SOFIE - Secure Open Federation for Internet Everywhere

779984

DELIVERABLE D6.9

Exploitation Strategy and Roadmap

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Summary of changes compared to previous version

Version	Major changes
1.10	In the updated version of deliverable 6.9 "Exploitation Strategy and Roadmap" the primary changes include: 1) added text to section 2.1 "The SOFIE Value Proposition" to expand on the potential financial impact of SOFIE developments; 2) added column to "SOFIE assets" table (see Table 1) about involved partners under section 2.2 "Exploitable Assets"; 3) added texts to section 2.2 "Exploitable Assets": 1) explaining the exploitable foreground and 2) explaining the SOFIE components' business scenario deployment in the project; 4) a slight adjustment to structure under 2.2 "Exploitable Assets" where the section "Commercial assets" was moved under section 2.2.1 "Exploitable foreground" as section 2.2.1.1; 5) added text to section 2.3 "Community awareness", under topic: Open data and open source, expanding on open-source community engagement; 6) added sentence to the introduction of section 4 "Exploitation Report of Industry Partners", in the introduction about the commitment of partners to exploit SOFIE results; 7) modified section of 5.1 "Exploitation Stages" with a) a sentence in the second paragraph about individual partners' commitment to exploitation and b) minor changes to the fourth paragraph to clarify the stage 4 exploitation of the project.

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1. Introduction

This document reports on the main aspects of the exploitation strategy of the results and the knowledge obtained from the SOFIE project. It describes the roadmap of exploitation during and beyond the project's lifetime. All consortium partners contributed to this deliverable, describing the assets they exploit and related exploitation activities. The document begins with a description of SOFIE's value proposition in section 2, followed by the description of SOFIE's general exploitation approach, bringing out the academic and commercial assets, as well as presenting the work in standardisation. Sections 3 and 4 are dedicated to the individual exploitation results of both industrial and academic partners. Finally, section 5 describes the overall roadmap of exploitation activities highlighting past (M0-M36) and future exploitation milestones through the accumulated know-how and the technological results of SOFIE. This includes academic, business, and open community activities.

This deliverable D6.9 is part of the activities of WP6 "Communication, Dissemination, and Exploitation." It is a public document, which is available on the project website for those stakeholders interested in the SOFIE project. This document is inherently connected to Deliverable D6.10 "Business Planning" (M36), which describes specific steps undertaken and being planned primarily by the industrial partners in order to achieve the exploitation of SOFIE, and Deliverable D6.11 "Final Report on Communication, Dissemination and Exploitation" (M36), which primarily lists in detail the actions and outcomes of communication and dissemination efforts, also contributing to exploitation.

2. Overall Exploitation Strategy of SOFIE

The goal of the exploitation strategy is to enable the take-up of the exploitable results created by SOFIE to generate a long-lasting positive impact on European business and technological development. Additionally, it aims to ensure the sustainability of the project's proposed technologies beyond the end of the project and to demonstrate how SOFIE has contributed to the EU socio-economic landscape.

This section outlines the exploitation approach of SOFIE. The exploitation effort of SOFIE is targeted at potential adopters who are interested **to facilitate the smooth creation of new IoT or data business platforms through secure and potentially open federation** in industrial and other sectors. SOFIE takes advantage of blockchains and interledger approaches, but also innovative self-sovereign identities and decentralised identifiers, as well smart contracts and corresponding constructs in permissioned DLTs to secure and automate transactions among potentially distrusting parties, leading to expanded cooperation and improved economic outcomes. Through strengthening security and allowing users to control their data, SOFIE aims to diminish business and privacy concerns in data use and sharing, expand interoperability, increase IoT usability and support the emergence of open markets for IoT data, services, and innovative business opportunities.

The SOFIE framework is released under an open-source software license (Apache License, Version 2.0), which simplifies its bottom-up adoption and attracts wide attention. Related produced open-access publications in journals, conferences, and workshops and additional documentation and presentations in scientific and business meetings and webinars support and explain the software and the technologies produced and guide their use and extension.

Planning, conducting, and reporting of SOFIE exploitation has been conducted in three main verticals: **academic, commercial,** and **community.** It is important to note that, during the first year of the project it was identified that results that are closely related to the four SOFIE pilots have the strongest chance to move to the pipeline for commercialization. Thus, **commercial exploitation is conducted mainly through the pilots**.

Exploitation on the academic vertical:

- *Research & development* - e.g., engaging with new projects, publishing SOFIE inspired publications etc.
- *Education* - e.g., courses at the undergraduate or graduate level, or course projects, theses, Ph.D. dissertations, etc.
- *Knowledge transfer* - from academia to industry through personal and external networks, events, other projects etc.

Exploitation on the commercial vertical

- *Financial exploitation* - e.g., building products or services based on the project results, conducting market analysis and stakeholder mapping and engagement etc.
- *Indirect Financial exploitation* through internal business development into infrastructural or core technologies.

The community vertical

- *Contributions to open-source projects* and *standardisation* - through publication of the open-source framework and software components.
- *Community-building* around the topics of the project, raising awareness for the addressed problems and the proposed solutions.

2.1 The SOFIE Value Proposition

As the IoT becomes more mainstream, related technology becomes cheaper and therefore more accessible to people and companies worldwide. Due to the considerable increase in the number of deployed IoT devices, the IoT market continues to grow. The IoT market size was USD 250.72 billion in 2019 and is projected to reach USD 1,463.19 billion by 2027, exhibiting a CAGR of 24.9% during the forecast period[1]. Through enabling various and different types of distributed ledgers to be used simultaneously and exploiting the robust automation provided by smart contracts, SOFIE facilitates the smooth creation of new (IoT) business platforms, including through the federation of existing ones, thus expanding their scope, and increasing super-linearly their relevance and value. The accessibility of data, generated by IoT is the cornerstone of all businesses created around this technology and roughly 15% of the IoT market is directly related to data distribution, governance, quality, and validation. The SOFIE value proposition is an excellent match to these challenges targeting the huge current and future 6 billion USD total available market of the IoT (in 2021). Out of this, the estimated service market is approximately 10%, reaching 600 million USD.

SOFIE is driven by the needs and opportunities of real-world applications, relying on four pilots by established industrial partners, operating in three different business domains: the energy sector, the food supply chain, and mobile gaming.

Through its developed framework and components and the project pilots, SOFIE offers numerous solutions, advantages, and innovations. For example, SOFIE allows end-users to receive accurate, fine-grain information of growth and transportation conditions of agricultural produce over the whole supply chain (e.g., detailed provenance, amount of used fertilizer, whether the proper temperature was kept during transportation etc.), through flexible and immutable data sensing and common semantics throughout many industries, companies, and federated heterogeneous IoT environments. Auditability is guaranteed and many automation actions are possible, e.g., prioritized processing or forwarding of produce based on sensed transportation parameters.

The Food supply chain business domain's larger impact is related to the rapidly growing global blockchain in agriculture and food supply chains. Current market size is 133 million USD (2020) and is projected to reach USD 948 million by 2025, at a CAGR of 48.1%[2]. The goal is to offer the services that food industry giants (Walmart (US), Bumble Bees (US), Nestle (Switzerland), and JD.com (China)) are looking and investing in 2–3-year period. Securing the field-to-fork data feed, reducing transactional data duplication, and providing authentication and evidence for end users as well as commercial and regulatory needs are key pillars to be addressed, which SOFIE has.

In addition, SOFIE helps to liberate energy data (e.g., any person can choose how and what kind of energy data to provide or exchange at what price or terms) and to create a decentralised and flexible energy marketplace enabled by smart contracts and blockchain technology (e.g., electric vehicle owners can choose the optimal price and location for recharging their batteries, but also to benefit from incentives to help balance the electric grid by including renewable energy sources and bidding in the energy market).

By focusing to specific application areas, like the energy sector, SOFIE has additional market impact potential. The SOFIE value proposition focuses on the smart meter data management

[1] https://www.globenewswire.com/en/news-release/2021/04/08/2206579/0/en/Global-IoT-Market-to-be-Worth-USD-1-463-19-Billion-by-2027-at-24-9-CAGR-Demand-for-Real-time-Insights-to-Spur-Growth-says-Fortune-Business-Insights.html and https://www.fortunebusinessinsights.com/industry-reports/internet-of-things-iot-market-100307

[2] https://www.globenewswire.com/news-release/2020/11/23/2131535/0/en/The-global-blockchain-in-agriculture-and-food-supply-chain-market-size-is-estimated-to-be-USD-133-million-in-2020-and-is-projected-to-reach-USD-948-million-by-2025-at-a-CAGR-of-48-.html#:~:text=sign%20in-,The%20global%20blockchain%20in%20agriculture%20and%20food%20supply%20chain%20market,at%20a%20CAGR%20of%2048.1%25

market that is estimated to reach 428 million USD in 2023 at a CAGR of 20.48%[3]. SOFIE impacts how the approach from centralized management could be transformed into decentralized and flexible management and enabling the trust by applying smart contract and blockchain technology.

The data management and governance is a subsection of a whole advanced metering infrastructure (AMI) that is also growing at a CAGR of 6,7% to be reaching 26,8 billion USD (in 2025)[4]. The two SOFIE energy pilots are targeting these fast-growing markets by delivering data centric technologies to enable accessibility, trust and governance of data flows generated by AMI and IoT.

Moreover, by using IoT-based beacons and a DLT backed ecosystem, SOFIE technologies enable context-aware mobile gaming and many new features for the players and all involved business entities. It also becomes technically easy to enable true open business platforms. E.g., one or many suitable smart contracts on a public blockchain combined with permissioned DLTs and an appropriately designed gaming platform could allow any third party to augment the gaming platform with new functionality in the form of “challenges,” greatly expanding the range of games and the retention of players. Alternatively, or in addition, the gaming platform owner could similarly allow any third party to contribute potentially context-based advertisements of benefit to all parties (e.g., the platform owner can automatically receive a payoff for any invocation or interaction with any advertisement, the invoking or interacting player could receive a direct or indirect benefit, and the advertisers achieve their goals).[5]

2.2 Exploitable assets

During the SOFIE project we have identified 16 assets that can be used for SOFIE exploitation. This section includes a short description of each of these assets, its potential target group, and a list of key features that it provides. The process of identifying the assets was conducted during the first two years of the project in both the academic and the commercial verticals driven by the project’s pilots. Eventually the development of SOFIE framework components and the product ideas have led to the presented list of assets in Table 1 (see below). The list of assets has been compiled based on:

1. purposefulness of an asset in the SOFIE concept and its functionalities,
2. asset’s clearly identified value for the end-user,
3. asset’s ranking (“high”/“low”) in terms of potential commercial exploitability.

Moreover, out of all the assets, **three** have been approved by SOFIE partners to be continued to commercialize in 2021. These assets are: the Decentralised Energy Data Exchange (DEDE) federation adapter (no. 8, owned by Guardtime), the Decentralised Energy Flexibility Marketplace (DEFM) federation adapter (no. 9, owned by Engineering) and the SynField platform for traceability and audit services (no. 12, owned by Synelixis). These assets have viable business and stakeholder engagement plans set up to move forward. These are presented in more detail in deliverable D6.10 under the respective pilot’s Business Plans sections and elaborated also in Section 4 of the current document under paragraphs dedicated to exploitation activities of Guardtime, Engineering and Synelixis.

For the remaining 13 SOFIE assets the evaluation of commercial potential will be ongoing during the first half of 2021, considering the same three evaluation aspects listed above. The ambition is to push forward 1-2 additional assets that successfully acquire additional resources and can pursue commercial success.

[3] https://www.marketsandmarkets.com/Market-Reports/meter-data-management-system-market-144621226.html
[4] https://www.marketsandmarkets.com/Market-Reports/smart-meter-366.html
[5] See the following SOFIE journal paper published after the end of the project:
I. Pittaras, N. Fotiou, V.A. Siris, G.C. Polyzos, “Beacons and Blockchains in the Mobile Gaming Ecosystem: A Feasibility Analysis,” *Sensors*, vol. 21, no. 3, January 2021.

Table 1: SOFIE assets

ID	Name of the Asset	Description of the Asset	Technology Readiness Level (TRL)[6,7]	Involved partners
1	Interledger	enables secure federation by providing support for atomic transactions spanning two or more ledgers	7	Aalto, AUEB, ASM, EMOT, ENG, GT, LMF, OPT, Rovio, SYN
2	Identity, Authentication and Authorisation	provides IAA functionalities for the different entities in the system by supporting multiple authentication and authorisation techniques	7	Aalto, AUEB, GT, LMF, OPT, SYN
3	Privacy and Data Sovereignty	provides mechanisms that enable data sharing in a controlled way and supports privacy preserving surveys using differential privacy techniques	7	Aalto, AUEB, LMF
4	Semantic Representation	enables semantic level interoperability between different IoT systems, services, and data by describing what functions they provide and what interfaces and formats they utilise	7	LMF, EMOT, ENG, LMF, Rovio, SYN
5	Marketplace	allows participants to trade resources by creating auctions, placing offers, and tracking trade completion in a secure, auditable, and decentralised way	7	Aalto, AUEB, ASM, EMOT, ENG, Rovio
6	Provisioning and Discovery	enables management and discovery of IoT devices, services, and data	6	Rovio, LMF, Aalto, AUEB
7	Transportation Federation Adapter	provides the functionality required to federate the Transportation IoT platform to the Food Supply Chain pilot platform of SOFIE	7	SYN, OPT
8	Decentralised Energy Data Exchange adapter[8]	provides access control and governance to smart meter data and datahub integration	7	GT

[6] TRL levels are:
TRL 3 – experimental proof of concept
TRL 4 – technology validated in lab
TRL 5 – technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 6 – technology demonstrated in relevant environment (industrially relevant environment in the case of key enabling technologies)
TRL 7 – system prototype demonstration in operational environment
TRL 8 – system complete and qualified

[7] SOFIE assets' detailed descriptions of TRLs are presented in D2.7 and D5.4.

[8] Also referred to as "DEDE adapter".

9	Decentralised Energy Flexibility Marketplace federation adapter[9]	provides data exchange from IoT to energy flexibility services	7	EMOT, ENG
10	Decentralised Marketplace for Energy Flexibility Services	provides an energy flexibility provisioning and energy supply	7	ENG
11	SynField Federation Adapter	provides integration mechanism to exchange of data between an IoT platform and Food Supply Chain platform	7	SYN, OPT
12	SynField platform for traceability and audit services	provides access control, overview, and traceability services for Food Supply Chain participants	7	SYN
13	Aberon Federation Adapter	connects the warehouse automation platform (Aberon) with the SynField platform	7	SYN, OPT
14	Scavenger Hunt game	provides location-based game to search for events in IoT environment, solve puzzles and receive rewards (real life interaction)	6	Rovio
15	SMAUG	provides access control, governance, sharing of assets and payment mechanism for IoT smart locker cabins	3	LMF
16	System dynamics models of business platforms federations	provides models to study (IoT) data markets and business platforms	4	Aalto, AUEB

2.2.1 Exploitable foreground

SOFIE's exploitable foreground consists of all the abovenamed assets and has matured during the lifetime of the project. During the first half of the project the exploitable foreground consisted mainly of general advancements of knowledge. During the second half of the project, the results progressed towards new levels of technological readiness and the foreground expanded. The commercial assets of the exploitable foreground got crystalized and are presented here under separate section through related partners.

