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NRG-5

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

Deliverable 1.1

Use Case scenarios analysis and 5G requirements

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Abstract: This document focuses on three 5G Smart Energy vertical use case scenarios dealing with smart metering (UC1), predictive maintenance (UC2) and dispatchable demand response (UC3). For each use case actors, scenarios, pre and post-conditions, the flow of actions and application requirements are analysed from the energy, telecom and ICT perspectives. The associated 5G network requirements and KPIs are clearly formulated, setting the foundation for the further stages of the project.

Disclaimer

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02	THALES Communications & Security	TCS	France
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1 Introduction

1.1 Purpose of the Document

The purpose of the Deliverable D1.1 is to refine the NRG-5 use cases scenarios [1] and analyse their 5G requirements in order to show how crucial is the 5G seamless application in developing new services for the Energy vertical sector, supporting and improving what has been reported in the 5G PPP white paper “5G and Energy” [2]. Three extremely demanding 5G Smart Energy vertical use case scenarios dealing with smart metering (UC1), predictive maintenance (UC2) and dispatchable demand response (UC3) have been chosen for demonstrating three groups of Machine Type Communication (MTC), such as Massive MTC (UC1 and UC2), Enhance Mobile Broadband (UC2) and Ultra Reliable Low Latency Communication (UC3).

The document sets the foundation of the project and serves as the main starting point for the research and development activities of the NRG-5 project. By means of a thorough analysis of both the three use cases and the 5G network, the purpose of the document is to blend energy, telecom and ICT skills during the whole UC elaboration process in order to rich an holistic vision of the use case scenarios. Using this approach actors, scenarios, pre- and post-conditions, flow of actions and requirements of each NRG-5 use case as well as the 5G requirements and KPIs have been analysed and depicted.

Moreover the document describes and compiles all the results of the first task of the WP1. Although during the project lifetime requirements may evolve based on the new knowledge, a commonly shared understanding of the goals during the first months is needed for building a suitable architecture and the new functionalities foreseen in the NRG-5 project.

1.2 Scope of the Document

This document is produced within the Work Package 1 in order to refine the NRG-5 use case scenarios, identifying their 5G requirements and the 5G KPIs. It specifically addresses the Smart Energy-as-a-Service concept, laying the foundation for demonstrating three 5G Smart Energy vertical use cases where all three 5G services identified by the 5G-PPP, namely Enhanced Mobile BroadBand (***eMBB***), which is also referred as Extreme Mobile Broadband (***xMBB***), Ultra-reliable Machine Type Communications (***uMTC***), which is also referred as Ultra-Reliable Low latency Communications (***URLLC***) and Massive Machine-Type-Communications (***mMTC***), will be implemented. Information reported in this document are crucial for the design of the NRG-5 reference architecture (Task 1.2) and for their components functional decomposition (Task 1.3).

1.3 Structure of the Document

The document is organised as follows: Section 2 presents a brief description of the scope of the NRG-5 project. This vision has been used as reference for the use case scenarios and requirements definition. Section 3 is dedicated to the NRG-5 use case analysis; for each use case the scenario, actors, conditions, technologies involved, energy requirements and KPIs have been reported. Each UC analysis ends with the identification of the specific 5G traffic requirements. Section 4 describes the 5G network requirements and KPIs and their mapping to NRG-5 use case scenarios. Section 5 outlines the conclusion for each NRG-5 use case scenario in terms of 5G requirements and KPIs and refers to the next steps. The document gathers the references in Section 6, the list of figures in Section 7, the list of tables in Section 8 and the acronyms in Section 9 and also includes three annexes presenting the complete set of the requirements for each UC.

2 NRG-5 Objectives

The overall objective of NRG-5 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.

The project is structured in 8 work packages (WPs), where the firsts five are of technical nature and will primarily deliver technical results and findings. The final three WPs deal with dissemination, impact, ethical, management and will monitor ongoing work according to the project description, as well as make sure the project outcome becomes visible and communicated in efficient ways in 5G initiatives.

This deliverable, named *Use Case scenarios analysis and 5G requirements* is the first output from WP1 and describes the targeted use cases and associated key performance indicators (KPI), and is intended to guide the technical work in WP2-5.

The work done in the Task 1.1 has been refining and analysing the NRG-5 use case scenarios and applications that will address the challenges of Smart energy. This work covers heterogeneity requirements in terms of embedded devices, access networks and minimum devices. It defines HW and SW requirements to run the NRG-5 framework as well as communications requirements, such as response time for the electricity and the gas network assets, round trip delay, jitter and bandwidth requirements, networking & VNF functions, scalability, robustness and open interfaces, supporting migration of IT load to the edge cloud, security, privacy, trust, access control and interoperability requirements, flexibility, fast deployment and service programming model and tools including VNF deployments, VNFFG and SFC and even energy consumption of the 5G devices.

The ultimate objective of this deliverable is to select NRG-5 use cases in order to refined them with descriptions of the actors, scenarios, pre-and post-conditions, the flow of actions, application requirements and the improvements of the essential system attributes that NRG-5 architecture and 5G features should guarantee to be achieved.

Moreover, this work has been done closely working together with the 5G PPP Working Groups and 5G Initiatives. Studying and using some of the results coming form both Phase 1 projects and collaborating with same Phase 2 projects. The starting point has been the already outlined proof-of-concepts (PoC) in the project application which originate from fundamental 5G studies [2]. The traditional electricity business model in Europe is still subscription-based, ensuring stability for both suppliers and customers: stable income for utilities; stable supply for customers at predictable and affordable prices. But the huge wave of DERs such as renewable resources, batteries and the new and ongoing deregulation process are leading toward the new innovative business models in the utility sector that has occurred with new service provision and the search for cost efficiencies.

In this respect, NRG-5, leveraging the 5G features, aims at validating the extremely demanding 5G Smart Energy vertical use case, which requires openness, resilience, security and high availability of the whole intertwined infrastructure.

For this reason, NRG-5 stresses 5G current results co-developing a new 5G communication infrastructure in terms of security, privacy, trust and high availability investigating on:

- **Security** deploying and operating a huge number of end- points, avoiding lock-in strategies,
- **Resilience** of infrastructure via Predictive Maintenance and self- healing via assets' virtualization and timely energy re-routing,

- **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.

The 5G Infrastructure Association (5G IA) members have released a Phase 2 Pre-structuring Model version 2 enriching the Target Actions model built on the Phase 1 projects targeting a successful and coherent PPP Phase 2 research programme and building on PPP Phase 1 experience, the 5G IA members have developed this in order to ensure that the forthcoming set of projects (portfolio) is cleverly work together in Phase 2, between Phase 2 and Phase 1 and later on between Phase 2 and Phases 3. Among the activities of this Model, NRG-5 is in the mostly aligned with the objective and scope of following Target Actions (TAs):

TA13 Security, Privacy, Resilience and High Availability.
Security, privacy, resiliency, and high availability are mandatory for 5G success and adoption both in general, and specifically by (e.i. Smart Energy) verticals. Existing methods of assuring these aspects fall short of delivering the required levels of reliability, thus require further research and innovation for enabling 5G deployments.

TA6: Seamless Integration of Satellites Networks and Air Platforms into 5G
Satellite and high altitude platform solutions, thanks to their inherent characteristics will contribute to augment the 5G service capability and address some of the major challenges: multimedia traffic growth, ubiquitous coverage, M2M communications and critical telecom missions whilst optimizing the value for money to the end-users.

TA7: 5G for Future MTC Solutions
The vertical industry is expected to be supported by 5G networks in highly efficient manner. These vertical industries have a diverse set of usage scenarios and it will be required to meet new challenging KPIs , e.g. very low latency, ultra high reliability, low energy consumption, support of massive connections, etc. The main driver for this action is to acquire realistic requirements from the vertical industries and provide integrated subsystem (e.g. latency, reliability, power...) solutions embedded in 5G cellular networks or network slices. Related business models will be considered for the design of adequate network and transport functions.
TA14: Multi-Tenant & Multi-Domain Plug & Play Control Plane
5G networks will support a concept of "slicing" that allows providing different sets of services to different groups of terminals, such as smart phones, cars, sensors, etc. NRG-5 should address how to realize the slicing concept in a dynamic and multi-party environment with multiple heterogeneous access domains. In this which specifically considers “Smart Energy” Vertical and is committed to the proposed 5g PPP program level coordination activities. NRG-5 has defined three general use cases with the intention of cover and satisfy all objectives of above TA listed.

Just thanks its ambitious objectives, NRG-5 has a clear position in the 5G PPP Phase 2 – Pre-structuring Model [3]. Through the interactions with 5G-PPP Phase1 and Phase 2 projects and 5G-AI, NRG-5 aims at defining and specifying some vertical additional use cases focusing on utilities domain, mainly gas and energy. The Use Cases described in NRG-5 fallen on a small set of basic *5G service classes*, which have been consolidated and agreed in the context of 5G-PPP as follows

- Enhanced Mobile Broadband (eMBB),also called Extreme Mobile Broadband (xMBB)
- Ultra-Reliable Machine Type Communications (mMTC), also called Ultra-Reliable and Low Latency Communications (URLLC), and
- Massive Machine Type Communications (mMTC)

The three general Use Cases defined during the proposal time are:

<u>Use Case 1</u>: Realizing decentralized, trusted lock-in free Plug & Play vision

Provide a framework that will allow for easy, real-time, automated devices identification so that network auto-configuration can be achieved automatically. Unified AAA should be achieved in a homogeneous manner, to reduce the chances of AAA misconfigurations among different services of the same or different tenant, to address multi-tenancy under geographically unbound mobility scenarios. Last, secure communications should be achieved irrespectively of the network service provided and the physical entity initiating the connection.

This Use Case 1 addresses

a) *mMTC* via the vast number of smart meters and
b) *uMTC/URLLC* as most VNFs require real-time control of the smart energy services. It is important to note that all proposed VNFs may be applied well beyond utility networks to any type of mobile hardware constrained terminal.

<u>Use Case 2</u>: Enabling aerial Predictive Maintenance for utility infrastructures

Low-delay, 5G-enabled Predictive Maintenance may significantly help in more efficient operation, accidents avoidance and fast restoration of energy networks, leading to reduced maintenance costs and increasing the QoE offered by the Utilities to the citizens.

This Use Case 2 addresses:

a) *xMBB/eMBB* communications via the vMPA VNF for video streaming from the drones and analysis to the xMEC and the utilities control centre, and
b) *uMTC/URLLC* communications via the vDFC VNF for controlling the flight of drones.

