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Abstract

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

Keywords:

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

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4 ANALYSIS OF THE EUROPEAN CLOUD LANDSCAPE

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

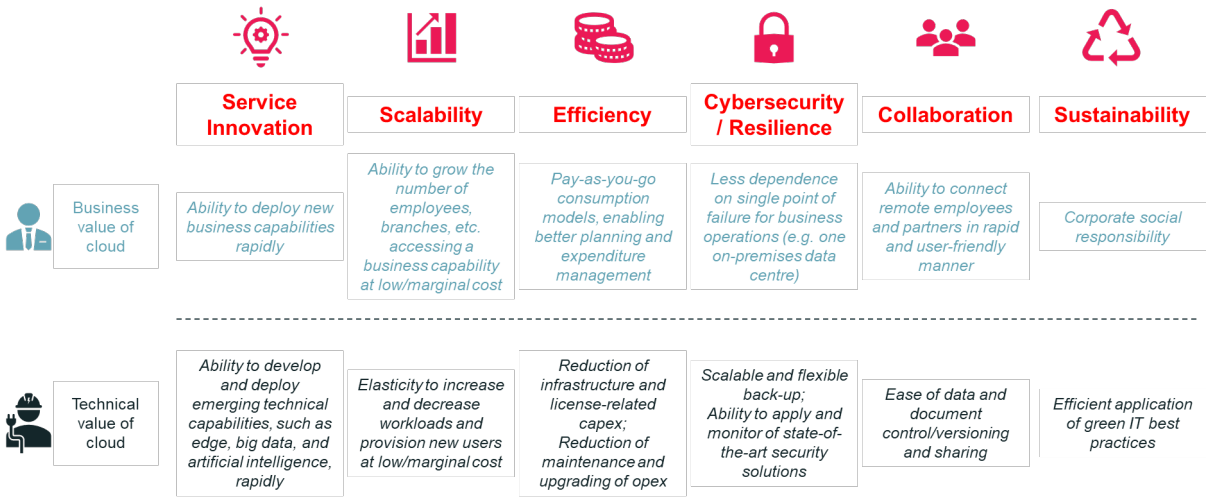

Figure 7: The Potential Business and Technical Value of Cloud Computing

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

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

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

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

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4.1 Cloud Federation

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

There is still no common approach or description for cloud federation, but one thing is clear – the objective is to bring cost efficiency, scale and speed to the complex IT tasks that European organisations need to implement. Federated models are common in the public sector, such as APIS IT[10] in Croatia, STATENS IT[11] in Denmark, or BRZ[12] and eGIZ[13] in Austria, building on the public sector's long history of collaborative delivery of IT services across government departments and agencies. By contrast in the private sector, competitive pressures have historically represented a barrier; nevertheless, federated approaches are being increasingly explored in the private sector, as a way to develop and scale ecosystem-centric business models that span multiple organisations.

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

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

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

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

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

[10] https://www.euritas.eu/2017/01/30/apis-it-croatia/
[11] https://statens-it.dk/
[12] https://www.brz.gv.at/en/
[13] https://www.a-sit.at/egiz/e-government-innovationszentrum-egiz/

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- Support for cultural and attitude shift.

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

R&I initiatives

The R&I cloud federation projects analysed[14] are initiatives aimed at bringing to the market codes, data exchange platforms, and tools to help developers focus on building customer solutions (such as smart contracts, or faster software development). These projects are also European in scope indicating the value of R&I collaboration and synergies to make cloud federation successful. The R&I cloud federation projects depend on the ecosystem to combine technologies, infrastructure layers and data sources to create business value for users.

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

Public/public-private initiatives

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

One of the most notable cloud federation projects is GAIA-X[15]. The vision of the initiative is to create a connected and open data infrastructure layer to create an open, digital ecosystem to collect, share and analyse data without compromising on European privacy regulation requirements. GAIA X plans to connect decentralised infrastructure services such cloud and edge, and it is not intended to be competitive to global hyperscalers — it will be a layer on top of their services.

There are several other cloud federation projects, such as International Data Spaces[16] at the EU level, but also others at national level such as CODE-DE[17] (Germany) or Estfeed[18] (Estonia), are public-private initiatives. These projects create a common platform to connect ideas and outcomes, so more organisations can adopt the practices and scale the benefits.