It should be noted that based on the expansion of knowledge and gathered feedback during the project lifetime, it was concluded that the exploitation of SOFIE components is most effective

[9] Also referred to as "DEFM federation adapter".

and responsive when they relate to specific business cases and sectors, thus the exploitation of SOFIE components is strongly connected to their deployment in SOFIE pilots that have in-depth business plans (presented in D6.10).

Interledger

The purpose of the SOFIE Interledger component is to enable secure transactions between actors and devices belonging to IoT platforms (silos) using different or separate blockchains. The Interledger component then enables interaction between the ledgers, including atomic transactions across ledgers.

With the Interledger component, it is possible to, e.g., integrate multiple ledgers to a cohesive platform that enables the most suitable type of DLT to be used for the type of information at hand and to enable cross-ledger transactions, thus harnessing the individual strengths of the different DLTs. In SOFIE, it is used to 1) transfer data from one ledger to another, 2) store hashes of data located in a private ledger to a public ledger, to benefit from the higher trust in the public ledger, 3) transfer state of e.g. in-game assets between ledgers, 4) automate asset exchange using Hash Time Locked Contracts (HTLCs).

The Interledger component is used in all SOFIE pilots and the Secure Marketplace for Access to Ubiquitous Goods (SMAUG) reference implementation.

Identity, Authentication and Authorisation (IAA)

The goal of the SOFIE Identity, Authentication, and Authorisation (IAA) component is to provide mechanisms that can be used for identifying communicating endpoints, as well as for authenticating and authorising users wishing to access a protected resource.

User authentication and authorisation is implemented using *access tokens*. In its present form, the IAA component can use the following types of access tokens: Hyperledger Indy Decentralised Identifiers (DIDs) and Verifiable Credentials (VC), W3C-based VCs, JSON Web Tokens (JWT), and JWT backed by Ethereum ERC-721 tokens.

The IAA component is used by the Food Supply Chain and the Decentralised Energy Data Exchange pilots and SMAUG.

Privacy and Data Sovereignty (PDS)

The SOFIE Privacy and Data Sovereignty component provides mechanisms that allow actors to better control their data, as well as mechanisms that protect client privacy.

PDS enables the creation of privacy preserving surveys. These are surveys that allow users to add noise to their responses using local differential privacy mechanisms. The addition of the noise prevents third parties from learning meaningful information about specific users, but at the same time meaningful aggregated statistics can be extracted.

PDS also implements an OAuth 2.0 Authorisation Server. This server accepts authorisation grants and, if the grant is valid, it generates an access token encoded using the JWT format. Accepted types of authorization grants are: Decentralised Identifiers (DIDs), Verifiable Credentials (VCs), and pre-shared secret keys. The generated access token can be used by any Web service, as well as with SOFIE's IAA component.

The PDS component is used by the Food Supply Chain and the Decentralised Energy Data Exchange pilots and SMAUG.

Semantic Representation

Semantic representation is a mechanism for describing the data model and the services of IoT devices. The component defines a common representation data model for IoT devices (Things), their services and their data, which enables interoperability and automation in the deployment of services and applications on top of federated IoT environments.

The data model is then managed by the component, which allows users to define the accepted data models in the system. The benefits of using Semantic Representation is to make systems more transparent to external users.

The Semantic Representation component is used by the Food Supply Chain, Decentralised Energy Flexibility Marketplace, and Context-Aware Mobile Gaming pilots and SMAUG.

Marketplace

The goal of the SOFIE Marketplace component is to enable the trade of different types of assets (e.g., electricity for charging a vehicle) in an automated, decentralised, and flexible way. The Marketplace is implemented on top of the Ethereum blockchain and it allows operation without a single entity owning or managing it, which in turn increases competition and enhances its security, resiliency, transparency, and traceability. The marketplace can be either partially decentralised, when e.g. a group of independent agriculture producers and retailers are managing it through a private Ethereum blockchain, or fully decentralised and open, when anyone can join and use the marketplace.

The Marketplace component provides the following functions: A manager can create auctions, bidders can make bids for the item, after which the manager decides the winner based on the type of the auction. Once the winner has paid and the item has been delivered, the winner can then confirm the receipt, thus concluding the transaction.

The Marketplace component is used by the Decentralised Energy Flexibility Marketplace and Context-Aware Mobile Gaming pilots and SMAUG.

Provisioning and Discovery

The goal of the provisioning and discovery component is to enable the discovery of new IoT resources and their related metadata. Using this functionality, it is possible to decentralise the process of making new resources available to systems utilising the SOFIE framework and to automate the negotiations for the terms of use and the compensation for the use of these resources.

The component provides the following functionalities:

- Provisioning of IoT resources (configuration of devices, enrolling new devices to the system)
- Discovery of new IoT resources (using Bluetooth Low Energy or DNS-service discovery)
- Licensing of the resources

The Provisioning and Discovery component is used by the Context-Aware Mobile Gaming pilot and SMAUG.

SOFIE Federation Adapters

The SOFIE federation adapters are used to interface IoT systems with the SOFIE Architecture, which allows the IoT systems to interact with SOFIE while requiring no changes to the IoT systems themselves. Different scenarios and pilots can utilise different types of federation adapters, which expose only the required parts of the SOFIE functionality to the IoT system, and which can implement support for different protocols, standards etc., depending on the application domain and devices used.

The SOFIE pilots have implemented 5 federation adapters: one adapter for the Decentralised Energy Flexibility Marketplace (DEFM), one for the Decentralised Energy Data Exchange (DEDE) pilot, and 3 federation adapters for the Food Supply Chain (FSC) pilot, where they are used to adapt 3 pre-existing IoT platforms, SynField of Synelixis, Aberon of Optimum, and a Transportation Federation adapter. The Context-Aware Mobile Gaming (CAMG) pilot and the SMAUG reference application do not include any adapters as they are new applications designed and implemented based on SOFIE, without the need to adapt to pre-existing platforms.

SMAUG: the SOFIE reference implementation

A SOFIE reference implementation has been developed as a practical realization of the SOFIE architecture and framework. The reference implementation goes under the name “Secure Marketplace for Access to Ubiquitous Goods” (SMAUG). As the name suggests, the reference implementation realizes a secure and decentralised marketplace, specifically for renting smart lockers for short periods. SMAUG natively integrates all SOFIE framework components.

System dynamics models of business platforms federations

System dynamics models exploit causal loop diagrams, which can lead to analytic and simulation models explaining long-term platform behaviour and outcomes. Real-world data can be fed as inputs to the models, but also what-if parameters and sensitivity analysis can be performed to study various scenarios. These models can be used to study (IoT) data markets, and business platforms in general, focusing on their economic sustainability and evolution and their sensitivity to various endogenous and exogenous parameters and strategic alternatives.

2.2.1.1 Commercial Assets

Emotion SRL Assets:
SOFIE Decentralised Marketplace for Energy Flexibility Services

The pilot platform developed for the Italian pilot allows DSOs, Energy Retailers, and EV Fleet Managers to operate a decentralised marketplace for energy flexibility provisioning and energy supply, needed for grid balancing in a condition of high penetration of distributed renewable energy plants. The core functionalities are provided by using the SOFIE Marketplace component jointly with ASM (DSO) and EMOT (eMobility) platforms. The smart contract running the marketplace was developed by extending the generic SOFIE Marketplace smart contract and the ERC20 fungible token interfaces. In this way the marketplace functionalities, the attributes for both requests and offers, and the payment process were tailored on the pilot use cases. The access to the smart contract is facilitated by the marketplace back-end, and the platform is completed by the SOFIE Interledger component which can be used to create *trust anchors* on public ledgers for the key events registered by the marketplace (i.e. request/offer matchmaking and payments finalization). EMOT is the owner of the eMobility running platform and controls access to it.

Engineering Ingegneria Informatica SPA Assets:
SOFIE Decentralised Energy Flexibility Marketplace (DEFM) Federation Adapter

The federation adapter allows the exchange of data between (IoT) smart meters and the pilot platform. It supports JSON payloads over MQTT connections. It provides access to the context updates from the various smart meters, manages the persistence, and provides access to historical data. It validates the historical data by utilizing the SOFIE Semantic Representation component. The connection with the MQTT smart meters leverages the FIWARE JSON IoT Agent, so it is possible to support different payloads or connection methods by using a different IoT Agent, properly configured.

SOFIE Decentralised Marketplace for Energy Flexibility Services

The pilot platform allows DSOs, Energy Retailers, and EV Fleet Managers to operate a decentralised marketplace for energy flexibility provisioning and energy supply. The core functionalities are provided by using the SOFIE Marketplace component. The smart contract running the marketplace was developed by extending the generic SOFIE Marketplace smart contract and the ERC20 fungible token interfaces. In this way the marketplace functionalities, the attributes for both requests and offers, and the payment process were tailored to the pilot use cases. The access to the smart contract is facilitated by the marketplace back-end, and the platform is completed by the SOFIE Interledger component which can be used to create *trust* *anchors* on public ledgers for the key events registered by the marketplace (i.e., request/offer matchmaking and payments finalization).

Guardtime OÜ Assets:
SOFIE Decentralised Data Exchange Federation Adapter.

The adapter will allow interested TSOs/DSOs to grant access to data, track the process of who gives/receives data through their platform and creates immutable evidence for auditing and security purposes.

The adapter enables secure connection functionality to all participants that are in the network. This includes the possibility to search and interact with interested party is the first step in the governance and control. Using the identifiers and credentials a secure protocol is applied to grant and revoke the access to digital assets, in DEDE's case the latter is smart meter data. The privacy by design allows to create the connections with no private data sharing between participants. This information lies in each participant wallet (onboard the infrastructure they control like mobile app, local instance, datahub component). There is constant monitoring and event registering procedure in place that is secured by creating immutable evidence. These events can be trusted by all participants and be verified by third parties for auditability and regulatory purposes. The DEDE adapter's implementation to the national datahubs is practical contribution from SOFIE project to solve the security network code, platforms interoperability challenges.

LMF Ericsson's Assets:

SMAUG

The Secure Marketplace for Access to Ubiquitous Goods, or SMAUG, is a decentralised and open marketplace developed as a reference implementation for SOFIE framework component usage. SMAUG demonstrates how smart locker owners can put their smart lockers for rent, and potential smart locker renters can place bids, for those smart lockers to get the authorisation to use them. Smart locker owners publish the availability of smart lockers on the marketplace by creating a request, i.e., a request for offers. The bids that smart locker renters place for those requests are called offers. SMAUG places itself as a reference implementation, to show how all the different SOFIE components can be used together to develop a system that benefits from all the properties that the SOFIE framework provides. One important target for SMAUG, during the SOFIE project, was to provide high-quality feedback to SOFIE component developers about the set of features the components offer, their level of reusability and extensibility, and their quality relating to how easily they can be integrated into systems other than the four pilots under development. SMAUG is available as open source code in the SOFIE GitHub directory and can be used by anyone as a reference implementation for how all six SOFIE framework components can be used to realize a real-world use case. SMAUG has also been accepted as a proof of concept in the ETSI Industry Specification Group (ISG) Permissioned Distributed Ledgers (PDL) working group, in the PDL-005 "Proof of Concepts Framework" draft specification.

Optimum Anonimi Etairia Technologies Pliroforikis' Assets:

SOFIE Aberon Federation Adapter

During the project, a Federation Adapter, namely the Aberon Federation Adapter, has been developed in order to on-board Aberon, the Warehouse Automation platform that has been enhanced with further IoT capabilities, to the pilot platform of the Food Chain Pilot. This procedure has provided the technical expertise required to assist other companies in the logistics sector (but not limited to that sector) to join the pilot platform.

Rovio Entertainment Corporation’s Assets:

Scavenger Hunt game

Rovio has open-sourced (Apache License, version 2.0) the Scavenger Hunt game use case by releasing code and documentation that has been written throughout the project timeline. This Scavenger Hunt game prototype is a bare-bones example of a location-based game that uses Bluetooth beacons for positioning the player. The gameplay itself revolves around reading text tasks and answering questions. When the player opens the Scavenger Hunt game, they see which hunts are nearby based on their GPS location. After starting a hunt, the player sees a clue. It is a riddle that points them to the next physical location. When in the correct location, the player sees a question. By observing the physical surroundings and answering the question correctly, the player gets the next clue. After all clues in a hunt are completed, the player receives rewards: coins, gems, stars, and possibly virtual items. The player also gains experience points (XP) and levels up their character. This proof-of-concept may serve as a template for future researchers who wish to further investigate IoT and blockchain technologies in the context of gaming. A journal paper regarding this use case has been published by the Rovio designers in *IEEE Access* that describes an example implementation of such an architecture in detail. This proof-of-concept may serve as a template for future researchers who wish to further investigate IoT and blockchain technologies in the context of gaming. By open-sourcing the project, Rovio hopes the adverse aspects of these technologies may be combated, and their additional yet unseen benefits may be discovered by future developers, designers and problem-solvers.

Synelixis Solutions SA Assets:

SOFIE SynField Federation Adapter

SynField is an IoT platform for smart farming and irrigation. It provides valuable information to the farmer and the agriculturist by utilizing a plethora of sensor devices. SynField was federated to the Food Supply Chain pilot platform using a Federation Adapter. The adapter allowed for the SynField platform to share (meta)data with the pilot platform and take advantage of its provided services (product tracing, auditing) in a not intrusive way (i.e, without the need to make changes in the existing commercial platform). In general, this is the adapter that needs to be developed for any IoT platform that wishes to join the pilot platform. It is a software component that allows the exchange of data between an IoT platform and the pilot platform by utilizing the SOFIE Semantic Representation component. It also implements the authentication process that is required to get authenticated/authorized in the pilot platform by making use of the Identity, Authentication, and Authorization (IAA) component from SOFIE. Each IoT platform might require a different realization of a SOFIE Federation Adapter; however, the (SynField) Federation Adapter developed in the context of the Food Chain Pilot can very well act as an implementation reference since much of the functionality can be used as is; only the IoT platform-specific parts need to be modified. Synelixis can leverage on the expertise and know-how it gained during the project and provide support to other parties that would also like to create such adapters to join the pilot platform.

SOFIE pilot platform traceability and audit services

In the context of the Food Supply Chain Pilot, traceability and audit services are being provided via the pilot platform and its components (Supervisor, Blockchains). The pilot platform allows for companies from sectors such as the Farming sector, the Logistics sector, and the Retail sector to have their IoT platforms federated and gain access to traceability services on their products as well as auditing services in cases of disputes. The pilot platform, among others, has the Interledger component of SOFIE at its core.

2.3 Community awareness

General Outreach

According to the SOFIE Communication and Dissemination Plan (set in D6.6.), one of our aspirations has been raising awareness among the general public (people interested in blockchains, IoT systems, and their applications in various fields) and to propose solutions through communication and dissemination activities for the problems SOFIE relates to. The SOFIE consortium has used its webpage, social media posts, newsletter and various promotional materials and interpersonal tools (meetings, calls etc.) to push out the know-how produced as the result of the project and to raise general awareness.