<u>Use Case 3</u>: Enabling resilience and high availability via Dispatchable Demand Response (DDR)

The stability and resilience of the energy grid in the presence of high share of RES, greatly depends on the fast response. Given that most of the times storage is not available on-site, ultra-low (below 5ms) response from the energy operation centre is of vital importance. The enablement of large scale DDR requires extreme (for today's standards) communication requirements as metering and associated computational processes should be performed at very high frequencies.

This Use Case 3 addresses:

a) *mMTC* communications via the huge number of RES, DES and controlling units and
b) *uMTC/ URLLC* communications as most VNFs require real-time control of the smart energy services.

The defined use cases fall on three use cases groups defined by 5 IA members, are following

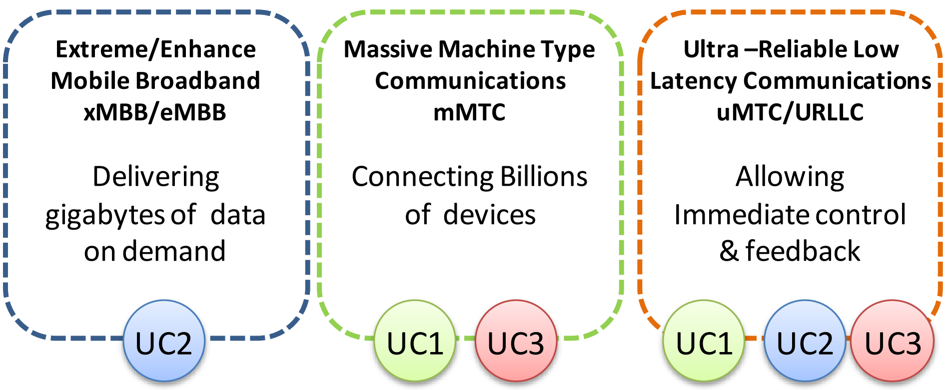

Figure 1 - Use cases groups defined by 5 IA members

The next sections depict and detail the above use cases in order to encourage the NRG-5 consortium to both examine how already defined 5G radio features could be used in Energy Use Cases and even how them can be extended for meet the some of Energy requirements and define NFV concepts as contributions to 5G studies which would optimize the performance for 5G network in the upper layers, to support the use case requirements.

2.1 NRG-5 from 5GPPP perspective

The work done in the 5G-PPP Phase 1 projects based on identifying the requirements for the 5G network infrastructure a large number of use cases have been described and analysed in the context of standards bodies, such as 3GPP and ITU-T, industry forums such as NGMN, has produced an overview of the use cases and models that were developed for an evaluation of different 5G radio access network concepts. They are not meant to be exhaustive with full coverage of all technical aspects related to 5G. The main scope is instead to describe a guide of the research and innovation in these projects towards demonstrating their scientific and technological achievements.

The white Paper on 5G-PPP use cases and performance evaluation [4] provides an overview of the use cases that are used for evaluation of different 5G radio access network concepts. It refines the use case classes provided above, by defining use case family groups in order to better reflect their use in 5G-PPP phase 1 projects and 5G-PPP phase 2 projects. The identified groups are:

Use Case Classes	
Dense urban	Both indoor and outdoor in dense urban environment
Broadband (50+Mbps) everywhere	Focus on suburban, rural and high speed trains
Connected vehicles	uMTC and/or xMBB on cars. V2V and/or V2X
Future smart offices	Very high data rates indoors and low latency
Low bandwidth IoT	A very large number of connected objects
Tactile internet / automation	Ultra- reliable communication with xMBB flavour

2.2 Key performance indicators

In order to evaluate the results of the solutions proposed and implemented within NRG-5, it is necessary to quantify the tangible and measurable impacts which contribute to the specific EU policy goals, identifying some of KPI showed in the Figure 2, which also gives a snapshot of the Use Cases, KPIs and capabilities groups identified analysing the literature. To this end, selecting KPIs help to grasp objectives and monitor the performance of the specific use case scenarios developed over the project. Moreover, KPIs aim to highlight the added value of the solutions proposed in European projects and their alignment with EU ambitions and targets for future power grids.

KPIs’ role is to be used from active policy actors, energy market players and telecom operators to contribute in future decisions concerning network planning and operation. KPIs’ main focus is to facilitate the monitoring of research activities and link them with EU goals. Their usage enables the exploitation of the experience gained from European research activities and projects, without intention to compare or rank project results.

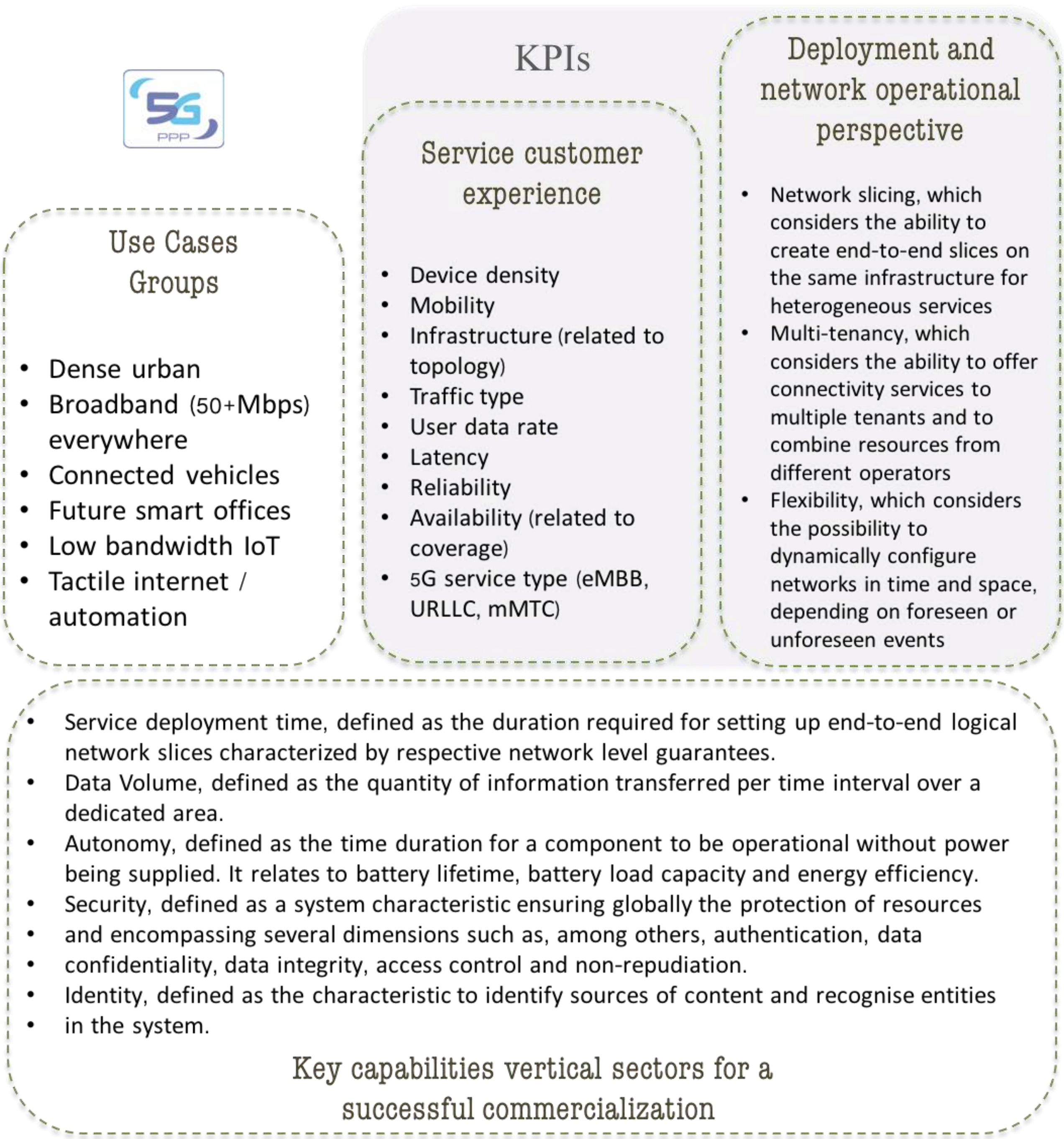

Figure 2 - Use Cases, KPIs and capabilities groups

2.2.1 KPI selection

Being part of the 5G-PPP initiative, the NRG-5 project refers to the list of KPIs already defined by the EC in the final report *A Framework for monitoring the impact of 5G Public Private Partnership and the associated Key Performance Indicators (KPIs)* [4]. In detail, operating, performance and societal KPIs were mapped and evaluated for both the energy sector and the NRG-5 use case scenarios. The values considered for the KPIs used for clustering the NRG-5 use case scenarios were selected by the telecom partners and then validated by the energy utilities and the technology providers by using the following ranges set by the 5G PPP.

- **Device Density**
  - High : ≥ 10000 devices per km^2
  - Medium : 1000 – 10000 devices per km^2
  - Low : < 1000 devices per km^2
- **Mobility**
  - No: Static users
  - Low: Pedestrians (0-3 km/h)
  - Medium: Slow moving vehicles (3 – 50 km/h)
  - High: Fast moving vehicles, e.g. cars and trains (> 50 km/h)
- **Infrastructure**
  - Limited: No infrastructure available or only macro cell coverage
  - Medium density: Small amount of small cells
  - Highly available infrastructure: Big number of small cells available
- **Traffic Type**
  - Continuous
  - Burst
  - Event driven
  - Periodic
  - All types
- **User Data Rate**
  - Very high data rate: ≥ 1 Gbps
  - High: 100 Mbps – 1 Gbps
  - Medium: 50 – 100 Mbps
  - Low: < 50 Mbps
- **Latency**
  - High: > 50 ms
  - Medium: 10 – 50 ms
  - Low: 1 – 10 ms
- **Reliability**
  - Low: < 95%
  - Medium: 95 – 99%
  - High: > 99%
- **Availability (related to coverage)**
  - Low: < 95%
  - Medium: 95 – 99%
  - High: > 99%
- **5G Service Type**
  - xMBB/eMBB, where extreme Mobile Broadband is the key service requirement
  - uMTC/URLLC, where the reliability is the key service requirement of the UC
  - mMTC, where the massive connectivity is the key service requirement of the UC

3 NRG-5 Use Cases analysis

Use cases, broadly speaking describe a particular goal an actor wants to achieve with a system of interest. How the actor achieves this goal (under normal or exceptional conditions) is described in several steps and is the part in which the UCs are detailed. As the UC description progresses, it should not lose sight of what are the real objectives in the frame of the 5G approach. For this reason, it is useful having as reference project cartography. This cartography is a project tracking dashboard able to show how the project is doing towards goals and targets and assures the project stay on track respect to the 5GPPP target actions. In this cartography will be possible to follow how the target actions are addressed through the UCs and which KPIs has to be followed to fulfil the 5G requirements. With this in mind in the following table we show the NRG-5 target action enlisted in DoW and their mapping with quantifiable KPIs and which UC addresses these KPIs.

