H2020 5Growth Project
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D1.2: Techno-economic analysis and business model validation methodology

Abstract

This document reports a preliminary quantitative analysis of the economic benefits introduced by the adoption of innovations enabled by 5G in the case studies belonging to the four pilots, pillars of 5Growth project. In order to provide a quantitative analysis a methodology is described and uniformly adopted in all case studies.

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List of Acronyms

AIC – Automotive Intelligence Center

AGV – Automated Guided Vehicle

AQCS – Advanced Quality Control Systems

ASF – Automotive Smart Factory

CapEx – Capital Expenditures

CMM – Coordinate Measuring Machine

CPE – Customer Premises Equipment

CPPS – Cyber Physical Production System

DSO - Distribution Service Operator

DSS – Decision Support System

DTC - Distribution Transformer Controllers

eMBB – enhanced Mobile Broadband

EU – European Union

IoT – Internet of Things

LoRA – Long Range

LX – Level Crossing

LV – Low Voltage

M2M – Machine-to-machine

MANO – Management and Orchestration

mMTC – massive Machine Type Communications

MTTR – Mean Time to Repair

MV – Medium Voltage

NR – New Radio

OpEx – Operational Expenditures

PLC – Power Line Carrier

QoS – Quality of Service

RASTA – Rail Safe Transport Application

RoI – Return on Investment

SAIDI – System Average Interruption Duration Index

SCADA – Supervisory Control and Data Acquisition

SIL – System Integrity Level

SIM – Subscriber Identity Module

TCO – Total Cost of Ownership

URLLC – Ultra Reliable And Low Latency Communications

YTCO – Yearly Total Cost of Ownership

ZDM – Zero Defect Manufacturing

Executive Summary and Key Contributions

This document reports the work done in Task 1.2 "Techno economic analysis and business model validation", resulting in a *preliminary* quantitative evaluation of the economic benefits introduced by 5G technologies into vertical industrial use cases and the activities envisaged by 5Growth. In particular, in this deliverable we propose a common methodology for the business model validation and apply it to calculate the overall economic benefits for each use case, which are projected to a European scale. The distribution of these costs among the different stakeholders, will be further analyzed and reported in the final D1.3 deliverable [35].

The analysis has been carried out by creating and applying a common methodology, devoted to understanding the economic advantages of adopting the solutions and innovations promoted by 5Growth (and described in deliverable D2.1 [34]). The business analysis aims to evaluate the difference in expenditures between a situation with and without applying 5G technologies, considering the solutions envisaged by 5Growth. In fact, we identify, for each pilot, where the introduction of new technologies can bring benefits from an economical point of view. Some of these benefits refer to investment, other to operational expenditures or new revenues. In order to consider multi-year expense savings and revenues we introduce of the "Yearly Total Value".

All the use cases described in the project have been analyzed using this methodology. For each use case we identify the requirements, in terms of rough economic benefits, i.e. cost saving percentage and qualitatively advantages by identifying, for each use case, its peculiarities. We next summarize the main findings of the deliverable per 5Growth pilot family:

- **Industry 4.0 Pilot - INNOVALIA**

  The main benefits for this pilot can be grouped in two large blocks, each corresponding to each of the use cases included: on one hand, the reduction of trips for the set-up and maintenance of the Coordinate Measuring Machine – CMM (ranging from the reduction of the travel expenses, increasing the availability of experts, reducing the response time and also the maintenance costs); and, on the other hand, the optimization of the usage of the CMM (including this item and the reduction of the lot size). Also considering the additional cost of the technology (spectrum, network slices, edge computing and video platform), the expected benefits on a European scale will exceed 16.9M€. It is worth noting that most these benefits are in the category of OpEx, what means that the saved money is immediately available for other purposes (contrary to CapEx, that require a disinvestment to make the money available).

- **Industry 4.0 Pilot - COMAU**

  Main economic benefits are a consequence of the introduction of 5G technologies in the factories, simplifying the acquisition and centralization of the information in order to have always updated data which provides continuous monitoring and simplifies decision making in the production chain. This innovation increases the quality of the resulting product, allowing significant savings, due the reduction in the number of discarded pieces. Additionally, the flexibility of the wireless deployment reduces the costs of a traditional wired deployment, including the civil works and the operational and provisioning tasks. We estimate that, in a European scale, the yearly benefits would almost reach 10.5M€. Similar to the INNOVALIA case, cost savings in the COMAU's pilot are related to OpEx.

- **Transportation Pilot - EFACEC Engenharia e Sistemas**

  In this pilot, social benefits are substantial, as it is expected that the deployment of the pilot will significantly reduce the number of accidents and will allow to avoid a 5% of the deaths on railway crossings in Europe.

  But the pilot also has significant economic benefits, mainly due to the flexibility of the wireless mobile deployment compared to the wired solution, leading to a reduction in installation, maintenance, and security costs. What makes this pilot particularly interesting in terms of expected benefits, is the replicability of the implementation, as it is considered that the European market could accommodate up to 60,000 new generation level crossings, which would represent a yearly benefit of more than 2.2 billion euros.

- **Energy Pilot - EFACEC Energia**

  For the Energia Pilot one of the main sources of benefit, is the reduction of the Energy Not Supplied (ENS) which is measured through the Value of Lost Load (VOLL). However, there are other items also relevant, such as the maintenance costs (both local and remote), the edge computer or the network operational costs. When projected on a European scale, the benefits are estimated in the range between 110M€ and 245M€.

  There are some additional benefits that have not been considered as they cannot be projected to a European scale, because of the different regulations for the different countries.

Approximately, 50% of the reported benefits are directly attributable to the innovations developed in the 5Growth project that are described in D2.1 [34] and mapped to the pilots in D3.1 [33]. The remaining 50% are obtainable due to the introduction of 5G, not specifically associated with 5Growth.

It is important to highlight that the income statement concerns mainly savings on investments, operating costs, or an increase in production and, consequently, in revenues, due to higher sales.

Collateral advantages are hardly taken into consideration, which are difficult to monetize, such as lower environmental impact, greater safety, a better overall life of citizens.

The exceptional situation due to the COVID-19 pandemic has impacted some of the work of Task 1.2 due to the partial stop/slowdown of the activity of some key vertical partners. Because of this, some items of the techno-economic analysis, such as the analysis of the distribution of the costs among the different stakeholders, will be delivered in D1.3 [35], together with updates of some parts addressed in this document.

Last, but not least, it is worth mentioning that 5Growth has contributed to a whitepaper [31] organized by the 5G Public Private Partnership (5G PPP) and the 5G Infrastructure Association (5G IA) that summarizes the progress and results produced by 5G PPP projects, while developing some innovative 5G network services and solutions for vertical industries. The white paper provides information about requirements and addressed business cases. It also discusses in detail several exemplary use cases from eleven different vertical sectors and identifies key 5G features that have been used to meet the specified requirements.

In addition to this, different videos are being generated by 5Growth explaining the overall goals of the project as well as the use-case/pilot specifics, including the identified benefits. At the time of the publication of this deliverable, some of these videos are already available on the 5Growth YouTube channel[1], while others are under preparation.

[1] https://www.youtube.com/channel/UCfIAsV6AdEibRteQp2ftpgw

1. Introduction

This document summarizes the work done under Task 1.2 (T1.2) by estimating the possible economic advantages due to the implementation on EU scale of the use cases envisaged by 5Growth of which 5G is a facilitator. The economic advantages are mainly attributable to savings on CapEx and OpEx, due to better organization and monitoring obtainable thanks to more advanced communication techniques. Other economic advantages can instead be found in a greater increase in production capacity in some sectors, which results in an increase in revenues.

This deliverable is organized as follows. Section 2 expands the results reported in D1.1 [3], summarizing vertical Pilot's requirements (for the sake of self-containment) and reporting what is expected from an economical point of view from each of the 5Growth use cases.

Section 3 first presents the methodology followed for the quantitative evaluation. Then, a detailed analysis of the four vertical Pilots is provided, reporting numerical preliminary evaluations about savings and new revenues obtained by the adoption of the 5G (general and 5Growth-specific) envisaged innovations and solutions.

Finally, section 4 outlines the conclusions of this study. The main conclusion is that huge cost savings are expected by the introduction of 5G in the 5Growth verticals. The main economic advantages are related to the possibility for remote operations that were traditionally handled on site, reducing the cost of operation (OpEx savings). The "softwarization" of some activities, e.g., monitoring, quality check, safety assurance, will further reduce costs. It is fundamental to highlight that, alongside important economic advantages (which certainly represent a driver for the adoption of these technologies) there are also social advantages as enhancing physical security with the consequent saving of human lives, reduction of pollution and better quality of life for citizens.

For the sake of a better readability, we have kept the content of this deliverable short. Please, also note that D1.3 [35] will provide updates of certain aspects, complementing this deliverable, and reporting on the work of T1.2 and T1.3.

2. Summary of vertical Pilot's overview and requirements

This section summarizes vertical Pilot's requirements reported in D1.1 [3] and highlights the business benefits of the pilots, to setup the starting point for the techno-economic analysis.

2.1. Industry 4.0 Pilot - INNOVALIA

INNOVALIA's industry vertical pilot will deploy two use cases. The first use case, *Connected Worker Remote Operation of Quality Equipment* (show in Figure 1) will explore how 5G technologies can be used to enable remote access to M3BOX, an edge device used to control the Coordinate Measuring Machine (CMM), in order to perform setup and configuration operations that nowadays require an expert to travel to the customer's premises. The second use case, *Connected Worker Augmented Zero Defect Manufacturing Decision Support System* (shown in Figure 2) will involve the development of a Machine to Machine (M2M) collaboration system using 5G technologies that will improve the flexibility and productivity of the CMM. More information can be found in D1.1 [3] and D3.2 [30].