We have written 30+ blog posts that are suitable for a general reader with interest in the field of IoT and released a quarterly newsletter for our 70+ subscribers. For our scientific audience, we have offered 30+ publications, given 50+ talks, and organized three SOFIE dedicated workshops, delivered several higher education courses and helped to initiate and contributed to Master's theses and PhD dissertations, all of which revolutionize how we conceptualize decentralisation in the IoT, how we approach building interoperability between IoT devices and how we improve privacy in the IoT.

Last but not least, SOFIE has seized numerous opportunities to engage with other projects or initiatives in order to build a wider web of connections and exchange knowledge. For example, SOFIE has been participating in the work related to the Bridge initiative (https://www.h2020-bridge.eu/). In collaboration with the Bridge initiative during the first half of 2020 we have been focusing on cybersecurity of energy data access and SOFIE adapter alignment with various energy standards and initiatives. Also, there has been close cooperation between the SOFIE and Sysflex projects and collaboration with the SecureIot project, the Cyberwatching.eu initiative, the NGIoT project and the IoTCrawler project. And we have built strong relationships within the IoT security and privacy cluster for which, among other things, we delivered joint presentations and we have contributed to a book.

Open data and open source

SOFIE participates in the Open Research Data Pilot. As outlined in deliverable D6.5 - Data Management Plan, the open data from the SOFIE project was deposited in the Zenodo open access repository. Data that could compromise commercialization prospects or has inadequate protection of, e.g., personal information, is not published. When the data is related to a publication, it is linked to it via OpenAIRE.

The SOFIE framework has been published and its components have been released as open source software. The code is available under Apache License, version 2.0 at https://github.com/SOFIE-project/Framework. During the lifespan of the project, SOFIE has released code five times. We have succeeded with the plans for all releases. The code was released as follows:

1. The first code release was made in September 2018.
2. The second code release was made in October 2019.
3. The third code release was made in April 2020.
4. The fourth code release was made in September 2020.
5. The fifth code release was made in December 2020.

Between main releases, the code base was constantly improved through continuous integration, deployment, and validation processes.

Moreover, direct work was conducted to include the open-source community to our developments and results, e.g., open-source communities who use Zenodo, GitHub, Cyberwatching.eu platform, SecureIoT marketplace, have (had) access to our developments where the components are easily accessible and attract the community to take interest in and utilize SOFIE framework and components. We received requests through these channels from the community members to engage further and elaborate on the components and the SOFIE value proposition.

Additionally, we utilized numerous other dissemination methods to inform and engage with potential interested parties, like establishing a dedicated web sub-page for the source code, releasing several website news about the framework updates[10] and promoted the framework and the components on our social media[11], presented and promoted the developments and results during our workshops/events for various communities (open-source included). The list of events is reported in detail in D6.11.

Furthermore, several projects with SOFIE partners have already been utilizing SOFIE results, e.g., H2020 PHOENIX, H2020 IoT-NGIN, EMPIR SmartCom, and EIT Climate-KIC GOWOOD. Moreover, the H2020 PLANET project is interested in using the SOFIE Interledger component.

Standardisation

IoT related standardisation suffers from a fragmentation similar to that of the field in general, with tens of competing standardisation organisations, such as ISO, ITU, ETSI and IEC, and well over a hundred different standards. During the SOFIE project, we have seen an uptake of blockchain related standardisation activities. The recent, increased focus towards ledger interoperability in standardisation proves the relevance of the interledger research and realization that has taken place in the SOFIE project.

As different standardisation bodies work with a different pace and slightly different scope, it was not clear in the beginning of the SOFIE project which standardisation bodies would be best to work with. Being a strong industrial partner and world leading company in telecommunications, Ericsson is active in most technology standardisation bodies and has been driving the standardisation related work in SOFIE. During the project we have found a good way to collaborate with and contribute to the ETSI Industry Special Group for Private Distributed Ledgers (ISG PDL). Ericsson is a founding member and active participant in this group. To date, SOFIE members have made significant contributions to the “ETSI PDL-004 Smart Contracts” draft, “ETSI PDL-005 Proof of Concepts Framework” draft and the “ETSI PDL-006 Interoperability” draft.

In addition to ETSI ISG PDL, SOFIE partners have also contributed to several other standards. The following table summarizes the key contributions in this area.

Table 2. SOFIE standardisation activities

Activity	Responsible Partners	Area of contribution
W3C	AUEB, AALTO	Contributions in security and privacy to WoT IG and WG Participating to the Blockchain and Interledger CGs Invited presentation “Using Verifiable Credentials in IoT Services” (slides archived in W3C github repository)
IETF/IRTF	AUEB	Participation in a pre-standardisation IRTF workshop on Decentralized Internet Infrastructure (DINRG, https://trac.ietf.org/trac/dinrg/wiki) with a presentation on SOFIE’s ideas on a secure, open, decentralised IoT
ETSI ISG PDL	LMF, AALTO, AUEB	PDL-004 Smart contracts, contributions by LMF based on research and deliverables developed in the SOFIE project

[10] For example, https://www.sofie-iot.eu/news/further-updates-to-the-sofie-framework

[11] For example, https://twitter.com/EU_Sofie/status/1341011765535141890 and https://twitter.com/EU_Sofie/status/1328960574164774914

		PDL-005 Proof of Concepts Framework, significant contribution by LMF; SMAUG was accepted as a Proof-of-Concept (PoC) for this draft and plan to propose 5G Spectrum Leasing, which builds further on SMAUG, as a second PoC for this draft PDL-006 Interoperability, significant contributions by AALTO, AUEB and LMF based on research and deliverables developed in the SOFIE project

Activities by partners in standardisation bodies

The World Wide Web Consortium (W3C)

AUEB:

1. Dr. Nikos Fotiou (AUEB) was invited and made (on 22/06/2020) a presentation titled “Using Verifiable Credentials in IoT Services” (slides archived in the W3C GitHub repository) to the workshop organised jointly by the IRTF Thing to Thing Research group (T2TRG) and the W3C Interest Group (IG) on the Web of Things (WoT), where new proposals for advancing the WoT standards are discussed.
2. Dr. Nikos Fotiou (AUEB) is a participant (2020) in the W3C Credentials Community group.

Aalto:

1. Dmitrij Lagutin (Aalto) presented SOFIE and work on decentralised identifiers on W3C virtual face to face meeting on 18.3.2020, slides were made in cooperation with AUEB.
2. Dmitrij Lagutin (Aalto) contributed to AUEB's presentation on 22.6.2020 W3C virtual face to face meeting.

Engineering Task Force/The Internet Research Task Force (ETF/IRTF)

AUEB:

1. Prof. George C. Polyzos (AUEB) participated (17/02/2018) in a (pre-standardisation) meeting of the IRTF Decentralized Internet Infrastructure (DIN) Research Group (DINRG, https://irtf.org/dinrg, https://trac.ietf.org/trac/dinrg/wiki) with a presentation on SOFIE’s ideas on a secure, open, decentralised IoT.
2. Dr. Nikos Fotiou (AUEB) participated (2019 Q4, 2020 Q1) in the discussions on the IETF Internet-Draft (draft-fett-oauth-dpop-04) OAuth 2.0 Demonstration of Proof-of-Possession at the Application Layer (DPoP).

ETSI Industry Specification Group (ISG) Permissioned Distributed Ledger (PDL)

LMF Ericsson:

1. LMF has regularly participated in the bi-weekly PDL conference calls, drafting sessions and plenary meetings.
2. LMF contributed to "PDL-004 Smart Contracts" draft during spring 2020 and autumn 2020 with submissions and participation in drafting sessions.
3. LMF contributed to "PDL-005 Proof of Concept" draft during autumn 2020. The SMAUG PoC was included in this draft specification.
4. LMF contributed to "PDL-006 Interoperability" draft during summer 2020 and autumn 2020 with submissions and participation in drafting sessions.

AUEB:

1. Prof. Vasilios A. Siris (AUEB) contributed to the PDL-006 Interoperability document, mainly in the sections related to (i) the motivation for interoperability between different ledgers and (ii) the tradeoffs between different ledger types and (iii) the interledger mechanisms and approaches.

Aalto:

1. Contributed to the PDL-006 Interoperability document during summer 2020.

3. Exploitation Report of Academic Partners

This section describes exploitation efforts and future exploitation work of the SOFIE academic partners.

3.1.1 Aalto University

Foreground to be exploited: the components: Interledger, IAA, PDS, Marketplace, and the System Dynamics models of business platforms federations.

Measures taken so far: Two PhD students are working on the SOFIE project, and Aalto has also supervised two SOFIE-related master's theses. A graduate course “Postgraduate Seminar in Communications Engineering on Data Economics” was held in Autumn 2018, and the “Microservice architectures and serverless computing” course was held in Spring 2019 and Spring 2020 at Aalto University.

SOFIE results have already been utilised in Aalto participating projects H2020 PHOENIX, H2020 IoT-NGIN, EMPIR SmartCom, and EIT Climate-KIC GOWOOD.

Phase 1 of exploitation (2018)

A graduate course "Postgraduate Seminar in Communications Engineering on Data Economics" was held in Autumn 2018. Two PhD students started working on the SOFIE project. Aalto has also published several scientific publications and held several presentations.

Phase 2 of exploitation (2019)

"Microservice architectures and serverless computing" course was held in Spring 2019. Aalto supervised one SOFIE-related master’s thesis. SOFIE results were utilised by H2020 PHOENIX, EMPIR SmartCom, and EIT Climate-KIC GOWOOD projects. Aalto also published several scientific publications and held several presentations.

Phase 3 of exploitation (2020)

"Microservice architectures and serverless computing" course was held in Spring 2020. Aalto supervised also second SOFIE-related master’s thesis. SOFIE results were utilised by H2020 PHOENIX, H2020 IoT-NGIN, and EMPIR SmartCom projects. Aalto also published several scientific publications and held several presentations.

Future work and impact: SOFIE results will be utilized also in the future in several EU- and national-level research projects, including H2020 PHOENIX, H2020 IoT-NGIN, and EMPIR SmartCom. Aalto will continue to offer master thesis topics, guest lectures, seminars, and/or special courses related to the results of the SOFIE project.

3.1.2 Athens University of Economics and Business

Foreground to be exploited: The SOFIE framework components: Interledger, IAA, PDS, and Marketplace and the System Dynamics models of business platforms federations, but also the whole SOFIE concept and approach, including evaluation methodologies and results.

Measures taken so far: AUEB has led the development of the Identity, Authentication and Authorisation (IAA) and Privacy and Data Sovereignty (PDS) components and was intimately involved in most aspects of the project, in particular because of its leadership of the evaluation work. AUEB has already made available its implementation of the IAA and PDS components as open-source software part of the SOFIE framework release, but also through AUEB MMlab’s github repository. The open-source software includes the *differential privacy* mechanism for privacy-preserving data aggregation as a standalone module. The software implementations were also used in the work of one completed MSc thesis not part of SOFIE.

In addition to permanent AUEB personnel, two PostDocs and two PhD students have been attracted and contributed to the SOFIE project, one additional PhD dissertation is being undertaken in the related area of Blockchain Security and three SOFIE related MSc theses have been completed. A new graduate course was introduced in the AUEB Computer Science program with title "Blockchains and Smart Contracts" and has been offered for three years now, with big success. SOFIE has been instrumental in attracting some of the best AUEB students and researchers to perform research and study in this area. In addition, the SOFIE experience and results have been instrumental in attracting further research projects.

Phase 1 of exploitation (2018)

A PhD student has been attracted and contributed to the SOFIE project with working title of his PhD dissertation being: "IoT resource access based on blockchains." One additional PhD dissertation is being undertaken in the related area of blockchain security.

A new course was introduced in the AUEB graduate Computer Science program as an elective with title "Blockchains and Smart Contracts" for the first time in the Spring of 2018 and was taught by Dr. Nikos Fotiou, a PostDoc researcher being funded by SOFIE. Almost all MSc CS students elected to take the course. This would not have been possible without SOFIE.

Phase 2 of exploitation (2019)

The SOFIE experience and know-how have been instrumental in being invited to contribute to proposals leading to projects, such as the H2020 Innovation Action "Interoperable Solutions Connecting Smart Homes, Buildings and Grids" (InterConnect). The project relates to and can benefit from SOFIE in the areas of interoperability, IoT, blockchains, user privacy and engagement and other areas.

The "Blockchains and Smart Contracts" graduate Computer Science course, introduced in the AUEB program in 2018, was taught again in the Spring of 2019, this time by Assistant Professor Spyros Voulgaris, also a SOFIE contributor. Again, almost all MSc CS students elected to take the course. Students studied and did class projects including on the SOFIE related topics of interledger technologies and smart contract writing. Note that Professor Spyros Voulgaris is a new addition to AUEB and the group and the expectation of involvement in SOFIE was a key reason for attracting him.

Two MSc theses directly related to SOFIE have been completed this year ("Interacting with the Web of Things using Blockchains," and "Interledger Approaches") and one of the students was recruited to continue to the PhD program with PhD dissertation topic: "Secure interoperability for Internet of Things data and actuation" and contributes to the SOFIE project. Two additional related MSc theses were completed (under the supervision of Prof. Polyzos, AUEB SOFIE PI) with titles: "Consensus in Blockchain" and "Creating a 'Store of Value' platform for cryptocurrencies."

Phase 3 of exploitation (2020)

Two new related research projects have been started: "Self-Certifying Names for Named Data Networking" from the 1st Open Call of H2020 NGIatlantic.eu, proposing to use DIDs as (network layer) names for the Named Data Networking internet architecture, with exciting security properties and decentralisation capabilities, and "Eclipse-Resistant Network Overlays for Fast Data Dissemination," with funding from IOHK/Cardano and expected impact on the Cardano blockchain, being led by Prof. Spyros Voulgaris who has extensive experience in P2P systems and overlay networks, as well as broad distributed systems expertise.

The "Blockchains and Smart Contracts" graduate course, has been taught again, this time in the Fall of 2020, by Prof. Voulgaris. Again, all but one (14 out of 15) MSc CS students elected to take the course.

Finally, an additional SOFIE related MSc thesis has been completed with title "Internet of Things Gateway Access Control." The approach is based on OAuth 2.0 and JSON Web Tokens and used the SOFIE IAA component. It provides security and user role management for the *open Home Automation Bus* (openHAB), one of the most widely used open software platforms for home automation, and to control the operation of smart Things.

Future plans and impact: SOFIE know-how and results will be utilized also in future research projects for which proposals have or will be submitted by AUEB. Also, AUEB will continue to offer PhD and master thesis topics, seminars, and courses related to or based on the results of the SOFIE project, expecting to attract top notch talent. AUEB's expertise in SSIs, DIDs, VCs, interledger technologies and smart contracts, accumulated mostly because of the SOFIE project, has invigorated the group and expanded its visibility within AUEB, nationally, and internationally. With respect to the IAA and PDS components, the group has plans to support and expand them beyond the end of SOFIE and to promote them for adoption as open source solutions in various practical settings. For example, AUEB considers contributing the IAA component and an extended version of the software from the above mentioned IoT Gateway Access Control thesis to the *openHAB* open source repository.

