Research & Innovation Actions

5G PPP Research and Validation of critical technologies and systems:
Enabling Smart Energy as a Service via 5G Mobile Network advances.
Project: H2020-ICT-07-2017

Enabling Smart Energy as a Service via 5G Mobile Network advances

Deliverable 7.2
Validation period project progress report

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Abstract:

This deliverable describes the research progress of the NRG-5 project during the reporting period. It analyses and updates the objectives of the project, the activities of all partners during the reporting period, dissemination and communication activities and deviation of resources as compared to the original planned effort. This deliverable describes all the achievements made by the project from M14 to the end of the project.

Disclaimer

The NRG-5 Consortium is the following:

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02	THALES Communications & Security	TCS	France
03	SingularLogic S.A.	SiLO	Greece
04	Ineo Energy & Systems	ENGIE	France
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1 Overview of the progress

1.1 Objectives

In the first period of the project documented in [1], the main goals achieved has been to set up the development and the initial implementation of a 5G architecture (WP1) but also to develop the first "enabling layer" of components (WP2) on top of which built the different energy VNFs and the related energy services.

From this point on, the second period has been based on the evolution of the main achievements above detailed and has been focused on the delivery of the main results of the NRG-5 projects that we can summarize as follows:

1. Three use cases based on VNFs and energy services developed for the smart grid domain.
2. A robust lab environment where test the VNFs and the related communication infrastructure to create a bunch of energy services to be implemented in the real pilot scenarios.
3. The creation of a resilient infrastructure both from the point of view of the communication layer and then energy domain based on different VNFs capable to add to the smart grid the self-healing functionalities but also an enabler of a resilient and high-performance infrastructure to provide users and field devices with wireless connection. To support the stable storage and management of the persona user data in secure and privacy preserving way thanks to the creation of a virtual twin modelling the smart grid devices like the 5G-Norm.
4. The software and applications designed and developed in WP1 and WP2 have been exploited in WP3 that has been involved in the creation of the different analytics application components to guarantee the energy monitoring, the dispatchable demand response and the predictive maintenance for keep the smart grid secure, stable and resilient.
5. Once the communication infrastructure and the software has been created the further step was to test in both lab environment and in the real pilot site the 3 NRG-5 UC. The main results obtained after a few round of validation tests can be summarized as a different number of VNFs and energy services to be deployed in a flexible way, thanks to the OSM integration and open stack infrastructure to assure the availability, reliability and security of the 5G energy services.
6. The overall group of results have been then used to support the creation of two important white paper related to the WGs of software network and architecture [2], [3]. With this purpose many phone calls and real meetings has been used to align the project outcome to the activities related to standardization operated in 5G-PPP providing a strong base for the future development of a smart grid energy slices based on cloud native approach and easy re-instantiable energy functions.

The above summarized history of the project can be better explained if exploded enlisting the crucial steps and achievements that have been covered in the project based on the description of work. The main motivation that push the development of NRG-5 sat on the fact that despite a number of software frameworks and reference architectures have been made available for 5G enabling technologies, there is a clear gap to bridge towards 5G seamless application with a number of "vertical" sectors. Energy vertical represents undoubtedly one of the most significant "test cases" for 5G enabling technologies, due to the need of addressing a huge range of very diverse requirements to deal with across a variety of applications (stringent capacity for Advanced Metering Infrastructure (AMI) versus latency for supervisory control and fault localization).

In this respect, NRG-5 developed three specifics and vertical use cases in order to validate the overall objective of the project which is to guarantee optimal communications of the energy grid, which is believed to be the most complex, heterogeneous and gigantic machine ever made in human history, deploying, operating and managing existing and new 5G communications techniques and

energy infrastructures (in the context of the Smart Energy-as-a-Service) easier, safer, more secure and resilient from an operational and financial point of view.

However, to effectively support energy utilities along their transition towards more decentralized renewable-oriented systems, several open issues still remain as to 5G networks management automation, security, resilience, scalability and portability.
To meet these challenges, NRG-5 developed a novel 5G PPP-compliant software framework specifically tailored to the energy domain, with

- trusted, scalable and lock-in free plug 'n' play support for a variety of constrained devices
- 5G devices' abstractions to demonstrate mMTC (Massive MTC), uMTC (Critical MTC) and xMBB (Massive broadband) communications coupled with partially distributed, trusted, end-to-end security and MCM (Machine Type Communications) to enable secure, scalable and energy efficient communications
- extended Mobile Edge Computing (xMEC) micro-clouds to reduce backhaul load, increase the overall network capacity and reduce delays, while facilitating the deployment of generic MTC-related NFVIs and utility-centric Virtual Network Functions (VNFs)
- an extended 5G ETSI-MANO predictive analytics framework to support automated, dynamic, elastic VNF reconfiguration.

All this pillars has been deployed and tested in two pilot sites (Italy, France) where proof-of-concept implementations for 5G-enabled electricity and gas distribution network optimized management has been offered while offering support to 5G PPP phase III projects via demonstrating high replication potential towards other verticals modelling the general replication guidelines.

1.1.1 Projective Objectives

Measurable Objective	Measurable goal	Methodology	Target
Core 5G PPP KPIs	Lower latency, improve energy savings,	xMEC offloading, Self* functions, MCM, NFVs deployment and CI-SLAs	We have demonstrated that with the deployment of VNF in the xMEC and

	battery lifetime, service creation time		the usage of shorter TTI in 5G-NR the latency will be reduced below 20 ms, which is the typical latency requirement for smart grid use cases.
Trustworthy interoperability across multiple virtualized domains	Time, effort and OPEX efficiency to deploy, manage and expand the communications network	Innovative architecture combining novel multi-RAT connectivity, blockchains trusted communications, and(edge) cloud networks	NRG -5 developed a Project Reference architecture for addressing both energy and 5G requirements . This architecture enable the deployment of AMIaaS, PMaaS and DDRaaS by means of the involvement of the project VNFs in NS.
Proof-of concept and demonstrators of 5G advances	Number of real-life Trials, 5G Laboratory Emulators	Apply NRG-5 developments in smart energy use cases	3 Use Cases 3 +1 Labs 2 real-life trials
Contributions to standardization	Number of contributions to relevant SDOs	Close monitoring and proactive contributions	We have impact on 5GPP/5G standards, IoT standards, Edge computing Standards, and Smart Grid Standards. The NRG-5 consortium has been most active in 5GPP regarding 5G standards with NRG-5 members contributing through participation in the relevant meetings and activities.
Interest in the combined communications and energy sector	Number of interested stakeholders in a community eco-system	Promote the technical results via dedicated workshops and events	We promoted the results of the project in EUCNC 2019, and two open day in which we have the involvement of the interested stakeholder like.

Table 1 : Project objectives

1.2 Strategic Objectives

The NRG-5 project envisages to contribute to the 5G PPP/5G Initiative research and development activities and the relevant 5G Working Groups by delivering a novel 5G-PPP compliant, decentralized, secure and resilient framework, with high availability, able to homogeneously model and virtualize multi-homed, static or moving, hardware constrained (smart energy or in general IoT) devices, edge computing resources and elastic virtualized services over communications' and energy utilities' infrastructures. The ultimate project goal is to render the deployment, operation and management of existing and new communications and energy infrastructures easier, safer, more secure and resilient from an operational and financial point of view.

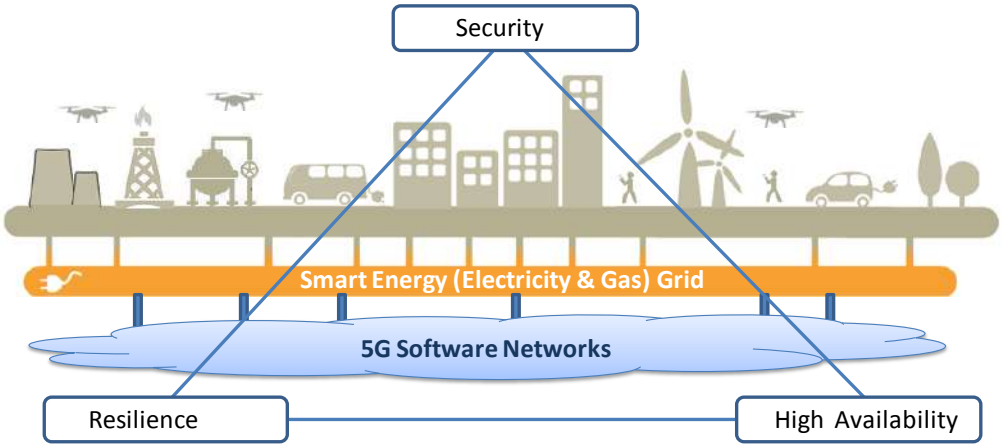

Figure 1 : Next Generation 5G & Energy Smart Grid core requirements triangle

NRG-5 investigates on extensive modelling and virtualization of electricity and gas infrastructure assets combined with the telecommunications infrastructure covering the full spectrum of the communication and computational needs. These evolving networking requirements raise critical challenges that urge for extended flexibility in the energy service provisioning which, in turn, can be translated as requirements for

1. ***Security*** in the deployment and operation of a huge number of end-points, avoiding lock-in strategies,
2. ***Resilience*** of infrastructure via Predictive Maintenance and self-healing via assets' virtualization and timely energy re-routing,
3. ***Highly Availability*** via smart grid stabilization. These challenges are also framed by the urgent need for protection against (combined) cyber and physical security threats and attacks, to avoid cascading effects to a great number of other critical infrastructures and services.

In other words, NRG-5 uses 5G peculiarities for building a new generation of smart infrastructure where all assets are virtualized in order to digitise the entire energy smart grid. The new offered services provided by NRG-5 solution adds a new set of tangible and untenable value for making more the Smart Grid more secure, resilient and available as well as more and more effective.

1.2.1 Progress towards the Strategic Objectives during Period M14-M30

All the strategic objectives have been achieved.

The project has designed, developed, and validated in pilot field trials, a novel holistic 5G-PPP compliant, decentralized, secure and resilient framework, with high availability, able to homogeneously model and virtualize energy field devices, edge computing resources and then providing elastic virtualized services over communications and energy utilities layer.
The framework will significantly speed up the deployment, operation and management of communications and energy infrastructures in an easier, safer way guaranteeing as stated and demonstrated in the Project :

1. ***Security*** in the deployment and operation of a huge number of end-points, avoiding lock-in strategies thanks to the virtual network functions named : vAAA, vBCP, vMME working with vSON and vTSD.

2. ***Resilience*** of infrastructure via Predictive Maintenance and self-healing via assets' virtualization and timely energy re-routing enabled by the means of vDFC, vMPA, vESR, vDES ,vRES
3. ***Highly Availability*** encapsulating solutions in three use cases which focused on the Research, Implementation and Evaluation concepts of flexible and adaptive learning. This environment has been tailored to dynamically adapt the software infrastructure to the energy and communication requirements enabling a 5G-ready software layer.

1.3 Technical Objectives

As stated in the first periodic report the technical objectives for the project were encapsulated in 3 project principles as defined by the project consortium industrial partners, academic experts, telcos and energy Utilities:

- ***Trusted and scalable "Plug 'n' Play" vision.*** An important part of the vision for 5G systems relates to the trust in shared resources. This trust depends on necessary security functionality, such as identity management and pervasive integrity protection. NRG-5 will research towards truly distributed self-discovery and self-organization mechanisms and decentralized identity and key management schemes by combining inherited physical encryption functions (such as PUF) of the low-end constrained devices with distributed key management mechanisms based on ledger technologies (such as blockchains). Moreover, by stepping upon BT's IoT Data Hub, NRG-5 will push machine-type communications (MTC) from machine-to-machine(M2M) to machine-cloud-machine (MCM), abstracting technology silos, enabling interoperability with legacy systems and scalable operation.
- ***There is no "one-size fits all"***. Each segment of the telecom and the energy infrastructure has specialized requirements ranging from ultra-fast response, efficiency**,** reliability and high availability, especially if cost is considered. Though NRG-5 will consider network/logical slicing implementation as input from other 5G PPP (Phase 1 and 2) projects, it will analyse the architectural effect of evolving multi-RATs (like LTE, satellite and new 5G Radio) and propose 5G enhancements. On top, NRG-5 will introduce the concept of ***Critical Infrastructures' Service Level Agreement (CI-SLA)***, as an extension to security SLAs[i], combining the ability of the network (from security and resilience perspective) to support zero delay *energy infrastructure assets' communication, high availability and self-healing requirements, with* the overall network CAPEX and *OPEX, considering the infrastructure segment operational severity* and *cascading effect in case of unavailability*.
- ***Sustainability via 5G PPP cooperation.*** The results of the 5G PPP Phase 1 projects provide a solid starting point for the work of NRG-5. NRG-5 will build on these results, along with state-of-the-art **cooperative virtualization technologies**, to deliver a utility-oriented Management and Orchestration (MANO) framework for the provisioning 5G services to core utilities operations and contribute new concepts and prototype implementations of potential 5G networking functionality to the 5G Initiative WGs for discussion, consideration, pre-standardization and later product development.
- NRG-5 will extensively apply the concept of NFV in the Smart Energy-5G vertical use case. NRG-5 will consider smart energy services as complex VNF Forwarding Graphs (VNF-FG), where energy management functions will be dynamically connected/disconnected to facilitate effective energy management, based on operational needs, business priorities and policy rules, enabling high availability via self-healing/energy re-routing functions.

1.3.1 Progress towards the Technical Objectives during Period M14-M30

Respect to the 4 items representing the NRG-5 objective all the challenges were tackled and covered:

- The trusted and scalable plug and play vision was obtained finalizing a protocol based on beacon and control messages for the network discovery of unknown devices and which has been the starting point for the realization of a network topology repository for connecting in a mesh network devices without radio connection available. This topology model and repository has been enriched with self-organization and self-healing network functions, involved in the construction of multiple virtual routing trees over a single fixed physical layer. These functionalities increased the network robustness thanks to a resource monitoring mechanism able to thoroughly update the routing topologies with mobility Management functionalities deployed via vMME. The important aspect of scalability needed for the resilience of the network was obtained thanks to the vMCM VNF that has been an important achievement to map all the energy assets in the edge cloud to shorten the time of processing needed for the network services. To support the edge cloud functionalities and all the decentralized aspects promised in NRG-5 we have finalized the implementation of the blockchains-based trust management framework composed of vAAA and vBCP provided of necessary flexible and adaptive flavours for utility-oriented implementation.
- As regards the enabling of 5G slicing the work done by NRG-5 was mainly aimed on the deployment of a mandatory prediction framework based on evaluation of models based in metrics for putting in place CI-SLA. The evaluation of logistics regression, decision trees, random forests, SVM and multilayer perceptron has been involved to predict classes of link quality in the network.
- The 5G-PPP cooperation has been used and investigated firstly to create and provide a catalog for enable the run of all the NRG-5 use cases on OSM version 5. We designed and realized a deployment templates for a service slices composed of Virtual Network Function Descriptors (VNFDs), Network Service Descriptors (NSDs) and Slice Templates together. This catalogue built on top of the experience of the other 5G-Project like SONATA easily allowed the on-board of VNFs with OpenStack and OSM operated by NRG-5 in POPs and RWTH premises.
- The development and deployment of different energy VNFs to support the Project UCs the complex energy system represented by the smart grid through the AMIaaS and DDRaaS. The development of energy VNFS like: vDES modeling 2nd life batteries and EV charging station, vRES mapping the renewables energy resources like photovoltaic installations and the vESR for optimize and keep the grid stable. The related demonstration in the validation phase of the project that these energy functions can be deployed and re-instantiated thanks to VNF forwarding graph functions paving the way towards a flexible environment in which the slice requirements are tailored on the needs of the vertical.