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

Private initiatives

Although the federated cloud model is mostly present in the public sector, there is a growing number of private initiative-based cloud federations in Europe (Cloud28+[19], AquaCloud[20] among others). Most of the private initiatives related to federation aim at building cloud capabilities uniquely required in Europe – such as services that comply with specific regulations around data and security including GDPR.

[14] For the complete list of initiatives with the related federation categories, see Appendix C.
[15] https://www.data-infrastructure.eu/GAIAX/Navigation/EN/Home/home.html
[16] https://www.internationaldataspaces.org/
[17] https://code-de.org/de/
[18] https://eu-sysflex.com/estfeed-data-exchange-platform-by-elering/
[19] https://cloud28plus.com/EMEA
[20] https://aquacloud.ai/

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4.2 Edge Computing

The edge market remains in a phase of infancy in Europe. The analysis of the initiatives collected reveals that the large part of them are connected to private-sector deployment or research and innovations projects, with no intervention of the public even in a mixed public/private way. The market is still fragmented, with many independent initiatives using different standards, that do not even connect, much less point the way to a future consolidated ecosystem. At this point most initiatives focus more on enabling infrastructure and platform (e.g. K3S[21]) for distributed services, maintaining a cloud-native type of approach.

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

The technologies that are most interested in relation to edge computing are the Internet of Things and big data, with a component of artificial intelligence that IDC expects to be of increasing interest in the future[22], as soon as the infrastructure and platform technology stacks will become more standard and commonly adopted.

R&I projects

R&I initiatives are starting to target the creation of a common ground for different players to build on top of the infrastructure and platforms that are available and distributed, targeting the developer environment. Two key aspects are at the centre of many projects: (1) the creation of a continuum from edge devices, to networks and cloud, and (2) the development of toolsets for application development. For example, the RADON[23] project aims to establish a European DevOps framework for creating and managing microservices-based applications, running on Edge at platform layer. UNICORE[24], instead, looks to be an enabler, creating tools helping EU players to lead the next generation of cloud computing services and technology. Federation is targeted as well by R&I projects that aim to develop standards, as in the case of UNICORE, securing the data, as in the case of DECODE[25] activity, and industry specific applications, as in the case of Fed4IoT[26].

Private initiatives

Private-sector deployment initiatives are more popular, both from a provider standpoint and a user standpoint, very often already at the operational deployment stage of the project lifecycle. From a provider standpoint, the focus is largely on distributing capabilities, especially infrastructure capabilities, near to the customer premises in a hybrid approach. This is behind the value proposition of recent, locally-focused initiatives as Edge Infra[27] as well as of established and global ones like Threefold[28]. Hybrid is one of the keywords for

[21] K3S is a lightweight version of the orchestration tool Kubernetes [“K8S”] now being increasingly adopted in the cloud.
[22] IDC, Worldwide Edge Spending Guide
[23] https://radon-h2020.eu/
[24] http://unicore-project.eu/
[25] https://decodeproject.eu/
[26] https://fed4iot.org/
[27] https://www.edgeinfra.net/
[28] https://threefold.io/

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edge as IDC European research reveal that European buyers prefer to run edge workloads on-premise or hybrid environments[29].

This approach raises sustainability considerations, since broader distribution of less optimised infrastructure (compared to a cloud central data centre) may result in a higher consumption of resources. Some of the analysed initiatives address this increasing topic: Threefold has the reduction of the global internet consumption as one of its core values. The Green Edge Cloud[30] initiative, beyond using green energy to run the data centre facilities, re-uses the waste-heat to substitute the use of fossil-fuel.

The analysis also highlights that the overall edge market, particularly for the private initiatives, is skewed towards heavy asset industries, such as manufacturing, utilities and energy, and transportation. For these industries, digital transformation requires the addition of instrumentation and intelligence to critical operating assets (such as presses, cutting machines, generators, pipelines, locomotives) so that they can be connected to the IT backbone to access the large amount of data generated and more efficiently manage the equipment. Examples are iXworld[31], Mindsphere[32], Wordsensing[33].

4.3 Green IT

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

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

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

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

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[29] IDC, “Are Digital Leaders Deploying Edge Workloads in the Cloud?”, October 2020, https://www.idc.com/getdoc.jsp?containerId=EUR146952120
[30] https://www.greenedge.cloud/
[31] https://www.index-traub.it/en/ixworld/
[32] https://siemens.mindsphere.io/en
[33] https://www.worldsensing.com/

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5 CONCLUSIONS

5.1 The Current European Cloud Landscape

This analysis of the European Cloud Landscape, including 210 R&I projects and deployment initiatives, shows that:

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

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

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

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

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

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

5.2 Next Steps

The information collected in the European Cloud Portfolio will represent the main content of

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the online catalogue available to all relevant stakeholders interested in obtaining deeper knowledge of what is being developed within the European cloud computing arena. The first version of the catalogue will be released in 2021 (Q1).