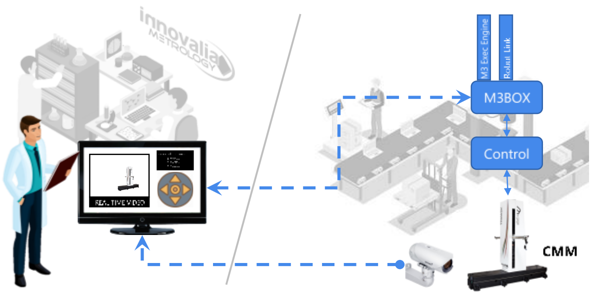

FIGURE 1: CONNECTED WORKER REMOTE OPERATION OF QUALITY EQUIPMENT

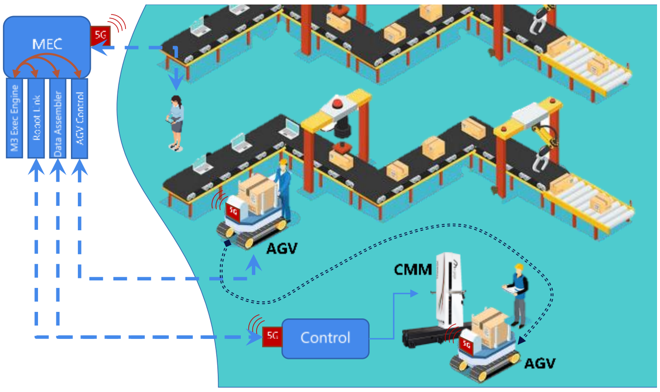

FIGURE 2: CONNECTED WORKER AUGMENTED ZERO DEFECT MANUFACTURING DECISION SUPPORT SYSTEM

2.1.1. Trial use cases

2.1.1.1. P1UC1: Connected Worker Remote Operation of Quality Equipment

This use case investigates 5G network slicing capabilities and latency reduction to enable the implementation of a global virtual joystick for remote programming, configuration, and calibration of the CMM for quality control routines.

The remote operator will be able to control the movement of the CMM by means of a virtual joystick and two video cameras: one providing a real-time video stream with a general vision of the CMM and another one a detailed vision of the surface being scanned (with another camera mounted on the optical sensor).

This will allow to perform one of the most usual maintenance tasks remotely: the setup of the CMM with a new measuring program, and the fine tuning of the program.

When a customer wants to measure a new reference, the program is designed and coded offline, but an Innovalia expert has to travel to the customer site to fine-tune the program and setup the CMM - to run the program. This use case will enable Innovalia to perform this task remotely, saving money both for the company and the customer.

2.1.1.2. P1UC2: Connected Worker Augmented Zero Defect Manufacturing (ZDM) Decision Support System (DSS)

This use case deals with how 5G technologies can be used to support large (automotive chassis) 3D point cloud for computational geometry processing and visualization while keeping the time required to perform this analysis low. The pilot will assess the processing and visualization of large 3D point clouds using Cloud Edge technologies.

A second aspect addressed in this use case, is the development of a new M2M collaboration process, to automate the process of loading the inspection program for the CMM, while an AGV is transferring the piece to be measured from the production line to the measuring station.

2.1.2. Target Business KPIs

Table 1 summarizes the target business Key Performance Indicators (KPIs) for the INNOVALIA pilot.

TABLE 1: TARGET BUSINESS KPIS FOR THE INDUSTRY 4.0 PILOT – INNOVALIA

5G Service required These use cases will require both requires eMBB for the 4K video streaming and the communication between the CMM and the Cloud-Edge service, and URLLC for the virtual joystick operation.	• Reduce cost of production by 10% • Increase the production throughput by 15% • Reduce customer visits by 40% • Reduce scrap of at least 10% with an objective of 100% • Predict up to 30% of form and/or welding errors • Reduce service response time by 50%
Output The use case will prove that the network delay and resilience provided by either eMBB or URLLC are needed to make this use case properly work for latching between the 4K video and virtual joystick service in the remote configuration of the Vulkan equipment.	
Benefit Customers will not be forced to send large parts of their equipment to Innovalia Metrology laboratories (high cost and waste of time) while, at the same time, Innovalia will not need to send workforce abroad to program control strategies, for long periods of time. Also, the optimization of the usage of the CCM, as it will be possible to measure different references in a much faster way.	

2.2. Industry 4.0 Pilot - COMAU

In the case of COMAU's industry vertical pilot there are three use cases. First, the deployment of *Digital Twin Apps* (Figure 3), that will allow the plant manager to receive live information about the production line through a digital representation of the factory. Second, the development of *Telemetry/Monitoring Apps* (Figure 4), that will provide deeper information, monitoring the status of the equipment installed in the stations (robots, conveyors, motors, and so on), by installing a high number of sensors that use 5G communication technologies. Finally, the last use case will develop *Digital Tutorials and Remote Support* (Figure 5), to enable a high-resolution interface to remotely train and assist the worker on certain tasks. More information can be found in D1.1 [3] and D3.2 [30].

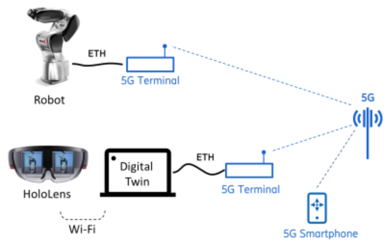

FIGURE 3: DIGITAL TWIN APPS

FIGURE 4: TELEMETRY/MONITORING APPS

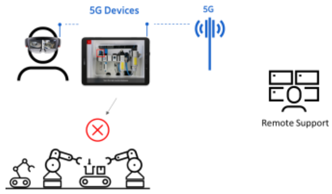

FIGURE 5: DIGITAL TUTORIALS AND REMOTE SUPPORT

2.2.1. Trial use cases

2.2.1.1. P2UC1: Digital Twin Apps

The main idea is to replace the existing infrastructure by enabling communication through 5G and, instead of being the owner of it, just pay for the service provided by telco companies.

The real devices and machines are equipped with a massive number of sensors sending status data to its virtual reproduction on a constant basis. In addition, controllers (e.g., PLCs) feed the virtual replica with status data.

5G wireless networks offers low and predictable latency, under different traffic patterns and network loads. Wi-Fi on the other side provides low average latency but is more sensitive to varying network loads. On the other hand, cellular networks provide better mobility support than Wi-Fi due to its connection handover capabilities.

2.2.1.2. P2UC2: Telemetry/Monitoring Apps

Failure detection is a challenge that exists throughout the manufacturing industry. Issues, such as vibration patterns affecting the robots, could be revealed by monitoring the process in real time.

5G facilitates using a plethora of new wireless sensors, easy to attach on robots even in legacy plants: sensors with long lasting batteries and communicating few data in real time. Example of sensors are pressure, temperature, vibration (IMU). Correlating data from these sensors would enhance monitoring and prevention.

The use case explores the capabilities of 5G to support massive communication with sensors pinging data, in all machines on the shop floor, maintaining at the same time the same availability/reliability over wireless, compared to the one offered by conventional wired connections.

2.2.1.3. P2UC3: Digital Tutorials and Remote Support

This use case has the objective to reduce the Mean Time to Repair (MTTR), as well as the cost of maintenance and fixing activities. It is achieved by providing a of a digital tutorial library combined with remote support thank to high definition streaming and live connection. Hence, it is not strictly necessary to get skilled people directly where the problem actually happens; a local technician could be assisted there by a more specialized staff physically far from him. Doing that it is possible to reduce costs and increase the availability of technical staff that can operate remotely.

The value of 5G here is mainly related to its provided high data rates to stream video flows at any definition with no interruptions and with the possibility to scale up the number of active users, using the application.

The value of 5G here is mainly related to its provided high data rates to stream video flows at any definition with no interruptions and with the possibility to scale up the number of active users, using the application.

2.2.2. Target Business KPIs

Table 2 summarizes the target business KPIs for the COMAU pilot. The objectives listed in the table should be interpreted as "objectives" obtainable with the concurrent implementation of all three use cases, rather than associating them with each one individually. For example, reducing repair time by 20% can be a goal that can be achieved both by having an eye on the digital twin of the plant (UC1), and by having monitoring information available for predictive maintenance (UC2), and finally having the remote support tools (UC3) for the technician on site.

TABLE 2: Target Business KPIS FOR THE Industry 4.0 Pilot – COMAU

<table>
<tr><th>5G Service required</th><td rowspan="6">Reduce infrastructure cost by 20%
Reduce MTTR by 20%
Reduce of technicians' travels by 30%
Reduce of failure rate at least of 20% with objective 90%
Service response time reduced by 30%</td></tr>
<tr><td>This set of use cases require eMBB to deliver the un-interrupted video streaming to multiple users with high definition formats.</td></tr>
<tr><th>Output</th></tr>
<tr><td>Given the fact that 5G can support increased bandwidth demands, these use cases will deploy applications that will allow users to remotely access digital tutorials and support remote technicians though live connections at high resolution.</td></tr>
<tr><th>Benefit</th></tr>
<tr><td>Main benefits will be an increase in productivity due to the possibility to access live tutorials/instructions and video tutorials, as well as a reduction of MTTR thanks to the real-time connection with technicians in remote locations supporting maintenance and repair operations.</td></tr>
</table>

2.3. Transportation Pilot - EFACEC Engenharia e Sistemas

The transportation vertical pilot, led by EFACEC Engenharia e Sistemas, proposes to use the 5G slice capabilities in order to replace the wired communication used nowadays on railway level crossing environments and reinforce the safety conditions by transmitting video images to train drives and maintenance agents, supported by 5G communications. This is the basis to deploy two use cases: Safety Critical Communications (Figure 6) which are focused on railways signaling operations and Non-Safety Critical Communications (Figure 7), which provide additional information (video images), to reinforce the safety conditions avoiding accidents at Level Crossing area. More information can be found in D1.1 [3] and D3.2 [30].