- NRG-5 energy operators/utilities have analysed the various use cases focusing mainly on the decentralized, trusted lock-in free Plug & Play vision, the aerial Predictive Maintenance for utility infrastructures and the dispatchable demand response opportunities provided by 5G to the energy sector.
- Based on NRG-5 results, NKUA (successor or TEISTE) already offers a MSc course on Smart Grid Management, where 5G and security have been included as extra lectures.
- NRG-5 has significantly increased the position of the consortium beneficiaries. We need to highlight as a key success story the collaboration between BT and POPs (Synelixis spin-off). The collaboration has been awarded with two very prestigious awards with significant visibility.
    - BT and POPs have been granted the prestigious award of "**Highly Commended" (2nd position prize)** for the category "Communications" at the **IET Innovation Awards 2019**. The Institution of Engineering and Technology (IET) Innovation Awards recognise and

celebrate the very best new innovations across the breadth of science, engineering and technology.The prize was granted based on Next Generation Energy Grid Management (GEM-NG) framework, partly developed within the H2020 research project NRG-5. GEM-NG offers an innovative solution to secure and simplify the work and collaboration of Smart Grid operators and IT service providers and facilitate their inter-operation. It builds upon and integrates some of the latest developments in the leading-edge communications world including Blockchains, 5G, Multi-Access Edge Computing and Network Function Virtualisation and applies them to the energy sector. GEM-NG successfully showcases significant improvements in the fields of advanced metering and active control in smart energy grids

Figure 2 : BT – Power Operations IET Award 2019

- ***BT and POPs have been nominated as finalist at the UK IT Industry Awards 2019 ceremony, under the category of "Emerging Technology of the Year".*** The UK IT Industry Awards are the UK's largest and most respected IT industry awards. Presented by the BCS and Computing, the awards are a benchmark for outstanding performance throughout the UK computing industry. BT and Power-Ops were named finalists in the Emerging Technology of the Year category. As the UK IT Industry Awards explain, "this category is awarded to recognise an innovative new development or service that is intended to enable a new class of solution or type of benefit".

Figure 3 : UK IT Industry Awards 2019 ceremony - BT and Power-Ops as finalists

On , you can see Alistair Duke, Senior Researcher at BT (right) and Georgios Nikolakis, Power-Ops Director (left) at the Award Ceremony that took place on 13 November 2019 at Battersea Evolution in London

- NRG-5 consortium organized in Terni, Italy an Open Day on 17 Oct. 2019 to present the results of NRG-5 project to public audience. The impact of the 5G network on the energy sector has been discussed, while NRG-5 specific use cases regarding, "AMIaaS: Realizing decentralized, trusted lock-in free Plug & Play vision", "PMaaS: Enabling aerial Predictive Maintenance for utility infrastructures" and "DRaaS: Enabling resilience and high availability Dispatchable Demand Response" have been presented. The attendance in NRG-5 Open day was impressive, whilst the audience has shown great interest, participated lively and expressed enthusiastic comments. The NRG-5 Open day has been covered by **TGT Teleterni (Terni Local TV)** and by **RAI news (Italian National TV network)** as shown on Figure 4.

Figure 4 : NRG-5 Open day has in Terni – TV news coverage

- ENGIE organized an H2020 NRG-5 OPEN DAY on Nov 25th 2019 at his headquarter in Paris – La Défense. This event introduced both the NRG-5 Project and the different business cases for industry verticals related to the NRG-5 Project.

Figure 5 : NRG-5 Open day in Paris – Live conference from Storengy UK

- Speakers included prestigious experts and high-level executives from Engie, Siradel, Storengy, Nokia, Air France-KLM, Thales, British Telecom and Engineering Ingegneria Informatica.
- As shown on Figure 5, the live conference with ENGIE Storengy UK witnessed about the effective services added within the Use Case 2 (Predictive Maintenance as a Service).

1.4 Operational Objectives:

As stated in the first periodic report the operational objectives for the project were:

- Analyse existing and anticipated communication infrastructure limitations in view of the smart energy highly demanding area and identify criteria to classify the infrastructure assets.
- Analyse in theory, design, implement and evaluate in laboratory tests and real trials5G reference network architecture to support an access agnostic control framework and pave the way for next generation energy and communications infrastructure.
- Realize an open source, micro-cloud proof-of-concept xMEC software stack, facilitating fast and optimal deployment of generic and utility-centric VNFs.
- Push MTC from M2M to MCM via network self-* functions implemented as VNFs and abstract representations of terminals in the (edge) cloud.
- Achieve truly decentralized, secure and trusted plug ‘n’ play, by combining MTC VNFs and inherited physical functions of low-end devices with distributed key management mechanisms.
- Achieve interoperability at the data level by abstracting technology silos through catalogues of semantically annotated data starting from BT’s information hub.
- Prototype utility specific VNFs, which model components, assets and functionalities of both the ICT infrastructure (i.e. edge computing, storage, network) and the electricity/gas infrastructure (i.e. meters, RES, DER, LPTs, PMUs, etc.) as virtual resources.
- Realize an extended 5G ETSI-MANO framework including two new interfaces (Os-An, An-Ma) as shown in Figure 18 integrating analytics in the orchestration and management processes addressing smart energy applications’ VNF optimal sizing and chaining.
- Demonstrate the efficiency and lifecycle management of advanced smart energy applications as services (such as AMIaaS, DDRaaS, PMaaS), implemented as chained connected graphs of dynamically connected/ disconnected VNFs following the ETSI VNF Forwarding Graph and ETSI SFC paradigms as documented in ETSI GS NFV-EVE 005ii.
- Extend the developments of 5GPPP Phase 1projects (METIS II, SONATA, 5G-Crosshaul) and combine them with advanced, network analytics to provide a framework for automated sizing, placing and deployment of VNFs as well as network assets reconfiguration to match the varying needs of the smart energy applications.
- Promote recommendations on scalability, sustainability and efficiency by means of CI-SLA modelled in NRG-5.

1.4.1 Progress towards the Operational Objectives during Period M14-M30

All the operational objectives has been achieved:

- A fully-fledged classification of the energy asset depending on the communication requirements needed has been planned and realized in the architecture of NRG-5
- The validation in the pilot site of the NRG-5 architecture and orchestration functionalities for the management of the energy UCs.
- The deployment when requested by the network condition of virtual network function in the edge cloud near the user consuming the service enabling the deployment of utility virtual functions.
- Realization of a vMCM virtual function to support the abstract representation of field devices and the retrieving of data semantically classified.
- The above-mentioned functionalities of machine cloud machine communication achieved within a trusted environment supported by vAAA and vBCP.
- Developed all the prototypes of utility specific VNFs: RES, DER, PMUs, etc.) general VNFs for enable mesh network like VTSD, VSON, and for the trusted environment like vAAA, vBCP, vMCM, vMME as well as the virtual network functions for drone as vMPA, vDFC.

- Enabling of the proper interfaces between the ETSI MANO framework with logic analytics managing smart energy sizing and chaining
- Implementation of AMIaaS, DDRaaS and PMaaS as chained of connected graphs representing dynamically connected/ disconnected VNFs following the ETSI VNF Forwarding Graph and ETSI SFC paradigms.
- Realized the extension of the 5GPPP Phase 1projects (METIS II, SONATA, 5G-Crosshaul) and combination of them with network prediction metrics for automated sizing, placing and deployment of VNFs to match the varying needs of the smart energy applications.
- Promote recommendations on scalability and energy efficiency to address short, medium- and long-term requirements along with business models to handle CI-SLAs.

1.5 Impact Objectives

NRG-5 address the societal KPIs of EU Commission and in particular those related to the creation of new economically-viable services of high societal energy value. In this course, NRG-5 aims to:

- Contribute towards core 5GPPP KPIs by publishing our research concepts and roadmap and demonstrating/validating NRG-5 core technology components beyond phase I projects.
- Assess and model flexible and trusted distributed access connectivity proof-of concept, applied to the highly demanding area of energy networks
- Create impact on Europe economic development through novel business models, SMEs and start-up support and job creation in the telecommunications, ICT and Energy sectors
- Build on a successful exploitation policy, enhancing NRG-5 consortium position in the market, empower the utilities/end users with knowledge and initiate the creation of new spin-offs (e.g. POPs is Synelixis Solutions spin-off to exploit FINESCE results).
- Creating a culture of training on our novel approaches to secure critical utility networks via massive communication means, MSc and free Massive Open Online Course (MOOC) course.

1.5.1 Progress towards the Impact Objectives during Period M14-M30

In the table below the expected project impacts are reproduced from the DoA. A progress update and updates are introduced in the third column.

Main Point of the Call	Expected Impact (DoA)	Progress and Update M30
Overarching impact: 40% of the world communication infrastructure market for EU headquartered companies;	TCS is one the largest European telecom manufacturers and hold a significant part of the communication infrastructure share, which is expected to be significantly extended via NRG-5, while the consortium is clearly European and headquartered in EU.	We studied the application of 5G to the energy domain and we investigate the possibility to exploit the energy market with telco solution. Before NRG-5 the telcos for having a dedicated communication infrastructure need to pay for ad hoc and expensive network generally without standard requirements. Now with NRG-5 we investigate how to provide to them a flexible network to address their requirements both in energy and communication
Demonstrated progress towards core 5G PPP KPI's: 1000x capacity, 1ms latency, 90% energy savings, 10x battery lifetime, service creation in minutes,…10x lower energy consumption for low power MTC	NRG-5 mainly contributes in Strand 3. Yet, many of these KPIs will be addressed. Indicatively, tasks offloading to xMEC will enable significantly lower energy consumption. Moreover, MCM communications will enable 5G-NORM devices to remain at sleep mode for large amounts of time, further increasing energy saving and lower energy consumption for low power Machine type communication. On the other hand, Self-* functions will establish multiple routes significantly reducing communication latency and increasing capacity. Finally, the VNF catalogue will enable a new range of services to be created in minutes by means of proper VNF-FGs.	We have demonstrated that with the deployment of VNF in the xMEC and the usage of shorter TTI in 5G-NR the latency will be reduced below 20 ms, which is the typical latency requirement for smart grid use cases. Also, in those specific applications where higher latency are supported we have tested the usage of NB-IoT. Packet size and bit rate values have been recommended in order to be compatible with the technology.
Novel business models through innovative sharing of network resources across multiple actors	NRG-5 address 5G energy vertical requirements, enabling the same infrastructure to be used by Electricity and gas utilities, along with telecom operators. Moreover, (micro) Data centres and xMEC offered by the Telcos will be available for generic services provisioning, while drones remote control may apply to a number of service areas	The innovation plan developed in the different deliverables in WP6 covered the topic of novel business models

Definition of 5G network architecture and of core technological components	NRG-5 WP1 will focus on the use case analysis, requirements capture and mapping to NRG-5 reference architecture. This will provide functional decomposition of energy related function on a 5G reference architecture.	The degree of maturity reached in the architecture has been testified and reported in the creation of white paper that summarized the architecture achievements of the different 5G-PPP phase 2 projects
Proof-of-concept beyond phase one and validating core functionalities and KPI's in the context of specific use cases with verticals closely associated to the demonstrations and validation.	NRG-5 aims to cover both the electricity and the gas/LNG 5G vertical use cases, creating real life proof-of concepts and demonstrators beyond phase I projects. Beyond realistic laboratory simulators (e.g. RWTH lab will be a fully end to end utility network emulator, featuring a real 5G Base station and Rutgers/WinLab ORBIT Testbed with LTE and Cloud Radio), ENGIE, ASM, and eMotion will offer 2 significant demonstrators facilities where 5G KPIs will be tested and validated using a real environment.	TRIANGLE testbed has been used to test and validate end-to-end performance in use case 2 and use case 3.
Novel connectivity paradigms, beyond the Client server model and enabling massive edge network deployments	NRG-5 will offer a trusted, scalable and lock-in free plug ‘n’ play solutions that will be based on an embedded cryptography and a fully distributed key management system. In this way, 5G terminals may be instantly deployed without the need to communication with a server and, if needed, offload tasks to nearby xMEC edge network equipment.	To satisfy this point the project implemented and tested in the UCList of VNFs that enabled plug and play features . With this aim we developed vTSD,vSON,vMCM dedicated to device handling and vMME, vAAA, vBCP for self-organization and self-optimization of the communication and routing services between devices that have limited network access.
Network function implementation through generic IT servers (target) rather than on non-programmable specific firmware (today)	NRG-5 core functionalities, including uMTC and mMTC will be implemented as VNFs and VNF chains deployed on generic xMEC edge network equipment. Moreover, 5G-NORM will be a generic 5G terminal (interfacing an off-the-self smart meter) able to operate as electricity or gas meter, electricity PMU or any other 5G terminal (e.g. part of the	The progress is guaranteed by the VNFs implemented to create the VNFs chains related to the work of field devices like :vDES, vESR, VRES and vMCM for handle virtual twin data.

	functionality may be offloaded from drones to xMEC).	
Trustworthy interoperability across multiple virtualised operational domains, networks and data centres;	NRG-5 will extensively use blockchains technology as a distributed, traceable monitoring trust enabler. This may allow the creation of decentralized trustworthy and interoperable solutions, that are directly verified without the need for a central server.	The blockchain technology was successfully integrated in the vBCP developed for the project allowing other VNFs (such as the vAAA), devices and third-parties to benefit from the merits of trusted, permissionable blockchain infrastructures, without necessitating any kind of blockchain-related enabling technology.

Table 2 : Expected impact

The deployment of network functions as virtual components (NFV) is one of the most import paradigm in 5G. In the three uses cases, we have demonstrated the feasibility of developing some of the key network functions in smart grid network as VNFs. One of the most challenged was the development of the virtual Authentication, Authorization and Accounting VNF (vAAA) in use case 1. Moreover, in use case 2 and use case 3, we have tested the end-to-end communication between the VNFs and the applications running in the mobile devices.
In use case 2, “Enabling aerial Predictive Maintenance”, we have tested the communication between the drone, equipped with a cellular interface for communicating with the network, the vMPA (virtual Media Processing & Analysis VNF) and the vDFC (Drones Flight Control VNF). This use case addresses xMBB communications, which require high data rates in the uplink as the Drone is streaming the video to the control centre and low latency and high reliability (uMTC) in both directions for the remote control of the drone. In D5.3 we have reported the performance results obtained in this use case. Four different scenarios were provided, each one of the scenarios provides different latencies and throughput. The target of the test were to analyse the impact of mobility impairments into the remote operation of the drones and the delay introduced in the notifications of the events interchanged between the Drone and vMPA. Latency requirement for smart grid use cases are up to 20 ms. In the LTE ideal scenario we have measured a RTT end-to-end of 28 ms. User plane latency in LTE as defined in 3GPP TR 38.913 and in four different 5G-NR configurations is shown in Figure , for a 10% of BLER in the radio interface. Radio latency is reduced significantly in 5G-NR. Latency in the core network can be reduced deploying the VNF close to the radio.

