Grant Agreement N°: 871920
Topic: ICT-13-2016
Type of action: CSA

Horizon Cloud – The Forum for Strategy Focused Cloud Stakeholders

D1.4: Success Stories and Good Practices Guide

Second release

Revision: v.1.0

Work package	WP 1
Task	Task 1.2
Due date	May 2021
Submission date	July 2021
Deliverable lead	IDC Italy
Version	1.0

Abstract

This deliverable represents the second release of the H-CLOUD Success Stories and Good Practices Guide. It identifies and describes initiatives that provide added value to what is currently considered state of the art within the European cloud landscape and presents recommendations for future actions in the cloud computing field.

Keywords:

Cloud computing, cloud federation, edge computing, green IT

Document Revision History

Version	Date	Description of change	List of contributor(s)

Disclaimer

Project co-funded by the European Commission under the Horizon Cloud Programme		
Nature of the deliverable:	R	
Dissemination Level		
PU	Public, fully open, e.g. web	√
CI	Classified – information as referred to in Commission Decision 2001/844/EC	
CO	Confidential to the H-CLOUD project and Commission Services	

** R: Document, report (excluding the periodic and final reports)*
DEM: Demonstrator, pilot, prototype, plan designs
DEC: Websites, patents filing, press & media actions, videos, etc.
OTHER: Software, technical diagram, etc

EXECUTIVE SUMMARY

This deliverable represents the second release of the H-CLOUD **Success Stories and Good Practices Guide**. The report describes 58 private, public and research cloud activities providing added value to the state of the art within the European cloud landscape, investigating their key success factors and drawing conclusions and recommendations. The report builds upon and enriches the first release by adding a substantial number of additional good practices, deepening the analysis and drawing new conclusions and recommendations. All the information collected and presented in these deliverables is published in the **Online Catalogue and Knowledge Transfer** (D1.5), in order to share it with the H-Cloud community and interested third parties through the project's website.

The deliverable is part of the outcomes of the H-CLOUD project. 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 researchers, industry stakeholders, and users into a participatory and sustainable open forum. To address the challenges and opportunities arising at the research, technology, policy, standardisation, and organisation 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.

Success stories and good practices in this deliverable have been identified primarily through a series of executive interviews, complemented by desk research.

The 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. Taking as reference the sources used in Cloud Computing Portfolio (D.1.1 and D.1.2, including H2020 cloud-related funded projects, IDC's industry cloud tracker, and IDC Government Insights research), the research expanded beyond these sources and included the GAIA-X use-case directory, the International Data Spaces (IDS) use-case directory, and the Cloud28+ directory, as well as major EU telecommunications companies and governments' websites.

The interviews aimed at assessing whether the cloud-related initiatives could be considered success stories and good practices based on five identified criteria: Business Impact, technology innovation, organisational structure, data governance, and Green IT (environmental & sustainability performance).

The 56 cloud computing good practices (28 identified in the 1st release and 28 in the 2nd release) were selected out of a long list of 200 candidate initiatives (65 in the 1st release and 135 in the 2nd release) identified through desk research and preliminary analysis. The good practices featured in this report were analysed through in-depth interviews performed from June 2020 to September 2020 (1st release) and from January 2021 to May 2021 (2nd release) (their record cards are published as a separate report as an Appendix). Overall, 16 of the good practices come from the public sector, 30 from the private sector, 7 are selected from research projects, and 3 are public-private partnerships (PPPs).

The research highlighted that many challenges are being addressed with creative solutions, but there is still a long way to go to come up with a general set of good practices that can be applied broadly.

The key success factor in **federation** is adoption/participation. As indicated in both the H-CLOUD Green Paper and good-practices analysis, an increase in the number of users of shared, community, or federated services generates a positive network effect. However, it must be noted that it is difficult to achieve widespread adoption and collaboration due to, among others, organisational resistance and the presence of competing companies. Realising the benefits of collaborative programmes such as community clouds and federated clouds revolves around an ability to bring people together through the service lifecycle, from design

and financing to implementation, operations, and consumption. The good practices identified succeeded in this by creating organisational and cultural change mechanisms that foster collaboration and by establishing structures and processes that make the collaborative supply of cloud services efficient, effective, and compliant with regulations – in particular, compliance with data laws and policies.

We have learned of ways to overcome these challenges. For example, Cloud28+ created a community of service providers with a shared business interest. These providers publish their services using a joint service catalogue on the Cloud28+ platform; City Network has adopted OpenStack as its underlying technology to enable federation at the technology architecture level; and Aquacloud, Polymore, and GAIA-X are working to provide a standard data model to create value for participants in their ecosystems. Academic research networks had to find effective IAM solutions to manage users across dynamic communities.

The H-CLOUD Green Paper highlighted various **edge**-relate challenges, mostly resulting from ad-hoc innovation from different initiatives in this space, often without coordination or even collaboration on basic principles and standards. Concerns include edge investments ROI, development and adoption of edge standards, the scalability and affordability of solutions, especially for SMEs, and interoperability. Many of the initiatives featured in this report are active in researching and developing new solutions that leverage **edge computing**. For these initiatives, the business case is quite clear, as edge is seen as the enabler of use cases that could not be developed in other ways, thus diminishing doubt regarding ROI for edge solutions.

With reference to **edge** good practices, a Business Impact is present across the majority of the initiatives analysed (Vivacity Labs, Axis, and the City of Valencia, among others), which underlines how technology suppliers and end-user organisations are looking at edge innovation to gain business benefits. As identified in the initiatives analysed, technology innovation represents another big-impact area. The approach of distributing computing capabilities is not a new trend, but edge can be seen as an emerging technology, with hardware and software platform innovations opening up new possibilities. Moreover, when edge computing is combined with other emerging technologies/innovation accelerators, it offers great potential. The main challenges to emerge from the interviews relate to technology – edge innovation still being in its infancy and difficulty in utilising developments in chip manufacturing (silicon), hardware infrastructure, and software platforms – and compliance (i.e. hurdles related to GDPR compliance). To promote edge computing it is important to develop the relevant skills, to implement and scale up 5G networks which support edge-to-cloud integration by its nature, and to ease and rationalise regulations and governance concerning cloud-to-edge interoperability in Europe, in the same data-flow continuum.

In the second release we found a higher number of good practices in the field of **Green IT** and sustainability, even though Green IT is still not a mainstream achievement. There are companies optimising their entire value chain to optimize energy consumption and minimise CO2 emissions, such as Green Data Center and OVHcloud. Several initiatives are working to develop new models and metrics to calculate CO2 impacts (for example of cloud microservices). For many cloud organizations though Green IT is an afterthought or a by-product of IT infrastructure transformation rather than a strategic priority.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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 in 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.

One of the key goals of this project is to investigate and describe the landscape of cloud computing initiatives in Europe. This was undertaken through the development of the **Cloud Computing Portfolio,** described in two successive deliverables (D.1.1 and D.1.2). The other major objective was to analyse the cloud landscape identifying good practices providing lessons learned and insights on main success factors. This is the objective of this report "**Success Stories and Good Practices Guide**" which builds on in-depth interviews in order to:

- Identify the positive outcomes of the work undertaken by the European cloud community, highlighting success stories and good practices.
- Develop recommendations for the implementation of future actions in the cloud computing field.

This deliverable D.1.4 is the second release of the "**Success Stories and Good Practices Guide**", which builds upon and enriches the first release by adding a substantial number of additional good practices, deepening the analysis and drawing new conclusions and recommendations. However, the analysis and the recommendations concern the whole group of good practices, not only those of the second release. All the information collected and presented in these deliverables is published in the **Online Catalogue and Knowledge Transfer** (D1.5), in order to share it with the H-Cloud community and interested third parties through the project's website.

1.2 Methodological Approach

The identification of success stories and good practices in this deliverable is based on desk research and a series of interviews.

The qualitative research encompasses European initiatives that have taken place or are being developed at a local, national, European, or global level and have been collected from different sources. Taking as reference the sources used in D1.1 and D1.2 Cloud Computing Portfolio (i.e., H2020 cloud-related funded projects, IDC's industry cloud tracker, and IDC Government Insights research), the research expanded beyond these sources and included the GAIA-X use-case directory[1], the IDS use-case directory[2], and the Cloud28+ directory[3], as well as major EU telecommunications companies and governments' websites.

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

The interviews aim to assess whether cloud-related initiatives could be considered success stories that include good practices based on five identified criteria: Business Impact, technology innovation, organisational structure, data governance, and environmental & sustainability performance.

The methodology used in this report adopted the following steps:

a) It started with a broad review of opportunities and challenges in cloud federation, edge computing and green IT. This desk research included a review of a sample of scientific literature[4], the IDC knowledge base[5] and EU funded projects.
b) It entailed an analysis of the research findings to cluster the long list of opportunities and challenges that were identified into key areas where good practices could lead to improved outcomes:
    - Business Impact
    - Technology innovation
    - Successful governance/organisational structure
    - Efficient and effective data governance
    - High environmental and sustainability performance

    For example, challenges such as technical resource optimization, virtualization and load balancing, and opportunities, such as the emergent technologies like AI and augmented reality/virtual reality that are often cloud native, were clustered under 'technology innovation'. While challenges such as data security and privacy, data sharing and ethical use of data, were clustered under 'efficient and effective data governance'. This part of the analysis was conducted in close alignment with WP3.
c) The good practice areas were the basis for the creation of the interview guide.
d) In parallel, the portfolio of initiatives identified in D1.1 and D1.2 was reviewed to identify those that could represent good practices, in at least two of the key areas that could lead to improved outcomes/impacts.
e) The outreach to executives and managers of those potential good practices continued until the good practice interview covered of all key areas of where good practices could lead to improved outcomes/impacts, for cloud federation, edge computing and green IT.
f) Once the interviews had been conducted, they were analysed to elaborate and present the main result of the analysis (i.e. the production of this deliverable).

1.3 Structure

This deliverable has the same structure as the previous release but with a more articulated classification of good practices and more in-depth analysis of results. The report is structured as follows:

- Chapter 1 outlines the background, methodology, and structure of the deliverable.

[4] https://www.researchgate.net/profile/Faraz-Fatemi-Moghaddam/publication/282755844_Cloud_Computing_Challenges_and_Opportunities_A_Survey/links/561b79b308aea80367239862/Cloud-Computing-Challenges-and-Opportunities-A-Survey.pdf;
https://journals.sagepub.com/doi/full/10.1155/2014/190903;
http://text2fa.ir/wp-content/uploads/Text2fa.ir-A-Survey-of-Load-Balancing-in-Cloud-Computing-1.pdf;
https://arxiv.org/ftp/arxiv/papers/1201/1201.4522.pdf;
http://weisongshi.org/papers/shi16-edge-computing.pdf;
https://arxiv.org/pdf/1609.01967.pdf;
https://arxiv.org/abs/2008.03252;
https://ieeexplore.ieee.org/abstract/document/7977013;
https://www.researchgate.net/publication/342096188_Green_Computing_-Trends_and_Challenges;
https://www.ijser.org/researchpaper/Emerging-Issues-of-Green-Computing-in-IT.pdf;;

[5] https://www.idc.com/getdoc.jsp?containerId=US46020420;
https://www.idc.com/getdoc.jsp?containerId=US46098520

- Chapter 2 provides an explanation of the criteria used to identify success stories through the interview guide.
- Chapter 3 presents the good practices in summary and provides an analysis of their achievements according to the 5 areas of analysis, that is Business Impact, technology innovation, governance and organisational structure, data governance, and Green IT and environmental performance.
- Chapter 4 provides an overview of the key messages from the good practices from the point of view of H-Cloud strategic priorities: federated clouds, edge computing and green IT.
- Chapter 5 concludes the deliverable with the lessons learnt from the cases presented and proposes some recommendations on how to overcome challenges to EU cloud providers and to policy makers.
- **Appendix**: the appendix presents the record cards of 60 interviewed initiatives (even though only 56 are good practices). This is a separate report for practical reasons, because of its length (almost 200 pages).

2 INTERVIEW GUIDE STRUCTURE

The research undertaken for this deliverable aims to identify examples of success stories and good practices in the European cloud computing landscape. In particular, the objective is to identify initiatives particularly successful in relation to three main areas: cloud federation, edge computing, and green IT.

As indicated above, for a case to be classified as a success story/identified as a good practice, the initiative concerned needed to fulfil at least two of the following outcomes/impacts:

Business Impact/ Impact: For private initiatives, the requirement is to show a combination of results about users, offering, and revenues. A success story should be beyond the proof-of-concept (PoC) stage (i.e., actual usage in operation for some real scenarios) and should demonstrate good performance in at least two of the following areas:

- Uptake: service user numbers equal to or better than planned
- Uptake growth rate: positive user growth – above a certain threshold (10%) compared with the previous year
- Revenue growth: positive revenue growth – above a certain threshold (5%) compared with the previous year
- Customer satisfaction: measured and higher than expected
- High quality offering: equal to or better than planned, measured by the number, scope, and quality of the services delivered
- Increase in usage volume: measured as an increase in transactions compared with the previous year

For R&I or PPP initiatives with pre-commercial services, we consider their actual or potential **Business Impact** defined as successful pilots, clear targeted market, high quality exploitation plan, high potential Business Impact when going to market.

Technology Innovation: The initiative should offer highly innovative cloud services based on cutting-edge technologies – edge computing – with a disruptive impact on business processes. The main questions to identify a success story in this case are:

- Does the initiative include at least one innovation accelerator – augmented reality/virtual reality (AR/VR), blockchain, artificial intelligence (AI), the Internet of Things (IoT), edge, and/or next-gen security?
- Does the initiative have an impact on business processes?

Governance/Organisational Structure: The initiative should deploy a successful cloud federated model (or another collaborative model, such as a procurement alliance) and have a substantial breadth of representation of the stakeholder ecosystem. For an initiative to be identified as a success story, one or more of the following should be achieved:

- An organisational structure that successfully supports active collaboration and stakeholder participation
- Participant-organisation numbers by country, industry, and company size equal to or better than planned

Data Governance: The initiative should have efficient and effective data governance (an excellent performance in at least one aspect). To be considered a success story, the initiative should show an excellent performance in at least one of the following aspects:

- Data protection compliant with regulations and good practices
- The implementation of data sovereignty for stakeholders
- Effective and efficient data sharing

- Efficient and effective data security

Green IT (Environmental and Sustainability Performance): The initiative should address green computing/energy efficiency. For an initiative to be identified as a success story, one or more of the following elements should be present:

- The use of efficient IT cloud architecture and resources
- The use of renewable energy sources
- The use of energy efficient technologies

The methodology described above allowed us to identify some interesting cases within the cloud computing landscape. However, another objective of this deliverable was to develop guidance and recommendations for future actions in the cloud computing field. For this reason, the interviews included questions to identify technical, legal, and economic barriers and to collect lessons learnt. In this respect, interviewees were asked to provide a description of the barriers encountered during the implementation of the initiatives, if any, and how they addressed and potentially overcame those barriers.

All success stories and good practices have been annotated in 'record cards' (Appendix 1).

3 SUCCESS STORIES AND GOOD PRACTICES OVERVIEW

The Success Stories and Good Practices Guide presents 56 cloud computing success stories (28 identified in the 1st release and 28 in the 2nd release) with specific achievements in the area of federated clouds, edge computing, and green computing. They were selected out of a long list of 200 candidate initiatives (65 in the 1st release and 135 in the 2nd release) identified through desk research and preliminary analysis. The good practices featured in this report were analysed through in-depth interviews performed from June 2020 to September 2020 (1st release) and from January 2021 to April 2021 (2nd release) (their record cards are published as a separate report as an Appendix). Overall, 16 of the good practices come from the public sector, 30 from the private sector, 7 are selected from research projects, and 3 are public-private partnerships (PPPs) as shown in the table below.

In the second round of interviews the authors focused specifically on the private sector to provide insights on the European cloud offerings and achievements, as suggested by H-Cloud mid-term review. The team carried out 23 interviews out of which 19 good practices were identified. The 4 companies not considered good practices are profiled in the record cards appendix.

Area	No. of potential good practices (1st release)	No. of potential good practices (2nd release)	No. of good practices (1st release)	No. of good practices (2nd release)	Total Good Practices
Public sector	17	3	10	6	16
Private sector	31	97	11	19	30
Research & innovation	14	32	5	2	7
Public private partnerships	5	3	2	1	3
TOTAL	**65**	**135**	**28**	**28**	**56**

Table 1: Overview of Good practices by type

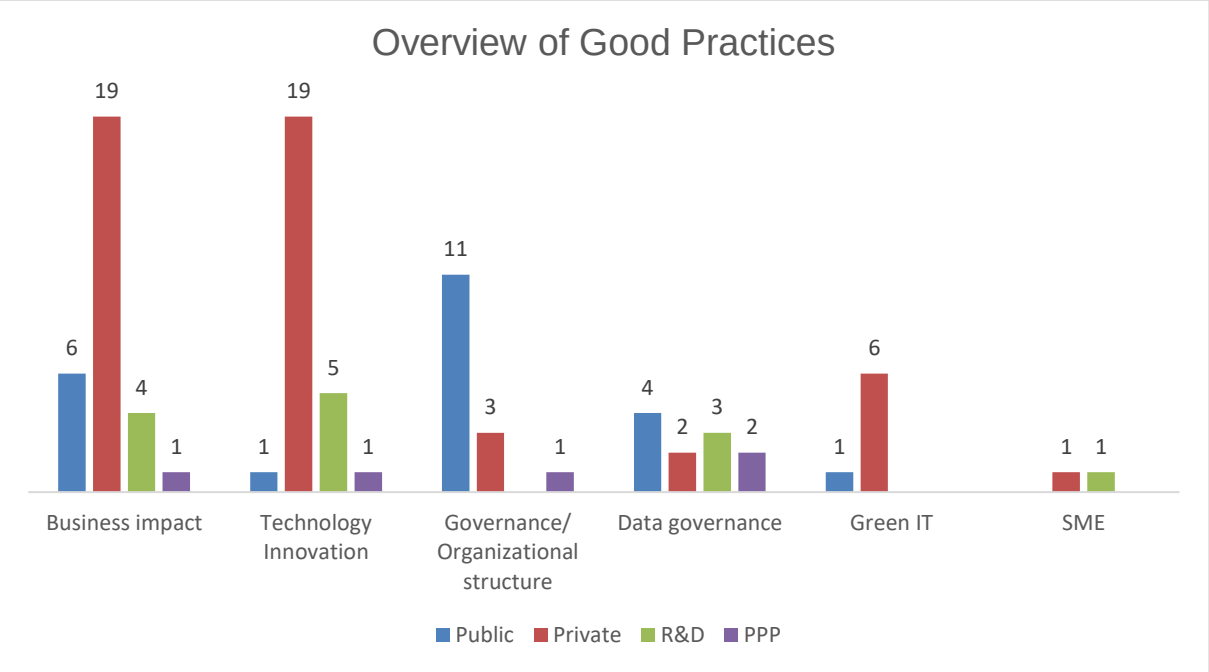

Figure 1: Good Practices by Type (Practices may qualify for more than one criterion)

The distribution of good practices by success criteria (Figure 1) shows that almost all private initiatives achieve Business Impact and a majority feature well for technology innovation. About a third are also successful in Green IT, but relatively few private initiatives can be considered good practices for data governance and organizational structure (at least based on our criteria). Many public initiatives show good practices achieving Business Impact, but also for data governance and organizational structure. R&I initiatives as could be expected show good practices for technology innovation. PPPs (a very small group with only 3 cases) perform well for data governance and organizational structure, as it can be expected given that public-private alliances must by definition develop well-balanced governance models.

The following sections provide more in-depth analysis of the good practices, articulated by type, success factor and activity in the key H-Cloud domains, that are federated cloud models, edge computing and green IT.

3.1 Description of Stories

3.1.1 Public Sector

European public administrations have shared their IT resources for over 30 years to achieve economies of scale in procurement, skills, and operations. The 15 cases analysed here offer a wide variety of experiences; in fact, they represent 12 different countries, 11 of which are EU members, plus the UK. And they cover all layers of government, from national to regional/state to local/city (see *Table 2* below).

