



Blockchain for the Next Generation Internet



ONTOCHAIN IMPACT REPORT

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ABSTRACT	This report summarizes the impact of the ONTOCHAIN project in economic, societal, scientific, environmental, ethical and political terms. These impacts are based on ONTOCHAIN KPIs and feedbacks collected from beneficiaries, third parties and advisors. This report includes also lesson learnt.
KEYWORDS	impacts, economic impact, societal impact, scientific impact, environmental impact, ethical impact, political impact

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6	ELLINOGERMANIKO EMPORIKO & VIOMICHANIKO EPIMELITIRIO	GHCCI	EL
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EXECUTIVE SUMMARY

This deliverable summarizes the impact of the ONTOCHAIN ecosystem in economic, societal, scientific, environmental, ethical and political terms as identified by project beneficiaries and third parties. Moreover it summarizes the lessons learnt and the alignment with the NGI vision for project beneficiaries.

The ONTOCHAIN project has developed a new technical infrastructure and business model for blockchain to be exploited in the business starting from the ecosystem already build up in the 3 ONTOCHAIN calls. This vibrant ecosystem includes technology providers, application developers and development tools providers in blockchain (chapter 2).

ONTOCHAIN's impacts analyzed in this reports are 1) economic 2) societal 3) scientific, 4) environmental 5) ethical, 6) political. All of these impacts have been considered in short term, to provide measurable evidence at the end of the project. Moreover, for the economic impact, also the medium term dimension has been mentioned, as more specifically related to the exploitation actions planned at the end of the project.

Any impact has been further structured in different dimensions and for any dimension the list of evidences has been reported, and for any evidence specific contributors are mentioned. Just to make an example, the impact *societal* mentions, between others, the dimension *new applications of relevant social impact for citizens, as for inclusion and common goods*, with specific contributors mentioned, any of which with a quick presentation and the clickable link to the ONTOCHAIN's website for further details (chapter 3).

The inputs of this report have been contributed with the 7 ONTOCHAIN beneficiaries, advisors and the 44 third parties participants, with information extracted from KPIs already detailed in the deliverable D4.9, integrated by information specifically collected for this impact analysis report (chapter 4).

This general impact analysis report includes specifically also the impacts directly contributed by the different beneficiaries, lessons learnt (chapter 4) and moreover an overview of main impacts identified by third parties (chapter 5) and an overview of main impacts identified by advisors (chapter 6).

This report is intended to provide a quick reference and entry point to main results achieved within the project. Moreover this report is intended to provide a guidance to exploitation activities and plans at the end of the ONTOCHAIN project and after the end of the ONTOCHAIN project.

TABLE OF CONTENTS

TABLE OF CONTENTS.....	7
LIST OF FIGURES.....	9
LIST OF TABLES.....	10
1 INTRODUCTION.....	12
1.1 Impacts: a framework.....	12
1.2 ONTOCHAIN impacts: definitions and sources.....	13
1.3 Content of this deliverable.....	15
2 THE ARCHITECTURE AND ECOSYSTEM.....	16
3 ACHIEVEMENTS AND IMPACTS.....	17
3.1 Economic Impact.....	17
3.2 Societal Impact.....	20
3.3 Scientific Impact.....	22
3.4 Environmental Impact.....	24
3.5 Ethical Impact.....	24
3.6 Political Impact.....	25
4 IMPACT AS EVALUATED BY BENEFICIARIES.....	26
4.1 Beneficiaries overview.....	26
4.2 European Dynamics.....	28
4.3 University of Ljubljana.....	41
4.4 iExec.....	44
4.5 IntelliSemantic.....	47
4.6 GERMAN HELLENIC INDUSTRIAL AND COMMERCIAL CHAMBER.....	55
4.7 F6S.....	57
5 IMPACT AS EVALUATED BY THIRD PARTIES.....	60
6 IMPACT AS EVALUATED BY ADVISORS.....	62
6.1 Advisory Board objectives and activities.....	62

6.2	Economic impact.....	63
6.3	Societal impact.....	64
6.4	Technical and scientific impact.....	64
6.5	Environmental impact.....	65
6.6	Ethical impact.....	66
6.7	Political impact.....	66
6.8	Key comments and insights.....	67
7	CONCLUSIONS.....	67
	REFERENCES.....	69

LIST OF FIGURES

FIGURE 1: DIAGRAM OF ONTOCHAIN FUNCTIONAL ARCHITECTURE..... 16
FIGURE 2: ONTOCHAIN APPLICATION FAMILIES..... 19

LIST OF TABLES

TABLE 1: Impacts	13
TABLE 2: ED Lesson learnt	35

ABBREVIATIONS

CDE	Communication, Dissemination, Exploitation
DAO	Decentralised Autonomous Organisation
DID	Decentralized Identifier
DLTs	Distributed Ledger Technologies
DMA	Digital Markets Act
DRM	Digital Rights Management
DSA	Digital Services Act
EBSI	European Blockchain Services Infrastructure
eIDAS	electronic IDentification, Authentication and trust Services
EVM	Ethereum Virtual Machine
FAIR	Findable, Accessible, Interoperable, Usable
GDPR	General Data Protection Regulation
IA	Impact Analysis
NFT	Non Fungible Token
NGI	Next Generation Internet
OC1	ONTOCHAIN Open Call 1
OC2	ONTOCHAIN Open Call 2
OC3	ONTOCHAIN Open Call 3
SSI	Self Sovereign Identity
STEEP	Social, Technological, Economic, Environmental, and Political

1 INTRODUCTION

1.1 IMPACTS: A FRAMEWORK

The impacts generated by European projects are more and more important in their evaluation, and are analyzed more and more deeply also from a methodological point of view ¹, as in the following references [1] [2].

To make an example of the methodology used, the impact of the Horizon Europe initiative as a whole ² has been described according to a three levels taxonomy, whose the upper two levels are:

- scientific impact
 - creating high quality scientific knowledge;
 - strenghtening human capital in Research and Innovation;
 - fostering the diffusion of knowledge and Open Source software.
- societal impact
 - addressing EU policy priorities and global challenges through research and innovation;
 - delivering benefits and impact through research and innovation missions;
 - strengthening the uptake of research and innovation in society.
- technological/economic impact
 - generating innovation-based economic growth;
 - creating more and higher-quality jobs and working places;
 - leveraging investment in Research and Innovation.

A third level of this taxonomy is the time, to distinguish short term, medium term and long term impacts.

¹Impact assessment, evaluation and monitoring of EU research and innovation programmes https://research-and-innovation.ec.europa.eu/strategy/support-policy-making/shaping-eu-research-and-innovation-policy/evaluation-impact-assessment-and-monitoring_en

²Horizon Europe programme analysis https://research-and-innovation.ec.europa.eu/strategy/support-policy-making/shaping-eu-research-and-innovation-policy/evaluation-impact-assessment-and-monitoring/horizon-europe-programme-analysis_en

1.2 ONTOCHAIN IMPACTS: DEFINITIONS AND SOURCES

The impacts summarized in this report are those defined since the beginning of ON-TOCHAIN project, and more specifically:

- Economic impact,
- Societal impact,
- Scientific impact,
- Environmental impact,
- Ethical impact,
- Political impact.

For each of these impacts this report is focused to describe the "short term", since "short term" can be really measured at the end of the project. In the case of the economic impact also medium term perspective have been mentioned, as specifically relevant for the exploitation plan.

Any impact has been further distinguished in different components specific for the ON-TOCHAIN project, which are summarized in the following table. Some components can be associated to more than a single impact: for example "contributions to standards" can be considered a political impact as well as a scientific impact: these situations are also mentioned in the table.

TABLE 1: Impacts

Impact	Kind of Impact	Secondary Impact
Economic (present)	Specific technical infrastructure and pilot network	Scientific
	Specific business model to simulate different exploitation paths	Scientific
	Technical collaboration between complementary partners	Scientific
	Diversified verticals addressed	
	New business opportunities	
	New visibility opportunities	

Impact	Kind of Impact	Secondary Impact
Economic (planned)	New insights opportunities	Societal
	Solutions to avoid the information concentration on a single platform	Economic (present)
	Business enabled jointly, through by the foundation	Economic (present)
	Business enabled through independent exploitations	Economic (present)
Societal	Other new business enabled though visibility	
	New applications of social impact for citizens	
	New applications of social impact for professionals and small business	
	Technologies of social impact	Ethical
	Solutions to avoid the information concentration on a single platform	Economic
Scientific	Specific technical infrastructure and pilot network	Economic (present)
	Specific business model to simulate different exploitation paths	Economic (present)
	New technology evolutions	
	Scientific publications	
	Technical collaboration between complementary partners	Economic (present)
	New standards contributed	Political
Environmental	Low energy protocols	
	Energy efficient applications	
	Energy efficient technologies	
Ethical	Technologies of ethical impact	Societal
	Inclusion oriented applications	

Impact	Kind of Impact	Secondary Impact
Political	Pursuing objectives aligned to the EU's digital strategy New standards contributed	Scientific

Components of different impact presented in this report emerge from:

- KPI results,
- beneficiaries input,
- third parties input.

KPIs have been extensively documented in the final section of the deliverable D4.9 [3]. This present report mentions only a subset of them, more specifically those affecting the impact.

Impact as identified by the 7 project beneficiaries, is detailed in the chapter 4, which includes specific partner contributions. The ONTOCHAIN beneficiaries are rather diversified: they include large companies, SMEs and universities. This variety is also reflected by the diversity of the impacts.

Impact as identified by third party participants is based on the content of their deliverable D4 provided at the end of their project. These D4s, which follow a standardized format, include sections as: Project innovation and KPI, Business Model, Exploitation Plan, Your Testimonial, which are useful to identify the impact from third parties.

1.3 CONTENT OF THIS DELIVERABLE

In the following, the chapter 2 summarizes the ONTOCHAIN architecture and ecosystem.

The chapter 3 details the ONTOCHAIN impacts main components.

Inputs for this chapter 3 is provided by impacts components identified by different beneficiaries, detailed in chapter 4, and impacts identified by different third party, summarized in chapter 5.

2 THE ARCHITECTURE AND ECOSYSTEM

The ONTOCHAIN project ³ is a NGI cascade funding project aimed at developing a new software ecosystem for trusted, traceable & transparent ontological knowledge on blockchain ecosystem and including new technologies and applications. A more recent overview of the ONTOCHAIN architecture is provided in the short paper by Papaioannou et al. [4].

Further details about the updated version of the architecture diagram, including the mapping of the projects of all the three Open Calls, are presented in the ONTOCHAIN Deliverable D3.7 Framework Specification (Simonet-Boulogne et al. [5]) from which the following block diagram, provided by the University of Ljubljana, is extracted.

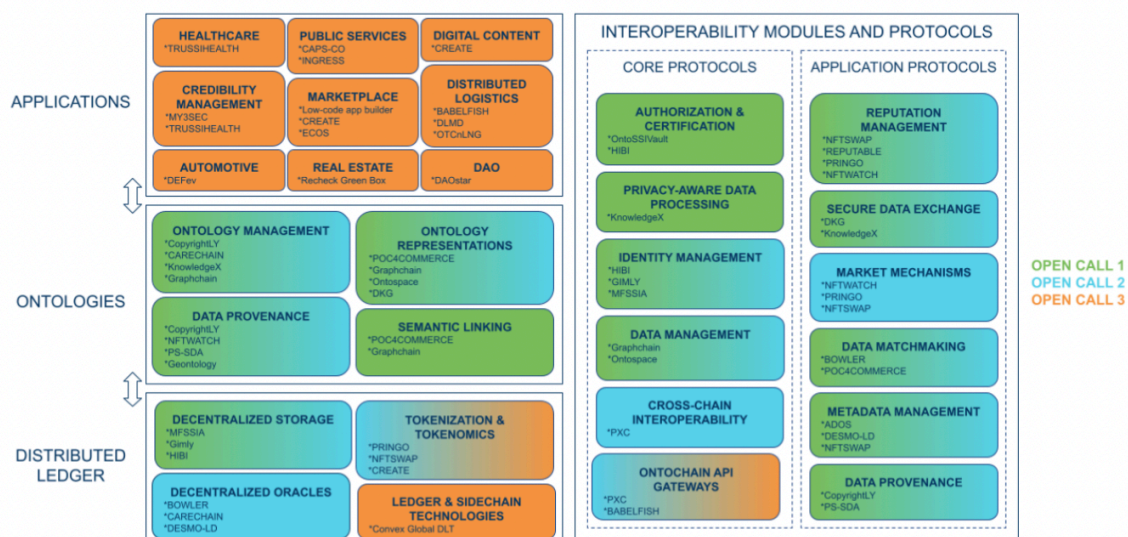


FIGURE 1: DIAGRAM OF ONTOCHAIN FUNCTIONAL ARCHITECTURE

This block diagram identifies:

- the main components of the architecture as applications, ontologies, distributed ledger, core protocols, application protocols;
- the third party beneficiary which has developed a specific technology block or application ⁴;

³ <https://ontochain.ngi.eu/>

⁴ More details about third parties and their results are available on the page <https://ontochain.ngi.eu/selected-projects> of the ONTOCHAIN portal.

- the specific Open Call (OC1, OC2 or OC3) in which a technology or an application has been developed.

3 ACHIEVEMENTS AND IMPACTS

3.1 ECONOMIC IMPACT

3.1.1 Present economic impact

Main economic impacts at the end of the ONTOCHAIN project are:

- specific technical infrastructure and pilot network available and running since May 2022;
- specific business model to simulate different exploitation paths relying on the technical infrastructure just mentioned;
- technical collaborations established between complementary parties, as technology providers, application providers and tool providers;
- diversified verticals addressed, as Energy, Logistics, e-Commerce, Finance, and business models (B2B, B2C);
- new business generated, for beneficiaries and third parties;
- new visibility and brand reputation generated, for beneficiaries and third parties;
- new insight generated, for beneficiaries and third parties;
- solutions avoiding the information concentration in a single platform ⁵.

Specific technical infrastructure and pilot network available and running since May 2022, to host applications and technologies developed in ONTOCHAIN. This has both a scientific impact as an economic impact as well. This pilot network is based on the Bellecour sidechain, includes nodes by IEXEC, AUEB, UL, IS and is described in more detail on the deliverable D3.7 [5].

Specific business model to simulate different exploitation paths relying on the technical infrastructure just mentioned. This business model has been developed by AUEB and is detailed in deliverables D5.3 [6] and D5.4 [7]. This of course has a scientific impact as an economic impact as well.

⁵This has a societal impact as well an economic impact, hence will be included in both.