Step	Parameter	LTE Release 10	NR-FDD Case #1	NR-FDD Case #2	LTE Release 10	NR-TDD Case #1	NR-TDD Case #2
1	**Subcarrier Spacing**	15 kHz	15 kHz	60 kHz	15 kHz	15 kHz	60 kHz
2	**OFDM symbols per TTI**	14	2	2	14	7	4
3	**DL/UL configuration**	NA	NA	NA	LTE Conf. #6	LTE Conf. #6	S-U repeated
4	**Processing Delay**						
	4.1 Transmitter processing delay	1 ms	0.143 ms	0.0357 ms	1 ms	0.5 ms	0.0714 ms
	4.2 Frame alignment time	0.5 ms	0.071 ms	0.0179 ms	1.4 ms (DL) 1.4 ms (UL)	1.325 ms (DL) 1.025 ms (UL)	0.0714 ms
	4.3 Transmission Time (= TTI)	1 ms	0.143 ms	0.0357 ms	1 ms	0.5 ms	0.0714 ms
	4.4 Receiver processing delay	1.5 ms	0.214 ms	0.0536 ms	1.5 ms	0.75 ms	0.1071 ms
5	**One Way Latency** = 4.1 + 4.2 + 4.3 + 4.4	4 ms	0.571 ms	0.1429 ms	4.9 ms (DL) 4.9 ms (UL)	3.075 ms (DL) 2.775 ms (UL)	0.3124 ms
6	**HARQ RTT (round-trip time)**	8 ms (n + 4 NACK, n + 4 Re-Tx)	1.142 ms (n + 4NACK, n + 4 Re-Tx)	0.2143 ms (n + 3NACK, n + 3 Re-Tx)	11.2 ms (DL) 11.5 ms (UL)	4.65 ms (DL) 4.825 ms (UL)	0.4286 ms
	User plane latency with 10 % HARQ BLER 10 % (one way latency) + 0.1 × (HARQ RTT)	4.8 ms	0.685 ms	0.1643 ms	6.02 ms (DL) 6.05 ms (UL)	3.54 ms (DL) 3.2575 ms (UL)	0.355 ms

Figure 6 : Latencies comparison (Source: http://www.techplayon.com/5g-nr-user-plane-latency/)

As conclusion, extrapolating the results obtained in 4G to 5G, we can conclude that 5G fulfil the delay requirements requested by this use case. 5G improvements such as short TTI will enable the reduction of the delays. With the respect of the throughput in 5G-NR for a configuration of 100 Hz of bandwidth, 1 layer (number of MIMO layers), a modulation of 64 QAM in FR1we can reach close to 500 Mbps in the uplink. As shown in D5.3 the video transmitted by the drone consumed around 8 Mbps in the uplink. We can conclude that 5G-NR will support the video transmission from 68 drones. This number can be multiplied by 2 if we use 2 layers. Finally, in use case 3, during the initial testing of the vPMU developed in the project we observed a high resilience in the presence of high delays. This fact, together with that it was wanted to reduce the costs, made us think on the usage of NB-IoT for the communication of the remote nodes distributed along the power supply network, which also requires a high coverage, one of the most important advantages provide by NB-IoT. In the last two years, the evolution of 3GPP standards related to IoT has accelerated due to the pressure of cellular stakeholders who require a standard solution to go one step beyond to provide a real cellular and standard solution for LPWA (Low Power Wide Area) networks. Behind this pressure are the billions of potential new subscribers from the IoT use cases, such smart energy grid. IoT covers a wide range of use cases, which can only be partially covered by other previous 3GPP technologies such as GSM or Machine Type Communication (MTC) introduced in Release 8, and new ones such as eMTC or EC-GSM and unlicensed LPWA such as Lora or Sigfox. In contrast, NB-IoT is a 3GPP effort to penetrate the ultra-low cost, power and throughput, extended coverage and delay tolerant IoT marketplace, which, in 5G terminology, is the massive Machine Type Communication (mMTC) use case. This use case contains the greatest number of potential IoT subscribers, of the order of several billion.

5G NR (New Radio), the term coined for the global 5G standard new radio access technology, will cover, in the first version, eMBB (enhanced mobile broadband) and URLLC (ultra-reliable, low-latency communication) use cases. mMTC will not be considered until Release 17. In the meantime NB-IoT will provide the solutions to cover the 5G mMTC use case. This will convert this technology into the foundation for NB-5G.

The first version of NB-IoT was released in July 2016, as part of Release 13 in TR 45.820. This version of the NB-IoT standard focused on improving indoor coverage, support for massive numbers of low throughput device sensitivity, ultra-low device cost, low device power consumption and optimized network architecture (see Table 3)

Massive deployments	NB-IoT support IoT devices connections from up to 50.000 to the same LTE base station
Reduced data rates	3GPP offers transfer rate of 100 kbps in the downlink and 20 kbps in the uplink

Extended coverage	Device link budget of 164 dB maximum coupling (MCL)
High allowed latency	Uplink latency can be up to 10 seconds
Low power consumption	10 years of battery life, assuming a 5Wh battery capacity and a data transfer per day of 200 bytes in the uplink, 20 byte in the downlink at 164 dB MCL
Extremely low cost devices	3GPP NB-IoT standard provides a 15% reduction in modem complexity with respect to the Cat-1 category, standardized in Release 8 as part of MTC standard.

Table 3 : NB-IoT features

We have used NB-IoT to communicate Novel grid node from ASM with the VNFs developed in use case 3. The conclusion of the tests are included in D4.4. The summary is that the protocol used in the node at the application level (MQTT) is not adequate for NB-IoT. In D4.4 we recommended a set of reference values related of the packet size and the bit rate used at the application level that have to be configured in order to be able to use NB-IoT. Release 14 added support for more LTE features to increase functionality and the number of use cases covered by NB-IoT. Features in Release 14 included support for ECID (Enhanced Cell Identifier) and OTDOA (Observed Time Difference of Arrival) positioning and mobility and service continuity enhancements and peak throughput improvement in the downlink (144 kbps) and in the uplink (142,5 kpbs). Release 15 introduced TDD (Time Division Duplexing support, higher spectral efficiency, early data transmission, wake-up mechanism and on demand network access for UE power saving, NPRACH (NB-IoT physical random access channel) reliability and range enhancement, small cell support and LTE Device to Device, UE to Network Relays for IoT and wearables. Some of the latest additions to Release 15 are the coexistence of NB-IoT with 5G NR and the coexistence of NB-IoT with eMTC. As many NB-IoT devices are expected to live more than ten years after being deployed, they are expected to be compatible with future 3GPP releases. In addition, as suggested by multiple 3GPP contributions, both NB-IoT and eMTC are also expected to coexist and converge in the future towards mMTC, but that does not mean that every new feature will be added to both eMTC and NB-IoT. Instead, quite likely a decision should be taken case by case depending on the needs of the specific use cases. For those use cases which requirements do not fit into the requirements provide by NB-IoT there is a new item introduced in Release 16, "New Radio Industrial Internet of Things" (NR-IIoT), which is focused on factory automation use cases. The key technology enablers of NR-IIoT are the NR URLLC (short TTI, reliability) and the Time Sensitive Networking (TSN) (accurate reference time, QoS for wireless Ethernet, Ethernet compression, etc). In Release 17 has been also included a new topic NR-Lite, which addresses new IoT use cases which requirement cannot be meet with previous technologies: higher data rate and reliability and lower latency that eMTC and NB-IoT, wider coverage than URLLC and lower cost than eMBB. This is the case of vPMU. In D4.4 we studied the impact of 4G technologies in the data transmitted by vPMUs developed as part of the project. LTE technology affected negatively to the performance system, specifically LTE connection introduced fluctuations in the voltage. However, NB-IoT doesn't meet the requirements of throughput. The 5G scenarios emulated in D4.4 demonstrated that 5G features introduced previously in this section provide lower phase deviations in the voltage.

As summary, we have demonstrated that 5G-NR full the requirements of smart energy grid networks. Moreover, we have identified that it is possible to achieve higher improvements by applying NR-IIoT technology introduced in Release 16 or NR-Lite, topic that will be part of Release 17, which specification will be initiated in January 2020.

2 WBs and Progress towards the Objective during Period M14-M30

2.1 Explanation of the work carried per WP

2.1.1 Work Package 1 - Use Case Analysis & NRG-5 software network architecture [M1-M18]

WP1 Leader: ***WIND****, Participants: ENG, TCS, SiLO, ENGIE, RGAZ, ASM, BT, HIS, EMOT, CRE, Rutgers*

Planned Objectives

- Refine the overall NRG-5 reference architecture, including all building block components useful for the final 5G-PPP Architecture for 5G networks.
- Refine the NRG-5 use cases and their requirements.
- Extract and formulate 5G-related requirements and KPIs correlated to the 5G-PPP suggestions.
- Complete the analysis for the functional decomposition and detailed specification of the architecture components and APIs.

A summary of progress towards objectives and details for each task

Task 1.1: From Smart Energy Use cases to 5G Network requirements

- CLOSE

Task 1.2: 5G Reference Network Architecture

- CLOSE

Task 1.3: 5G components functional decomposition & design

The architectural components identified in T1.2 have been further described in this task. A consistent approach of identifying external service interfaces and interaction flows has been advocated. This has been adopted in D1.2, D2.1 and D3.2 which describe (network and energy specific) VNFs and application logic in these terms and include the use of sequence diagrams to further describe how components interact. After the activities done in the previous period the process included all components: the D1.3 provided the NRG-5 Final 5G architecture supporting the smart energy NRG-5 use cases updating the NRG-5 Reference Architecture provided in D1.2 focusing on the communication and computing requirements and providing initial laboratory results. In details: an updated set of requirements based on what has emerged from the work already carried out have been analysed, relevant architectural innovations from the smart energy domain as well as innovative architectural design principles and enablers have been applied. Further detail is provided on the nature of the energy and telecommunications layers of the architecture as well as how it meets the various security and privacy challenges. The architecture will enable network services to be delivered and these have associated quality of service requirements and KPIs which are introduced. To complete the activities for this task, an evaluation of how the architecture meets the use case requirements has been provided with the functional decomposition of the architecture and its components. Each of the Virtual Network Functions (VNFs) of NRG-5 are described with a particular focus on networking and interaction with other components. For the three services Advanced Metering Infrastructure as a service (AMIaaS), Predictive Maintenance as a service (PMaaS) and Dispatchable Demand Response

as a service (DDRaaS) composed of different VNFs and virtual interfaces of physical devices all aspects were defined and designed. To complete the analysis a first prototype of virtual functions were deployed to obtain the initial laboratory results.

- The architecture of NRG-5 has been focused on the further clarifications of the NRG-5 xMEC definitions as particularly derived from the functional requirements of the NRG-5 UCs.
- Clearly identify the set of possible NS definitions as connected sets of VNFs and VNFFGs as well as NS configurations that may either serve as adequate enablers for new services under the umbrella of the NRG-5 UCs or pave the way for new services that, based on the NRG-5 definitions, will use them to offer added-value services.

Highlight clearly significant results

Task 1.1: From Smart Energy Use cases to 5G Network requirements

- Already described

Task 1.2: 5G Reference Network Architecture

- Already described

Task 1.3: 5G components functional decomposition & design

- Architectural components including VNFs and application logic have been described in terms of external
  - service interfaces,
  - interaction flows,
  - sequence diagrams.
- Measure and model the performance of the NRG-5 VNFs under conditions of heavy load
- Determine the sizing requirements of the Networks services so that they can be properly scaled under conditions of heavy load

Deviations and/or Failure to achieve objectives (if applicable)

N/A

Deliverables

Del No.	Title	Lead Beneficiary	Due Date	State
D1.1	Use Case scenarios analysis and 5G requirements	ASM	6	Submitted
D1.2	Reference Architecture & Functional Decomposition	WIND3	10	Submitted
D1.3	Final 5G Network Architecture to support smart energy	BT	18	Submitted

Milestones

Mil. No.	Title	Lead Beneficiary	Due Date	State
MS1	Final 5G Architecture to support smart energy	WIND	10	Achieved
MS2	Final 5G Architecture to support smart energy	BT	18	Achieved

Involved partners	Activities description and deviation
ENG	ENG partecipated to the D1.3 creation and consolidation. It has been involved in conf call for the finalization of the architecture and also provided description and

	functionalities of the interfaces and interaction that regarded DDRaaS and the workflow among the different VNFs involved in this UC.
TSC	For Task 1.2, TCS has provided an in-depth security analysis for 5G networks that will benefit the overall NRG-5 architecture. The provided analysis covers AAA, Privacy, Trust management, monitoring, and slice security. For Task 1.3, TCS has provided the specification for the vAAA service employed in NRG-5. TCS acted as reviewer for the resubmitted deliverable 1.2 and 1.3.
SiLO	During this period, participating in tasks 1.2 and 1.3, SiLO focused on the refinement of the NRG-5 reference architecture, particularly with respect to the definition of a flexible VNF and NS lifetime management and overall policy governance model. The results of this work were documented in deliverable D1.3 and are reflected, in practice, in the context of the WP3 activities, particularly T3.3 and T3.4 and the associated report, deliverable D3.3.

ENGIE	ENGIE has refined the NRG-5 architecture and VNFs. In particular, the use case 2 (predictive maintenance as a Service) was refined and tailored to match on site constraints. The two main VNFs were detailed, ie. vDFC-virtual Drone Flight Control (telemetry) and vMPA-virtual Media Processing Analyzer (video image processing). Authentication that was initially identified as a VNF, was performed by User Log-in control. The drone scenarios to be performed via the vDFC were organised in three flying modes: automatic, manual and the so-called “remote access” via the satellite link. The different video analysis to be performed by the vMPA were structured per their operational priorities:
	• Predictive maintenance:
	  ○ detection of technical defaults via video analysis with daylight camera and detection of overheat zones / hotspots where the insulator has worn via color changes after video analysis with thermal camera,
	  ○ field / terrain changes, holes diggings and vehicle detection to avoid works on the buried pipes, via video analysis with daylight camera
	• Security :
	  ○ Human and vehicle detection to support intrusion detection and SAR (search and rescue) services in case of accidents and emergency situations.
	The overall Project architecture was refined taking into consideration allowed trajectories on the STORENGY gas plant.
	Capabilities of the available drones, ie. the Project drone and the STORENGY drone, were also integrated in the on-site trial book. This included the drone communication modes (IP over WIFI and/or proprietary), the communication range, and then power autonomy.

RGAZ	RGAZ, based on a typical extraction field structure and typical underground storage facility and the requirements of a gas production company for predictive maintenance, RGAZ provided the initial inputs for UC2 scenario. RGAZ participated in the preparation stage. Accordingly, RGAZ contributed to to functionalities contained in D1.1 and D1.2 . RGAZ has offered the expertise in this project - beneficiary of 5G infrastructure as a company whose core business is natural gas exploration and production.
ASM	ASM led the activities of T1.1, already reported in the previous reporting period. ASM contributed on D1.3 which is an updated version of D1.2, manly focusing on UC1 and UC3 perspective.
BT	In leading Task 1.3, BT proposed an approach to provide consistent descriptions of architectural components for the project enabling functional decomposition to be

	carried out. This involved describing component interfaces and interactions and the provision of sequence diagrams to illustrate this. A distribution of partner responsibilities was developed, and coordination achieved via regular calls and reviews. Following the work to resubmit deliverables D1.1 and D1.2, D1.3 was submitted in M20.
WIND3	WIND3 leads activities in WP1: in the framework of Task 1.3, WIND3 participated to the deliverable D1.3 consolidation. In the course of the task activities WIND3 has provided update information to improve the description and analysis of 5G Network requirements and KPIs; the network requirements and the KPIs have been correlated with the NRG-5 use cases to complete the analysis according to the different requirements for the services offering more elements. WIND3 has offered the contribution to refine the reference architecture compliant with the expected functionalities as required by the analysis performed in T1.1/T1.2 and described in D1.1/D1.2. In the course of the task activities WIND3 has provided an improved description and analysis of 5G Network requirements and KPIs; the network requirements and the KPIs have been correlated with the NRG-5 use cases to complete the analysis according to the better available details. The first architectural schema has been improved to allow the other process for different WPs like WP2 and WP3. Besides, WIND3 actively interacted and participated in discussions by mails, phone, teleconferences and face to face meetings with a strong collaboration with the ASM, BT and ENG and all the involved partners to get the final result.
HIS	Hispasat (HIS) has contributed to the analysis of use case 2 in the D1.3. Final 5G Network Architecture to support smart energy. It worked on the architecture on the NRG-5 project through the inclusion of satellite to implement the predictive Maintenance application already designed.
EMOT	Emotion collaborated to analyse and decompose the architectural elements that have been identified in Task 1.2, with particular focus on Use Case 3 elements. Furthermore, Emotion contributed to the deliverable D1.3, mainly providing contribution on NRG-5 architecture requirements from NRG-5 use cases section. Finally, Emotion actively interacted and participated in discussions related to the Task 1.3 activities by mails, teleconferences and direct communications.
CRE	From the perspective of the partner involved in defining UC1 - Realizing decentralized, trusted lock-in free Plug & Play vision and during the reporting period CRE contributed to the validation of 5G telco requirements and to VNFs for this UC, as well as to the development of Smart Energy Specific VNFs, especially with reference to vPMU: description, interoperability, operation, protocol description (in the context of deliverables D1.2 and D1.3)
Rutgers	Rutgers supported the WP1 activities completing the available analyses and offering decisive ideas

2.1.2 Work Package 2 - 5G trusted, scalable & lock-in free plug' n' play [M1-M22]

*WP2 Leader: **BT**, Participants: ENG, TCS, POPs, OPT, TEISTE, NKUA*

Planned Objectives

- Design and implement a protocol based on beacons and control messages (such as UPnP or DLNA), suitable for Network Discovery along with the NRG-5 nodes and network topology repository.
- Realise Self-organization/Self-healing network functions, constructing multiple virtual routing trees over a single fixed physical topology for increase robustness.
- Provide mechanisms for physical resource monitoring and accepting alerts to automatically update the routing topologies and perform Mobility Management.
- Increase scalability via MCM and semantic mapping of energy assets values at the (edge) cloud.
- Realize decentralized trust management by design by combining strong encryption of hardware constrained devices (such as PUF) with decentralized crowd-based repositories based on blockchains.
- Realize the above functionality as VNFs accordingly to achieve flexibility and adaptive deployment through a Utility-oriented NFV implementation.