Name	Country	Level of Government	Relevance for H-Cloud Key Areas	Status of the Initiative	Type of Good Practice
Austrian Federal Government EGIZ and BRZ*	Austria	National	Federated cloud	In operation	• Governance/ Organizational structure

Bulgarian Ministry of Transport*	Bulgaria	National	Federated cloud	In development	• Data governance
City of Valencia*	Spain	City	Edge computing	In operation	• Business Impact
de.NBI	Germany	National	Federated cloud	In development	• Governance& Organizational structure • Data Governance
Digital Portugal	Portugal	National	Federated cloud	In development	• Governance/ Organizational structure
EGI Federation	Multinational	European	Federated cloud	In operation	• Business Impact • Governance/ Organizational structure
eSPAP	Portugal	National	Federated cloud	In operation	• Governance/ Organizational structure
G-Cloud*	UK	All levels	Federated cloud	In operation	• Business Impact • Data governance
International institution	Multinational	European	Federated cloud	In operation	• Business Impact • Data Governance
Irish Government Cloud*	Ireland	National	Federated cloud	In development	• Governance/ Organizational structure
Logius*	Netherlands	National	Federated cloud	In operation	• Governance/ Organizational structure • Technology innovation
Polish Common State IT Infrastructure Program – WIIP*	Poland	National	Federated cloud	In operation	• Data governance
Regional government IT shared service centre*		Regional	• Federated cloud • Green IT	In operation	• Business Impact • Green IT
SPOTES*	France	National	Federated cloud	In development	• Governance/ Organizational structure
Statens IT*	Denmark	National	Federated cloud	In operation	• Business Impact • Governance/ Organizational structure

WeNMR	Netherlands	National	Federated Cloud	In operation	• Governance/ Organizational structure

Table 2: Summary of Public Sector Initiatives Featuring Good Practices (= included in the 1st release of the deliverable)*

At least 8 of these public initiatives have followed a common journey, whereby the government launched programmes to centralise IT services and then leveraged the shared service centre to embrace the cloud computing paradigm. It must be noted that the business model for shared service centres varies across cases. Some of the analysed examples invested primarily to centralise the delivery of IT operations, while others acted primarily as brokers/buyers of services purchased on behalf of multiple government institutions from external service providers. When these jurisdictions transitioned to the cloud, those that had built a central IT operations centre invested first to become full integrators of private and public cloud services, while those that were primarily brokers and buyers of services set up marketplaces for public cloud services.

In the context of the H-CLOUD study, these experiences are relevant because they provide important lessons/learnings, particularly in terms of governance and organisational change that can be applied to federated cloud programmes. They provide some evidence around green IT sustainability, but mostly as a by-product of the efficiencies that come from centralising and modernising the delivery of IT infrastructure and operations. One of them, the City of Valencia, provides anecdotal evidence in the context of understanding the uptake and impact of edge computing in government. It indicates that European governments are at a very early stage of discovering potential use cases of edge – for instance, in the context of Smart Cities.

3.1.1.1 Austrian Federal Government *

The Austrian government started a digital reform process almost 20 years ago. Austria was lagging behind in terms of the EU's eGovernment Benchmark. So, the decision was taken to create two agencies at the federal government level, which took the lead in digital transformation programmes:

- The eGovernment Innovation Centre (EGIZ)[6] is in charge of strategic innovation. EGIZ focuses on the feasibility and prototyping of new solutions. EGIZ has an unbiased perspective of companies selected to do the work to implement those solutions in a production environment. One of EGIZ's strategic goals is to ensure openness and interoperability are the gold standard for government technology innovation. Any organisation, down to the municipal level, can leverage the work of EGIZ. The need to do so is particularly urgent in small to medium-sized public administrations because, internally, they have the resources only to carry out day-to-day activities.
- The Federal Computing Centre (BRZ)[7] is the operating arm. It provisions finance applications, citizen web portals and registries, scanning and printing services, and business intelligence (BI) and analytics solutions for the federal government.

The Austrian Federal Government's initiative includes a good practice related to **governance for federated cloud**.

Governance and Organizational Structure

Separating innovation (EGIZ) from implementation (BRZ) has helped the Austrian Federal Government focus all government innovation decisions on interoperability standards, feasibility, and prototyping, as defined in a minimum set of guidelines. At the operational level,

[6] https://www.egiz.gv.at/en/
[7] https://www.brz.gv.at/en/

the key goal is to keep the service catalogue commercially competitive in the long run for the Austrian Federal Government by continuously adjusting the balance of the service portfolio between what is shared and what is left to the individual ministries. EGIZ and BRZ collaborate closely. But they are managed and funded separately – EGIZ is contracted for work by the Federal Ministry of Digital and Economic Affairs, while BRZ is partially funded through a chargeback model – to maintain the independence of decision making. And they have a different set of expertise. In fact, EGIZ is mostly staffed by academic researchers, while BRZ is staffed by IT management experts. Committee meetings every six months are held to foster alignment with CIOs in each ministry. The challenge is that decision making, particularly at EGIZ, is very much dependent on political commitment to advance work. So, it becomes very hard to keep the political focus on the value of IT innovation when politicians have their own short-term electoral goals in mind; the most innovative projects may produce benefits only in the long term.

3.1.1.2 Bulgarian Ministry of Transport *

The Ministry of Transport, Information Technology, and Communication is in charge of designing and implementing policies that impact the development of critical physical and digital infrastructure for the country. One critical area that the ministry oversees is the construction of transport infrastructure, and it is investigating the usage of data to make more informed decisions about planning, construction, inspection, and maintenance. In particular, the ministry is studying the value of the huge volume of data generated during the construction phase, such as data that becomes relevant for timely maintenance and the avoidance of incidents, data that can be used for predictive analytics for preventive maintenance, and data to enhance the effectiveness of initial investments.

Data Governance

The ministry considers cloud an enabler of more advanced analytical capabilities. But it also considers **federated cloud** to have no value without appropriate **data governance**, which would enable information sharing across the ministry, local governments, the private sector (e.g. engineering and construction companies), and even European Union countries. Hence, the ministry is working on an initiative to establish data sharing good practices for data governance relating to the construction of transport infrastructure. The challenge is that, in the different Member States, legislations mandate different requirements in terms of documents to be collected in the construction phase. This prevents the transnational use of data. Legal interoperability is needed.

Transport infrastructure construction phase data includes both technical data and contract implementation data. All of that could be fed into a cloud-based open data space that can be then analysed to detect anomalies that could trigger preventive maintenance. For example:

- Certification laboratories/bodies control whether construction materials are compliant with safety regulation. Different legislations mandate different requirements in terms of the certification process (who signs the certificates) and governance (national or regional government audit and oversight responsibilities).
- Testing standards can be different. For instance, in Bulgaria, some of the bridge load design and testing standards are, or were until very recently, based on normative documents implemented during the soviet era.
- Construction projects have different timings. Depending on how long the project is, reporting requirements differ regarding how to document problems that arise during the project. These audit logs could be used as red flags for predictive maintenance.

3.1.1.3 City of Valencia *

The Valencia Smart City Project[8], which began in July 2014, aimed to the integrate data and processes of municipal services into a platform that would help improve the efficiency and responsiveness of administration. This project, which includes 17 initiatives, aims to provide the city with new solutions in five different areas – mobility, governance, environment, society, and wellbeing.

The València City Platform (the VLCi Platform) is the first Smart City commercial platform deployed in Spain that uses the European FIWARE Smart City context broker. The core capability of the VLCi Platform consists of the integration of data from many municipal information systems (population registries, integral water cycle, mobility, municipal assets, digital services, and the national statistical office [INE]), with data feeds from devices that are deployed in the city (environmental noise and traffic sensors, traffic control cameras, lighting controllers, municipal building controllers, etc.).

Business Impact

The Valencia Smart City project is an example of the potential value of integrating systems of records data (e.g. enterprise resource planning [ERP] and citizen registries) with feeds from IoT and edge computing. The Valencia initiative includes a good practice related to **Business Impact of edge computing** because of how it uses the data integrated on the platform to improve citizen services. During the COVID-19 crisis, the data platform was used to offer citizens updated and consolidated information and communication through the Information Unified COVID19 site[9] and AppValència. These services provide real-time information about the crisis, such as dynamics dashboards, information on municipal services, news and tweets from the municipality, and an overview of the situation on a national level. The website also has a section called New Normal, which provides guidelines for various activities – work, shopping, restaurants, beaches, hotels, sports, cultural events and venues, transport, and so forth.

3.1.1.4 de.NBI

The 'German Network for Bioinformatics Infrastructure – de.NBI' is a national, academic and non-profit infrastructure supported by the Federal Ministry of Education and Research providing bioinformatics services to users in life sciences research and biomedicine in Germany and Europe. The partners organize training events, courses and summer schools on tools, standards and compute services provided by de.NBI to assist researchers to more effectively exploit their data. de.NBI is part of EOSC-life (European Open Science Cloud-life).

deNBI nodes, which are based in eight academic institutions across Germany, offer two types of services:

- Cloud services, which are aimed to support short-lived workloads, where the user requires a dedicated instance with the flexibility of changing configurations for each use case.
- HPC services, which are aimed to support more stable analysis intensive workloads, with little flexibility in terms of configurations, including job scheduling and queuing.

deNBI includes good practices in terms of **data governance** and **organizational structure.**

Governance and organizational structure

The coordination across the eight locations is ensured by a special interest group that is in charge of training and support, as well as aligning architectural roadmap choices, such as launching or sunsetting services. This does not prevent each location to maintain its

[8] http://smartcity.valencia.es/en/
[9] https://coronavirus.valencia.es/

independence, for instance, although OpenStack is the standard cloud deployment and management platform, each location can choose whether to use the free software version or purchase commercial offerings.

Data Governance

Identity and access management combines rigor and flexibility. Users have to apply on the de.NBI website to be authorized. They place a request for resources, where they describe the project and whether they use sensitive data or not. de.NBI then sets up a tenant for the user for the project, and let the user configure the resources and give access to others. Being able to delegate access to the system and allowing people to use the institution account is a huge driver for research consortia. Some hurdles still remain, particularly when cross-institution collaboration is required. One of the biggest hurdles is data protection of sensitive medical data. If someone at one of the nodes wants to use resources from another node of de.NBI cloud, they need to sign dedicated data processing agreements, which makes the process more complicated.

3.1.1.5 Digital Portugal

Digital Portugal is the Portuguese government digital agenda. The agenda includes three pillars:

- ICT capacity and digital inclusion – Portugal lags behind in terms of IT literacy in the DESI index, so filling this gap is a very high priority for the government.
- Digitization of enterprises – A strong focused is placed on the digitization of SMEs through training, knowledge transfer from academia to businesses, and the creation of digital innovation hubs.
- Digital transformation of public administration – This includes a strategy specifically dedicated to cloud computing.

Governance and organizational structure

The strategy coordination is assigned to a nimble program management team, which represents a good practice in terms of **governance and organizational change**. In fact, given the small size of the team and the limited resources, the Digital Portugal program office has prioritized a few practical lines of work:

- Establishing Memoranda of Understanding with global technology suppliers, such as Nokia, AWS, Microsoft and Google to help grow digital literacy, starting from the collaboration with schools and universities, but including also programs dedicated to SMEs and startup.
- Cooperating with national and European institutions to advance regulation that can empower both private and public sector to use public cloud in a secure manner, so that it will become an enabler of strategic data-driven innovation.
- Working in close collaboration with eSPAP (see paragraph 3.1.1.7), which has a bigger scale operation, to deliver on some of the key goals of the public administration digital transformation pillar, such as cloud computing.

3.1.1.6 The EGI Foundation

EGI is a federation of computing and storage resource providers united by a mission to support research and development. The federation is governed by the participants represented in the EGI Council and coordinated by the EGI Foundation.

The EGI Federated Cloud is an 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. It provides advanced computing and data analytics services for research and innovation as well as delivering advanced computing services to

support scientists, multinational projects and research infrastructures. The EGI e-infrastructure is publicly funded and comprises hundreds of data centres and cloud providers spread across Europe and worldwide. The EGI Services are provided by EGI's federated cloud providers and data centres while the services can be requested by everyone involved in academic research and businesses via an EGI Marketplace.
They have 23 research centres: some use Open Nebula, and some OpenStack. For this second one, there is a huge participation in development from Europe. EGI started with 70% Open Nebula and 30% open stack. EGI has two infrastructures:

- High throughput
- Federated cloud

The EGI Federation is a good practice for Business Impact and governance structure.

Business Impact
The adoption of EGI cloud services has been ramping up over the last 3 years with a number of users currently over 72,000 researchers globally. EGI increased by 100% the capacity made available and actively used by scientific collaborations. Success has been driven by European open science cloud initiative by promoting cross-disciplinary access to data.

Governance and organizational structure
EGI is the largest cloud federated infrastructure in the world. During the COVID-19 pandemic, EGI has supported the research community, by delivering IaaS and PaaS and leveraging partnerships with research institutes that deliver SaaS to researchers. One of EGI partner provided simulation tools for molecular docking, which is used against the virus. In summary, the key element of success for EGI is to provide added value services on top of cloud infrastructure like IaaS; the SaaS layer is familiar for researchers freeing them of worrying about the infrastructure.

EGI is publicly funded to help researchers access technical infrastructures, since funding in research is impacted by economic cycles and operates at constant or decreasing level. Research institutes tend to have little money to invest in technologies and need to share access to common data processing resources. EGI shows that federating infrastructures helps organizations without a sufficient budget for their own technical needs.

3.1.1.7 eSPAP

eSPAP is the largest shared service entity of the Portuguese national government. It was established in 2012, to secure the development and provision of shared services within the public administration, as well as design, manage and evaluate the national procurement system and the state fleet management, supporting the development of strategic policies of information and communication technologies (ICT) of the Ministry of Finance. eSPAP offers five main types of shared services:

- Finance
- Human Resource (HR)
- Procurement
- Information and Communication Technology (ICT)

eSPAP also offers project management office capabilities to plan, design, implement and realize the benefits of digital transformation initiatives for departments and agencies.

Espap has adopted cloud in various ways:

- Infrastructure as a service – public administration systems are obsolete, and there was limited budget to invest in new systems. IaaS services have been purchased

initially to provide backup services that cloud replace legacy storage tapes and then now is being expanded to other capabilities, such as website hosting.

- Software as a service – eSPAP have a longer-term experience in both designing and purchasing SaaS on behalf of other government entities in areas, such as e-procurement, electronic invoicing, and collaborative tools; for instance, they are currently helping rollout O365.

Governance and Organizational structure

From an organizational point of view, eSPAP has a flat structure with business units aligned to each line of service, which ensure that the end-to-end service life-cycle, from design to development, procurement, maintenance and support are built to bring together supply-side technology innovation and buyer-side user requirements. The eSPAP Board is also supported by a dedicated strategic planning and management control unit, which ensures strategic alignment and coordination of continuous improvement across the individual lines of service.

From a governance standpoint eSPAP has designed and implemented a set of rigorous policies for anti-fraud, ethical conduct, client relationship, and service performance management that have enabled it to deliver customer focused services.

The success of eSPAP makes the entity a central pillar of the Digital Portugal strategy, which entails a plan for public administration modernization, including a cloud strategy that promotes a vision to adopt "public cloud first, when possible and in an intelligent, secure and efficient manner." However, many challenges are still to be addressed in terms of skills, both for procurement personnel that must be empowered to competently purchase services from cloud providers and for technical personnel that must transition from deploying and maintaining systems in government datacentres to securely provisioning, integrating and managing cloud services. eSPAP and the broader Portuguese public sector also must change the budget appropriation process to realize the full benefits of cloud computing, because both national government funds and European Union funds are structured to pay for capital investments in ICT, rather than services.

3.1.1.8 G-Cloud *

In the UK, the move to cloud started with the 2011 Government Cloud Strategy[10]. The G-Cloud programme entailed five elements that the 2011 strategy spearheaded:

- A cloud-first policy[11] (first issued in 2013) mandates that central government 'departments remain free to choose an alternative to the cloud but will need to demonstrate that it offers better value for money,' whereby 'cloud first' means 'public cloud rather than a community, hybrid, or private deployment model'. The policy is not mandatory, but 'strongly' recommended for the rest of the UK public sector.
- The Digital Marketplace[12] enables any supplier that is pre-qualified through framework contracts to advertise and sell its services.
- A standardised cloud information assurance[13] approach includes a pan-government accreditation mechanism that suppliers must undergo. The mechanism is based on a formal and independent process similar to the ISO 27001 standard and based on the Government Protective Marking Scheme, which guides the classification of information.

[10] https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/266214/government-cloud-strategy_0.pdf
[11] https://technology.blog.gov.uk/2019/10/31/cloud-first-is-here-to-stay/ and https://www.gov.uk/guidance/government-cloud-first-policy
[12] https://www.digitalmarketplace.service.gov.uk/
[13] https://www.ncsc.gov.uk/collection/cloud-security

- A coordinated governance assigned responsibilities in the initial phases of the programme for proofs of concepts to various public sector entities, but it then centralised the scaling and operations of the programmes into the Government Digital Service (GDS)[14] and the Crown Commercial Service (CCS)[15]. GDS is in charge of defining and disseminating the strategic and technical guidelines for digital transformation across government, such as the Technology Code of Practice[16]. CCS is in charge of managing pan-government procurement programmes, including the G-Cloud framework, which qualifies suppliers to sell via the Digital Marketplace.
- Crown Hosting[17] data centres, a public private partnership, offers managed private cloud services to those organisations that are not ready to migrate all of their systems to public cloud or to build and run their own private cloud data centres.

G-Cloud includes good practices related to **Business Impact and data governance for federated cloud**.

Business Impact

As of Q1 of fiscal year 2020/21 (June 2021), the cumulative value of cloud services purchased through the Digital Marketplace[18] amounted to £6.43 billion, out of which £5.11 billion was purchased by central government departments and agencies, to which the cloud-first policy mandate applies. The Digital Marketplace has also made it easier for SMEs to do business in the public sector, which was one of the strategic goals of G-Cloud. By May 2013, there were over 700 suppliers, over 80% of which were SMEs.

Data Governance

Data governance: One of the key factors that drove up the level of trust of UK government CIOs in cloud was the common and transparent approach to information assurance adopted by G-Cloud. Policies are issued and overseen by the Government Digital Service, which is a part of the Cabinet Office, and by the National Cyber Security Centre, a part of Government Communications Headquarters (GCHQ) – a British intelligence and security agency. The key information assurance milestones of the G-Cloud programme included the launch of a pan-government accreditation mechanism. The pan-government accreditation mechanism was particularly helpful for smaller government agencies that could not afford a thorough review and audit of services, as it enabled them to make their own decisions (which remained their full responsibility) based on a standard accreditation mechanism. The information assurance guidelines that formed the basis of the pan-government accreditation mechanism were:

- A formal and independently verified process similar to the ISO 27001 standard
- The Government Protective Marking Scheme (GPMS), which describes how 'government classifies information assets to ensure they are appropriately protected, to support public sector business and the effective exploitation of information, and to meet the requirements of relevant legislation and international/bilateral agreements and obligations.'

The pan-government accreditation process had certain drawbacks. In particular, it proved rather slow and expensive for both buyers and suppliers. As a result, in 2014, the UK government took two steps to streamline it. Firstly, in April 2014, a simplified GPMS entered into force. The new GPMS classifies information assets into official, secret, and top secret. Secondly, at the end of July 2014, the Government Digital Service (GDS) issued a

[14] https://www.gov.uk/government/organisations/government-digital-service
[15] https://www.gov.uk/government/organisations/crown-commercial-service
[16] https://www.gov.uk/government/publications/technology-code-of-practice/technology-code-of-practice
[17] https://crownhostingdc.co.uk/
[18] https://app.powerbi.com/view?r=eyJrIjoiNTEyMTZhZDAtZGNiNi00OWQxLWI5ODYtMjg1ZWNlMmNkODVhIiwidCI6IjlmOGMwZDc5LTNlODctNGNkMy05Nzk5LWMzNDQzMTQ2ZWE1ZSIsImMiOjh9

communication that indicates that suppliers on G-Cloud will no longer need to obtain pan-government accreditation and that G-Cloud will also stop accepting new accreditation submissions. G-Cloud suppliers are instead required to self-certify their services, and buyers will become responsible for assessing and selecting the most appropriate cloud services to meet their individual security requirements. However, cloud services that connect to the Public Services Network (PSN)[19] still require pan-government accreditation (PGA).

3.1.1.9 International Institution

This international institution, like many other public sector entities, has more than 100 IT systems most of which were custom developed over the past 20 years. These legacy systems are a hurdle to digitally transforming internal and citizen facing services. Over the past five years, this organization has grown its adoption of cloud, in particular Software as a Service as a lever to augment the capabilities of those legacy systems, and over time to migrate away from them. Workloads, such as HR, CRM, document management have been the first target use cases for adoption of SaaS. COVID-19 has accelerated the transition to cloud services to scale remote working practices.
This agency includes good practices in terms of **Business Impact** and **data governance**.

Business Impact

The adoption of Software as a Service for customer relationship management and case management workloads has enabled the agency to empower customers to interact digitally even before they had to submit official documentation to apply for a service from the institution. This ensured that these customers could share preliminary documentation and ask questions, so that they were ready to submit complete and accurate documentation at the time of completing the full-service application. This sped up the review process that the institution had to complete, because of fewer requests to submit clarifications and duplicate work that would have been necessary to correct mistakes.