4. Exploitation Report of Industry Partners

In this section SOFIE industrial partner report on their exploitation efforts and future work. It should be noted the level of future exploitation and related activities vary amongst the partners due to market traction.

4.1.1 ASM Terni SPA

ASM Terni offers specialized and public services to citizens of Terni and its surrounding area, namely water and electricity grid management that can be dramatically improved by implementing cutting-edge technologies such as a potential federation composed of different platforms connected to each other. ASM Terni, as responsible for the power distribution network, has the potential to offer a significant change in terms of energy availability by providing safe and secure operation and management of the electrical Distribution Network. In this case, renewable energy has the paramount benefit to meet the local green economy.

Foreground exploited: Although ASM Terni is not the IPR holder of the KERs (Key Exploitable Results), the contribution to their exploitation is relevant being both a stakeholder and an end-user; in actual fact ASM Terni will be available after the end of the project to showcase most of them as well as to implement SOFIE's solutions in other EU projects.

The SOFIE exploitable results tested and demonstrated in Terni and what is interesting for ASM in terms of exploitation are as follows:

Interledger - enables transactions between actors and devices belonging to different IoT silos, notably they could be different Advanced Metering Infrastructures (e.g., electrical grid and hydro system) as well as different subsystems (e.g., EV charging stations, Smart Home appliances).

Marketplace - enables the trade of different types of assets (e.g., electricity for charging a vehicle) in an automated, decentralised, and flexible way. This component is considered promising for optimising activities related to the smart chargers, providing flexibility to the power distribution grid. The use of this tool in Terni after the end of the project could result in discounted EV charges, network balancing and efficient integration of renewable energy into the grid.

Phase 1 of exploitation (2018)

ASM Terni was involved in exploiting the SOFIE's results during the second (2019) and the third year (2020) of the project. On 2018 ASM Terni contributed to the exploitation by validating the exploitation plan and strategy set by Guardtime.

Key results

- Exploitation plan and strategy shared with the consortium

Phase 2 of exploitation (2019)

During the second year of the project ASM Terni exploited SOFIE's results throughout different actions and channels: networking with other EU initiatives (e.g., IOTA), participation to conferences and events, exploitation of SOFIE's results in other EU projects.

Key results:

- Networking with IOTA project
- Exploitation of SOFIE results in H2020 PHOENIX
- Presentation of project results in scientific and conferences

Phase 3 of exploitation (2020)

To enable the most extensive use of the project outputs, during the third year of the project ASM Terni exploited the SOFIE's results participating to conferences, workshops, using them in further research and innovation activities. Moreover, ASM Terni contributed to the stakeholder consultation.

Key results:

- Interview to an IT company and a e-mobility provider
- Publication of a scientific paper
- Presentations of project results in scientific conferences and workshops
- Exploitation of SOFIE results in H2020 IoT-NGIN

Future work: Apart from the aforementioned KERs, ASM Terni has reached additional results which will be internally exploited, as follows:

1. Enhanced understanding in cutting-edge smart grid solutions: The work carried out over the project has provided ASM TERNI with new knowledge in terms of technical and strategic approaches. Moreover, thanks to the SOFIE's solutions new integrated functionalities will be taken in consideration for a future exploitation.

2. Multinational and multidisciplinary collaboration: A significant outcome arising from working on SOFIE consists of strengthening multinational and multidisciplinary collaboration with public and private European Entities working on developing, deploying and evaluating advanced tools and ICT services for DSO and electric cooperatives, enabling active consumers' involvement. Networking activities carried out over the project lifetime have allowed ASM to go forward in terms of innovation (new businesses, advanced solutions and services, etc.), evaluating new visions and strategies suitable for DSO activities.

4.1.2 Emotion SRL

Emotion is part of the Italian Energy pilot providing monitoring and management services for electric vehicles and charging stations. The acquired knowledge is exploited to increase Emotion SRL business, offering to the market products and services enhanced with the project, with the aim of giving strength to electric mobility, for cleaner mobility, allowing an increasingly massive deployment of electric vehicles and charging stations and an increasingly intense use of renewable photovoltaic energy that is mainly produced at lunchtime, when consumption is lower and when the vehicle could be parked in charge.

Foreground to be exploited: **Foreground to be exploited**: Interledger, Semantic representation, Marketplace, DEFM Federation Adapter.

Measures taken so far: Thanks to SOFIE project, Emotion Srl has refined its skills and improved its awareness. Electric mobility IoT, smart contracts and distributed ledger technologies offer a solution to the complex management of distributed generation from intermittent renewable energy sources. During SOFIE project Emotion Srl enhanced its electric mobility platform which not only allows real-time monitoring and remote management of electric vehicles and charging stations, but also predicts in advance the amount of flexibility that can be provided, by an electric vehicle or a fleet of electric vehicles, to the DSO to stabilize the electric grid. Furthermore, it was possible to demonstrate how Demand Response campaigns can benefit from the aforementioned technologies, enabling an easy, quick and resolute marketplace in which DSOs, Fleet Managers and Energy Retailers meet to satisfy their needs, increasing their efficiency and reducing the environmental impact of their daily work. Following is described an overview of the exploitation activities divided into the three phases of SOFIE project.

Phase 1 of exploitation (2018)

During the first stage the main focus was on the requirements for Decentralised Energy Flexibility Marketplace solution that Emotion Srl was building for the SOFIE energy pilot. With the aim of getting a better list of requirements, a stakeholders' confrontation was set up through the dissemination of the SOFIE project via Emotion Srl web site, Emotion Srl social media account and a public event. Moreover, electric vehicle data related to the Italian energy pilot has been collected by Emotion Srl and periodically released as an open data in Zenodo, following the Data Management Plan (DMP) defined in WP6.

Key results:

- Created the end-user requirements list for Decentralised Energy Flexibility Marketplace solution
- Collected and published IoT open data

Phase 2 of exploitation (2019)

The second phase was focusing on the exploitation of the results that were already created during the first year of SOFIE project. Based on that, a scientific paper titled “Secure Open Federation of IoT Platforms Through Interledger Technologies - The SOFIE Approach” was published. Furthermore, a first demo of Decentralised Energy Flexibility Marketplace solution was performed, and results was disseminated to the stakeholders via social media and international social events, as Energy Industry Mixer 2019, were Emotion Srl attended.

Key results:

- Material created for exploitation activities
- Approach and onboarding end-users in industrial events and SOFIE workshops
- Creation of end-to-end demonstration of Decentralised Energy Flexibility Marketplace solution

Phase 3 of exploitation (2020)

The aim of the third exploitation phase was to present to stakeholders the full capability and value proposition of Decentralised Energy Flexibility Marketplace solution together with SOFIE general concept.

Key results:

- Finalizing the demonstration of the Decentralised Energy Flexibility Marketplace solution
- Conducting the 3rd SOFIE workshop

Future work:

1. Emotion SRL will leverage the work done during SOFIE project to offer the Demand Response service to EV users when the Italian energy authority will soon allow the deployment for business operation of this mechanism; following up legislation that is in the progress to update with technology development, Emotion SRL will make exploitable in real life results obtained thanks to the experiments conducted at the Italian pilot site, conveying the EV users to the charging stations located in the critical nodes of the electricity grid. EV users will thus be able to charge their vehicles at a discounted price and participate in the difficult and inevitable challenge of transitioning to a low carbon economy.
2. Emotion SRL will refine its services and products as well as its staff with the aim of enhancing what has been learned and developed during the SOFIE project, both from a technical and social point of view.
3. SOFIE outcomes will continue to be disseminated to eMobility potential stakeholders and SOFIE solutions will be exploited within other EU H2020 research and development projects where Emotion SRL participates, like BRIGHT project.

4.1.3 Engineering Ingegneria Informatica SPA

The results of the project, in particular the components related to the Decentralised Marketplace and the DSO forecast and congestions detection dashboard, will be exploited in several

European research projects exploring the usage of distributed ledger solutions in the energy field; moreover, these technologies will be made available to the related Engineering business unit. In fact, Engineering addresses the specific market with its business unit "Energy & Utility" to provide its own value proposition as the complete solution for its customers. In the Engineering innovation model, the goal of the R&I activity is to contribute to the change in markets and companies via solutions that can create innovative experiences for the users, in order to encourage a safe and aware use of information technology. The process is composed of three macro steps:

1. Develop and consolidate the results of research projects.
2. Define and execute experimental checks of developed solutions – or components – including the activity to assure the replicability of processes.
3. Capitalize the investment providing via Engineering's Business Unit Business Offer to the clients according to a specific business plan.

Part of this last step is the actual commercialization process, including the work of the business unit to extend the company offer portfolio and address the worldwide market with a proper marketing strategy.

Foreground to be exploited: Interledger, Semantic Representation, and Marketplace Components, DEFM Federation Adapter, DEDE Adapter together with Decentralised Marketplace for Energy Flexibility Services.

Measures taken so far: Involvement of the "Energy & Utility" Business Unit (BU). In a first stage, the BU was involved in the scenario identification, preliminary pilot use cases design, and first requirement analysis. Later on, the BU participated in a live demo of the Terni pilot demonstrating the complete prototype functionalities end-to-end.

Phase 1 of exploitation (2018)

On the first phase, the focus was on the involvement of the internal stakeholders for the requirements elicitation. The whole project was promoted on the company website, with specific focus to the relevance of the Decentralised Energy Flexibility Marketplace in the energy sector. Preliminary use cases and results were communicated internally.

Key results:

- End users' requirements, scenarios, and use cases
- Internal reporting about preliminary UC and results

Phase 2 of exploitation (2019)

In the second phase, a first demonstrator for the DEFM pilot was developed, to demonstrate the technical feasibility of the blockchain-based marketplace and to validate the use cases. The preliminary version of the value proposition and the business model canvas have been defined.

Engineering presented the pilot results during the first SOFIE workshop ("Decentralized", 2019, Athens) and, in addition, we tried to disseminate the outcomes to potential stakeholders in the DLTs domain. The project consortium prepared a video describing the benefits of using SOFIE for an energy flexibility platform in a short and easy-to-understand manner.

Key results:

- end-to-end DEFM demonstrator
- presentation of project results during the first project workshop

Phase 3 of exploitation (2020)

The last phase of the exploitation activities is focused on the deployment, validation, and demonstration of the final version of the pilot platform and the release of the pilot's Federation Adapter as part of the SOFIE software release. Preliminary market analysis and financial analysis were included in D6.10. In addition, Engineering continued to participate in workshops and conferences to present the pilot's results, highlighting the features of the platform to attract potential new customers. The end goal has not changed and is still to exploit the results of the SOFIE project by including them in the business offer to its customers. In fact, Engineering provides services and projects to more than 300 clients in the field of Smart Energy & Utilities. The solutions composing this offering are internationally recognised for their excellence, like Net@Suite that has been recognised from Gartner as a leader in the CIS (Customer Information Systems) and MDM (Meter Data Management) sector since the 2009.

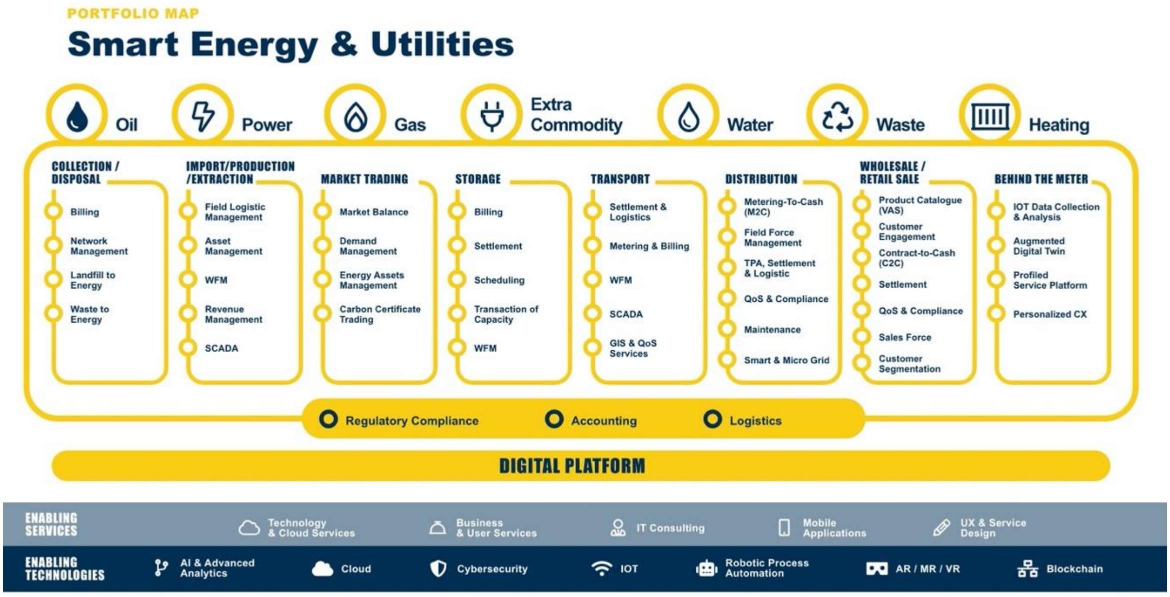


Figure 1. Engineering Portfolio for Smart Energy & Utilities

In detail Net@Suite is a cloud-based platform for the energy, water and gas, waste management and public lighting sectors built as a modular solution including for i) Billing and Back-end for gas and electricity sales, (ii) Operation Management for gas and electricity distribution, (iii) Business Intelligence Systems, (iv) Real Time Meter Data Management for Enhanced Analytics, (v) Drones Integration and Management to support WorkForce Automation and O&M for utilities. In this perspective, the decentralised marketplace for the energy flexibility could be seen as a further modular extension of the tool suite enriching its offer with a marketplace for DSO and energy district stakeholders such as electric vehicles fleet manager and EV-charging stations manager.

Key results:

- DEFM FA release
- DEFM pilot presentation to workshops and conferences
- Contribution to the publication of a scientific paper
- Market and Financial Analysis

Future work:

1. Carry on with the company innovation process in term of technical support to the internal Business Units for the knowledge transfer; This step of the innovation process is preliminary to the preparation of offers for potential customers requiring decentralised solutions for energy management and trading.

2. Engage new potential adopters, mainly DSOs, EV fleet managers, EV users, and energy retailers, interested to test the applicability of the DEFM platform for their operations; In fact one of the modalities that ENG adopt for the exploitation of research project results,

the technological asset, is the establishment of pre-procurement agreements with potential clients, either single stakeholder or cluster of stakeholders, in order to make available to them a tailored pilot enabling a realistic validation of the asset using their own data in their processes.

3. Investigate potential applicability of decentralised marketplaces in different domains or in different segments within the energy domain. For example Financial domain could leverage on the decentralised marketplace for investment risks reduction; the application could provide to Investors, that are investing in renewable energy plants, a mechanism for revenue sharing; the revenues earned in the marketplace energy or flexibility selling could be automatically shared between the renewable energy plant owner and the Investor that financed the plant realization, the sharing conditions could be handled via smart contract in automatic way.