A summary of progress towards objectives and details for each task

Task 2.1: NFV for self-*

Beyond the work that had been done described in D7.1 already, we have refined the design of the self-* VNFs. The refined version of VNF description has been documented into D2.3.

Task 2.2: NFV for MCM

The vMCM VNF was further developed during the reporting period with a focus on integration with other VNFs and application logic. Additional components were created which support the integration and are deployed alongside the core of vMCM in the xMEC and on user equipment where it acts as a client.

Task 2.3: VNF for Mobility Management

During this reporting period, focus was led on the finalization of the specification of the NRG-5 supplementary vMME VNF as well as its implementation and integration in the overall project's control and data flows. Lightweight integration with OpenAirInterface was achieved, though focus was put on the additional functionalities of the NRG-5 vMME companion software as well as on the accompanying vMME client software. The result was a combination of coordinated, loosely-coupled set of services that expose multi-protocol interfaces, particularly supporting RESTful as well as publish-subscribe protocols. The vMME VNFD and accompanying VIM (Openstack) image were implemented and tested and their functional operation was validated. Last, significant focus was put on the streamlined integration of vMME with the rest of the NRG-5 activities and VNFs in particular. The results of this work were documented first in deliverables D2.2 and D2.3.

Task 2.4: VNF for Decentralized Trust Management

During this reporting period, the consortium focused on the formalization of the specification as well as the implementation of the blockchains-based trust management framework of NRG-5, summarized in the context of the two enabling VNFs, that is vAAA and vBCP. In particular, the APIs were enriched in order to be able to support more use cases and options. Attribute-based Access Control was introduced and implemented. The vBCP and vAAA clients were re-written in order to be more efficient and support batch information sharing in case of resource-pconstrained UE. In this framework, integration activities with the rest of the NRG-5 VNFs were coordinated and achieved. The results of the task activities were documented in deliverable D2.4.

Highlight clearly significant results

Task 2.1: NFV for self-*

We have refined the design of self-* VNFs, vTSD and vSON, and documented the refined version in detail into D2.3 [2].

We have implemented the self-* VNFs, vTSD and vSON, as well as the corresponding modules installed on UEs based on both a small-scale testbed made of several Raspberry Pi v3 computers and a large-scale testbed operated by FIT IOT-Lab [3].

Task 2.2: NFV for MCM

A vMCM VNF was created, able to act as a digital twin for multiple devices at the xMEC and able to integrate with other VNF from this WP and from WP3

Task 2.3: VNF for Mobility Management

The final version of the vMME was delivered, featuring both RESTful and publish-subscribe communication protocols. VNF images were appropriately built and the relevant VNFDs were dully specified.

Task 2.4: VNF for Decentralized Trust Management

vAAA and vBCP design was crystalized and implemented. Integration activities with other VNFs were successful. VNF clients were produced and successfully evaluated from a functional point of view.

Deviations and/or Failure to achieve objectives (if applicable)

Deliverables				
Del No.	**Title**	**Lead Beneficiary**	**Due Date**	**State**
D2.1	NRG-5 Low-Layer Networking VNFs	SU (UPMC)	11	Submitted
D2.2	NRG-5 Virtual Network abstraction	BT	16	Submitted
D2.3	5G trusted, scalable & lock-in free plug' n' play	POPs	22	Submitted

Milestones				
Mil. No.	**Title**	**Lead Beneficiary**	**Due Date**	**State**
MS3	NRG-5 Low-Layer Networking VNFs	SU (UPMC)	11	Achieved
MS4	5G trusted, scalable & lock-in free plug' n' play	POPS	22	Achieved

Involved partners	**Activities description and deviation**
TCS	"TCS finalized the work performed in Task 2.4 providing vAAA functionalities connecting to the vBCP. In particular, TCS contributes to the decentralized authorization part of NORM devices using Attribute based Access control (ABAC) mechanism. The main properties provided are:

	flexible and fine grained authorization management, more expressive and can support multi-factors decision. "
BT	BT continued to lead the WP, leading the delivery of D2.2 and overseeing the delivery of D2.3 as the final deliverable from the work package. The deliverables describe the technical achievements of the work package, which for BT was principally the creation of the vMCM VNF. During this reporting period, the initial version of vMCM was extended to include greater integration with other VNFs.
POPs	POPs participates in two tasks, namely T2.1 and T2.4, leading the latter as well. During this reporting period and with reference to T2.4, POPs focused on the finalization of the specification, implementation and integration in the overall control streams of NRG-5 of the vAAA and vBCP VNFs. POPs also led the editorial activities of D2.3 related to the 5G trusted, scalable & lock-in free plug' n' play notion of NRG-5. Such integration activities were the core focus of the participation of POPs in T2.1. Last, POPs actively contributed to the content of deliverable D2.2.
OPT	During this reporting period, OPT contributed to tasks 2.3 and 2.4. In particular and with respect to T2.3, the vMME client software and several parts of the relative VNF parts related to the orchestration of the NRG-5 vMME client messages were designed and implemented. Similarly, part of the vAAA and vBCP clients were designed, implemented and tested by OPT
NKUA	During this reporting period, TEISTE/NKUA focused on the design and development of the vMME software, leading the activities of task T2.3. The result of this work was mainly documented in deliverable D2.2. Under an integration with the rest of the core NRG-5 VNFs perspective, TEISTE/NKUA also contributed to tasks T2.1 and T2.2. In addition, TEISTE/NKUA continued with the refinement of the vMME NRG-5 VNF and its integration with the rest of the NRG-5 components. The final result of the work performed is documented in deliverable D2.3.
SU	SU has refined the design of self-* VNFs and implemented prototype systems based on both a small-scale testbed made of several Raspberry Pi v3 devices and a large-scale testbed operated by FIT IOT-Lab. SU has also contributed to document D2.3.

2.1.3 Work Package 3 - VNF automated deployment [M1-M24]

*[WP3 Leader: **ENG**, Participants: TCS, SiLO, WIND, VIS, EMOT, JSI, CRE]*

Planned Objectives
• Provide the NFV, VNF and NS NRG-5 Catalogue that will provide a centralized repository of NFVDs, VNFDs and TSDs as a combination of the former • Implement the functionalities that will be used as application logic for the services that will be validated in WP4 and demonstrated in WP5. • Determine a scalable and efficient framework for performing meaningful, elastic SFC via VNFFG, to be able to create NSs using NFV abstractions and VNFs as appropriate.

- Design and develop an effective VNF deployment and relocation framework that will take care of VNF portability, respecting NF mobility and ensuring naming compatibility without compromising security.
- Desing and implement an effective SLA monitoring mechanism able to cover the needs of the network and energy operators, combined .

A summary of progress towards objectives and details for each task

T3.1: VNFs Catalogue

In the reporting period the development and onboarding of assets on the catalog has been finalized to be ready to run the NRG-5 use cases on OSM. We designed the deployment templates for a service slices composed of Virtual Network Function Descriptors (VNFDs), Network Service Descriptors (NSDs) and Slice Templates together with day-0 and day-1 configuration data. Onboarding was done on OpenStack and OSM operated by NRG-5 partners for integration purposes (located in POPs and RWTH premises). The work performed has been described in deliverable 3.3 that overviews all such definitions and network setup to deploy the smart energy slices.

T3.2: Application Logic Development

During this reporting period ENG organized ad hoc phone call to coordinate the effort of all the partner inovled towards the establishment of guidelines and practical approaches to put in place the application logic. With this aim in mind ENG drove the task partners through the assessment and deployment of the functionalties needed to put in place all the energy VNFs and the related NS. All the functionalities and applications related to energy have been developed and made available to experimentation in WP4 and final validation in WP5.

T3.3: Efficient & Reliable VNF chaining

During this reporting period, the task activities focused on the implementation of the self-optimizing framework that governs the overall NRG-5 flexible service provisioning. In particular, following the cloud-native paradigm, several micro-services were engineered to support a MAPE-K-oriented optimization loop. A plugin-like architecture was achieved, by employing a star architecture holding a high-performance publish-subscribe mechanism (based on Apache Kafka). Services related to VNF monitoring, VIM to MANO and vice versa translation combined with high-performance dashboards were implemented. For the analysis part, a policy-based complex-event-processing-oriented approach was adopted, implemented and validated.

T3.4: Optimal VNF deployment & relocation

In coordination with T3.3, this task focused on the design of algorithms that will be used under the MAPE-K perspective so that based on the available analytics and events emitted by the Analysis Engine and stored in the Knowledgebase, timely decisions on the optimal deployment of VNFs and NSs can be made, particularly in cases of moving loads. To this end, the task implemented tuned the analysis module to emit events that are, in turn, streamed to a service that identifies the optimal placement of new or scaled NSs based on criteria related to the users connected to each xMEC, the current CI-SLAs as evaluated by T3.5 activities, the availability of cloud edge infrastructures and the actual traffic that needs to be accommodated.

T3.5: CI-SLA monitoring & enforcement

During this reporting period, the activities of this task focused on the implementation of the prediction framework and evaluation of models that predict metrics relevant to CI-SLA monitoring. The prediction framework ingests input data from sensors and provided by various services, then performs preprocessing steps that include data cleaning and alignment. Next, feature engineering, model building and evaluation are needed to find the most suitable one to be deployed for a specific purpose. For instance, we evaluated logistics regression, decision trees, random forests, SVM and multilayer perceptron to predict classes of link quality,

Highlight clearly significant results

T3.1: VNFs Catalogue

ALL required VNFs, NS and Slices developed in the project are onboarded on the OSM of the project, tested, and ready to be run.

T3.2: Application Logic Development

This task finalizing the realization the underlying application logic functionalities for all the NS. At this purpose different approaches has been selected and declined for the different VNFs taking in account all the best solution for data clustering and fast data processing. When needed proper ResFul API has been developed for the integration of the different VNFs.

T3.3: Efficient & Reliable VNF chaining

The final version of NRG-5's elasticity provisioning framework prototype has been achieved and has been tested against the latest stable version of OpenStack and against OSM RELEASE 5.

T3.4: Optimal VNF deployment & relocation

In parallel to T3.3, the analysis component was tuned to handle the automated re-deployment of NSs to xMEC instances based on the availability of resources in the neighbouring xMECs and the need for extra VNF presence in these xMECs.

T3.5: CI-SLA monitoring & enforcement

Predicting the future most likely state of the CI can help configure the network services in a pro-active way ensuring more reliable SLA. Predicted values for network and service parameters such as connection reliability of resource availability can then be taken into account when decising for VNF deployment and relocation.

Deviations and/or Failure to achieve objectives (if applicable)

Deliverables

Del No.	Title	Lead Beneficiary	Due Date	State
D3.1	Semi-automatic NS/VNF deployment	TCS	8	Submitted
D3.2	NRG-5 application logic framework	ENG	16	Submitted
D3.3	VNF lifecycle management	SiLO	24	Submitted

Involved partners	Activities description and deviation
ENG	ENG was the leader of this WP and from the management point of view coordinated all the phone calls needed to orchestrate the different partner work with the aim to achieve the WP goals. As regarding the different Deliverables Eng was directly involed in the creation of D3.2 as leader of the document, and as one of the contributors of D3.3. His main role and expertise was involved in the catalogue and VNF realization . With this aim ENG realized as synergic work with all the other involved partners for the catalogue creation and for the different models for NS VNFD and TSD. This work was the preliminary goal achieved for the final realization of the deployment and relocation framework that has been achieved as final milestone. Regarding the all VNFs functionalities ENG was involved in their creation and in how to implement in the related application logics . It developed a dashboard for final user of SO to integrate the energy virtual function reports. It also was involved in the creation of requirements to put in place SLA and VNF chaining.

TCS	TCS led task 3.1 that ended in M24. TCS coordinated the work to deliver the finalized and tested version of the NRG-5 catalog, which consisted in the collection of software artifacts and related configurations from partners, the creation of VNF and NS descriptors in line with the requirements, the onboarding and testing on the integration platforms. TCS contributed to the delivery of deliverable 3.3.
SiLO	SiLO led both the research and development activities of tasks T3.3 and T3.4, actively coordinating with T3.1, in an attempt to offer an integrated, generic approach towards optimizing the deployment of VNFs and NSs and optimally managing their sizing requirements. In this reporting period and in the framework of T3.1, SiLO led the activities related to the definition of the Os-An and An-Ma interfaces as part of the MAPE-K optimization framework specification. In tasks T3.3 and T3.4, SiLO finalized the scalability and optimal re-location of the NRG-5 NSs. The results of this work are summarized in the context of deliverable D3.3.
WIND3	WIND3 contributed to D3.2 - NRG-5 application logic framework, with a particular focus to the Telco aspects. Besides, we collaborated in the analysis of the application logic of the services, as Telco, to be validated and demonstrated in in WP5 and actively interacted and participated in discussions to improve the analysis and the final results.
HIS	Please, consider that we have added in the comments of the deliverable that Hispasat is not a partner of WP3. In the last update of the European Commission, changes proposed in the amendment were included correctly. So, we should not be still included like participant in WP3, although we should be included in participants of Task 4.3 (WP4).
VIS	Visiona contributed to D3.2 - NRG-5 application logic framework, with a particular focus to the Predictive Maintenance as a Service (PMaaS). Visiona develope the two main VNFs of the use case 2, the vDFC and the vMPA fulfilling the requirements of the previous deliverables. The developed VNFs are validated in the WP4 and tested in a real-world in the WP5. For the T3.5, conversations with JSI have taken place to accomplish the task objectives. Visiona was a essential part of the discussions of the UC2 related developments
EMOT	Emotion contributed to D3.2 - NRG-5 application logic framework, with a particular focus to the Demand Response as a Service (DRaaS) of which it was in charge together with Engineering. Emotion collaborate in the development of the application logic of the services to be validated in WP4 and demonstrated in real-life trials in WP5 and actively interacted and participated in discussions by mails, teleconferences and direct communications.
JSI	JSI led both the research and development activities of task T3.5 by looking at approaches and methods of ensuring CI-SLA. The suitability of various machine learning algorithms, including decision trees, multi-layer perceptrons and deep learning for approximating and predicting aspects of CI-SLA has been assesed and their relative performance quantified. The results of this work are summarized in the context of deliverable D3.3. JSI contributed also to the development of a proof of concept of the AMIaaS specification and architecture reported in D3.2. The prood of concept used streaming NORM data fed to an Influx DB and visualized using Grafana dashboards integrated into our custom Videk platform.
CRE	Within the second reporting period CRE was involved in the Task 3.2, specifically for supporting the elaboration process and providing input for the deliverables D3.2 (NRG-5 application logic framework) and D3.3 (VNF lifecycle management).

	In both deliverables, the CRE contribution was dedicated to the Energy VNFs chapter, more specifically to the virtualization of the Phasor Measurement Unit (vPMU) functions – Description, Interoperability, Operation and Protocol description.

2.1.4 Work Package 4 - Integration & Laboratory evaluation [M5-M28]

WP4 Leader: ***RWTH****, Participants: ENG, TCS, ENGIE, POPs,HIS, VIS, OPT, EMOT, UPMC, CRE, Rutgers*

Planned Objectives

- Define the end-to-end laboratory system integration guidelines.
- Realise the NRG-5 platform software integration.
- Implement the 5G-NORM smart meter as a generic 5G terminal prototype supporting mMTC by design, with built in trusted, scalable and lock-in free plug'n'play capability
- Implement and integrate the use cases based on modules already developed in WP2-WP3
- Perform laboratory testing & evaluation
- Create and update the NRG-5 open Data Management Plan (DMP) (to be realized in WP5 & WP6)

A summary of progress towards objectives and details for each task

Task 4.1: Integration Guidelines & Open DMP

During the second reporting period the second version of D4.2 Integration Guidelines & Open DMP v2 was developed and delivered.