Data Governance

In terms of data governance, adopting SaaS required to assess product compliance with GDPR and other policies and most importantly making sure that ongoing consumption of those services did not lead to breach in compliance. This was ensured by combining the appointment of a central highly skilled expert in charge of data protection and data management with making the heads of the various business divisions accountable for implementing adata governance policies, such as approving access rights to document sharing and being accountable for enforcing retention periods.

3.1.1.10 Irish Government Cloud *

The 2016 Irish Government ICT Strategy[20] followed three key principles:

- Digital services transformation
- Data sharing solutions and skills
- The Build to Share concept: If there is a good idea, build it once, build it well, and make it available for others to share.

[19] https://www.gov.uk/government/publications/public-services-network-psn-service-compliance/psn-compliant-services
[20] https://ictstrategy.per.gov.ie/

The Build to Share part of the strategy aimed to bring together 20 departments. So, a roadmap for hybrid delivery was seen as an opportunity to scale ICT infrastructure capabilities. The roadmap included two steps:

1. Step 1, Guidance:[21] The policy left the option open for private vs. public based on data sensitivity and other factors, including:
    a) The availability of commercial solutions for different workloads/use cases
    b) The complexity of migrating core legacy systems
    c) The need to audit systems, whereby auditors want to see the physical security, which is difficult with public cloud
    d) Accessibility for users outside government, in which case, it is easier to build the systems outside of the government firewall
2. Step 2: Build government private cloud capability with the ability to burst to hyperscaler services. The environment is fairly cheap and reliable, and full automation enables remote maintenance, which has proven very valuable during the COVID-19 crisis. But it cannot cope with huge scalability requirements. For instance, www.gov.ie was getting 70,000 hits per minute after the COVID-19 announcements; the web server is hosted on AWS, because it was not scalable in private cloud.

Governance and Organizational structure

The Irish government Build to Share strategic programme includes good practices related to governance and organisational structure for federated cloud. The strategy implementation governance includes three tiers:

- Civil service management board: This includes secretary generals of every department; the government CIO gets invited twice a year and shows a dashboard about the progress of the strategy.
- Sub-group: These are co-chaired by two of the most influential secretary generals (finance department and welfare department). This is where the collective decision making happens about the overall government digital strategy.
- ICT advisory board: This is the head of IT of every department; in some departments, this is a role reporting to the secretary; in others, they are more junior, and they discuss more technical and tactical guidelines and action plans.

The success at the central government level is driving the CIO's office to consider a memorandum of understanding to enable local governments to access some resources, but local councils are still very independent and have their own shared service entity[22].

3.1.1.11 Logius *

Logius[23] employs about 500 people. It is a shared service entity that provides critical digital services for the Dutch public sector, such as:

- Dutch digital ID for citizens (DIGID)
- Freight/Port customs declaration management systems (XBRL-based declarations)
- Dutch digital ID for businesses

To deliver its services, Logius uses two infrastructures:

[21] https://www.gov.ie/en/publication/078d54-cloud-computing-advice-note-october-2019/
[22] https://www.lgma.ie/en/
[23] https://www.logius.nl/english

- A data centre platform acquired from another government entity that supports applications of national interest, such as DIGID
- A data centre that supports less critical applications

Logius includes good practices related to **technology innovation and governance& organisational change for federated cloud**.

Governance and Organizational structure

The Logius internal operating model and culture is changing to offer more agile and scalable services to government departments. Big product/application silos were broken up in 2019. In the production house, planning is carried out in three-month cycles. Everything is based on business-case discussions that rigorously evaluate potential demand, legacy migration costs, and other factors. The challenge is that large agencies and departments have a disproportionate level of influence, which may create biases in decision making.

Technology Innovation

Logius considers cloud computing a key pillar for agility. Logius is working on developing a Kubernetes container-based orchestration layer that aims to rollout to AWS, Azure, and government private cloud data centres, representing a truly interoperable orchestration layer for agile deployment. The orchestration layer, which Logius is building on Open Source (OpenStack and OpenShift), aims to include all the capabilities necessary to manage cloud federation, from service catalogue to performance dashboard and backup.

3.1.1.12 Polish Common State IT Infrastructure Program *

Wspólna Infrastruktura Informatyczna Państwa – the Polish Common State IT Infrastructure Program (WIIP) – aims to increase the security of data processed by public administration entities and optimise the costs of ICT systems. WIIP's strategic goal is to optimise existing ICT resources and applications in public administration by providing modern and cost-effective solutions. This way of operating public administration will enable priorities to be set in terms of security improvement, comprehensive migration plans, and balancing the use of cloud solutions.

WIIP comprises multiple projects and initiatives. Two of the planned deliverables are:

- Government Cloud: This comprises private cloud for central and local government and is currently in development; some services are already available. The Government Cloud will be completed in 2022. For now, it offers basic IaaS services. There are plans to gradually add more complex IaaS services, and the service catalogue will expand to include everything as a service (XaaS).
- Cloud Service Provision System (ZUCH): ZUCH is a marketplace through which certified cloud partners can offer their cloud services in the government sector in Poland. ZUCH was launched in Q2 2020 and currently has more than 20 tech partners.

Data Governance

The WIIP initiative includes a good practice related to **data governance for federated** cloud. WIIP used the same approach as that taken for the UK's G-Cloud and adapted it to the Polish context so as to follow clear guidelines established by the Ministry of Digitalisation regarding both government users of services and tech suppliers participating in the programme.

- Classified data (confidential) CANNOT be stored or processed in any cloud.
- Sensitive data can be stored and processed in Government Cloud (private cloud).
- Personal data (and systems handling such data) that has to be GDPR compliant may be stored or processed in public cloud BUT only if the data centre is located in Poland.

Other data (from small systems, websites, office apps, and open data databases) may be stored and processed in public clouds that use data centres located in Europe.

Tech suppliers that want their cloud services to be available to public administrations are certified before being accepted into the ZUCH. Verification is formal (whether a company is legitimate, pay taxes, has no debts, and is generally a reliable partner), as is security verification (whether all norms, certificates, and security policies are met). Each provider must complete a questionnaire. Service providers must be verified by the ministry before being added to the marketplace to ensure their services meet all requirements. The biggest challenge was to standardise services criteria for providers willing to join ZUCH: Services must be compliant with regulations and security policies in terms of both technologies and pricing/invoicing. Achieving this took a long time – especially as providers differ significantly in the ways they offer their services. In some cases, the ministry decided to focus on the comprehensiveness of services rather than on individual parameters. Framework agreements have also been introduced.

3.1.1.13 Regional Government Shared IT Service Centre *

This is the shared service unit of a regional government. (The interviewee expressed a preference to remain anonymous.) The unit provides:

- Private cloud infrastructure services (via three data centres)
- System and technical architecture services
- Database administration services
- Solutions and products – essentially, shared applications, such as collaborative tools, virtual agents, and identity and access management

The unit serves regional government departments, local departments, and health authorities in the region.

In 2014, the share service centre started a community cloud programme with the intention of offering IaaS to the same users to which the unit has offered other services for over 20 years. An additional aim was to provide a platform to collaborate across the local small and medium-sized enterprise (SME) ecosystem. A lack of public cloud skills and pricing thresholds that hyperscalers have in their terms and conditions have limited the ability to experiment with public cloud services in a more agile manner.

This regional government shared service centre includes good practices related to **Business Impact and sustainability for federated cloud and green IT**, although challenges remain in terms of data governance and technology innovation.

Business Impact

The cloud strategy empowered this regional shared service centre to work with other industries and, in particular, to drive revenue growth with local technology SMEs. Local technology SMEs that have IT solutions – PaaS and software as a service (SaaS) – that need an infrastructure provider to host their services can rely on the shared service centre. The value-add for the SMEs is twofold: They can use a certified data centre, which qualifies them for public tenders, and they obtain access to support services to configure and maintain IaaS virtual machines, which hyperscalers would not offer to small companies. The regional shared service centre being accountable for data governance, including for sensitive data managed on behalf of healthcare authorities, has driven investment into owned data centres, instead of experimenting with public cloud.

Green IT and Sustainability

The implementation of the cloud data centre based on virtual machines reduced the energy bill by over 50% in just one year, even though the new data centre hosted more data and higher workloads.

3.1.1.14 SPOTES IT *

SPOTES is a marketplace for IT services for government employees that the Ministry of Ecological Transition is developing and piloting on behalf of French government digital agency DINUM. The marketplace is now running on the ministry's private cloud and is based on OpenStack. The service catalogue includes:

- Workplace services
- Collaborative tools
- IaaS
- PaaS
- Helpdesk support
- Architecture and methodology

Services are available both individually and as packaged solutions.

Governance and Organizational Structure

SPOTES includes good practices in **governance and organisational structure for federated clouds.**

The main challenges were to change the minds of engineers and end users and to shift the focus from IT assets to a user-oriented service value chain – service choice, ordering, payment, and support. To tackle these challenges:

- Joint governance committees with representatives from all ministries were set up.
- A common service taxonomy was defined.
- Access to services was granted to all ministries by offering different authorisation profiles/roles.
- Common key performance indicators (KPIs) were defined and are monitored – user experience, number of transactions, number of registered users, number of tickets, and number of offerings.
- Knowledge is shared through events, seminars, educational material, and blogs made available in the marketplace.

The ministry has received funding from DINUM to act as a pilot user for SPOTES.

3.1.1.15 Statens IT *

Statens IT[24] is the shared IT service centre for the whole of the Danish central government. It operates under the umbrella of the Danish Ministry of Finance. Statens IT started as a cost efficiency programme in 2010. It currently serves 30,000 government end-users; if one includes education institutions, that figure goes up by an additional 15,000 users.

Statens IT's portfolio encompasses end-user computing services, such as helpdesk and IT infrastructure & operations services, such as data-centre and application management. Statens IT leverages cloud computing in three ways:

- GovCloud.dk: Statens IT runs a community cloud within Statens IT data centres. It offers infrastructure-as-a-service (IaaS) solutions built on OpenStack and platform-as-a-service (PaaS) solutions built on HPE MapR software[25].

[24] https://statens-it.dk/english/
[25] https://www.hpe.com/us/en/software/data-fabric.html

- Service brokerage for public cloud services: In particular, Statens IT is building capabilities to evaluate and procure services centrally, from AWS, Microsoft, and IBM, and to offer a federated identity system so that each government ministry and agency can securely consume those services.

Statens IT includes good practices related to **Business Impact, governance, and organisational change from federated clouds**, although challenges remain in terms of technology innovation. Statens IT is trying to go above and beyond the provisioning of federated identity management (e.g. single sign-on) for commercial cloud services. In particular, they are trying to build 'shared tenant' with sub-tenants for each user that could be swapped, so that they can avoid having to purchase a lot of new licenses. However, the technology suppliers' terms and conditions make it difficult to implement this concept of 'consolidated clients'.

Business Impact

In the past 10 years, Statens IT has grown to serve 30,000 government end-users; if one includes education institutions, that goes up by an additional 15,000 users. The key performance indicators that they focus on are customer satisfaction, continuity of operations, competitive pricing, reliable projects, and high-level information security.

Governance and Organizational structure

The first phase of the programme had a slow start because few government agencies – especially the largest ones – wanted to give up their IT experts and assets to the central shared service. The Ministry of Finance eventually mandated the usage of Statens IT. But, to compensate for the mandate, they created mechanisms for Statens IT 'customers' to influence decisions. This happens via a governance board and via a customer board. These boards take care of strategic decisions regarding the long-term roadmap and the business model. Working groups cover specific topics. All of these layers of governance involve customer representatives. Statens IT is solely funded by 'customer' demand. Prices are calculated by dividing the cost of operations by estimated demand. This chargeback model is a strong incentive to align with customer needs.

All the people initially transferred from individual departments and agencies to Statens IT were operations people. They did not have a digitally enabled business innovation perspective in mind. And they depleted each ministry of technical skills. So, when Statens IT started to return to 'selling' services to ministries, few understood the technical language on the demand side. Statens IT then started to put together a service catalogue to make their offerings more structured. They joined Euritas[26] to learn from peers around Europe, and they invested in personnel certification and security clearance to offer high-quality information assurance. All of these organisational change investments improved relationships with customers.

3.1.1.16 WeNMR

The University of Utrecht has been providing capabilities for computational structural biology since 2008. They lead the WeNMR thematic services under the European Open Science Cloud - Hub project (EOSC-Hub) and are part of the EGI federation. The WeNMR suite of computational tools is composed of eight individual platforms:

- DISVIS, to visualise and quantify the accessible interaction space in macromolecular complexes
- POWERFIT, for rigid body fitting of atomic structures into cryo-EM density maps
- HADDOCK, to model complexes of proteins and other biomolecules

[26] https://www.euritas.eu/

- AMBER, a web portal for Nuclear Magnetic Resonance (NMR) structures
- CS-ROSETTA, to model the 3D structure of proteins
- FANTEN, for multiple alignment of nucleic acid and protein sequences
- SPOTON, to identify and classify interfacial residues as Hot-Spots (HS) in protein-protein complexes.

UUL act as an intermediary between researchers (21,000 registered users from all over the world; the majority from India, then EU, then US, UK, China and some users in Africa).

Governance and Organizational structure

The University of Utrecht WeNMR service includes good practices in terms of **governance.** They have clear policies and procedures to register and onboard users, such as trial licenses, different levels of authorization, based on user needs and expertise, and commercial licenses for private sector. The UUL software defines the workflow and the computational model. The researchers can change configurations (depending on their level of authorization: easy-expert-guru). This allows UUL to control the consistency and robustness of the model, to have error catching and error checking, validation of input data, and to avoid failures and queues. Too much freedom would result in high risk of failure that would create a lot of support work.

They rely on EGI workload manager to allocate and manage resources in the back-end grid, but they still monitor any major disruption, because they are the first line of support for end-users.

3.1.2 Private Sector Overview

Private sector organisations in Europe generally build their own cloud services and cloud marketplaces and are not inclined to federate their offerings, as the business model for federation is not clear and the security standards and auditing mechanisms are not well established. We have identified 33 private cloud initiatives featuring good practices representing a wide variety of experiences, industries and solutions. From the geographical point of view, the initiatives come from 16 different countries, 12 of which are EU members, plus the UK, Canada, Norway, and the USA. (Figure 3).

Despite their vastly different use cases, important lessons can be learnt around the necessity for substantial economic investment in marketing solutions and achieving broad market acceptance, the need to have a standardised data structures and IT infrastructure to create federation, and the necessity to decide at which levels federation should happen.

The good practices are clustered in 4 main groups, selected for their relevance for H-Cloud analysis:

- Cloud and Federated Clouds
- Edge Computing
- Green IT and Sustainability
- Cloud system Integrators

Their profiles are reported below, with an asterisk if they were interviewed in the 1st release of this report.

3.1.3 Private/ Cloud & Federated Cloud

Name	HQ Country	Relevance for H-Cloud Key Areas	Status of the Initiative	Type of Good Practice
A1 Digital	AT	• Cloud/ Federated cloud	In operation	• Business Impact
AquaCloud*	NO	• Cloud/ Federated cloud	In development	• Governance/ Organizational structure • Data Governance
Citynetwork*	SE	• Cloud/ Federated cloud	In operation	• Business Impact • Technology innovation
Cloud 28+	EU	• Cloud/ Federated cloud	In operation	• Business Impact • Governance/ Organizational structure
CloudFerro	PL	• Cloud/ Federated cloud	In operation	• Business Impact • Technology innovation
CloudSME	DE	• Cloud/ Federated cloud	In development	• Technology innovation
Comarch	PL	• Cloud/ Federated cloud	In operation	• Technology innovation
GEVA group	DE	• Cloud/ Federated cloud	In operation	• Business Impact • Technology innovation
KeepIt	DK	• Cloud/ Federated cloud	In operation	• Business Impact • Technology innovation
Sovereign Cloud Stack	DE	• Cloud/ Federated cloud	In operation	• Technology innovation
Talentsoft	FR	• Cloud/ Federated cloud	In operation	• Business Impact • Technology innovation
ThreeFold Grid	BE	• Cloud/ Federated cloud	In development	• Business Impact • Governance and organizational structure

Table 3 Cloud and Federated Cloud Initiatives – Good Practices

3.1.3.1 A1 Digital Exoscale

Exoscale is the public cloud division of Austrian Telekom A1 Digital and offers infrastructure as a service (IaaS). The company has developed a fully automated platform based on Open Source technologies and its own internally developed software. A1 Digital Exoscale also runs a marketplace for SaaS solutions from various software vendors. The company offers a full portfolio of IaaS services (S3 storage, compute, networking) and a Kubernetes service fully integrated in the platform, all accessible through APIs and provisioned with Terraform. They

offer all services through a self-service portal, with true pay-per-use pricing model, no hidden costs.

Exoscale is very active in the Open Source developer community and a day 1 member of the Gaia-X initiative. The company operates datacenters in Austria, Bulgaria, Germany and Switzerland. A1 Digital Exoscale can be considered a good practice for Business Impact.

Business Impact

The company has been growing its customer base consistently over the last two years and customers are also moving more workloads to the platform, so that their consumption also steadily increases, which is one of the key metrics for success that A1 Digital Exoscale is tracking. Customer satisfaction is the third main KPI which A1 Digital Exoscale measures and customer satisfaction is consistently high. Many new customers are coming based on recommendations from existing customers. The company offers its cloud services at a very competitive price, lower than the global cloud providers and still makes a profit.

3.1.3.2 Aquacloud *

Aquacloud[27] is an innovation initiative 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. Aquacloud includes good practices related to **organizational structure and data governance**.

Governance and organizational structure

The initiative is running on specific project funding at the moment, and the long-term structure has not yet been decided. The plan is to move to a commercial model that will make Aquacloud self-sustainable, but it will remain a non-profit organization. Aquacloud is governed by a steering committee from the participating companies.

The definition of success has changed over the lifetime of the project. At first, success was defined as solving the sea-lice prediction problem to achieve sustainable growth for the aquaculture industry. During the project, the most important success criteria has become the learning curve that comes from collaboration. Over time, it has become clear that the real benefits are the establishment of a shared data model based on an updated standard for collecting relevant data and an ability to share this data across a wide ecosystem. The importance of creating a meaningful governance framework became apparent. In fact, the project has evolved from a pure-sea-lice forecasting asset into an industry hub that includes companies from multiple subsectors of the industry.

Data Governance

Aquacloud has built a central repository for data that integrates the production systems of aquaculture companies. Improving data quality has also emerged as a success criterion, as well as identifying next steps and widening the stakeholder group to achieve networking effects and drive the adoption of data standards. Ultimately, the goal is to drive innovation through shared data.

3.1.3.3 City Network *

City Network[28] is a European cloud service provider headquartered in Sweden and provides scalable and cost-effective cloud services from its own data centres around the world. Its public cloud platform, City Cloud, enables customers to get instant access to cloud computing power and complete control over where and how their data is stored. Its hosted private cloud service is used in industries such as finance, healthcare, and the public sector. Beyond that, City

[27] https://seafoodinnovation.no/whatwedo/aquacloud/

[28] https://citynetworkhosting.com/

Network offers managed cloud services, professional cloud services, and cloud training services.

City Network includes good practices related to the **Business Impact of cloud and technology innovation**.

Business Impact

Customers (especially in finance, healthcare, and the public sector) and revenues are growing exponentially. This also enabled City Network to help European organisations develop their skills by educating their employees and customers in the latest cloud-native technologies available in Europe.

Technology Innovation

City Network drives technology innovation internally by building leading cloud services – in particular, for highly regulated industries. It invested into AI through partnerships with European AI companies. City Network is also engaged in the GAIA-X process and will support the GAIA-X initiative.

City Network can be considered a valuable asset for Europe because of its approach and potential towards cloud federation. City Network offers an OpenStack-based public cloud service that can be federated with other OpenStack-based public cloud services, of which there are 20 across Europe. Because OpenStack is an open-standards-based technology stack for infrastructure provision and management, federating OpenStack-based clouds is easier than federating other clouds.

Barriers to participation in cloud federation initiatives include huge investments in infrastructure. In addition, there is no customer demand at the moment to justify such investments. However, the GAIA-X initiative could provide a technology to implement and to ensure greater data sovereignty across Europe. City Network would benefit from GDPR and if the data protection authorities were to enforce the Schrems II ruling about the inadequacy of the EU-US Privacy Shield. Moreover, it would be better if European companies and European public sector organisations bought from European-headquartered cloud providers instead of large cloud providers headquartered outside of the EU.

3.1.3.4 Cloud28+ *

Cloud28+ is an initiative that was started by HPE in 2015 to provide a marketplace through which European cloud providers could federate and showcase their cloud services built on HPE and OpenStack technology.