Technical collaborations between complementary parties were established in OC2 and OC3, in such a way to support the use of ONTOCHAIN developed technologies by application developers and also by other technology providers, as mentioned in the deliverable D4.9 [3], Table 7, KPI 4.5. As a result of these collaborations:

- the SSI technology OntoSSIVault/Gimly ⁶ is used in DEFev and in CopyrightLY;
- ADOS (AirTrace Decentralized Oracle System) ⁷, an AI-based oracle system for securing off-chain IoT data integrity when injecting in the blockchain, is used in the application CARECHAIN;
- the Decentralised and Scalable Knowledge Graph DKG ⁸ is used in MFSSIA, ReCheck Green Box, OTCnLNG;
- GraphChain a framework for on-chain data management ⁹ is used with CopyrightLY;
- Low-code app builder ¹⁰, a IDE to facilitate the development of applications in the ONTOCHAIN framework, integrates PXC, NFTSwap, MFSSIA and REPUTABLE technologies.

Other collaborations are expected also after the end of the ONTOCHAIN project.

Diversified verticals are addressed in different applications, as mentioned in the application section of the software ecosystem figure, at <https://ontochain.ngi.eu/projects-map>, credited by the University of Ljubljana, which is included here.

New business generated and new prospects has been mentioned by different third parties. As an example of this, we can mention here this testimonial *"We do recognize NGI ONTOCHAIN programme has opened doors to industry-leading companies, enabling us to onboard early adopters and forge invaluable connections with potential investors"* (OTCnLNG).

New visibility and brand reputation generated as exemplified by different testimonials of beneficiaries and third parties. Just to mention the testimonial of iExec: *"The iExec's participation in various events for ONTOCHAIN and the ONTOCHAIN projects success have enabled an increased visibility of the iExec infrastructure and enriched the potential partnerships. Thanks to the successful popularity of the iExec platform from developers, a program for developers in the iExec community has been implemented to incentive their creativity. Interacting with these developers has highlighted the need for a robust commercial strategy, which iExec has meticulously refined. Additionally, the ONTOCHAIN project has enabled the recruitment of top talents to support*

⁶<https://ontochain.ngi.eu/content/gimly-id>

⁷<https://ontochain.ngi.eu/content/adoss>

⁸<https://ontochain.ngi.eu/content/dkg>

⁹<https://ontochain.ngi.eu/content/graphchain>

¹⁰<https://ontochain.ngi.eu/content/startin%E2%80%99blob-low-code-app-builder>

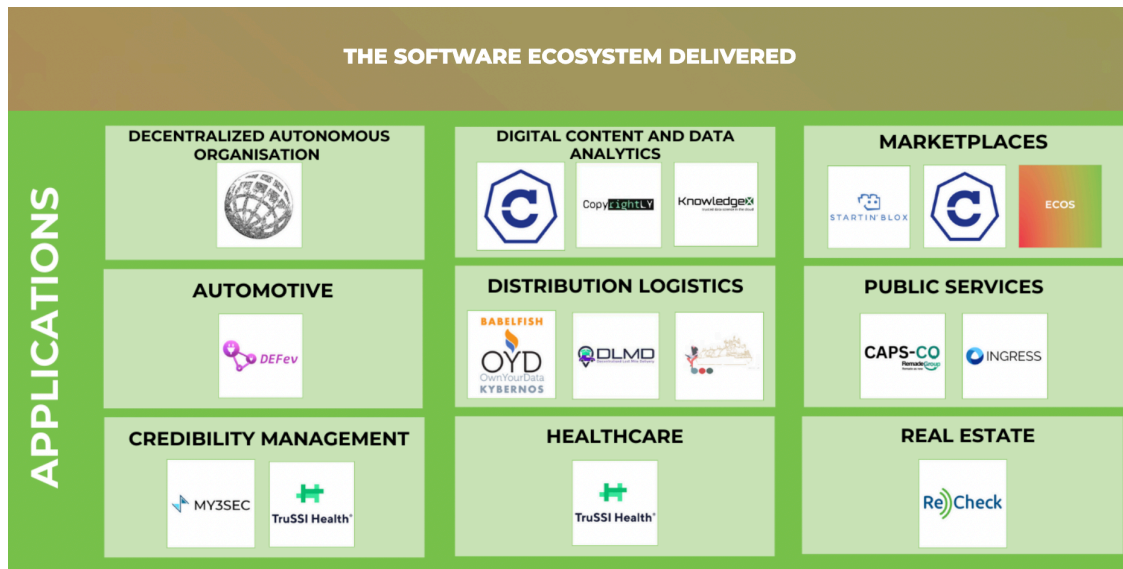


FIGURE 2: ONTOCHAIN APPLICATION FAMILIES

the ONTOCHAIN project and assist third-party developers in the advancement of their solution".

New insight generated about blockchain opportunities, as mentioned for example by European Dynamics.

Moreover, the ONTOCHAIN project developed applications which avoid the information concentration in a single platform, with an economic and a societal impact well.

These applications are summarized in D4.9 [3] Table 11, KPI A.3.2 and A3.3, and include decentralised social networks and publishing platforms, as CREATE ¹¹, a decentralized content marketplace for content creators, to assure fair revenues to quality contents, KnowledgeX ¹², a solution to provide adequate security and privacy in business interactions between data analysts and data providers, My3Sec ¹³, a PM and HR suite to support freelance workers, PRINGO ¹⁴, i.e. Private Incentives for Common Goods), to face the present inefficiency at funding and curating public/common goods, and, at a more infrastructural level, Low-code app builder ¹⁵, BABELFISH ¹⁶, Convex Global DLT ¹⁷.

¹¹ <https://ontochain.ngi.eu/content/create-content-registry-and-tokenized-exchange>

¹² <https://ontochain.ngi.eu/content/kx-knowledgex>

¹³ <https://ontochain.ngi.eu/content/my3sec-ultimate-pm-hr-suite-smart-workers-smart-workers>

¹⁴ <https://ontochain.ngi.eu/content/pringo>

¹⁵ <https://ontochain.ngi.eu/content/startin%E2%80%99blox-low-code-app-builder>

¹⁶ <https://ontochain.ngi.eu/content/babelfish-service-integration-heterogeneous-environments>

¹⁷ <https://ontochain.ngi.eu/content/convex-global-dlt-convex-hosting-infrastructure-and-decentralised-ledger-next>

3.1.2 Mid term economic impact planned

In the case of the economic impact, it seem useful also to mention at least at the qualitative level mid term expected impacts, which are summarized in the following:

- joint business possible to ONTOCHAIN project participants suitably associated: the business model enabled by the ONTOCHAIN architecture in Fig. 1 has been elaborated by the Athens University of Economics and Business (AUEB) team and is described in D5.3 [6] and D5.4 [7];
- business possible also through the independent exploitation of ONTOCHAIN beneficiaries and third party, as exemplified by this European Dynamics testimonial *As the demand for green and sustainable solutions continues to grow, ED is likely to encounter new business opportunities. Organizations across various industries are actively seeking technologies that reduce their environmental footprint, and EDs expertise in this area positions it well to address these needs.;*
- related business possible through the increased visibility of ONTOCHAIN project beneficiaries and third parties.

3.2 SOCIETAL IMPACT

Main dimensions of the societal impact include:

- new applications of relevant social impact for citizens, as for inclusion and common goods;
- new applications of relevant social impact for professionals and small business;
- technologies of significant social impact, as SSI, provenance, digital rights management;
- infrastructures of significant social impact, as those avoiding the concentration of data and information in a few platforms.

Applications of relevant social impact for citizens developed the ONTOCHAIN project are PRINGO (i.e. Private Incentives for Common Goods) ¹⁸, to face the present inefficiency at funding public/common goods, INGRESS to support the financial inclusion of refugees and citizens of developing countries ¹⁹, Carechain ²⁰, a microinsurance application for small farmers and developing countries.

¹⁸<https://ontochain.ngi.eu/content/pringo>

¹⁹<https://ontochain.ngi.eu/content/ingress-gateway-financial-inclusion>

²⁰<https://ontochain.ngi.eu/content/carechain>

Applications of relevant social impact for professionals and small business developed the ONTOCHAIN project are CREATE ²¹, a decentralized content marketplace for content creators, to assure fair revenues to quality contents, KnowledgeX ²², a solution to provide adequate security and privacy in business interactions between data analysts and data providers, My3Sec ²³, a PM and HR suite to support freelance workers.

Technologies of significant social impact, as SSI, provenance, digital rights management, are detailed in the following and will be mentioned also as those contributing to the ethical impact.

- SSI technological solutions developed in ONTOCHAIN are the SSI suite OntoSSIVault, developed by the companies Gimly and Sphereon ²⁴, the solution HIBI ²⁵ which leverages the established EU framework for electronic identification and trust services (eIDAS), and the solution MFSSIA (Multi-Factor Self-Sovereign Identity Authentication) ²⁶, to provide SSI decentralisation.
- Provenance has been addressed by the project REPUTABLE ²⁷, which developed a provenance-aware decentralized reputation system for blockchain-based ecosystems.
- Digital Rights Management has been addressed by the project CopyrightLY ²⁸, which developed a Decentralised Copyright Management for Social Media.

Infrastructures of significant social impact, as those avoiding the concentration of data and information in a few platforms are summarized in D4.9 [3] in the Table 11, KPI A.3.2 and A3.3, and include decentralised social networks and publishing platforms, as CREATE ²⁹, a decentralized content marketplace for content creators, to assure fair revenues to quality contents, KnowledgeX ³⁰, a solution to provide adequate security and privacy in business interactions between data analysts and data providers, My3Sec ³¹, a PM and HR suite to support freelance workers, PRINGO ³², i.e. Private Incentives for Common Goods), to face the present inefficiency at funding and curating public/common goods, and, at a more infrastructural level, Low-code app builder ³³, BABELFISH ³⁴, Convex

²¹<https://ontochain.ngi.eu/content/create-content-registry-and-tokenized-exchange>

²²<https://ontochain.ngi.eu/content/kx-knowledgex>

²³<https://ontochain.ngi.eu/content/my3sec-ultimate-pm-hr-suite-smart-workers-smart-workers>

²⁴<https://ontochain.ngi.eu/content/gimly-id>

²⁵<https://ontochain.ngi.eu/content/hibi>

²⁶<https://ontochain.ngi.eu/content/mfssia>

²⁷<https://ontochain.ngi.eu/content/reputable-provenance-aware-decentralized-reputation-system-blockchain-based-ecosystems>

²⁸<https://ontochain.ngi.eu/content/copyrightly>

²⁹<https://ontochain.ngi.eu/content/create-content-registry-and-tokenized-exchange>

³⁰<https://ontochain.ngi.eu/content/kx-knowledgex>

³¹<https://ontochain.ngi.eu/content/my3sec-ultimate-pm-hr-suite-smart-workers-smart-workers>

³²<https://ontochain.ngi.eu/content/pringo>

³³<https://ontochain.ngi.eu/content/babelfish-service-integration-heterogeneous-environments>

³⁴<https://ontochain.ngi.eu/content/babelfish-service-integration-heterogeneous-environments>

Global DLT ³⁵.

3.3 SCIENTIFIC IMPACT

Main dimensions of the scientific impact include:

- specific technical infrastructure and pilot network available and running since May 2022;
- specific business model to simulate different exploitation paths relying on the technical infrastructure just mentioned;
- new specific technology improvements;
- scientific publications;
- collaboration established between partners, which belongs also to the economic impact;
- new standards contributed, which has also a political impact.

Specific technical infrastructure and pilot network available and running since May 2022, to host applications and technologies developed in ONTOCHAIN. This has both a scientific impact as an economic impact as well. This pilot network is based on Bellecour sidechain, includes nodes by IEXEC, AUEB, UL, IS and is described in more detail on the deliverable D3.7 [5].

Specific business model to simulate different exploitation paths relying on the technical infrastructure just mentioned. This business model has been developed by AUEB and is detailed in deliverables D5.3 [6] and D5.4 [7]. This of course has a scientific impact as an economic impact as well.

New specific technology improvements. Examples of a technology improvements can be as follows:

- conceptual improvements;
- performance improvements;
- bring technical concepts in new application or business context;
- develop further technical topics or concepts;
- develop new technical concepts;

³⁵<https://ontochain.ngi.eu/content/convex-global-dlt-convex-hosting-infrastructure-and-decentralised-ledger-next>

- o document the developments in a scientific publication.

Such evolutions will be detailed in the following sections for each consortium partner.

More specifically, scientific publications published by consortium members and/or by third parties can be accessed at <https://ontochain.ngi.eu/Resources>. This list includes 11 scientific papers published by consortium members and 17 scientific papers published by third parties.

Technical collaborations between third parties were established in OC1 and OC2, in such a way to support the use of ONTOCHAIN developed technologies by application developers and also by other technology providers, as mentioned in the deliverable D4.9 [3], Table 7, KPI 4.5. As a result of these collaborations:

- o the SSI technology OntoSSIVault/Gimly³⁶ is used in DEFev and in CopyrightLY;
- o ADOS³⁷, an AI-based oracle system for securing off-chain IoT data integrity when injecting in the blockchain, is used in the application CARECHAIN;
- o the Decentralised and Scalable Knowledge Graph DKG³⁸ is used in MFSSIA, ReCheck Green Box, OTCnLNG;
- o GraphChain a framework for on-chain data management³⁹ is used with CopyrightLY;
- o Low-code app builder⁴⁰, a IDE to facilitate the development of applications in the ONTOCHAIN framework, integrates PXC, NFTSwap, MFSSIA and REPUTABLE technologies.

Standards contributed, as new standard (PS-SDA⁴¹, DAOstar⁴²), 1 standard extended (ReCheck Green Box)⁴³ and 6 standards ongoing (DKG⁴⁴, PXC⁴⁵, MFSSIA⁴⁶, Ontospace⁴⁷, DKG⁴⁸, NFTSwap⁴⁹), as mentioned in D4.9 [3], Table 6, KPI 3.3.

³⁶<https://ontochain.ngi.eu/content/gimly-id>

³⁷<https://ontochain.ngi.eu/content/ados>

³⁸<https://ontochain.ngi.eu/content/dkg>

³⁹<https://ontochain.ngi.eu/content/graphchain>

⁴⁰<https://ontochain.ngi.eu/content/startin%E2%80%99blobx-low-code-app-builder>

⁴¹<https://ontochain.ngi.eu/content/ps-sda>

⁴²<https://ontochain.ngi.eu/content/daostar-semantic-api-standards-daos>

⁴³<https://ontochain.ngi.eu/content/recheck-green-box-digital-building-logbook-store-secure-share-and-extract-val>

⁴⁴<https://ontochain.ngi.eu/content/dkg>

⁴⁵<https://ontochain.ngi.eu/content/perun-x>

⁴⁶<https://ontochain.ngi.eu/content/mfssia>

⁴⁷<https://ontochain.ngi.eu/content/ontospace>

⁴⁸<https://ontochain.ngi.eu/content/dkg>

⁴⁹<https://ontochain.ngi.eu/content/piswap>

3.4 ENVIRONMENTAL IMPACT

Main components of the environmental impact include:

- low energy protocol used by the infrastructure;
- energy efficient applications developed;
- energy efficient technologies developed.