Task 4.2: 5G-NORM Integration & Validation

During the reporting period it has been continued the support activity for allowing integration of all components of 5G-NORM. The Smart Meter gave the environment support to allow the final integration and validation of different functionalities. Partners contributing at the different VNF developments were able to integrate and test on laboratory level the specific applications, in a Raspberry Pi (RPI) environment, using both real RPI platforms or virtual machines simulating the RPI device and accessible remote by partners. The task activity allowed to prove the project generic and specific VNF functionalities. The final laboratory validations are described in deliverable 4.4.

Task 4.3: Drones Integration & Validation

In the reporting period the implementation details of the NRG-5 VNFs, including their placement and mutual relationships inside the NRG-5 architecture have been finalized. Type of dron and flight controller to use in the project has been analyzed. Validation of the integration with the drone flight controller has been done. SLAM algorithms have been analyzed and tested evaluating the impact in the compute power onboard the drone. MultiRAT integration in the UC2 and how to implement it analyzed. Testbeds are implemented, illustrating the outcomes of the laboratory design and activities carried out in the scope of Work Package 4. Together with the testbeds descriptions, the relevant test cases are reported, highlighting the objectives of such tests, in terms of number and type of functionalities to be assessed. Leaving the implementation and validation of the relationships inside the NRG-5 architecture to the Task 4.4 (and it's deliverable).

Task 4.4: xMEC OpenVNF Integration & Validation

During this reporting period, the testbed setup introduced in the first project period was updated and validated. In particular, OSM was upgraded to v5 in order to better support the WP3 activities related to elastic VNF scaling. Further, the updated OSM infrastructure was expanded in order to offer support for multi-point-of-presence installations. In this course, on top of the original

infrastructure (provided by POPs), OpenStack installations representing NRG-5 points of presence at Germany (RWTH) and Italy (ASM Terni) were integrated and validated. To this end, coordination among the infrastructures was achieved so that NS deployment is seamless regardless of the virtual infrastructure manager (effectively point of presence) of choice.

Task 4.5: Laboratory Testing & Qualification

During the second reporting period the integration and testing of VNFs was done. This includes testing of the single VNFs by the involved partners, integration of the communication between the different VNFs and finally the testing of services utilizing multiple VNFs. During the testing of single VNFs the impact of a 5G-like radio channel was evaluated against a 4G radio interface with the vPMU as phasor calculator. Furthermore the composed DDRaaS was ran on an edge cloud-like environment using Openstack and Open Source Mano. This environment is part of the RWTH testbed also consisting of a NORM Emulator to emulator the UE side with the client software needed by the VNFs.

Highlight clearly significant results

Task 4.1:Integration Guidelines & Open DMP

During the second reporting period the second version of D4.2 Integration Guidelines & Open DMP v2 was developed and delivered.

Task 4.2: 5G-NORM Integration & Validation

The task activity provided 5G-NORM environment to allow integration and validation of different project components in the Smart Meter. The specific validation activities for the VNF functionalities have been achieved in further tasks of the WP. Additionally, simulations of the NORM devices made possible to test and validate vPMU as an orchestrator, by combining large number of PMU data with a simulated microgrid having high RES penetration. This functionality particularly highlighted that synchronized voltage angles in microgrids with large deployment of PMU functionality can bring valuable information for microgrid observability and can bring support for future microgrid dispatch, by assessing the microgrid status based on aggregated PMU data concentrated in the vPMU-Orchestrator application.

Task 4.3: Drones Integration & Validation

Testbeds designed for validation of the use cases involved VNFs and early tests performed. Future tests to fulfil project objectives planned to realize them in the next task.

Task 4.4: xMEC OpenVNF Integration & Validation

Updated OSM version, integrated two more points of presence, validated the WP3-provided NSs configuration and operation and coordinated the configuration of the NRG-5 points of presence.

Task 4.5: Laboratory Testing & Qualification

One of the key achievements of this period has been the addition of cellular networks to the laboratory. The work has been carried out in two stages. In the first stage, the TRIANGLE testbed has been interconnected with the RWTH testbed. This enabled the consortium to analyse the performance impact when different cellular network technologies (from 4G to 5G-like). Results reported in D4.4 confirm the need of 5G systems to properly meet the smart grid vertical requirements. These results highlight the importance of mobile edge cloud computing which drastically reduces the delay. In the second stage, RWTH and KEYD worked together to include a cellular network test network in the RWTH testbed. The emulated 5G-Norm devices can be routed through the cellular network link or wired connections as desired by the experiment controller. In this second and final stage, RWTH and KEYD were able to verify that the system works using a 5G-like networks.

The RWTH testbed integrated VNFs needed for running the DDRaaS service and showed the control of a simulated power grid through the NRG-5 software stack, including the vESR, vMCM, vBCP and vDES on the edge cloud side as well as the emulated 5G NORMs running the vMCM cleint, vBCP cleint and vDES client. The vDES client is able to directly communicate with the

simulated power grid and can manipulate battery setpoints inside the simulation. That way the impact of the NRG-5 software stack and edge cloud based control can be examined

Deviations and/or Failure to achieve objectives (if applicable)

N/A

Deliverables

Del No.	Title	Lead Beneficiary	Due Date	State
D4.1	Integration Guidelines & Open DMP v1	RWTH	6	Submitted
D4.2	Integration Guidelines & Open DMP v2	RWTH	18	Submitted
D4.3	Intermediate NRG-5 laboratory validation	VIS	20	Submitted
D4.4	Final NRG-5 laboratory validation	RWTH	28	Submitted

Milestones

Mil. No.	Title	Lead Beneficiary	Due Date	State
MS7	Integration Guidelines & Open DMP	RWTH	6	Achieved
MS8	Intermediate NRG-5 laboratory validation	CRE	20	Achieved
MS9	Final NRG-5 laboratory validation	RWTH	28	Achieved

Involved partners	Activities description and deviation
TCS	TCS worked in task 4.3 related to the integration of NRG-5 technologies in UAV platforms. TCS developed an early demonstration to showcase the idea of distributed management of flows by using source routing techniques, video flows analysis and target identification deployed at the edge and service orchestration (an early example was demonstrated during the first review meeting). TCS contributed then to the delivery of D4.2 by providing the main scenario for integration.
ENGIE	ENGIE supported Task 4.3 to check coherence between laboratory tests and planed on-site tests. ENGIE made several recommendations to UC2 partners to ensure that the requested KPIs can be measured on site too (please refer to D5.3 for final results). Despite UMA late entry in the Project, they supported KPIs measurements whenever it was possible.
POPs	POPs participates in T4.4 related to i) the integration of the MANO framework with the VIM of choice and ii) the validation of this integration at the level of proper end-to-end NFV functionality. In this context, POPs offered their testbed as primary computational infrastructure. POPs led the activities of integrating the various NRG-5 points of presence and organized the experimentation and deployment of the VNF instances into the points of presence.
VIS	Visiona led task and deliverable 4.3 coordinating the efforts to deliver a complete document that reflects the first work of integration in laboratory of all use cases. Visiona contributed to the D4.3 by providing information related to the vMPA and vDFC and also the related testbed, architecture and integration of the UC2. Analysis of the drone and related hardware and characteristics have been explained.

	In the D4.4 details of the integration in the NRG-5 stack have been provided as well as the full use case 2 setup.
HIS	HIS participated in the D4.3: Intermediate NRG-5 laboratory validation. And in particular worked on T4.3.: Drones Integration and Validation.Hispasat (HIS) has done the study of experiment 2, which was based on the integration of the drone system with a satellite solution to offer connectivity. In addition, Hispasat has contributed to the project knowledge about the definition of the reference architecture: Multi-RAT (Radio Access Technology). Hence, it has demonstrated the functionalities and limitations of legacy systems (4G-LTE, 3G, 2G) in satellite architecture through the combined connection between satellite / wifi / cellular. Finally, as part of the validation on the integration of the drones, a trail took place in Arganda (Madrid) and it was made by Hispasat and Visiona.
OPT	During this reporting period, OPT participated in tasks 4.1, 4.4 and 4.5. In this framework, OPT significantly contributed to the generation of the second version of the project's data management plan that was delivered in M18. OPT coordinated the activities under the context of T4.4. In this context, the integration of the MANO framework of choice (OSM) and the virtual infrastructure manager of choice (OpenStack) were led by OPT. The results of such integration were reported in D4.3 and partly D4.4. Finally, in T4.5, OPT contributed to the delivery of the tests performed at NFV level, the relevant results being presented in D4.4.
EMOT	EMOT contributed to D4.3 – Intermediate NRG-5 laboratory validation, with particular focus on architecture, scenarios and integration section and UC3 testbed section. EMOT contributed to D4.4 – Final NRG-5 laboratory validation providing information on the electric vehicle and charging station API laboratory validation. In Task 4.4, EMOT contributed to the implementation of the test setup, with a particular focus on electric mobility test setup. Emotion actively interacted and participated in discussions by mails, teleconferences and direct communications.
RWTH	In the second reporting period RWTH focused on T4.1 leading "D4.2 Integration Guidelines & Open DMP v2" and on T4.5 leading "D4.4 Final NRG-5 laboratory validation". In order to do the testing for the contribution to D4.3 and D4.4 the final integration of different VNFs was done. This includes the communication between the VNFs as well as the communication to the NORM Emulator and the RTDS real time stimulator, to finally run service level teste of the DDRaaS controlling a simulated grid.
NKUA	During this reporting period, TEISTE/NKUA focused on the generation of the integration guidelines and the data management plan of the project, in the context of their participation in T4.1 At the same time, significant effort was spent on task T4.2 related to the 5G NORM integration and validation. Particular focus was laid on the relevant communication aspects and the integration with the low-level VNFs, vMME in particular. In addition, significant focus was put on the laboratory validation and integration tests focused on vRES in the context of vDDRaaS. These tests were carried out on the NFVI operated by RWTH and documented in Deliverable 4.4
SU	SU has done the laboratory validation tests for vDES, vTSD and vSON and contributed to the DDRaaS laboratory validation test. The tests of vTSD and vSON were conducted based on FIT IOT-Lab. The tests of vDES and DDRaaS were conducted on the NFVI operated by RWTH. The test results have been documented in to D4.4.
CRE	Within the second reporting period most of the activities of Task 4.2: 5G-NORM Integration & Validation were carried out, CRE having the role of task coordinator. This task was performing integration and validation of the 5G-NORM smart meter by testing in the laboratory the integration and use scenario of NORM (smart meter developed in the SUCCESS project) in the context of 5G based NRG-5 applications. Within this activity, it has been enabled and organized a simultaneous development and testing activity for all involved partners, having different components related to NORM level.

	CRE has defined, developed and tested by simulations a "vPMU orchestrator", working as a virtual function which receives PMU data from different points of the grid (usually a local microgrid) and which monitors and provides grid status assessment based on phasor data. Other additional components of NORM, such as Smart Meter Gateway, especially related to the trend of virtualizing different functions that are needed either for the communication network, or for the power grid network, have also been considered and tested in this scenario with CRE contribution. All contributions can be found specifically presented in the WP4 deliverables, to which CRE has contributed: D4.2 (Integration guidelines and open DMP), D4.3 (Intermediate NRG-5 laboratory validation), and D4.4 (Finally NRG-5 laboratory validation).
Rutgers	Participated in discussions by mails, teleconferences and direct communications, with a focus on preparing radio and next generation communication.
KEYD	Keysight contributed to D4.4 laboratory validation of UC1. Two cellular network technologies, namely LTE (4G) and NB-IoT (5G), have been selected by using the Keysight UXM network emulator in the two measurement campaigns (i.e., smart meter SLAM and PMU) performed at UMA to analyse the performance impact when different cellular network technologies are used. Within each cellular network, three networks scenarios (e.g., good, robust, and extreme) and additional impairments have been developed by Keysight to emulate real network conditions under different cases, with the objective to understand the performance limitations imposed by cellular networks. In addition, KEYD added a cellular network in RWTH testbed.
UMA	UMA contributed with D4.4. Laboratory validation of UC1, a set of tests has been performed for both the smart meter SLAM under different mobile technologies, LTE and NB-IoT and the analysis of the PMU performance under 4G and 5G scenarios to demonstrate the advantages of the second over the first. The testing is carried out into TRIANGLE testbed, an End2End testbed which allows extensive laboratory testing of services against different scenarios and configurations in a realistic and controllable manner.

2.1.5 Work Package 5 - Proof-of concept Trial Demonstrators [M11-M30]

WP5 Leader: **ENGIE**, Participants: ENG, SiLO, ASM, HIS, VIS, EMOT, RWTH, JSI, CRE

Planned Objectives

- Perform on site trials, check KPIs and draw outcomes (see D5.3) following laboratory tests

A summary of progress towards objectives and details for each task

Task 5.1: Trials set-up

This task has started at M11 and has seen intense activity from the beginning with the editing of the deliverable "NRG-5 Trials set-up" (D5.1), culminated with the submission in M20 after four round of contributions by the partners involved in the task, and with the achievement in M20 of the MS10. The task 5.1 provides the analysis results of the integration and validation requirements per trial, including the required adaptation and customization so that the NRG-5 will be fine-tuned, tested and validated in the real-life trial. Moreover, it specifies all the necessary hardware and software to be procured and installed in the testbed and it provides the adaptation guidelines focused on the NRG-5 methodologies framework specified in WP1, to ensure proper adaptation and trial integration of the modules implemented in WP2 and WP3 and validated in laboratory environment in WP4. In conclusion, after the submission of the deliverable 5.1, it was provided support to T5.2, T5.3 and T5.4, strongly connected to T5.1.

Task 5.2: AMI as a Service Validation

During the task lifespan, ASM coordinates activities of the involved partners. ASM deployed a Virtual Machine in which DevStack instance has been installed. ASM provided external access to the VM by means of a VPN connection provided by RWTH. ASM configured NORM devices in order to allow access from external partners. Configuration activities have been carried out by POPs, RWTH, EMOT, ENG, SiLO in order to: Enable device communication by means of vAAA e vBCP. Dashboard and AMI as a Service have been installed and demonstrated.

Task 5.3: PM as a Service Validation

During task 5.3 ENGIE built beginning of 2019 the precise test schedule and the detailed test book to make sure it is completed on time. Preliminary unitary tests and site survey were performed early in 2019 with VISIONA and HISPASAT. The full field trials were conducted mid-July 2019 with all partners on the industrial STORENGY gas storage plant in UK as per their own planning constraints. Then additional unitary tests were performed in September 2019 by UMA for specific RF environment testing, and by VISIONA following drone flying restrictions. The overall test report was ready in September 2019 and was enhanced with latest test sessions results and with synthesis.

Task 5.4: DDR as a Service Validation

This task started in M17 and ended at the end of the project M30 . It has achieved the validation of demand response as a service mainly executing the validation of the field ecosystem composed of 5G-NORMs, PV installation and 2nd life batteries. This fields devices has been linked with the EV charging station to offer the DR service for the Utility operator.

Task 5.5: Assessment and Replication Guidelines

The task started in M21 and has been finished at the end of the project, in M30. The task achieved the assessment of NRG-5 concepts and developments by providing operational results of the NRG-5 field trials for User Cases 1, 2 and 3 and validated appropriate 5G KPIs. Moreover, replication guidelines have been provided for each use case - AMI as a service, Predictive

Maintenance as a Service, Dispatchable Demand Response. The task activity is reported in the deliverable D5.3.

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Highlight clearly significant results

Task 5.1: Trials set-up

- UC1 trial setup
- UC2 trial setup
- UC3 trial setup

Task 5.2: AMI as a Service Validation

First of all the following goals have been succesfully achieved:

- 5G- NORM image deployed in Trial equipment
- NORM is a vBCP client
- vMCM deployment and availability
- Connection between devices and vMCM through vBCP
- vMCM availability and connection between the devices
- Dashboard deployment
- Data visualization of the Smart Meter
- Real time data acquisition and phasor calculation with the 5G-NORM and the vPMU
- Communication channel impact on the vPMU calculation results

Tests pointed out that 5G is expected to have a beneficial effect, drastically minifying the overall communication delay at both average and standard deviation level.