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

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

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APPENDIX A - GLOSSARY

Cloud Computing

The original meaning of cloud computing related to having characteristics such as elasticity of resource supply and the automated provision of services, rather than any specific IT technologies. NIST's definition[34] of the five essential characteristics of the "cloud" is widely accepted:

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

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

Cloud Federation

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

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

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

Federations exhibit several essential characteristics:

- A federation is an alliance of multiple organisations.
- Participating organisations are "members" of the federation and collaborate for common goals.
- Each federation has a "federating entity" at its core -- which can be either virtual or a real organisation separate from any member.

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

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- Members agree to conform with various technical standards and operating procedures that enable interoperation, collaboration and sharing, appropriate to the type and purposes of the federation.
- Participation can involve a degree of sharing resources (including services, data, metadata or other assets).

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

Edge Computing

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

Green IT

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

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APPENDIX B – PORTFOLIO STRUCTURE

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

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

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

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

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

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

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

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

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

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

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

R&I Initiatives Related to Cloud Federation

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

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

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R&I Initiatives Related to Edge Computing

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

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

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

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R&I Initiatives Related to Green IT

Name	Focus
COMMUNITY CLOUD	Developing a cloud service to replace centralised server farms with a distributed data centre based on a peer-to-peer network free of infrastructural costs
CLOUDWATCH2	Supporting EU R&D on cloud computing, software, and services across the full innovation lifecycle and move to market, promoting technology advancements and supporting OS software reusability
AFarCloud	Providing a distributed platform for autonomous farming to enable the integration and cooperation of agriculture cyber-physical systems in real-time to increase efficiency, productivity, animal health, and food quality and to reduce farm labour costs
FNS-Cloud	Aiming to overcome fragmentation problems by integrating existing FNS data – which is essential for high-end pan-European FNS research – and by addressing FNS, diet, health, and consumer behaviours, as well as by promoting the exploitation of sustainable agriculture and organic farming
Blue Cloud	Aiming to federate leading European marine data management infrastructures and horizontal e-infrastructures – data resources, computing resources, and analytical service resources – to capitalise on what already exists and to develop and deploy a Blue Cloud framework as a thematic EOSC cloud

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Deployment initiatives related to cloud federation

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

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

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Bulgarian Ministry of Transport, Information Technology, and Communications	Public sector	Structured marketplace	Initiative to establish data sharing good practices for data governance relating to the construction of transport infrastructure.
Romanian Government Cloud	Public sector	One-stop-shop	Government cloud aiming to provide the necessary infrastructure for all institutions that have the obligation to take over and store the information of the beneficiaries of public services, as well as to protect their data.
APIS IT	Public sector	Full integrator	Government cloud IT infrastructure defining, implementing and maintaining the technology and best practices that support eGovernment.
Estonian Government Cloud	Public sector	Reseller	Government cloud aiming at increasing the cost-effectiveness of the public sector, increasing the public information security capacity and carrying out large-scale temporary projects, enabling the provision of high-quality uninterrupted service.
NIZS	Public sector	Structured marketplace	Creation of a new data center capacity in several premises enabling the operation of the new Hungarian governmental systems, the establishment of a server park affected by cloud-based operation, furthermore, the replacement of some existing machine rooms in a substandard condition.
CODE	Private sector	Structured marketplace	Driving innovation and supporting improvements in cancer care, addressing information gaps by providing timely information on anti-cancer medicine use via healthcare systems
Aquacloud	Private sector	Structured marketplace	Innovation project from the Norwegian aquaculture sector that collects and consolidates data sets from different aquaculture companies to solve a shared problem – predicting and preventing the outbreak of sea lice.
Advaneo Data Marketplace	Private sector	Structured marketplace	Decentralised portal where all relevant and possibly sensitive raw data always remains with the data provider and only is transferred directly – peer to peer – to the buyer in the