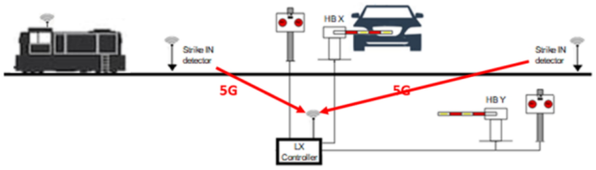

FIGURE 6: SAFETY CRITICAL COMMUNICATIONS

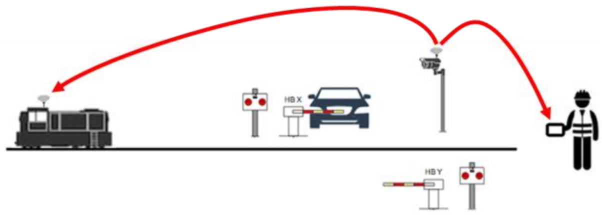

FIGURE 7: NON-SAFETY CRITICAL COMMUNICATIONS

2.3.1. Trial Use Cases

In the pilot, it is desirable to replace cabled based networks by 5G technologies, assuring two types of critical communications: safety critical and non-safety critical.

In the field trial, 5G communications is used to support railway signaling operations, in particular to meet railway level crossing communication requirements (M2M), namely:

- for safety critical communications from approaching train detectors (Strike In detectors) to the level crossing controllers
- for transmission of level crossing real-time video images to mobile devices on approaching trains and to maintenance agent's tablet devices

These Use Cases are supported by the 5G-VINNI 5G infrastructure, extending the coverage to the Aveiro UC locations (in particular for the transportation UC).

2.3.2. Target Business KPIs

Table 3 summarizes the target business KPIs for the transportation pilot.

TABLE 3: TARGET BUSINESS KPIS FOR THE Transportation Pilot – EFACEC ENGENHARIA E SISTEMAS

5G Service required	• Reduce system capex by 20% • Reduce system installation cost by 50% • Reduce installation time by 50% • Reduce cable cost by 80% • Reduce maintenance visits by 20% • Reduce service response time by 20%
This pilot requires URLLC in order to transmit the safety critical communications between the Level Crossing (LX) controller and the level crossing train detector. And eMBB to transmit high definition video to the train controllers and also URLLC to transmit alarms and controller status to the maintenance agents.	
Output	
In this pilot a complete half barrier level crossing control system in a railroad crossing in the Aveiro harbor premises will be installed. The system will include a LX controller cabinet equipped with SIL48 safety PLC, an axle counter train detection system, EMC protections devices, an uninterruptible power supply and a 5G CPE. Each approaching train detectors will use a 5G CPE to communicate with the level crossing controller. Two half barrier drives, controlled by the LX controller, will protect the entry of cars in the rail crossing during the train approaching and passing. All the communications will be supported by safety-critical protocols (Safe Ethernet and RASTA), developed and certified under the scope of the project. Besides, a train engine will be equipped with an onboard 5G tablet, a level crossing with an HD video camera and a server that will connect the LX controller and the camera to the cloud using 5G communications. A mobile tablet will allow the monitoring and control of the level crossing systems. An app running in the maintenance agent tablet will allow the remote control of all LX system.	
Benefit	
The solution should reduce the level crossing capex by 20%, the XSafe (EFACEC_S Level Crossing solution) level crossing system product will become more competitive with respect to the traditional wired level crossing signaling solutions. The level crossing time installation will be reduced by 50%. Also, the development of a new market for the mobile video level crossings safety reinforcement with public standard communications. The remote asset monitoring using 5G will allow much more competitive, flexible and agile solutions compared to the actual wired solutions, allowing the reduction of costs and service response time, and creating new market.	

2.4. Energy Pilot - EFACEC Energia

EFACEC Energia's energy vertical pilot will involve the deployment of two more use cases: *Advanced Monitoring and Maintenance Support for Secondary Substations MV/LV Distribution Substation* (Figure 8), consists of a system to assist the maintenance team when repairing the substation by providing information with augmented reality. The *Advanced Critical Signal and Data Exchange Across Wide Smart Metering and Measurement Infrastructures* (Figure 9) use case will deploy a system to use the last gasp of energy before an outage to save and transmit important information to identify and prevent greater problems. More information can be found in D1.1 [3] and D3.2 [30].

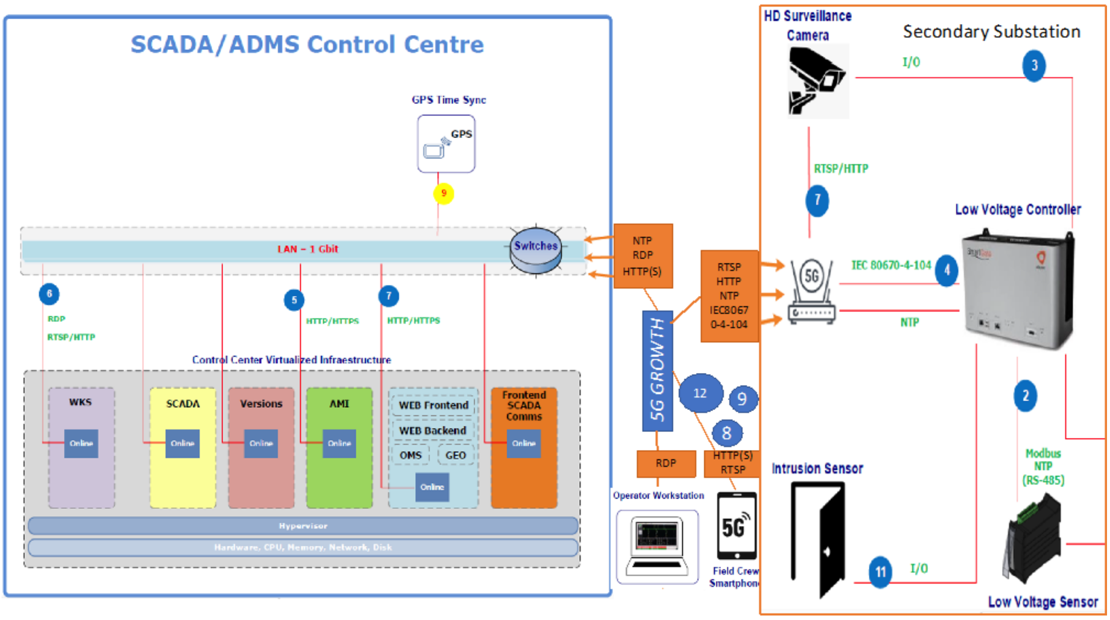

FIGURE 8: ADVANCED MONITORING AND MAINTENANCE SUPPORT FOR SECONDARY SUBSTATIONS MV/LV DISTRIBUTION SUBSTATION

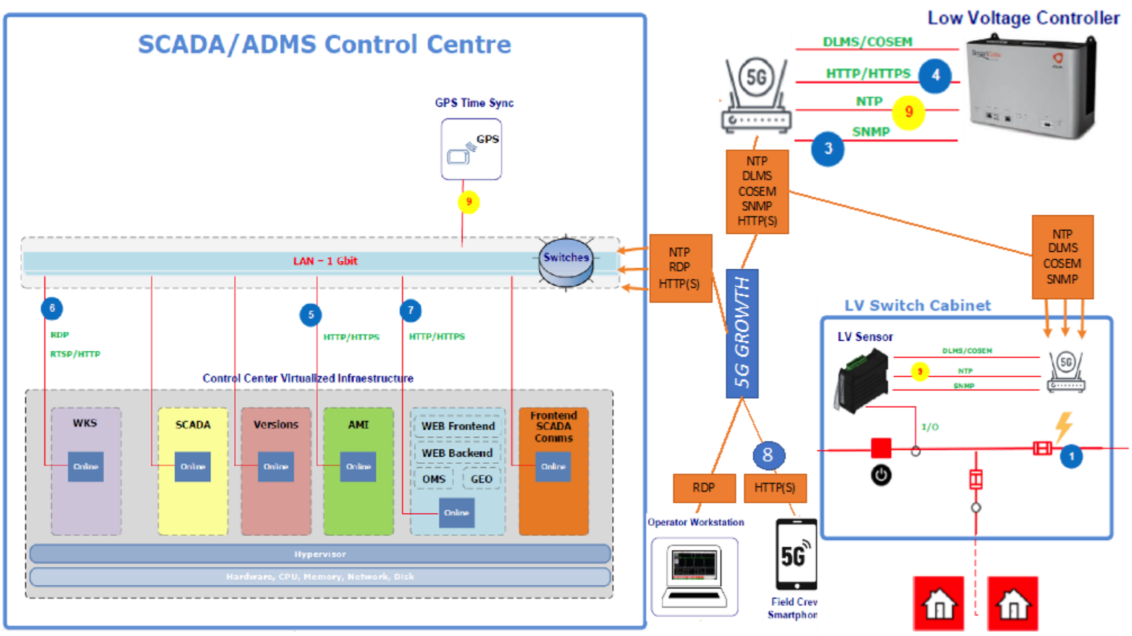

FIGURE 9: ADVANCED CRITICAL SIGNAL AND DATA EXCHANGE ACROSS WIDE SMART METERING AND MEASUREMENT INFRASTRUCTURES

2.4.1. Trial use cases

An enhanced performance from the critical signals' communication, across wide smart sensors infrastructures, is crucial for the deployment of advanced control applications. Also, the advanced monitoring and maintenance support of secondary substation is crucial to improve the outage management and match the high reliability indexes required within a smart grid environment.

Supported by smart devices, e.g., sensors, distributed controllers and concentrators, cloud based edge, electric data meters and more centralized advanced management systems with very low latency communication, the pilot permits targeting an agile signal exchange, between the devices deployed across the network, placed within an area up to 10 km^2, and both the distributed intelligence and the centralized controllers.

This will enrich the information and the current status of low-voltage distribution networks. From the standpoint of maintenance and operation, it will take advantage of 5G's communication capabilities to streamline the process, delivering robust results.

Edge computing will add enhanced distributed control and the capacity to run critical applications for the supervision and control of multiple LV-Smart Grids, and the advanced management of LV Micro Grids.

Concerning 5G communication connectivity, the energy pilot will be supported by the 5G-VINNI experimental site, located in Aveiro and operated by Altice Labs.