The ONTOCHAIN project is from its beginning aimed at providing an energy-efficient and eco-friendly infrastructure. In fact, the consortium partner iExec, which provided the Pilot Infrastructure, voided to use the Proof-Of-Work protocol and adopted a sidechain based on the Proof-Of-Execution concept, aimed at optimizing the use of the energy power, carbon footprint and hardware resources, hence belonging to "Green Computing".

Some third party projects have a primary ecologic objective, as for example ecOS ⁵⁰, which used blockchain technologies in order to address a more efficient use within the energy communities, CAPS-CO ⁵¹, which used blockchain technologies in order to minimize the carbon footprint along the supply chains, DEFev ⁵², which used blockchain in order to make more efficient and easier the charging phase of the electric cars.

Moreover, some projects had the objective to measure and support a more efficient use of the whole Blockchain infrastructure, notably the efficient cross-chain infrastructure Perun-X ⁵³ and KUMO ⁵⁴. Such attitude of the project ONTOCHAIN towards an environmentally-friendly strategy and developments is also measured by the KPI A1.2, from the Table 9 of D4.9 [8].

3.5 ETHICAL IMPACT

Main dimensions of the ethical impact include:

- technologies of ethical impact, as SSI, provenance, digital rights management.
- inclusion oriented applications.

SSI technological solutions developed in ONTOCHAIN are the SSI suite OntoSSIVault,

⁵⁰<https://ontochain.ngi.eu/content/ecos-energy-community-operating-system>

⁵¹<https://ontochain.ngi.eu/content/caps-co-carbon-accounting-product-supply-chains-using-ontochain>

⁵²<https://ontochain.ngi.eu/content/defev-dlt-ecosystem-electric-vehicle-charging>

⁵³<https://ontochain.ngi.eu/content/perun-x>

⁵⁴<https://ontochain.ngi.eu/content/kumo>

developed by the companies Gimly and Sphereon⁵⁵, the solution HIBI (Human Identity Blockchain Initiative)⁵⁶ which leverages the established EU framework for electronic identification and trust services (eIDAS), and the solution MFSSIA (Multi-Factor Self-Sovereign Identity Authentication)⁵⁷, to provide SSI decentralisation.

Provenance has been addressed by the project REPUTABLE⁵⁸, which developed a provenance-aware decentralized reputation system for blockchain-based ecosystems.

Digital Rights Management has been addressed by the project CopyrightLY⁵⁹, which developed a Decentralised Copyright Management for Social Media.

Inclusion oriented applications developed in ONTOCHAIN are INGRESS⁶⁰, a gateway for the financial inclusion (refugees, developing country citizens) and CARECHAIN⁶¹, a microinsurance solution for small farmers and developing countries.

3.6 POLITICAL IMPACT

Main dimensions of the political impact include:

- pursuing objectives aligned to the EU's digital strategy, including the Digital Services Act (DSA), the Digital Markets Act (DMA), the European Digital Identity strategy, the European Data strategy;
- strengthen the role of EU in standardisation activities.

The Digital Services Act (Ensuring a safe and accountable online environment)⁶² is specifically addressed by projects REPUTABLE⁶³, CARECHAIN⁶⁴, MFSSIA⁶⁵.

The Digital Markets Act (Ensuring fair and open digital markets)⁶⁶ is specifically addressed by projects POC4Commerce⁶⁷, PRINGO (Private Incentives for Common

⁵⁵ <https://ontochain.ngi.eu/content/gimly-id>

⁵⁶ <https://ontochain.ngi.eu/content/hibi>

⁵⁷ <https://ontochain.ngi.eu/content/mfssia>

⁵⁸ <https://ontochain.ngi.eu/content/reputable-provenance-aware-decentralized-reputation-system-blockchain-based-e>

⁵⁹ <https://ontochain.ngi.eu/content/copyrightly>

⁶⁰ <https://ontochain.ngi.eu/content/ingress-gateway-financial-inclusion>

⁶¹ <https://ontochain.ngi.eu/content/carechain>

⁶² https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/digital-services-act-ensuring-safe-and-accountable-online-environment_en

⁶³ <https://ontochain.ngi.eu/content/reputable-provenance-aware-decentralized-reputation-system-blockchain-based-e>

⁶⁴ <https://ontochain.ngi.eu/content/carechain>

⁶⁵ <https://ontochain.ngi.eu/content/mfssia>

⁶⁶ https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/digital-markets-act-ensuring-fair-and-open-digital-markets_en

⁶⁷ <https://ontochain.ngi.eu/content/poc4commerce-practical-ontochain-commerce>

Goods)⁶⁸, NFTSwap⁶⁹, PXC (PolyCrypt)⁷⁰.

The European Digital Identity Strategy⁷¹ is specifically addressed by projects ONTOSSI-VAULT/GIMLY⁷², HIBI⁷³, TRUSSIHEALTH (Decentralized Trustworthy Health Information Exchange for Patient's Self-Sovereign Medical Records)⁷⁴.

The European Data strategy⁷⁵ is specifically addressed by project PS-SDA (Provenance services with Smart Data Agreement)⁷⁶.

Moreover, the ONTOCHAIN strengthen the role of EU in standardisation activities, with 2 new standard (PS-SDA⁷⁷, DAOstar⁷⁸), 1 standard extended (ReCheck Green Box⁷⁹ and 6 standards ongoing (DKG⁸⁰, PXC⁸¹, MFSSIA⁸², Ontospace⁸³, DKG⁸⁴, NFTSwap⁸⁵), as mentioned in D4.9 [3], Table 6, KPI 3.3.

4 IMPACT AS EVALUATED BY BENEFICIARIES

4.1 BENEFICIARIES OVERVIEW

The ONTOCHAIN project's 7 consortium partners are well differentiated and complementary. They are in fact:

- o Large companies: European Dynamics (ED)⁸⁶.

⁶⁸ <https://ontochain.ngi.eu/content/pringo>

⁶⁹ <https://ontochain.ngi.eu/content/piswap>

⁷⁰ <https://ontochain.ngi.eu/content/perun-x>

⁷¹ https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-digital-identity_en

⁷² <https://ontochain.ngi.eu/content/gimly-id>

⁷³ <https://ontochain.ngi.eu/content/hibi>

⁷⁴ <https://ontochain.ngi.eu/content/trussihealth-decentralized-trustworthy-health-information-exchange-patients-s>

⁷⁵ https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en

⁷⁶ <https://ontochain.ngi.eu/content/ps-sda>

⁷⁷ <https://ontochain.ngi.eu/content/ps-sda>

⁷⁸ <https://ontochain.ngi.eu/content/daostar-semantic-api-standards-daos>

⁷⁹ <https://ontochain.ngi.eu/content/recheck-green-box-digital-building-logbook-store-secure-share-and-extract-val>

⁸⁰ <https://ontochain.ngi.eu/content/dkg>

⁸¹ <https://ontochain.ngi.eu/content/perun-x>

⁸² <https://ontochain.ngi.eu/content/mfssia>

⁸³ <https://ontochain.ngi.eu/content/ontospace>

⁸⁴ <https://ontochain.ngi.eu/content/dkg>

⁸⁵ <https://ontochain.ngi.eu/content/piswap>

⁸⁶ <https://www.eurodyn.com/>

- Technical Innovative SMEs: iExec (IE) ⁸⁷ and IntelliSemantic (IS) ⁸⁸.
- Academics: University of Ljubljana (UL) ⁸⁹ and Athens University of Economics and Business (AUEB) ⁹⁰.
- Community developers and CDE experts: F6S ⁹¹ and German Hellenic Chamber of Industry and Commerce (GHCC) ⁹².

Their specific perceived impact is detailed in the following paragraphs of this chapter.

In any case, they all agree that the overall impact is towards strengthening the European SMEs and academic ecosystem by:

- fostering synergies across multiple actors from different European countries;
- advancing cross-industry innovation from technology, social, ethical and business point of views;
- giving the opportunity to each innovators to reach a broader audience and technology and business environment.

Other impacts which are more specifically mentioned in specific groups of beneficiaries.

More specifically, the big ICT company European Dynamics:

- Better awareness about new technology trends;
- Identification of new investment opportunities.

Instead, SMEs mention as impact:

- new possibilities to develop innovative technologies within a environment suitable for synergies;
- improving their visibility across the international community.

Finally academics mention:

- Occasion for collaborations with other research groups and to publish papers in international conferences and reviews.

The following paragraphs of this chapter detail the impact view of any partner.

⁸⁷<https://iex.ec/>

⁸⁸<https://intellisemantic.com/>

⁸⁹<https://www.uni-lj.si/university/>

⁹⁰<https://www.aueb.gr/en>

⁹¹<https://www.f6s.com/>

⁹²<https://www.ahk.de/en/greece>

4.2 EUROPEAN DYNAMICS

4.2.1 Impact assessment

For ED, the commitment to conduct impact assessments in research and innovation projects, such as ONTOCHAIN NGI, is a wise and forward-thinking approach. In ONTOCHAIN, impact assessments (IA) has not been only valuable for accountability but also plays a crucial role in ensuring ONTOCHAIN's sustainability and broader influence. In particular, impact assessment efforts have been instrumental in achieving the following:

- **Exploitation and Sustainability Planning:** IA helps ONTOCHAIN partners, including ED, understand the outcomes and consequences of their work. This information is essential for making informed decisions about how to exploit project results and ensure long-term sustainability. It guides the development of strategies for exploitation, scaling, and ongoing support.
- **Strategic Decision-Making:** IA provides data and insights that inform strategic decision-making. It has help ONTOCHAIN consortium to identify which aspects of the project have the most significant impact, where improvements were needed, and where to allocate resources for maximum benefit and full sustainability. This has been the case especially regarding the business strategy to adopt in the long term.
- **Knowledge Transfer:** IA has facilitate knowledge transfer within ONTOCHAIN consortium and the overall ONTOCHAIN community. It ensures that lessons learned, best practices, and innovations are shared among the ONTOCHAIN stakeholders. This knowledge transfer is essential for maintaining the project's momentum and fostering collaborations.
- **Next Generation Internet Initiative (NGI) Impact:** Beyond ONTOCHAIN itself, IA has the potential to demonstrate the broader impact of ONTOCHAIN within the NGI initiative at the EU level. This can highlight how the project contributes to the NGI's overarching goals of building a more human-centric and value-driven internet.
- **Evidence-Based Advocacy:** IA can provide evidence of the project's value and contributions. For ONTOCHAIN, these evidences has been used for advocacy efforts, such as securing additional funding (HORIZON EUROPE TRUSTCHAIN project, GA No 101093274), attracting partners, or influencing policy decisions related to technology and innovation (participation in NGI event, working group EBSI, NGI, eIDAS, etc.).
- **Continuous Improvement:** Regular impact assessments has enabled ONTOCHAIN to create a feedback loop that has enabled continuous improvement. When ON-

TOCHAIN partners were identifying areas for enhancement, they were able to iteratively refine project activities and strategies. It has been especially the case after OC1 to maximise achievements, OC2 projects have been distributed around short projects and long projects to benefit about tangible outcomes from both type of projects which was not the case in OC1 with the selective process of innovators that can reach phase 2 for full implementation of their project.

- Transparency and Accountability: Demonstrating a commitment to IA has enhance transparency and accountability in ONTOCHAIN.
- Demonstrating value and long-Term Viability: Understanding the impact of the project in any case has help ONTOCHAIN consortium plan for its long-term viability in particular with the ONTOCHAIN foundation. It has ensured that ONTOCHAIN remains relevant and effective as it was evolving over time. Moreover, by sharing meaningful results with and demonstrating value to stakeholders, including funders, participants, and the wider community it helps fostering support and involvement of the community in ONTOCHAIN's future phases.

The following sections describe ED perspectives about IA, how it impacts its own activities in terms of business, the lesson learnt with regards to the initial impact foreseen at the time of the proposal and finally how impact alignes with the vision of the Next Generation Internet.

4.2.2 Impact assessment

A STEEP (Social, Technological, Economical, Environmental, and Political) analysis has been realised for assessing the factors that can impact EDs competitiveness and strategic decision-making in terms of ED own business, in terms of a software company member of the ONTOCHAIN consortium and more generally in the broader Next Generation Internet (NGI) initiative. Qualitative trends of the ONTOCHAIN impact on ED are summarised hereafter.

1) Social

Thanks to ONTOCHAIN, ED has become a facilitator of a more user centric and trustworthy internet by supporting the development of an ecosystem of solutions/applications for trustworthy data/services exchange as well as trustworthy data handling. ED's commitment to social accountability, is evident through its involvement in ONTOCHAIN. By incorporating human rights values, considering human needs, and promoting ethical practices, ED is not only strengthening its reputation but also contributing positively to society's digital well-being. ED approach through ONTOCHAIN aligns with the principles of social responsibility and accountability in the digital age. The aforementioned has/will have numerous benefits for the company, that are identified more in details at

the economical level.

2) Technological

ED's participation in ONTOCHAIN has not only expanded its knowledge and skills but also positioned the company as a leader in innovative technologies. In fact, this enhanced technological capacity building has several direct and tangible benefits for ED that are described hereafter:

- ED's newfound expertise enables it to innovate its products and services. By integrating blockchain, smart contracts, and other NGI technologies, ED can develop more competitive and innovative solutions that meet the evolving needs of its customers.
- Being at the forefront of innovative technologies positions ED as a leader in its industry. This enhanced reputation for innovation and expertise can give ED a significant competitive advantage in attracting customers and partners.
- ED's participation in joint research and development efforts within ONTOCHAIN has likely resulted in valuable technological partnerships. These partnerships can lead to collaborative projects, knowledge sharing, and access to cutting-edge technologies.
- ONTOCHAIN's collaborative environment fosters groundbreaking open innovations. ED's involvement in such innovations not only contributes to the development of new technologies but also strengthens its position as an innovative thought leader.
- Such ED engagement in innovative projects has the potential to create valuable intellectual property (IP) that can be monetized or used to gain a competitive advantage in the market.