Target Action 13	Objective	KPI	UCs
A resilient & secure dynamically configurable, adaptive and highly available virtualized/sliced infrastructure supporting end-to-end 5G services as well as critical vertical services	NRG-5 focuses on various innovative aspects (such as PUF and blockchain) and VNF optimal placement to ensure security, resilience and high availability in end-to end 5G services as well as the smart energy vertical.	• Availability • Latency	UC1, UC2
Secure (and privacy-preserving) and reliable solutions for setting up services across multiple domains	NRG-5 decentralized, trusted and lock-in free plug 'n' play approach and traceable VNFDs will enable high reliability and traceability.	• Reliability • Latency • Availability	UC1, UC3
Designing and implementing high availability of 5G services and solutions	NRG-5 will provide for automated infrastructure reconfiguration to make sure that sufficient resources are available at the right place at the right time, significantly improving availability of 5G services and solutions.	• Availability • Latency • User data rate	UC1,UC2,UC3
End-to-end security of 5G services and solutions in virtualised and softwarised deployments that include multi-domain services and service-chains deployed over on-demand infrastructure.	NRG-5 will consider a multi-tenancy compliant vAAA scheme which coupled with PUF and distributed trust based on blockchains at the field level ensuring security in multi-domain, service-chained 5G environments.	• Reliability • Availability • Latency • User Data Rate • Mobility	UC3
Integrate security risks into availability considerations by extending reliability models by cyber-attacks as causes for failure	NRG-5 will capitalize on the work performed in the SUCCESS project and employ cyber-security threats modelling in an end-to-end manner.	• Reliability • Availability • Latency	UC2,UC3

Supporting 5G MTC with specific protocols and critical requirements	NRG-5 offers a variety of self-x VNFs able to assist MTC by implementing a plug 'n' play vision for IoT.	• User Data rate • Device density	UC1,UC2,UC3
Supporting integrated and predictive monitoring of 5G IoT stack implementation	NRG-5 leverages on streaming predictive analytics to extract metrics and trends related to the communications behaviour of the supported terminals to optimize the network resource allocation.	• User Data rate • Device density • Availability	UC1,UC2
Target Action 6, 7	Objective	KPI	UCs
Seamless Integration of Satellites Networks and Air Platforms into 5G 5G for Future MTC Solutions	NRG-5 targets mMTC and uMTC applications, fully supporting the resource constrained, low bandwidth and low resources IoT paradigm. Moreover, introduces seamless integration of satellite and considers satellite integration in the mMTC context, especially for IoT applications (smart terminals and drones) that do not have access to terrestrial coverage.	• User Data rate • Mobility • Availability • Reliability	UC2
Target Action 14	Objective	KPI	UCs
Multi-Tenant & Multi-Domain Plug & Play Control Plane	NRG-5 aims at delivering plug 'n' play and self-organization in IoT networks for the Smart Grid case that will be readily reusable by other use cases as well, in a multi-tenant environment.	• Infrastructure • Reliability • Availability • User Density	UC1

Table 1 - NRG-5: TAs, Objectives, KPIs, UCs relationship

With this reference frame in mind, we will describe the 3 UCs of NRG-5 in the energy 5G vertical domain providing a scenario overview, actors and technologies involved and finally, the last section provides a summary of the planned and committed KPIs requirements, including how they map to targeted use cases. The scope of NRG-5 is to investigate if and to what extent smart energy grids existing or new services/applications/use cases may expect to gain significant benefits from the 5G advent.

Summarizing NRG-5 use cases are focused on the following topics

- Smart Grid monitoring and control applications, tailored to network operators (TSOs, DSOs) such as supervisory monitoring on wide area monitoring system (WAMS) enabling optimized operation/control management energy re-routing, or security management (fault localization)

- Aerial Maintenance and Surveillance with automatized and remotely controlled drones, tailored to automatize the execution of various tasks in the context of critical infrastructures such as power plants, and ranging from gas and steam leaks identification, to intrusion detection.

- Non grid-owned dispersed assets near real time flexibility aggregation management (e.g., loads, storage, EVs aggregated management), tailored to behind-the-meter stakeholders, such as aggregator-level flexibility resources portfolio management, tariff-based flexibility end user flexibility provisioning

- Scalable secure remote metering

NRG-5 key objectives are to identify, develop and integrate a number of innovative smart grid services and applications that may benefit greatly from the low latency communication paradigm, the large data rates, the massive number of communication devices, the localized network service deployment, and the high availability and reliability promised by 5G, as described in Figure 3.

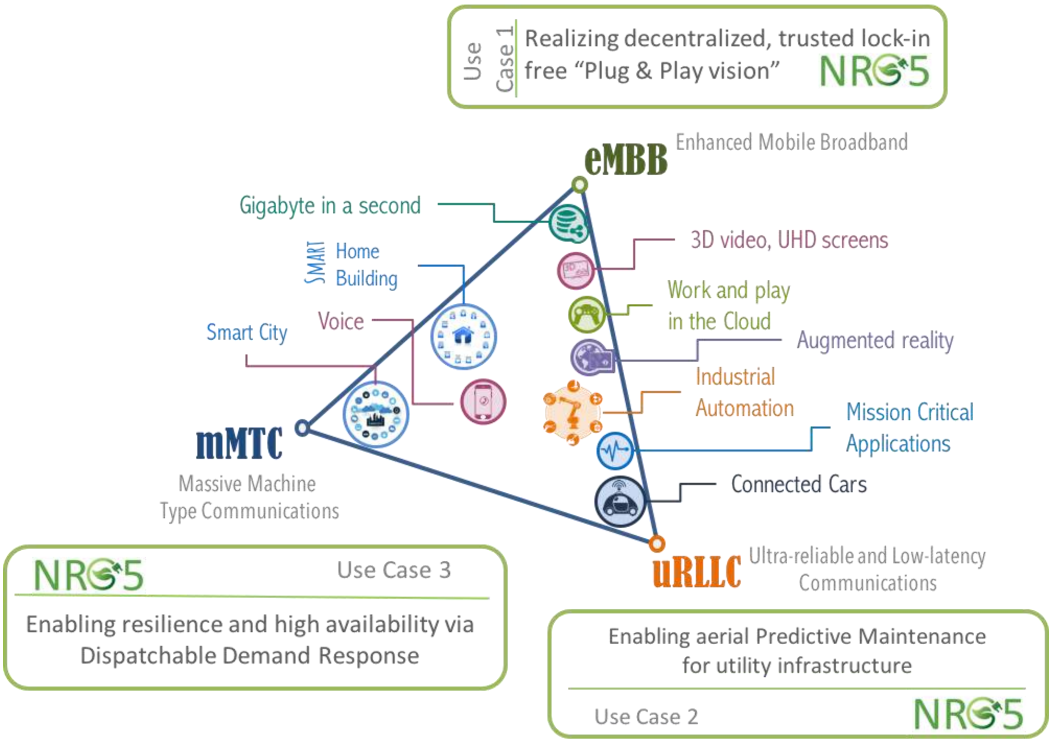

Figure 3 – NRG-5 Use Case vs. 5G KPIs

3.1 UC1: Realizing decentralized, trusted lock-in free "Plug & Play vision"

3.1.1 Scenario PMU-based near real time monitoring for power network optimized operation overview

This UC provides a framework that will allow for easy, real-time, automated devices identification so that network auto-configuration can be achieved automatically. The AAA is achieved in a homogeneous manner, to reduce the chances of AAA misconfigurations among different services of the same or different tenant, to address multi-tenancy under geographically unbound mobility scenarios. In this framework secure communications has to be achieved irrespectively of the network service provided and the physical entity initiating the connection. In such scenario, the main actor will be the smart metering devices that will exhibit a far more complex profile than today, offering services beyond traditional 15 minutes reporting, including support for real-time measurements, service discovery, infrastructure automation and AAA

Based on the H2020 SUCCESS unbundled smart meter architecture this UC will help to define a scalable cloud-based stack, optional multi-RAT access interface with the goal to enriche security and trust features forming the next generation smart meter as 5G device. In order to allow the fulfilment of the 5G requirements this UC will implement both PUF encryption and Blockchain to offer a decentralized trust & identity management mechanism, supporting end-users privacy by design. In a more general way this UC will describe a novel, open solution, applicable not only for smart meters but any hardware constrained device, with built in trusted and vendor/utilities lock-in free Plug 'n' Play functionality.

The solution described in this UC shows the need for efficient mMTC communications and for the realization of the "plug & play vision" in metering resources. It will be based on a novel and scalable xMEC paradigm offering a group of VNFs to facilitate distributed, scalable and trusted plug 'n' play functionality of hardware constrained devices.

3.1.1.1 Current situation

Smart Meters (SM) and the Meter Data Management (MDM) system are part of the critical infrastructure known as Smart Grid, where SMs provide to utilities and customers with a two-way flow of data required to manage distributed energy resources (DER), energy storage, flexibility on energy use, efficiency in demand response (DR) and network protection. At utility level, the huge volume of data generated through automated metering is handled by a MDM system. Currently, Multiple Automated Meter Reading (AMR) systems send their data via their respective head-end servers to the MDM, where Validation, Estimation, and Editing (VEE) routines fill in any gaps in the data, creating clean, integrated and bill-ready data sets. Backend utility systems such as billing, data warehouse, or outage management, in turn, obtain their data from the MDM for their specific purposes.

However, up to now smart metering devices are not for measuring energy use at customer premises in real time mode, even though it is widely agreed that they need to exhibit a more advanced service portfolio than today, including support for:

- uninterrupted/continuous service delivery,
- multimillion sensors and metering devices,
- time critical adjustments and adaptations for a balanced energy distribution,
- real time measurements,
- service deployment, discovery, operation, monitoring and update in a real-time fashion,
- infrastructure automation
- authentication-authorization-accounting functions.

Nowadays, SMs, which record electricity consumption in intervals of an hour or less (up to 15 minutes) and communicate that information to the utility at least once per day for monitoring and billing, are considered as being part of a second SM generation, with large deployments in the last years over Europe. Indeed, the first generation, mainly based on very low PLC (Power Line Communication) in most situations and GPRS for some segments, started the deployment around 2005 in early adopting countries, such as Italy or Sweden. The second generation is based on improved PLC and on GPRS/3G communication in some cases. Second generations SMs also feature more complex functionalities, such as net-metering, to be prepared for prosumers (both consume & produce electricity), and on complex structures of tariffs, to enable more flexible participation to market opportunities. In the first generation of SM there is a single communication modality from the users to the DSO (Distribution System Operator) whilst the second generation also provides, in some situations, an interface to the end user. The integrated system of SM, communications networks, and data management systems that enables two-way communication between utilities and customers is generally referred to as Advanced Metering Infrastructure (AMI).