Business Impact

Since its launch in 2015, the cloud28+ community has expanded beyond Europe and is now a global initiative. It now has more than 1,200 partners in more than 100 countries, with 85,000 services published and federating 790+ datacentres**.** The most important requirement for being in the marketplace is ensuring that all participants comply with their self-declared security and compliance standards. This guarantees full compliance and security to the users. Furthermore, it quickly became clear that the substantial marketing budget was a key success factor making European customers aware of the Cloud 28+ marketplace, enabling participating partners to gain traction. The key learning from Cloud28+ is that a platform driven by a strong partner like HPE can support the competitiveness and market success of multiple service providers. HPE drives the development, management, and marketing of the digital cloud service platform, enabling economies of scale particularly for marketing investments which each individual company could not afford. This allows the providers active on the platform to achieve visibility and market reach.

Governance and Organizational structure

Cloud28+ is not technically a federation, but it is a multi-stakeholder platform and community financially supported by HPE, with contributions from its members. The aim of the platform is to promote cloud service providers that are building local and regional cloud services built on HPE technology. After four years, the platform has become self-funded through the offering of partner marketing services and solutions tied to the core intellectual property underlying it.

3.1.3.5 CloudFerro

CloudFerro is a European public cloud provider based in Warsaw, Poland, where its main laboratory and datacenter are located. CloudFerro presence is disseminated across Europe and worldwide leveraging partners' locations. The company focuses on the space sector, with the core activity being CREODIAS, the public cloud dissemination and processing of earth observation data as part of Copernicus (the European Union's earth observation programme by the European Commission). CloudFerro launched in 2015 as cloud infrastructure provider, starting with the earth observation cloud project for a data repository established in Poland. In 2018 the company developed the cloud infrastructure under the CREODIAS project for storing and disseminating Copernicus programme earth observation data and services to every stakeholder. As a following step, CloudFerro developed other services as public cloud providers looking to establish financial independency from the initial European funding.

CloudFerro includes good practices related to **Business Impact and technology innovation.**

Business Impact

There are different ways CloudFerro uses to measure success, and usually depends on the activity. CREODIAS activity has been growing fast as follows:

- Users and growth of usage KPIs: despite being crucial, these KPIs are not always indicative of revenue success as some user could be non-paying users or very immature users looking only for few images for communication purposes. In 2020 CREODIAS number of users exceeded 6.100 users (+80% vs 2019) and CloudFerro delivered 18.2 PB of earth observations data to users (+91% vs 2019).
- Data KPIs (amount of data storage and managed). Locally available earth observation data has already exceeded the number of 20 PB of data, gathering up to 2PB of observation data each day and 20.4 PB of data available on CREODIAS in December 2020 (+40% vs December 2019).

Technology Innovation

CloudFerro manages and constantly develops innovative solutions for earth observation data storage and dissemination, based on Open Source technology. It operates data repository that has exceeded 21 PB in the beginning of 2021. Recently performed tests has proved that CloudFerro can provision over 2PB of data daily to users, with a clear path to double that number in near future. To be able to do that, CloudFerro developed extensive know-how and best practices how to index, store and disseminate EO data, using variety of interfaces. In the development process CloudFerro is continuously reviewing its developments against user requirements and state-of-the-art in relevant fields of technology. CloudFerro's innovation is mainly linked to IoT and AI on the images collected.

3.1.3.6 CloudSME *

CloudSME is a spin-off of the CloudSME Project and is today a private sector company that specialises in the commercialisation of MiCADO technology, which was developed under the EU funded COLA project. CloudSME includes a good practice related to technology innovation.

Technology Innovation

It is a highly scalable multicloud Kubernetes orchestration engine, specialising in supporting compute-intensive simulations. CloudSME includes a good practice related to technology innovation. CloudSME works closely with the universities that helped develop the technology and focuses on taking MiCADO to market. Reaching a broader market and obtaining relevant certifications are challenges still to be overcome.

3.1.3.7 Comarch

Comarch provides loyalty software for enterprises. Comarch started as a provider for very large enterprise customers, but with the advent of SaaS, Comarch has built a product for the midmarket that will be available in a cloud-based SaaS model. The new software will offer additional functionality to the loyalty program and will become a complete marketing software package with data analytics for midmarket organisations. Comarch can be considered a good practice for technology innovation.

Technology Innovation

Comarch is a very innovative company with many technology innovation initiatives on the roadmap.

- AI/ML: Comarch has invested in in AI/ML for the past 3-4 years, and has already done successful implementations in the areas of fraud detection, optimization for marketing, algorithms helps to decide when to send messages to clients / promotions, customer services, sentiment analytics, chatbots, how people are describing brands, monitoring of social media for sentiment analysis
- IoT: location-based services, locating people indoor and outdoor, reacting to their location and send promotions related to their location.
- Connected devices: device usage, including cars.
- Mobile payments: blended with loyalty tools, centre of customer knowledge and interactions.

Comarch makes sure that all applications are compliant with data privacy regulations globally, for example GDPR in Europe and data privacy regulations in the US (California).

3.1.3.8 Geva Group

Geva Group provides payment solutions for financial sector and public sector organizations as well as commercial clients. They started their cloud journey in 2019, as customers wanted to consumer software rather than operate software themselves. Today, customers can choose between a dedicated hosted solution and a SaaS solution, both are running on the IBM cloud for banking and financial services. They also want to become an ISV solution on the IBM cloud for financial services marketplace. Geva Group focuses on the German, Austrian, Benelux, Italian markets and with some customers in Spain and Portugal. Geva group can be considered a good practice in the areas of Business Impact and technology success.

Business Impact

Geva Group continues to grow its customer base, as customer are keen to consume payment solutions as a service. Geva Group also has a significant pipeline of new customers due to the demand for their solutions. They can offer the services at a competitive price, because a lot of the legal certifications are already taken care of by IBM cloud for financial services. They are covering the full spectrum of customers from SME banking customers to large organizations in the public and private sector. Their market strategy focused on customers' needs is their competitive advantage.

Technology innovation

Geva group has successfully developed a dedicated hosted offering and a SaaS solution built on a cloud platform. These services run on a fully encrypted database. They are currently re-

architecting their entire application stack to make it available on a container-based infrastructure in the future.

3.1.3.9 Keepit

Keepit is a Danish software company specializing in Cloud-to-Cloud data backup and recovery. Deriving from 20+ year experience in building data protection and hosting services, Keepit is pioneering the way to secure and protect cloud data at scale. Starting in 2014, Keepit re-designed its entire software stack from scratch, including the file system and the object storage system. The new data protection and archiving service was launched in 2016 and enables customers to backup cloud-based data like O365.
Keepit can be considered a good practice both in Business Impact and technology innovation.

Business Impact
Keepit has grown its revenues 130% in 2020 and continues to grow the number of users as well, as the market for backup of SaaS solutions is growing very fast.
Keepit also secured a series A funding of 30 million USD from OnePeak investments in September 2020 to drive its future growth strategy.

Technology innovation
Keepit has specifically designed its backup solution for the SaaS market, which gives them a competitive advantage. They have designed the full stack themselves which allows the company to scale the solution both horizontally and vertically and to innovate at a fast pace. The object store is designed around a Merkel tree, like github. Deduplication of data and storage optimization are included as part of the platform at no extra charge. Data is immutable once written to Keepit and customers can manage their own encryption keys if they want to.

3.1.3.10 Sovereign Cloud Stack

Sovereign Cloud Stack is part of the Gaia-X infrastructure workstream. It started in November 2019 based on an open-source approach to the Gaia-X infrastructure stack and has been accepted into Gaia-X in 2020.

Technology innovation

The company is showing how to interact with the Gaia-X approach. Sovereign Cloud Stack is building an open-source based cloud software stack with a focus on cloud federation at the infrastructure layer by putting the right networking and technical interfaces in place. The plan is to provide a container layer by the end of 2021. In addition, sovereign cloud stack also wants to deliver templates for self-description of services built on it. In addition, Sovereign cloud stack is also trying to increase the knowledge of best practices in the space of IT operations / cloud operations, and create a knowledge sharing community. Service management and commercial management still need to be addressed. Key to success is going to be adoption because developers only invest time in well-adopted platforms.

3.1.3.11 TalentSoft

Talentsoft, is a French ISV, providing human capital management software and SaaS solutions for organizations. Their solutions are used by employees, managers, HR teams and candidates. Talentsoft can be considered a good practice for Business Impact and technology success.

Business impact
Talentsoft measures its Business Impact through several KPIs:

- Revenue growth: Revenue has been growing steadily since the inception of the company
- Number of users: 11 million users in 2020 and steadily growing.
- Traffic reflects usage of application: number of pages or HTTPS transactions over period of time continues to grow.

For the last 10 years, traffic is growing faster than revenue. Revenue is based on number of managed people, traffic growth is based on more intensive usage of Talentsoft by the various users, spanning more of the offered modules.

Technology innovation

Talentsoft uses AI technologies built into their processes. Talentsoft has developed a software stack that they can deploy on any IaaS / kubernetes / infrastructure as code, which gives them independence of the IaaS layer. Talentsoft manages data in compliance with regulation and best practice. Implementation of data sovereignty for stakeholders where possible. Talentsoft enables effective and efficient data sharing across its platform and has efficient and effective data security built in.

Sustainability for a software company mainly depends on the underlying infrastructure it runs on and Talentsoft chooses sustainable infrastructure providers. There is a need to develop metrics for understanding the efficiency of software code.

Talentsoft focuses on two customer segments at the moment: midmarket (1000 to 15000 employees) and large accounts. Talentsorft is working on developing a self-service solution for the SME segment.

3.1.3.12 ThreeFold Grid *

ThreeFold Grid[29] is a peer-to-peer network of storage and compute capacity developed by ThreeFold Technologies (TFT). It creates a decentralised, privacy focused, and secure resource pool of participants that add their compute and storage capacities to a grid. TFT has developed its own operating system, which turns any server or storage system into a node of the grid, with the same security attributes, and federates all of the diverse compute resources into one unified resource pool (the grid). All resources that are added are managed by blockchain, so there is full transparency and immutability of the resources added. TFT solves the problem of IT hardware diversity by adding its own operating systems to every resource, large or small, before including them in the grid.

ThreeFold Grid includes good practices related to business impact and governance.

Business Impact

ThreeFold Grid is growing at a double-digit rate, with country-level projects increasing. This is because ThreeFold Grid enables the establishment of peer-to-peer networks at different levels – at the community level, regional level, country level, and global level, depending on the defined scope. Another key area of growth is partner adoption. These features have enabled TFT to increase its audience. According to the interview, the organization is the the largest P2P cloud available today and the first and only, now coming to market (stats) with no Initial Coin Offering (ICO).

Governance and organizational structure

TFT has created an independent peer-to-peer network in which every organisation can participate, has added its own resources to the grid, and is being compensated for it. TFT enables a true bottom-up cloud-based federated initiative and has developed a mechanism to manage the technical aspects of federating highly diverse resources in a secure and efficient

[29] https://threefold.io/

way – in contrast to the highly centralised global cloud providers, which effectively build the whole infrastructure themselves. There is a fast-growing partner ecosystem and an expanding community (farmers, ambassadors, token holders, etc.).ThreefoldGrid is a community and partner ecosystem run as a P2P network. The partner ecosystem consists of CISPE, ThreeFold Foundation, Hewlett Packard Enterprise, DigiByte, Stellar, TomoChain, Harmony, Selfkey and many others. Blockchain is the main technology innovation driver for ThreeFold Grid. Other technology innovations have also expanded – for example to non-profit foundations, technology companies, municipal councils, and large organisations. Furthermore, the compute-and-storage grid is TFT's first major use case to prove the technology and potentially deliver a meaningful impact for humanity and the planet.

Using green and efficient energy and technology, TFT combines IT innovation with a forward-looking vision aimed at improving human lives and the planet. The barriers the company faced related to costs, complexity, non-scalability, and security. No legal barriers arose, and the economic barriers have been overcome with other solutions that ensure sovereignty, scalability, sustainability, and security.

3.1.4 Private/ Edge Computing

Name	HQ Country	Relevance for H-Cloud Key Areas	Status of the Initiative	Type of Good Practice
Axis*	IT	• Edge	In development	• Business impact • Technology innovation
BrianzAcque*	IT	• Edge	In operation	• Business impact • Technology innovation
Leading EU car manufacturer*	PL	• Edge	In development	• Business impact • Technology innovation
Nodeweaver	IT	• Edge	In operation	• Business impact • Technology innovation
QBeyond	DE	• Edge	In operation	• Business impact • Technology innovation
T-Systems	DE	• Edge	In operation	• Technology innovation • SME
Vivacity Labs*	UK	• Edge	In development	• Business impact • Technology innovation
Worldsensing*	ES	• Edge	In development	• Business impact • Technology innovation

Table 4 Edge Computing Initiatives – Good Practices

3.1.4.1 Axis *

Axis[30] is an IP camera producer, developing products that use open standards and are scalable and easy to integrate into different platforms. Axis has embraced open standards and edge to guarantee lower connectivity levels and server loads. Axis is focusing on developing its proprietary hardware platform, which features a deep-learning processing unit (DLPU). The application layer has been developed partially internally and partially leveraging third-party developers. This will enable the camera to perform different tasks by leveraging edge hardware (e.g. security applications, business management applications, and camera plug-ins) and offers the possibility to develop features and change the camera's scope. The cameras have an internal computing platform for analysis and to run applications that usually run on servers. These applications support insights (metadata) and facilitate other layers of the solution (e.g. different connectivity platforms that would be difficult to integrate elsewhere, cybersecurity, and the management of the device or of other devices (e.g. turning on smart lighting via motion detection). Axis's aim is to move integration complexity to the edge camera to ease partners' integration, development, and use of software. Even though new intermediate edge architectures are now being developed, Axis sees no need to adopt/incorporate them at the present time.
Axis includes good practices related to the **business impact of edge and technology innovation.**

Business impact

This is measured via the usual business KPIs – revenues (despite not always being meaningful, as video surveillance is a growing sector) and profits – and other metrics, including the number of sensors sold, the number of ecosystem apps running in its systems, the number of cameras running edge analytics in relation to the total, the number of cameras (around 300–400 cameras per city of 1 million inhabitants), the number of edge-enabled cameras per use case (e.g. traffic monitoring), and the numbers of partners and partner apps migrating to the edge (which is growing fast).

Technology innovation

The edge solutions are mainly connected via IoT to the cameras. The innovation lies in developing cameras that are computing platforms. 5G could be a very interesting technology innovation to adopt in the future: 5G can be very relevant in a video surveillance scenario, but only if the cameras have edge capabilities – mostly, for scalability, latency, and bandwidth. Axis's approach to innovation is driven by the hardware platform, and this pushes innovation to the software development side.

3.1.4.2 BrianzAcque *

BrianzAcque[31] is a public company that manages wastewater and water treatment in Brianza, a territory in Northern Italy comprising 56 towns and villages and approximately 900,000 inhabitants. The company started the Casette dell'acqua initiative to distribute outdoor high-quality filtered drinking water dispensers (the Casette) throughout the territory for the citizens. The water can be dispensed as still, sparkling, and cooled. In a similar way, the company is distributing indoor dispensers – in schools, libraries, and so forth. The target is to reduce the use of plastic bottles across the territory, with benefits including less traffic, less pollution, and lower consumption of plastic.

The Casette dispenser 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. Each outdoor dispenser includes a technological solution to monitor the status of the dispenser, count how much water has been delivered, manage

[30] https://www.axis.com/en
[31] http://www.brianzacque.it/

maintenance, provide communication to users via a screen, and manage the security of the data and data transmission. Each dispenser is managed with a micro PC, which is deployed at the edge and features tailored Linux OS and custom applications for different functions.

IoT components continuously exchange data with the central cloud platform, which manages the IoT network and provides the information shared on the screens of the dispensers. The screen can share information regarding water provision and water quality, as well as public utility information from BrianzAcque and partners (e.g. local government).

BrianzAcque includes good practices related to **business impact and technology innovation**.

Business impact

The main KPIs relate to the number of Casette installed (currently 70, with a target of 100 in total in 2021, covering the whole territory); the number of dispensers installed (currently 50, with a target of 80 in total by end of 2020); and the number of litres dispensed (10 million litres in 2019, with a strong increase expected for 2020, even though the COVID-19 outbreak forced the temporary closure of Casettes in spring 2020). Another significant KPI is how the service to citizens evolves in terms of information about water quality and customer service. Despite being difficult to monitor and monetise, usage patterns say a lot about this.

Technology innovation

The main aspect of innovation relates to the mix of IoT, edge, and cloud computing and the capabilities that mix enables. The initiative had a huge impact on company processes, as it is a part of a more general digital transformation of the company, whereby the whole architecture has shifted to services enabled by cloud-native applications on a single cloud platform.

3.1.4.3 Leading European Car Manufacturer *

A factory (located in a CEE country) of a leading European car manufacturer has developed an initiative related to the real-time monitoring of its uninterrupted power supplies (UPSs) and UPS management system. The factory is equipped with about 50 UPSs, placed in rack cabinets located around the plant, and two heavy-duty galaxy-class UPSs that support two data centres. The data centres host all the IT infrastructure for the office and production parts of the factory. The initiative tied to the new UPSs was driven by the following challenges:

- The very difficult management of dispersed infrastructure – a lack of visibility and UPS status information collected manually by administrators.
- Lack of predictive maintenance – service work often performed after breakdowns.
- The instability of UPSs when operating in an emergency state.
- Alerts only displayed on the UPS panel.

The IT department initiated the project for replacing the business-critical UPSs, choosing UPSs equipped with sensors for collecting data about the UPSs' statuses – sensors capable of conducting basic analysis at the edge, as well as visualising the data on each UPS screen and transmitting the data. The UPS manufacturer provided the company with a UPS management application, which helps IT administrators detect failures and potential threats. All of the data transmitted from all UPSs is collected and further analysed in the data centres for a holistic view of the overall power infrastructure. Despite all the data being collected in the data centres for further use, the edge capabilities are key to initial analysis and fast reaction to problems/alarms.

The leading car manufacturer initiative includes good practices related to the **business impact of edge and technology innovation.**

Business impact

Several KPIs have been used to measure the success of the project:

- No downtime due to power failure (Power failures have been eliminated.)
- A massive reduction in failure time
- The removal of reliance on battery power in emergency status
- Information visibility – the ability to visualise data both centrally and locally, using the internal analysis and visualisation capabilities on the UPSs

Technology innovation

The main aspect of innovation relates to the use of IoT in the USPs. The devices are equipped with sensors that capture various parameters, analyse the data, and generate alerts and triggers based on the locally gathered data (i.e. at the edge). The benefits of the initiative were substantial enough to overcome the barriers, especially since the project was financially predictable and financed from the IT budget.

3.1.4.4 NodeWeaver

NodeWeaver provides a software-defined operating platform that simplifies the deployment, management, and orchestration of edge infrastructure and applications. The company started as CloudWeaver around 10 years ago working on a platform for helping IT resiliency in SMEs through virtualization. Few years later, NodeWeaver decided to steer towards the nascent idea of Edge Computing, and focused the platform to address the unique requirements of edge, renaming it into NodeWeaver. In the last 3 years the company concentrated efforts on optimizing the product for edge computing and have achieved success across a variety of verticals, but primarily in the industrial sector.
NodeWeaver installs on the bare metal of nearly any hardware and enables the deployment of highly resilient, agile and scalable nano-clouds capable of running multiple virtual machines and container-based workloads, reliably and cost-effectively. It is focused at the edge as usually the devices managed through NodeWeaver are on the field, outside datacentre facilities.
The key enabling factors for NodeWeaver, when considering edge deployments are:

- The possibility of running the platform on virtually any hardware with very limited technical requirements, expanding the spectrum of edge devices which can support the deployment
- The possibility to install the platform without any IT skill needed, with a 4-minutes plug-and-play installation and configuration
- The ability to abstract the physical layer and letting customers and developers see only the virtual layer. This helps the deployment of applications on any type of device.

NodeWeaver includes good practices related to **business impact and technology innovation.**

Business impact

The company measures success as follows:

- Business metric: since the business model is based on software license sale by node (physical device), the company looks at the number of nodes deployed. Another aspect is to look at the number of verticals covered, and the number of nodes by verticals. NodeWeaver is targeting, and delivering, 12% monthly growth rate for licenses. To sustain the growth the company has business metrics to target new tier 1 and tier 2 partners every 6 months.
- Clients metric / effectiveness to the client: it relates to the number of experimentations that converts into live deployments. The company targets 80% of PoCs positively closed. Another important aspect is the number of licenses per deployments.

Technology innovation

NodeWeaver platform is mainly linked to AI at the edge and IoT use cases, spanning from vision (images, videos) to the use of different types of sensors (e.g. preventive maintenance), to massive data gathering (e.g. autonomous vehicles data download to be transferred in burst during refuelling). Other innovative initiatives are linked to the implementation of blockchain functionalities in the platform, to verify that the data has not been touched by anyone, NodeWeaver included (i.e. using digital sign to demonstrate that logs are consistent).