2.4.2. Target Business KPIs

Table 4 summarizes the target business KPIs for the energy pilot.

TABLE 4: TARGET BUSINESS KPIS FOR THE Energy Pilot – EFACEC ENERGIA

<table>
<tr><th>5G Service required</th><td rowspan="6">Reduce SAIDI for LV (Low Voltage) in 15%: System
Average Interruption Duration Index (SAIDI) measures the average of the total long duration of interruptions affecting the average delivery point for a given year
Reduce ENS in 5%: Energy not supplied</td></tr>
<tr><td>This pilot requires eMBB to support the video camera and augmented reality streaming, complemented with additional URLLC services for the time sensitive augmented reality application. It also requires mMTC to connect a high number of smart meters and URLLC for the transmission of critical signals.</td></tr>
<tr><th>Output</th></tr>
<tr><td>An advanced monitoring and maintenance support should be available to assist the remote operator and then the crews dispatched to the field to better assess the severity and the impact of the outage they are facing. From the local surveillance systems available in the secondary substation, an HD video signal must be streamed in nearly real-time to the control center and to the mobile devices of the maintenance crew moving to the site. Aware of the infrastructure state, the crew and the operator managing the intervention, can be more efficient when implementing contingency and service restorations measures. Locally, the crews should also be capable of assessing and broadcasting an augmented reality experience on the affected critical assets. The crews will thus gain an insight over the damage magnitude and the immediate consequences of the outage they are dealing with, leading to shorter response times.</td></tr>
<tr><th>Benefit</th></tr>
<tr><td>Enhanced performance from the advanced monitoring and maintenance support of secondary substation is crucial to improve the outage management and match the high reliability indexes required within a smart grid environment. Additionally, the improvement of the advanced critical signal and data exchange across wide smart metering and measurement infrastructures is crucial for the deployment of advanced control applications.</td></tr>
</table>

3. Economical evaluations

3.1. Methodology

5Growth aims at developing and validating a business model for the use cases in a coordinated way, directly engaging all the stakeholders involved, especially vertical actors and their customers, whilst protecting strategic EU IP and ensuring long-term social acceptance and economic sustainability, extending beyond the lifespan of the project through a joint commercialization plan. This business model enables involved stakeholders and external international actors to understand and exploit the project results. For this reason, a methodology devoted to understanding the economic advantages of the adoption of the 5G in general and the solutions envisaged in 5Growth has been considered and adopted to the project's use cases.

Traditional business analysis (e.g., the one performed by the 5G-Crosshaul project, reported in [11]) focuses on the difference in expenditures between a given situation with and without the innovative solution. Since 5G and its application (i.e. 5Growth Innovations) represent a real revolution and not only provides the same results with lower costs, but opens a door to new services and products, this classic approach is not enough. Therefore, a new methodology will take into account not only the traditional cost-reduction approach, but it will also consider the new product/services developed and the new revenue streams associated.

Having as our main goal to show the benefits introduced by 5G and 5Growth and to demonstrate that the project use cases are economically viable, the study includes the benefits for all the stakeholders involved, including EU citizens. Towards that end, we performed a detailed analysis, identifying for each pilot a set of items where the introduction of new technologies (i.e. 5G and all the solutions envisaged by 5Growth) can bring benefits from an economical point of view. Some benefits refer to investment (i.e. Capital Expenditures - CapEx), other to operation (i.e. Operational Expenditures – OpEx) and finally new revenues (RE).

Some of these savings, specially CapEx savings, are often long-term savings that should be annualized to be able to be compared. By adding all the values, annualized when required, we obtain the Yearly Total Value (YTV), which is the parameter that will allow us to compare between legacy and new solution networks:

$$YTV = \sum_{i=1}^{N} \frac{CAPEX_i}{AP_i} + \sum_{j=1}^{M} OPEX_j + \sum_{k=1}^{R} RE_k$$

where:

- $CAPEX_i$ is the i-th component of the N identified items of Capital Expenditures, i.e. the amount of cash flow that a company uses to purchase, maintain or implement its operating assets, such as buildings, land, plants or equipment.
- $OPEX_j$ is the the j-th components of the M identified items of the Operational Expenditures, i.e. operating, maintenance and management costs.

- RE_k is the component of new revenues.

In order to harmonize the sum, each CapEx has to be annualized, splitting the investment by the appropriate Amortization Period (AP). This is the easiest way to calculate the Total Value of a system taking into account CapEx, OpEx and new revenues, neglecting inflation and cost of the money used for investment (for example interests on outstanding debts like bonds, bank loans, etc.).

The analysis performed so far in 5Growth allows us to project these benefits to a European scale. Future work, that will be reported in D1.3, will deepen in this analysis with the objective to obtain the distribution of these advantages among the different stakeholders, and the link between the benefits and the 5Growth innovations deployed in the pilots (initially described in D3.1 [33]).

3.2. General considerations

Although the pilots for which we have assessed the economic benefits brought by the introduction of 5G and the technologies introduced by the 5Growth project are very different, there are nevertheless some common items of expenditure and savings that are worth analyzing in advance, before considering in the specific the various use cases.

The calculated economic advantages, which will be detailed in the next chapter, are based on 3 main pillars:

- Spectrum
- Reduction of installation and maintenance costs
- Better service offered

Spectrum is actually a cost rather than a savings item. In fact, operators have paid portions of spectrum to the nation states to enable 5G frequencies on their network. This expense is passed on to end users, an expense that was not present in solutions that did not include wireless communications. However, this expenditure is enabling 5G which, in turn, enables the technologies that allow to obtain the considerable savings pertaining to the two following pillars and, furthermore, to savings or increase in revenues specific to the individual use cases, which will be analyzed in detail in the following sections.

Personnel costs are usually the largest single cost factor in a company's budget. New technologies that rely on 5G connectivity enable the possibility of making the installation, upgrade, and maintenance of production and control elements more flexible. Often these operations no longer require the presence of the operator in the field (requiring long and expensive transfers) but can be managed remotely. Obviously, this leads to a reduction in operating costs and, in the case of important upgrades, also in a significant reduction in investments.

5G connectivity, together with advanced visualization and sensor systems, allows to obtain a level of control on safety and quality unimaginable before. This allows to obtain better quality of work and to offer customers better products and services. In the manufacturing sector, a more streamlined and efficient quality control allows to reduce the semi-finished products discarded due to insufficient quality and to speed up the production chain. As a consequence, there will be an increase in the number of finished products per unit of time, among other things of higher quality. Obviously, this translates into an increase in revenue.

We provide next a detailed analysis of the four vertical Pilots, reporting numerical preliminary evaluations about savings and new revenues obtained by the adoption of the 5G (general and 5Growth-specific) envisaged innovations and solutions.

3.3. Industry 4.0 Pilot – INNOVALIA

3.3.1. Travel Reduction

For INNOVALIA, the main benefit of the 5G application for the first use case is the reduction of travelling required to provide some of the maintenance services for the CMM.

Until now, every time a customer from INNOVALIA wants to measure a new piece, or redesigns a piece that is being measured, changing the shape and geometries, an expert from INNOVALIA has to travel to the customer facilities to perform some highly sensitive tasks that will ensure the later usage of the CMM without damaging the piece or the sensor. These travels usually take from 3 to 7 days (depending on the size of the piece, and the tasks to perform). It varies quite a lot, depending on the service, but we could set an average cost of around 2.5k per trip. As right now we have around 100 travels per year in Spain and expecting to reduce it on a 60% thanks to the new 5G app, we would have **an OpEx saving of around 150k€.** This savings would be shared between INNOVALIA (100k€) and their customer, as INNOVALIA would reduce the maintenance fee by 50k€ for the clients that use the remote operation application.

3.3.2. Experts availability

As an average, the maintenance trips imply that the expert remains almost totally unavailable for at least one day (half day for each journey) when travelling.

Furthermore, when performing the maintenance tasks there are significant idle periods that the expert is unoccupied. If he/she can perform some of these tasks from the central office, the time he/she has to wait while the CMM carries out certain tasks (which is idle time), can be seized and do something else. Our calculation is that an average of the 50% of the maintenance time is waiting time. If this new app allows an expert to use half of that time, that will mean that INNOVALIA could save another day of work form the expert.

Adding these savings, we could say that the Remote-Control Application could save 2 days of work of an expert per trip, that is (if we manage to shift 60% of the maintenance trips to remote) 120 days per year. If the average cost per day of an expert is close to 800€, that would mean **a total saving of 95k€**.

3.3.3. CMM maintenance costs

This is a saving for INNOVALIA's Customer. As we have seen, the new application would significantly reduce the cost of the travel for INNOVALIA, and that also means that their customers would also take profit of this new app.

As mentioned previously, the savings regarding the travel reduction would be shared among INNOVALIA and its customers, as the service fee would be reduced. **The customer's savings have been estimated to around 50k€.**

3.3.4. CMM maintenance response time

Because of the expert's availability item (see section 3.3.2), the customers would also benefit from a faster service. This item is very difficult to quantify, as it depends a lot on the type of product that the customer produces. An average savings of around 500€ for each client is estimated, as the manufacturers of the most expensive parts usually have backup processes to ensure the quality and very small lots, what would mean a total of 3k in Europe (for approximately 60 customers).

Usually, the Quality Control process (in which the INNOVALIA CMM is more often involved) is not in the production line, so in most cases a delay in the maintenance of the CMM will not directly affect production. However, if a defect is not identified because the CMM was not ready to operate, this could imply that a whole lot must be rejected. In most cases, this would lead to an "unacceptable" loss for the company, therefore, even if it is not strictly necessary for production, its failure or misconfiguration could result in the halt of the production line.

3.3.5. CMM usage optimization

One of the main benefits of this use case, is the possibility to share a CMM between two (or more) production lines in a more effective way. The fact that the AGV and the CMM share the information on the piece that is being transported to the measuring station and the status of the measuring process would enable this shared usage.