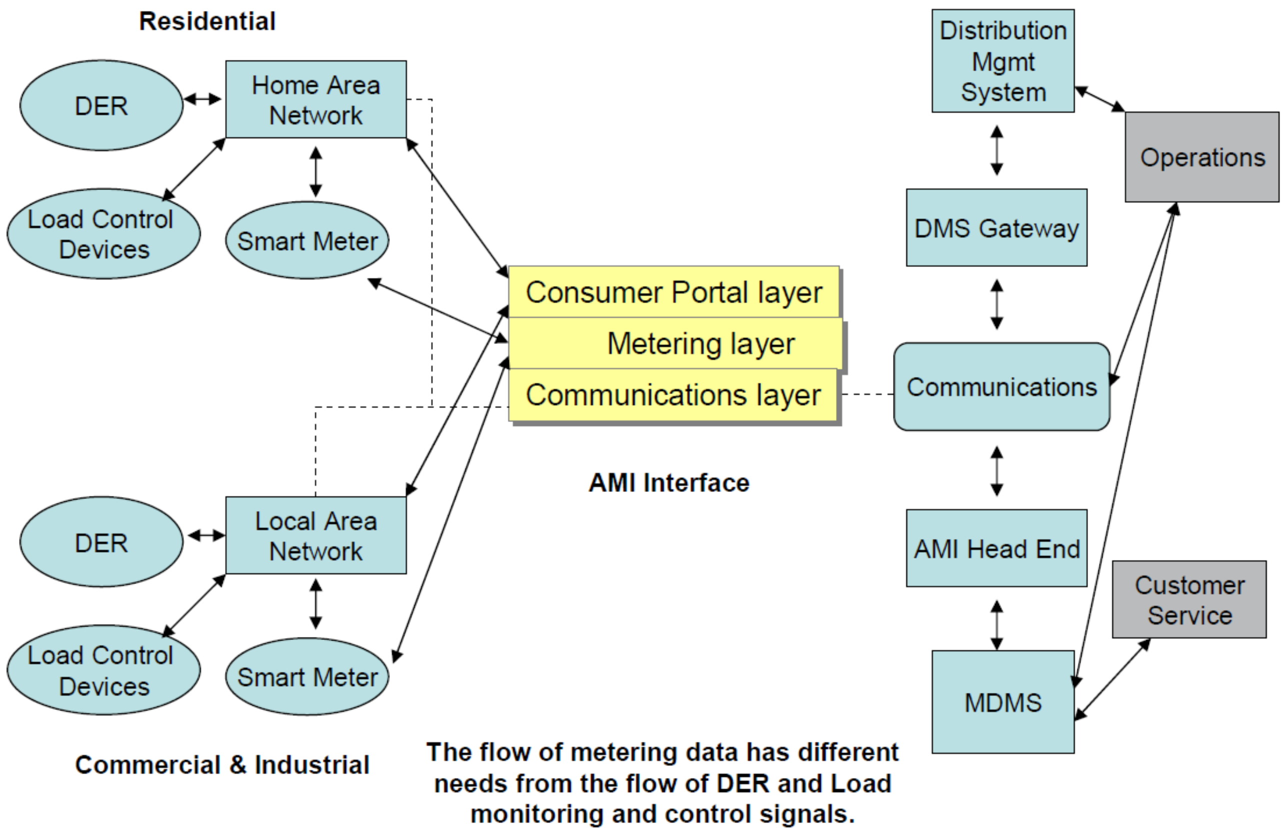

Figure 4 – Overview of AMI

Deploying an AMI is a fundamental step towards grid modernization. Initially, AMR technologies were deployed to reduce costs and improve the accuracy of meter reads. However, the quick understanding of the benefits of two-way interactions between system operators, consumers and their loads and resources led to the evolution of AMR into AMI. Indeed, AMI allows for:

1. motivation and inclusion of the consumer in the power network;
2. generation and storage options distributed at consumer locations;
3. connection of the consumers to the grid, permitting them to actively participate, either as loads directly responsive to price signals, or as part of load resources that can be bid into various types of markets;
4. rapid detection, diagnosis and resolution of Power Quality (PQ) problems by means of smart meters equipped with PQ monitoring capabilities;
5. the emergence of a more distributed operating model that reduces the vulnerability of the grid to terrorist attacks;
6. self-healing by assisting outage management systems to detect and locate failures more quickly and accurately.

AMI can also deliver a ubiquitous distributed communications infrastructure that can be used to accelerate the deployment of advanced distribution operations equipment and applications. Last, AMI data provide the granularity and timeliness of information needed to decisively improve asset management and operations.

In this regard, state of the art SMs [5] are characterized by complex functionalities as follows:

- Active and reactive energy measurement with metrology certification;
- Complex tariff implementations;
- Design based on communication with DSOs—as market facilitator in most EU countries, or the independent central hub—as third-party market facilitator;

- Standard protocols are used for the data readout from smart meters specialized for the above-mentioned AMR/AMI data collection, such as the DLMS/COSEM protocol and its associated data model;
- Smart meters are able to provide, on request, instrumentation measurements at high reporting rates, between 1 and 10 s, as possible support for SCADA (Supervisory Control And Data Acquisition) functionalities and different smart grid functionalities. This instrumentation data (e.g., voltage, current, active power, reactive power) is not used at its full potential, for various reasons: the communication path is too slow, protocol is not appropriate for SCADA, etc.;
- Load Profiles (LP) of energy, instrumentation and of other data can be stored for medium to long periods, such as one month to several months, depending on the selected time for LPs memorization;
- Some electrical energy smart meters have functionalities to collect data from other local meters: gas, water or heat meters; this architecture enables multi-utility/multi-service smart metering, allowing for improvements in energy and market efficiency;
- Some electrical energy smart meters have a local interface to communicate with local devices and with end-users, thus enabling different services for final users. An important step towards standardization has been made with the Open Meter project which provided a comprehensive set of open and public standards for advanced metering infrastructure supporting multiple commodities (electricity, gas, water and heat).

For advancing towards a smart grid, and complex energy and energy services market, there are several aspects not implemented, or not well approached, in today's smart meters:

- Multi-user communication with the smart meter is usually not possible, because there is only one direct communication interface to remote users; thus, data availability is delayed through a trusted party (DSO or independent central hub) which collects meter data at regular intervals, such as each one day, or each six to one hour; the flexible data access point manager (DAM) approach is not applicable because the remote communication is used solely by the trusted party;
- Complex services using real-time (s) and/or near real-time (intra-hour) data cannot be used, due to low communication speed with the DSO, especially through the PLC technology;
- SCADA functionalities are not easily used by the DSO's dispatch centres because there is no real-time functional link between today's AMR/AMI systems and DSO SCADA systems. Moreover, the direct communication of the dispatch centre's front-end cannot be made directly with the meter, due to protocol incompatibility (AMR protocols, such as DLMS, are different from SCADA protocols, such as IEC61850);
- There is no strong redundancy concept in the acquisition of data, in order to validate/ invalidate acquired data at the meter level;
- Smart meter cyber-security strength is still not very high and smart meters are prone to direct cyber-threats; there is no holistic concept on the whole data chain to mitigate cyber-attacks, starting from the meter as the primary source of data; There is no functionality related to the integration of synchronous phase measurements (PMU), even if this becomes more and more important, especially in active distribution networks with high penetration of renewables. Different barriers regarding PMU large deployments are listed below:
    a) Even by integrating the PMU similar to another "local meter", the PMU measurements are still difficult to introduce, due to difficulties in providing GPS synchronization, which need sky visibility;
    b) PMU protocols are also different than SCADA protocols and there are difficulties with merging them, due to similar barriers as with meters: special acquisition and storing systems are specific to PMUs, which are different from the SCADA systems;

c) PMU data has higher reporting rate of measured data compared with, allowing one to 25, 50 (per each period) or even 100 (each semi-period) measurements per second, thus having greater dynamics in comparison to the maximum energy meter reporting rate;
d) Regarding the collection of data from other local meters (gas, heat, water), there are still a limited number of meter types which can be accessed, for example, the “main” smart meter.

It can be observed that there is not yet ICT-enabled equipment to address, in a unified manner, the needs of smart metering, smart grids and advanced cyber-security. In general, it is missing a standardized way to link the customer in the system, and to unlock a two-way communication in order to be used for the large deployment of various services, in a flexible multi-user approach.

In the new scenario involving 5G communication an interest grew in realizing decentralized, trusted lock-in free “Plug &Play vision”, allowing easy, real time, automated device identification so that network configuration can be achieved automatically, under a highly heterogeneous landscape in terms of devices and services. Real-time SM can enable detailed monitoring of the grid status and energy consumption behaviour of connected stakeholders, implementing powerful control mechanisms, flexible billing processes, and unmatched value-added services. In Europe, there are high expectations for smart grids to have an adjustment ability involving consumers, and there is lively discussion of platforms referred to as the “*flexibility*” for achieving this. In the customer-centred Smart Grid fed by renewable energies it is expected that real-time SM will enable real time energy optimization and management operations.

Therefore, to provide a framework that will allow for easy, real-time, automated device identification so that network configuration can be achieved automatically, it is compulsory to make use of low cost, secure and real time metering devices. In this regard, NRG-5 will exploit the Next Generation Open Real Time Smart Meter (NORM) already developed in the SUCCESS project [6] and based on the unbundled meter concept introduced in the Nobel Grid project [7].

The energy market during the last few years, is witnessing a number of revolutionary changes. It is well accepted that changes are caused, enabled or accelerated by:

- The advancements in smart metering technology, supporting real time and two way communications,
- The introduction of renewable energy sources, at local, regional and national level,
- The shift from the well-established energy producer and consumer paradigm, towards the energy prosumer paradigm,
- The advancements on the technology that made efficient and affordable solutions of energy storage available for a wide range of applications,
- The adoption of a multi-tariff approach in selling or buying energy, through market places or even in a planned/automatic way.

Building up on those changes, it is now possible to design and deliver new families of energy related applications that exhibit novel characteristics, compared to the existing ones:

- Continuous service provisioning, combined with reliable service delivery, for mission critical applications
- Low-latency communications
- Increased density of communications, able to support multimillions of SM, in wide-spread locations
- Requests/response communications of real time nature

- Bandwidth demanding for high quality multimedia content, combined with virtual reality (VR) or augmented reality (AR)

3.1.1.2 Scenario description

The use-case is considering the emerging neighbourhood market of energy and energy services, in the context of a local microgrid which aims to maximize microgrid self-consumption and to reduce the energy exchange to the higher-level grid. The real case is either considering a LV network with high RES penetration and supplied by a MV/LV transformer (microgrids have usually only one point of connection with the main grid, which is here the MV/LV transformer) or an MV grid with high RES penetration and supplied by a HV/MV transformer (as the point of connection with the main grid).