The most innovative aspect of NodeWeaver's platform is the ability to deliver full cloud capabilities in a small footprint, which opens for a greater scale and different architectures, as well as the autonomous features and management simplicity which again enable deployment at mass scale. The combination of fewer bigger nodes running heavier workloads and huge number of small devices from different sensors and standards, with minimal processing capabilities, helps reducing data transfer to bigger nodes by 90%. Combined with the limited cost of the small devices, even if thousands per each deployment, this saves data transfer costs, making possible the business case for edge.

3.1.4.5 q.beyond (edge)

q.beyond is a German technology provider that developed the Edgizer platform, with an industrial IoT proposition targeting mainly companies within manufacturing, logistic, retail, energy and healthcare verticals. Edgizer has as main goal to operate a large number of remote, edge devices as cloud does today, with the ability to deploy applications on any device, leveraging any backend the customer prefers. The software platform wants to enable the management of large scale of IoT edge devices, including their computing capabilities, with a cloud-like experience. It includes easy onboarding and commissioning of the devices, needing just power and internet connection, with also device and connection management capabilities. Further to that, the platform includes the ability to drag and drop applications onto thousands of device / sites enrolled in the platform with a single click, and to manage the exchange of meaningful information from edge to core and vice versa balancing the workload execution where most meaningful.

q.beyond includes good practices related to **business impact and technology innovation.**

Business impact

Despite the Edgizer platform has only been recently launched, expectations are to grow at least at 20%-30% up to 100% rate as a new product adoption increases. Some of the KPIs that q.beyond monitors are:

- Number of devices enrolled in the platform, with an expectation for 2021 of around 10.000 boxes managed.
- Value of the service offered to customer, which is directly linked to the applications that the platform will manage for the customer. This KPI has a direct correlation to revenues as well.

Technology innovation

Edgizer platform is linked mainly with IoT and AI technologies. IoT in particular is the primary source of data and information that needs to be collected, managed and analysed at the edge. This may include aspects of retrofitting of machines in the industrial ecosystem. The platform eases also the management of the skyrocketing amount of data that is being created at the edge, opening also to other technologies that leverage on those data and the platform, like the possibility to run AI application within the platform or the enablement of higher security standards working with blockchain technologies.

3.1.4.6 T-Systems

T-Systems is an IT service providers and supplier of digital services. It supports more than 1,000 clients, including all DAX 30 companies in Germany and 100 of the Fortune 500 companies globally. As a subsidiary of Deutsche Telekom, T-Systems provides all important building blocks for innovative information technology and digitalization. This includes development, implementation, integration, and sale of private and public IT infrastructures and applications, including strategic digitalization and the transformation solutions that accompany this. They also provide consultancy services, drawing from their deep knowledge of the industry and with the help of over 4,000 SAP experts around the world. T-Systems is also investing heavily in building out edge infrastructure and use cases and can be considered a good practice in technology innovation.

Technology innovation
T-Systems is building out all elements of edge computing, including mobile networks and edge networks and enable local data processing for industrial use cases. They process data on the edge and are key providers for the automotive and manufacturing industry. They are working with several companies that have dedicated a company division for this product portfolio.

3.1.4.7 Vivacity Labs *

Vivacity Labs[32] is a British company that provides artificial intelligence-based products and services to support municipalities in traffic management. Its solutions leverage images and videos to gather anonymous movement data. The company provides both AI-enabled sensors (cameras) and a platform for data communication, storage, and management. Insights relate to how roads are being used, classifying different road-user types (car, truck, pedestrian, cyclist, …) and how they interact on the road. This more recently includes measuring social distancing and interaction between people. The company has more than 3,000 sensors deployed around the world, but it is mainly active in the UK. Vivacity Labs' use of edge includes the deployment of smart cameras running AI at the edge and leveraging edge computing platforms, like edge GPUs, to run image detection and analysis and to extrapolate anonymous insights sent from the camera to the software platform. The key drivers behind edge, for Vivacity Labs, are:

- A desire to run AI locally, at the Edge, to support low latency use cases.
- A desire to reduce bandwidth and camera connectivity costs.
- Privacy by design, including deleting sensitive and/or personal information before it leaves the sensor (depending on the use case implemented)

Vivacity Labs includes good practices related to **business impact and technology innovation.**

Business impact

The company measures success at different levels (using various KPIs). The number of sensors (cameras) deployed worldwide (but primarily in the U.K.) currently exceeds 3,000. Revenues have grown consistently since 2015, doubling every year. Other KPIs include:

- Client adoption and usage KPIs: the number of accesses to data on the dashboard/via an API; the number of customers buying sensors (currently 60%); and the number of cities adopting sensors (increased from 20 in January 2020 to 30 in July 2020)

[32] https://vivacitylabs.com/

- Use-case-level KPIs: results achieved by the use case for the customer, such as achieving and improving traffic throughput and savings through more efficient traffic (e.g. the number of cyclists using a junction)

Technology innovation

Vivacity Labs mainly researches and develops software solutions and algorithms to extract the highest value from a combination of innovative technologies, such as AI, IoT, and edge. Innovation is driven by the internal design and development of technology and AI algorithms to better use edge hardware and address new needs in the market. Another key element from the technology standpoint is involvement in the technology ecosystem for every aspect.

3.1.4.8 Worldsensing *

Worldsensing 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. The company offers a suite of products to wirelessly connect a wide range of 3rd party geotechnical sensors, as well as edge gateways capable of data collection, data analysis, and network management at the edge. Data is then sent to a cloud location for further analysis.

Worldsensing leverages edge capabilities by using dataloggers and edge gateways. The dataloggers are battery powered and have limited capabilities in terms of computing power. These devices connect wirelessly to the edge gateway using standard IoT connectivity. Each edge gateway is equipped with computing and storage capabilities and is able to gather data, translate different formats, manage the network, perform basic data analysis and visualisation, and, in some cases, generate alerts. Each gateway is connected to a public or private cloud location for central data analytics, storage, dashboard, and alarms, using various connectivity types, depending on availability. The edge devices are resistant to harsh environmental conditions (water, dust, temperature, and vibration) and consume very little energy. Edge is needed to ensure the continuity of service in remote locations where connectivity is unreliable.

Worldsensing includes good practices related to the **business impact of edge and technology innovation.**

Business impact

Revenues have been increasing constantly since 2016. Another interesting KPI is how much money Wordsensing customers/partners save by deploying the company's solutions, which adds to the other measured benefits derived from the real-time availability of geotechnical data, such as the increased safety of workers, citizens, and the environment. The overall result is usually high return on investment (ROI), depending on the project setup.

Technology innovation

The company’s focus is primarily on R&D – developing new solutions and leveraging the latest technology trends on the market (LoRa LPWAN and 5G, batteries for sensors, and new edge servers/gateways with increasing computing and storage capabilities).

The Worldsensing solution is at the crossroads between IoT (the dataloggers) and edge (where the data is processed). The solution relies on a centralised (cloud) platform to which all data is sent from dataloggers; edge is critical in delivering value. Cloud is used as a central resource for central data analytics, storage, dashboard, and alarms, and it enables remote device management. The company is very much focused on edge-network infrastructure. It relies on engineering service provider partners to integrate and deliver the final solution to customers. Nevertheless, the company has historically been active in developing a decentralised and coordinated edge-to-cloud management ecosystem. In this regard, in 2017, Worldsensing was

awarded the mF2C H2020 project[33] – Towards an Open, Secure, Decentralised and Coordinated Fog-to-Cloud Management Ecosystem.

3.1.5 Private/ Green IT and Sustainability

Name	HQ Country	Relevance for H-Cloud Key Areas	Status of the Initiative	Type of Good Practice
1&1 IONOS	DE	• Cloud/ Federated cloud	In operation	• Business impact • Green IT
Cloud+Heat		• Green IT	In operation	• Green IT
Green Data Center AG	DE	• Cloud • Green IT	In operation	• Green IT
OVHcloud	FR	• Cloud • Green IT	In operation	• Green IT
Polymore*	DE	• Federated cloud • Green IT	In development	• Business impact • Green IT
Scaleway	FR	• Cloud	In operation	• Green IT

Table 5 Green IT Initiatives – Good Practices

3.1.5.1 1&1 IONOS

1&1 IONOS is a cloud services and IT hosting company from Germany, owned by United Internet. Ionos offers three main cloud computing services: compute engine, private cloud powered by VMware and managed Kubernetes.
Ionos Cloud standardizes IT infrastructure on its own IT stack and builds their services on top of it. Ionos Cloud is a big believer in Open Source and building open-source communities. Once the infrastructure is completely standardized, innovative services can be built on top of the infrastructure. Ionos and its parent company United Internet have a fibre network, 5G licenses and are able to offer different use cases on the cloud-edge continuum. The company is also very engaged in Gaia-X as a day one member of the initiative.

Business impact

Ionos is very engaged in providing climate-neutral IT hosting and cloud services. Datacenters in Germany and the UK are operated 100% based on renewable energy. Other locations are compensating their CO2 emissions. The supply chain is also optimized for sustainability.

Ionos can be considered a good practice because:

- They maintain a high NPS score (Net Promoter score, a customer satisfaction measurement) which signals that they achieve a high customer satisfaction rating, they have low customer churn and acquire new customers at a healthy rate. Revenues were 948 million Euros in 2020 for the parent company United Internet.

[33] https://www.mf2c-project.eu/index.html#

- Cost competitiveness: they price their services lower than the market leader AWS and they rely on efficiency and productivity to be profitable.

Green IT

1x1 IONOS SE is very engaged in providing climate-neutral IT hosting and cloud services. Data centres in Germany and the UK are operated 100% based on renewable energy. Other locations are compensating their CO2 emissions. The supply chain is also optimised for sustainability.

3.1.5.2 Cloud + Heat

C+H is a startup created in 2011 to take advantage of the fact that computer servers generate heat, and rather than spending money to "get rid" of this heat, use it productively. The original idea did not prove feasible, so the company pivoted business model in 2014-16 becoming a more traditional CSP with a focus on high energy efficiency and reuse. Today they have over 100 employees and raised over 10 million euros from venture investors. Given the company's focus on "green ICT", which in 2011 was quite revolutionary, this represents significant Business Impact, with continued growth in basic business lines as well as exploration of the many points of intersection between "cloud" and "green" business.

Green IT

C+H can be considered a good practice in Green IT which they pioneered. Rather than considering the company's ESG performance as a "secondary" concern, environmental and sustainability performance are tightly linked to the vision and mission of the company and are considered in all of their business decisions. The company has some proprietary solutions. They have some patents for allocating loads relative to requirements for heating. They have developed the Krake orchestration tool as a Prototype, K8S based. Cloud+Heat has unique capabilities: very few companies can control the whole stack from hardware to software to orchestration. They are partners in an EC H2020 project AI Sprint and are applying for another research project, multi-stage. The goal is developing a technology to shift workload timing to optimize CO2 impacts, looking to take advantage of excess (stranded) wind energy.

3.1.5.3 Green Data Center AG

Green Data Center is a Swiss datacentre, hosting and cloud service provider serving both the SME and enterprise market, as well as the global cloud providers. Green Datacenter AG is focused on providing sustainable datacentre and IT services and can be considered a best practice in Green IT and sustainability.

Green IT and Sustainability

Green Datacenter operations are designed to minimize environmental impacts and energy consumption as well as recycling energy. The company builds large datacentre campuses that can be used by cloud providers and focus on carbon neutral buildings, sustainable type of materials, optimized free cooling, low PUE (Power Usage Effectiveness). The campus is equipped with solar panels, while the office buildings have photovoltaic elements. The company optimizes heat consumption by working with heat networks, that is distributing heat to the campus in other facilities as well as to the city. They are also using electrical vehicles, bikes, cars on campus. They leverage renewable sources of energy (solar, aqua and wind energy) to power the datacentre campuses.

Green Data Center is running a carbon recovery project with the Technical University in Zurich. All water systems are running on high containment level and they do not create waste gasoline. They have sustainability ISO certifications according to ISO 50001

3.1.5.4 OVHcloud

OVHcloud is a global technology company with more than 1.5 million customers and serving developers, entrepreneurs, and businesses with the dedicated server, software and infrastructure building blocks to manage, secure and scale their data. OVHcloud focuses on building an open standards based ecosystem and open cloud infrastructure and is very active in the European cloud ecosystem and supporting Gaia-X and other European cloud initiatives. They manufacture their own servers, own and manage 30 data centres, and operate their own fiber-optic network. OVHcloud can be considered a good practice for green IT and sustainability.

Green IT and sustainability

OVHcloud is using a machine learning model developed by research institution INRIA to improve the accuracy of measuring the CO2 impact of cloud computing services. The model currently measures the energy usage of CPUs and memory within servers and will be expanded to include the entire energy consumption of the development and production of servers. It is an open source model, accessible to everyone, and will be integrated with OpenStack.

3.1.5.5 Polymore*

Polymore[34] is a start-up owned by Kraussmaffei that helps clients find in a few clicks the right business partners for plastics compounders and converters. Polymore matches user requests with the most suitable suppliers. Through Polymore's web interface, suppliers create offers and buyers fill out online requests. Once offers have been made, buyers can directly contact the respective suppliers for more details and/or to negotiate terms.

The Polymore initiative includes good practices related to **business impact and green IT.**

Business impact

Polymore has many website visitors (web traffic/impressions), offers online marketing, has many registered and active users, and records many transactions. Polymore's business achievements include:

- 60,000 tons of plastics requested – 80% recycled
- 200–300 unique visitors per week
- 2–3% click-through rate
- Hundreds of sellers in the portfolio of traders and producers
- Polymore is also increasing its revenue through subscription/membership fees.

Through its online platform, Polymore enables customers and suppliers to connect with each other, thus satisfying both stakeholders. The platform does not allow the sharing of customers' personal data. Polymore relies on AWS to protect data. Polymore is struggling to find an AI solution to automate matchmaking, which is currently done manually. To circumvent this problem, Polymore currently utilises AWS's microservices. Nevertheless, from a sustainable point of view, Polymore meets all European Commission requirements.

Green IT and Sustainability

Sustainability is a part of Polymore's business model, as the platform enables full-circle plastics production. As a part of this approach, Polymore includes reusable materials and post-industrial waste (by-products) in its portfolio, thus helping to improve the sustainability of

[34] https://www.polymore.com/en/buyers

Polymore users and the plastics industry as a whole. Polymore's parent company, Kraussmaffei, is also active in lobbying. The Germany-based company adheres to green computing principles, using renewable energy sources and energy-efficient technologies to reduce its CO2 footprint.

3.1.5.6 Scaleway

Scaleway is a European cloud service provider owned by telecom operator Illiad which provides both colocation services and public cloud services. Scaleway has a focus on SMEs, start-ups, cloud-native organizations, academic institutions across all industries. Scaleway can be considered a good practice in green IT and sustainability.

Green IT and sustainability
Scaleway has invested in the latest datacentre and sustainability technologies, driving down its PUE to 1.15 through the use of evaporate cooling technologies. They are also very efficient in their water usage, use no chemicals.
They use renewable energy from hydropower as well as nuclear power and are very focused on continuously driving down their energy consumption while growing the customer base.

3.1.6 Private/ Cloud System Integrators

These players have been added compared to the first release of this report, in order to provide a more comprehensive view of the industry and of the cloud ecosystem.

Name	HQ Country	Relevance for H-Cloud Key Areas	Status of the Initiative	Type of Good Practice
Capgemini	FR	• Cloud	In operation	• Technology innovation • Green IT
CS Group	FR	• Federated Cloud • Edge • Green IT	In operation	• Business Impact • Data Governance
OpenNebula	ES	• Cloud • Edge	In operation	• Technology innovation
Reply	IT	• Edge	In operation	• Business impact • Technology innovation

Table 6 Cloud System Integrators – Good Practices

3.1.6.1 Capgemini

Capgemini is a France-based global consulting, outsourcing, and IT services vendor with around 270,000 employees serving clients in almost 50 countries in the Americas, Europe, Asia/Pacific, Africa, and the Middle East. Capgemini's key service lines are Strategy and Transformation, Applications and Technology, Operations and Engineering, and Capgemini Invent. The latter is the strategy and transformation arm of the group. It supplies digital strategy consulting and related professional services, including design and data science services.

Technology innovation

Capgemini sees more and more customers using cloud centres of excellence within the organization to help their own digital transformation. Capgemini focus is supporting the

development team in customers' transition to cloud. To do so, Capgemini leverages a wide range of innovative technologies, including edge and AI, tailored to different customers' needs. They have many projects around Edge. Capgemini's portfolio includes Blockchain in a marginal way, for example in the retail industry, where Capgemini uses it to guarantee the transparency of the supply chain. However, the demand from customers seems limited with only few blockchain projects ongoing. According to IDC[35], Capgemini is a good choice for organizations looking for a partner with strong IT consulting skills and a good understanding of the connection between business and technology drivers. For example, Capgemini offers EAPM, an AI-enabled portfolio management software tool that provides a detailed digital model of a client's application portfolio landscape and evaluates the health of the portfolio against benchmarks from hundreds of engagements. Another tool is the Intelligent Automation Platform, a cloud-ready, technology-neutral, plug-and-play platform designed to take clients from limited deployments and proofs of concept (POCs) to intelligent automation at scale. This helps customers accelerate their innovation adoption.

Green IT

Capgemini's sustainability-focused offerings put a strong emphasis on environmental topics such as decarbonization — both internally and externally. Capgemini assists clients with green IT–related efforts (e.g., reducing carbon footprint of IT assets and services and advice on how to decarbonize and digitize the business as well as enable new business models through the introduction of circular economy propositions). Capgemini considers green computing as a a "hygiene factor": they make sure to sell a service fulfilling customers' needs in this domain. For example, by guaranteeing the use of renewable energy sources and helping customers minimise their energy consumption footprints, for example turning off computing resources when they are not needed. Cloud computing of course helps to maximise efficiency by handling peak computing workloads without needing to instal excess capacity, generating savings in data centers' facilities and management. Capgemini makes also sure to run customers' workloads in the most efficient way providing tools to scale up and down the use of computing resources as needed.

3.1.6.2 CS Group

The CS Group is a mid-size European software provider present in multiple EU countries and the USA. The group has been working with cloud for several years. The software they develop is also in the cloud and they have built their own internal cloud for their developments. In addition, they are also using external cloud providers. In the space industry, they have a lot of experience in using the cloud and developing and integrating on top of the cloud for their customers.

Business Impact

CS Group defined its cloud strategy 10 years ago, and they developed their software as intellectual property. Today, they have chosen an Open Source strategy and have a deep knowledge of the ecosystem. When customers integrate their cloud, they reuse Open Source software, in different layers, like Copernicus and Kafka. They have defined what they call a landscape, where they categorize what software and what methodologies to use and make sure they use the best software for each function.
Their Open Source offering is a good practice in terms of avoiding customers' lock-in by proprietary technology and at the same time helping their customers optimizing their cloud infrastructure. The group is up to date with the most recent technology trends, using edge, AI,

[35] IDC MarketScape: Worldwide Digital Strategy Consulting Services 2021 Vendor Assessment, June 2021, https://www.idc.com/getdoc.jsp?containerId=US46766521

and next generation security. Plus, they do Virtual Reality (VR) and Enhanced Reality in their human-machine interface.

Data Governance

The CS Group counts among its clients the European Commission, the European Space Agency and other European organizations which prioritize European data sovereignty. Therefore, the CS Group has developed a strategy which can be considered a good practice in this field: they developed a software C-Scale, which is an open-source multi-use cloud management system: any application developed under C-Scale is portable to other cloud software. CS Group also has a specific business unit called cybersecurity business unit, which they use and integrate with all their projects dealing with data sovereignty.
They are also able to build a network of different cloud infrastructures. CS Group leads the Space Dataspace of Gaia-X so they are part of the most high profile data sovereignty initiative in Europe. The CS Group is convinced that European providers must federate in order to provide a valid alternative to the power of Global hyperscalers. Today, sometimes CS Group cannot find sufficient machines in the cloud from European infrastructures and has to use hyperscalers for their own projects.

3.1.6.3 OpenNebula

OpenNebula is an open-source platform for virtualizing data centres and cloud management capabilities. In the last two years the company focused on "One edge" initiative, building and extending capabilities to reach the edge, with distributed private cloud and hybrid cloud capabilities integrated, in order to put resources closer to end users and reduce latency. OpenNebula integrates a broad catalogue of bare metal providers, delivering a distributed cloud management platform that aggregates on-demand cloud resources across multiple edge locations.

The vision is to mix cloud and edge, enabling an easier management of edge cloud and give the ability to enable private cloud on different location on demand, utilizing bare metal cloud resources around the globe, configuring cluster in easy way.