This optimization will result on a greater number of measured parts. Moreover, since a production failure will be detected earlier, in turn this will mean a reduction in defective products and scrap. The initial estimations are that the scrap can be reduced in a 10% as an average, what would mean **an approximate OpEx savings of around 85k€** adding the individual savings for all our customers.

3.3.6. Lot-size reduction

Aligned with the previous item, the more measured products, the lower the lot-size would be. That allows to produce more personalized products, meaning a more efficient production and a more adaptable system. But in this case the vision is more focused on the flexibility, meaning on the new incomes that the adoption of these technologies may bring, instead of the savings.

Being more flexible and capable of producing less units per lot makes a company more competitive. We estimate that these new capabilities will come with **an initial increase of the revenues of at least 50k€,** although this is expected to grow in time.

3.3.7. Edge device maintenance

By using a Cloud-Edge service, INNOVALIA would not have to worry about the maintenance of the edge device that currently is deploying in their customers premises to operate the CMM. If the client hires the operator (or any other external service provider) to run this cloud-edge service, the provider would be the responsible for its maintenance.

Currently the maintenance tasks for the edge device are performed simultaneously with other maintenance tasks of the CMM, so costs are negligible. However, with the new deployment many of the maintenance task will be performed remotely, so this new item will have to be taken into account. An average yearly cost of 1.200€ per customer is estimated, what means **around 72k€ in all Europe** (for approximately 60 customers).

3.3.8. Spectrum

In Spain, the spectrum auction has not yet been held at the time of the writing of this document, due to the effects of the COVID-19 pandemic. A total of 200 MHz in the 3.6-3.8 GHz frequency band will be auctioned within the four main operators in the Spanish mobile telephone market. The 200 MHz are distributed in 40 blocks of 5 MHz each. The output price of each block has been set at 2.5 million.

According to [7] for 320MHz can provide service to 150M SIMs if not transmitting simultaneously. Consequently, each of the 5MHz blocks bided by Spain could provide service to approximately 2.3M SIMs in the same conditions. The cost per SIM can be obtained by making a simple calculus considering the 2.5 million per 5MHz block resulting in an equivalent cost of approximately 1.1€ per SIM.

Analyzing the two INNOVALIA use cases we can conclude the estimation of the total cost per Industry 4.0 use case:

- In the Remote Operation of Quality Equipment use case according to section 3.3.1 a reduction of 60 trips per year has been estimated. Taking into consideration that at least 5 experts will be working in the factory, **65 SIMs** are required in total, which results in **71.5€.**
- Estimating the **ZDM** use case is more complicated. By assuming that it is installed in 10 clients it would comprise 10 CMMs, using 2 AGVs and 2 operators per machine. This estimation would result in approximately **50 SIMs** with a cost of **55€.**

According to [8] initial bids in Spain open with a price of $ 0.06 / MHz / pop. In other European countries, the price is general in line with that of Spain reaching in $ 0.05 / MHz / pop in Ireland or $ 0.03 / MHz / pop in Finland. The only exception is Italy where prices climbed up to $ 0.42 / MHz / pop. However, in a **European horizon** the cost per SIM can be considered low enough so that, when taking an amortization time as long as 20 years**,** the cost for **on a European can be lower than 5k€ and considered therefore negligible.**

3.3.9. Network Slices (URLLC and eMBB Network Slices)

Since the incipient emergency of network slicing service offerings, it is not yet clear the actual costs benefit of going through this model versus the conventional one.

In [1] it is claimed a potential savings of 13.85% in CapEx for network operators when moving to SDN and NFV technologies for implementing their services. In [2] an analysis is performed to compare the cost levels of a slice-based service when using virtualized vs traditional 5G core. The cost reduction levels are in order of 44.7% in the cost per Mbps and 11,7% in the cost per user. The absolute values obtained are respectively 21€ and 53€. The cost values refer to eMBB type of slice.

Assuming this as reference cost values and taking into account the requirements described in D1.1 [3], it is possible to establish the following costs associated to the eMBB and uRLLC slices.

Remote operation of Quality Equipment

<u>eMBB slice:</u>

The following values are considered:

- Slice bandwidth – 100 Mbps.
- Users – 65.

<u>uRLLC slice for Innovalia use case:</u>

The following values are considered:

- Slice bandwidth – 0,4 Mbps.
- Users – 65.
- Differential incremental value of uRLLC slice vs eMBB slice: it is assumed as working hypothesis that uRLLC slice will cost a 100% more than an eMBB slice in order to ensure the stringent KPIs due to uRLLC.

ZDM

<u>eMBB slice:</u>

The following values are considered:

- Slice bandwidth – 1000 Mbps.
- Users – 50.

Assuming the parameters above, the following costs are assumed (Table 4).

TABLE 5: NETWORK SLICES YEARLY COSTS FOR THE INNOVALIA PILOT

Use case	Slice	Formulation	Final cost
Remote Operation	eMBB	(65x 21€) + (100x 53€)	6,665 €
	uRLLC	[(65x 21€) + (0,4x 53€)] x2	2,772 €
ZDM	eMBB	(50x 21€) + (1000x 53€)	54,050 €
		Total cost	**63,487 €**

3.3.10. Edge computing

When considering edge computing deployments on vertical premises, it is necessary to understand the proper dimensioning of the compute capabilities there.

There are three different compute environments according to their purpose and energy consumption:

- Hyperscale data centers: with a global reach, they have a high energy consumption (>10MW). Used for cloud applications, Global platforms and Xaas.
- Edge data centers: with a local reach, their consumption is moderate (1-10MW), and is basically used for networking, content streaming, gaming, etc.
- MicroEdge data centers: low-consumption systems (>1MW), are designed for IoT applications, autonomous vehicles, and smart cities applications.

Here is where the concept of micro-edge arises. The micro-edge approach basically consists of the deployment of compute facilities in few racks, even in single-rack form factor. Those deployments concentrate on serving a very local environment, as could be the one in a factory.

The categorization is a bit blur and different providers, such as Schneider [4] of EdgeConneX [5] characterize in a different way this kind of environments. For instance, Schneider characterize the micro datacenters as computing facilities consuming around 5 kW/rack, while EdgeConneX establish the consumption in less than 10 kW.

For determining the cost of a micro datacenter, here it has been considered the modelling of NFVI infrastructure developed in the 5G-TRANSFORMER project [6] adapting the infrastructure to the concept of micro datacenter. The modelling is specified in Table 6, resulting in a monthly cost of 2,724$ assuming a depreciation of 36 months. Maintenance costs are not included as supposed to be part of the cost paid to the integrator/operator.

TABLE 6: CHARACTERIZATION OF A MICRO DATACENTER

Concept	Units	Capacity	Units
Leaf switches	1	vCPUs	288
Management switches	1	RAM	756
Controller nodes	1	Block Storage	21600 (GB)
Compute nodes	2	Energy	2,6 kW
Block storage nodes (HDD)	2	**Cost**	**2,724$**

3.3.11. Video Platform network

At the moment of writing this deliverable, the cost of broad cast quality HD video with low latency video is around 400$ per dedicated encoder and 1-2K$ per camera. A good practice in this kind of scenario is embedding the NR modem in this setup it would increasing the price in another 500$. That would make a total price of 900$. In the case of including low latency and broadcast quality with 4K, that will be around 7K$ with the similar products that are available today in the market.

The previous numbers are based on using off the shelf broadcast cameras. As a result, it is possible to build high end 4K video camera with H.265 real-time encoder profile with around **1300$** (200$ camera, 600$ encoder chip encoder chip, 500$ NR modem) for industrial scenario.

3.3.12. Summary of the INNOVALIA Pilot analysis

In order to project the economic contribution of the pilot development at European level, we tried to estimate the future savings and new incomes that the two INNOVALIA use cases would generate among our European customers.

Table 7 summarizes the analysis reported in the previous sections. For each economic item, first we have the type of item (if saving OpEx, saving CapEx or New Revenues). The third column describes the benefit introduced by the deployment of the pilot, and then what is the multiplying factor that is used to project the results to a European scale (describing both what is the factor and its value). By multiplying the results and the factor we have the total European benefit, which is the annualized by applying an amortization time.

Finally, we estimate the percentage of these benefits that can be attributed to the 5Growth activities and innovations. Since the link between the innovations and the applications is still being defined, this is a preliminary estimation that will be refined and detailed in future deliverables.

TABLE 7: INNOVALIA PILOT, ECONOMIC BENEFITS (NUMERICAL EVALUATIONS)

Economic item	Type	Difference (cable vs 5G) [k€]	Multiply factor		Total EU [k€]	Amortization time [years]	Total EU (yearly) [k€]	% 5Growth contrib.	Total Europe (yearly) [k€] 5Growth contrib.
			What	#					
Travel Reduction	SO	100	# customers adapted	60	6,000	1	6,000	100	6,000
Experts Availability	SO	95	# customers adapted	60	5,700	1	5,700	100	5,700
CMM Maintenance cost	SO	50	# customers adapted	60	3,000	1	3,000	100	3,000
CMM Maintenance response time	SO	0.5	# customers adapted	60	3	1	3	100	3
CMM Usage Optimization	SO	85	# customers adapted	30	2,550	1	2,550	100	2,550
Lot Size Reduction	GR	50	# customers adapted	30	1,500	1	1,500	100	1,500
Edge Device Maintenance	SO	1.2	# customers adapted	60	72	1	72	100	72
Spectrum	GR	-	-	-	-5	20	-0.25	20	-0.05
Network Slices	GR	-1	# customers adapted	60	-63.5	1	-63.5	20	-12.7
Edge computing	GR, SC, SO	-29	# customers adapted	60	-1,740	1	-1,740	60	-1,044
Video platform network	GR	-1.3	# customers adapted	60	-78	1	-78	100	-78
TOTAL							**16,913.25**		**17,690.25**

3.4. Industry 4.0 Pilot – COMAU

3.4.1. Spectrum

The adoption of 5G implies the usage of spectrum, bought through public auction by Operators. In order to evaluate the cost of the spectrum dedicated to a car manufacturer fabric, we can consider the following values:

- TIM, with 2.407 billion, was awarded one of the two 80 MHz maxi-blocks in the 3.7 GHz band, one block in 26 GHz and two in the 700 MHz. A simply calculus that 2.4 G€ covers more than 150M SIM according to [7], implies the cost for each SIM equivalent to 16 € per SIM.
- According to [8] Bids closed in Italy ($ 0.42 / MHz / pop), are significantly higher than bids in the UK and Spain, which reached prices of $ 0.17 / MHz / POP and $ 0,06 / MHz / POP respectively, the cost per SIM can be considered as lower in an EU horizon.

