hubs, which can sustain investments in renewable energy sources and energy efficiency.

Deployment initiatives related to cloud federation

Name	Sector	Federation business model	Focus
CINECA	Public sector	Full integrator	High performance computing, focusing on IT solutions and services for universities and for the Italian Ministry of Education and Research
PagoPA	Public sector	Reseller	Increasing the uptake of trusted digital payments in the public sector
SPOTES	Public sector	Structured marketplace	Enhancing the IT services experience for French civil servants
BUILD TO SHARE	Public sector	One-stop-shop	Accelerating the digital transformation of the Irish government and providing common capabilities across departments of different size
BMI	Public sector	Full integrator	Sharing secure data-centre infrastructure across the German federal government
STATENS IT	Public sector	Full integrator	Managing IT operations to improve capacity utilisation and asset maintenance
LOGIUS	Public sector	One-stop-shop	Offering lower expenditure, improved efficiency, and better services for citizens and businesses through smart ICT solutions
VALTORI	Public sector	Full integrator	Providing high-quality, reliable, and harmonised basic IT services
CSI Piemonte	Public sector	Full integrator	Delivering shared IT infrastructure, applications, and end-user support services
Trentino Digitale	Public sector	Full integrator	Delivering shared IT infrastructure, applications, and end-user support services
SIAG	Public sector	Full integrator	Delivering shared IT infrastructure, applications, and end-user support services
Arsenàl.IT	Public sector	One-stop-shop	Delivering a shared platform and application services
ARIA	Public sector	One-stop-shop	Delivering shared IT infrastructure, applications, and end-user support services
Lepida	Public sector	Full integrator	Delivering shared IT infrastructure, applications, and end-user support services

Insiel	Public sector	Full integrator	Delivering shared IT infrastructure, applications, and end-user support services
Dataport	Public sector	Full integrator	Delivering a shared platform and application services
AGID Cloud Marketplace	Public sector	Structured marketplace	A catalogue of AGID-certified cloud service providers
BRZ	Public sector	Full integrator	Delivering shared IT infrastructure, applications, and end-user support services
NICS-ESS	Public sector	Full integrator	Delivering efficient and effective customer-focused services, combining HR, IT, finance, digital services, and property management
G-Cloud	Public sector	Structured marketplace	A catalogue of cloud services certified by the UK government and included in framework procurement agreements
P-Direkt	Public sector	Reseller	HR application and business processing services
NoiPA	Public sector	Full integrator	HR application and business processing services
LGMA	Public sector	Reseller	HR application and business processing services
SPCSS	Public sector	Full integrator	Delivering IaaS, PaaS, and SaaS services in the public sector
DCOM	Public sector	Reseller	SaaS solutions developed for local administration
CIRB/BRIC	Public sector	One-stop-shop	Offers e-government services through platforms for citizens (IRISbox, Fix My Street, smartcity.brussels portal) and specific platforms (for pooling CCTV images, BOS, Nova).
Polish Common State IT Infrastructure Program – WIIP	Public sector	Full integrator	Responsible for increasing the security of data processed in IT systems of public administration entities and for optimising the costs of maintaining these systems.
Romanian Government Cloud	Public sector	One-stop-shop	Government cloud aiming to provide the necessary infrastructure for all institutions that have the obligation to take over and store the information of the beneficiaries of

			public services, as well as to protect their data.
APIS IT	Public sector	Full integrator	Government cloud IT infrastructure defining, implementing and maintaining the technology and best practices that support eGovernment.
Estonian Government Cloud	Public sector	Reseller	Government cloud aiming at increasing the cost-effectiveness of the public sector, increasing the public information security capacity and carrying out large-scale temporary projects, enabling the provision of high-quality uninterrupted service.
NIZS	Public sector	Structured marketplace	Creation of a new data center capacity in several premises enabling the operation of the new Hungarian governmental systems, the establishment of a server park affected by cloud-based operation, furthermore, the replacement of some existing machine rooms in a substandard condition.
eSPap	Public sector	Structured marketplace	The Public Administration Shared Services Entity, IP (eSPap) has the mission of ensuring the development and provision of shared services within the scope of the Portuguese Public Administration
CODE	Private sector	Structured marketplace	Driving innovation and supporting improvements in cancer care, addressing information gaps by providing timely information on anti-cancer medicine use via healthcare systems
Aquacloud	Private sector	Structured marketplace	Innovation project from the Norwegian aquaculture sector that collects and consolidates data sets from different aquaculture companies to solve a shared problem – predicting and preventing the outbreak of sea lice.
Advaneo Data Marketplace	Private sector	Structured marketplace	Decentralised portal where all relevant and possibly sensitive raw data always remains with the data provider and only is transferred directly – peer to peer – to the buyer in the event of a purchase
ThreeFold Grid	Private sector	Structured marketplace	Peer-to-peer network of storage and compute capacity. It creates a decentralised, privacy focused, and secure resource pool of participants that add their compute and storage capacities to a grid.