Task 5.3: PM as a Service Validation

All the Trial tasks were performed on time, but the UC2 trials had to cope with last minute issues since the Project drone appeared to be unavailable for the field trials, as reported in the D5.3. The test book carefully prepared by ENGIE was very useful during the test week. Test results and conclusions are included in the deliverable D5.3.

Task 5.4: DDR as a Service Validation

The main achievement of this task was to provide the validation activities regarding the leverage of the different data from the field devices and their related use for the DDRaaS validation tests. At this purpose a fully-fledged Demand Response scenario has been demonstrated . The main outcome of this use case was demonstrated and the project main goal was to show that an increasing of the density of DR signal (as enabled by a 5G infrastructure can improve the resolution of the operation on the smart grid. The validation tests also showed how it is possible to create a list of set point to act on renewables and 2nd life batteries through the VNFs .

Deviations and/or Failure to achieve objectives (if applicable)

N/A

Deliverables

Del No.	Title	Lead Beneficiary	Due Date	State
D5.1	NRG-5 Trials set-up	EMOT	M20	Submitted

D5.2	Intermediate NRG-5 proof of concept	ENG	M24	Submitted
D5.3	Final assessment and replication guidelines	CRE	M30	Submitted

Milestones				
Mil. No.	**Title**	**Lead Beneficiary**	**Due Date**	**State**
MS10	NRG-5 trails ready for testing	EMOT	M20	Achieved
MS11	Final NRG-5 assessment and replication guidelines	ENGIE	M30	Achieved

Involved partners	**Activities description and deviation**
ENG	ENG actively contributed to D5.1 elaborating strategies and proposing solution for the initial set up of the ASM Terni pilot site. It has been involved in the assessment of the HW and SW needed to create the installation that has been validated in theT5.4. It has lead the deliverable D5.2 for the initial testing evaluation of the NRG-5 trials collecting also the initial feedback related to 5G advances. It provide the result of the validation of DDRaaS in the D5.3
SiLO	During this reporting period and in the context of tasks T5.2 and T5.4, SiLO focused on the finalization of the definition, implementation and proper demonstration of the AMI as a Service and Demand Response as a Service use cases of NRG-5. The results of this work are summarized in deliverables D5.1 and D5.2. Further, SiLO assisted consortium work related to the final NRG-5 assessment and replication guidelines, documented in D5.3.
ENGIE	ENGIE took the decision to choose the storage gas storage plant site in STUBLACH UK as the most appropriate for the UC2 trials. ENGIE prepared and coordinated the site survey with the STORENGY UK and France site and maintenance managers in order to : a) Set-up before the tests a test book, precise, exhaustive and customised to the site, and coherent with the previous Tasks that established and validated the UC2 KPIs, b) get the site clearances to perform the required tests, c) inquire for the administrative and security procedures to be complied by each member of the UC2 partners d) define and clarify the different locations to deploy the required equipment and establish safe drone trajectories e) inquire for the equipment delivery / reception f) organize and participate to the on-site meetings with the STORENGY teams g) gather and analyse all the test results, stimulate the analysis and the discussion of : the operational and technical KPIs obtained, the different possible architectures (embedded, edge, ½ edge, cloud), the UC2 extensions within the NRG-5 frame ie feasibility of the UC2 integration in a full 5G infrastructure such as the one developed by the NRG-5 5G-VINNI Project, or after the NRG-5 Project The site survey was performed with the UC2 team in 2Q2019. The internal test book was initiated before and the test report was finalised after the site survey. ENGIE established and followed up the planning before and during the trial week in coordination with the STORENGY team and the U2C partners. All the Trial tasks were performed on time, but the UC2 trials had to cope with last minute issues since the Project drone appeared to be unavailable for the field trials, as reported in the D5.3.

	The test book carefully prepared by ENGIE was very useful during the test week. Test results and conclusions are included in the deliverable D5.3 From the point of view of the overall WP5 management, ENGIE originated and coordinated WP5 partners progress reports for the plenary meetings. ENGIE reported the on-site trials main results during the plenary meeting and the open day session in TERNI (IT), Oct 2019. At the plenary meeting in TERNI, ENGIE promoted the WG Trials works, in particular the WG Trails WEB site. The contact with the 5G PPP WG Trial was established via the former WG TRIAL correspondent. It seems as if there is no more WG TRIAL correspondent now (Oct-Nov 2019).
ASM	During this reporting period, ASM contributes on T5.1, T5.2 and T5.3, notably: Task 5.1 – ASM defined the trial set up for UC1 and UC3 definitions, it arranged the foreseen NORM devices connected to the power devices (i.e., PV plants, EV charging stations, HVAC of the building). Moreover, server infrastructure has been defined Task 5.2 – ASM configured NORM devices for enabling remote connection, deployed VM for DevStack instance in its server farm Task 5.3 – ASM provided energy infrastructure, metering devices, server farm for the demonstration of UC3
HIS	Hispasat was involved in this WP5 in the PMaaS where satellite connectivity was tested to demonstrate the predictive maintenance in Manchester's trials in remote locations. In those test Hispasat provide Internet access via satellite link between Stublach (Manchester) facilities and Arganda Teleport.
VIS	Visiona contributed to the D5.3 by providing the requirements, designing setting up the VNFs and selecting the proper hardware for the tests scenarios in order to reach the objectives in the past deliverables for the UC2.
EMOT	Emotion led T5.1 and D5.1 - NRG-5 Trials setup. Emotion actively organized, participated and interacted in discussions by mails, teleconferences and direct communications, coordinating the partners involved in task 5.1 and in deliverable 5.1 to reach the Milestone 10 (achieved in M20) and to reach the D5.1 submission (achieved in M20). Emotion laid the foundation of the Deliverable 5.1, assembling and refining the document. Moreover, technical contributions were provided to D5.1, with a particular focus on UC3 Trial Set-up section. Emotion contributed to D5.2, especially in DDRaaS section (trial design/architecture update, evaluation scenarios and trial deployment action plan). Finally, Emotion contributed to D5.3, with a particular focus on UC3 section (trial design/architecture update, evaluation scenarios and results comparison and evaluation).
RWTH	RWTH combined the vESR, as part of the DDRaaS, together with a simulated power flow calculation to run a cosimulation including real sensor data from Terni trial site and simulated data.
JSI	JSI collected PMU data from Terni and publicly available weather data in the scope of implementing a system able to forecast production or renewable energy. The predictions from the system can then be used by the controlling infrastructure to perform actuation.
CRE	CRE has been involved in WP5 activities, especially regarding the trial design and architecture update and evaluation scenario for Advanced Metering Infrastructure (AMI) as a service. This was a preliminary phase of involvement - Intermediate NRG-5 proof of concept in the context of D5.2, followed by the involvement of CRE in coordinating the elaboration of the deliverable D5.3 regarding the Final assesment and replication guidelines

2.1.6 Work Package 6 – Impact Creation [M1-M29]

WP6 Leader: ***TCS****, Participants: ENG, SiLO, ENGIE, RGAZ, ASM, BT, WIND, HIS, OPT, EMOT, RWTH, JSI, TEISTE, NKUA, UPMC, CRE, Rutgers*

Planned Objectives

- Create the marketing material to foster business innovation.
- Perform continuous Analysis to identify necessary reorientation early in time and specify new business models in the forthcoming 5G era.
- Form an Advisory Board for collecting feedback and advise on system approach.
- Specify the exploitation plans, both for the consortium and individually for each partner.
- Create and update the project web site and social media.
- Disseminate project results to scientific targets (in tandem with the industry focus).
- Develop MSc courses and a MOOC on 5G network architecture and smart energy. Contribute to relevant Standards Development Organizations and the pre-standardization 5G WG.

A summary of progress towards objectives and details for each task

Task 6.1: Fostering business innovation

Marketing material was updated to better reflect the advancement of the project (e.g., new set of leaflets, booth material). A YouTube channel has been prepared with material from the project, including demo videos, platforms, dissemination. D6.5 “Report on marketing & promotional tools – V2” has been delivered on M21. A face-to-face Advisory Board meeting has been held in conjunction with the EuCNC 2019 event in Valencia (Spain). The project was present during the EuCNC 2019 conference and Fiware Summit 2019 with well-attended booths, showcasing three live demos.

Task 6.2: Exploitation and Sustainability plans

The task has continuously analyzed the exploitable outcomes of the partners of the project (both tangible and intangible). The market analysis has been updated providing both a PEST and a SWOT analysis, and the identification of potential customers and stakeholders. Several potential business models for the project have been defined as well as the IPR approach and the project outcomes licenses policies. Finally, the individual exploitation plans of partners have been updated with the exploitable outcomes directly emerging from the project. The task has delivered both the D6.4 and D6.7 “Market analysis & exploitation plans v1-v2” during this reporting period (respectively on M20 and M29 respectively).

Task 6.3: Dissemination & Training activities

This task has seen the participation of NRG-5 representatives to several high-profile conferences with the publication of several conference papers and journals. After a successful edition of 2018, NRG-5 repeated the organization of a special session at EuCNC 2019 dedicated to “5G trials for vertical industries” with the participation of several representatives from the project. This was also a good opportunity to strengthen links with other 5G PPP projects (in particular, 5G-Essence, 5G-City, 5G-Media). Moreover, the project reached its dissemination target by organizing two well-attended open day events in Terni (October 2019) and Paris (November 2019).

Task 6.4: Standardization & Public outreach activities

The task mapped the standard of interest for NRG-5. Together with Task 6.3 it delivered D6.3 and D6.6 “Dissemination & Standardization Activities” on M20 and M29 respectively.

Highlight clearly significant results

T6.1: Fostering business innovation

YouTube channel of the project providing project's videos. Increased number of Twitter followers. Advisory Board meeting held (MS12 achieved). Organization of two booths in major events (FIWARE summit and EuCNC 2019).

T6.2: Exploitation and Sustainability plans

Analysis of the project exploitable outcomes for the project and each partner. Updating of the market analysis for the project sectors. Identification of the project key exploitable outcomes and their value proposition. Development of business model for the project. Elaboration of the individual and joint exploitation approaches.

T6.3: Dissemination & Training activities

Organization of a Special Session at EuCNC. Several workshops organized. Organization of two Open day events in Terni and Paris to showcase results of the project.

T6.4: Standardization & Public outreach activities

The contribution of this task was to ensure that the project activities and results were correctly aligned and represented in relevant standardization bodies and widely disseminated via a range of events, media and publications. D6.6 was delivered in this period and reported on the dissemination and standardization activities in the latter part of the project, including several 5GPPP working groups, high-ranked international journals and conferences, special events and award nominations. The project has been very successful in its dissemination activities, reaching or exceeding all but one of its target KPIs.

Deviations and/or Failure to achieve objectives (if applicable)

The face to face meeting with the Advisory board, originally to be held on M11 has been done on M24, focusing more on the outcomes of the project and their framing in the context of the evolving energy market.

Both D6.3 and D6.4 were submitted on M20 instead of M17.

Deliverables

Del No.	Title	Lead Beneficiary	Due Date	State
D6.1	Project Web site	TEISTE	2	Submitted
D6.2	Report on marketing & promotional tools v1	TCS	7	Submitted
D6.3	Dissemination & Standardization Activities v1	UPMC	17	Submitted
D6.4	Market analysis & exploitation plans v1	ENG	17	Submitted
D6.5	Report on marketing & promotional tools v2	TCS	21	Submitted
D6.6	Dissemination & Standardization Activities v2	BT	29	Submitted
D6.7	Market analysis & exploitation plans	ENG	29	Submitted

Milestones

Mil. No.	Title	Lead Beneficiary	Due Date	State

M12	1st Advisory board meeting held	ENG	11	Achieved
M13	Final exploitation and sustainability plans	ENG	29	Achieved
M14	Marketing materials V1	ENG	7	Achieved

Involved partners	Activities description and deviation
ENG	ENG led the task 6.2, handling the delivery of D6.4 and D6.7, respectively "Market analysis and exploitation plan v.1 and v.2. ENG was in charge of continuing and updating the market analysis necessary for the elaboration of the value proposition and the sustainable business model The continuous monitoring of market trends has been carried out leading to the final elaboration of a PEST Analysis and a SWOT Analysis. ENG has produced a series of surveys and team work for engaging all the partners and, aimed at collecting data on the ideas of exploitation of the project results. Those data has been then analyzed and processed by ENG in order to elaborate the final business model and to the potential joint exploitation. In the D6.7 the value proposition has been updated and improved with respect to the previous version of the market analysis (D6.4). The potential Business Model has been defined following the methodology of the Business Model Canvas. Finally, the potential Joint Exploitation strategy has been defined, based on the involvement of partners, objectives and typology.
TCS	TCS led the Work Package 6 by overseeing the activities of the project related to impact creation, namely marketing, dissemination, participation to events and standardization, arranging intra WP calls and participating to the overall communications (Web, Twitter, and YouTube). TCS led T6.1 and edited the D6.5 “Report on marketing & promotional tools V2” that was delivered on M21. Also, TCS organized the Special Session “5G trials for vertical industries” held at EuCNC 2019, contributing also to the organization of the booth. TCS contributed to exploitation strategies for the project (T6.6) by analyzing the potential of blockchain technology for the energy marketing, and identifying the exploitable outcomes. Moreover, TCS provided the overall framework for the Advisory Board meeting (documents to be shared and overall organization). TCS participated in the SDO mapping in T6.4.
SiLO	Contributed to the generation of marketing and dissemination material with a focus on EUCNC project presentations. Also, SILO participated in the project activities discussions by mails, teleconferences and direct communications.
ENGIE	Concerning the dissemination activities, ENGIE have organized the NRG-5 OPEN DAY on Nov 25th, 2019 in his headquarter in Paris – La Défense. This two-fold event introduces both the NRG-5 Project and the different business cases encompassed by the Project. Speakers are from Engie, Siradel, Storengy, Nokia, Air France-KLM, Thales, BT et Engineering. ENGIE has put special efforts to select the most relevant topics : **Towards zero carbon energy with more connectivity** Lucile Hofman, Connectivity Director, ENGIE Nathalie Allegret, Head of organic growth, Global Business Line Client Solutions

	Clément Chevallier, Connectivity specialist, ENGIE **5G infrastructure design optimization** Sylvain Aubin, Director Infra Network Design, ENGIE Siradel **Air France introduces IoT and 5G on Hubs** Christian Régnier, Critical Communications Architect, Air France-KLM - AGURRE secretary **5G communications for mission critical use** Emmanuel Dotaro, Director Cyber-Security, Thales **Enabling New Smart Grid Protection Solutions** Philippe Dauchy, CTO Energy, Nokia
RGAZ	RGAZ participated to project-specific activities, discussions, communications and to several actions organized by the partners aiming distributing NRG-5 project results such as: “Securing the smart grid towards up to 100% renewables” - Open Day in Terni, ”**ROMANIAN ENERGY DAY – THE EUROPEAN DEVELOPMENT SECTOR POST 2020 CHALLENGES AND OPPORTUNITIES”** The company informed its collaborators on the benefits of NRG5, including publishing the article “Romgaz contribution to NRG5 project” in the Oil and Gas Monitor (Romanian publication).
ASM	ASM contributed on exploitation activities by providing DSO point of view in this activity ASM organized an Open Day in which NRG-5 achievements and objectives were presented. This event took place in Terni in the Hotel Michelangelo in the 17th October, about 80 people attended the event from relevant stakeholders; notably Distribution System Operators, Industries and Telco Operators. Open day and project has been communicated with local news agency, available at these links: https://www.rainews.it/tgr/umbria/notiziari/video/2019/10/ContentItem-769d22d4-829e-4fb3-aaa2-900e15e7bbe4.html (at min 9:30) https://youtu.be/W3nRPDnbRbE?t=595 ASM carried out communication activities on NRG-5 project during the open day of ELSA project ASM carried out communication activities on NRG-5 project during a workshop in Sapienza – University of Rome. ASM participated in the project activities discussions by mails, teleconferences and direct communications. ASM carried out a video describing the benefits of NRG-5 project as enabling technologies of UC1 and UC3, for a generic target audience. Video has been published in the website of the project and the company.
BT	BT led the effort to complete D6.6 Dissemination & Standardization Activities v2. BT also contributed to a number of high profile dissemination activities in this period including EuCNC ’19, the Terni NRG-5 open day and the Engie NRG-5 event in Paris. Together with POPS, BT were finalists for two UK awards for our work on the AMIaas use case. Firstly, the Institute of Engineering and Technology Innovation Awards where we received a ‘Highly Commended’ award in the Communications category and, secondly, the UK IT Industry Awards where we were a finalist in the Emerging Technology category.