4. Further dissemination of SOFIE outcomes to potential stakeholders in the energy domain and exploitation the results within other EU H2020 research and innovation projects where Engineering is currently participating, e.g. the BRIGHT project, or will participate in the future. Moreover, Engineering business Unit organizes periodic events with its main customers in order to inform them on the innovations that the company promote as part of its offer, SOFIE result will be considered by business unit in order to promote them according to the specific audience needs.

4.1.4 Guardtime OÜ

Guardtime is the largest industrial blockchain platform provider, offering KSI Blockchain technology that enables massive scale data authentication without reliance on centralized trust authorities.

Guardtime's plan is to use the results achieved from the SOFIE project in order to enable new applications and services to the energy sector. Together with energy sector IoT providers (Elering (TSO), Elektrilevi (DSO) baseline stakeholder), the distribution of SOFIE DEDE adapters can firstly create a mechanism to link geographically different IoT providers and secondly provide transparency and data integrity for smart meters and its supporting systems. Keeping in mind the initial goal of reducing energy consumption and enabling different actors to cooperate. Main focus of the cooperation is to be able to generate value from new services. TSOs and DSOs are in the centre of this transformation as they are the current gatekeepers of the running infrastructure and when connecting their assets, the whole energy ecosystem will benefit.

The Guardtime exploitation plan includes the potential use of the KSI Blockchain in combination with other SOFIE pilots and the products derived from those results.

Foreground to be exploited: Interledger, IAA component, DEDE SOFIE Federation adapter, KSI blockchain.

Measures taken so far:

The exploitation activities of Guardtime can be divided into three different sections:

- user requirements and customers onboarding,
- the first concept building and demonstrating, and
- full capability testing with business process match and integration challenges evaluation.

These three sections follow the SOFIE project timeline and research/development plan.

Phase 1 of exploitation (2018)

In the first phase of activities the scope of potential end-users was set at wider range. The key value proposition of liberating the stand-alone energy smart meter data hubs was presented to

Elering, Tennet, Energinet, Elektrilevi and several other TSOs (Transmission system operator) and DSOs (Distribution system operator) in Europe. The approach to reach the one-to-one discussion with end-users was done via existing business contacts that Guardtime had from other Energy project, contacts through EU energy regulation/standardisation boards and business network.

Besides the energy data hubs, the exploitation activities in the first stage also included customer segment closer to smart meters and building the data security solution on-board the smart meter chip. The security solution providers for smart grid infrastructure were targeted as SOFIE federated adapter users in order to be part of national level procurements from TSO/DSO that purchase grid infrastructure and system upgrades.

The aim for the first stage was to update and confirm the requirements for Decentralised Energy Data Exchange solution (DEDE) that Guardtime was building during the SOFIE energy pilot. Also, the input collection to the high-level reference architecture of SOFIE and the interledger approach together with the general components was conducted.

In order to move to the second stage, it was necessary that the clear confirmation from stakeholders about the requirements and onboarding them to the DEDE.

The first main end-user for the DEDE was Elering and getting their approval to be included was achieved. This also gave an opportunity to approach other TSOs and DSOs with some strong reference from stakeholder’s side.

Key results:

- Creating the end-user requirements list for DEDE
- Narrowing down the end-users: the smart grid infrastructure partners were removed, and main focus was given to Energy Data hub operators together with data owner (smart meter owner on household or company level)
- Preliminary list of customers to address in the phase 2

Phase 2 of exploitation (2019)

The second phase was focusing on the exploitation of the results that were already created during SOFIE project. The creation of demos, that provided simplified view how data access control could be solved, enabled to target TSO and DSO level end-users and start working on the business cases and shape the value proposition. The result of the interaction with end-users was creation of Business Canvas for the pilot. Besides targeting the end-users, the EU level legal and regulatory focus group was approached in order to educate and share the SOFIE concept in energy sector more widely. The EU policy makers workshops was a great platform where to approach the stakeholders and create more contacts for exploitation actions.

During the second phase, the first workshop “Decentralized 2019” was held in Athens, where DEDE solution was introduced and contacts from this event helped to scale up the exploitation plan. The first workshop was also a key milestone to have all the materials that could be used for exploitation activities ready. These included SOFIE video, DEDE end-to-end demonstration, pilot one-pager and business value proposition to TSO, DSO level. In order to create these materials, the preliminary requirements, business roles and system use-cases had to be finalised.

One of the goals for exploitation activities in phase 2 was also to narrow down the countries where SOFIE DEDE platform would be offered first. As the end-users were already selected in phase 1 and the TSO/DSO level had the highest potential to start using the solution that was proposed by Guardtime the was a need to focus on specific customers in potential countries. The first and the second workshop of SOFIE helped to gather information on what countries to target. Also, the visibility in the EU policy makers level was used to finalise the selection. Eventually the countries that were selected to more hands-on approach were Estonia, Poland, Netherlands, Demark and Finland.

Key results:

- Material created for Exploitation activities
- Approach and onboarding end-users in 1st and 2nd SOFIE workshop
- Creation of end-to-end demonstration of DEDE solution
- Selection of target markets and customers for exploitation activities

Phase 3 of exploitation (2020)

The aim of the third exploitation phase was to present to stakeholders the full capability and value proposition of DEDE solution together with SOFIE general concept. The questions/answers that were driving the discussion with stakeholders were: what we offer, what is the added value, how much it costs and what could be the next business opportunities. The 3rd SOFIE workshop enabled Guardtime to conduct one to one interview and to get answers to these questions.

The exploitation activities were also focused to present the full DEDE solution, that was developed to larger audience, keeping in mind the key countries that were selected during phase 2.

Key results:

- Finalizing the demonstration of the DEDE solution
- Selection of three potential end-users to be part of post SOFIE project activities.
- Conducting the 3rd SOFIE workshop

Future work:

The plan is to carry on with the exploitation in the four main topics:

1. Finalizing the proof-of-concept proposals to DSOs and TSOs in order to get post SOFIE financing for the DEDE adapter implementation and to develop the solution further. There is open dialogue with the TSOs Elering (Estonia), PSE (Poland), Fingrid (Finland), Tennet (Netherlands) and DSOs Elektrilevi (Estonia), 50hertz (Germany) in order to reach an agreement to propose a customer specific Proof-of-Concept (PoC) and the financing mechanism on this.

2. There is also the medium-term plan to have a solution ready in order to bid in national level energy network upgrade procurement. This means that existing system integrators and smart grid providers will be using DEDE adapters to solve part of the procurement requirements. There is ongoing discussion with Enoco (Norway), AKKA (France)and Spotty energy (Germany) to do the preliminary match of resources and architecture concept.

3. Work related to the legal and regulatory side. Both GDPR and flexible open energy market activities, with Entso-E and EU commission bodies, workgroup initiatives related to Energy sector. Guardtime will continue its participation in these groups. There is also the business networking being part of this activity to open up more opportunities that the follow the same path as described in two previous activities.

4. The future use of Guardtime's business network in energy sector (information exchange, joint events, cross usage of sales/marketing force), thus making sure that the approach towards industry is constantly and widely targeted. This means that the Exploitation roadmap, commercial achievements so far from SOFIE and the ambition (business goals + BMC) are to be prepared and evaluated by Guardtime management board in order to allocate additional resources to carry on with the exploitation.

4.1.5 LMF Ericsson

Ericsson is responsible for integration and validation of the academic and commercial assets in this project. Ericsson has also developed the SMAUG reference implementation that demonstrates the use of the SOFIE academic assets in a decentralised marketplace realization. More widely, Ericsson's specific interest in this project is in the federated Interledger approach. Ericsson has also been driving standardization related activities in this project.

Foreground to be exploited: Interledger, IAA, Semantic representation, PDS

Measures taken so far: Research and results from SOFIE have been evaluated in Ericsson internal projects.

Phase 1 of exploitation (2018)

In this phase, the applicability of the SOFIE approach for use cases in Ericsson's interest was evaluated in relation to several research projects and technology proof of concepts. The use case areas that were primarily looked at were IoT, 5G and contract automation for OSS/BSS applications. The outcome of the evaluation is described under "Phase 2 of exploitation (2019)" and "Phase 3 of exploitation (2020)".

Key results:

- Successful identification of potential use cases in relation to IoT and telecom.

Phase 2 of exploitation (2019)

In this phase, one of the identified applicable use cases during Phase 1 was realized as pilot project related to business contract automation. The handling of distributed identifiers – as described by the SOFIE framework - was applied as part of this work. Moreover, Ericsson also made a decision to extend our originally agreed SOFIE scope of work with an internal SOFIE pilot that later was to be named to SMAUG.

Key results:

- The open federation approach and handing of distributed identifier in SOFIE was applied in an Ericsson internal research project related to business contract automation. The results of this project have been later applied in a production solution for automation of Ericsson's inter-company invoicing process.

Phase 3 of exploitation (2020)

In this phase, Ericsson developed the SMAUG reference implementation and started development of a pilot project related to 5G spectrum sharing which builds further on SMAUG.

Key results:

- Demonstration of the use of the SOFIE academic assets in a decentralised marketplace realization (SMAUG). This project was successfully completed, results released as open source and SMAUG included as a proof of concept in the ETSI ISG PDL-005 specification.
- 5G Spectrum Sharing pilot as a decentralised marketplace was demonstrated internally

Future work

1. Propose the inclusion of 5G Spectrum Sharing as a proof of concept in the ETSI ISG PDL-005 specification. Further development of this pilot and evaluation of possibility for business adoption. Inclusion of 5G Spectrum Sharing proof of concept in the ETSI ISG PDL-005 specification. This use case becoming a regulatory requirement in many markets and Ericsson will continue to explore further the applicability of the results from SOFIE to address this area.

2. Ericsson will continue with technology research and business development in relation to applicable use cases where the problem statement includes interledger and federation aspects. Mainly these use cases are in the 5G, IoT, OSS/BSS and data security areas.

4.1.6 Optimum Anonimi Etairia Technologies Pliroforikis

Optimum participates in the food supply chain pilot and implements the federation adapter of the Aberon IoT platform to support tracking of environmental conditions in the warehouse. Optimum is focusing on the convergence of DLTs with IoT and how the first can address challenges relate to cybersecurity, data privacy and integrity, and scalability of next generation IoT services.

Foreground to be exploited: Interledger, Authentication and Authorisation (IAA), Semantic representation, SOFIE Federation adapters.

Measures taken so far: Further evaluation and analysis of users' feedback for the pilot platform. Presentation of the SOFIE business platform to partners and commercial customers to inform them about new business opportunities towards integrating end-to-end secure traceability in logistics and warehouse management. More emphasis was given to the challenges that were raised due to the pandemic and the pilot platform could potentially address, such as companies in the logistics chain that were forced to decrease, or even cease, their operations.

Phase 1 of exploitation (2018)

During the first phase of exploitation activities, Optimum contacted several stakeholders from our existing customer network in order to discuss about new business opportunities towards integrating end-to-end secure traceability in logistics and warehouse management. The discussions provided us with their views on how these services should look like and what capabilities they should provide, i.e., Optimum gathered end-user requirements from potential customers of our services.

Key results:

- End-user requirements collection
- Contacting existing customers and inform them about SOFIE and the Food Supply Chain pilot in specific

Phase 2 of exploitation (2019)

During the second phase Optimum focused on contacting potential adopters of the logistics part of the pilot platform and contacted mainly existing customers (e.g., Vivartia group) in order to present the benefits of our SOFIE-based solution. The aim was to trigger them into evaluating our business proposition and get involved in future trials. The pilot platform was presented both within our customer network but also during SOFIE first workshop (Decentralized, 2019, Athens).

Key results:

- Presentation of the logistics part of the Food Chain pilot platform to existing customers
- Presentation of Food Chain pilot platform during SOFIE workshop
- Use user requirements gathered during phase 1 to adapt our Aberon platform for the purposes of the Food Chain pilot

Phase 3 of exploitation (2020)

During the third phase of the exploitation activities, Optimum finalized the Aberon platform according to the feedback received from several stakeholders. Optimum has also had several discussions within our customer network for potential collaboration. An important achievement during this phase was that we had the chance to have discussions with people from companies that are already using our platform and could potentially adopt our SOFIE-enhanced platform in a trial. Optimum has engaged these companies in having interviews in the context of the third

SOFIE workshop and we plan to follow-up on these discussions with further collaboration after the end of the project.

Key results:

- Engagement of existing customers to consider the adoption of our SOFIE-enhanced platform for a trial
- Finalization of the Aberon platform with a full set of SOFIE-related features
- Compilation of a business proposal for our customers that will include the pilot's outcomes

Future work

The following actions are planned in relation to SOFIE:

1. Triggering discussions with a number of existing business partners for the possibility of adopting the pilot platform. Discussions concern existing business partners in the fields of Food Retail and Electronics Retail. In the former case, we have communicated with Barba Stathis and Delta from the Vivartia group, which are both leading companies in Greece in the areas of frozen agricultural products and dairy products respectively. In the latter case, we have established contact with Kotsovolos, one of the biggest electrical appliances and electronic devices stores in Greece.

2. Further improving services of Aberon tailored to the warehouse management by using blockchain technology. At the moment, Aberon has been SOFIE-enhanced at a prototype level. The goal is to move beyond the prototype and explore incorporating full functionality of the Aberon platform which is a complete warehouse automation suite. Investigating the possibility to embed some of the pilot platform's functionalities in the commercially offered product (e.g., the Federation Adapter to make the product SOFIE-compliant).

3. Further business evaluation of the implemented business platform to identify potential exploitation opportunities in the logistic area, also in other verticals. What has been identified is the relevance of the value of the business platform to other verticals, such as the electrical/electronic devices (electrical appliances and electronic devices).

4.1.7 Rovio Entertainment Corporation

Rovio leads the Context-Aware Mobile Gaming Pilot in the project. We aim to seek and identify where data platforms using DLTs can have a significant impact on the gaming industry. We also build prototypes for leading use cases and validate game experience and business potential for DLTs and IoT in gaming.

Foreground exploited: Interledger, Marketplace, Semantic representation, Provisioning and Discovery.

Measures taken so far:
One Blockchain research developer (PhD student) working on identifying use cases, current challenges to implement those use cases and their possible solutions. A research paper was prepared and submitted for publication. A wider team internally from Rovio is involved in the prototype development. To date, we have developed three prototypes in total to explore the foreground and understand the use of DLTs and IoT in games. The first one enables creating, buying and selling of in-game assets. The second one is a location-based scavenger hunt game prototype that uses IoT beacons for positioning players and stores rewards on the blockchain. The third and the most recent prototype is a distributed avatar management application and standard, allowing for a distributed avatar to be displayed and utilized in different applications and potentially enabling cross-game interoperability. A journal paper relating this use case is

also submitted in IEEE for publication. SOFIE components have been integrated with developed use cases. Furthermore, system requirement and architecture of a fourth use-case has been completed and implementation is underway which will seek to understand the potential for DIDs in mobile advertisements.

Phase 1 of exploitation (2018)

During the first phase, the main focus was on the requirements for Mobile gaming pilot. Rovio held an internal hackathon where their first DLT based prototype was designed. Rovio also contributed to the exploitation by validating the exploitation plan and strategy set by the consortium.