ED's enhanced reputation and expertise in NGI and blockchain technologies, in turn, has direct economic benefits, including improved business processes, product innovation, competitive advantage, and opportunities for collaborations and grant funding. That are described hereafter.

3) Economical

ED's participation in ONTOCHAIN has had and will continue to have a multi-faceted economic impact. It encompasses job creation, reputation enhancement, access to new markets, open source advantages, and potential benefits from the ONTOCHAIN Foundation [6]. An analysis covering the short, medium and long term effects of this impact is justified hereafter.

- Short-Term Impact
 - Increased Employment: ED has immediately increased its workforce to manage ONTOCHAIN project activities, resulting in short-term job creation.

- o Enhanced reputation and expertise in NGI and blockchain technologies and securing research funding: It likely played a crucial role in being the coordinator of the only HORIZON EUROPE call CL4-2022-HUMAN-01-03 granted project: TRUSTCHAIN (GA 101093274).
- o Medium-Term Impact:
 - o Multiplier Effect: In the medium term, the implementation of the ONTOCHAIN Foundation may require additional human resources, leading to further job creation and a positive impact on the company's operations.
 - o Reputation Enhancement: ED's commitment to ethical values, human rights, and innovative software solutions enhances its reputation and brand image over the medium term. This improved reputation can attract socially conscious consumers and foster brand loyalty.
 - o Access to New Markets: Demonstrating commitment to ethical standards positions ED to access new markets and industry networks, thereby expanding its reach and recognition in the innovative field.
- o Long-Term Impact:
 - o Open Source Benefits: ED recognizes the advantages of open source solutions, which align with ONTOCHAIN's goals. In the long term, thank to its involvement in Open source development, ED anticipates attracting users and organizations that may not have considered its proprietary offerings, leading to broader business opportunities and new client acquisition.
 - o ONTOCHAIN Foundation Implementation: The potential implementation of the ONTOCHAIN Foundation presents substantial long-term economic benefits:
 - o Revenue Generation: ED's participation in the Foundation activities can lead to the development of new software products, services, or intellectual property, contributing to revenue generation.
 - o Access to Funding: The Foundation's ability to provide access to various grants and subsidies can support ED's research initiatives and reduce the financial burden of innovation.
 - o Differentiation and Competitive Advantage: ED's association with the ONTOCHAIN Foundation can differentiate it from competitors over the long term, strengthening its position in the market.
 - o Access to Expertise: Leveraging the expertise within the Foundation can lead to product enhancements, process improvements, and a more competitive software offering.

- o These economic effects will contribute to ED's growth, competitiveness, and long-term sustainability in the software industry.

4) Environmental

The integration of green solutions development and a focus on environmental sustainability within the ONTOCHAIN project reflects a forward-thinking approach to technology innovation. Here are several key points that highlight the positive impacts of this approach on ED's brand reputation and business opportunities.

- o **Alignment with Eco-Conscious Values:** The incorporation of green solutions and environmental sustainability aligns with the growing trend of eco-consciousness in the world. Consumers and businesses increasingly prioritize environmentally friendly practices. ED's commitment to these values enhances its image as a responsible and forward-looking organization.
- o **Positive Brand Reputation:** By supporting projects like PRINGO within ONTOCHAIN OC2, ED demonstrates its dedication to addressing environmental challenges through technology. This commitment positively impacts its brand reputation, positioning it as a socially and environmentally responsible company.
- o **Competitive Advantage:** In a business landscape where sustainability matters, ED's focus on green solutions and environmental sustainability can serve as a competitive advantage. Potential clients and partners may prefer to collaborate with a company that shares their commitment to eco-friendly practices.
- o **Market Differentiation:** Considering green solutions sets ED apart from competitors who may not prioritize sustainability. This differentiation can be an attractive feature for clients seeking environmentally conscious technology solutions.
- o **Business Opportunities:** As the demand for green and sustainable solutions continues to grow, ED is likely to encounter new business opportunities. Organizations across various industries are actively seeking technologies that reduce their environmental footprint, and ED's expertise in this area positions it well to address these needs.
- o **Policy Alignment:** ED's commitment to green solutions and environmental sustainability is likely aligned with broader policy goals related to sustainability and environmental protection. This alignment can open doors to government contracts, grants, and collaborative projects that further expand business opportunities.
- o **Market Expansion:** ED's reputation as a company dedicated to green solutions can facilitate market expansion. It may attract clients and partners who are specifically looking for technology providers with a strong sustainability focus.

The alignment between ONTOCHAIN activities in terms of environmental sustainability

and ED's policy in this regard positions the company well for continued growth and success in an eco-conscious world.

5) Political

ED's role as the ONTOCHAIN project coordinator has provided valuable opportunities to actively engage with the broader blockchain community and inform policy-makers about ethical and regulatory considerations related to blockchain and semantic technologies. This proactive involvement in shaping the future of technology and its societal impact has several noteworthy benefits and implications:

- **Policy Influence:** By participating in NGI activities (whole duration of the project and more), NGI forums (2020, 2021), ONTOCHAIN Summits (2021,2022) , and events like the European Blockchain Week (2022), ED has established itself as a voice in the blockchain and semantic technology space. This position allows the company to directly influence policy discussions and decisions related to these technologies.
- **Ethical Considerations:** ED's commitment to ethical considerations in the use of blockchain and semantic technologies showcases its responsible approach to innovation. This emphasis on ethics is essential in guiding policy-making and regulatory frameworks that promote responsible and ethical technology adoption.
- **Regulatory Support:** ED's engagement with policy-makers can result in the creation of regulatory frameworks that are conducive to innovation while ensuring user protection and ethical practices. These frameworks can benefit the entire industry.
- **Leadership Position:** Through its active participation and contributions, ED has naturally gained a leadership position in the blockchain and semantic technology landscape. This leadership can attract attention from stakeholders, partners, and clients looking for guidance and expertise in these domains.
- **Collaborative Opportunities:** ED's active role in policy discussions and the broader blockchain community can lead to collaborative opportunities with government agencies, industry associations, and other technology leaders. Such collaborations can drive innovation and promote responsible technology use.
- **Alignment with NGI, EBSI, eIDAS:** ED's participation in NGI activities aligns with the goals of the Next Generation Internet initiative, which aims to create a more human-centric and trustworthy internet. Additionally, involvement in initiatives like EBSI (European Blockchain Services Infrastructure) and eIDAS (Electronic Identification and Trust Services) demonstrates ED's commitment to advancing digital trust and security.
- **Industry Recognition:** ED's active role in policy advocacy can enhance its industry recognition and reputation as a thought leader in blockchain and semantic technologies. This recognition can attract clients and partners seeking guidance and

expertise.

- Societal Impact: Policy advocacy and ethical considerations contribute to the responsible and positive societal impact of blockchain and semantic technologies. ED's active involvement helps ensure that technology is developed and used in ways that benefit society as a whole.

In summary, ED's participation in ONTOCHAIN and its engagement with the broader blockchain community and policy-makers have positioned the company as an active and influential actor in the landscape of blockchain and semantic technologies. This leadership role not only benefits ED but also contributes to the responsible and ethical advancement of these technologies for the benefit of society.

4.2.3 Lessons learnt

Participation in research and innovation projects like ONTOCHAIN, especially when involving core partners and third-party innovators, can indeed be complex and challenging. These endeavors often come with unexpected challenges and valuable lessons. Here are some common challenges and lessons learned, particularly regarding the immediate impact foreseen at the time of the ONTOCHAIN proposal.

TABLE 2: ED Lesson learnt

	Challenges	Lesson learnt
<p>Growing the blockchain and next generation internet community, through a three year project with many vertical and horizontal actions towards the empowerment of communities as well as the inclusion of cross sectorial applications and the involvement of experts covering a wide spectrum of expertise.</p>	<ul style="list-style-type: none"> ○ Being inclusive. Welcoming participants from diverse backgrounds, including different sectors, industries, and areas of expertise as well as encourage the participation of underrepresented groups. ○ Creating a sense of belonging and ownership among community members (more than 44) when the scope of the overall project and its objective are set by a consortium of 7 partners. 	<p>Building a community takes time, effort, and a thoughtful approach that ONTOCHAIN has been able to achieve by:</p> <ul style="list-style-type: none"> ○ exposing a clear vision and goals from the very beginning of the project to our audience, ○ providing value such as knowledge, expertise, networking opportunities, sense of belonging, ○ showing how being part of the community can benefit individual members especially with respect to business aspects and joint exploitation, ○ being consistent, regularly engaging with members individually through scrum meetings but also collectively through joint technical meetings, hosting broader events (ONTOCHAIN Summit) and always maintaining open communication channels, ○ encouraging active participation of all stakeholders, to connect with each others and listening to all of them, giving feedback. <p>Building trust and a sense of belonging takes time, but the rewards of a thriving, engaged community can be significant. This has been achieved by the ONTOCHAIN consortium.</p>

	Challenges	Lesson learnt
<p>Educating and providing finding to a large number of researchers, innovators, start ups, SMEs, use case holders, increasing their awareness towards a more trustworthy and decentralised internet that could offer several societal and economic benefits.</p>	<ul style="list-style-type: none"> ○ Balancing the educational, training, and mentoring aspects with the need for quick project outcomes in a short period of time can be a challenging endeavor, especially when it comes to innovation. ○ Shifting the focus from technologically driven solutions to user-centric solutions considering their needs as driver of the technology development. 	<p>Flexibility, effective mentorship, and clear communication are key to achieve this balance successfully. In the context of ONTOCHAIN, the challenge has been tackle as much as possible by:</p> <ul style="list-style-type: none"> ○ Providing clear expectation and prioritizing the focus with the innovators from the outset. ○ Identifying shortcuts and setting best practises with the innovators to accelerate the progress. In particular the coaching, the promotion of an iterative approach to achieve progress and the evaluation method set in D5.1 have been effective. ○ Fostering cross-functional collaboration and co-creation with end user is crucial. Synergies between technologists, developers, behavioral scientists, domain experts and users to address user needs comprehensively is paramount to achieve scalability and full adoption of the developed solution. In ONTOCHAIN, coaches provided innovators with as much information and guidance as possible to help them adopt good practice. Good achievements with regards to those aspects have been produce especially in ONTOCHAIN OC3.

	Challenges	Lesson learnt
<p>Providing the workspace for building and validating a new technological framework, created within ONTOCHAIN and proposing new economic schemes towards a human centric evolution for the future internet.</p>	<p>Building and validating a technological framework in a complex project like ONTOCHAIN, where developers/innovators may primarily focus on their own solutions rather than the broader ecosystem, is a challenging endeavor. Developers often have their specific goals and objectives for their individual components or solutions and it could lead to a siloed development approach where they prioritize their solution's success over the success of the overall ONTOCHAIN framework.</p>	<p>To tackle this challenge, ONTOCHAIN partners have understood that they should encourage developers/innovators to adopt an ecosystem-centric mindset and to prioritize the validation of the overall technological framework. On a three years projects this approach started to be effective in the last year. The strategy was as follows:</p> <ul style="list-style-type: none"> ○ Establish clear and well-defined interoperability guidelines at the outset of the project. These guidelines were outlining how different components should interact and interoperate within the ecosystem. ○ Encourage regular communication and collaboration among OC1, OC2, OC3 developers. ONTOCHAIN has organize several meetings where developers can discuss their progress, challenges, and potential synergies with others ONTOCHAIN innovators. ○ Incentivize Ecosystem Thinking: Provide incentives that motivate developers to consider the broader ecosystem's success by deploying their solution on the ONTOCHAIN testnet (iExec Bellcour network). ○ Prototyping and Testing: Proof-of-concept implementations (ONTOCHAIN testnet) that demonstrate how individual solutions can work together within the larger framework.

	Challenges	Lesson learnt
		<ul style="list-style-type: none"> ○ Cross-Component Testing: Necessary to identify and resolve any interoperability issues. ONTOCHAIN OC3 innovators have participated in these testing efforts. ○ Documentation and Knowledge Sharing is also a cornerstone: Documenting how individual solutions fit into the larger ecosystem is crucial and OC1, OC2 developers were encourage to share their knowledge and insights with OC3 ones. Feedback mechanisms that allow developers to provide input on how their solutions fit into the broader framework and where improvements can be made is also essential and ease by the open source requirement set at the beginning of the ONTOCHAIN project so that the community can always contribute and enhance solutions according to the overall framework goal. ○ Strong project leadership play also a crucial role in guiding developers to consider the broader ONTOCHAIN ecosystem. The technical coordinator (UL) supported by the innovation manager (AUEB) has play a major role to communicate the project’s vision and emphasize the importance of collaboration.

	Challenges	Lesson learnt
<p>Creating the required proof-of concept and the adequate knowledge for providing recommendations and a roadmap towards a more focused and efficient European policy making process.</p>	<p>The following were the challenges to tackle to achieve this impact:</p> <ul style="list-style-type: none"> ○ Interoperability, ○ Lack of standardization, ○ Testing in Real Context: Conducting a meaningful pilot or real-world test of the ONTOCHAIN PoC within the context of European policy-making is logistically complex especially in a three years projects involving 33 solutions, ○ Complexity of Policy-Making, ○ Lack of regulatory frame related to blockchain technologies. 	<p>To address these challenges, ONTOCHAIN has noticed that it is crucial to engage with a diverse group of stakeholders, including policy-makers, technologists, legal experts, and civil society representatives. Collaboration, transparent communication, and a well-thought-out strategy are key to successfully creating a PoC and providing recommendations for a more focused and efficient European policy-making process. Additionally, flexibility and adaptability in the face of unforeseen challenges is also important throughout the project. In some aspects ONTOCHAIN has been successful to tackle the challenges but not all. In particular, policy making process time development are not in adequation with a three years projects and should be envisage in the long term. Nonetheless, ONTOCHAIN consortium intends to be successful in this endeavor through the ONTOCHAIN foundation that will pursue such activities.</p>

4.2.4 Alignment with the vision of the Next Generation Internet

ONTOCHAIN's alignment with the vision of the Next Generation Internet reflects its commitment to advancing digital trust, security, and the development of a more human-centric and trustworthy internet. It reflects the ONTOCHAIN consortium's dedication to creating a more user-friendly, trustworthy, and diverse internet ecosystem. Contribution to this vision has happened at different levels:

- Human-Centric Approach: ONTOCHAIN has placed all along the project a strong emphasis on empowering individuals, enhancing their privacy and control over data,

and fostering trust in digital interactions.