Cloud 28+	Private sector	Structured marketplace	Provides a marketplace through which European cloud providers can showcase their cloud services built on HPE and OpenStack technology.
Container xChange	Private sector	Structured marketplace	Neutral online platform for organisation of one-way container moves, digitisation of operational handling, container tracking and invoicing.
Datahub	Private sector	Open marketplace	Ensures uniform communication methods and standardised processes for professional participants in the Danish electricity market in order to stimulate competition and optimise market conditions for electricity consumers.
365FarmNet	Private sector	Open marketplace	Digital platform allowing farms to be managed across different business units - without being dependent on a brand or manufacturer.
Oren	Private sector	One-stop-shop	Mining and B2B industrial marketplace offering solutions, software, services and integrated workflows to accelerate digital and sustainability transformation across the end-to-end value chain.
Atrias	Private sector	Open marketplace	Joint initiative of Belgium's six electricity and gas distribution grid operators, to build, deploy and manage a single clearing house application.
WeNMR	Private sector	Open marketplace	WeNMR is a Virtual Research Community aiming at bringing together complementary research teams in the structural biology and life science area into a virtual research community at a worldwide level.
EODC Cloud	Private sector	Open marketplace	The EODC is a start-up company aiming at working together with multi-national partners from science, the public and private sectors in order to foster the use of earth observation (EO) data.
EGI	Public-private	Full integrator	The EGI Federated Cloud is a IaaS-type cloud, made of academic private clouds and virtualised resources and built around open standards. Its development is driven by requirements of the scientific community.

Helix Nebula Science Cloud	Public-private	Full integrator	A hybrid cloud platform linking commercial cloud service providers and publicly funded research organisations' in-house IT resources, via the GEANT network, to provide innovative solutions in support of data-intensive science
CREODIAS	Public-private	Full integrator	Cloud infrastructure adapted to process large amounts of Earth observation (EO) data, including an EO data storage cluster and dedicated IaaS cloud infrastructure for the platform's users
WEkEO	Public-private	Open marketplace	The EU's Copernicus DIAS reference service for environmental data, virtual environments for data processing, and skilled user support
CODE-DE	Public-private	Open marketplace	Offering high-performance access to all Copernicus data throughout Germany
GAIA-X	Public-private	Full integrator	Aiming to connect decentralised infrastructure services, such cloud and edge, via a user-friendly homogeneous system
SENSORIS	Public-private	Open marketplace	A data standard and exchange for the automotive industry that defines consistency for gathering in-vehicle data
IDS	Public-private	Full integrator	Aiming to create a secure data space that supports enterprises in different industries and of different sizes in the autonomous management of data
Estfeed (E-elering)	Public-private	Open marketplace	Energetics-centric IT infrastructure developed in cooperation with partners to offer all interested parties the chance to develop, market, and use smart solutions
Entso-e	Public-private	Open marketplace	Providing continuous and free access to key information on the European grid for all market participants and other stakeholders
ELIXIR	Public-private	Open marketplace	ELIXIR is an initiative that will allow life science laboratories across Europe to share and store their research data as part of an organised network.
de.NBI Cloud	Public-private	Open marketplace	de.NBI is a national, academic and non-profit infrastructure providing bioinformatics services to users in life sciences research and biomedicine in Germany and Europe.