WIND3	Wind3 contributed to the different tasks in particular to Fostering business innovation, Dissemination and exploitation of the results of the NRG55 project. In particular WIND3 offered the TELCO vision to deliver a novel 5G-PPP framework to model and virtualize infrastructures and services in the energy context; according to this, Wind Tre was exploring in NRG-5 how to evolve the business opportunities according to the new requirements coming from the Energy Vertical. Wind3 contributed to the preparation of dissemination material during EUCNC19 in Valencia and cooperated to organise the special session "5G trials for vertical industries". Wind3 participated to the 5G PPP Architecture Working Group and to Workshop organized by the group for presenting the "Architecture White Paper" during the EuCNC2019 in Valencia. Wind3 participated together ASM and the other involved partners to the organisation of the Open Day in Terni: in particular Wind3 invited different Italian utilities (Acea, Enel, Estracom, Terna) to disseminate the results obtained in NRG5.
HIS	**D6.4. Market analysis and exploitation plans v1.** Hispasat, as a provider of satellite capacity in the NRG5 project, has described the background of the organization of the company and the operating advantages that it intends to achieve with the results of this project in potential markets such as Drone manufacturers, drone service providers, Transmission System Operators and Internet Service Providers. As part of the NRG-5 Exploitation Strategies, Hispasat has acquired knowledge in the different communications scenarios that were raised, which will allow the company to define new business opportunities as exploitation of the objective results of this project. **D6.6. Dissemination and Standardization Activities.** Dissemination and impact creation activities of the NRG-5 project have taken place at other national and international conferences in which Hispasat has participated. **D6.7. Market analysis and exploitation plans.** As part of Task 6.7, HISPASAT has progress towards the individual exploitation plan and strategy to be followed during and after the project. Finally, Hispasat completed a questionnaire on the business model based on what was described above.
POPs	During this period, POPs contributed to the preparation and authoring of the dissemination and communication material for the project presentations in EUCNC 2019, with a particular focus on the AMIaaS use case, for which particular software infrastructure to enable proper software demonstration was delivered. In the same context, POPs was a co-author (together with TCS) of a poster published in EUCNC 2019, entitled "***Towards a distributed authentication and authorization mechanism via Blockchain in 5G Energy Applications*"**. Further, POPs, together with BT, presented the core of the NRG-5 framework related to AMIaaS UC to the **UK IT Business Awards 2019** (a live pitch in front of experts was also delivered in Manchester, UK) as well as the **IET Innovation Awards 2019**. Both applications were both shortlisted and were award candidates at the categories of "Emerging Technology of the Year" and "Communications", respectively. **As announced in November 13, POPs and BT won the "Highly Commended Award" at the IET Innovation Awards 2019 – Communications Category.** Last, POPs contributed to all relevant WP deliverables.
VIS	Visiona contributed in D6.3 and D6.6 in the dissemination of the NRG-5 project in different events by conferencing and papers have been published. Also contributed to exploitation strategies and marketing analysis in D6.4 and D6.7.

	Visiona presented the paper "How 5G Enables Smart Energy: Setup and First Experiences from the NRG-5 Pilots", a part of the Special Session "5G trials for vertical industries" held at EuCNC 2019. Also, VIS explained the PMaaS demo in the EUCnC 2019 for the 5GPPP youtube channel: https://www.youtube.com/watch?v=9M4Rr-zvsfY
OPT	During this reporting period, OPT contributed to the creation of the project marketing and dissemination material. We also focused on the realization of the EUCNC presentations and demonstration outcomes of the project.
EMOT	Emotion disseminated NRG-5 project attending to Energy Industry Mixer 2019, an industrial energy conference, performed in Wroclaw (Poland), where flyers were distributed and dialogues undertaken with participants (350 approximately). Furthermore, Emotion contributed to D6.3 - Dissemination & Standardization Activities v1, D6.4 - Market analysis & exploitation plans v1, D6.6 – Dissemination & Standardization Activities v2 and D6.7 - Market analysis & exploitation plans v2. Emotion actively interacted and participated in discussions by mails, teleconferences and direct communications.
RWTH	RWTH did develop specific exploitation plans for the main outcomes of the activities carried out in the scope of NRG-5, namely the vPMU concept and vESR functionality. Additionally, during the second reporting period, RWTH did disseminate the results of the project both in scientific conferences and with invited talks at industry-oriented events. Finally, RWTH actively participated in the Trial Site open day in Terni and in the organization of the NRG-5 project's booth at the EuCNC 2019 in Valencia, presenting the two use cases of AMIaaS and DDRaaS with live demonstrations.
JSI	JSI has published a number of scientific publications related to various results of the project. First, together with BT, co-edited a Wiley book that contains Chapters related to NRG-5 topics. Then we have published 2 open access journal papers, another one is under revision, a conference paper is also published and another conference paper is submitted.
NKUA	During the reporting period, TEISTE/NKUA participated on dissemination and impact creation activities of the NRG-5 project that have taken place in national and international level. In the same time, TEISTE/NKUA has put effort on updating and maintaining project's website that has implemented, by putting together content related to NRG-5 dissemination activities and news. In addition, TEISTE/NKUA contributed to this topic by publishing 2 open access journal papers at (IEEE access and MDPI Sensors Journals). Lastly, TEISTE/NKUA participated in all the relevant project activities, discussions and teleconferences.
SU	NRG-5 core concepts, architecture, and core network VNFs are introduced in some sessions of a Master 2 level student class, "Smart Mobility System", in Sorbonne Université. NRG-5 partners were invited to present NRG-5 related work on ACM MAGESys'19, a workshop co-located with ACM SIGCOMM'19. the flagship conference in networking and communication.
CRE	During the reporting period, CRE was especially involved in WP6, both by participating in dissemination events presenting the NRG-5 project concept and results, and by publishing articles related to the above mentioned results in specialized publications. A brief report on these activities can be found in D6.6 - Dissemination and standardization activities v2. In the context of the same deliverable, CRE contributed to a research on the standards context and potential standard changes that may intervene in the context of deploying the 5G based services and solutions proposed

	by NRE-5 project. CRE also contributed to the activity referring to the potential exploitation of the project results, in the context of D6.7 - Market analysis and exploitation plans v2 (developing three proposals regarding vPMU as an orchestrator, Education & Training, and 5G-NORM).
Rutgers	During the reporting period Rutgers accomplished the project activities and the results consequently were correctly aligned and represented in relevant standardization bodies

2.1.7 Work Package 7 - Project Management [M1-M30]

WP7 Leader: **ENG**, Participants: TCS, ENGIE, BT, WIND, RWTH

Planned Objectives

The main focus of this workpackage was to drive and coordinate the entire project and the related activities. The overall task has been achieved thorugh the deep and coordinated actions of plan, monitor and control of the use of resources. The overall workplan has been continuously checked and risk mitigation action put in place therefore in the entire time span of the project the progress has been robust and complete. The Project coordination handled the entry of two new beneficiares : UMA and KEYD that replaced Ericsson in provide the infrastructure for 5G-like demonstrations.

A summary of progress towards objectives and details for each task

T7.1: Project Management

The project management has progressed smoothly during the entire project lifetime. A range of small grant agreement amendments were organised to facilitate changes within partner organisations.. The first and final Periodic Reports have been compiled and submitted and the quality control and submissions of all deliverables was organised in a timely manner. All milestones and goals were achieved or exceeded by the project.

As in the first reporting period, the project was also operationally coordinated using the periodic voice conferences and the quarterly face-to-face project meetings in the second reporting period. WP meetings were generally organised by work package leaders on weekly or bi-weekly basis. Technical coordination voice conferences were organised as required to ensure sound interactions and synergies between work packages and to ensure the coherence of the project results.

The project management has been effective and enabled the project participants to reach the project goals and to be periodically updated about the activities of the 5GPPP boards and WG.

T7.2: Innovation & IPR Management

In this task has been executed the identification, management and protection of IPR related to the innovation planned and created in the project

T7.3 Quality Assurance & Risk/opportunities Management

The entire project lifecycle was ensured through risk management actions and a strong effort was dedicated to put in place strategy to promote and amplify all the communication channels among partners.

T7.4 Liaison with 5G-PPP/5G Initiative

This task main achievement was to set up a strong link with the 5G-PPP projects and the contribution in the steering and technology boards. An important contributions was the one regarding the support of the actions related to the WG and the strong contribution that the project

brought to the writing two of the white paper on software network working group and on the architecture group. Another goal was to test part of the NRG-5 UC in the 5G-Vinni test bed.

Highlight clearly significant results

In the 2nd period the main focus of project management has been on the promotion of the project results and the development remaining part of the work.

Specific activities and goal achieved:

- The preparation of the final event in Brussels
- The organisation of fruitful project meetings in Milan, Malaga and Terni
- The preparation and quality control organisation of the deliverables due during the reporting period, and the follow up of the recommendations of the 1st project review.
- Organization of the EUCNC 2019 work of NRG-5
- Organisation of the Advisory Board meeting
- Coordination of the two Open Days at ASM and ENGIE premises
  Successful conclusion of the feasibility study to integrate the UC2 analytics in the 5G-VINNI full-5G infrastructure

Deviations and/or Failure to achieve objectives (if applicable)

Deliverables :

Del No.	Title	Lead Beneficiary	Due Date	State
D7.1	Research Period Project progress Report	ENG	13	Submitted
D7.2	Validation Period Project progress Report	ENG	30	Submitted

Milestone :

Mil. No.	Title	Lead Beneficiary	Due Date	State
MS15	Research Period Project progress Report	ENG	16	Submitted
MS16	Validation Period Project progress Report	ENG	30	Submitted

3 Deliverables and Milestones

Table 4 - Deliverable submitted in this period (ordered by WP, date)

Del. no.	Title	WP	Lead Beneficiary	Nature	Dissemination Level	Due Date (in months)	Actual date of release
D2.2	NRG-5 Virtual Network abstraction	2	BT	R	PU	M16	M16
D3.2	NRG-5 application logic framework	3	ENG	R	PU	M16	M17
D6.3	Dissemination & Standardization Activities v1	6	SU	R	PU	M17	M20
D6.4	Market analysis & exploitations plans v1	6	ENG	R	PU	M17	M20
D1.3	Final 5G Network Architecture to support smart energy	1	BT	R	PU	M18	M20
D4.2	Integration Guidelines & Open DMP v2	4	RWTH	R	PU	M18	M18
D4.3	Intermediate NRG-5 laboratory validation	4	VIS	R	PU	M20	M20
D5.1	NRG-5 Trials Set-up	5	EMOT	R	PU	M20	M21
D6.5	Report on marketing & promotional tools v2	6	TCS	R	PU	M21	M22
D2.3	5G trusted, scalable & lock-in free plug' n' play	2	POPs	R	PU	M22	M22
D3.3	VNF lifecycle management	3	SILO	R	PU	M24	M26
D5.2	Intermediate NRG-5 proof of concept	5	ENG	R	PU	M24	M24
D4.4	Final NRG-5 laboratory validation	4	RWTH	R	PU	M28	M29
D6.6	Dissemination & Standardization Activities v2	6	BT	R	PU	M29	M29
D6.7	Market analysis & exploitation plans v2	6	ENG	R	CO	M29	M29
D5.3	Final assessment and Replication Guidelines	5	CRE	R	PU	M30	M31
D7.2	Validation period project progress report	7	ENG	R	PU	M30	M31

Table 5 : Deliverable submitted

De. no.	Title	WP	Lead Beneficiary	Due Date (in months)

MS5	Preliminary NRG-5 VNF orchestration framework	3	ENG	M16
MS15	Research period project Review	7	ENG	M16
MS2	Final 5G Architecture to support smart energy	1	BT	M18
MS8	Intermediate NRG-5 Laboratory validation	4	CRE	M20
MS10	NRG-5 trials ready for testing	5	EMOT	M20
MS4	5G trusted, scalable & lock-in free plug' n' play	2	POPs	M22
MS6	Final NRG-5 VNF orchestration framework	3	SILO	M24
MS9	Final NRG-5 laboratory validation	4	RWTH	M28
MS13	Final exploitation and sustanability plan	6	ENG	M29
MS11	Final NRG-5 assessment and replication guidelines	5	ENGIE	M30
MS16	Validation period project Review	7	ENG	M30

Table 6 : Milestones achieved

4 5G-PPP events, meeting, phone call attended

Name and description of the 5G-PPP event/meeting	When	Where	Attendees (name and organization) and role
5G PPP Security Virtual Meetings	2 July 2018, 17 August 2018, 7 September 2018, 12 December 2018, 9 April 2019, 22 May 2019, 27 September 2019,	Phone calls	F. Rebecchi, P. Bisson (Thales)
5G PPP Architecture WG	Periodic (each 2 week)	Phone calls	Antonello Corsi (ENG), Rita Spada (Wind3)
5G PPP Security WG physical meeting	25 October 2018	Brussels (BE)	F. Rebecchi, P. Bisson (Thales)
5G PPP Architecture WG: Meeting for White paper preparation	18-20 March 2019	Munich	Rita Spada (Wind3)
NRG-5 WP3 Call	26/07/2018	Phone call	All WP partners
5G PPP Steering board meeting	17/07/2018	Phone call	Giampaolo Fiorentino (ENG)
5G PPP Steering board meeting	13/09/2018	Bruxelles	Giampaolo Fiorentino (ENG)
NRG-5 WP3 Call	23/10/2018	Phone call	All WP partners
5G PPP Steering board meeting	12/11/2018	Phone call	Giampaolo Fiorentino (ENG)
NRG-5 consortium Call	05/01/2019	Phone call	All WP partners
NRG-5 WP4 Call	10/01/2019	Phone call	All WP partners
NRG-5 WP3 Call	16/01/2019	Phone call	All WP partners
NRG-5 WP3 Call	18/01/2019	Phone call	All WP partners
5G PPP Steering board meeting	29/01/2019	Bruxelles	Giampaolo Fiorentino (ENG)
NRG-5 WP5 Call	04/02/2019	Phone call	All WP partners
NRG-5 WP3 Call	25/02/2019	Phone call	All WP partners

Name and description of the 5G-PPP event/meeting	When	Where	Attendees (name and organization) and role
5G PPP Steering board meeting	03/03/2019	Phone call	Giampaolo Fiorentino (ENG)
NRG-5 WP3 Call	27/03/2019	Phone call	All WP partners
NRG-5 WP6 Call	27/03/2019	Phone call	All WP partners
NRG-5 WP5 Call	04/04/2019	Phone call	All WP partners
NRG-5 consortium Call	10/04/2019	Phone call	All WP partners
NRG-5 consortium Call	26/04/2019	Phone call	All WP partners
NRG-5 consortium Call	08/05/2019	Phone call	All WP partners
NRG-5 WP5 Call	08/05/2019	Phone call	All WP partners
5G PPP Steering board meeting	16/05/2019	Bruxelles	Giampaolo Fiorentino (ENG)
NRG-5 WP5 Call	24/05/2019	Phone call	All WP partners
NRG-5 WP5 Call	24/05/2019	Phone call	All WP partners
NRG-5 consortium Call	31/05/2019	Phone call	All WP partners
5G PPP Steering board meeting	28/06/2019	Phone call	Giampaolo Fiorentino (ENG)
NRG-5 consortium Call	02/07/2019	Phone call	All WP partners
NRG-5 consortium Call	12/07/2019	Phone call	All WP partners
NRG-5 consortium Call	15/07/2019	Phone call	All WP partners
NRG-5 consortium Call	25/07/2019	Phone call	All WP partners
NRG-5 WP3 Call	25/07/2019	Phone call	All WP partners
NRG-5 WP4 Call	25/07/2019	Phone call	All WP partners
NRG-5 WP3 Call	01/08/2019	Phone call	All WP partners
NRG-5 WP4 Call	01/09/2019	Phone call	All WP partners