It is considered that prosumers with excess energy produced by their PV resources and having also storage means for flexibility are interested to sell their energy or to provide flexibility / balancing services inside the local microgrid.

More particularly, the energy consumer or prosumer is capable of negotiating, in a dynamic manner, the agreements that outline the buy and/or sell energy relationship with the energy market. These agreements can be considered as micro-contracts, with a temporal and/or spatial validity. This means that a buy (or sell) micro-contract may be valid for a certain time period, or even offer the possibility to serve only certain locations of the consumer. In this way, the consumer is able to select dynamically the most cost efficient energy provider, while the prosumer would be additionally able to select the most profitable energy provider for selling back locally produced energy.

In this manner, we manage to constitute, both the energy consumer and prosumer, independent from the retail and wholesale energy providers, respectively, implementing, for the very first time, a lock-in free energy service. The energy consumer or prosumer is no more bound to a specific energy provider, but it is possible to have an on-the-fly and on-demand switching of the energy providers, utilising the notion of micro-contracts.

One of the main objective of NRG-5 project is to achieve truly decentralized, secure and trusted plug ‘n’ play by combining MTC VNFs and inherited physical functions of low-end devices (focus on smart meters) with distributed key management mechanisms. With reference to the Mobile Edge Computing (MEC), combining elements of information technology and telecommunications networking, novel and scalable xMEC paradigm focused on energy will be realized. In so doing, customers will be able to play an active role in energy flexibility, exploiting efficiently decentralized energy generation and local storage and enabling intensive neighbourhood / local energy related activities with the support of xMEC functionality.

The scenario involves the use of real time SM NORM, characterized by a low cost, high level of security and suitable operational functions. NRG-5 extensions developed over the project will facilitate distributed, scalable and trusted plug ‘n’ play functionality of hardware constrained devices (SM contains a Linux machine with limited resources, where the SMG is implemented with single board computers such as Raspberry Pi3 or Beagle bone Black) in order to allow for easy, real time, automated devices identification. In so doing, misconfigurations among different services can be avoided and a secure communication can be reached.

Basically, in this scenario three essential components will make up the xMEC architecture: *edge devices* connected to the network (NORM being chosen as the appropriate edge device in this project); *edge cloud* deployed in mobile base station with the responsibility of traditional network traffic control and hosting various mobile edge applications, and the *public cloud*, cloud infrastructure hosted in the Internet.

NORM is a pivotal edge device which supports the prosumers and consumers to establish such near-real time energy and balancing services market, with complete bid/gate-closure/operation/settlement in very short times needed by the higher volatility of the microgrid, meaning e.g. each 1 to 5 minutes for energy and each 5 seconds to 1 minute for balancing services. NORM is an open platform where new functionalities can be added to standard meters within the Smart Meter Gateway (SMG), an enhanced version of Smart Meter Extension (SMX). NORM could be used as a new stand-alone meter (when equipped with the proper metrology and hard-real time features) or it could be used to expand legacy meters with more functionalities and securities and with added hard real-time features such as PMU functionality [5].

The near-real-time markets and operation are supported by the 5G low latency technology, which allow predictable reaction for the different steps on the entire chain of operations, thus allowing also the shot-time periods especially for the balancing services.

In Figure 5 below it is presented the use-case overview.

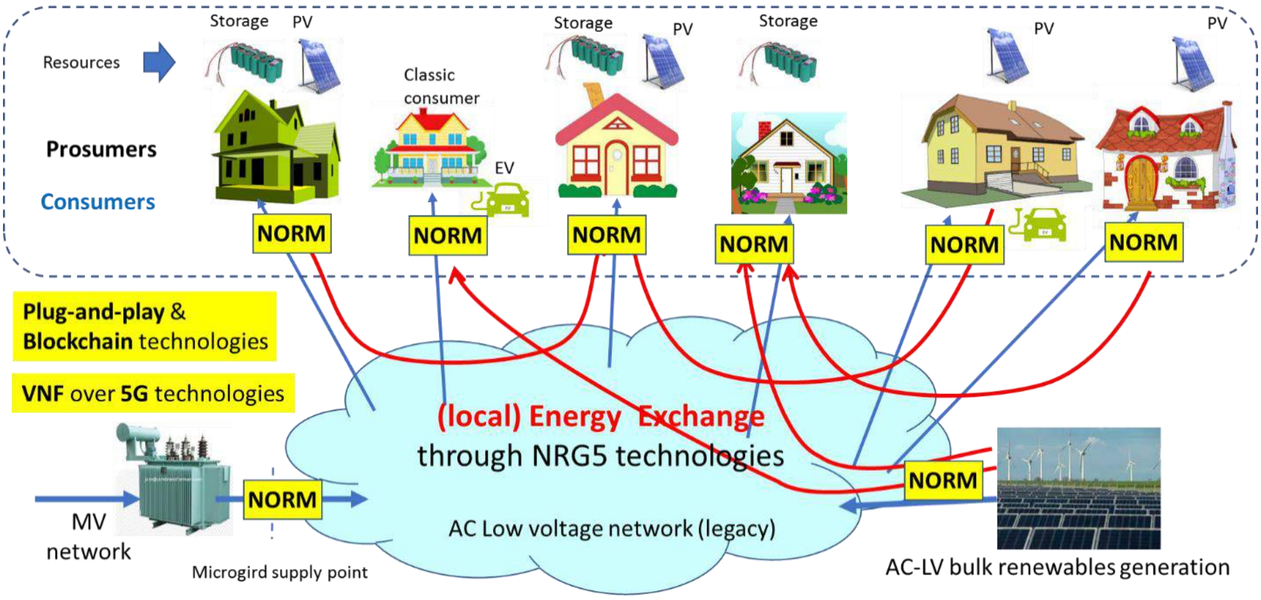

Figure 5 - UC1 overview: Microgrid advanced energy and energy services market and operation with NRG-5 technologies

It can be seen that peer-to-peer connections are possible, functionalities to be developed under NORM equipment associated with each prosumer or consumer. The implementation of this use-case requires all the listed VNFs with a specific attention to the plug-and-play facility to make the trustful connections between the prosumers and consumers, the blockchain based transactions, the operation, measurement and settlement of the transacted services.

The following distributed energy resources are considered in the use-case: PV arrays and battery storage.

The use case scenario needs to meet the following major group of requirements, referring to:

(i) heterogeneity, both in terms of involved embedded devices, access networks, delivered services and minimum devices' HW and SW requirements to run the NRG-5 framework;

(ii) communications requirements, such as response time for the electricity and the gas network assets, round trip delay, jitter and bandwidth requirements;

(iii) ubiquitous networking access;

(iv) network services (NS) flexibility as expressed by their dynamic reconfiguration as a set of service function chains (SFCs), virtual network functions forwarding graphs and paths (VNFFGs and VNFFPs, respectively) and, subsequently, virtual network functions (VFNs);
(v) scalability, robustness and open interfaces, supporting migration of IT load to the edge cloud;
(vi) security, privacy, trust, access control and interoperability;
(vii) ultra-fast deployment and service programming model and tools including VNF deployments, VNFFGs and SFCs;
(viii) the need for minimizing the energy consumption of the 5G devices.

In this course, six VNFs will be rolled out in order to:

i) identify nodes in the advanced xMEC network (vTSD);
i) select and establish networking path between nodes and edge routers, based on functional and non-functional requirements (vSON);
ii) provide caching services for the SM data on the xMEC (vMCM); these caching services will consider privacy aspects for the xMEC mirrored data;
iii) supply memory transfer and tagging for idle mobile devices;
iv) furnish trust services based on the blockchains technology (vBCP)
v) allow for authentication, authorization and accounting by means of cutting edge cryptographic approaches implemented on the SM with blockchains technology (vAAA), overcoming utilities lock-in.

3.1.2 Actors, conditions and technologies involved

3.1.2.1 Storyline

The consumer / prosumer centric approach is enabling the European Commission to bring higher power enforcement at the local level, as well as a better implication in all smart-grid related activities. New aspects of this empowerment also include the necessity of resilience and immunity. In short, the use-case considers an advanced neighbourhood market of energy and energy services based on plug-and-play features, blockchain transactions and real-time operation, in order to maximize self-consumption in a microgrid environment.

The scenario that we have envisaged is one where the energy consumer or prosumer is able to pursue, enter or change a business agreement with energy providers in a dynamic and real time manner. Negotiations on the energy price are foreseen and will take place interactively, between energy consumer/prosumer and energy providers, or automatically, driven by predefined criteria and pricing/consumption/production thresholds. Each step, during the negotiation process, as well as the final result of the negotiation, which could be an agreement or a disagreement, will be preserved in a non-disputable manner. This will increase the confidence and trust of the involved parties, especially of the retail consumer/prosumer. At the end of a successful negotiation, a new smart-contract will be established and acknowledged, by both parties. This smart-contract will entail all the necessary terms and conditions of an energy agreement.

More particularly, the energy consumer or prosumer is capable of negotiating, in a dynamic manner, the agreements that outline the buy and/or sell energy relationship with the energy market, at large. These agreements can be considered as smart-contacts, with a temporal and/or spatial validity. This means that a buy (or sell) smart-contract may be valid for a certain time period, or even offer the possibility to serve only certain locations of the consumer. In this way, the consumer is able to select dynamically the most cost efficient energy provider, while the prosumer would be additionally able to select the most profitable energy provider for selling back locally produced energy.

In this manner, we manage to constitute, both the energy consumer and prosumer, independent from the retail and wholesale energy providers, respectively, implementing, for the very first time, a lock-in free energy service. The energy consumer or prosumer is no more bound to a specific energy provider, but it is possible to have an on-the-fly and on-demand switching of the energy providers, utilising the notion of smart-contracts.

As far as the smart-contract is concerned, this is going to be the implementation of a legal bind between the consumer/prosumer and the energy provider. Such a contract will need to be negotiated on demand, and, eventually agreed electronically. As such, the smart-contract will identify the two participating entities and the conditions mutually agreed in a non-disputable manner.