Deployment Initiatives Related to Edge Computing

Name	Sector	Focus
MindSphere	Private sector	Industrial IoT as a service solution that uses advanced analytics and AI to power IoT solutions from the edge to the cloud.
Osram LIGHTIFY	Private sector	IoT platform to control lighting elements individually or in groups
Green Edge Cloud	Private sector	Distributed cloud infrastructure based on OpenStack that reduces CO2-equivalent life-cycle emissions through the reuse of waste-heat.
Libelium IoT	Private sector	Platform tracking goods and production assets through technology solutions based on IoT
EdgeInfra	Private sector	Provides neutral micro-datacenter and colocation services at the ultra-local edge of network and mobile infrastructure in Europe.
q.beyond	Private sector	Full-stack provider, q.beyond provides all the essential elements for ready-to-use, scalable IoT solutions via edge computing.
CloudFerro	Private sector	Offers elastic and customisable cloud solutions in a public, private or hybrid cloud deployment model, based on open source technologies.
Ansaldo SpA	Private sector	Gathers and analyses equipment data as a basis for Predictive Maintenance and Service to facilitate faster, more efficient processes
iXworld	Private sector	Cloud-based platform that covers every aspect of the customer machine, from researching specifications during the purchasing process to monitoring and optimising operations to requesting service for the machine.
Vizuu	Private sector	Digital cockpit for industrial containers (IBC) creating real-time transparency for the entire logistics chain.
ThreeFold Grid	Private sector	Peer-to-peer network of storage and compute capacity. It creates a decentralised, privacy focused, and secure resource pool of participants that add their compute and storage capacities to a grid.
Vivacity Labs	Private sector	Captures and classifies real-time transport usage through cutting-edge Machine Learning techniques

BrianzAcque	Private sector	The Casette dispenser (system to distribute outdoor high-quality filtered drinking water dispensers throughout the territory for the citizens). It can be seen as a multifunctional edge IoT device able to run cloud-native applications locally that have been developed as a part of a larger architectural digital transformation of the company.
Axis	Private sector	IP camera producer, developing products that use open standards and edge and are scalable and easy to integrate into different platforms.
Worldsensing	Private sector	Designs and builds sensing solutions to remotely monitor critical assets (and the structural health thereof) within mining, construction, and rail networks, helping engineers to monitor and anticipate geotechnical incidents, such as ground movements/landslides, to ensure the safety of workers, passengers, and citizens.
K3S	Private sector	Kubernetes distribution designed for production workloads in unattended, resource-constrained, remote locations or inside IoT appliances.
Qarnot	Private sector	Qarnot provides cloud HPC on a disruptive platform.
Nodeweaver	Private sector	NodeWeaver is a zero-management Edge cloud fabric - integrating storage, networking and virtualization in a single system.
Eurotech	Private sector	Eurotech is a global company following the technological paradigm of Pervasive Computing which involves miniaturisation and the distribution in the environment of intelligent devices and their possibility of communicating.
Uni Systems	Private sector	Unisystems is an IT company offering computer systems integration design services and maintenance services.
Capgemini	Private sector	Capgemini is a global leader in consulting, digital transformation, technology and engineering services including cloud, digital and platforms.
Plusserver	Private sector	Plusserver is a managed cloud service provider for small and medium-sized enterprises.
The Valencia Smart City Project	Public sector	Integrates data and processes of municipal services into a platform that would help improve the efficiency and responsiveness of administration.
GAIA-X	Public-private	Aiming to connect decentralised infrastructure services, such cloud and edge, via a user-friendly homogeneous system.

FIWARE	Public-private	A framework of open-source platform components to accelerate the development of smart solutions.

Deployment Initiatives Related to Green IT

Name	Sector	Focus
Polymore	Private sector	A digital B2B-market for the sustainable plastics industry (compounds, recyclates, and post-industrial waste) in Europe.
Green Edge Cloud	Private sector	Distributed cloud infrastructure based on OpenStack that reduces CO2-equivalent life-cycle emissions through the reuse of waste-heat.
ThreeFold Network	Private sector	Peer-to-peer network of storage and compute capacity. It creates a decentralised, privacy focused, and secure resource pool of participants that add their compute and storage capacities to a grid.
Cloud & Heat	Private sector	Cloud&Heat Technologies develops, builds and operates energy-efficient data centers.
Estfeed (E-elering)	Public-private	E-elering – a portal to give customers access to data and services. Estfeed data platform – an energy data exchange for accessing, sharing, and managing meter data across data suppliers (data hubs), data users, applications (via the E-elering app store and data access management), and customers.
Entso-e	Public-private	A transparency platform to provide continuous and free access to key information on the European grid for all market participants and other stakeholders.
CODE-DE	Public-private	Offering high-performance access to all Copernicus data throughout Germany.