- Innovation: ONTOCHAIN's focus on blockchain, semantic web technologies, and decentralized solutions that completely aligns with NGI's goal of advancing innovative technologies that reshape the internet and its services.
- Sustainability: ONTOCHAIN's commitment to green solutions and environmental sustainability reflects NGI's broader concern for sustainability and responsible technology development.
- Values of Privacy:
 - Data Ownership: ONTOCHAIN's use of blockchain and semantic technologies enhances individuals' control over their data. By providing users with more control and ownership of their data, ONTOCHAIN supports this value of privacy.
 - Transparency and Consent: Privacy is also supported through transparency and consent mechanisms enabled by blockchain and ONTOCHAIN solutions. Users can have more visibility into how their data is used and grant or revoke consent more effectively.
 - Data Minimization: ONTOCHAIN promotes data minimization and aligns with privacy principles by reducing unnecessary data exposure.
- Values of Participation:
 - Open Source: ONTOCHAIN follows the open source model, allowing for widespread participation and contributions from the ONTOCHAIN developer community.
 - Inclusivity: ONTOCHAIN's has enables a wider range of stakeholders to participate in the ecosystem and contribute to its development.
 - Community Building: ONTOCHAIN's activities, such as the ONTOCHAIN Summits and engagement with the NGI community, has encouraged active participation and knowledge sharing among diverse stakeholders.
- Values of Diversity:
 - Interdisciplinary Approach: ONTOCHAIN's interdisciplinary nature, combining blockchain, semantic web, and distributed ledger technologies, has welcome contributions from a diverse set of experts and professionals.
 - Global Collaboration: Collaboration within the NGI community and involvement in international events like the European blockchain week has promoted diversity by bringing together stakeholders from various regions and

backgrounds.

ED's alignment with the next generation internet vision reflects its commitment to key principles such as human-centricity, trust, security, and innovation in the digital realm. These alignments provide opportunities for collaboration, policy influence, and market growth, ultimately contributing to a more secure and user-friendly digital environment in Europe and beyond.

4.3 UNIVERSITY OF LJUBLJANA

4.3.1 Impact assessment

1) Economic impact

The ONTOCHAIN project has wielded a significant economic influence, with its diverse array of outcomes, encompassing applications protocols, core protocols, decentralized ledger technologies, and ontology technologies, finding active adoption and application among a wide range of third-party entities (funded entities within the open calls, as well as third party entities from the Hackathons and the different open communities of developers). This extensive adoption is not only a testament to the project's technological relevance but also to its potential as an economic driver and an incubator for innovation. As we move forward, the University of Ljubljana is eager to participate in establishing the ONTOCHAIN foundation and further harness the ONTOCHAIN platform's capabilities, capitalizing on its potential for developing a spectrum of applications, including digital student index, decentralized microcredentials, and decentralized publishing organizations, among other exciting prospects. This commitment underscores the university's dedication to pushing the boundaries of blockchain and semantic web technologies for economic and societal advancement. In addition, the University of Ljubljana as a co-founder of the Blockchain for Trusted Data Ecosystems Digital Innovation Hub will transfer its knowledge and experience from the ONTOCHAIN project to its partners from the industry and academia as well as to the projects within the digital innovation hub.

2) Societal impact

The ONTOCHAIN project extends its impact beyond economics to influence society at large. By fostering the development and adoption of decentralized technologies and semantic web solutions, it empowers individuals and organizations to regain control over their data and information. This has the potential to enhance privacy and security for users across various sectors, from education and publishing to countless other fields. The ONTOCHAIN project carries substantial social impact by directly addressing users' fundamental needs for trust, privacy, and security while championing inclusivity

in digital interactions. By prioritizing these core elements, ONTOCHAIN not only ensures a safer and more reliable digital ecosystem (e.g. Reputable, ADOS, DESMO-LD) but also actively promotes the principles of transparent and trustworthy data management (e.g. KnowledgeX, PRINGO, Graphchain, Ontospace, DKG), identity management (e.g. HIBI, Gimly), credibility management (e.g. TrussiHealth). Ultimately, ONTOCHAIN's societal impact is poised to create a more inclusive, transparent, and efficient digital environment that fosters collaboration, innovation, and trust among all stakeholders in the ecosystem.

3) Scientific impact

The scientific impact of the ONTOCHAIN project is notable for its contributions to the fields of blockchain, semantic web technologies, and decentralized systems. The project has expanded the frontiers of knowledge in these areas, fostering advancements that have practical applications and implications across various industries. By pioneering innovative solutions and protocols, ONTOCHAIN not only promotes the adoption of blockchain technology but also enhances the understanding of the semantic web and the possibilities it offers for data interoperability and integration. Its interdisciplinary approach to merging blockchain and ontology technologies has the potential to revolutionize how data is stored, shared, and utilized, while its research and developments drive forward the scientific community's understanding of these emerging technologies. The high-quality research and development activities within the ONTOCHAIN project resulted with publishing multiple scientific papers:

- Papaioannou, Thanasis G., Vlado Stankovski, Petar Kochovski, Anthony Simonet-Boulogne, Caroline Barelle, Alberto Ciaramella, Marco Ciaramella, and George D. Stamoulis "A New Blockchain Ecosystem for Trusted, Traceable and Transparent Ontological Knowledge Management: Position Paper. "Economics of Grids, Clouds, Systems, and Services: 18th International Conference, GECON 2021, Virtual Event, September 2123, 2021, Proceedings 18. Springer International Publishing, 2021.
- Kochovski, Petar, Vlado Stankovski, Sandi Gec, Maja Klun, and Mitja Deman. "Reaching Sustainable Development Goals Through Tax Reductions and Incentives within a Trustworthy Decentralized Autonomous Organization.", 2022 International Conference on Computational Science and Computational Intelligence (CSCI). IEEE, 2022.
- García, Roberto, et al. "Copyrightly: Blockchain and semantic web for decentralised copyright management."International Conference on the Economics of Grids, Clouds, Systems, and Services. Cham: Springer International Publishing, 2021.
- Bella, Giampaolo, et al. "Semantic representation as a key enabler for blockchain-based commerce."Economics of Grids, Clouds, Systems, and Services: 18th International Conference, GECON 2021, Virtual Event, September 2123, 2021, Proceedings 18. Springer International Publishing, 2021.

- Bella, Giampaolo, et al. "The Ontology for Agents, Systems and Integration of Services: recent advancements of OASIS." Proceedings of WOA. 2022.
- Preece, Joseph David, Christopher Morris, and John Easton. "Leveraging Ontochains for Decentralised Public Transit Ticketing: An Investigation with the System for Ticketing Ubiquity with Blockchains."
- Tomaszuk, Dominik, et al. "A distributed graph data storage in ethereum ecosystem." International Conference on the Economics of Grids, Clouds, Systems, and Services. Cham: Springer International Publishing, 2021.
- Sopek, Mirek, et al. "Technological foundations of ontological ecosystems on the 3rd generation blockchains.", IEEE Access 10 (2022): 12487-12502.
- Gec, Sandi, et al. "A Recommender System for Robust Smart Contract Template Classification." Sensors 23.2 (2023): 639.

4) Environmental impact

The environmental impact and sustainability focus of the ONTOCHAIN project exemplifies a responsible approach to technology development. While the solutions prioritized compatibility with the Ethereum Virtual Machine (EVM), they consciously avoided deployment on Proof-of-Work (PoW) networks, known for their substantial energy consumption. Instead, the project has chosen to build on the Bellecour network, a more energy-efficient alternative where the projects consortium hosted multiple network nodes. This strategic decision underscores the project's dedication to reducing its carbon footprint and promoting eco-friendly blockchain and semantic web technologies. By opting for a greener network, ONTOCHAIN sets a valuable example for the tech industry, emphasizing that innovative solutions can coexist with sustainability, aligning with the broader global goal of mitigating the environmental impact of emerging technologies.

5) Political impact

The ONTOCHAIN project wields a significant political impact by fostering principles of transparency, trustworthiness, and data decentralization. By enhancing these aspects in the digital landscape and enabling further exploitation of its technologies it can further contribute to the creation of a political environment that prioritizes data privacy, safety, and security, because the decentralization of data fosters a more democratic information ecosystem, where power is distributed, and individual privacy is protected. This, in turn, can aid in the fight against fake news, disinformation, and propaganda, as the projects technologies enable users to have access to more reliable and verifiable information sources.

4.3.2 Lessons learnt

The ONTOCHAIN project has delivered invaluable outputs that resonate across the technological landscape. One of the key takeaways is the immense potential of blockchain technology, highlighting its capacity to transform data management, privacy, and security. Additionally, the project has demonstrated that the integration of blockchain and semantic technologies are not just a theoretical concept but can be practically implemented. These lessons are now paving the way for the next stage, where the accumulated know-how can be harnessed for further advancement and research in the realm of trustworthy digitization of various domains. The project's results will undoubtedly contribute to the evolution of self-sovereign identities, decentralized marketplaces, Metaverse development, reputation management, and numerous other applications. By building on the foundation laid by ONTOCHAIN, the technological community is poised to explore and innovate in these domains, ultimately fostering a more secure, decentralized, and user-centric digital landscape that respects individual data rights and catalyzes progress in the digital era.

4.3.3 Alignment with the vision of the NGI

The ONTOCHAIN project aligns seamlessly with the vision of the Next Generation Internet (NGI), which seeks to create a more human-centric, open, and inclusive digital ecosystem. By emphasizing principles such as trust, privacy, security, and decentralization, and developing applications and protocols following those principles, ONTOCHAIN directly contributes to NGI's overarching goals. ONTOCHAIN's focus on advancing blockchain, and semantic web technologies reflects NGI's ambition to promote cutting-edge solutions that empower individuals and drive economic and societal progress.

4.4 IEXEC

4.4.1 Impact assessment

1) Economic impact

The iExec's participation in various events for ONTOCHAIN and the ONTOCHAIN project's success have enabled an increased visibility of the iExec infrastructure and enriched the potential partnerships. Thanks to the successful popularity of the iExec platform from developers, a program for developers in the iExec community has been implemented to incentive their creativity. Interacting with these developers has high-

lighted the need for a robust commercial strategy, which iExec has meticulously refined. Additionally, the ONTOCHAIN project has enabled the recruitment of top talents to support the ONTOCHAIN project and assist third-party developers in the advancement of their solution.

2) Societal impact

The ONTOCHAIN project brought together multiple teams, fostering an environment where innovative ideas have been developed. A mentoring program has been seamlessly integrated to provide support and guidance to third-party projects, facilitating their development. This contributes to the iExec team's enhancement of mentoring skills. In parallel, a robust support platform has been developed by the iExec team, directly stemming from this collaborative context, which serves as a valuable resource for both ONTOCHAIN developers and those yet to come. This support platform guarantees not only a seamless implementation process for their projects but also customer and developer satisfaction. Furthermore, the ONTOCHAIN project has fortified connections with external developers, acting as a driving force for knowledge exchange and the natural expansion of the iExec community.

3) Scientific impact

The ONTOCHAIN project has enriched the scientific knowledge in the field of blockchain through the publication of several scientific papers. In addition, the ONTOCHAIN project enabled the integration of the first external projects onto the iExec platform. Some of these projects have resulted in hybrid solutions with the iExec functionalities and external capabilities. The success of these first external projects and the increased utilization of platform features have not only expanded the iExec network but also propelled the platform into a state of dynamic innovation, catering to a wide range of project requirements. Additionally, the ONTOCHAIN project also helps to understand the limitations of the Bellecour blockchain, thus providing invaluable insights for its optimization and enhancement. Thus, the iExec documentation has been improved thanks to the feedback received from the developers, enabling a better and clear understanding of the iExec platform and its functionalities. Finally, the increased activities on the blockchain, including a substantial number of tests at a European scale, have delivered a positive scientific impact on the iExec platform. This has not only affirmed the platform's robust performance but also validated the practicality and value of its capabilities.

4) Environmental impact

The ONTOCHAIN infrastructure is based on Ethereum Virtual Machines (EVMs). On the one hand, this is for ensuring that upcoming updates to the Ethereum protocol and implementation will benefit ONTOCHAIN services and applications. On the other hand, this choice avoids the use of the Proof-of-Work (PoW) mechanism used by the Ethereum network that was energy-consuming. Therefore, Bellecour sidechain devel-

oped by iExec is provided to deploy the ONTOCHAIN projects, considering the Proof-of-Authority (PoA) mechanism. Thus, thanks to the ONTOCHAIN project, the Bellecour sidechain could have been decentralized with new nodes managed by the consortium partners across different countries. This decentralization initiative aligns with the commitment to maintaining an energy-efficient network, one of the major concerns for the ONTOCHAIN project.

5) Ethical impact

Throughout the ONTOCHAIN project, encompassing a range of initiatives like participation in events and the implementation of a mentoring program, the consortium, including iExec, has defended an ethical obligation to offer precise and transparent information to prospective developers, clients, and the general public. Simultaneously, it has actively promoted ethical values that develop talent, foster growth, and create an inclusive and supportive work environment.

6) Political impact

The establishment of new partnerships and the rigorous testing of the iExec platform have collectively yielded a significant political influence. Indeed, this initiative enabled iExec to fortify its presence and extend its influence within the industry while concurrently demonstrating its commitment to responsible participation. These efforts position iExec as a pivotal player, wielding substantial political impact, promoting and protecting its business priorities in a dynamic and evolving industry landscape.

4.4.2 Lessons learnt

The ONTOCHAIN project has provided a deep understanding of the influences that projects can have on a company, particularly for iExec in its role as a technical partner. Through this experience, the iExec team has recognized the importance of aligning their actions with the project's impacts and objectives. Over the three-year ONTOCHAIN project and with successful outcomes from third-party teams, iExec has achieved significant technological advancements. The integration of feedback from developers and the resolution of issues have been instrumental in improving the iExec's platform, underlining the value of engagement and collaboration. Scientific progress is not just an outcome but an integral aspect of the experience, shaping the iExec platform's capabilities and functionality. These lessons will persistently guide the iExec approach, ensuring that every action taken aligns with the core values and contributes to the iExec mission and growth.

4.4.3 Alignment with the vision of the Next Generation Internet

The ONTOCHAIN project has been proposed with a vision in harmony with that of the Next Generation Internet, which closely aligns with the vision of iExec. At the core of the iExec’s vision lies a commitment to providing decentralized services that empower service providers while safeguarding the assets of users. This vision seamlessly aligns with several fundamental concepts of the NGI and the ONTOCHAIN project. Decentralization is the cornerstone of the iExec approach, granting autonomy and control to service providers while fostering trust in the iExec ecosystem. Trustworthiness is prioritized to ensure that the users can rely on the security and integrity of their assets within the iExec decentralized framework. The interoperability of iExec ensures that the services are accessible and usable for all, emphasizing inclusion and openness. The iExec human-centric approach places users and their assets at the center of the iExec’s focus, ensuring that their needs and aspirations are crucial in the evolution of the iExec services. In embracing these concepts, iExec not only fulfills the ONTOCHAIN and NGI vision but also develops an environment that supports both user autonomy and asset protection.