Technology innovation

OpenNebula is a good practice in terms of the implementation of edge computing which became completely operational in the first months of 2021. The company approach aims at expanding cloud capabilities to the edge and edge locations, supporting the increasing needs of customers in terms of latency, with the ability to deploy edge private cloud cluster on different locations and infrastructure. OpenNebula measures success based on KPIs like the number of downloads, number of active clouds, numbers of datacentres and cores. Other KPIs include the number of connections (5.000 connections worldwide) and downloads (500 times per months).

3.1.6.4 Reply

Reply is a system integrator specialised in consulting and digital services. The objective of the company is to help clients in the whole path of digital transformation. Reply is a group structured in multiple companies specialised in different technologies and vertical markets, approximately 150 legal entities, localised mainly in Italy, Germany, UK and the US. Approximately 20 companies in the group are specialized in cloud computing, typically each one is bound to a single vendor (Microsoft, IBM, Oracle, Google, Amazon…), mainly in the IaaS and PaaS space. Others are dedicated to specific markets, or to vendors that are offering SaaS like Salesforce and Oracle. Their target markets include telecom and media; industry and services; banking and insurance; and public sectors. Reply Spa has worked on cloud since 2008 with AWS.

Business Impact

The good practice component of Reply's approach is their ability to help customers adopt advanced cloud technology prioritizing the satisfaction of their business needs. The company identifies two main key competitive success factors:

1. time to market - the shortest possible time for the IT to provide new functionalities and satisfy business needs.

2. Cost efficiency - how much organizations can optimize in terms of costs, without giving up on performance or operational efficiency.

Reply's approach is to replicate the original services and take gradual, incremental steps introducing innovation, measuring results at each step, to optimize results. In this way they help customers to adopt technology innovation demonstrating their business benefits. The cost savings depend on two main aspects: lower spending with cloud providers, typically around minus 5-10% (for example by using less disk or different types/hierarchy of disks, or different type of services); the second concerns the benefits of the automated cloud model (reducing the need of human intervention for example for scaling up computing power at demand) which can yield savings up to 30%-40%.

Technology Innovation

Reply has embraced almost all recent technologies: AR/VR, Blockchain, AI, IoT, Edge, next-generation security. They often use the computational power of AI offered by cloud providers to help customers develop advanced services. For example, on behalf of a car insurance company, they are using AI empowered image recognition to check damages resulting from low value accidents, substituting human intervention, saving personnel costs. This service has been developed by training the AI capability and ML (Machine Learning) algorithms offered by the cloud provider. With proper training, the precision in the results of damage checks can be over 95%.

3.1.7 Research and Innovation Initiatives

The cases presented here concern research and innovation projects conducted or still running in the EU between 2016 and 2020. Each project was/is funded by the Horizon 2020 (H2020) funding programme of the European Commission. All of these projects have similar organisational structures:

- Lead organisation: often a research institute or university, led by a principal investigator.
- Academic partners: partnering researchers with complementary areas of expertise and complementary project tasks.
- Industrial partners: large and small organisations that offer inputs (perhaps proprietary) to the proposed project and/or that represent target use cases for the planned innovation. EC-funding favours projects that involve SMEs, and most projects include their participation.
- Multinational: EC-funding also favours projects whose partners come from across the EU – ideally, from both large and small Member States.
- Specific time frames and funding, along with well-defined deliverables specified as part of the initial project proposal.

EC-funded projects are focused on collaborative, pre-commercial research and/or promotion of take-up of innovative technologies, through the demonstration of the benefits of the business case, and/or identifying and overcoming barriers to adoption. In the Horizon 2020 Programme the EC has adopted the TRL – Technology Readiness Scale –to classify the expected outcomes of projects, for example from TRL 3 (experimental proof of concept) or 4 (validation in a lab) all the way to TRL9 (actual system proven in operational environment such as manufacturing). A project with TRL 3 or TRL4 will most often be followed by another project to

further develop the technology towards market adoption. Some projects (for example innovation action and large-scale pilots) aim for a higher TRL and focus on developing the value chain for specific technologies, pulling together the stakeholders and implementing use cases in operational environments.

The measure of success for R&D projects therefore must be aligned with the project's position in the path from research to market and whether it has demonstrably achieved its own expected impacts. The projects described below are good practices because they have successfully solved technology challenges (technology innovation criterion), demonstrated use cases and paved the way towards market success (Business Impact criterion) experimented or generated innovative governance and organizational models (governance structure criterion), pioneered innovative solutions for data protection, data sharing, data sovereignty (data management criterion) or made progress in developing technologies able to reduce energy consumption and maximize environmental impacts of ICT (Green IT).

Name of the project	Relevance for H-Cloud Key Areas	Status of the Project	Type of Good Practice
COLA* Innovation action	Federated cloud	Complete, with follow-on projects in progress	• Business Impact • Technology innovation
LightKone* Research and innovation action	Cloud Edge	Complete, followed by start-up	• Business Impact • Technology innovation
MORPHEMIC Research and innovation action	Multicloud	In progress	• Technology innovation • Data governance
OCRE Pre-commercial procurement	Federated Cloud, Edge Computing	In progress	• Business Impact • Technology Innovation
PLEDGER Research and Innovation action	Cloud Edge	In progress	• Business Impact • Technology innovation • SME
RestAssured* Research and Innovation action	Cloud	Complete, followed by FOGPROTECT project	• Data Governance
SUNFISH* Research and Innovation action	Cloud Federated cloud	Complete	• Data Governance

Table 7: Summary of Research Sector Initiatives That Include Good Practices

3.1.7.1 COLA *

COLA[36] (Jan 2017–Sep 2019) addressed the following challenges: (1) describing the structure of containerised/virtualised applications and their behaviour to control their lifecycles in a cloud-agnostic way, (2) supporting the deployment and run-time orchestration and optimisation of such applications, taking various QoS parameters into account, and (3) creating and running near production level applications in the cloud.

COLA's MiCADO solution extends state-of-the-art virtual machine management beyond the level offered by Terraform and extends container management beyond the level offered by Docker Swarm and Kubernetes. COLA makes it easier to manage applications across hybrid- and multi-cloud environments. Using COLA, application developers can create cloud-enabled

[36] https://project-cola.eu/

applications from existing applications with minimum effort and can make them available to customers.

Business Impact

COLA created a technically strong, production-ready tool that is relevant in the fast-moving cloud development tools market. It has resulted in a promising spinoff research product, supported by a dedicated company. From a business standpoint, MiCADO is now being used in several follow-on research projects (e.g. DigitBrain and Asklepios), and commercial marketing is handled by CloudSME. However, commercial adoption of MiCADO beyond the correlated stakeholders has been very slow.

Technology Innovation

Technically, the COLA project was very successful. The EC ranked COLA among the top 10 projects submitted under its H2020-ICT-06-2016 cloud computing call. This was achieved despite the rapid rate of change in cloud tools at the time, with the originally targeted Occupus and Docker Swarm tools overtaken in the cloud developer market by Terraform and Kubernetes, respectively. COLA was able to manage this transition with modest effort, highlighting the intelligent design of the MiCADO solution.

3.1.7.2 LightKone *

The goal of LightKone[37] (Jan 2017–Dec 2019) was 'to develop a scientifically sound and industrially validated model for doing general-purpose computation on edge networks.' LightKone approached this objective by rejecting the idea that data collected at the edge should be transported to a central cloud to continue storage and processing and instead worked to create a robust architecture for independent edge networks.

Business Impact

- LightKone's solution for Peer Stritzinger, a German industrial IoT company, has seen growing adoption. This solution motivated the development of a lightweight edge-computing device (GRiSP), which is now reaching quantity production.
- The LightKone programming model is being commercialised by Paris-based start-up Concordant.

From a good-practice standpoint, LightKone achieved significant success with a novel approach, including the creation of a promising commercialisation venture. Given the promise of LightKone's developments, one would hope to see go-to-market plans and wider adoption of this approach, but LightKone's next steps remain confidential.

Technology Innovation

A key component of this architecture is the 'conflict-free replicated data type' (CRDT), which allows particular pieces of data to exist in multiple places across a network, and for the copies of that data to remain consistent without centralised synchronisation or continuous communication. (CRDT is used by other solutions and companies – for example, the Redis and Riack data systems, TomTom navigation system, and Facebook's Apollo data system.) The CRDT's resiliency makes it ideal for use in edge networks, and the LightKone project has built a unified programming model, with three implementations (Antidote, Lasp, and Legion) adapted to specific edge circumstances, all based on the CRDT, as well as the gossip networking protocol. LightKone successfully applied these technologies to a number of use cases, and the solution was achieved at the edge in each case, without requiring centralised computation or control in the cloud. In the future, LightKone partners envision the growth of edge computing without relying on any cloud-based resources, but such a new architecture would represent a significant paradigm shift.

[37] https://www.lightkone.eu/

3.1.7.3 Morphemic

The MORPHEMIC project builds upon and extends the H2020 EU MELODIC project. The MORPHEMIC platform supports the multicloud, edge, hybrid and IoT deployment models in an automatic and optimized way, increasing the effectiveness of the deployed applications in the multicloud domain. It is used for deployment and optimization particularly AI based applications, as the MORPHEMIC contains support for hardware accelerators: GPU and FPGA. It significantly reduces cost of application usage.

Technology Innovation

The project implements three use-cases that will better define and evaluate the MORPHEMIC platform. The three use-cases belong to different application domains covering a wide range of usage possibilities.

1. E-Brain Science, proposed by Centre Hospitalier Universitaire Vadois (CHUV), one of the five Swiss University hospitals. Specifically, the use-case can be applied to the work of the Laboratoire de recherche en neuroimagerie (LREN), which consists of a cross-disciplinary team of basic and clinical neuroscientists with an interest in the role of human brain structure and function in neurological disorders and healthy aging. Objective of the case is to analyse data on populations of patients for diagnosis and research. Currently part of this task is performed through software solutions that clinicians, neuroscientists and epidemiologists can run on their laptop or desktop or, in case of large patient cohorts, on HPC. However, the increased complexity and data available will make necessary the use of cloud computing and GPUs to achieve the desired results in a reasonable amount of time. For this reason, MORPHEMIC will be used to make more efficient the use of computing and storage resources to obtain the same results keeping a high level of security.
2. Computational Fluid Dynamic Simulation (CFD), proposed by ICON. ICON Technology & Process Consulting Limited provides blue-chip multi- sector engineering companies, their suppliers and consultants with the ability to predict fluid flow using 3D computer simulation. Specifically, MORPHEMIC will support the deployment of three CFD scenarios different in terms of requested resources.
3. Virtualized base station for 5G cloud-RAN, proposed by IS-Wireless. IS-Wireless is a leader in the development of algorithms, protocols and tools for 4G and 5G mobile networks. IS-Wireless provides licensable, NFV-compatible (Network Function Virtualization) software implementing standard-compliant RAN (Radio Access Network) protocols ready for evolution to 5G. MORPHEMIC platform will ensure close to optimal balance between performance and costs for ISW's SD-RAN product. On one hand, it will be able to optimize the deployment costs (CAPEX) related to the design phase of network slices which will be automated and simplified by adopting CAMEL formalism and Modelio design tool. On the other, operational costs (OPEX) will be reduced due to the flexible and optimized choice of deployment form (VM, unikernel, container, FPGA, etc.). In addition, thanks to the rich modelling and performance optimization capability of MORPHEMIC, it will be possible to design custom application descriptors (though the CAMEL model) for different verticals with myriads of specific scenarios. As a result, MORPHEMIC will help ISW to address and expand quicker to new markets.

Data Governance

The use cases implemented in the project collect and experiment with datasets provided by the relevant stakeholders as follows:

- e-BrainScience use case by CHUV will be used as input images from the freely publicly available anonymized MRI data sets: OASIS, UK biobank, IXI. The extent of their use concerns only the development phase of the MORPHEMIC platform.
- Computational Fluid Dynamics Simulation use case by ICON will be using publicly available geometric data for the CFD simulation's execution.
- Regarding data generated and published from the use case application validation phase, use case Virtualized base station for 5G cloud-RAN by IS-Wireless will publish the RAN performance validation data set, which could be useful for simulating network performance over time for a Cloud-RAN deployment for further research purposes.

The project experiments with data sharing in a cloud continuum and will make available most of these data through the MORPHEMIC OpenAIRE page, as well as through the project's website. Additionally, data will also be made available through Zenodo, an open research repository created and supported by OpenAIRE and CERN.
The collected data content may be of interest to both the commercial sectors from which they were collected, as well as to a wider community of data scientists, or students of data science, to carry out machine learning research. DevOps operators may be interested in the application and infrastructure monitoring data as a means of comparison against their own practices.
Open-source solutions, such as Docker, git and web technologies will be used. The open-source contributions are one of the key goals of the MORPHEMIC project. All open-source software components developed and enhanced by the consortium members for the MORPHEMIC project will become publicly available as Docker images.

3.1.7.4 OCRE

The OCRE[38] project (Open Clouds for Research Environments Jan 2019–Dec 2021) facilitates the pre-commercial procurement of cloud services, providing the main near-term procurement opportunity for the public research and education sector in the context of EOSC (European Open Science Cloud). (*OCRE is also featured as an initiative by the Helix Nebula PPP in par.3.1.4*). The OCRE consortium partners (GÉANT, the pan-European science network organization, CERN, Trust-IT, RHEA) all have outreach mechanisms to promote rapid, agile innovation. GÉANT and the NRENs (National Research and Education Networks) provide extensive support to the European research community and cloud marketplace through OCRE and other projects. This support is aimed at driving collaboration between the R&E community and suppliers by means of webinars, tools training, conferences etc.

Business Impact

The project is not completed yet but it has already demonstrated a relevant Business Impact as originally planned, more specifically:

- The OCRE framework attracted an unprecedented 1100 bids from the market and led to the signature of 473 contracts across 40 countries in Europe. The project has high visibility and has resulted in extensive outreach from the market to the research community in Europe. Activities include webinars, training, and other forms of enablement.
- The first open calls for funding for cloud and EO services attracted 70 compelling proposals from significant research projects across the region, indicating significant demand for commercial digital services within the community.
- The partners carry out an ongoing activity of evangelization and promotion in the stakeholder community of the consumption of commercial services in support of agility and innovation.

[38] https://www.ocre-project.eu/

- OCRE's outreach into the immature EO marketplace focuses specifically on the commercialization of services supplied by the SME community. The large cloud platforms provide extensive support for startups, SMEs and enterprise ISVs (Independent software vendors)

Technology Innovation

The OCRE framework is designed to promote the adoption of innovative cloud-based technologies in the research environment:

- Each of the commercial platforms on the OCRE framework offers a range of platform services that are complementary to the base infrastructure (IaaS) offering through a marketplace. These services include platforms in support of Blockchain, ML, AI, the abstraction of data from connected devices (IoT), and more. The research community is asking for these technologies as shown in the open calls for funding organized by the project.
- The suppliers have all agreed to driving innovation through their outreach and demonstration of the commercial services. A good example of this would be a semantic mining tool developed by a supplier to interrogate research data workloads and assist the researcher in the auto-generation of standardized metadata in support of the FAIR data principles.
- All the providers registered with OCRE have agreed to guarantee a series of requirements particularly important for the research and education community, and this is a major benefit for the community, relieving them from the need to check and verify their compliance b potential suppliers. These requirements include:
    - All suppliers are registered operators within Europe and are therefore GDPR compliant.
    - All suppliers have local European data centers and allow the R&E community choice in terms of where their data is stored.
    - All suppliers support dual encryption with the second key known only to the consumer.
    - Most suppliers offer cold storage in support of cost-efficient FAIR (Findability, Accessibility, Interoperability and Reusability) principles of data storage.
    - All suppliers have their own SOCs (Security Operations Centers) and have unparalleled capacity in terms of threat surveillance, identification and resolution.
    - All platforms will peer with the GÉANT network and waive most data ingress and egress charges.

3.1.7.5 PLEDGER

The PLEDGER (Performance optimization and edge computing orchestration for enhanced experience and Quality of Service, 2019-2021) project aims at delivering a new architectural paradigm and a toolset that will pave the way for next generation edge computing infrastructures, tackling the modern challenges faced today and coupling the benefits of low latencies on the edge, with the robustness and resilience of cloud infrastructures.

Business Impact

PLEDGER is focused on providing high-quality tools and services that can attract customers for more than one sale, increasing their satisfaction, becoming a reliable provider.

Apart from the common collaboration in any research project, the project has created a User Group. This is an initiative that external stakeholders can join by signing a MoU. In this way external stakeholders can make limited use of PLEDGER resources, including software, infrastructure and documentation with the compromise of not sharing any confidential information and provide feedback about the proposed solution. While PLEDGER partners provide support to them, guidelines and make any information or resource needed available.

There is an ongoing discussion with two external entities so they can test project results and develop their own use cases on top of them.

The PLEDGER solution is mainly focused on smart manufacturing and smart cities, although it can be extended to any other domain. In these two domains, privacy and security are the most important aspects to deal with. Although PLEDGER is not dealing with personal data, it is important to ensure compliance with, at least, GDPR. Ensuring data protection when moving data analysis to the cloud is also important.

Technology Innovation

The PLEDGER platform includes blockchain technologies for securing microtransactions and develop smart contracts at user level. It also provides mechanisms for operating at the edge, including deployment and execution of applications. Finally, there are security mechanisms implemented to beat one of the cloud pain adoption points: data privacy and security when executing applications on the cloud. In addition, one of the PLEDGER use cases is a VR/XR (Virtual/ Extended Reality) application, which is used to make more attractive the final offering.

PLEDGER does not directly address energy efficiency considerations. However, a proper service placement on the edge or on the cloud can also improve the energy consumption at software level. Energy efficiency at software level is the next step to be performed when everything is done at infrastructure level. Use of renewable sources or implemented energy efficiency measures can be also included as part of the infrastructure provider profile and can be included in the trustworthiness mechanisms so the final user can take the decision also based on green considerations.

Focus on SMEs

One of the project's use cases is provided by a SME. In this way, PLEDGER can measure how costly is to use the proposed solution and to adapt the existent software to it. On the other hand, PLEDGER plans to provide its results licensed under open-source schemes what will make them cheaper. Thus, making them more affordable to SMEs who usually have less economic resources.

3.1.7.6 RestAssured *

RestAssured[39] (Jan 2017–Dec 2019) set out to provide end-to-end security for sensitive data, with four components: '(1) fully homomorphic encryption to process data without decryption, with cloud enablement of SGX hardware for protected data processing, (2) sticky policies for decentralised data lifecycle management, (3) models@runtime for data protection assurance, and (4) automated risk management for run-time data protection'.

Data Governance

- Project partner IBM successfully developed Parquet Modular Encryption (PME), improving security for Parquet, a common storage service used with Apache Spark. This has been adopted by the Apache Spark user community, and uptake has been significant. However, this approach does not achieve fully homomorphic encryption, and additional data protection is needed (using Secure Enclave CPUs for local processing, as well as Transport Level Security for data transmission).
- Project partner IT Innovations, the University of Southampton's innovation unit, has refined a System Security Modeller, which can perform risk assessments of static IT configurations. IT Innovations has embedded this capability in several service offerings,

[39] https://restassuredh2020.eu/

along with a productised SpydeRisk security compliance documentation tool. (The level of uptake is unknown.)

- The architecture developed to implement 'sticky policies' was found to be complicated and cumbersome.
- Similarly, automated risk management, particularly the automated evaluation of data queries against privacy policies, remains a challenging research problem.

From a good-practice standpoint, the RestAssured project was well managed and successfully achieved innovative technology development, which is now being further developed by a follow-up project FOG PROTECT dealing with remaining technology challenges.

3.1.7.7 SUNFISH *

SUNFISH[40] (Jan 2015–Dec 2017) prototyped and demonstrated the secure interoperation of separate cloud systems using a federation-as-a-service approach. This approach goes beyond the adoption of interoperability standards, since those standards are still a work in progress. The approach also avoids creating a separate entity to manage the federation – instead, setting up robust peer-to-peer protocols for creating, operating, and eventually dismantling a federation.

The Sunfish architecture is built on a variety of tools/functions that address security and privacy in particular and SLA (Service Level Agreement) compliance in general. These capabilities are fundamental to Sunfish architecture, representing 'privacy by design', rather than being 'bolted on' as is sometimes seen in other efforts.

Data Governance

Sunfish assumes blockchain and distributed-ledger technology (DLT) can be used in the future to ensure the verifiability of communication among federation partners, to manage compliance with contractual terms (smart contracts), and to register the status of resources across the federation. DLT will also pave the way for cultural and organisational change, allowing hierarchically 'equal' departments to collaborate on projects without problems of rivalry or territoriality. Unfortunately, the computational burden and latency of proof-of-work DLT prevented adoption at the time of the project, but emerging proof-of-stake schemes should enable this ability in planned future implementations.