Key results:

- First DLT prototype was designed and developed in the hackathon.
- Exploitation plan and strategy shared with the consortium.

Phase 2 of exploitation (2019)

During the second phase, Rovio had a session with GoFore discussing uses of IoT beacons in mobile games. Rovio had several web meetings with the Amazon Web Services (AWS), Dapperlabs and Equilibrium with the objective to discuss different use-cases for SOFIE and also received feedback from experts on distributed ledger technologies. Rovio held another internal hackathon where “Blockmoji” decentralised avatar prototype was developed. Rovio hosted a partner challenge in the Junction hackathon in Espoo, Finland where participants had to create a game over the weekend that utilizes any emerging technology, including IoT devices and DLTs. Furthermore, the first demo of mobile gaming pilot was performed, and results were disseminated via international social events.

Key results:

- Material created for Exploitation activities.
- Creation of end-to-end demonstration of Mobile gaming pilot.
- Presentation of the pilot in conferences and publications.
- Discussed and prototyped new use cases for the blockchain and IoT technologies in mobile games

Phase 3 of exploitation (2020)

During the last phase, Rovio’s’ main focus was on demonstrating the final version of the pilot platform highlighting the full set of features that it offers. We have the chance to conduct interviews with gaming industry experts’, where we discussed the benefits of technologies used in gaming pilot and SOFIE platform in the gaming industry. Furthermore, the Scavenger Hunt game was open-sourced

Key results:

- Demonstrating the final version of the gaming pilot.
- Conducting interviews for the 3rd SOFIE workshop.
- Presentation of the pilot in conferences and publish research papers.
- Open-sourced Scavenger Hunt game.

Future work

1. Two more research papers to be submitted:
    a) SOFIE provisioning and discovery
    b) Decentralised Identifies for mobile advertisements

   These research articles focus on the work done during the SOFIE timeline and will be published mainly for the research community.

2. Implementation of the Decentralised Identifiers (DID) for Mobile Advertisements. The use-case focuses on using Blockchain based framework to generate DID of the user for managing mobile advertisements. Using the DID, an individual should own and control their identity without the intervening administrative authorities. Limiting the control over who has access to the consumer identity attributes, which are stored locally on the consumer's device. The results from the research will be published in a research article and also included in the Doctoral thesis.
3. In addition, the business requirement assessments for the gaming pilot implemented during the SOFIE project will be used by Rovio internally for future decision making and it will also be included in the doctoral thesis.

4.1.8 Synelixis Solutions SA

Synelixis is interested in the semantics schema developed in the scope of SOFIE to support supply chain management, especially that part that matches processing of data from a farming system (as it is managed by SynField IoT platform) to the other segments of the chain. SynField is a commercial, cloud based IoT solution for precision agriculture and smart water irrigation. Proper adaptation of SOFIE pilot blockchain-based data model into SynField mechanisms for data serialization and farming objects identification can be used to develop custom protocols and secure modules that allow easy adaptation and integration of the last as part of complex networks of IoT and other operational technologies enabling traceability of resources in large, multi-segment food supply chains and networks (agriculture 4.0).

Foreground to be exploited: Interledger, Authentication and Authorisation (IAA), Semantic representation, SOFIE Federation adapters.

Measures taken so far: Exploitation activities so far have focused on adapting SOFIE technology and implementing Food Supply Chain services according to the requirements and business needs highlighted by 7GRAPES Pegasus, which also is considered as an early adopter and customer of the SOFIE food supply chain environment. The on-site deployment of the pilot platform and the live testing that followed the adaptation phase provided more user feedback and triggered further discussions with 7GRAPES about potential adaptation and adoption of the pilot platform to their processes.

Phase 1 of exploitation (2018)

The first period of the project was dedicated to requirement collection from various stakeholders. Given the role of Synelixis in the Food Supply Chain pilot, focus was on producers and logistics (i.e., transportation, warehouse storage) vendors. For that reason, the pilot along with SOFIE was presented to 7GRAPES-Pegasus (http://www.7grapes.gr/) at their headquarters; both technical and business aspects were presented. The feedback received was valuable as it reflected the needs of a candidate early adopter and potential customer. The information gathered would help towards the creation of a valid business proposition for potential customers.

Key results:

- Presentation of Food Supply Chain pilot to potential early adopter and customer
- Collection of user requirements for the Food Supply Chain pilot

Phase 2 of exploitation (2019)

During the second period of the project, Synelixis focused on leveraging on the information gathered during the first phase in order to create our business proposal to potential customers. During this phase the value proposition of the pilot platform (still under development at that time) and the business model canvas have been generated. In the meanwhile, we evaluated feedback from stakeholders in order to adapt our pilot platform according to their needs and therefore make it more attractive to customers. Communication and close contact with 7GRAPES-Pegasus was strategic in our exploitation plan, hence, another presentation at their premises has been held, along with a first visual material collection session (i.e., photo-shooting at their premises). This presentation included updates on the features of the pilot platform as well as in SOFIE in general. The pilot platform was also presented during the first SOFIE workshop ("Decentralized, 2019, Athens)". In addition, we could further disseminate SOFIE outcomes to potential stakeholders in the agricultural domain. An important achievement during this phase was also the exploitation of SOFIE solutions within other EU H2020 research and development projects where SYN participates, e.g. PHOENIX.

Key results:

- Creation of the business proposal to potential customers
- Presentation of the pilot platform and its features during SOFIE workshop
- Further engagement and keeping close key stakeholders
- Exploit SOFIE outcomes in other EU H2020 research and development projects

Phase 3 of exploitation (2020)

During the last exploitation activities phase, the main focus was on demonstrating the final version of the pilot platform, highlighting the full set of features that it offers. On top of that, the fine-tuned business proposition was in place, aiming to attract potential adopters and customers. During the 3rd SOFIE workshop, we have the chance to conduct interviews with people from companies that are considered key players in the regional food supply chain. Another aim of this phase was to identify and make contact with companies in order to form a first -basic- ecosystem after the end of the project that will draw more attention -and customers- to our platform.

Key results:

- Demonstrating the final version of the pilot platform on-site
- Contacted new candidate adopters of the pilot platform
- Conducting the 3rd SOFIE workshop

Future work: Future exploitation will result through the main research, development, and dissemination activities of SOFIE, and especially the Food Supply Chain outcomes, where Synelixis is actively involved and interested. In this scope, the following priorities are planned for the next period:

1. Evaluation of users' feedback and making any necessary adjustments to a business proposal that will include the pilot platform with SOFIE components.
2. Trigger further discussions with 7GRAPES Pegasus about the possibility of adopting the pilot platform for a testing period under regular daily operations.
3. Engage new candidate adopters that have been identified (e.g., Cooperative Winery of Nemea). These candidates have already expressed their interest in the Synelixis SynField platform; hence, it is planned to enhance this offering with a testing period of the pilot platform from SOFIE.
4. Investigating potential companies from the different segments of the Food Supply Chain and how to make on-boarding to the pilot platform attractive to them. The aim is to find a few (not directly competing, i.e., from different regions) companies (from the farming sector, the logistics sector, and the retail sector) to get on-boarded and therefore form a first -basic- ecosystem.
5. Further dissemination of SOFIE outcomes to potential stakeholders in the agricultural domain and exploitation of SOFIE solutions within other EU H2020 research and development projects where SYN participates, e.g., the PHOENIX project.

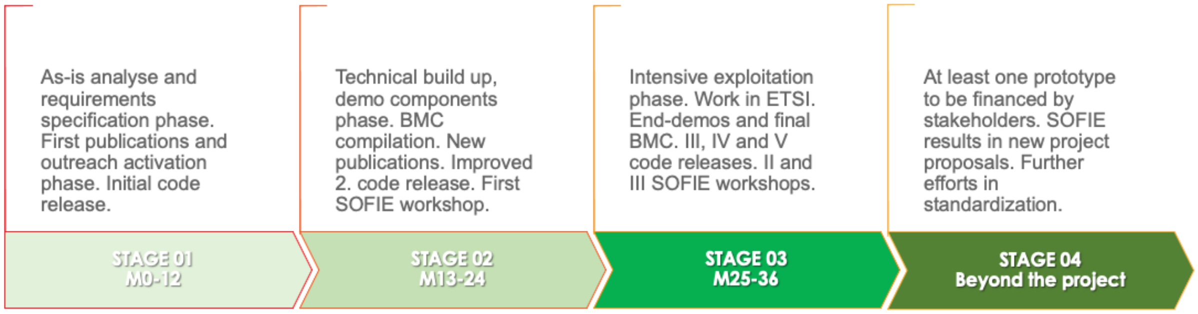
5. Exploitation Roadmap

This section provides an exploitation roadmap for SOFIE, explaining how the SOFIE consortium will secure a sustainable future for the results produced withing the project. The “Project Maturity Timeline” (Figure 2) and “Roadmap” (Figure 3) visualize the exploitation of results during and beyond the project, helping to simplify and clarify the many actions undertaken by all partners.

The exploitation of the project outcomes, especially beyond the project timeline are driven by the partners' organizational goals and demands, requiring individual effort by the partners with dedicated resources. Thus, it must be noted that due to budget constraints related to activities beyond the project’s official duration, the expected future results presented in the academic, commercial, and community verticals, cannot be guaranteed. The SOFIE consortium will make every effort possible to achieve the goals and we have confidence in reaching our targets.

5.1 Exploitation Stages

The presented timeline (Figure 2) reflects that the project’s exploitation actions grew consistently over time and matured in parallel with the produced research and technological advancements.



As-is analyse and requirements specification phase. First publications and outreach activation phase. Initial code release.

Technical build up, demo components phase. BMC compilation. New publications. Improved 2. code release. First SOFIE workshop.

Intensive exploitation phase. Work in ETSI. End-demos and final BMC. III, IV and V code releases. II and III SOFIE workshops.

At least one prototype to be financed by stakeholders. SOFIE results in new project proposals. Further efforts in standardization.

Figure 2. The Project Maturity Timeline

“The Project Maturity Timeline” presents a 4-stage timeline that illustrates how the SOFIE project was (stage 1-3) and will be (stage 4) materialised from the exploitation perspective. The plans for future exploitation are described as the last, fourth stage, explaining the exploitation goals and work to be done with the projects’ assets, beyond the project.

During the **first stage** we focused on producing initial scientific results and gathering relevant information to build business hypotheses and onboarding different key experts.

In the **second stage**, we targeted business opportunities horizontally through the project and gathered input from both the IoT community and from our stakeholders more generally, relying on the efforts we had already made in Stage 1. Strong demonstrations in each of the business verticals (energy flexibility marketplace and energy data exchange, food supply chain and context-aware mobile gaming) were created.

During the **third stage**, SOFIE produced the core exploitable results and identified the most viable elements that get pushed to exploitation beyond the project. We placed our efforts onto customer environments and business case development. The third stage relates to the final fourth stage through the fact that by the end of the third phase our three most viable assets (introduced in Section 2) were ready to be pushed to the market and the stakeholders’ evaluation of our assets had produced tangible results.

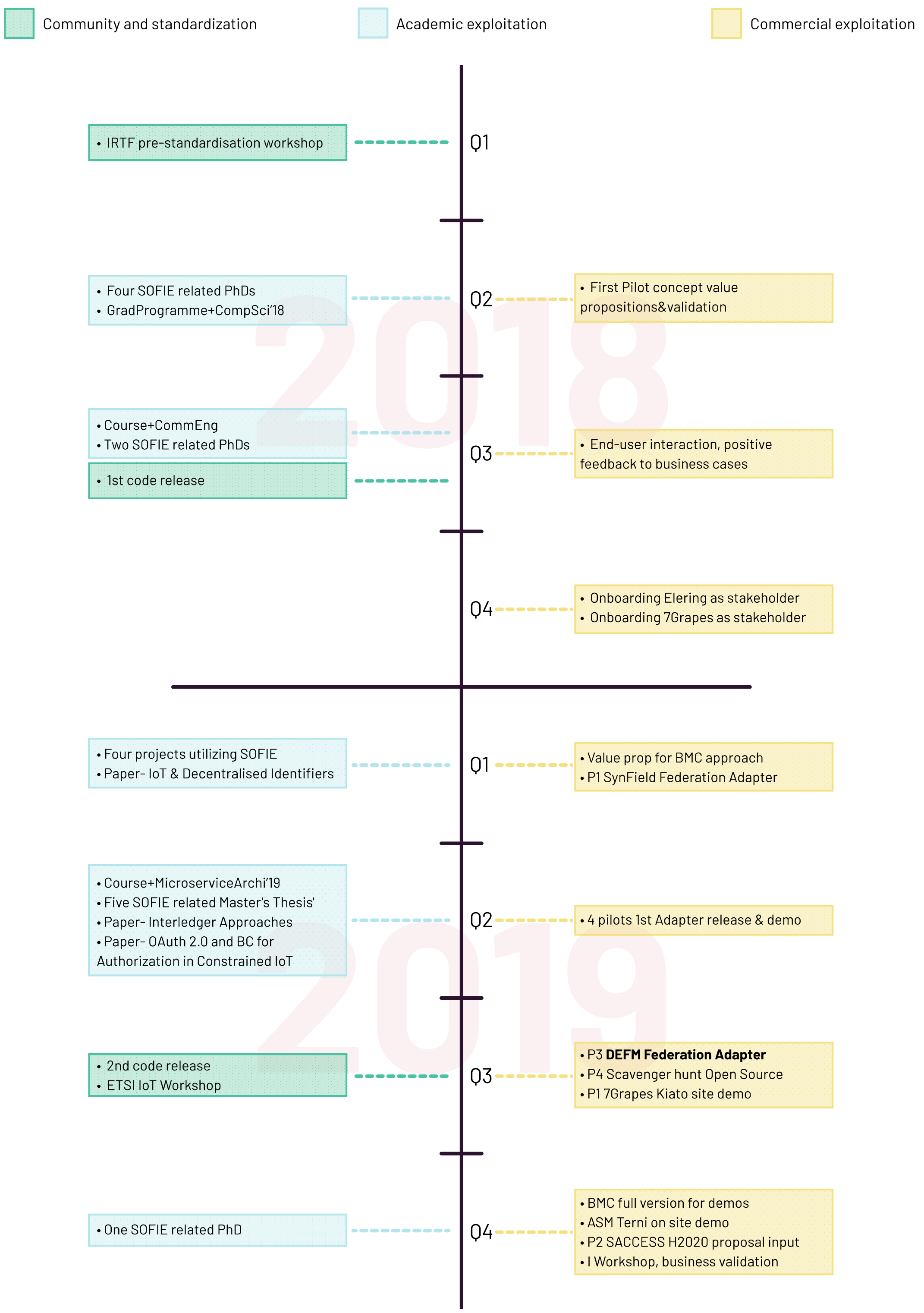
During **the fourth stage,** we aim to continue the dialogue with specific stakeholders in the energy business vertical with 2 SOFIE assets (1 from the DEDE pilot and 1 from the DEFM pilot) and in the Food-Supply-Chain (FSC) vertical with 1 SOFIE asset (from the SOFIE FSC pilot). We have agreed on the scope, financing, and timeline of the commercial activities. The general aim by all SOFIE consortium partners is to get enough interest from the stakeholders so that the prototypes, created and showcased during the demonstrations (e.g., during SOFIE's workshops, individual customer deployments/demos and final project demonstration), could be financed so that commercial Proof of Concept studies can be conducted in customers premises. Based on the interest and market potential that the prototypes attract, it is also possible, that SOFIE project members will finance (at least partially, at least one of) the other 13 assets in the list (Table 1) in order to achieve a maturity level appropriate to be proposed as a solution in the market environment. Future work related to this goal will be convincing the Management Boards of the commercial SOFIE partners to build a product or service that derives from SOFIE components. This will be an individually conduced effort by the partners. These activities will be ongoing in the first half of 2021.