For this reason, for an entire production chain the cost can be less than 5k€, amortization time 20 years, so negligible.

3.4.2. Energy

Energy is an important share in OpEx, so it can be considered both as a KPI standalone (a research project, as well as the introduction of a new technology, should consider the sustainability of the solutions) and as an OpEx item.

The power consumption due to radio access is about 10 kW (to be verified for 5G, once clarified the number of Radio DOTs). 10 kW means about 80.000 kWh per year, which is 100k€.

3.4.3. Infrastructure initial deployment

This item considers the cost of the infrastructure (with the exception of civil works, it has a decrease for maturity of about 4% per year). Note that 5Growth it is not a technological project, and therefore what is needed is the cost of devices, in order to evaluate the funding that manufacturers can invest on this new product line.

For a production chain part of an entire production line we consider the following 5G RAN infrastructure to cover 7700 m^2 and serving 44 robots + a team of 10 people for maintenance support (the technical data are taken from sec. 2.2 of D2.1 of 5G-EVE project [9]):

- 10 Radiating points (each one covering 800 m^2) controlled and fed by 2 Radio Units via LAN cables. The Radio Units are connected to a Baseband Module via optical fiber.
- The above infrastructure should serve the traffic generated by the 44 robots (about 12.5 kbit/s each -> 0.55 Mbit/s total) and by the 10 people of the maintenance staff (about a total of 40 Mbit/s assuming 4 Mbit/s for each Holo Lens of the staff people). Such infrastructure is future proof since its capacity is well below its overall capacity (*2* Gbit/s per radiating point).

The cost of the wireless solution is about 14k€ per product chain, in comparison with 100k€ of the wired solution. **The CapEx savings are about 86k€.**

3.4.4. Civil works

The main advantage of 5G is a negligible infrastructure and independent with the update of product chain. On the other hand, A typical production chain consists of:

- 7700 m^2
- 4 PLC
- 16 AGV
- 20 stations
- 44 robots.

It needs about 1 km cable for the industrial network (e.g. Siemens Profinet [10]). This implies a civil work of about 40 € per meter **(CapEx savings are about 40 k€).**

3.4.5. Operational and provisioning

The efficiency in provisioning and the deep monitoring make possible a savings passing from 4% to 3% of CapEx (yearly), with the exception of cable [11] and [12]. The cost per product chain might be about 200k€, so the saving is about 1% of 200k€, that is **2k € per year**, including predictive maintenance.

3.4.6. Change of production line

In a wired solution, each station is reached by a data cable. This is eliminated by wireless solutions. This simplification is very important, when the update/upgrade of the production chain is necessary. In fact, it is not necessary to re-build the data cable connectivity, but only a software update.

The work to be eliminated is equivalent to 2 people working 2 days each 4 years **(400 €/year).**

3.4.7. Cloudification

The cost of the server hosting cloudification software and data is that of two typical medium size servers (one server needed for redundancy purpose). According to [11], a typical server might be based on an Intel Hexa-Core Xeon E5-2420, with 96 GB of RAM and 4 TB of hard disk and, concerning the elaboration system, we can consider that present high-end size servers, with 2 Xeon CPU (12 cores each) and 192 GB of RAM, can support traffic rates of 40 Gbit/s and up to 100 Gbit/s which is expected in the future, and cost about 5000 €, considering redundancy x2 = 10k€. Considering an amortization time = 10 years => 500 €/year.

Furthermore, the cost includes system for monitoring, first of all high-resolution cameras, i.e. 20 per production line (e.g. UHD+ cameras and HSI technology) 8k€ x 20 = 240k€.

The total cost is 250 k€. More accuracy in defect checking can involve a better production system and, as a consequence, reduce the defect rate. Currently, a standard number for defect rate in automotive industry is 20 ppm [13].

Furthermore, according to [14] we should consider the "Defective Units / Recall Rates", i.e. the cars called up for small potential defects. This value is much higher (about 5 for every 1000 copies produced). Other interesting considerations about how it is possible to achieve better level of quality through machine learning is reported in [15].

Accordingly, we have 2 types of defects: 20 PPM of total defects (i.e. that the car cannot leave the factory) which need about half of their cost to be replaced (€ 8000). With an accurate automatic monitoring system, the processes can be reviewed, and the number reduced to 15 PPM. Similarly, 5 out of 1000 machines are recalled in the first 3 years. On average there will be an intervention of € 500. With an accurate automatic monitoring system, processes can be reviewed, reducing the number to 3 cars are every 1000. 60 jobs/hour is a fair number. Considering 16 hours per day and considering the pure defect rate, the decreasing of 5PPM means **a saving of 14k€/year.**

Currently an average of 1750 cars out of 350.000 produced in a year are recalled. We can decrease this number to 1050. **The saving is 700 * 500 = 350 K€ per year. The balance is a saving of 350 + 14 – 0.5 = 363.5 k€ per year.**

3.4.8. Summary of the COMAU Pilot analysis

The final outcome is a preliminary computation on how the solutions envisaged by the project facilitated by the adoption of 5G can give their contribution from an economic point of view.

To achieve this goal, we made the effort to project the savings/increasing revenues for one production chain to the entire Europe and we tried to split the contribution to the evolution of transmission in general (5G) and the share specifically due to 5Growth.

Table 8 reports the preliminary numerical evaluation of the economic benefits.

TABLE 8: COMAU PILOT, ECONOMIC BENEFITS (NUMERICAL EVALUATIONS)

Economic item	Type	Difference (cable vs 5G) [k€]	Multiply factor		Total EU [k€]	Amortization time [years]	Total EU (yearly) [k€]	% 5Growth contrib.	Total Europe (yearly) [k€] 5Growth contrib.
			What	#					
Spectrum	SC	-5	# (new) production lines in EU	25	-125	20	-6.25	20	-125
OpEx energy	O	-100	# (new) production lines in EU	25	-2,500	1	-2500	0	0
Infrastructure initial deployment	SC	86	# (new) production lines in EU	100	8,600	10	860	0	0
Civil Works	SC	40	# (new) production lines in EU	25	1,000	20	50	0	0
Operational and provisioning	O	5	# (new) production lines in EU	100	500	1	500	20	100
Change of production line	SC	400	# (new) production lines in EU	25	10,000	4	2,500	20	500
Cloudification	SO	363.5	# (new) production lines in EU	25	9,087.5	1	9,087.5	50	4,543.75
TOTAL							**10,491.25**		**5,142.5**

** In section 3.3.12 there is a detailed description of each of the columns of the table

In order to define the economic benefits at a European scale, for estimating a sort of Return on Investment (RoI) of 5Growth, it is important to select a criterion to spread the data in EU size. Combining the site [16], where it is reported that for the plant 1700 robot are necessary with [17], for understanding the locations of factories we can confirm the presence of 25000 robots in Europe and that in each chain there are about 200 robots. The number of production chains in Europe is about 25000 / 200 = 125. We consider that 80% adopts the new technologies, approximatively 100. The chains should be renewed each 4 years, i.e. about 25% per year (100 /4 = 25).

Therefore, for the car manufacturing sector, the total gain, due essentially to CapEx and OpEx savings attributed to the new technologies and innovative processes that 5G facilitates, is more than 10M€ in Europe, half of them due to the specific innovations envisaged by 5Growth.

3.5. Transportation Pilot – EFACEC Engenharia e Sistemas

3.5.1. Train accidents

The use of 5G in level crossing (LC) scenarios will reinforce the safety conditions and may reduce the number of train accidents. These benefits can have a significant impact in the costs associated with damages (material) and human lives (persons who can die or be injured) [18].

According to [19], there are currently about 120000 level crossings (LC) in the EU. Therefore, there are, on average, 50 LC per 100 line-Km. Half of these LC are active and have some level of automation and the other ones have no type of active equipment meaning that are only equipped with a St. Andrew's cross traffic sign (passive). There is a relationship between the kind of LC (active, passive/unprotected) and the number of accidents meaning that the number of train accidents is higher at unprotected LCs. The statistics show that LC accidents occur at passive LCs (39,8 %) while at active LCs this percentage ranges from 4,1% to 30,6% depending on the level of automation.

According to these considerations, we believe that the European market can accommodate 60000 new generation level crossings (automated and supporting advanced communication technologies).

Our estimations consider 5% of Safety benefits in terms of human lives, using automation and video images to reinforce the safety conditions (use case 1 and use case 2 of the Transportation Pilot). Taking in consideration total costs estimated at €1 billion per year [18], the safety benefits represent 50000 M€ per year. EFACEC_S is considering that the average cost of transforming a passive LC in an active LC is about 150 k€. Therefore, for the estimated 60000 new LC, the total investment will be about 9000 M€, which means that only considering the economic value the benefits are considerable. This represents an average safety benefit of **683 k€** every year per Level Crossing. For the calculations we are considering that the amortization time is 20 years.

3.5.2. Installation cost

The installation costs will be reduced once the 5G technology is adopted. The savings are related to the fact that there is no need to dig cable ditches or to install cable ducts (civil works and cable installation services).

Considering a Level crossing where a cable duct of 1200 meters (average) is needed, the installation cost is typically 30% of the total amount of the solution (an average of 140 k€ was estimated). Therefore, **the CapEx savings per Level Crossing are about 40 k€.**

We must considerer a total cost of about 20 € per year regarding SIM cost, according to section 4.3.6.