In order to better understand how the energy sell or buy smart-contracts could be established, the energy transaction can be divided into three distinct service steps and respective time-frames:

- First time frame is the "**Transaction ahead period**" (TAP), which includes the preparation and the commitment to perform a certain transaction; this may include preparations, which are performed only once, at the beginning of a set of TAPs, such as entering in a specific market pool; During the TAP time frame, operations like search for selling or buying energy, based on flexible criteria, negotiate conditions for selling/buying energy, simulate the potential micro-contact, may take place. It must be noted, that such operations may be initiated by thousands or even millions of potential energy buyers or sellers, either automatically or on demand, concurrently or within the same time window.
- Second time frame is the "**Transaction execution period**" (TEP), which is the execution of the energy transfer of energy service obligations, which are decided in TAP. This is a real-time activity, where the smart-contract is established. This implies the control of energy resources, so that the transaction obligations (aka smart-contract) are fulfilled; TEP includes also the necessary measurements and records, which describe the performance of the service; this is the transaction period TP, the former TAP being a preparatory period. TEP is very critical, as it contains the establishment of a smart-contract that has been previously negotiated and agreed. As such, the TEP phase needs to make absolutely certain that the agreed smart-contract cannot be disputed, in any way, by any of the involved parties. Furthermore, the establishment of the smart-contract needs to be open and transparent, and possible to be proven that it was established following the a pre-agreed set of business criteria and conditions.
- Third and last time frame is the "**Transaction settlement period**" (TSP), which implies the clearance of transaction obligations, by acceptance of the results and necessary payments from all parts implied in the transaction chain. TSP ends with payment of all fees, as compensation for the different services executed during TEP, as compared with the duties established during TAP.

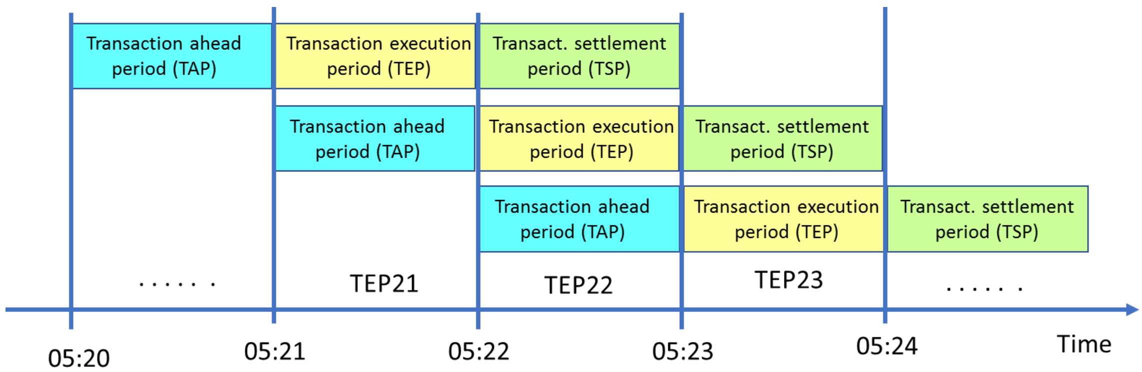

Figure 6 – Transaction execution periods (TEP / TP) and the overlapping of the period with ahead period (TAP) and settlement period (TSP) of other TEPs

Figure 6 shows the three periods and how they overlap. The example is given for a dynamic transactive energy environment with TEP = 1 minute.

Sequence of actions		Actors involved
1	Statement of access to the 5G platform for microgrid transactions, and confirmation of fitting into a profile type of those defined at platform level (consumer / buyer, producer / seller and consumer / buyer, intermediary, related service provider, etc.). This is performed during TAP.	Consumer, Producer, Prosumer, Aggregator, DSO, Supplier
2	Each participant (belonging to a predefined profile within the platform) will define its set of parameters according to its own needs (based on operating scenarios such as: selling energy if the output exceeds a predetermined level, or buying energy if what it produces in conjunction with the needs of consumption in a certain period covers the level of energy produced; the option to participate in preferential transactions and under what conditions; establish the bid selection algorithm, the transaction tracking algorithm and their validation, response parameters and service delivery automatically, etc.). This activity is happening in real time and, depending on the conditions, it could be triggered by many different energy buyers or sellers that are searching for new opportunities or respond to an energy business request. This activity is performed during TAP	Consumer, Producer, Prosumer, Aggregator, DSO, Supplier
3	Carrying out the real-time obligations for the agreed transactions, based on predefined parameters at the level of each participant in microgrid transactions, with validation / blocking of transactions in real time, also depending on the parameters set (e.g. additional human in the loop actions such as "I want to be asked for reconfirmation or transaction made completely automatically according to the parameters introduced in the system", or complete automated transaction) - both from the perspective of buyers and sellers of energy, as well as from service providers and the validation of transactions by DSO. This is a TEP activity	Consumer, Producer, Prosumer, Aggregator, DSO, Supplier, TELCO
4	Measuring de-facto transferred energy or energy service. This is a TEP real-time activity supported by NORM measurement features during the execution period (e.g. 1 minute)	Consumer, Producer, Prosumer, Aggregator, DSO, Supplier, TELCO
5	Readout and Integration of measured/logged data into transaction history in the system, and automatically communicating data to participants (depending on the rights established in the system for each participant, with reference to their own transactions or from the perspective of transaction monitoring). This is a TSP activity.	Consumer, Producer, Prosumer, Aggregator, DSO, Supplier, TELCO

6	Acknowledge from each participant of the qualities and quality of the performed services during TEP and the additional rewards or penalties due to difference from obligations during TAP. This is a TSP activity.	Consumer, Producer, Prosumer, Aggregator, DSO, Supplier, TELCO
7	Commercial transaction – payment of services. This is a TSP activity.	Consumer, Producer, Prosumer, Aggregator, DSO, Supplier

Table 2 – UC1 Storyline description

The context of this scenario refers to the application of a new concept called "transactive energy" [8], [9] which starts from the fundamental basis that all network problems are resolved through dynamic, transparent contractual transactions, not through regulations (regulations should also apply, but their role will decrease in the transactive energy framework, being transformed from interaction-driving entities to policy compliance safeguards).

3.1.2.2 Goal(s)

The primary objective of UC1 is to work in the direction of shifting the energy related services to a more transactive oriented paradigm. In this paradigm, energy services, like selling or buying, will be the result of instantaneous exchange of messages (requests/replies) between the involved parties (Consumer, Producer, Prosumer, Aggregator, DSO, Supplier). Through this dynamic process, the involved parties may come into an agreement for selling/buying energy, represented by a smart-contract. With this particular UC, we are actually building the infrastructure for the real-time controlling of the actual energy flows within the smart grid. We may picture this as something similar to the control plane of data networks that dictates the way data are handled and routed throughout the network. Similarly, our UC will introduce transactional interactions among the actors of the smart grid, especially, between energy consumers/prosumers and energy providers, that will allow them to alter the flow of energy on demand and in real time.

Another core objective of UC 1 is to validate a decentralized, trusted lock-in free Plug & Play vision in metering devices, improving already developed real time SMs (NORM) in a novel and scalable xMEC architecture exploiting 5G communication. In so doing metering functions and data will be implemented overcoming utilities lock-in and guaranteeing an automatic communication network auto-configuration, secure communication and multi-tenancy under geographically unbound mobility scenarios.

The neighbourhood energy and energy services scenario is a need to improve energy efficiency (by increasing local self consumption) and resilience (the neighbourhood is seen as a microgrid able to adapt and survive, even as stand-alone entity, in case of main system problems). However, in order to be operational, the energy neighbourhood ecosystem needs technical and commercial support to be able to work independently or to be low-dependant to the main grid. As technical needs, such as energy balance in the microgrid can be approached within the transactive energy paradigm, a complete energy and energy services environment is needed for each microgrid, with higher dynamics than in the main power system, due to more volatility within a small system (high numbers, high mediation do not apply, stochastic energy production and low inertia are also more difficult to be addressed in small systems). The use-case is providing such local highly secure, high speed / low granularity transaction architecture, in order to provide the appropriate platforms for managing neighbourhood/microgrid environments.

3.1.2.3 Actors

Actor	Role in the UC1
DSO	The actor in charge of connecting SMs and controlling smart grid infrastructure.
Energy Supplier/ Retailer	The company which sells the energy to the customers
TELCO	Provider of telecommunication services
Consumer / Prosumer	The central actor, as being the empowered citizen connected to the power network and having consumption and production + storage resources
Aggregator	A special energy service company (ESCO) which aggregates resources and offer aggregated services to other actors, e.g. to DSO
Producer	The empowered entity (actor/company) connected to the power network and having energy production only

Table 3 – UC1 Actors

3.1.2.4 Preconditions

- Real time measurements are available from NORMs, reporting rate of one second is desirable
- NORM must be able to use 5G network, in order to allow high throughput, low latency communication between the neighborhood / microgrid actors.
- NORM must be able to include advanced cryptographic features to support secure communication and blockchain mechanisms
- Measurement at the MV/LV injection point need to be monitored for being able to increase microgrid self-consumption and possible resilience
- The neighborhood / microgrid has various distributed energy and energy storage resources which can balance an increasing part of the local consumption (microgrid self-sufficiency is increasing in time)

3.1.2.5 Post-conditions

KPIs to be demonstrated:

1. Multi-micro transactions must be possible in peer-to-peer fashion, supported by automated NORM-based blockchain mechanism. Transactions will be mostly related to neighbourhood (local) energy networks
2. The transaction periods (TPs) should go down to small commercial intervals, from today 1 hour to 15 minutes to one minute (60 seconds) based transactions enabled by 5G connectivity; the framework will accept also formats for sub-minute TPs (e.g. TP = 10, 15 or 30 seconds), but these will not be tested in the real UC, as even the one-minute TP is a challenging goal.
3. Transactions should be proven on both energy and balancing (ancillary) services inside the microgrid.

4. Redundancy within the micro-cloud communication should be also proven. In this respect, re-routing and taking redundant data in case of communication segments failure should be also considered.

3.1.3 Requirement definition

In Annex 0 the requirements list is presented with a short description of each one; for the Use Case 1 Smart metering, transmitting real-time information towards the customer is the target: in this case above all the parameters foreseen the Massive Machine Type Communication (mMTC) plays an import role. It is possible to summarise in the following the requirements from 5G solutions taking into account the indicators described in the Methodology (§3.2.1). It is also fundamental to underline the importance of the new architectural features available in the 5G context. They are enabling new capabilities which are mandatory to realise the new expected services in particular providing an adequate experience when the opportunity described in the use case will be introduced.