5.2 Exploitation Roadmap and Related Future Activities

The project maturity timeline above (Figure 2) presents the stages of the project. The more in-depth path of project assets' development and exploitation is presented in the following paragraphs and on the exploitation roadmap (Figure 3). The SOFIE exploitation roadmap presents the collaborative effort to systematically exploit the project's outcomes during the project lifetime and show how the consortium partners will continue the exploitation activities beyond the lifetime of the project.

The roadmap mediates the project's achieved exploitation and its future exploitation and covers academic, commercial, and community work. For better visual clarity the graph is linear and 2-dimensional, but it should be noted that all exploitation activities were synergised, supported each other, and assisted the onboarding of interested parties, from students to potential buyers of the SOFIE solutions. For example, our publications have enabled or strengthened both producing relevant PhD theses and the business proposals that each SOFIE pilot is delivering to key end-users. An expanded list of items presented on the map is compiled into Appendix 1. For example, the highlighted papers, conferences, and GitHub code releases on the roadmap illustrate the contributions to formulating and exploiting open-source commercial assets. The realisation of assets, the deployment in customer environments, and the demonstrations mark out the road to selecting the assets that will feed the exploitation beyond the project.

The 2021 section on the SOFIE exploitation roadmap presents the key achievements (e.g., Proof-of-Concepts and procurement proposals, assets use-cases, commercial contracts etc.) we have set as goals for the near future. The plan is to reach these achievements through the combination of exploitation activities of all assets. **Our primary future goal is to secure additional business financing by partners individually to continue the commercialisation activity based on the assets we have created.** For each of the SOFIE assets there were specific exploitation steps taken. Firstly, the asset owner decided to prepare and present the results to stakeholders. Secondly, end user interest was explored and confirmed in order to go forward with commercial exploitation. This has been highlighted in the SOFIE roadmap by on-site demos to end-users. As a third and vital step, the future activities and allocation resources from SOFIE partners Management Boards were approved. Nevertheless, the exploitation of SOFIE will also include the academic and community related verticals that have been in the scope of the project and are described below in separate sub-sections.



🟩 Community and standardization
▢ Academic exploitation
🟨 Commercial exploitation

2018

Q1
- IRTF pre-standardisation workshop

Q2
- Four SOFIE related PhDs
- GradProgramme+CompSci'18
- First Pilot concept value propositions&validation

Q3
- Course+CommEng
- Two SOFIE related PhDs
- 1st code release
- End-user interaction, positive feedback to business cases

Q4
- Onboarding Elering as stakeholder
- Onboarding 7Grapes as stakeholder

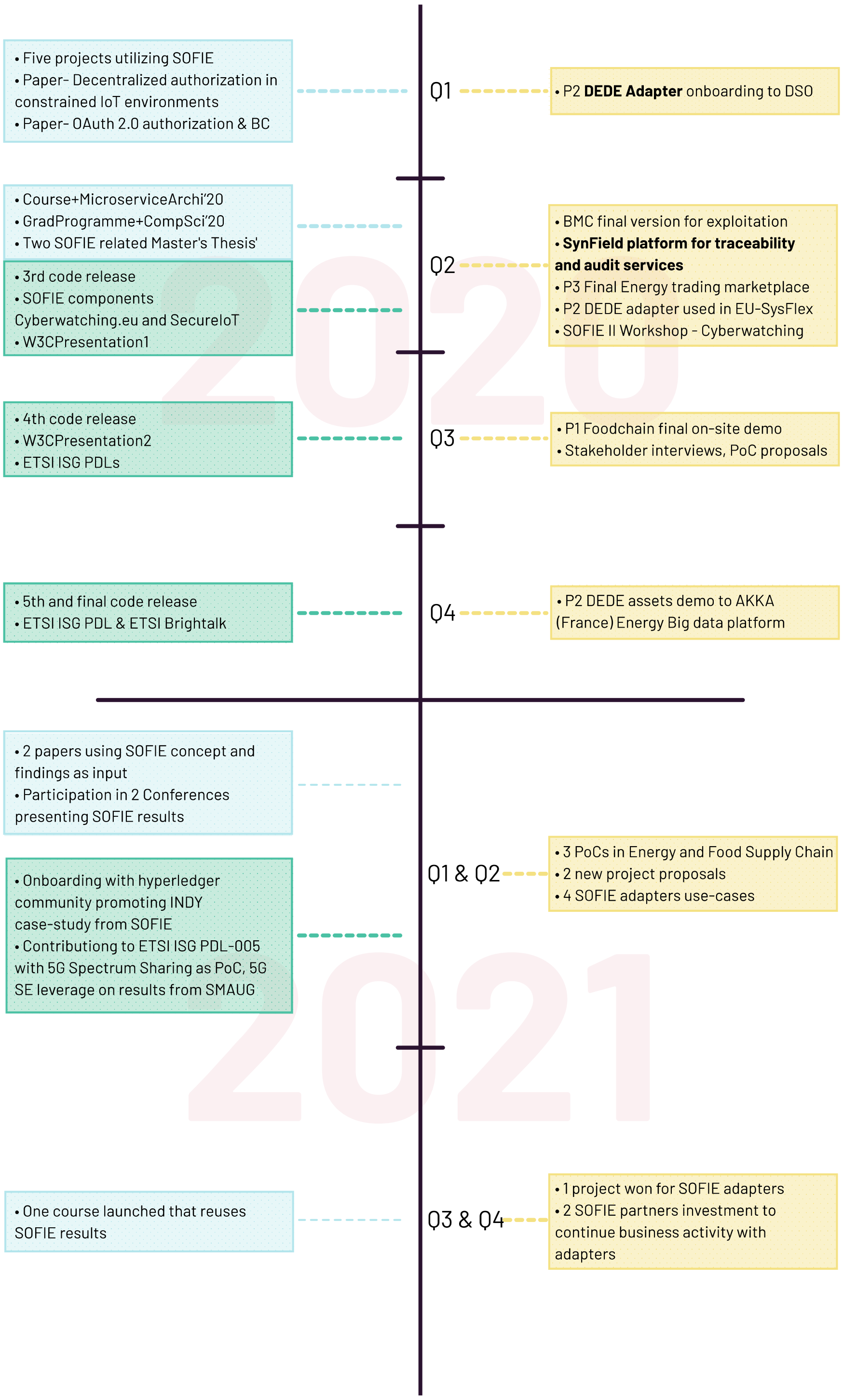
2019

Q1
- Four projects utilizing SOFIE
- Paper- IoT & Decentralised Identifiers
- Value prop for BMC approach
- P1 SynField Federation Adapter

Q2
- Course+MicroserviceArchi'19
- Five SOFIE related Master's Thesis'
- Paper- Interledger Approaches
- Paper- OAuth 2.0 and BC for Authorization in Constrained IoT
- 4 pilots 1st Adapter release & demo

Q3
- 2nd code release
- ETSI IoT Workshop
- P3 **DEFM Federation Adapter**
- P4 Scavenger hunt Open Source
- P1 7Grapes Kiato site demo

Q4
- One SOFIE related PhD
- BMC full version for demos
- ASM Terni on site demo
- P2 SACCESS H2020 proposal input
- I Workshop, business validation



Q1

- Five projects utilizing SOFIE
- Paper- Decentralized authorization in constrained IoT environments
- Paper- OAuth 2.0 authorization & BC

- P2 **DEDE Adapter** onboarding to DSO

Q2

- Course+MicroserviceArchi'20
- GradProgramme+CompSci'20
- Two SOFIE related Master's Thesis'

- 3rd code release
- SOFIE components Cyberwatching.eu and SecureIoT
- W3CPresentation1

- BMC final version for exploitation
- **SynField platform for traceability and audit services**
- P3 Final Energy trading marketplace
- P2 DEDE adapter used in EU-SysFlex
- SOFIE II Workshop - Cyberwatching

Q3

- 4th code release
- W3CPresentation2
- ETSI ISG PDLs

- P1 Foodchain final on-site demo
- Stakeholder interviews, PoC proposals

Q4

- 5th and final code release
- ETSI ISG PDL & ETSI Brightalk

- P2 DEDE assets demo to AKKA (France) Energy Big data platform

Q1 & Q2

- 2 papers using SOFIE concept and findings as input
- Participation in 2 Conferences presenting SOFIE results

- Onboarding with hyperledger community promoting INDY case-study from SOFIE
- Contributiong to ETSI ISG PDL-005 with 5G Spectrum Sharing as PoC, 5G SE leverage on results from SMAUG

- 3 PoCs in Energy and Food Supply Chain
- 2 new project proposals
- 4 SOFIE adapters use-cases

Q3 & Q4

- One course launched that reuses SOFIE results

- 1 project won for SOFIE adapters
- 2 SOFIE partners investment to continue business activity with adapters

DEDE - Decentralised energy data exchange pilot (pilot 2)
BMC - Business Model Canvas- plan how to build busniess from SOFIE results
DSO - Distribution system operator
TSO - Transmission system operator
BC - Blockchain

P1 - Pilot 1 - SOFIE foodchain pilot in Greece
P2 - Pilot 2 - SOFIE energy data exchange pilot in Estonia
P3 - Pilot 3 - SOFIE energy marketplace pilot in Italy
P4 - Pilot 4 - SOFIE mixed reality gaming pilot in Finland

Figure 3. The SOFIE Exploitation Roadmap

Future Academic Exploitation

During its lifespan, SOFIE was successful in academic exploitation. Our numerous publications ignited and enhanced the project's technological advancements. Each year we attracted new Master's and PhD students to be involved in SOFIE and write dissertations related to the challenges and the solutions that the project offers. Additionally, the project enabled the transfer of knowledge to current and future ICT specialists through several courses that our academic partners launched and upheld throughout the years of the project. Last but not least, SOFIE results have been used in other R&D projects, contributing to advancing other research challenges.

The future activities in the academic field are based on the same pattern as was followed during the project. SOFIE academic partners (Aalto and AUEB) will continue to put together the ideas for research papers that are based on the SOFIE academic results. There is also interaction between commercial SOFIE partners and academic ones. The aim is to contribute to joint papers as co-authors with concrete industrial and commercial viewpoints, as well as in some cases publish papers focused entirely on commercial partners perspectives and issues. For example, Rovio is planning to publish a paper about mixed reality gaming related technological achievements and findings. The main responsibility for the exploitation of the academic results will be on AUEB and Aalto.

Aalto University will continue actively participating in the academic community and plans to submit at least three scientific publications during 2021 related to Interledger, security and privacy, and system dynamics modelling.[12] The publications will be submitted to scientific journals and/or conferences or workshops in the field of IoT, distributed ledgers, and blockchains, with the aim to disseminate SOFIE results and create more liaisons with other researchers in relation to this topic.

Secondly, the contribution from AUEB to beyond the SOFIE project is similar to that for Aalto University. In order to raise the potential success and taking into account the expertise covered by AUEB, the academic components to work on beyond the project's end are different. AUEB will concentrate on the Identity, Authentication and Authorisation and Privacy and Data Sovereignty SOFIE components, but also auditability and automation in IoT through smart contracts with goal to prepare at least 3 papers to be submitted for publication in 2021.[13] The participation in conferences and workshops is approached in the same way with Aalto University and will support reaching the goals set in the SOFIE roadmap.

Additionally, both academic partners still plan to launch one additional course that relies on the SOFIE academic results.

Moreover, we will keep synergising academic results with commercial offers beyond the project. These actions are related to ongoing H2020 projects like H2020 PHOENIX, H2020 IoT-NGIN, H20202 InterConnect, and EMPIR SmartCom. These projects are continuing in 2021 and 2022 and SOFIE partners (Aalto, Synelixis, Engineering) that participate in the projects will use the projects' connections to find stakeholders that would be interested to test SOFIE commercial components. The goal is to have at least three collaborative discussions that would lead to one Proof-of-Concept proposed and eventually a commercial project.

[12] A SOFIE paper on Systems Dynamics modelling of IoT federations has been submitted at the end of April 2021.

[13] A journal paper on blockchain and smart contract based open mobile gaming ecosystems, was published after the end of the project by AUEB (as also mentioned earlier):

I. Pittaras, N. Fotiou, V.A. Siris, G.C. Polyzos, "Beacons and Blockchains in the Mobile Gaming Ecosystem: A Feasibility Analysis," *Sensors*, vol. 21, no. 3, January 2021.

Future Commercial Exploitation

The commercial exploitation gathered momentum during the first year of the project, as we settled in the SOFIE concept, components, adapters and related work. With the second year, the user interaction in each of the SOFIE pilots and in the project in general was raising and resulted in solid requirements to materialize the prototypes in each pilot. The integration of the pilots before the project's full review on the stakeholders' premises (2019 Q3) was a great achievement. Midway through the project it was determined that out of the four pilots three will have follow up financing and ongoing commercial activities. For 2021 we have planned multiple ways to achieve the commercial success with the SOFIE assets. The preferred one is getting financing for Proof-of-Concept (PoC) projects. Another option is to get financing through stakeholders' R&D resources by signing innovation project contracts. Achieving a commercial contract one or the other way will be the final step before proposing a product or service to end-users.

The exploitation of SOFIE results can continue realistically only if further resources are dedicated to the activities. The outcome of the SOFIE project is that currently three assets have reached the stage where additional resources have been committed to continue the activities beyond the project. The owners of these assets are Guardtime, Engineering, and Synelixis and are presented in Table 3. This was also mentioned in Section 2.

Table 3: SOFIE preliminary exploitable commercial assets

ID	Name	Description	Stakeholders
8	Decentralised Energy Data Exchange adapter	Commercial asset providing access control and governance to smart meter data and datahub integration (owner Guardtime)	Elektrilevi, Akka, PSE
9	Decentralised Energy Flexibility Marketplace adapter	Commercial asset providing data exchange from IoT to energy flexibility services (owner Engineering)	Italian DSOs, car charging network owners
12	SynField platform for traceability and audit services	Commercial asset providing access control, overview, and traceability services for Food Supply Chain participants (owner Synelixis)	7Grapes, Cooperative Winery of Nemea

The common future goal for these three assets is the possibility to invest resources for the commercialization within 3-6 months after the project ends and acting upon the business plans (presented in detail in D6.10) we have made for the beyond the project period. Making proposals to finance the PoCs, as well as compiling procurement documents and being involved in consortia that bid to the regional or national level procurements (smart grid building and upgrading, logistics and warehouse software etc.) are part of the planning. The direct outcome of these activities is expected to be at least one commercial project won during the second half of 2021.