Name and description of the 5G-PPP event/meeting	When	Where	Attendees (name and organization) and role
NRG-5 WP4 Call	09/09/2019	Phone call	All WP partners
NRG-5 consortium Call	10/09/2019	Phone call	All WP partners
5G PPP Steering board meeting	17/09/2019	Bruxelles	Giampaolo Fiorentino (ENG)
5G PPP WG Trial	10/2019	Phone call	Daniel Cabagnols
NRG-5 WP5 Call	02/10/2019	Phone call	All WP partners
NRG-5 WP5 Call	15/10/2019	Phone call	All WP partners
5G PPP Steering board meeting	29/10/2019	Phone call	Giampaolo Fiorentino (ENG)
NRG-5 WP5 Call	08/11/2019	Phone call	All WP partners
NRG-5 WP5 Call	15/11/2019	Phone call	All WP partners
NRG-5 WP5 Call	19/11/2019	Phone call	All WP partners
5G PPP Security WG physical meeting	22/11/2019	Chatillon (FR)	W. Ben Jaballah, P. Bisson (Thales)
NRG-5 Consortium Call	23/11/2019	Phone call	All WP partners
NRG-5 Consortium Call	27/12/2019	Phone call	All WP partners

Table 7 : 5G-PPP events, meetings and phone calls attended

5 Public events attended

Speaker	Title	Event / Type of dissemination	Time	Location
G. Fiorentino (ENG)	“Enabling Utility roaming through open marketplaces catalysed by blockchains and 5G”	AIOTI WG12 Smart Energy	March 8th, 2019	Brussels, Belgium
M.R. Spada (WIND3)	“Road to 5G - Smart cities: NRG-5”	Milano Digital Week	March 15th, 2019	Milan, Italy
J.M. Lalueza (VIS)	“How 5G enables Smart Energy: Setup and First	EuCNC 2019 – special session “5G trials for vertical industries”	June 20th, 2019	Valencia, Spain

	Experiences from the NRG-5 Pilots"			
A. Corsi (ENG)	"Progress towards cloud native paradigm for the energy domain services based on VNFs"	EuCNC 2019 – workshop " From Cloud-ready to Cloud-native transformation"	June 18th, 2019	Valencia, Spain
M. Cresta (ASM)	"LOCAL ENERGY COMMUNITIES | Minaccia o opportunità per le Utility? Come dovrà evolvere il Business delle Utility in un futuro in cui le Energy Community saranno una realtà?" (in italian)	Italian Utility Day	November 27th, 2019	Milan, Italy
M. Cresta (ASM), M. Bertoncini (ENG), M.R. Spada (Wind3), A. Duke (BT), F. Rebecchi (THALES), G. Lipari (RWTH), D. Cabagnols (ENGIE), A. Corsi (ENG)	• "Connectivity revolution of electrical grid" • "5G in EU: 5G PPP" • "5G in UK: Virtualization and energy" • "NRG-5: the project" • "Realizing decentralized, trusted, lock-in free Plug &Play vision (AMIaaS)" • "Enabling Aerial Predictive Maintenance for utility infrastructures (PMaaS)" • Enabling resilience and high availability via Dispatchable Demand Response	NRG-5 1st Open Day - "Impact of 5G Networks on the Energy Sector"	October 17th, 2019	Terni, Italy
E. Barthoux, L. Hofman, N. Allegret, C. Chevallier, D. Cabagnols, J. Romeyer, B. Ratcliffe, S. Aubin (ENGIE), E. Dotaro, F. Rebecchi (THALES), N. Sánchez Almodóvar (VIS), G. Fiorentino (ENG)	• "Towards zero carbon energy with more connectivity", • "5G infrastructure design optimisation", "5G communications for mission critical use", • "5G in UK and the 5G VINNI Project deployment", • "The 5G PPP Programme and the NRG-5 Project", "NRG-5 use cases : Advanced Metering	NRG-5 2nd Open Day	November, 25th, 2019	Paris, France

	Infrastructure and Demand Response as a Service", • "NRG-5 use case : Predictive maintenance as a Service – Operator's feedback"			
A.Voulkidis (POPs)	"Next Generation Energy Grid Management"	2019 IET Industry Awards (won the "Highly Commended" award)	November 13th , 2019	London, UK

Table 8 : Public events attended

NRG-5 was involved in the EUCNC 2019 and managed he special session "5G trials for vertical industries" held on 20 June event in Valencia, Spain. The special session proposal was born by the desire to compare different approaches to conduct trials for different vertical applications. The special session was organized by the NRG-5 consortium to bring together the latest trial results for vertical applications.
Moreover NRG-5 handle The advisory board meeting by taking advantage of the massive participation of partners of the project and interested stakeholders in Valencia during the annual EuCNC 2019 event showing the demonstration booth for showcase the innovations of the project.

Figure 7: NRG-5 at EUCNC 2019

6 List of publications and conferences

Authors	Title	Journal/Conference/Book name	Date	Location	DOI
C. G. Calò Carducci, G. Lipari, N. Bosbach, T. Di Raimondo, F. Ponci, A. Monti	A Versatile Low-Cost OS-based Phasor Measurement Unit	IEEE International Instrumentation & Measurement Technology Conference (I2MTC),	May 20-23, 2019	Auckland, New Zealand	10.1109/I2MTC.2019.8826894
F. Bellesini, T.Bragatto, D. Cabagnols, A. Corsi, G. Fiorentino, J. M. Lalueza, and F. Rebecchi	How 5G Enables Smart Energy: Setup and First Experiences from the NRG-5 Pilots	European Conference on Networks and Communications (EUCNC' 2019)	June 2019	Valencia (Spain)	N/A
N. Nomikos, E. Michailidis, P. Trakadas, D. Vouyioukas, Th. Zahariadis, I.Krikidis	Flex-NOMA: Exploiting buffer-aided relay selection for massive connectivity in the 5G uplink	IEEE Access Journal, Vol. 7, pg. 88743-88755	July 2019		10.1109/ACCESS.2019.2926770
P. Trakadas N. Nomikos,E. Michailidis, Th. Zahariadis,F. Facca, D. Breitgand, S. Rizou	Hybrid clouds for data-Intensive, 5G-Enabled IoT applications: an overview, key issues and relevant architecture	MDPI Sensors, Vol. 19, Iss. 16,3591, pp. 1-19	August 2019		https://doi.org/10.3390/s19163591
M. Sanduleac, C. Chimirel, M. Paun	PMU Orchestrator as a solution for managing microgrid monitoring with 5G communication	Universities Power Engineering Conference 2019 (UPEC 2019)	3-6 September 2019	Bucharest, Romania	10.1109/UPEC.2019.8893555
V. García Rubio, J. A. Rodrigo Ferrán, J. M. Menéndez	Automatic Change Detection System over	MDPI Sensors	October, 2019		https://doi.org/10.3390/s19204484

García, N. Sánchez Almodóvar, J. M. Lalueza, F. Álvarez	Unmanned Aerial Vehicle Video Sequences Based on Convolutional Neural Networks				
T. Šolc, H. Yetgin, T. Gale , M/ Mohorčič, C. Fortuna	Whitelisting in RFDMA Networks	IEEE Access		October 2019	10.1109/ACCESS.2019.2950754
J. Davies, C. Fortuna	Internet of Things: From Data to Insight	Wiley book		December 2019	ISBN: 978-1-119-54526-2
C. Fortuna, T. Gale	Stream Data Processing for IoT	Wiley book chapter		December 2019	ISBN: 978-1-119-54526-2
A. Voulkidis, T. Zahariadis, K. Kalaboukas, F. Santori, M. Vučnik	Use Case: IoT and Smart Energy	Wiley book chapter		December 2019	ISBN: 978-1-119-54526-2
N. Sánchez, V. García, J. Lalueza, A. Rodrigo, J.M. Menéndez	Applied Machine Vision and IoT	Wiley book chapter		December 2019	ISBN: 978-1-119-54526-2

Table 9: List of publication and conferences

7 Project liaison activities

ENG, TEISTE, RWTH, Wind3, VIS and POPs have started collaboration and potential liaison activities with:

- The 5GPPP H2020-761493 project 5G-TANGO “5G Development and Validation Platform for global Industry-specific Network Services and Apps”
- The 5GPPP H2020 -671598 project 5G-Crosshaul “the 5G Integrated Fronthaul/Backhaul"
- The 5gPPP H2020 - 761699 project 5G-MEDIA “Programmable edge-to-cloud virtualization fabric for the 5G Media industry“
- The Critical Infrastructures Protection project H2020-740898 DEFENDER “Defending the European Energy Infrastructures”
- The Digital Security project H2020-700416 SUCCESS “Securing Critical Energy Infrastructures”
- 5G CITY
- 5G ESSENCE

8 Conclusion

The target of NRG-5 is to enable Smart Energy as a Service via 5G Mobile Network advances. Therefore, it designs and develops a novel 5G-based solution for the energy vertical context that represents one of the most demanding use case/test case for 5G enabling technologies, mainly due to the need of addressing a huge range of very diverse and stringent requirements to deal with a large variety of domain-specific applications, in terms of latency, resilience, availability, coverage, and bandwidth. The big challenge is to provide end-to-end, possibly leveraging an edge platform (i.e. the xMEC), network and cloud infrastructure slices over the same physical infrastructure to meet the energy vertical-specific requirements, historically addressed by a fully-dedicated infrastructure. Furthermore, novel scenarios related to the smart grids present new needs and issues, which point to the support of a powerful edge computing infrastructure with a multi-tenant nature.
NRG5 has identified three main scenarios which cover a wide set of use-cases, namely: Realizing decentralized, trusted lock-in free Plug & Play vision, supporting aerial Predictive Maintenance for utility infrastructures, and Enabling resilience and high availability via Dispatchable Demand Response.
For each of them, some given use-cases with business prospects has been specified and addressed. The first (set of) use-case(s) aims at demonstrating Advanced Metering Infrastructure (AMI) as a Service (AMIaaS, Providing to the DSO and smart grid actors real-time data about the general status of the network as well as information with higher granularity, at the level of PMU, DES and RES. Furthermore, it builds a micro-contract oriented, blockchain-enabled marketplace framework where utilities, prosumers and end-users will be able to interact in a lock-in free manner. The coordinated cooperation of the relevant (virtual) functional elements (i.e. VNFs) together with the application-specific logic in concert, represents a solution that will speed-up the openness of the energy market, also providing to utilities the ability to unlock the potential of 5G-based real-time monitoring and control that enables the two-way communication between utilities and customers, generally referred to as AMI. The second (set of) use-case(s) has some general and specific requirements. The general requirements are considered to extract and build a Preventive Maintenance as a Service (PMaaS) taking advantage of the 5G potential capabilities. A drone is used for video acquisition due to the easiness of deployment and accessibility to critical areas without putting at risk human workers. Using NRG5 solution we demonstrated that the 5G network is going to provide a real-time communication, high bandwidth to transmit videos and computing power over the edge to off-load computing power from the drone, increasing the battery life by reducing the computing complexity onboard. Both the monitoring and the management of an alert in the control-room (as specific to the energy domain) are addressed. Nowadays we are experiencing a transition in terms of power flows in the electricity grid: the advent of renewable energy generation plants.
Therefore, distributed generation has changed the power flow from unidirectional, from large power plants to end users, to be bidirectional. Renewable energy is often not consumed where it is produced and this causes problems of stability and security in the electricity grid. To avoid these problems and to optimize the use of renewable energy, it is necessary to monitor and control the electricity grid in real time, thus smartly managing the power flows. A massive distribution of measurement devices involves a huge flow of data in real time requiring advanced telecommunications technology to guarantee a continuous, complete and instant response service. For this reason, the purpose of the third (set of) use-case(s) is to illustrate the fundamental role of 5G networks in the smart grid as a means of enabling new applications tailored to optimize the operation and resiliency of the electricity grid, as well as to manage load flexibility.
A clear challenge and value-added of NRG5 is the ability to address the current and likely future needs of a critical market, namely the energy vertical, and utility ones in general. To achieve the purpose, the specified use-cases and the developed solution implies the integration of the telco and more specifically, the energy domains.

This open-up new service and application scenarios for the Telco involved as WindTre and BT and for the other companies involved in the NRG5; in particular , the acquired know-how, the foreground in the creation of network slices addressing the stringent requirements of Smart Energy as a Service

(SEaaS) in an open environment/ecosystem can make the difference when offering services in critical markets.
Guidelines and best-practices have been already and will be further learnt and experimented on field thanks to the project pilots (one for each (set of) use-case(s).
Extended Multi-access Mobile edge computing (xMEC), network function virtualization (NFV), software defined networking (SDN), management and orchestration of a multi-tier cloud architecture, massive collection of real-time data in a secure distributed way with critical control, Self-Organizing Networking (SON), Unmanned Aerial Vehicle (UAV) empowerment and creation of dedicated virtual networks with the needed facilities and resources (i.e. network slicing) are still pretty new achievements to evolve, almost revolutionize, the traditional cellular systems. Lessons-learned and investigated potentiality will pave the way for the implementation of the new 5G infrastructure.

The achievements of the project then can be summarize as the following pillars

Value proposition

- 5G connectivity with KPIs specification
- Multi tenancy
- Network slicing (with flexibility and fast deployment)
- Edge computing
- VNFM and NFVO with possible catalogue of network functions and services basically available

From the Traditional Telco approach to the new one based on

- “disruptive” technologies
- partnership with the players in the Verticals as the Energy one

Capitalize the knowledge

- deploy end-to-end services upon the offered physical infrastructure cooperating with the different involved actors
- important incremental market is expected for energy efficiency and security enhacement system for the different type of utilities
- Export the approach from energy vertical market to other markets (in particular considering sensors and drones services).

New processes for the new ecosystem

- operate a deep innovation in the company processes,
- new skills
- costs reduction and time-to-market.
- analyse a new telco paradigm to cooperate and create a new ecosystem, as requested in the modern and fully innovative 5G networks

9 References

[1] N.-5. Consortium, «Deliverable 7.1: Periodic Project Report,» NRG-5 , 2018.

[2] 5G-PPP, «Cloud-Native and Verticals' services 5G-PPP projects analysis,» 2019.

[3] 5G-PPP, «View on 5G Architecture V3.0,» 2019.

10 Abbreviations

Acronym	Explanation
3GPP	3rd Generation Partnership Project (standardisation body)
5G	5th Generation of Mobile Communications
AAA	Authentication, Authorisation and Accounting
AMI	Advanced Metering Infrastructure
AMIaaS	Advanced Metering Infrastructure as a Service
CI-SLA	Critical Infrastructures Service Level Agreements
DDRaaS	Dispatchable Demand Response as a Service
DER	Distributed Energy Resources
vDES	virtual Distributed Energy Storage
DoW	Description of Work
DSO	Distribution System Operator
EuCNC	European Conference on Networks and Communications
EV	Electric Vehicle
H2020	Horizon 2020
IPR	Intellectual Property Right
KPI	Key Performance Indicator
M2M	Machine to Machine
MANO	Management and Orchestration
mMTC	Massive MTC
NFV	Network Function Virtualization
NORM	New-generation Open Real-time Smart Meter
NSO	Network Service Orchestrator

PKI	Public Key Infrastructure
PMaaS	Predictive Maintenance as a Service
PMU	Phasor Measurement Unit
PUF	Physically Unclonable Function
QoS	Quality of Service
RES	Renewable Energy Sources
SDN	Software-Defined Networking
SON	Self-Organising Network
vAMI	Virtual Advance Metering Infrastructure
vBCP	virtual Blockchains Processing
vDER	virtual Distributed Energy Resource
vDFC	virtual Drones Flight Control
vESR	virtual Electricity Substation & Rerouting
vMCM	virtual Machine-Cloud-Machine
vMME	virtual Mobility Management Entity
vMPA	virtual Media Processing & Analysis
vPMU	virtual Phasor Measurement Unit
vRES	virtual Renewable Energy Sources
vSON	virtual Self-Organizing Networks
vTSD	virtual Terminals Self-Discovery
XaaS	Platform or Infrastructure as-a-Service
xMBB	Massive broadband
xMEC	extended Mobile Edge Computing

[i] https://www.ericsson.com/res/docs/whitepapers/wp-5g-security.pdf

[ii] http://www.etsi.org/deliver/etsi_gs/NFV-EVE/001_099/005/01.01.01_60/gs_nfv-eve005v010101p.pdf