4.5 INTELLISEMANTIC

4.5.1 Impact assessment

1) Economic impact

After our coaching and business, technical and scientific support, some projects from the teams are now stepping closer to business sustainability. In fact, our willingness towards encouraging the collaboration between different projects within a common infrastructure for data elaboration is in principle promising for different kind of future, scalable, businesses activities.

The ONTOCHAIN project aimed at creating a blockchain network ecosystem capable of empowering the current and future developments of third party technologies within one or more blockchain technology ecosystems. Moreover, the ONTOCHAIN infrastructure was conceived in order to promote synergies between different projects and then to fairly share the benefits amongst each one of them. In such regard, each funded project can look at the ONTOCHAIN integration platform as an additional opportunity for multiplying the dimension of its potential market and a support towards complementary technology integration activities, without any constraint of being part of such ecosystem. In other terms, each project was selected as potentially promising in terms of self-sustainability potential, with the opportunity of being part of a larger ecosystem composed from complementary technologies and business sectors. Given

these objectives, we addressed also one of the more challenging aspects of Blockchain technologies, which is the interoperability between different existing technologies and projects.

Relating the economic impact, particular attention was given to aspects such as the future business and technical sustainability of the projects, including the scalability potentials from both point of views. When possible, synergies between economics aspects and other aspects were pursued (e.g. environmental, societal etc.) and, at the end of such effort, we are convinced that some further promising results will be produced in the future.

A demonstration of the ONTOCHAIN project strategy towards the interoperability and scalability aspects was documented in the pilot infrastructure network along the iExec's Bellecour sidechain, where each of three partners (AUEB, IS, UL) activated validation nodes, announced on June 2022 ⁹³.

In order to correctly address the work, some IP assessments were also conducted along the project. Moreover, IS made also dissemination activities about the Intellectual Property work within the EU context, thanks to the IntelliSemantic's experience in this field. In parallel, IntelliSemantic conducted regularly innovation trend analysis with the help of IntelliSemantic's tool, MyIntelliPatent.

2) Societal impact

The social impact of blockchain technologies is currently facing an open debate across several actors. We aimed to foster society improvements in several ways, using a NGI (New Generation Internet) technologies. A pivotal aspect of our work was bringing the European socioeconomic equilibrium to a new phase, e.g. facing environmental, informative and economic aspects together in a more effective way positive for the European citizens and professionals. As for example, we took some special care about the topic of the fair remuneration of the creative and scientific contents production by an appropriate use of blockchain technologies placing emphasis of the transparency of the content production process. Another aspect that we highlighted in the project is also the energy and environmental sustainability, due to the impact on society as a whole, which must be consistent with economic and business sustainability. In addition, some teams worked more specifically on the empowering specific social sectors, as for example of specific kind of workers or even political refugees. Moreover, after the project, the experience and the knowledge acquired during ONTOCHAIN will be part also of IntelliSemantic's activity in coaching and teaching, for example in the promotion of the Italian ITS (Higher Technical Institute), where IntelliSemantic is currently involved also in the teaching activities.

3) Scientific impact

⁹³"iExec to provide Pilot Infrastructure for ONTOCHAIN", <https://medium.com/iex-ec/iexec-to-provide-pilot-infrastructure-for-ontochain-1bd19bc0b981>, Jun 15, 2022

Scientific impact is related to blockchain technologies, more typically in OC1 and OC2, and blockchain applications, more typical in OC3. In particular the OC3 call was diversified to different application domains.

The background for preparing the OC3, for application specific call, comes from corresponding chapters in the state of the reports D3.1 [9] and D3.2 [10] contributed by IntelliSemantic.

Applications in this report are categorised into 15 domains (or verticals), such as agri-food, art and creativity, constructions, education and science, energy, fashion and luxury, finance and banks, health-care, industry and manufacturing, information and media, insurances, logistics, mobility, smart cities, tourism. For each domain, up to 10 subdomains have been analysed, identifying reasons why to adopt blockchain. Each use case is associated with motivations to use blockchain architectures. In evolutionary cases the use of blockchain adds security and privacy or increase the efficiency and reduces operational costs in comparison to centralised data base architectures. In more advanced and even disruptive cases the use of blockchain architectures enables new applications and/or business models.

During the ONTOCHAIN project, a good number of scientific papers were published. Some of such papers comes from the teams coached by IS (in total 12) and are joint contributions with the ONTOCHAIN consortium. Those papers were published across different international conferences and review (including on "Class A" journals, as in the case of García et al. 2022). In one case (Müller et al., 2021), a published paper reports a further development on the top of what was developed within ONTOCHAIN and immediately after it, documenting then a further collaboration with a member of the consortium with one of the OC winner teams.

Published papers from the teams coached by IntelliSemantic are:

- Müller, Marcel, Anthony Simonet-Boulogne, Souvik Sengupta, and Oliver Beige. "Process mining in trusted execution environments: Towards hardware guarantees for trust-aware inter-organizational process analysis." In International Conference on Process Mining, pp. 369-381. Cham: Springer International Publishing, 2021.
- García, Roberto, Ana Cediél, Mercè Teixidó, and Rosa Gil. "Copyrightly: Blockchain and semantic web for decentralised copyright management." In International Conference on the Economics of Grids, Clouds, Systems, and Services, pp. 199-206. Cham: Springer International Publishing, 2021.
- García, Roberto, Ana Cediél, Mercè Teixidó, and Rosa Gil. "Semantics and non-fungible tokens for copyright management on the metaverse and beyond." ACM Transactions on Multimedia Computing, Communications and Applications (2022).
- van den Heuvel, Willem-Jan, Damian A. Tamburri, Damiano D'Amici, Fabiano Izzo, and Sandra Potten. "ChainOps for smart contract-based distributed applications."

In Business Modeling and Software Design: 11th International Symposium, BMSD 2021, Sofia, Bulgaria, July 57, 2021, Proceedings 11, pp. 374-383. Springer International Publishing, 2021.

- Sopek, Mirek, Dominik Tomaszuk, Szymon Głąb, Filip Turoboš, Ivo Ziełiński, Dominik Kuziński, Ryszard Olejnik, Piotr Łuniewski, and Przemysław Grądzki. "Technological foundations of ontological ecosystems on the 3rd generation blockchains." IEEE Access 10 (2022): 12487-12502.
- Tomaszuk, Dominik, Dominik Kuziński, Mirek Sopek, and Bogusław Swiecicki. "A Distributed Graph Data Storage in Ethereum Ecosystem." In International Conference on the Economics of Grids, Clouds, Systems, and Services, pp. 223-231. Cham: Springer International Publishing, 2021.
- Tomaszuk, Dominik, Szymon Głąb, Filip Turoboš, Tomasz Pawlik, Dominik Kuziński, and Mirek Sopek. "Interwoven Hash of Vicious Circle Free Graph." In 2022 IEEE International Conference on Blockchain (Blockchain), pp. 449-454. IEEE, 2022.

Publisher papers where IntelliSemantic was directly involved as author or coauthor are:

- Papaioannou, Thanasis G., Vlado Stankovski, Petar Kochovski, Anthony Simonet-Boulogne, Caroline Barelle, Alberto Ciaramella, Marco Ciaramella, and George D. Stamoulis (2021). "A New Blockchain Ecosystem for Trusted, Traceable and Transparent Ontological Knowledge Management": Position Paper. In Economics of Grids, Clouds, Systems, and Services: 18th International Conference, GECON 2021, Virtual Event, September 2123, 2021, Proceedings 18 (pp. 93-105). Springer International Publishing.
- Papaioannou, Thanasis G., Petar Kochovski, Klevis Shkembli, Caroline Barelle, Anthony Simonet-Boulogne, Marco Ciaramella, Alberto Ciaramella, and Vlado Stankovski. "A Blockchain-based, Semantically-enriched Software Framework for Trustworthy Decentralized Applications." (Working paper, 2022).
- Klevis Shkembli, Petar Kochovski, Thanasis G. Papaioannou, Anthony Simonet-Boulogne, Marco Ciaramella, Caroline Barelle, Vlado Stankovski, "The semantic web and blockchain at a meeting point", Proceedings of the 30th International Electrotechnical and Computer Science Conference (ERK 2021), IEEE Slovenian section.
- Klevis Shkembli, Petar Kochovski, Thanasis G. Papaioannou, Caroline Barelle, Anthony Simonet-Boulogne, Marco Ciaramella, Vlado Stankovski, "Semantic Blockchain Software Tools and Services for Trustworthy Applications - ONTOCHAIN", 2023 World Congress in Computer Science, Computer Engineering, and Applied Computing, IEEE (to appear)

4) Environmental impact

IntelliSemantic feels strongly sensitive to environmental issues, then this feel was taken into account also in the involvement of third parties projects since the selection phase to the final evaluation.

A notable result regarding the environmental aspect comes from the project ecOS (teamed by the company Apio srl), which released a blockchain-empowered dApp aimed at fostering the European energy communities of any kind, with the institutional support of ENEA, then stepping forward a more sustainable management of energy power in Europe.

A critical aspect is the energy consumption of some Blockchain protocols, especially during the minting phase, as notably the Proof-Of-Work one. To face this aspect, we decided from beginning to use another more suitable protocol, Proof of Authority (PoA), within Ethereum-enabled technologies, as the main project technology framework. Moreover, the pilot infrastructure makes use of the iExec Bellecour sidechain, which reduces dramatically the energy consumption typically required by blockchain.

5) Ethical impact

The ONTOCHAIN project aimed at addressing values such as transparency and affordability, used also as criteria to foster productivity and fair collaboration within and outside the ONTOCHAIN project teams. We also took care about the fair use of the data and the privacy regulations, including the FAIR principles and the GDPR.

6) Political impact

The ONTOCHAIN Project aimed from the beginning at addressing political values such as inclusiveness, non-discrimination and, of course, democracy. A particular care was taken on the gender balance. In fact, we feel committed towards the inclusiveness of research and IT sector in regard of a gender-balanced representation across all the actors involved in the project.

4.5.2 Lessons learnt

The ONTOCHAIN cascading project was structured into three yearly calls (OC1, OC2 and OC3). The selection phase in the two calls (OC2 and OC3) was structured in two steps, i.e. evaluation of written applications and pitch session with a short list of projects, whilst the selection phase of the first call was bases only on evaluations of written applications. We strongly encourage the two step structure, especially for projects with a high number of applicants, as was the case for ONTOCHAIN, as this method at the end simplifies the convergence to the final list of winners.

Moreover, in the case of new cascade projects in NGI, we will suggest:

- to increase the percentage of accepted winners in open topics to be open to the proposals coming from possible applicants;
- to increase the weight of the impact, as an ever important factor in applied research and to decrease correspondingly the weight of the implementation.

Moreover, we think useful also to address some challenges faced by the project ONTOCHAIN as a cascade funding project aimed also at developing a ecosystem and a infrastructure and to sustain it after the end of the project, which is definitely more than required to a typical cascade founding project.

These extra efforts and costs, incurred or planned, so far are considered to be totally founded by ONTOCHAIN partners, outside the ONTOCHAIN grant.

It would be fair if the NGI initiative could allocate a category of specific grants/prizes to provide at least a partial support to investments of projects like ONTOCHAIN which intend to establish a whole ecosystem.

4.5.3 Alignment with the vision of the next generation Internet

1) Scientific impact AUEB, being an academic partner, was primarily focused on exploiting ONTOCHAIN 's results scientifically.

To this end, the scientific impact of ONTOCHAIN to AUEB (in particular, to the participating research group Services, Technologies and Economics (STECon), as well as more broadly) was manifold.

ONTOCHAIN was STECons first funded project in the areas of blockchain and Decentralized Applications (Dapps). The expertise acquired by the participation in ONTOCHAIN together with its financial support was instrumental in building a solid research foundation in these areas. This assisted in the successful implementation of another related project (with national-Greek funding) that started nine months after ONTOCHAIN. The AUEB team ONTOCHAIN significantly extended the scope of its expertise on business models and their analysis, by addressing these in the context of the blockchain-based ONTOCHAIN ecosystem. This expertise, from both a scientific and applied viewpoint, has been recognized internationally and led to AUEB 's publication in the GECON22 conference (entitled A Business Model for Multi-Tiered Decentralized Software Frameworks: The Case of ONTOCHAIN) receiving the best paper award. Additional scientific publications (related to ONTOCHAIN, not necessarily funded by):

- K. Shkembli, P. Kochovski, T. G. Papaioannou, C. Barelle, V. Stankovski. Semantic Web and Blockchain Technologies: Convergence, Challenges and Research Trends. Journal of Web Semantics, 2023.

- E. Athanasakis, Z. Sakellariou, G. Darzanos, S. Polymeni, G. Spanos, Thanasis G. Papaioannou, Konstantinos Votis, Dimitrios Tzovaras, Trustworthy Decentralized Management and Governance of Internet of Things Data Federations. IEEE IoT&IS23.
- T.G. Papaioannou, G. D. Stamoulis. A Business Model for Multi-Tiered Decentralized Software Frameworks: The Case of ONTOCHAIN: GECON'22.
- K. Shkempi, P. Kochovski, T. G. Papaioannou, A. Simonet-Boulogne, M. Ciaramella, C. Barelle, V. Stankovski, The semantic web and blockchain at a meeting point, Proceedings of the 30th International Electrotechnical and Computer Science Conference (ERK 2021), IEEE Slovenian section.
- Papaioannou, T.G. et al. (2021). A New Blockchain Ecosystem for Trusted, Traceable and Transparent Ontological Knowledge Management. In: Tserpes, K., et al. Economics of Grids, Clouds, Systems, and Services. GECON 2021. Lecture Notes in Computer Science(), vol 13072. Springer, Cham.
- J. Arshad, M. A. Azad, A. Prince, J. Ali and T. G. Papaioannou. REPUTABLE–A Decentralized Reputation System for Blockchain-Based Ecosystems: in IEEE Access, vol. 10, pp. 79948-79961, 2022, doi:10.1109/ACCESS.2022.3194038.

The expertise and inspirations acquired through AUEB's participation in ONTOCHAIN led to the introduction of related material in the undergraduate course Network Economics taught by Professor George D. Stamoulis (head of the research group STECon) in the fourth year of studies in the department of Informatics at AUEB. Moreover, one Masters thesis on reputation in blockchain-based environments was successfully completed, under the supervision of Professor George D. Stamoulis and Professor Thanasis G. Papaioannou. Further collaborations with interested students are underway.