5G Traffic Requirement	UC 1
User Density	High
User Data Rate	Medium
Mobility	Static
Infrastructure	High (*)
Traffic Type	Period / Event driven
Latency	Low
Reliability	High
Availability	High
eMBB	-
uMTC (URLLC)	X
mMTC	X

Table 4 – UC 1 5G Traffic Requirements

KPI ranges for the Use Case 1 are the following:

No	Description	Low	Medium	High
1	Device density (dev/km^2)			≥ 10.000
2	Mobility	< 3 (pedestrian)		
3	Infrastructure			Big number of small cells (>10)
4	Traffic type	Burst	Periodic	
5	User Data Rate (Mbps)		50 ÷ 100	
6	Latency (ms)	1 ÷ 10		
7	Reliability			> 99 %
8	Availability			> 99 %

Table 5 – 5G KPI for UC 1

3.2 UC2: Enabling aerial Predictive Maintenance for utility infrastructure

3.2.1 Scenario Aerial Predictive Maintenance overview

Implementing a regular predictive-maintenance program is challenging, especially for some non-homogenous environments where the areas to be survey and the quantity of checkpoint to verify are extensive. In the case of the gas plant used in this UC, Engie conducts monthly walk-on inspections hiring a thermographer for thermal infrared inspections over the heaters of the plant, semi-annual walk-on visual inspections of each component and every harvest time inspections at the surroundings to be sure that ground movements hasn't affected the underground gas pipes, without losing the communication with the farmer to raise an alert whenever a colour change is detected on the undergrowth, meaning a underground pipe gas leaking is near. Areal predictive-maintenance is meant to replace the most of human walk-on inspections, increasing the frequency of the inspections, reducing the time for detection, saving costs to the maintenance company and last but not less, maximizing the operation time, as having more and frequent information rebound in a better planning for interventions.

Generalizing the last paragraph, the Aerial Predictive Maintenance of distributed generation plants, energy transmission and distribution networks, like electricity cables and isolators, and gas/LNG tanks, pumps and pipelines, is an activity of utmost importance in achieving highest power network reliability. This UC targets especially TSOs/DSOs/Generation Plant O&M Service providers owning and operating the aforementioned infrastructures. In UC2, we propose to employ semi-autonomous swarms of drones taking multiple surveys from different views/cameras for executing complex, high-bandwidth demanding, computationally-heavy and time-critical applications.

The realization of UC2 is submitted to a series of very stringent requirements arising from the highly critical field of application and that span from the operational constraints, the communication capabilities, and the mission-specific objectives that are resumes in the following:

- **Operational requirements**, such as the capability to define a precise flight plan for each drone composing the swarm, to guarantee optimal coverage with using minimum resources, taking also into account the flight capability of each UAV/drone and their remaining battery, to define in real time specific objects to be detected and supervised (e.g., electrical lines, pipes, tanks, blades, and towers) real-time video analysis for inspection
- **Communication requirements**, such as to guarantee a high-bandwidth, low-latency, reliable communications, possibly exploiting multi-RAT capabilities (e.g., 5G NR, LTE or satellite links) for controlling the drones' flight, uploading captured video, and exchanging information.
- **Mission requirements**, since dealing with critical infrastructure protection and maintenance, UC2 execution must be secured from outside physical and cyber-attacks, privacy preserving and resilient to the possible operational failures.

The solution described in this UC shows the need to support: 1) xMBB communications for streaming data (in particular, video feeds) from the drones both towards the locally deployed mobile edge processing nodes (xMECs) that perform the video analysis, and towards the utility control centre; and 2) uRRLC communications to enable real time control of the flight of drones via the feedback from the image analysis results performed at the edge.

Moreover, for operational reasons, the time to deploy the specific service (i.e., the objective of the detection) needs to be in the order of minutes with the appropriate level of security. The envisioned solution proposes to use a *plug & play* system by deploying the automated flight control and the image analyser module as a group of VNF over the closest available xMEC.

3.2.1.1 Current situation

The market for drones performing inspection and protection routines in Energy Sites is gaining traction in the last few years. As of today, different types of data could be collected (and eventually transmitted) by drones, including HD Video (H264 or HEVC streams), various sensors, and localization data (i.e., GPS, GLONASS, Galileo, or other global positioning systems). Nevertheless, several technical limitations hinder the full operational capabilities of drones in such type of missions. Among others we can list the following:

- For COTS drones, most of the time the flying control is performed over a direct RF link between the drone and the controller (usually operating at 2.4 and 5.8 GHz frequencies). Transmitters have limited range due to the emission limits and the frequencies employed.
- For larger purpose-built drones, the main problem is cost and engineering, that makes them affordable only to larger enterprises for very high-priority tasks.
- As of today, there is no way to automatize the mission, and manual control of drones is required.
- In case of camera adaptation to stream, the image quality is often limited by the wireless link between the drone and the receiver; this turns out to be a problem in harsh environments like industrial complex and, in general, when neighbouring electromagnetic emissions are high.
- Both the pilot and the data transmission channels are generally unencrypted. This is a likely issue for operating them over critical infrastructures.
- Low range flying control due to the 2.4 GHz transmission frequency from the remote control.
- Only manual flying control through RF links or semi-automatic control over android devices.
- Flight camera recording locally on board, not live streaming.

NRG-5 vision is to mitigate such limits by fully exploiting 5G and network virtualization technologies, in order to open up the market for new applications of low cost automated drones backed by 5G capabilities in both critical and non-critical infrastructures. We plan to provide the following benefits to the execution of the UC2:

- Very low latency (<2ms) for flight control and real-time image processing via the deployment of specific VNFs as close as possible to the drone, on the edge ideally.
- Very high bandwidth (>15Mbps per camera) for the transmission of real time HD, 4K or simultaneous videos via the onboarding of multiple communication interfaces (5G NR, Satcom, and LTE) on the drone that could be aggregated or used in parallel. Multi-RAN access enable good connectivity even in case of emergency and disaster management.
- Reduced deployment and mission setup time from days to few minutes, as the specific video analysis can be deployed instantly as close as possible to the location of interest, and performed in real time to feed the piloting with useful data to command autonomous flight mode or commanded by an intuitive interface.
- Real-time registration of events in a secure and non-disputable fashion.
- Virtualized 5G architecture, able to simplify 5G coverage extension and centralized applications, fully integrated in the 5G architecture layers.

3.2.1.2 Scenario description

The scenario is based on the use of a single drone or a swarm drones connected to NRG-5 enabled xMEC to perform automatically a set of monitoring activities (currently manually operated), as follows:

- Automatic predictive maintenance: deployment in few minutes of the drone and related VNFs to flight over pre-designated areas containing critical infrastructure allowing for regular survey missions. Different type of control can be selected.

- Specific local checks/incident detection: once the solution is deployed, real-time survey of specific infrastructures or sensitive modules to be engaged in case of process alarm or intrusion detection, analyzed and showed in the service.
- Real-time security oversight: real-time high video resolution sent to the service and the control room, analyzing over predefined round circuit, to check site boundary limits.
- Work places human activity support: real-time monitoring of worksite areas through ultra-low latency video streaming.
- People research (injured or intruders): involving the research of people after major incident or potential intrusion for multi-RAN testing in case of emergency and disaster management.
- Remote third party inspection: drone flights over non-accessible structures for inspection, in order to avoid process disruption. The drone is controlled remotely taking advantage of the ultra-low latency to be able to watch the drone video and react to it.

Figure 7 describes the UC2 high-level deployment and components.

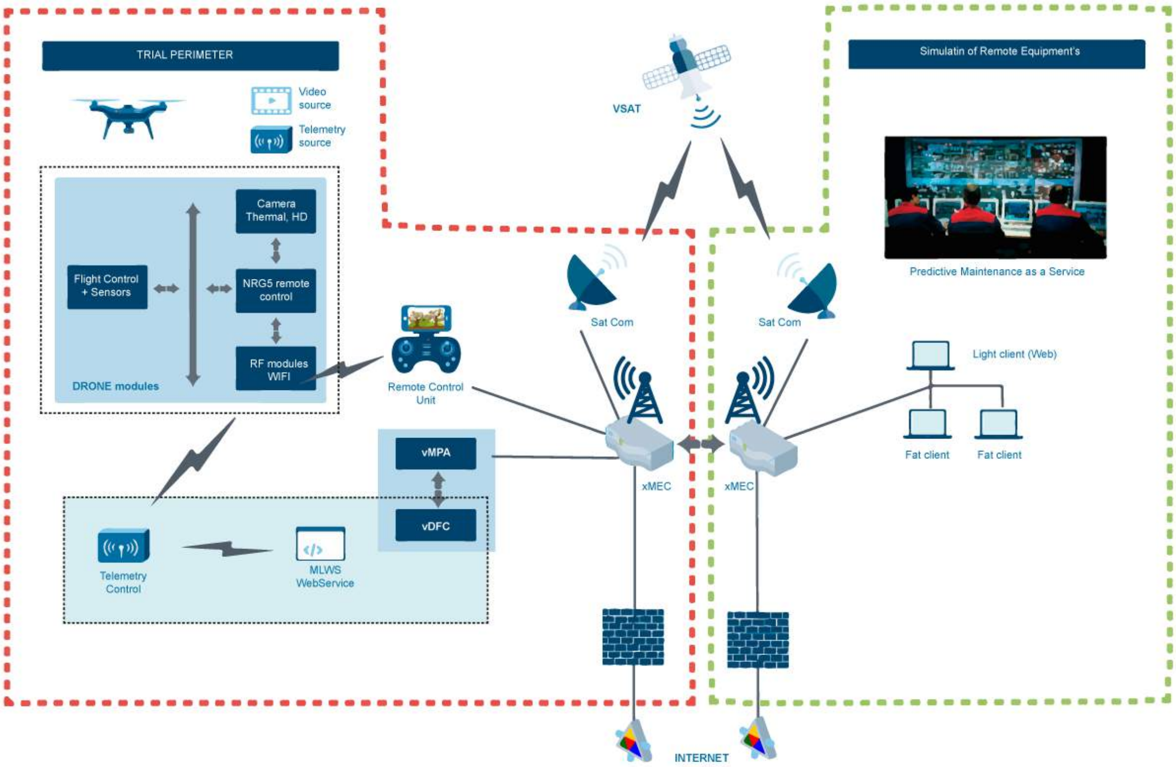

Figure 7 – UC2 high-level scenario deployment

To enable the realistic application of the above operations, the drone control configuration should be in the position of supporting three modes of flying:

- <u>Manual:</u> locally piloted by a licensed professional pilot. The flight is effectively governed by local authorities of civil aviation. Flight is currently restricted to a line of sight area (with the exception of drones limited in private areas). This mode should be used for exceptional maintenance checks.
- <u>Automatic</u>: in this case, drones flight will be engaged by the plant security system and automatically piloted to the alarm zone. Depending on the drone configuration and monitoring setup, thermal cameras could be used to identify the intruder(s) and follow their movement. This mode should be used for periodic scheduled maintenance surveys.