3.5.3. Installation time

The traditional Level Crossing (cable solution) installation typically takes between 2 to 4 weeks' time. This will lead to **an average value of 10 k€ per level crossing (CapEx saving)**, assuming an average of 1200 meters for cable duct purposes.

3.5.4. Maintenance cost

A traditional cable solution installation requires some maintenance services to assure the availability and communications integrity (failures, robberies) of the Level Crossing. A maintenance contract involving on average a value of 1000 € per year for each LC (2 annual site visit) is common for this kind of solution.

Since the 5G technology will overtake this type of restrictions, we estimate a reduction of maintenance cost (site visits) by 20%. **This represents a 200 € benefits per year per LC (OpEx savings).**

3.5.5. Cable cost

In a traditional Level crossing (wired solution) the communication between the trigger point (detecting a train is approaching the level crossing) and the LX controller is assured by a data cable.

Taking a reference scenario of 1200 meters (trigger point to LX controller), a cable of 1600 meters is needed for this type of communication. This cost is eliminated by the use of 5G wireless solutions.

This represent a cable cost saving of 6400 € per Level Crossing.

3.5.6. Spectrum

The ANACOM (Portuguese national communication regulatory entity) expects to raise a minimum of 237.96 million euros for the 5G spectrum. Penetration of mobile services reached 120.9 SIMs per 100 inhabitants in Portugal. Therefore, 12M 5G SIMs are expected, not considering the future IoT services. The spectrum cost is **19.75€ per SIM** to be amortized during the license lifetime (20 years), less than one euro per year per SIM. The pilot (which represents a LC) uses 3 SIMs: video camera and two sensors.

3.5.7. Network operational cost

Automated network management and configuration enabled by vertical orchestration and slicing, reduces human intervention and allows a significant decrease on Operations Expenditures/costs (OpEx).

Assuming a 3 sectors macro site, the estimated OpEx is 1300€ per year [25] (a ASN - Automated Sliced Network - results in a 9% lower CapEx relative to PCN - Physical CSP network), the major contribution to TCO reductions comes from a 23% decrease in OpEx [26]. Therefore, **OpEx savings of 300€ per site** can be expected.

3.5.8. Network resources optimization

Automated network management and configuration enabled by vertical orchestration and slicing, optimize the usage of the infrastructure which impacts CapEx savings. Assuming a 3 sectors macro site the estimated CapEx is 20K€ per year [25] an ASN results in a 9% lower CapEx relative to PCN, the major contribution to TCO reductions comes from a 23% decrease in OpEx [26]. Therefore, **CapEx savings of 1800€ per site** can be expected.

3.5.9. Edge Computing

The edge computing is a fundamental technology to guarantee QoS with URLLC for sensors but also to offload network traffic, providing an optimized use of the network transport resources. Achieving less than 1 ms end-to-end communication latency, required for certain 5G services and use cases is an ambitious goal; towards that end the service infrastructure and User Plane Function (UPF) optimal placement at the network edge is crucial. The right placement can get over 20 % cost savings for the service infrastructure deployment [27]. Considering the specifics of this pilot, CapEx savings of **4K€** can be expected.

3.5.10. Consultancy

A consultancy service is offered towards verticals and network operators with regards to architecture design, identification, selection and overall operational guidelines towards 5G/cloud deployment and usage. It also includes HW/SW trials for validation and certification of communication equipment. The cost associated mostly concerns human resources and overheads (special certification trialing may require equipment purchasing but these are discarded). For each consultancy action, it is expected that a full scientific team is able to operate within a 1-month timeframe. The first 2-weeks would be associated with the architectural training of the 5G consultancy client (either the vertical or the network operator), and the second 2-weeks would be a follow-up consultancy, in order to validate and/or certify the deployment. The main benefits that consulting brings are a potential increase in the institution funding, from added consultancy opportunities throughout Europe, due to acquired specialization on 5G+Vertical integration.

3.5.11. Summary of the EFACEC Engenharia e Sistemas Pilot analysis

The final outcome is a preliminary evaluation on the benefits – from an economic point of view – of the solutions envisaged by the project, facilitated by the adoption of 5G.

To achieve this goal, we made the effort to project the savings/increasing revenues of one level crossing to the European scale and split the contribution of 5G in general and the share specifically due to 5Growth.

Table 9 reports the preliminary numerical evaluation of the economic benefits.

TABLE 9: EFACEC_S PILOT, ECONOMIC BENEFITS (NUMERICAL EVALUATIONS)

Economic item	Type	Difference (cable vs 5G) [k€]	Multiply factor		Total EU [k€]	Amortization time [years]	Total EU (yearly) [k€]	% 5Growth contrib.	Total Europe (yearly) [k€] 5Growth contrib.
			What	#					
Train accidents	SO	683	# (new) 5G Level Crossing in EU	60,000	41,000,000	20	2,045,000	10	205,000
Installation Cost	SC	40	# (new) 5G Level Crossing in EU	60,000	2,400,000	20	120,000	10	12,000
Installation time	SC	10	# (new) 5G Level Crossing in EU	60,000	600,000	20	30,000	0	0
Maintenance cost	SO	0,2	# (new) 5G Level Crossing in EU	60,000	12,000	1	12,000	20	2,400
Cable cost	SC	6,4	# (new) 5G Level Crossing in EU	60,000	384,000	20	19,200	0	0
Spectrum	SC	-0.02	# (new) 5G Level Crossing in EU	60,000	-1,200	20	-60	20	-12
Network Operational cost	SO	0,3	# (new) 5G Level Crossing in EU	60,000	18,000	1	18,000	80	14,400
Network resources optimization	SC	1,8	# (new) 5G Level Crossing in EU	60,000	108,000	10	10,800	80	8,640
Edge Computing	SC	4	# (new) 5G Level Crossing in EU	60000	240,000	10	24,000	20	4,800
Consultancy	GR	6	# (new) 5G Level Crossing in EU	10	60	10	6	20	1.2
Total		**751,68**					**2,278,946**		**247,229.2**

** In section 3.3.12 there is a detailed description of each of the columns of the table

3.6. Energy Pilot – EFACEC Energia

3.6.1. QoS - SAIDI

One of the main key performance indicators used to evaluate the quality of service (QoS) of a Distribution Service Operator (DSO) is the SAIDI - System Average Interruption Duration Index. The SAIDI measures the average of the total long interruptions weighted by delivery points for a given year.

The adoption of 5G mobile communications in the secondary substations and along the low voltage electrical grid allows the DSOs to increase the level of automation in the low voltage distribution electrical grid, and that way to react fast in the occurrence of outages keeping the service downtime at lower levels.

According to the Portuguese main DSO, comparing to the actual scenario, the adoption of 5G communications along the low voltage electrical grid supporting the described use cases can lead SAIDI LV (due to Low Voltage network interruptions) to **decrease by 15%**.

If we take into account that the current average value of SAIDI LV for the EU countries is according to [19] around 120 min/consumer*year, and that only a part of this value is due to incidents occurring in the low voltage network (~ 1/3, according to the Portuguese DSO), the implementation of a large scale 5G infrastructure supporting the automation of the low voltage electric grid would allow to lower the SAIDI LV to 114 min/consumer*year.

This decrease will have a positive effect in the DSO costs, and also a positive effect in the end consumers electrical energy service quality.

Due to several different approaches to the QoS from the national regulatory institutions across EU, it is not possible to monetize the SAIDI reduction effect on DSO side, on EU scale.

3.6.2. QoS - ENS

One of the concepts used to understand the effect of the contingencies in the electrical network operation is the ENS - Energy Not Supplied. Also referred as Power Not Supplied - PNS, it represents the amount of energy that normally would be delivered, but now is not because of an outage.

To monetize the effect of reducing lost load during contingency periods, the Value of Lost Load - VOLL - can be used. The VOLL is indeed a measure of the cost of ENS (the energy that would have been supplied if there had been no outage) to consumer.

According to the Portuguese main DSO, comparing to the actual scenario, the adoption of 5G communications supporting the automation along the low voltage electrical grid can lead ENS to decrease by 5%.

A strong constraint when extending the impact to EU scale is the fact that the VOLL can vary dramatically between European countries, and there is no overall European reference VOLL.

There are different methodologies for obtaining a credible estimate of the VOLL, the most accurate being based on surveys, and this calculation is crucial in estimating the social cost associated with energy not served.

According to [20], the VOLL across EU countries vary between 11€/kWh and 26€/kWh.

According to [21], there are 260M connected customers across EU, and 2700 TWh are delivered by EU DSOs to the connected customers.

According to [22], the average SAIDI LV across UE member states is around 120 min/consumer*year (=2h).

On the other and, the European project [22] states that the electricity consumption per household is around 4000 kWh per year for the EU average, being the number of households in UE around 195M according to [24].

Taking all these figures into account, we can estimate the ENS in EU in a 1 year period due to low voltage incidents to be: 2*4000/(24*365) = 0.91 kWh per household, reaching an EU overall of 0.91*195M = 178GWh.

A reduction of 5% in this value will represent a decrease of 9GWh in ENS in EU in 1 year.

According to the VOLL range mentioned above, this will lead to savings on EU consumers side between **98M€** and **232M€** per year due to the reduction of energy not supplied to the households.

3.6.3. Control of non-authorized access

Perimeter security is an important issue in electric grid installations that stand without regular human presence like the secondary substations. Every year a significant amount is spent in maintenance and in material/equipment renewal to overcome the effects of stolen or damaged material inside the electric network installations.

The indoor camera and sensor help to prevent non-authorized access damaging and stealing or at least the identification and recovery of the stolen goods.

Unfortunately, due to the lack of available data from the EU DSOs it is not possible to monetize the impact of this economic item.

3.6.4. Local Maintenance cost

The remote monitoring of the Secondary Substations and low voltage power grid allows a more planned and timely maintenance response. With a better knowledge about the location, nature and extension of the outage event, the DSO can optimize the Work Force Management concerning maintenance teams.