Two new PhD students have recently been recruited in areas of blockchain and trustworthy Internet services for the Next Generation Internet.

2) Economic impact

The economic impact of ONTOCHAIN for AUEB is also very important:

- The AUEB team gained significant visibility and appreciation within the European blockchain community, which had the following positive impact: The team was invited to participate in four proposals, with several new partners from the blockchain community; two of these proposals were successfully evaluated leading to two very interesting projects (NGI TRUSTCHAIN and BUILDCHAIN) that are currently in progress bringing a total funding of 800K EUR for AUEB.
- Future projects in the areas of blockchain and NGI will be actively pursued, building upon the legacy of ONTOCHAIN achievements.
- The team is currently playing a leading role in the creation of the ONTOCHAIN Found-

dation, whose goal is to maintain and further exploit the ONTOCHAIN software platform and ecosystem; AUEB will be one of the founding members of the Foundation, which could have a potentially significant strategic impact in the exploitation of EU funded research. Professor Thanasis G. Papaioannou has been pioneering the overall effort for the business analysis and the materialization of the ONTOCHAIN Foundation.

3) Ethical and societal aspects

ONTOCHAIN achievements have strong ethical and societal aspects, relevant not only to AUEB, but to the overall ONTOCHAIN consortium. ONTOCHAIN has developed mechanisms for more trustworthy services exchange and more trustworthy content handling. Moreover, its findings promote user and data privacy, self-empowerment, economic and power decentralization, and better incentives for high-quality contributions. Therefore, current ONTOCHAIN Dapps, but most importantly future Dapps enabled by ONTOCHAIN software are expected to significantly contribute to the aforementioned societal and ethical targets.

4.5.4 Lessons learnt

There have been some important lessons learnt for AUEB:

- Having the role of IPR manager in a project with many stakeholders with complex background and foreground scientific contributions, often co-owned by multiple entities, was a challenging exercise with a demanding objective that was accomplished by AUEB. Specifically, clear and innovative software contributions (foreground) have been delivered by all cascade funded projects in ONTOCHAIN. The software delivered is primarily open-source, hence can be freely used by the research community without having any blocking software dependencies.
- Having designed the SCRUM-based monitoring methodology of ONTOCHAIN and implementing it together with the other consortium members, namely UL, IEXEC, IS and AUEB has gained vast experience in coaching/mentoring complex technical activities of R&D teams.

4.5.5 Alignment with the vision of the Next Generation Internet

The Next Generation Internet (NGI) is a European Commission initiative that aims to shape the development and evolution of the Internet into an Internet of Trust. An Internet that responds to peoples fundamental needs, including trust, security, and inclusion, while reflecting the values and the norms all citizens enjoy in Europe. ONTOCHAIN

significantly aligns with the overall vision of the Next Generation Internet and particularly towards enabling decentralized applications involving trustworthy services/data exchange and trustworthy data handling.

ONTOCHAIN has proposed and implemented a layered architecture that faces the challenges of current Internet, namely centralization of power, user privacy violation, lack of trust in online transactions, non-credible data sources, biases in AI algorithms, unfair value sharing, lack of incentives for high quality contributions, among others. ONTOCHAIN has successfully addressed the trade-off between identification and privacy, by means of SSIs and VCs, the decentralization of knowledge and power, the data provenance, the trustworthiness assessment for data, services and entities, the data ownership, the data valuation estimation, the support for crowdfunding of public goods and even more, while following a user-centered design approach.

AUEBs alignment with the next generation internet vision was reflected in its work towards designing a totally decentralized business ecosystem for the ONTOCHAIN platform where all stakeholders can benefit, while the users can experience decentralized applications of high value. The proposed business ecosystem is open to be used by the users, either governments, or corporates or the general public, and open for service providers to provide functionality that serves the NGI vision. Moreover, research and teaching activities of the AUEB team have been influenced by ONTOCHAIN to align with the ideals of the NGI considering and investigating technological approaches such as those proposed by ONTOCHAIN, e.g., decentralized reputation services, verifiable credential chains, trustworthy data oracles, etc.

4.6 GERMAN HELLENIC INDUSTRIAL AND COMMERCIAL CHAMBER

4.6.1 Impact assessment

1) Economic impact

The ONTOCHAIN Project significantly boosted the European Blockchain ecosystem by disbursing funds through three Open Calls, benefiting multiple European nations, including Germany and Greece. Targeted mailings to members of the German Hellenic Chamber of Industry and Commerce and the European Community of AHKs piqued the interest of professionals seeking deeper involvement in Blockchain technology. Indirectly, the project met its objectives through various dissemination activities, informing potential stakeholders about Open Calls, ONTOCHAIN events, Hackathons, and outcomes. These efforts drove increased engagement within the Blockchain community, channeling them towards developing applications for a safer, more trustworthy internet for European citizens.

2) Societal impact

Within the ONTOCHAIN Ecosystem, specific projects were strategically tailored to address societal challenges faced by EU citizens regarding internet security, fraud, data breaches, and inefficiencies. The ONTOCHAIN Project has effectively promoted blockchain technologies among various target groups. The three open calls were extensively advertised on social media and in the press, conveying the message of a safer and trusted internet. Introducing blockchain to unrelated groups has also highlighted its benefits for the broader society and future business landscape.

3) Scientific impact

The outcomes of the ONTOCHAIN Project, facilitated by its three Open Calls, laid the groundwork for the progress of software technologies. The dissemination campaign for ONTOCHAIN events not only targeted various groups but also specifically focused on European universities with departments related to blockchain technologies in their curriculum. Information was provided to professors about events like the ONTOCHAIN Summits, with a strong emphasis on the ONTOCHAIN Hackathons, aiming to generate interest among students and engage them more deeply.

4) Environmental impact

Throughout the Open Calls of ONTOCHAIN, there was a continuous focus on the Environmental and Energy Element, which resulted in cases like projects ecOS and DEFev being directly related, and others indirectly contributing through their smart management and sustainability extensions. Tackling a balance between utilizing blockchain for environmental benefits and mitigating its ecological disadvantages was always among the priorities of ONTOCHAIN Project.

5) Ethical impact

The ONTOCHAIN Project consistently prioritized trust, transparency, intellectual property rights in all its activities, thus weighing in an extent the ethical impact of solutions provided through blockchain technologies. Balancing the aspects transparency and privacy was a challenge always in focus. While transparency is crucial for trust and accountability, privacy is important for protecting personal information.

6) Political impact

The political influence of the ONTOCHAIN Project stems from the broader implications and applications of blockchain technology, which the project both explores and develops. Key priorities on the ONTOCHAIN agenda include principles of transparency, combating fake news, fraud mitigation, and digital identity. Discussions during the ONTOCHAIN Summit 2022 and 2023 Roundtables with selected key speakers also addressed topics related to regulatory frameworks and EU policies concerning blockchain technologies.

4.6.2 Lessons learnt

During the execution of ONTOCHAIN Events, AHK Greece's Project team has gained valuable insights into the unique characteristics of the Blockchain community's target demographics, encompassing their behaviors and overall demographic profiles. This experience has enabled them to better understand the preferences, tendencies, and key traits of these specific target groups, enhancing their capacity to develop strategies and initiatives tailored to effectively engage with and serve the Blockchain community. Over the course of this 3-year project implementation, AHK Greece has significantly heightened its awareness of the potential synergies and interactions between traditional economic systems and the rapidly emerging Blockchain technology. The monthly Colleagues meetings of the AHK Greece about the ONTOCHAIN Project progress provided also the opportunity to the entire set of 32 colleagues and associates to get informed about the ONTOCHAIN project's activities, Blockchain technologies, and the potential for synergies and interaction with other initiatives of the German Hellenic Chamber of Commerce. This experience has enabled them to recognize the numerous opportunities for integration and collaboration, facilitating a deeper understanding of how Blockchain can reshape and complement various aspects of the conventional economy, thus providing future opportunities for further development.

4.6.3 Alignment with the vision of the next generation Internet

The Next Generation Internet (NGI) initiative, dedicated to delivering a safer and more trustworthy online experience for European citizens, closely parallels the vision of the ONTOCHAIN Project. Both endeavors share the overarching goal of enhancing the digital landscape for users. The ONTOCHAIN Project has made significant strides in this direction by conceiving and implementing a suite of innovative protocols and applications. These tools are designed to bolster the security, reliability, and credibility of online interactions, reinforcing the principles upheld by the NGI initiative.

4.7 F6S

4.7.1 Impact assessment

1) Economic impact

The ONTOCHAIN software ecosystem, being at the forefront of blockchain technology and ontological knowledge, has the potential to revolutionise various industries. By providing a trusted, traceable and transparent system, businesses can reduce costs asso-

ciated with fraud, data breaches, and inefficiencies. The three open calls of the project provided direct economic investment into third-party entities, fostering innovation and creating job opportunities in the tech sector. Furthermore, the ONTOCHAIN partners and third-parties co-developed a business model around the ONTOCHAIN software ecosystem that allows all parties involved to generate value and revenue.

2) Societal impact

ONTOCHAIN's transparent and traceable system can restore trust in digital transactions, which has been eroding in recent years due to high-profile data breaches and misinformation. By ensuring data integrity and transparency, individuals can have more confidence in online platforms, leading to increased digital participation. This can bridge the digital divide and ensure more equitable access to online resources.

3) Scientific impact

The fusion of blockchain and ontological knowledge in the ONTOCHAIN project represents an advancement in the field of computer science. It pushes the boundaries of what's possible in terms of data verification, storage, and retrieval. The project can serve as a foundation for future research, setting new standards for data integrity and transparency in scientific studies, especially in fields where data authenticity is paramount.

4) Environmental Impact

While blockchain technology is often criticised for its environmental footprint due to energy-intensive mining processes, ONTOCHAIN's approach can potentially mitigate some of these concerns. If implemented efficiently, the ecosystem can lead to reduced energy waste. However, it's essential to monitor the energy consumption of the ONTOCHAIN network to ensure it remains environmentally sustainable.

5) Ethical Impact

The ONTOCHAIN software ecosystem, with its emphasis on transparency and traceability, can set new ethical standards in the digital realm. By ensuring that data is authentic and hasn't been tampered with, it can prevent misinformation and unethical data manipulation. However, there's also a responsibility to ensure that the technology isn't used to infringe on individual privacy rights, making a balance between transparency and privacy crucial.

6) Political Impact

In an era where election integrity and misinformation are hot topics, ONTOCHAIN can offer solutions to ensure transparent and tamper-proof processes. By providing a system where data is traceable and cannot be altered without leaving a digital footprint, it can restore trust in digital processes. Additionally, public organisations can use the technology to ensure transparency in public processes, leading to more accountable

governance.

4.7.2 Lessons learnt

As WP leaders of the dissemination and communication activities of the project, F6S responsibility was to promote the project and foster a robust community around it. The journey was both challenging and enlightening, especially given the unique nature of Web3, which is still an emerging and rapidly evolving domain.

Understanding the Web3 audience: the Web3 community is a blend of tech enthusiasts, developers, early adopters, and visionaries. Tailoring the communication to resonate with this diverse group was crucial. It required a deep understanding of blockchain, decentralised applications, and the broader implications of a decentralised web. The establishment of synergies with relevant projects and initiatives played an important role raising awareness to the ONTOCHAIN activities, and contributing to the ONTOCHAIN community growth. Furthermore, the high number of people engaged in the ONTOCHAIN events, accessing the project online channels and applying for the ONTOCHAIN opportunities, largely surpassing the majority of the project communication KPIs, highlighted the relevance and the interest on the technologies developed.

4.7.3 Alignment with the vision of the next generation Internet

The ONTOCHAIN project and the Next Generation Internet (NGI) vision share a common goal of creating a more human-centric Internet. Here is how the ONTOCHAIN project aligns with the NGI vision:

Decentralisation: One of the core principles of the NGI vision is to promote decentralisation, ensuring that power and control over the Internet are not concentrated in the hands of a few entities. ONTOCHAIN developed a decentralised and trustworthy blockchain ecosystem, which aligns with this principle. **Trustworthiness:** The NGI vision emphasises the importance of trust in online interactions. ONTOCHAIN focuses on creating a trustworthy environment by integrating ontologies with blockchain. **Interoperability:** The NGI vision promotes an Internet where different systems and platforms can work together seamlessly. ONTOCHAIN's use of ontologies supports this by enabling semantic interoperability, ensuring that data and services can be understood and utilised across different systems. **Inclusion:** NGI envisions an Internet that is inclusive and accessible to all. ONTOCHAIN's decentralised approach promotes this by allowing various stakeholders, regardless of their size or influence, to participate in the ecosystem. **Openness:** The NGI promotes open standards, open-source software, and open data. ONTOCHAIN aligns with this by emphasising semantic standards and promoting the use of open-source tools and technologies. **Human-centricity:** Above all,

the NGI vision is about creating an Internet that puts humans at the centre, respecting their rights and ensuring their well-being. ONTOCHAIN's focus on trustworthiness, transparency, and decentralisation ensures that users' rights are respected and that they have control over their data.

This close alignment was ensured notably by F6S as one of the ONTOCHAIN's main contact points with the NGI Outreach Office, participating in the monthly NGI Communication Task Force meetings.

5 IMPACT AS EVALUATED BY THIRD PARTIES

It is useful to distinguish the impact produced by third parties on the whole ONTOCHAIN project and ecosystem and the impact produced to any third party by participating to the ONTOCHAIN projects. Both impacts are documented in the final deliverable D4 produced by any third party.

The impact produced by third parties on the whole ONTOCHAIN project and ecosystem is summarized in the deliverable D3.6 for first year projects [11], in the deliverable D4.8 for second year projects [12], and in the deliverable D4.9 [3] for third year projects.

For each project, these deliverables provide:

- The key functional results and the most relevant KPIs.
- The innovations achieved the possible future improvements.
- The exploitation plans and activities.

Main impacts emerging from these deliverables are already documented in chapter 3.

The impact produced to any third party by participating to the ONTOCHAIN project is summarized in the section 2.3 of their final deliverable D4, in which the following positive evaluations are typically mentioned:

- Good mentoring structure.
- Good possibility of horizontal cooperation between third parties, of the same call and even of different calls.
- Good opportunity for application developers to reuse technologies developed by technology providers.
- Good opportunity for technology providers to providing their technologies to application developers.

- Possibility to address new prospects during the project.

A sample of third party testimonials is exemplified below.