It should be noted that, based on the requirements of each commercial partner's Management Board, there are more detailed exploitation scenarios that include market segments that should be targeted, the estimation of potential cash flow, success rate of bids, and the timeline and financial expenditures calculation. The near-future portion of those company internal plans are manifested as actions which we also describe in D6.10, the business planning document.

Future Community and Standardization related exploitation

During the three years of the project, SOFIE succeeded in its goal to release our framework code as open source. Code versions were released 5 times within 3 years and are accessible through our GitHub repository. The code was constantly improved through continuous integration, deployment, and validation processes, to provide the best quality components and tools for anyone interested in using SOFIE solutions. Throughout the project, SOFIE was dedicated to liaison with other projects and made efforts to reach out to IoT related communities. SOFIE partners were also active in several standardization bodies, but our most substantial efforts were made through the ETSI Industry Special Group for Private Distributed Ledgers (ISG PDL). We made significant contributions to the ETSI PDL-004 draft on Smart Contracts and the ETSI PDL-006 draft on Interoperability and a proposal for including the SMAUG reference implementation in the ETSI PDL-005 Proof of Concepts Framework specification.

During the 2021year, SOFIE consortium partners intend to continue the engagement with the IoT community and to be involved in activities (e.g., interaction with relevant technology related social groups) to create more interest to use the SOFIE assets. Finally, we will utilize the SOFIE consortium members' networks to generate more interest (through articles, white papers, conference presentations) to use DLTs and Interledger for the "liberation" and governance of the IoT and data silos and pave the way to usage of both open source SOFIE assets as well as the SOFIE commercial assets. Additionally, we will continue providing input to standardisation bodies, especially to the ETSI ISG PDL, where the SOFIE results will push further topics such as: decentralisation, high-layer interoperability, federation, and openness of IoT and data business platforms.

5.3 Licencing and IPR

Intellectual Property Rights (IPR) and future exploitation of results is treated according to the principles and framework agreed in the Consortium Agreement.

The SOFIE open source framework components have been released under the Apache License Version 2.0. Licensing of pilot components is up to the pilots. Terms of licensing will be agreed between the owner of the IPR (e.g., pilot lead) and the potential user. IPRs are owned by the consortium partners that generated the intellectual property.

Since most of the results of the SOFIE project, such as the SOFIE federation framework, have been released under open source license and are described in scientific publications, other parties can easily utilize and exploit them.

6. Conclusion

The SOFIE project has reached considerable success in terms of exploitation, as shown by this deliverable, in the cases of academia, industry, and community. We have developed clear and strong value propositions and planned and realised out-reach activities to engage in mutually beneficial collaborations with our stakeholders (Elering, Elektrilevi, AKKA, PSE, ENEL, and 7Grapes Cooperative Winery of Nemea). The future of the SOFIE results reaching additional exploitation stages is viable and versatile.

Throughout the project, all SOFIE partners have maximized their efforts to strategically exploit both the scientific and commercial assets created in the project. Individual exploitation results and future plans have been presented for each partner, including the academic partners. The academic partners have already started to integrate SOFIE research and open-source software into courses and seminars. Additionally, SOFIE academic partners have received new grant funding in the fields of Smart Homes and Smart Energy Grid (H2020), Decentralised Storage (from Protocol Labs), Self-Sovereign, DID-based naming in the NDN Future Internet architecture (H2020 EU-US NGIatlantic.eu).

Individual exploitation results and future exploitation avenues for each of the industrial partners were also reported. Our exploitation roadmap shows how the commercial impact of e.g., the decentralised energy data exchange, the energy flexibility marketplace, traceability in food supply chain and utilizing DLT to enhance the gaming experience has begun. The actions, to contribute to these high-level challenges start with implementing SOFIE assets in each stakeholder premises (with the support of commercial investment). When having a wider coverage of the services in the targeted business sector it will result in more efficient effect on the larger goals of enabling new services to the market, visibility, and more efficient and high-quality services to end-users. In relation to that, the SOFIE framework has a crucial commercial importance to create business advantages for these fields, but also to facilitate the creation of cross-sectoral business opportunities. Given especially the heightened need to decentralise and liberate energy data (data access being a cornerstone of future services by the European Data Governance Act[14] of 2020) and to assure end-user control over their produced or consumed (energy) data, the exploitation of the energy data exchange use-case by Guardtime is very promising. Similarly, excellent further exploitation performance is expected from the food supply chain use-case, where Synelixis has already successfully carried out on-site deployment of the pilot on end-user's premises. The next step is to get a commercial service for a food supply chain in production and look for potential ways (e.g., cooperation with existing system operators) to expand the market reach.

In terms of offering the SOFIE Framework and components to be utilised by those interested, we have made the developed software available as open source on GitHub and promoted on other external channels. We envision our assets being utilised by various interest groups even beyond the specific use-cases our project has focused on. For this reason, we have demonstrated that the SOFIE high level reference architecture, supported by the 6 framework components, can be implemented in very different situations, through our reference implementation: Secure Marketplace for Access to Ubiquitous Goods (SMAUG). The latter showcases the practical realization of our developed architecture. SMAUG proves the benefits for workload reduction in the system development and implementation phases. In the future, LMF Ericsson is dedicated to developing a proof of concept for 5G Spectrum Sharing that relies on and builds further on SMAUG.

Additionally, the SOFIE project has successfully engaged with several standardization bodies and made significant contributions to the ETSI Industry Special Group for Private Distributed Ledgers (ETSI ISG PDL). This work will be pushed forward even beyond the project, as LMF Ericsson is planning further contributions to the Proof of Concepts Framework (PDL-005).

[14] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020PC0767

The SOFIE exploitation strategy and roadmap contribute to the success of the project and already show potential long-term commercial sustainability after the lifetime of the project. Therefore, academic development, academic-industry collaboration, industry commercialization, academic and industry alliances, and community development are assured to continue.

Appendix 1

This Appendix presents the expanded list of items showcased on Exploitation Roadmap (Figure 2) highlights. The items are segmented by topic and presented according to the exploitation verticals. It should be noted that on the Exploitation Roadmap many items were combined in order to simplify the visualization of the content.

Academic vertical

Courses:

- A graduate course "Postgraduate Seminar in Communications Engineering on Data Economics" was held in Aalto University, 2018 Q3
- Microservice architectures and serverless computing" course was held in Spring 2019 in Aalto University, 2019 Q2
- Microservice architectures and serverless computing" course was held in Spring 2020 in Aalto University, 2020 Q2.
- "Microservice architectures and serverless computing" course was held in Spring 2020, 2020 2Q.
- AUEB graduate Computer Science program “Blockchains and Smart Contracts,” 2018 Q2
- AUEB graduate Computer Science program “Blockchains and Smart Contracts,” Spring 2019, 2019 Q2.
- AUEB graduate Computer Science program “Blockchains and Smart Contracts,” Spring 2020, 2020 Q2.
- At least one course launched that reuses SOFIE results, 2021 Q3-4.

Theses:

- Two Aalto’s PhD Students started working on SOFIE, 2018 2Q
- Aalto supervised one SOFIE-related master’s thesis, 2019 2Q
- Aalto supervised second SOFIE-related master’s thesis, 2020 2Q
- AUEB PhD student contributing to SOFIE project PhD dissertation “IoT resource access based on blockchains” (working title), 2018 2Q
- AUEB PhD dissertation undertaken in the related area of Blockchain security, 2018 2Q
- AUEB MSc theses “Interacting with the Web of Things using Blockchains” directly related to SOFIE, 2019 2Q
- AUEB MSc theses “Interledger Approaches” directly related to SOFIE, 2019 2Q
- AUEB MSc theses “Consensus in Blockchain” related to SOFIE, 2019 2Q
- AUEB MSc theses “Creating a ‘Store of Value’ platform for cryptocurrencies” related to SOFIE, 2019 2Q
- AUEB PhD dissertations undertaken “Secure interoperability for Internet of Things data and actuation,” 2019 3Q
- AUEB MSc thesis “Internet of Things Gateway Access Control” related to SOFIE, 2020 2Q

Other projects utilize SOFIE:

- SOFIE results were utilised by H2020 PHOENIX, EMPIR SmartCom, and EIT Climate-KIC GOWOOD projects, (Aalto), 2019 Q1
- SOFIE results were utilised by H2020 PHOENIX, H2020 IoT-NGIN, and EMPIR SmartCom projects, (Aalto), 2020 Q1
- SOFIE connected H2020 project “Interoperable Solutions Connecting Smart Homes, Buildings and Grids” (InterConnect), (AUEB), 2019 Q1
- SOFIE results were utilised by undertaken project “Self-Certifying Names for Named Data Networking,” (AUEB), 2020 Q1

- SOFIE expertise exploited in undertaken project “Eclipse-Resistant Network Overlays for Fast Data Dissemination,” (AUEB), 2020 Q1

Top publications:

- Y. Kortesniemi, D. Lagutin, T. Elo, N. Fotiou, “Improving the Privacy of Internet of Things with Decentralised Identifiers (DIDs),” *Journal of Computer Networks and Communications*, vol. 2019 (Article ID 8706760), 2019 Q1
- V.A. Siris, P. Nikander, S. Voulgaris, N. Fotiou, D. Lagutin, G.C. Polyzos, “Interledger Approaches," *IEEE Access* 7: 89948-89966, 2019 Q2
- V.A. Siris, D. Dimopoulos, N. Fotiou, S. Voulgaris, G.C. Polyzos, “OAuth 2.0 meets Blockchain for Authorization in Constrained IoT Environments,” Proc. IEEE 5th World Forum on Internet of Things (WF-IoT), 2019 Q2
- N. Fotiou, I. Pitarras, V.A. Siris, S. Voulgaris, G.C. Polyzos, “OAuth 2.0 authorization using blockchain-based tokens,” Proc. Network and Distributed System Security Symposium (NDSS) Workshop on Decentralized IoT Systems and Security (DISS), San Diego, CA, USA, 2020 Q1
- V.A. Siris, D. Dimopoulos, N. Fotiou, S. Voulgaris, G.C. Polyzos, “Decentralized authorization in constrained IoT environments exploiting interledger mechanisms,” *Computer Communications* 152: 243-251 (2020), 2020 Q1
- Two papers using SOFIE concept and findings as input, 2021 Q1-2.

Academic events:

- Participation at least in two conferences presenting SOFIE results, 20221 Q1-2

Commercial vertical

Business Model Canvas:

- Stakeholders consolidated list and value prop for BMC approach, 2019 Q1
- BMC full version for demos, 2019 Q4
- BMC final version for exploitation, 2020 Q2
- Two SOFIE partners investment to continue business activity with adapters, 2021 Q3-4

Pilots value propositions:

- First Pilot projects concept value proposition, 2018 Q2
- Onboarding Elering as stakeholder (in advisory board), 2018 Q4
- Onboarding 7Grapes as stakeholder (in advisory board), 2018 Q4
- Midterm Pilots value proposition, 2019 Q3
- Onboarding DSOs/flexibility service providers (Elektrilevi, Scener), 2020 Q1
- 3 Proof-of-Concepts in Energy and Food Supply Chain, 2021 Q1-2
- Four SOFIE adapters use-cases, 2021 Q1-2

Software releases:

- P1 SOFIE SynField Federation Adapter release, 2019 Q1
- P1 SOFIE Aberon Federation Adapter, 2019 Q2
- P2 SOFIE Energy Data Exchange Adapter release, 2019 Q2
- P3 SOFIE DEFM Energy federation adapter, 2019 Q3
- P3 Decentralised Marketplace for Energy Flexibility Services, 2019 Q2
- P4 Scavenger Hunt game initial release - 2019 Q3
- P4 Scavenger Hunt game open source release - 2020 Q4
- P1 Final SynField platform for traceability and audit services, 2020 Q2
- P2 Final Energy Data Exchange Adapter release, 2020 Q3
- P3 Final Decentralised Marketplace for Energy Flexibility Services release, 2020 Q2

- P4 Final Mobile Gaming pilot release, 2020 Q1

On site demonstrations:

- P1 Food Supply Chain Kiato site demo to 7Grapes, 2019 Q3
- P1 Food Supply Chain pilot onsite demonstration, 2020 Q3
- P2 SOFIE DEDE adapter used in Elering Estfeed platform, 2019 Q2
- 2019 Q3 - P2 SOFIE DEDE adapter used in EU-SysFlex project, 2020 Q2
- P2 SOFIE assets demonstrated to AKKA (France) Datahub, 2020 Q4
- P3 ASM Terni on site demo, green energy and smart grid management, 2019 Q3
- P4 IoT beacons and Blockchain demo in Junction hackathon (Finland), 2019 Q2
- P4 Scavenger hunt demo to stakeholders, 2019 Q3

H2020 proposal inputs:

- P2 SOFIE concept used as input for SACCESS H2020 proposal, 2019 Q3
- Two new project proposals, 2021 Q1-2

Projects:

- One project won for SOFIE adapters, 2021 Q3-4

Top events:

- SOFIE I workshop at Decentralized, 2019 Q3
- SOFIE II workshop in collaboration Cyberwatching.eu, 2020 3Q
- P1 SOFIE III Workshop interviews,2020 Q4
- P2 SOFIE III Workshop interviews, 2020 Q4
- P3 SOFIE III Workshop interviews, 2020 Q4
- P4 SOFIE III Workshop interviews, 2020 Q4

Community and standardization

Open access releases:

- The first code release was made in September 2018, 2018 Q3
- The second code release was made in October 2019, 2019 Q3
- The third code release was made in April 2020, 2020 Q2
- The fourth code release was made in September 2020, 2020 Q2
- The fifth and final code release was made in December 2020, 2020 Q4
- SOFIE open-source components added to Cyberwathcing.eu marketplace, 2020 Q2
- SOFIE open-source components added to SecureIot.eu marketplace, 2020 Q2

Standardization:

- W3C Web of Things Interest Group
  - Presentation on “Using Decentralized Identifiers (and Verifiable Credentials) in IoT Services”, 2020 Q2
  - Presentation on “Using Verifiable Credentials in IoT Services”, 2020 Q3
- IETF/IRTF - Contributions to IRTF T2TRG and IETF CoRE WG
  - Participation in a pre-standardization IRTF workshop on Decentralized Internet Infrastructure with a presentation on SOFIE’s ideas on a secure, open, decentralized IoT, 2018 Q1
- ETSI
  - ETSI IoT Workshop - SOFIE’s work on the role of Distributed Ledger Technology (DLT) for authorization in environments with constrained IoT devices was presented, 2019 Q3

- ISG PDL Significant contributions to: PDL-004 Smart contracts PDL-005 Proof of Concepts (SMAUG, 5G Spectrum Sharing) (not available yet publicly) PDL-006 Interoperability, 2020 Q3
- ETSI ISG PDL Brighttalk - presenting SOFIE and SMAUG, 2020 Q3
- Onboarding with hyperledger community promoting INDY case-study from SOFIE, 2021, Q1-2
- Contributing to ETSI ISG PDL-005 with 5G Spectrum Sharing as PoC, 5G SE leverage on results from SMAUG, 2021, Q1-2