Sunfish focused on several public-administration use cases:

- Taxation (Italy): The Ministry of the Economy and Finance (MEF) handles payroll processing for over 2 million public-sector employees. Payroll taxes are calculated based on the employee's home address. MEF requires access to the home addresses of police employed by the Ministry of the Interior (MIN), but these addresses are personal information, and Italian law prevents their disclosure outside of MIN because of possible threats to police. Sunfish's secure federated cloud services enable the correct calculation of payroll taxes without exposing home addresses (even to another ministry of the Italian government).
- Taxation (Malta): Maltese businesses submit payroll information, financial statements, and accounting records to the Malta Taxation Department to calculate tax payments and refunds. Large organisations have internal IT resources to manage electronic submission of such data, but this is an onerous requirement for small organisations. Sunfish's secure federated cloud services make it easy for some small organisations to link their SaaS financial accounting services with the Taxation Department.

[40] http://www.sunfishproject.eu/

- Public Safety (UK): The UK's efforts against cybercrime are organised into nine regional cybercrime units, each of which is required to independently manage and store the data and evidence collected in its investigations, while at the same time enabling authorised access to this data from other units as investigations proceed. Transferring data outside each unit was not possible, nor was the merging of all units' data into a separate entity to enable search, analysis, and/or processing. Sunfish's secure federated cloud services enable cybercrime units to search other units' data without actually exposing or transferring that data to the other units.

From a good-practice standpoint, Sunfish demonstrates a technical solution (distributed ledger technology – specifically, smart contracts) that can help solve a key problem of data governance – namely, automatically supporting data subjects (or data stewards acting on their behalf) in responding to requests to access or exchange private data. Many implementation challenges remain, such as the need for 'social engineering' to ensure data subjects are sufficiently engaged to appropriately set up such smart contracts.

3.1.8 Public Private Partnerships

Name	Relevance for H-Cloud Key Areas	Status of the Initiative	Type of Good Practice
GAIA-X*	Federated cloud	In development	• Governance / organizational structure • Data governance
Helix Nebula*	Federated cloud	In operation	• Business Impact • Technology Innovation
IDS*	Federated cloud	In development	• Data governance

Table 8: Summary of PPPs That Include Good Practices

3.1.8.1 GAIA-X *

At its digital summit on October 29, 2019, the German Federal Ministry for Education and Research — together with the Federal Ministry for Economic Affairs and Energy (BMWi) — unveiled its vision for a connected cloud-based data infrastructure for Europe. GAIA-X[41] has two main goals:

- To win back the sovereignty of European citizen and company data by ensuring that such data does not leave European soil unintentionally.
- To reduce dependency and the risk of lock-in by enabling service and data portability.

By delivering on those two strategic goals, GAIA-X expects to encourage cloud-sceptic European organisations (particularly SMEs) to take advantage of cloud, while maintaining control of their data, and to foster the creation of an open digital innovation ecosystem in which data can be collected and shared securely, while adhering to European privacy regulation. It is not intended to compete with global hyperscalers; it will be a layer on top of their services.

GAIA-X includes good practices related to **governance and data governance for federated clouds.**

Governance and Organizational structure

GAIA-X has two tiers of governance:

[41] https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html

- Tier-1: During the first year after launch, the central programme management office was led by BMWi and it coordinated the work of founding members. This central PMO made the final decisions about long-term strategy, operating model, business model, and rules for other entities to participate in the programme and be certified as GAIA-X nodes. On September 15, 2020, the 22 founding members co-signed incorporation papers for GAIA-X's L'association internationale sans but lucratif (AISBL), a non-profit association that will be responsible for securing funding and commitment from members to fulfil the initiative's vision. The founding members and co-signers of AISBL include: 3DS OUTSCALE, Amadeus, ATOS engineering, Beckhoff Automation, BMW, Bosch, CISPE, DE-CIX, Deutsche Telekom, Docaposte, EDF, Fraunhofer Gesellschaft, German Edge Cloud, IMT, International Data Spaces Association, Orange, OVH, PlusServer, Safran, SAP, Scaleway, and Siemens.
- Tier-2: This has several workstreams, in which a large number of organisations participate, from regional government data centres in Germany to European vendors such as OVH and global cloud providers like IBM.

The GAIA-X project is divided into different workstreams for specific topics:

- User ecosystems and requirements
- Technical implementation
- A cross-functional unit known as the Joint Requirements Expert Tribe: This unit consists of two groups that are convened on a flexible basis and that deal with topics in which interdependency between the workstreams is strong. The project structure is agile in that it can be adapted over time, in line with framework conditions, and guarantees collaboration across separate topics.

Data Governance

From a data governance perspective, GAIA-X expands on the archetypes and processes developed by International Data Space to deliver:

- The implementation of secure federated identity and trust mechanisms (security and privacy by design)
- Sovereign data services, which ensure the identity of the source and receiver of data, as well as data access and usage rights
- Easy access to the available providers, nodes, and services, with data provided through federated catalogues
- The integration of existing standards to ensure interoperability and portability across infrastructures, applications, and data
- The establishment of a compliance framework and certification & accreditation services
- The contribution of a modular compilation of open-source software and standards to support providers in delivering secure, federated, and interoperable infrastructure

3.1.8.2 Helix Nebula *

Helix Nebula (HN)[42] is a partnership between industry, space agencies, and science with the goal to establish a dynamic ecosystem, benefiting from open cloud services for the seamless integration of science into a business environment. Today, the partnership counts over 40 public and private partners. The strategic goal is to enable the research community to use commercial cloud services rather than investing in their own infrastructure. To do so, HN has

[42] https://www.hnscicloud.eu/

launched a series of projects and created a pre-commercial procurement framework (to enable the adoption of innovative solutions) gradually developing the common cloud infrastructure.

Helix Nebula (June 2012–May 2014) started by bringing providers and 'buyers' together to discuss requirement and create technical and service architectures to frame the work, with the intention of creating a marketplace of cloud services that is structured to align with customer needs.

Three key challenges were encountered:

- Procurement: Despite success in defining the marketplace's operation, it was still difficult for customers (various research communities and infrastructures) to 'purchase' services through the marketplace, since this did not align with the procurement processes that were imposed on the institutions that were legally making the purchases.
- Trust: Despite the collaborative work on the technical details of Helix Nebula, customers were still unsure about the service offers being made and hesitant to take advantage of them. Some of this came from the perceived higher costs of these offers compared with customers' traditional on-premises capital expenditure-based infrastructures. Some of this related to a traditional distrust of commercial companies among academic institutions.
- Service definition: The providers built a technical catalogue of services that aligned with their practices, but these services did not align well with the buyers' needs. Buyers had difficulty identifying the services they needed, and certain services were assumed by providers to also be needed but overlooked by buyers, creating service gaps that reduced trust in what was being offered.

To deal with these issues, HC launched the project **Helix Nebula Science Cloud** (HNSciCloud, January 2016-December 2018) which organized a €5.3 million Pre-Commercial Procurement (PCP) tender, led by CERN, for the establishment of a European hybrid cloud platform to support the deployment of high-performance computing and big-data capabilities for scientific research. The HNSciCloud was launched in 2018 linking together commercial cloud service providers and publicly funded research organisations' in-house IT resources, via the GEANT network. The initiative was launched as one of the components of the nascent European Open Science Cloud (EOSC).

The initiative addressed the procurement, trust and service definition issues directly by engaging in a codesign process, using a pre-commercial procurement framework to specify requirements from a small number of customers (the 'buyers group'), inviting specific proposals from commercial providers, and developing solutions using an iterative process resulting in two suppliers (consortia) delivering validated solutions for customers. This structure directly addressed the procurement challenge, and its collaborative codesign nature enabled the building of trust between the two sides. In addition, specific project tasks addressed concerns around 'value for money' and comparative pricing, with detailed total cost of ownership (TCO) studies conducted for both research infrastructures and commercial offers and with specific use cases identified that made sense for each procurement approach. Testing and certification processes were established to objectively assess whether requirements were met, addressing the research community's subjective concerns about commercial providers. Finally, responsibility for creating the completely integrated service needed by buyers, as defined by their requirement, was clearly placed on providers, so that buyers could be sure they were getting a complete solution.

Business Impact and Technology Innovation

HN Science Cloud is widely seen as a success. It has triggered a re-evaluation of 'owned' research IT infrastructure, triggering growing use of cloud-based tools in research. For example, CERN, a key partner in both Helix Nebula and HN Science Cloud, has increased its use of cloud-based machine-learning tools, using AI to improve the capabilities and performance of the CERN research infrastructure (particularly the Large Hadron Collider – LHC). It has refined the understanding of the community of how to procure IT infrastructure – making sure these long-term procurements are fit for purpose for the mix of IT applications that in fact should be hosted on 'owned' infrastructure.

The follow-up to HNSciCloud is two more projects:

- The OCRE[43] project (Jan 2019–Dec 2021) facilitates the procurement of cloud services, providing the main near-term procurement opportunity for the public research and education sector to exploit the results of HNSciCloud in the context of EOSC. (*OCRE is also featured as a R&I good practice in par.3.1.3*).
- The ARCHIVER[44] project (Jan 2019–Dec 2021) is designed to create an eco-system for specialist ICT companies active in archiving, who would like to introduce new services capable of supporting the expanding needs of research communities. ARCHIVER combines multiple ICT technologies, including extreme data-scaling, network connectivity, service interoperability and business models, in a hybrid cloud environment to deliver end-to-end archival and preservation services that cover the full research lifecycle.

The sequence of projects and their evolution represent an interesting case study on the challenges of using commercial cloud to meet some very specific, yet innovative, requirements where the 'business case' is still evolving. Helix Nebula is based on a stepwise codesign approach, bringing providers and customers together, which is essential to enable related solutions in the future.

The Helix Nebula experience is quite unique but can be considered a good practice because it enabled research organizations to overcome barriers to innovation adoption through innovative collaboration and pre-commercial procurement. In the research as in the business environment a technology paradigm shift (such as the move from internal networks to cloud computing) encounters significant technical, cultural, organisational, and financial barriers. In addition, in the research context, there is no 'standard business case' (there is no direct ROI on research) so there is no apparent economic incentive to change technology model, even though there are benefits which can be demonstrated. Helix Nebula shows how complex but ultimately successful can be the effort to radically innovate a technology impacting research practice. The HN experience provides useful lessons learned for the next transitions (for example to edge computing) and other application areas, where paradigm shifts are expected (e.g. in healthcare or agriculture) rather than incremental operational savings.

3.1.8.3 IDS *

In 2014, the German Federal Government and the Fraunhofer Institute partnered with key German industry players to launch International Data Spaces (IDS)[45], a project that aims to improve European data sovereignty. IDS created a secure data space to help organisations from different industries monetise their data resources through cloud-based secure exchange and the easy combination of data in value chains – the foundation for smart services, innovative solutions, and automated business processes.

Data Governance

[43] https://www.ocre-project.eu/
[44] https://www.archiver-project.eu/
[45] https://www.fraunhofer.de/en/research/lighthouse-projects-fraunhofer-initiatives/international-data-spaces.html

IDS includes a good practice related to **data governance for federated cloud**. IDS provides a reference architecture, a formal standard, and reference implementations, including sample code. The two foundational elements of IDS are:

- IDS connector: The IDS connector acts as a gateway. It can be implemented in different ways, depending on the scenario – on micro-controllers, sensors, mobile devices, and servers and in the cloud. Due to the container architecture, the IDS connector also enables the trusted execution of apps – those that can sovereignly process data from different sources. These software services will not run in an ERP system, behind the firewall, but on cloud platforms – that is, 'at the centre' of the ecosystem. The connector is therefore a suitable execution component for Amazon Web Services (AWS), Data Intelligence Hub (DIH), SAP HANA, and so forth, because it enables the platforms to offer a secure environment in which data sovereignty is guaranteed[46]. Domain-specific application profiles enable embedding in specialist domains with different requirements (see DIN SPEC 27070).
- Certification: The certification concept confirms the conformity of components (connectors) and organisations with IDS architecture from independent organisations (e.g. PwC, TÜV, and Fraunhofer). This ensures that the organisations have taken all necessary measures for an IDS-compliant operating environment and use components that have been implemented according to the connector variant.

IDS has been able to apply these concepts to use cases that have business relevance in specific industries, such as the predictive maintenance of industrial equipment and shipment planning in logistics value chains. However, the existing applications involve bilateral data exchanges between two enterprises. It has not yet been scaled to multilateral data exchanges.

[46] www.internationaldataspaces.org/

4 ANALYSIS OF GOOD PRACTICES BY H-CLOUD KEY AREA

4.1. European Cloud Landscape Overview

When looking at the European cloud landscape, it is important to understand the different dynamics across the different layers. Infrastructure (hardware & software), Infrastructure as a service (IaaS), Platform as a service (PaaS), software as a service (SaaS) and systems integrators / cloud support services companies. They all play an active role in the European cloud landscape and influence cloud adoption in Europe.

- **Infrastructure (hardware & software)**: There is a limited number of international hardware and software infrastructure manufacturers that are headquartered in Europe; however, some cloud service providers, such as OVHcloud and Ionos, are producing their own hardware for their cloud datacenters. And Open Source initiatives are setting the basis for improved interoperability; for instance, Sovereign Cloud Stack is an Open Source initiative that defines a standardised cloud infrastructure stack based on Open Source components, which could be used as a basis for cloud federation in the context of Gaia-X.
- **Infrastructure as a service (IaaS):** European cloud providers are generally strong at competing with the basic IaaS services and offer better performance and better prices than their global competitors.
- **Platform as a service (PaaS):** the platform layer is the new frontier, were European cloud providers need to invest to compete effectively with their global competitors. Launching container services is a good first step, but the market is quickly moving to microservices and functions, which support new cloud-native application architectures and will need to be provided as well by European cloud providers, to achieve feature parity. The other element of the PaaS layer are data services, so offering a wide selection of database services and increasingly also AI and ML services will be critical for success in this market.
- **Software as a service (SaaS)**: Every European software company is in the process of turning into a SaaS company, as European businesses do not want to install and operate software packages anymore. They want to consume software as a service. As part of this transition (if they are not born in the cloud), European SaaS providers are changing their software architectures towards cloud-native application architectures and operate on an infrastructure as code architecture. They are not creating their own IaaS and PaaS services, but choose one or more cloud partners from the IaaS space as their backend. Increasingly, they want to offer their customers choice in the backend and run on several cloud providers, typically the largest IaaS providers, but increasingly there is a demand to also offer the choice of running on a European cloud provider. European IaaS providers in turn need to be able to deliver the infrastructure as code layer that is required to run cloud-native applications. When they are mature enough in their technology offering, European SaaS providers can integrate them as potential backends for their SaaS offerings. European SaaS vendors like Talentsoft and Comarch target a global customer base with their services and need to comply with data privacy regulations from various different countries. Offering their services from a European cloud provider helps them with GDPR compliance and other regulatory compliance requirements.
- **Systems integrators / cloud support services companies**. An important part of the European cloud landscape are European services companies, who help customers to implement cloud services. They are building out best practices for the most commonly used cloud providers, based on customer demand. That means that they are not focusing on implementing European cloud provider solution as the first step, because European customers primarily want help to implement the largest cloud provider's services. That puts European cloud providers at a disadvantage, because of cloud skills shortage in Europe, customers typically look for a cloud implementation partner

to get access to best practices. And if these services partners do not support European cloud provider's services, they will not be implemented.

Business Impact

European cloud providers are growing their businesses in Europe and building out their customers bases. But they are struggling to grow faster than the average market growth rate, which is mainly driven by global cloud provider's growth.

European cloud service providers like OVHcloud, Ionos, Scaleway, A1 Digital Exoscale, Citynetworks, etc are growing their customer base and revenues successfully because they can offer their services at more competitive prices than their global competitors and provide better performance in local markets. GDPR compliance and Gaia-X membership are additional differentiators. If they want to compete successfully with their larger global competitors, they need to grow their customer base at an even faster pace, which requires investments in sales, marketing, and consulting and support service resources.

Technology Innovation

European cloud providers are also going through a significant technology upgrade, as all have launched a container layer / Kubernetes service in their portfolio. Due to their smaller size and smaller R&D budgets, they cannot keep up with the pace of innovation from their global peers and need to focus on certain areas of the technology stack. For example, they are still in the beginning of their edge roadmaps. One argument that is often held against European cloud providers is the question of feature parity. Can they provide the same features and functions as their global peers? They need to implement emerging global standards like a Kubernetes engine and modern databases, but they also need to prioritize strategic investments in higher level functions like infrastructure as code, microservices, functions and AI /ML services to build competitive differentiation. Some examples:

- Telefonica have developed an edge solution for the shipyard in San Sebastian and work very actively in building out edge use cases
- OVHcloud is actively investing in their container layer and other PaaS services
- Ionos is looking to cover the entire edge-cloud continuum from a hardware and cloud services perspective
- KeepIT is building a SaaS data backup service in their own datacenters

Governance and organizational structure

European cloud providers are typically commercial businesses and have a commercial business governance and organizational structure. They are competing in the market and engaging in a federation was not a priority in the past. Nevertheless, also given the trend towards multicloud, we are starting to see examples of collaborative platforms (such as Cloud28) and an increasing interest in collaborative models. The successful models of cloud federation however are more likely to be found in the public sector and the research environment (EGI, Helix Nebula Science Cloud).

Data governance

In a shared responsibility model with the cloud provider, data governance is typically the responsibility of the customer. The responsibility with for example GDPR compliance is always with the data owner, but there are of course elements that are the responsibility of the data processor. Generally, GDPR compliance is a driver for adoption of European cloud services and stricter enforcement of GDPR and the Schrems II ruling could drive more customers to use European cloud services. However, there is not only data protection. Several of our good practices are engaged in data interoperability and data sharing, for example by participating to initiatives such as GAIA X.

Environmental Sustainability

Environmental sustainability is a key priority for European cloud providers and they all have programs in place to be as energy efficient as possible, starting with the hardware they are producing and using, to energy savings and focus on low PUE to water preservation projects.

4.1.1 Cloud Federation

Cloud federation has the potential to realise the economies of scale of a large cloud provider, while ensuring that both end users and small and medium-sized suppliers of technology services are not locked into one monolithic infrastructure and platform. However, many questions remain regarding the feasibility of cloud federation:

- What are the incentives to do it?
- Who guarantees that all participants in the federation live up to the same security standards?
- What is the commercial model?
- How do you ensure that all participants can deliver the same minimum service level?
- What is the right governance structure?
- How do you create customer trust in the federation?
- How do you advertise and market the federation?
- How do you technically set up the federation?

The initiatives featuring good practices that were analysed as part of this research offer learnings to overcome those challenges from multiple points of view.

Business Impact/ Impact: The key success factor for federation is adoption/participation. As indicated by public-sector initiatives featuring good practices, such as Statens IT and G-Cloud, an increase in the number of users of shared, community, or federated services generates a positive network effect. Higher participation drives economies of scale in terms of procurement and management. Good-practice knowledge sharing across participants favours continuous improvement in terms of technology and governance innovation. The French government's SPOTES programme defines and monitors a set of KPIs that tracks participation from multiple perspectives: user experience/satisfaction, number of transactions, number of registered users, number of tickets, and number of services offered. Utrecht University, which leads WeNMR, tracks the number of registered users, the number of computing jobs processed and the continuity of service.

However, it must be noted that it is difficult to achieve widespread adoption and collaboration. That is because:

- The federation may replace someone’s authority or job, so it will encounter organisational resistance.
- The federation may include multiple industries, with multilateral collaboration having no clear business case but requiring commitment to and experimentation with innovative use cases, an example being IDS.
- The federation may include competing companies that are concerned about disclosing trade secrets.
- The business case for the individual participating cloud providers might not be clear; business demand from customers might not be present; and the funds available for marketing the federation may be limited.

Technology Innovation: The good practices analysed are advancing the federated cloud technology innovation frontier along three main paths:

- Cloud provisioning and deployment across multi-cloud environments; for instance:
    - Logius is developing a Kubernetes container-based orchestration layer that aims to enable service rollout to AWS, Azure, and government private-cloud data centres. This orchestration layer, built on Open Source (OpenStack and OpenShift), aims to include all the capabilities necessary to manage a cloud federation, from service catalogue to performance dashboard and backup.
    - COLA's MiCADO solution extends virtual machine management beyond the level offered by Terraform and container management beyond the level offered by Docker Swarm and Kubernetes.
    - CloudSME is taking a container orchestrator technology to market that allows organisations to use multiple cloud platforms and move their workloads and data independently of the underlying infrastructure.
    - City Network is one of 20 OpenStack-based cloud providers in Europe, and it is building an open-standards-based cloud infrastructure that could be federated with other OpenStack-based cloud providers – if customer demand for it exists.
    - ThreeFold Grid offers a blockchain-based solution whereby any organisation can supply compute resources to the federated cloud grid based on an installed common operating system with security attributes included, and the whole federated infrastructure is managed automatically by blockchain.
    - 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.
    - The 'German Network for Bioinformatics Infrastructure – de.NBI' is a national, academic and non-profit infrastructure supported by the Federal Ministry of Education and Research providing bioinformatics services to users in life sciences research and biomedicine in Germany and Europe. The partners organize training events, courses and summer schools on tools, standards and compute services provided by de.NBI to assist researchers to more effectively exploit their data.
- Securing access to federated resources; for instance:
    - Sunfish assumes blockchain and DLT can be used in the future to ensure the verifiability of communication among federation partners, to manage compliance with contractual terms (smart contracts), and to register the status of resources across the federation.
- Reducing the cost of operating across multicloud environments; for instance:
    - Statens IT intends to build a shared tenant-based system with sub-tenants for users that can be swapped so that the user organisation can avoid purchasing a lot of new licenses.