- Good mentoring structure: *"The Ontochain program has been a moment of growth for us in the world of Blockchain solutions. The opportunity to engage weekly with mentors and biweekly with the network has allowed us to have a continuous feedback process on development"* (ecOS).
- Good possibility of horizontal cooperation between third parties: *"By interacting with fellow participants, we discovered synergies and potential collaborations that enabled us to leverage their solutions and expertise. This collaborative approach fostered innovation and encouraged the exchange of ideas, ultimately leading to a broader impact and greater advancements in our project. Overall, participating in ONTOCHAIN not only expanded our network but also facilitated productive collaborations and a sense of community within the European research and innovation landscape"* (TrussiHealth).
- Good opportunity for application developers to reuse technologies developed by others: *"We also had the chance to integrate already developed powerful OTC components This not only saved us time and effort but also enriched our program with cutting-edge functionalities. Our access to inspirational applications within the blockchain ecosystem further fuelled our creativity"* (DEFev).
- Good opportunity for technology providers to providing their technologies to application developers: *"The success of the project (Babelfish) is evident in its widespread adoption. More than a dozen projects are now using the Gateway API, and about 20 services have registered so far. This is a testament to the team's technical prowess, their understanding of the ecosystem, and their ability to deliver solutions that meet the needs of the users"* (Babelfish).
- Possibility to address new prospects during the project: *"We do recognize NGI ONTOCHAIN programme has opened doors to industry-leading companies, enabling us to onboard early adopters and forge invaluable connections with potential investors"* (OTCnLNG).

All these results have been achieved through well structured virtual meetings for coached projects, two summits, the first of each in presence (June 2022) and the other virtual (June 2023) and finally two virtual hackathons (July 2023 and August 2023).

In any case, a project suggested that some face to face meetings would be beneficial, as in this testimonial sentence: *"The projects virtual nature meant that we missed out on the opportunity to meet our coaches, partners, and fellow participants face-to-face at a live event. We believe there is immense value in building personal connections in such an innovative ecosystem. Trust and cooperation are the foundation of any successful collaboration, and meeting in person would have undoubtedly strength-*

ened these bonds. Nevertheless, we made the best of the situation, leveraging virtual communication tools to foster meaningful connections despite the physical distance" (CREATE).

6 IMPACT AS EVALUATED BY ADVISORS

6.1 ADVISORY BOARD OBJECTIVES AND ACTIVITIES

Roles, objectives and activities of advisors are detailed in D2.11 [13], delivered in the initial quarter of the ONTOCHAIN project, in D2.12 [14], which reports activities on Y1, D2.13, [15], which reports activities on Y2, and D2.14 [16], which reports activities on Y3 of the ONTOCHAIN project.

The initial set of advisors at the beginning of the ONTOCHAIN project is the Executive Advisory Board. The Executive Advisory Board is composed by 8 members, whose profile is detailed at the bottom of the page <https://ontochain.ngi.eu/About> and is further detailed in D2.11 ([13]). Members of the Executive Advisor Board have been selected between highly reputed experts, with the objective to cover in a balanced way all main topics addressed by the ONTOCHAIN project.

The initial set of advisors has been further extended in Y2 with experts who have participated as evaluators in OC1 and OC2 calls and which have confirmed their interest to collaborate as well as advisors. This new extended set of advisors of the ONTOCHAIN project is named External Advisory Committee and is composed by further 16 members, whose profile is detailed at the bottom of the page <https://ontochain.ngi.eu/About> and is further detailed in D2.13 ([15]).

Advisors were involved in the ONTOCHAIN projects in different ways, including presentations specific for them and questionnaires proposed to them about the ONTOCHAIN project itself and, more broadly, about opportunities and challenges of blockchain technologies and applications.

Advisors answers to questionnaires are detailed in D2.12 [14], for the Y1, in D2.13 [15], for the Y2, and in D2.14 [16], for the Y3. This present chapter does not repeat the analysis of these questionnaires, but in the last paragraph includes some suggestions extracted from the last D2.14 [16].

Moreover, at the end of the ONTOCHAIN project, a further questionnaire has been circulated to advisors to collect their impact evaluation, structured according the categories used in this report, i.e. economic, societal, scientific and technical, environmental, ethic, political. The following paragraphs summarize the most relevant insights which can be extracted from the answers of this questionnaire.

6.2 ECONOMIC IMPACT

Taking into account the economic impact of the ONTOCHAIN project as a whole:

- An advisor writes this testimonial: *"The need for solutions to fight the exchange of false data on the Internet is currently being felt across various vertical domains of the European economy. The EU-funded project ONTOCHAIN is contributing to solve this issue, through the development of a software ecosystem where information can be exchanged in a trusted, traceable and transparent way"*.
- Another advisor writes this testimonial: *"Advances in data sovereignty and empowering individual data ownership through initiatives increasing SDKs for self-sovereign identity are supporting new business models reliant on transparent data utilization. This allows European firms working with sensitive personal or B2B data sets to benchmark competitors lacking ethical data handling practices."*

Hence, the key economic impact of the ONTOCHAIN project is the development of a software ecosystem where information can be exchanged in a trusted, traceable and transparent way.

Taking into account the economic impact of different third party projects granted by the ONTOCHAIN project:

- An advisor mentions the economic impact of two third party projects, GraphChain and OTCnLNG, as examples of the potential impact of the ONTOCHAIN project, with this testimonial: *"ONTOCHAIN's drive towards decentralized and transparent management of ontological knowledge is expected to open up fresh markets for European startups and small and medium-sized enterprises (SMEs), reinforcing the digital economy's foundation. For example, the GraphChain project focuses on enhancing data management on the blockchain, which has the potential to refine business operations and facilitate cost reductions. Another project, OTCnLNG, aims to present a decentralized perspective on carbon-neutral liquefied natural gas (LNG) cargoes, which could make trade more efficient and economically advantageous"*.
- Another advisor mentions the economic impact of projects like Ontospace, BOWLER, Perun-X, PS-SDA, REPUTABLE with these sentences *"Standards and reference architectures established through projects like Ontospace, BOWLER and Perun-X lay important foundations for new forms of online marketplaces and service models to emerge in sectors like data analytics, creative works, logistics and more. Provenance tracking with PS-SDA and reputation scores through REPUTABLE help prevent fraudulent activities and validate product origins. Such near-term applications are expected to lower business costs."*

6.3 SOCIETAL IMPACT

An advisor mentions the societal impact of two third party projects, CARECHAIN and INGRESS, as examples of the potential impact of the ONTOCHAIN project, with this testimonial: *"The project's focus on ethical standards and adherence to legal norms showcases its dedication to upholding personal freedoms and societal morals. Projects such as CARECHAIN, which leverages blockchain for microinsurance, could revolutionize the implementation of social support frameworks. Similarly, the INGRESS project aims to widen financial inclusion, thus potentially bringing a larger segment of society into the fold of the economic system. Furthermore, ONTOCHAIN's global influence, marked by its connection with Web3 innovators across 46 countries and highlighted by initiatives like the ONTOCHAIN Hackathons, signals a societal shift. This international engagement suggests the potential for novel, culturally diverse solutions to surface, addressing wide-ranging societal issues on a global scale".*

Another advisor mentions the societal impact of two third party project TRUSSIHEALTH, as example of the potential impact of the ONTOCHAIN project, with this testimonial: *"Pilots of consent-based health data exchange through initiatives such as TRUSSIHEALTH are exploring optimizing medical research collaborations while respecting patient confidentiality."*

6.4 TECHNICAL AND SCIENTIFIC IMPACT

An advisor mentions the technical and scientific impact of the ONTOCHAIN project as a whole with this testimonial *"In the near-term, ONTOCHAIN-backed research projects are experimentally testing new distributed database architectures, blockchain optimization techniques, and knowledge representation forms such as property graphs. This includes evaluations of frameworks for on-chain data management, oracle networks combining on and off-chain data sources, and lightweight consensus mechanisms. Co-created ontologies standardizing domains like renewable energy markets or supply chain provenance hold potential to catalyze semantic technologies. Distributed ledger-enabled open science initiatives could optimize attribution, reuse and monetization of publicly funded investigational data/models".*

Other scientific impacts have been identified as contributed by specific third party projects.

In fact, an advisor mentions the technical and scientific impact of two third party projects, ISLAND and KnowledgeX, with this testimonial: *"Publications have enriched academic discussions by introducing peer-reviewed investigations into groundbreaking interoperability, setting the stage for further advances in distributed ledger technology research. The ISLAND project, for example, focuses on enhancing*

blockchain data with semantic information, thereby aiding scholarly comprehension of blockchain applications. Another project, KnowledgeX, aims to pioneer reliable and data-centric knowledge extraction, which aids in the scholarly investigation of data accuracy and its uses. Additionally, ONTOCHAIN's engagement with the wider community in developing a range of applications, protocols, and services within the blockchain sector not only enriches scientific literature but also demonstrates practical applications, underscoring the project's dual impact on scientific progress both in theory and in practice".

Another advisor mentions the contribution to the technical and scientific impact of two third party projects, GraphChain and CopyrightLY, with this testimonial: *"Early-phase scientific publications are validating these technical contributions through rigorous benchmarking and case studies. For example, performance tests of the GraphChain database or semantic annotation specifications by CopyrightLY".*

6.5 ENVIRONMENTAL IMPACT

An advisor mentions the environmental impact of third party projects, CAPS-CO and eCOS, as examples of the potential impact of the ONTOCHAIN project, with this testimonial: *"ONTOCHAIN-supported initiatives that advance energy-saving protocols or monitor carbon footprints, such as the CAPS-CO project for carbon accounting in supply chains, are poised to diminish the ecological footprint of digital services and foster more sustainable practices across different sectors. These technological advances are anticipated to cut down on energy use and improve resource allocation, which supports wider environmental objectives. For instance, the eCOS project is set on creating a system for managing community energy that promotes environmental sustainability. Moreover, the engagement of hackathon participants in projects that use blockchain to improve supply chain transparency and reward recycling activities showcases practical blockchain applications that are addressing ecological issues, demonstrating ONTOCHAIN's commitment to environmental innovation".*

Another advisor mentions the environmental impact of the third party project eCOS, as example of the potential impact of the ONTOCHAIN project, with this testimonial: *"It's evident renewable energy communities established through early-phase testnets like eCOS will accelerate decarbonization efforts, as will electric mobility networks leveraging inspection histories on blockchains. Supply chain transparency projects are already revealing sustainability issues to industries and regulators".*

6.6 ETHICAL IMPACT

An advisor positively assesses the ethical impact of the ONTOCHAIN project as a whole with this testimonial: *"ONTOCHAIN has a key ethical focus on a resilient internet (offering the protection of privacy, user empowerment, inclusiveness and openness), a trustworthy internet in terms of content, information exchange and trustworthy identities, a sustainable internet allowing interoperable services and data traceability"*.

Another advisor mentions the ethical impact of two third party projects, GraphChain and OTCnLNG, as examples of the potential impact of the ONTOCHAIN project, with this testimonial: *"ONTOCHAIN's drive towards decentralized and transparent management of ontological knowledge is expected to open up fresh markets for European startups and small and medium-sized enterprises (SMEs), reinforcing the digital economy's foundation. For example, the GraphChain project focuses on enhancing data management on the blockchain, which has the potential to refine business operations and facilitate cost reductions. Another project, OTCnLNG, aims to present a decentralized perspective on carbon-neutral liquefied natural gas (LNG) cargoes, which could make trade more efficient and economically advantageous"*.

6.7 POLITICAL IMPACT

An advisor positively assesses the political impact of the ONTOCHAIN project with this testimonial: *"Nowadays there is a worldwide concern over false information that can influence political, economic and social well being. Many semantically complex, decentralised and dynamically evolving ecosystems of public and private organisations, resources and actors, are in great need for trusted knowledge management. ONTOCHAIN project tackled such issues providing applicable solutions through its open calls"*.

Another advisor positively assesses the political impact of the ONTOCHAIN project with this testimonial: *"Cross-jurisdictional information frameworks proposed could promote international consensus on digital regulations. Reforms are informed by projects shedding light onto complex problems of data portability, copyright management online and supply chain exploitation. Use of decentralized identifiers to access public services pilots alternatives to centralized databases and set precedents for digital identity laws. Citizen science platforms experimenting with decentralized governance invite reflection on concerning issues of digital exclusion amplifying socioeconomic inequalities"*.

Another advisor mentions the political impact of two third party projects, OriginTrail DKG and OntoROPA, as examples of the potential impact of the ONTOCHAIN project, with this testimonial: *"In the near term, ONTOCHAIN's political significance is inter-*

twined with the European Union's overarching goals to bolster digital trust and empowerment. The initiative backs efforts that promote openness and the control over one's data, potentially shaping legislative approaches regarding digital identity, privacy, and digital infrastructure management. Additionally, it's poised to bolster the EU's digital independence by pioneering the integration of blockchain into public sector services and digital policy-making structures. Leading the charge are projects like OriginTrail DKG, which delivers mechanisms for dependable and transparent knowledge management, in step with the EU's vision for clear-cut governance, and On-to-ROPA, which is pioneering a framework for reliable data processing record".

6.8 KEY COMMENTS AND INSIGHTS

It has to be mentioned as well that according to answers to the questionnaire analyzed in D2.14 [16] (fig.20), most AB members answering believe that the ONTOCHAIN project has achieved its goal of developing a software ecosystem for trustworthy content handling and data/service exchange. However, one member suggested that further extensions and improvements should be considered to enhance the system.

The same advisor answering to the impact questionnaire mentions that the ONTOCHAIN has to continue further, with this testimonial sentence *"The most important, and I am sure you agree with me, is that a project continues to operate far outside the scopes of initial EU donation. This means that a project got its identity and respect among the community"*.

7 CONCLUSIONS

The ONTOCHAIN impacts analyzed in this reports are 1) economic 2) societal 3) scientific, 4) environmental 5) ethical, 6) political. All of these impacts have been considered in the short term, in order to provide measurable evidence at the end of the project. Moreover, relating the economic impact, also the medium term dimension has been mentioned, as more specifically related to the exploitation actions planned at the end of the project.

Any impact has been further structured in different dimensions, and for any dimension the list of evidences has been reported, and for any evidence specific contributors are mentioned. Just to make an example, the impact societal mentions between others the dimension "new applications of relevant social impact for citizens, as for inclusion and common goods", with specific contributors mentioned of which with a quick presentation and clickable link to the ONTOCHAIN website for further detail.

Hence this report provides a quick reference and an entry point of the main results

achieved within the ONTOCHAIN project and can be used in dissemination activities also after the end of the project.

Moreover, this report is intended to provide a framework for exploitation activities and plans at the end of the ONTOCHAIN project and after the end of the ONTOCHAIN project.

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