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			event of a purchase
ThreeFold Grid	Private sector	Structured marketplace	Peer-to-peer network of storage and compute capacity. It creates a decentralised, privacy focused, and secure resource pool of participants that add their compute and storage capacities to a grid.
Cloud 28+	Private sector	Structured marketplace	Provides a marketplace through which European cloud providers can showcase their cloud services built on HPE and OpenStack technology.
Container xChange	Private sector	Structured marketplace	Neutral online platform for organisation of one-way container moves, digitisation of operational handling, container tracking and invoicing.
Datahub	Private sector	Open marketplace	Ensures uniform communication methods and standardised processes for professional participants in the Danish electricity market in order to stimulate competition and optimise market conditions for electricity consumers.
365FarmNet	Private sector	Open marketplace	Digital platform allowing farms to be managed across different business units - without being dependent on a brand or manufacturer.
Oren	Private sector	One-stop-shop	Mining and B2B industrial marketplace offering solutions, software, services and integrated workflows to accelerate digital and sustainability transformation across the end-to-end value chain.
Atrias	Private sector	Open marketplace	Joint initiative of Belgium's six electricity and gas distribution grid operators, to build, deploy and manage a single clearing house application.
Helix Nebula Science Cloud	Public-private	Full integrator	A hybrid cloud platform linking commercial cloud service providers and publicly funded research organisations' in-house IT resources, via the GEANT network, to provide innovative solutions in support of data-intensive science
CREODIAS	Public-private	Full integrator	Cloud infrastructure adapted to process large amounts of Earth observation (EO) data, including an EO data storage cluster and dedicated IaaS cloud infrastructure for the platform's users

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WEkEO	Public-private	Open marketplace	The EU's Copernicus DIAS reference service for environmental data, virtual environments for data processing, and skilled user support
CODE-DE	Public-private	Open marketplace	Offering high-performance access to all Copernicus data throughout Germany
GAIA-X	Public-private	Full integrator	Aiming to connect decentralised infrastructure services, such cloud and edge, via a user-friendly homogeneous system
SENSORIS	Public-private	Open marketplace	A data standard and exchange for the automotive industry that defines consistency for gathering in-vehicle data
IDS	Public-private	Full integrator	Aiming to create a secure data space that supports enterprises in different industries and of different sizes in the autonomous management of data
Estfeed (E-elering)	Public-private	Open marketplace	Energetics-centric IT infrastructure developed in cooperation with partners to offer all interested parties the chance to develop, market, and use smart solutions
Entso-e	Public-private	Open marketplace	Providing continuous and free access to key information on the European grid for all market participants and other stakeholders

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Deployment Initiatives Related to Edge Computing

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

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		throughout the territory for the citizens). It can be seen as a multifunctional edge IoT device able to run cloud-native applications locally that have been developed as a part of a larger architectural digital transformation of the company.
Axis	Private sector	IP camera producer, developing products that use open standards and edge and are scalable and easy to integrate into different platforms.
Worldsensing	Private sector	Designs and builds sensing solutions to remotely monitor critical assets (and the structural health thereof) within mining, construction, and rail networks, helping engineers to monitor and anticipate geotechnical incidents, such as ground movements/landslides, to ensure the safety of workers, passengers, and citizens.
K3S	Private sector	Kubernetes distribution designed for production workloads in unattended, resource-constrained, remote locations or inside IoT appliances.
The Valencia Smart City Project	Public sector	Integrates data and processes of municipal services into a platform that would help improve the efficiency and responsiveness of administration
GAIA-X	Public-private	Aiming to connect decentralised infrastructure services, such cloud and edge, via a user-friendly homogeneous system
FIWARE	Public-private	A framework of open-source platform components to accelerate the development of smart solutions

Deployment Initiatives Related to Green IT

Name	Sector	Focus
Polymore	Private sector	A digital B2B-market for the sustainable plastics industry (compounds, recyclates, and post-industrial waste) in Europe
Green Edge Cloud	Private sector	Distributed cloud infrastructure based on OpenStack that reduces CO2-equivalent life-cycle emissions through the reuse of waste-heat.
ThreeFold Network	Private sector	Peer-to-peer network of storage and compute capacity. It creates a decentralised, privacy focused, and secure resource pool of participants that add their compute and storage capacities to a grid.
Estfeed (E-elering)	Public-private	E-elering – a portal to give customers access to data and services

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		Estfeed data platform – an energy data exchange for accessing, sharing, and managing meter data across data suppliers (data hubs), data users, applications (via the E-elering app store and data access management), and customers
Entso-e	Public-private	A transparency platform to provide continuous and free access to key information on the European grid for all market participants and other stakeholders
CODE-DE	Public-private	Offering high-performance access to all Copernicus data throughout Germany

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