Governance/Organisational Change: Realising the benefits of collaborative initiatives, such as community clouds and federated clouds, revolves around the ability to bring people together through the service lifecycle, from design and financing to implementation, operation, and consumption. This requires:

- Creating organisational and cultural change mechanisms that foster collaboration; for instance:
    - The first Helix Nebula project identified cultural and organisational differences between cloud service providers and organisations from the research community – including prejudice against commercial providers and the cloud in the research community and differing assumptions about procurement practices. HN Science Cloud's PCP approach enabled these differences to be

aired in a structured, goal-oriented context and solutions to be found that worked for both sides. HN Science Cloud assembled objective information to counter distrust. It conducted detailed TCO studies to resolve disagreements and misperceptions about the comparative costs of cloud-based and -owned infrastructure, as well as establishing automatic testing suites to objectively validate functional performance and compliance with specifications.

  - The French government's SPOTES invests in knowledge sharing through virtual events, seminars, educational material, and blogs that are made available on the marketplace to maintain momentum even during the COVID-19 crisis.
  - The Danish Statens IT initiative joined Euritas to learn from peer government IT modernisation programmes around Europe. The initiative invested in personnel certification and security clearance, to offer high-quality information assurance, and in training, to enhance technical personnel-customer relationship capabilities, to better align their offerings with the needs of individual government departments.

- Establishing structures and processes that make the collaborative supply of cloud services efficient, effective, and compliant with regulations; for instance:
  - Cloud28+ created a federation at the service catalogue level, whereby participating cloud vendors advertise their services through the Cloud28+ digital platform and marketplace.
  - G-Cloud realised an efficient and effective marketplace for certified cloud providers that want to supply services to the UK public sector.
  - The Austrian Federal Government separated technology innovation (EGIZ) from technology implementation (BRZ) to focus all government innovation decisions on interoperability standards, feasibility, and prototyping and then to define a minimum set of guidelines. At the operational level, the key goal is to keep EGIZ's service catalogue commercially competitive in the long run for the Austrian Federal Government. EGIZ and BRZ collaborate closely, but they are managed and funded separately so as to maintain independent decision making. They also employ different sets of expertise.
  - The Irish central government established a three-tiered IT governance model that includes: a) a civil service management board, which includes secretary generals of every department, with the government digital strategy discussed twice a year; b) a subgroup co-chaired by two of the most influential secretary generals (from the Finance Department and Welfare Department), where collective decision making happens about the government's digital strategy; and c) an ICT advisory board, including the heads of IT of every department, where more technical and tactical guidelines and action plans are discussed.
  - eSPAP has a flat structure with business units aligned to each line of service, which ensure that the end-to-end service life-cycle, from design to development, procurement, maintenance and support are built to bring together supply-side technology innovation and buyer-side user requirements. The eSPAP Board is also supported by a dedicated strategic planning and management control unit, which ensures architectural alignment and coordination of continuous improvement across the individual lines of service.
  - Academic research networks, like de.NBI and WeNMR, have identity and access management policies and procedures to register, onboard and manage users across dynamic communities that span multiple countries and transient users that move in and out of academic institutions. Requests for resources must for example describe the project requirements, the type and sensitivity of

data used. The administrator then sets up a tenant for the project with a lead user and delegation rights. These policies and procedures are not only meant to enable secure and convenient access to resources, but also allow the entity in charge of orchestrating the service to control the consistency and robustness of activities carried out when using the federated resources, to have error catching and error checking, validation of input data, to avoid failures and queues, which would create additional support work and costs.

- The work of GAIA-X is divided into different workstreams for specific topics: a) user ecosystems and requirements, b) technical implementation, and c) a cross-function unit known as the Joint Requirements Expert Tribe. This unit consists of two groups that are convened on a flexible basis and that deal with topics when interdependency between the workstreams is strong. The project structure is agile in that it can be adapted over time, in line with framework conditions, and guarantees collaboration across separate topics.

Data Governance: The analysed good practices are advancing federated cloud data governance capabilities along two main paths:

- Information assurance guidelines and certifications for suppliers of cloud services: Public sector and public private partnership good practice examples offer the most important learnings here. In fact, G-Cloud, WIIP, GAIA-X, and IDS have put in place a certification process that is used consistently to verify supplier's compliance with information assurance policies, before they are authorised to provide the service, and to audit them when they are operating in the environment.
- Data interoperability architectural standards and principles: Multilateral multi-industry programmes like GAIA-X and IDS strategically focus on interoperable data exchange. For instance, the IDS connector is a container architecture that can be implemented in different ways, depending on the scenario – on micro-controllers, sensors, mobile devices, and servers and in the cloud.

4.1.2 Edge Computing

Edge-related good practices can be divided into two main categories: what edge allows today, as a combination of already available resources, technologies, and approaches, often in collaboration with cloud; and how different aspects of edge technology are being developed and innovated.

Business Impact: The Business Impact is present across all the private initiatives analysed and in the City of Valencia initiative, which underlines how end-user organisations are looking at edge innovation to gain business benefits. Nevertheless, each initiative measures success and Business Impact in a different way. The City of Valencia's Smart City initiative focuses on a data-sharing platform that enables the delivery of a broad list of services. In the private sector, the number of edge endpoints deployed, the number of locations in which such solutions are deployed, and the number of clients adopting such solutions are, generally speaking, good KPIs for indicating the success of an initiative and its ROI. Additional KPIs include:

- Measuring how clients use the edge platform, the number of accesses to edge information, and the number of to edge applications is a popular way of understanding success (e.g. Vivacity Lab, Axis, and Wordsensing)
- Measuring the outcomes of the use case supported is another key point. These initiatives clearly underline that edge is not a universal fit; the solution, the technology, and the partner ecosystem are strictly dependent on use-case needs, which is why the Business Impact of the edge initiative in question relates strictly to the success of the use case supported. Vivacity Labs measures this through traffic efficiency on roads equipped with edge intelligent cameras, and BrianzAcque via the volume of water

dispatched and the service level delivered to citizens. A leading car manufacturer based in the EU correlates success in a factory in CEE with the service availability obtained by continuously monitoring uninterrupted power supplies. Wordsensing looks at how much customers/partners are saving by deploying the company's solutions, as well as the increases in the safety of workers, citizens, and the environment that edge-based geotechnical data management enables.

Technology innovation is another big impact resulting from the initiatives analysed. The approach of distributing computing capabilities is not a new trend, but edge can be seen as an emerging technology, with hardware and software platform innovations opening up new possibilities. Moreover, when edge computing is combined with other emerging technologies/innovation accelerators, it offers great potential. The LightKone research initiative, for example, focuses on a new architecture for computing and storing data at the edge, guaranteeing continuous alignment without the need for the core. The private initiatives researched feature, in particular, solutions that combine the Internet of Things, artificial intelligence, and analytics. Both Axis and Vivacity Lab, for example, enable artificial intelligence at the IoT edge (in smart cameras), with the former focusing on the deployment of more efficient hardware and the latter focusing on algorithm deployment. The solutions of BrianzAcque and the leading car manufacturer are based on the collection of IoT sensor data. Likewise, Worldsensing gathers IoT data, with its solution adding a layer of data analytics at the edge.

4.1.3 Green IT, Sustainability and Environmental Impacts

Green IT is increasingly an important topic in the cloud industry, with several cloud service providers announcing ambitious goals with regards to CO2 neutrality. However, compute needs will only increase globally, and offsetting the carbon emissions for computing will require clear goals and a focused strategy. Compute efficiency can be increased by moving to a highly virtualised, or even better containerised, infrastructure that is centralised in a data centre. The regional government shared services centre that was analysed managed to reduce its electricity bills by 50% by moving to a highly virtualised architecture. Containers are even more efficient than virtual machines.

The economies of scale of cloud data centres have a positive impact on environmental sustainability. Cloud data centres can afford to invest in features like power-saving stand-by modes, energy monitoring software, and efficient cooling systems and can increase server utilisation rates through virtualisation and automation. The public-sector regional IT shared service centre interviewed as part of this study provides evidence of how even a medium-sized private cloud data centre can reduce its energy bill by more than 50%. However, two factors must be considered for the realisation of environmental sustainability benefits:

- The energy efficiency of the existing IT infrastructure to be replaced with cloud: The more modern, virtualised, and efficient the legacy infrastructure is, the lower is the potential positive impact of cloud.
- The expected growth of IT infrastructure demand: Cloud's elastic pricing and provisioning models often induce a growth in usage, hence offsetting the energy efficiency per unit with overall growth in consumption.

Examples of best practices include:

- Green Data Center’s end-to-end green operations, and the carbon recovery project being developed with the Technical University in Zurich.
- OVHcloud working with a research organisation to build a model to calculate the CO2 impact of the consumption of microservices / cloud services.
- OVHcloud optimising their entire value chain from production of servers to running their datacentres for sustainability.

- Scaleway investing in water preservation programs.

The question is, will the move to edge deployments make the entire infrastructure more or less efficient and sustainable? So far, we have not found evidence from the analysed projects to answer this question.

5 CONCLUSIONS

When looking for good practices in the areas of cloud, federation, edge, and green IT, the research found that many challenges are being addressed with creative solutions, but there is still a long way to go to come up with a general set of good practices that can be applied broadly.

The main challenges that have emerged through the interviews centre around ability to identify business incentives, create a viable governance model, and make a Business Impact in the European market. If one objective is to improve the market penetration of European solutions in the areas of cloud, federation, edge, and green IT, then stronger incentives for users to adopt them and for companies to develop and market these solutions are needed. When there is no customer demand, it is likely that such solutions will not mature or be adopted.

5.1 Key findings

Federated Cloud

Federation projects are more successful in the public sector than in the private sector because the strategic incentive is strong to have full control over and sovereignty of IT infrastructure and to share data and insights across departments and agencies in the public sector, whereas the business incentives to create a federation are less strong in the private sector.

The key challenges identified in the H-CLOUD Green Paper are confirmed by the good-practice research effort:

1. Coordinated/Federated approaches must be structured around the objectives of their stakeholders, balancing community focused initiatives with pan-European solutions.
2. Universal challenges including defining, evolving, selecting, agreeing on, and managing the architecture, technical standards, and tools for federated clouds and for distributed data access and exchange.
3. Identity and access management (IAM) should be addressed as a top priority by any federation. Defining and administering the policies to authorize access to data, to allow users to configure services to better align their requirements, to delegate authority and so forth are important to drive the right balance between convenient user experience, compliance with data protection and intellectual property laws and policies, and reducing risks of mistakes and malicious behavior that can cause technical and reputational crisis that are costly to remediate.
4. Federated data has great potential to support the secure private sharing of data held by many different organisations.

We have learned of ways to overcome these challenges. For example, Cloud28+ created a community of service providers with a shared business interest. These providers publish their services using a joint service catalogue on the Cloud28+ platform; City Network has adopted OpenStack as its underlying technology to enable federation at the technology architecture level; and Aquacloud, Polymore, and GAIA-X are working to provide a standard data model to create value for participants in their ecosystems. Academic research networks had to find effective IAM solutions to manage users across dynamic communities.

Edge Computing

The H-CLOUD Green Paper highlighted various edge-relate challenges, mostly resulting from ad-hoc innovation from different initiatives in this space, often without coordination or even collaboration on basic principles and standards. Concerns include edge investments ROI, development and adoption of edge standards, the scalability and affordability of solutions, especially for SMEs, and interoperability.

Many of the initiatives featured in this report are actually active in researching and developing new solutions that leverage edge computing as a key part of their solutions. For these initiatives, the business case is often quite clear, as edge is seen as the enabler of use cases that could not be developed in other ways, thus diminishing doubt regarding ROI for edge solutions.

The main challenges related to edge computing emerging from the interviews are technological and legal:

- Technological aspects: Edge innovation is still in its infancy. Developments in chip manufacturing (silicon), hardware infrastructure, and software platforms are creating new possibilities, but coping with technology advances is challenging. Companies like BrianzAcque rely on partners to manage innovation. Those that, instead, want to drive innovation, such as Vivacity Labs, try to attract talent in universities, which is not an easy task. When innovative solutions are being developed, technical standards can sometimes be an obstacle. Vivacity Labs, Axis, and Worldsensing all view standards as a barrier, especially with regard to IoT connectivity, for which many standards are available. No plans exist for a common industry standard.
- Legal aspects mainly relate to GDPR compliance. Companies found it difficult to adapt to the new legislation. But other regions are now adopting similar policies, which places companies already equipped to comply with GDPR standards at an advantage.

The analysis of good practices has revealed some actions that would be beneficial for the edge environment:

- Investing in building the skills needed to sustain the next wave of innovation. Deep technical skills around firmware and software development, hardware infrastructure optimisation, and AI algorithm elaboration are key. Skills to integrate multiple technologies into complex solutions will also be important.
- Implementing and scaling 5G in a programmatic manner. As the telecom sector evolves towards the new standard, which supports edge-to-cloud integration by its nature, it is crucial to bring to market a mature 5G strategy, across multiple countries, connected to the development of the European edge ecosystem.
- Easing and rationalising regulations and governance concerning cloud-to-edge interoperability in Europe is also recommended. Edge and cloud are part of the same data-flow continuum. Having strict regulations that are not aligned with worldwide standards could slow the adoption of edge-to-cloud solutions and hinder market development.

Green IT

Green IT is the least developed area of the three, with the fewest identified initiatives featuring good practices. In order to drive awareness and accountability in this area, it is important to create a set of KPIs on which projects, initiatives, and private companies need to report. Further research in this area is needed before we can identify relevant challenges and provide good examples of how to successfully overcome those challenges.

Some Observations on Effective Research and Innovation Projects

Numerous R&D projects have been funded by the EU with the intention of reducing obstacles in the adoption of cloud computing, edge computing, and other emerging technologies and solve technology innovation challenges. The projects explored in detail in this report should be regarded as typical. In addition to the structural characteristics described earlier, they share some other practices, which should be regarded as positive:

- The active participation of organisations, including public administrations and SMEs, and well-defined use cases, with solutions successfully developed and prototyped by the projects.

- The development of reusable toolkits, methodologies, and ontologies and a strong emphasis on creating open-source components, without excluding commercial solutions.
- The exploration of various exploitation models – from public sector entities participating in projects that become operators of the services to disseminating toolkits so that commercial providers can embed them into their own solutions and creating dedicated legal entities (private or PPPs) to become operators.

These projects are by definition pre-commercial, cooperative research and innovation so they do not end with ready to market products and services. However all consortia are required to provide exploitation plans and suggest how the results achieved in the project will be used to achieve the impacts targeted in the projects' plans.

It is not easy to track the follow-up results but we noticed a few weaknesses in the exploitation results:

- Projects tasked participants to become operators of the services, but this usually happens at a pilot level without guarantees to implement scalability. These projects were valuable for the participating entities because they empowered project participants to experiment with leading-edge solutions, which otherwise they would not have done on their own for lack of resources or willingness to deal with the risk of failure. Normally, technical sustainability of the solutions after the project is not an issue, because most solutions are based on open standards and/or require replicability. Business exploitation on the other hand depends on the organizations willingness to invest in product management, marketing, sales management and support. It is difficult to find examples of relevant commercial success of a product or solution developed in a project.
- Projects deliberately promoted the uptake of reusable standard components among existing IT suppliers that already had the product management, marketing, and sales and support services capabilities needed, and somewhat better adoption was achieved. One example of such a project is FIWARE. Although not strictly a cloud project, FIWARE was initiated as an EC-funded project. It blossomed into a framework of open-source platform components and achieved good uptake. In particular, its core capability – as a context broker that aggregates and processes data by making it relevant for specific use cases through RESTful APIs – is experiencing good uptake in the Smart Cities space across many European countries, including Spain, France, Italy, and Portugal. One of the key success factors of FIWARE was the creation of a foundation that included the participation of ATOS engineering, Orange, and Telefónica. The foundation nurtured the community by empowering developers and users to adopt FIWARE, promoting the platform across the ecosystem, continuously augmenting its capabilities, protecting the trademark and code of conduct, and validating usage through quality assurance, training, and advisory services.

5.2 Recommendations to EU cloud providers

There are European suppliers across the entire landscape of cloud, edge and green IT. These includes both large corporations that hold significant market shares, and SMEs. There are opportunities for them to successfully contribute to evolution of federated cloud, edge computing and green computing; however, this analysis, implemented in D.1.2 Cloud Computing Portfolio (release 2) has highlighted a number of gaps European providers need to address both in terms of service offerings and in terms of go-to-market.

If European providers want to compete successfully with their larger competitors from the US and China, they need to do the following:

1. Establishing collaborations across layers of the cloud market to share resources aimed at achieving higher efficiency and effectiveness for capabilities that are less competitive in nature, such as energy efficiency.
2. Increasing their investment in technology to develop relevant features that European customers demand and keep up with the rapid pace of innovation driven by their larger competitors. This should not only include a more rapid transition to cloud-native architectures and multi-cloud orchestration capabilities, but also developing offerings that support the emerging demand for edge computing, data management, analytics and machine learning.
3. European software companies making the transition to SaaS providers will need to be able to offer their services on multiple IaaS & PaaS platforms, which could generate a positive multiplier effect for European IaaS and PaaS providers.
4. Increasing brand awareness and reputation amongst European cloud customers and establish themselves as a valid alternative to their competitors. This will require significant investment in marketing messaging around the business value that they provide, their industry specific expertise, the understanding of the local business and regulatory context, the willingness and agility to adapt to the needs of each customer, the ability to offer transparent pricing options that align with European customers' IT procurement and budgeting practices, the positive contribution that they make to the local economy by creating local jobs and paying taxes in Europe, the adherence to European values, such as data privacy, data altruism, ethical use of data, environmental sustainability, diversity and inclusion.
5. Actively participating in data-driven ecosystems, which are emerging under the auspice of the EC European Data Strategy and Gaia-X. European cloud providers will need to develop services that help organizations to monetize their data in accordance with regulation.
6. Investing more in sales, marketing and technical skills acquisition and development.
7. Investing more to enable partners and developers through training and joint go-to-market programs.

5.3 Policy recommendations

Both in terms of service offerings and go-to-market, European cloud providers suffer from a speed and scale gap, compared with global suppliers. A gap that is exacerbated in the case of SMEs. Market mechanisms, such as partnerships, mergers and acquisition will be the primary means through which European suppliers will gain bigger scale; however, European Union and member state policymakers can help reduce some of the gaps by:

- Introducing public procurement rules that require a share of each cloud tender to be allocated to SMEs or companies that can demonstrate (based on tangible KPIs) strict adherence to European public values, such as compliance with open standards, data altruism, environmental sustainability, creation of equal opportunity jobs in the local economy, paying a minimum share of their tax bills in the country. These measures must however avoid creating discriminatory practices that are illegal.
- Funding Research and Innovation projects related to PaaS and SaaS market opportunities while reducing funding for IaaS, because the IaaS market is already highly concentrated. And proactively inviting European companies, in particular SMEs to participate. Areas like cloud-to-edge, data management and analytics, cloud federation and multi-cloud deployment and orchestration should be prioritized.
- Incentivize large users (or prospect users) of cloud services to participate to research and innovation projects, and not limit the participation to technology companies, public sector institutions and academic institutions. So that the projects can address practical business problems for which there will be tangible demand in the market.
- Allocating more Research and Innovation budget on the commercialization of innovations. There is a gap between EU funded R&I and commercializing this technology in a meaningful way. There is not enough money spent on marketing to

publicize the newly developed technologies and to build strong commercial organizations to take these technologies to market and make them known to European customers to create a demand for them. To accelerate commercialization, policymakers could provide incentives for European developers and technology providers to certify products through global open source communities, such as the Cloud Native Computing Foundation, and EU member states could provide export support programs to European suppliers, particularly SMEs.

- Creating tax credits for sharing data center facilities across suppliers, if these shared facilities meet minimum requirements in terms of energy efficiency and carbon footprint.
- Funding cloud business and technical skills training programs with a curriculum that covers a mix of Open Source, global supplier and European supplier offerings. Grant discounts and allowances for SME attendance.