According to the Portuguese main DSO, in the latest years there was an average of 7500 incidents per year in the low voltage electrical grid needing local intervention of maintenance teams.

The average duration of incident location and repair is about 100 min per incident. 50% of it is due to location time effort. It is predicted that this component could be neglected if last gasp functionality, supported by 5G communication infrastructure would be in place in the whole low voltage grid.

In the calculations below an estimated 30€ unit cost (maintenance personnel cost per hour) will be considered.

Taking the Portuguese scenario described above as reference, scoping an electrical low voltage grid size of 70000 secondary substations, and extrapolating for the EU electrical grid size considering a potential market for the automation of 3M secondary substations in Europe [21], we can calculate the local maintenance cost savings as follows:

Time saved in local maintenance to the LV grid in EU per year = (7500*100/2)*3M/70k = 16M minutes = 268k hours

Cost savings in local maintenance to the LV grid in EU per year = 268k*30€= **8M€.**

3.6.5. Remote Maintenance Cost

Upgrading the low voltage electrical grid communications infrastructure to 5G will heavily impact in the operations cost of EFACEC, allowing savings in highly skilled manpower concerning remote maintenance plans.

According to internal reports regarding the maintenance contract with the Portuguese DSO concerning the low voltage grid automation and considering a currently covered LV grid size of about 6500 secondary substations, it is foreseen that cost savings around 11k€ per year can be achieved with the implementation of a 5G communications infrastructure supporting the LV grid automation.

Therefore, assuming the EFACEC scenario described above as reference and extrapolating to the EU electrical grid size considering a potential market for the automation of 3M secondary substations in Europe [21], we can calculate savings as follows:

Remote maintenance cost savings = 11k€ * 3M/6.5k = **5M€.**

3.6.6. Spectrum

The ANACOM (Portuguese national communication regulatory entity) expects to raise a minimum of 237.96 million euros for the 5G spectrum. Penetration of mobile services reached 120.9 SIM per 100 inhabitants in Portugal. Therefore, 12M 5G SIMs are expected, not considering the future IoT services. The spectrum cost is 19.75€ per SIM to be amortized during the license lifetime (20 years), less than one euro per year per SIM. The pilot uses 3 SIMs: video camera and two sensors.

3.6.7. Network Operational cost

Automated network management and configuration enabled by vertical orchestration and slicing, reduces human intervention and allows a significant decrease on Operations costs (OpEx).

Assuming a 3 sectors macro site, the estimated OpEx is 1300€ per year [25] (a ASN - Automated Sliced Network - results in a 9% lower CapEx relative to PCN - Physical CSP network), the major contribution to TCO reductions comes from a 23% decrease in OpEx [26]. Therefore, **OpEx savings of 300€ per site** can be expected

3.6.8. Network resources optimization

Automated network management and configuration enabled by vertical orchestration and slicing, optimize the usage of the infrastructure which impacts CapEx savings. Assuming a 3 sectors macro site the estimated CapEx is 20K€ per year [25] an ASN results in a 9% lower CapEx relative to PCN, the major contribution to TCO reductions comes from a 23% decrease in OpEx [26]. Therefore, CapEx **savings of 1800€ per site** can be expected.

3.6.9. Edge Computing

The edge computing is a fundamental technology to guarantee QoS with URLLC for sensors but also to offload network traffic, providing an optimized use of the network transport resources. Achieving less than 1 ms end-to-end communication latency, required for certain 5G services and use cases is an ambitious goal; towards that end the service infrastructure and User Plane Function (UPF) optimal placement at the network edge is crucial. The right placement can get over 20 % cost savings for the service infrastructure deployment [27]. For this pilot CapEx savings of **4K€** can be expected.

3.6.10. Consultancy

As in section 3.5.10, a consultancy service is offered towards verticals and network operators in regard to architecture design, identification, selection and overall operational guidelines towards 5G/cloud deployment and usage.

For this pilot, we considered the capability of providing consultancy towards EU's main DSO's with over 100k customers, reaching the value of 190 potential clients, according to [24]. It also includes HW/SW trials for validation and certification of communication equipment. The cost associated mostly concerns human resources and overheads (special certification trialing may require equipment purchasing but these are discarded). For each consultancy action, it is expected that a full scientific team is able to operate within a 1-month timeframe. The first 2-weeks would be associated with the architectural training of the 5G consultancy client (either the vertical or the network operator), and the second 2-weeks would be a follow-up consultancy, in order to validate and/or certify the deployment.

The main benefits for the consulting beneficiary result in an increase of the institution funding from added consultancy opportunities throughout Europe, due to acquired specialization on 5G+Vertical integration.

3.6.11. Summary of the EFACEC Energia

The final outcome is a preliminary computation on how the solutions envisaged by the project facilitated by the adoption of 5G can give their contribution from an economic point of view.

In order to estimate the impact of the economic benefits in the European Union hence demonstrating the benefits of 5Growth project, it is important to select appropriate criteria to scale the data to the EU size.

Scaling to EU size is not an easy job since the information related to electrical energy market is not available evenly across the EU countries and across EU DSOs. For instance, concerning the electrical distribution grid infrastructure, we can establish a fairly good ground for Portuguese case, but it is not possible to do the same for all the EU countries. For some cases it is possible to have an average across EU, but not for all.

Pilot scale:

1x SIM + 1x CPE per SS; 1x Secondary Substation

1x SIM per LV sensor in low voltage feeder; 2x LV sensors per low voltage feeder; 1x LV feeder

1x SIM + 1x 5G Mobile device per maintenance team; 1x maintenance team

Portuguese scale:

70000 Secondary Substations → 70000 5G CPEs.

1,1M LV sensors in BT grid → 1,1M 5G devices

700 maintenance vehicles (maximum declared, in storm conditions) → 700 5G mobile devices

EU scale:

3M Secondary Substations → 3M 5G CPEs.

48M LV sensors in LV grid → 48M 5G devices

Table 10 reports the preliminary numerical evaluation of the economic benefits.

TABLE 10: EFACEC_E PILOT, ECONOMIC BENEFITS (NUMERICAL EVALUATIONS)

Economic item	Type	Difference (cable vs 5G) [k€]	Multiply factor		Total EU [k€]	Amortization time [years]	Total EU (yearly) [k€]	% 5Growth contrib.	Total Europe (yearly) [k€] 5Growth contrib.
			What	#					
QoS – SAIDI LV	SO	NA	Secondary Substations	3M		1			
QoS - ENS	SO	0.5 to 1.2	households	195M	98 to 232	1	98 to 232	0	0
Control of non-authorized access	SC	NA	Secondary Substations	3M					
Local Maintenance cost	SO	2.7	Secondary Substations	3M	8	1	8	0	0
Remote Maintenance cost	SO	1.7	Secondary Substations	3M	5	1	5	0	0
Spectrum	SC	- 60	Secondary Substations	3M	-180	20	-9	20	-1,8
Network Operational cost	SO	0,3	Secondary Substations	3M	0,9	1	0,9	20	0,18
Network resources optimization	SC	1,8	Secondary Substations	3M	5,4	1	5,4	80	4,32
Edge Computing	SC	4	Secondary Substations	3M	12	10	1,2	80	0,96
Consultancy	GR	6	Main European DSOs (> 100k customers)	190	1.1	10	1,1	20	0,22
TOTAL							**110,6 to 244,6**		**3,88**

** In section 3.3.12 there is a detailed description of each of the columns of the table

4. Conclusions

This document has reported the work done in Task 1.2 "Techno economic analysis and business model validation", consisting in a preliminary numerical evaluation of the economic benefits introduced by 5G technologies into verticals' industrial activities and by the specific innovations envisaged by 5Growth.

Nine use cases, belonging to four main pilots have been considered and analyzed, related to the fourth industrial revolution (Industry 4.0) and to 5G technologies in the transportation and energy production and distribution pilots.

The main objective of the study summarized in this document is to understand if solutions proposed by the 5Growth project are also advantageous from an economic point of view.

The methodology adopted, and described in chapter 3, allows us to understand for each pilot what are the economic advantages, adding together the savings on investments, operating costs and increase on revenues. In order to consider multi-year expenses, savings and revenues we introduced of the "Yearly Total Value" obtaining annualized items, in particular those valid for several years. Furthermore, an effort has been made to understand what the benefits could be for the whole Europe, if the economic advantages obtainable on the single pilot could be extended to similar situations throughout Europe.

From a functional point of view, the introduction of 5G in the verticals involved in 5Growth allows a faster, safer connectivity, with a high bit-rate and access to a large number of devices in a highly reliable way. This enables a whole series of functions that can be grouped in two main blocks: centralized control with more rapid quality, monitoring and maintenance processes; and new real-time highly reliable remote services. These new or upgraded features, added to the flexibility of the wireless deployment, which reduces deployment and maintenance costs of the infrastructure, are the main pillars of the revolution that 5G will bring to the industrial, transport and energy verticals.

The results of the techno-economic analysis reported in this deliverable speak by themselves. On a European scale, we are talking about millions of euros saved by the different stakeholders involved in the deployment of 5G solutions. Approximately half of the achievable savings are directly attributable to the implementation of the pilots and the innovations of 5Growht project.

In addition, the study is highly conservative, since it does not consider collateral social advantages, which are difficult to monetize (e.g., reducing pollution or better quality of work) and other economic advantages such as the development and marketing of products that without these new technologies could not have been produced or it would not have been commercially viable to do so.

Our results among the unanimous researches that considers 5G to be very economically advantageous, such as a study by Spoel [29], according to which, in 2035, when 5G's full economic benefit should be realized across the globe, a broad range of industries – from retail to education, transportation to entertainment, and everything in between – could produce up to $12.3 trillion worth of goods and services enabled by 5G.

As it has been mentioned, this document reports the first results of the techno-economic analysis and the business model validation, which has been impacted by the COVID-19 pandemic. Future work, that will be reported in deliverable D1.3, will deal with the distribution of the benefits among the different stakeholders and will also analyze the impact of the different innovations developed in 5Growth (addressed by WP2).

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