- Remote: in this case, flying control could be initiated remotely by a centralized DDR centre. Remote control flying could be expressed in different modalities: directly operated by a pilot, or simplified to minimal functions, like clicking on an interactive map and selecting the direction view requested with the control camera. This mode should be used whether an experience supervisor is not in place or in case is catastrophe without physical or fast access to the plant

The drone is commanded through the service deployed on the xMEC, allowing the local and remote connection and command. Based on the above modalities, the general UC scenario might also be an arbitrary combination of simpler sub-use-cases. The first sub-UC involves the maintenance activities, using the automatic mode with a pre-selected flight plan. This will include a predefined predictive maintenance checks and the specific missions (e.g. process alarm, intrusion, thickness measurement, landscape movements, etc.) boosted by 5G capabilities as the real-time video streaming and piloting enabled by ultra-low latency, real-time image processing due to the xMEC computing capabilities and direct feedback from the video analysis to the drone control.

Further, additional flight plans may be added to control the borders around each critical site. This second sub-UC deals with emergency/unscheduled activities, caused by unexpected events. Indicatively, in the case of a security alert, the use of drones operating in manual mode should allow for the incident localization, support of the active team on their activities (construction phase or repair) and participation to human search and rescue operations (e.g. people lost, injured or intruder).

On the basis of the above analysis, the principal identified UC requirements are as follows:

i) Drones, and particularly swarms of drones, should be able to be coordinated in either an automated or a remotely-operated manner. This evidently involves ultra-low latency for acquiring the proper drone driving directives, as well as accurate positioning of drones and minimal base stations hand-overs, when these are deemed necessary by the relevant infrastructure.
ii) Drones should be able to transmit their captured video streams and high-resolution photographs in real time to the actor each time responsible (see 3.2.2.3 for a tabulated overview of the actors involved in this UC).
iii) The streaming of the drones should be able (at least to some extent) to be automatically processed with the lowest possible delay, transformed into contextual intel and semantically enhanced in a semi-supervised way, the results being sent to the Security Centre of the site and even to the drones for self-reconfigure the flight plan, themselves.

To this end, NRG-5 plans to design and implement two relevant software services packaged in VNFs to be deployed in xMEC (i.e., as close as possible to the drones):

i) A virtual Drones Flight Control (vDFC) service, able to perform real time autonomous and remote control of drones.
ii) A virtual Media Processing & Analysis (vMPA) service, able to perform near real time image processing and analysis so that results of the drones' mission are managed in real time, without necessitating the explicit presence of human controllers, when possible. Additionally, the vMPA feeds the vDFC with the proper reaction to the drone based on the image analysis results.

One of the advantages of the SDR/SDN and NFV technologies is that they could eventually enable implementation of satellite networks that could be updated on-the-fly in contrast to current solutions that are relatively fixed for the entire lifetime, typically from 10 to 15 years. However, the intelligence and the computations at the satellite end are partly limited e.g. by the thermal design issues and power budgets.

It is worth highlighting that even though the above VNFs will be designed and validated the in the specific operational context of UC2, their design and implementation will be as generic as possible so that they can be applied, with limited adaptations, for other, relevant applications, possibly entirely out of the energy domain to be a *ready to go* solution.
We can summarise that is possible to demonstrate using the UC2 the Ubiquitous Accessibility, the Enhanced Performance and Ease of Monitoring and Management.

3.2.2 Actors, conditions and technologies involved

3.2.2.1 Storyline

The objective is to bring a way of supporting current activities responsible as maintenance director and security/safety officer to improve the cost efficiency of their job and reducing the risks for human. The current limitation, in terms of data streaming performance, is blocking the generalization of drone's use. 5G, through NRG-5 has the potential of decisively increasing the network performance and reliability. This will allow a transition from experimental use to official process.

The finalized storyline will be defined at later stage in the project in D 5.2. However, in the following, we detail an indicative story line for the use case.

A regular inspection of the plan, wellhead and pipeline, in a specific rural location is scheduled to take place. The infrastructures in that area are reaching their maximum lifespan and it is critical to identify any damages in an accurate way. Because of the geography of the location, its rural nature and the extensiveness of the area to be covered, drone surveillance will be able to reduce time and costs in locating and identifying problems or misbehaviours, all around the site, increasing the human safety and giving the advantage to the workers to be better prepared to face the identified issue.

The local weather conditions shall be considered before any flight. The control centre, upon receiving this information, accesses the situation and decides to modify the flying parameters, which would allow the drones to fly closer to the ground and have better visibility of targets. At the same time, the virtual Media Processing & Analysis service, decides to alter the image processing parameters, which would allow the drones to filter out the blurring effects caused by the fog.

Because of the manual changes on the flight plan, the monitoring of the power lines is in delay. To compensate this, the flying speed of the drones will need to be adjusted, as well as the processing capabilities of the virtual Media Processing & Analysis service, so as to be able to process the multimedia content in less time than initially anticipated.

The same story line could also be applicable for the case where the whole flight is manually operated from the remote control centre, in which case the inspection is not prescheduled, but decided on demand, as a response to a reported incident. In such a case, the mission can be enlarged with the additional target to find out the root cause of the incident, together with the investigation of the potential damages on the power lines.

Moreover, NRG-5 plans to enable the execution different class of missions, as outlined in the following:

Regular predictive maintenance:

- Perimeter control for the main plant: control the state of access points of fences and perimeter protection – linear monitoring.

- Perimeter control of the wellheads: control the state of access point of fences and perimeter protection, engage a circle flight around the wellheads.
- Pipeline ground floor areas control: linear monitoring of buried pipe lines, monitoring of the surface of the ground, verification of work in progress or vegetation growth.
- Visual check of the wellhead industrial structures: visual detailed view of the wellhead infrastructure, more precisely check of specific points.
- Visual check of the plant industrial structures (zone per zone, compressors, regeneration (boilers), dehydration): visual detailed view of selected infrastructure, more precisely check of specific points.

Events intervention:

- Gas detection alarm or Intrusion or process alarm shall be confirmed by the duty officer. Duty officer could engage, on the drone application, a flight to take videos of targeted zone with a predefined flight plan.

Flight plan design:

For each scenario, the flight plan will be designed accordingly to the 3D environment. Drone(s) shall follow the flight plan according to the following instructions:

- Follow the target line including the height from the ground 3D.
- Avoid tree area.
- Avoid building area and industrial structures.
- Avoid public areas.
- Select the camera azimuth providing the best view to be analyzed and avoiding public zones.
- For detailed views, plan to rotate around the structure with vertical displacements to view all surfaces.

Video live time storage and image analysis: Drone video download and drone control are supported by a local 5G base station.

It's expected to have a 5G xMEC close to the location of interest for the deployment of the two services:

- Video storage and analysis (virtual Media Processing & Analysis (vMPA)).
- Drone remote control (virtual Drones Flight Control (vDFC)).

Figure 8 shows an example of an industrial structure visual control.

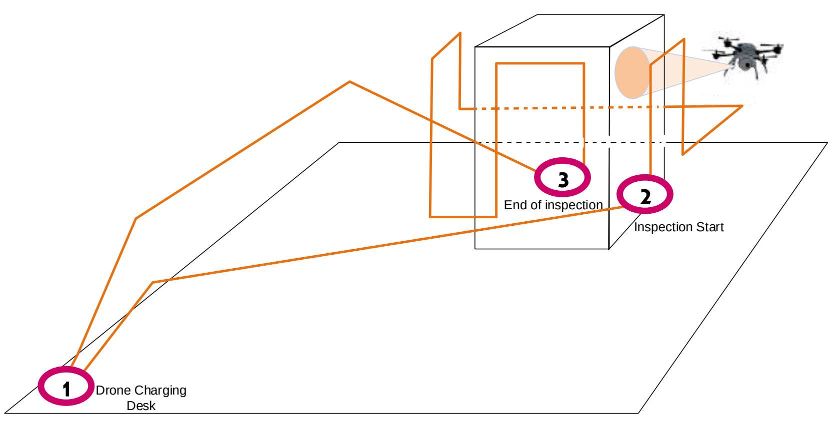

Figure 8 – Industrial structure visual control

3.2.2.2 Goal(s)

The objectives of UC2 are manifold. First of all, NRG-5 plans providing a ready to go solution for executing several maintenance and inspection missions in energy infrastructures, by employing 5G-enabled drones backed by local xMEC deployments. UC2 setup is based on several virtualized services to be deployed on demand to handle the automatic/remote piloting of drones together with video analysis services. The envisioned solution aims at reducing drastically the deployment and setup time of such complex operations to minutes, increasing the safety aspect for human (work in explosive/toxic atmosphere, work at height, etc…), and generating time and cost savings for specialist contractors executing fault finding in such critical infrastructures.

3.2.2.3 Actors

Actor	Role in UC2
Maintenance responsible	They are in charge of predictive and corrective maintenance
Security/Safety manager	They are in charge of the site security, intrusion, mustering and evacuations
Third party inspectors	They are in charge of the site validation, shall deliver the authorization to operate
Drone pilots	They are responsible for flying the drones in the case of manual or remote drone flight configurations
TELCO	Provider of telecommunication services

Table 6 – UC2 Actors

3.2.2.4 Preconditions

- Having the permissions and regulatory validations to flight in the area and for the drone pilot.
- The maintenance responsible and/or security / safety manager has the maps of the site in order to plan the flight in advance.
- The maintenance responsible and/or security / safety manager has enough knowledge of the situation and localization of the critical plant components.
- The security / safety manager has a valid account to
- Drone is ready to fly with full charged batteries and *clear to take off* status.

3.2.2.5 Postconditions

The objective is to compare at the end, the exact impact of using this new technology: **in the Use Case 2** drones could be used to setup video streaming to remotely control distributed infrastructures: **Video control,** correlated to the enhanced Mobile Ultra Broadband **(eMBB),** plays an import role.

KPIs e.g:

- Time saving: Drones are easily deployed in few minutes without drastic safety procedures which could be applied to workers and security people for safety reasons. 5G allow to deploy the full service in a few minutes.
- Video continuity and quality: Real-time video from the drone has to have continuity and has not loss of signal.
- Seamless drone control from the VNF on the edge.
- Improved performance, as reported in Table 7. :

UC2 requirements			
Item	**Actual in use**	**Future requests**	**5G objectives**
Data rate	10 to 30 Mb/s (5Ghz Wifi-WiMax, public 4G)	50 to 60 Mb/s 15Mb/s for each camera streaming HD video	10 Gb/s shared data rate; Guaranteed >50 Mb/s per user
Latency of radio access link	2 seconds via Satcom 50 to 200 ms local 3G, 5Ghz Wifi-WiMax	20 ms	1 ms
Registration time	2 seconds	2 seconds	less than 1 second
Handover	20 ms	20 ms	Handover guaranteed 5ms with preselection
Service deployment time	Hours or days	30 minutes	90 minutes

Table 7 – UC2 requirements

3.2.3 Requirement definition

In Annex the requirements list is presented with a short description of each one. UC2 specific requirements are requested to monitor and control in an effective way and to maximise the overall equipment effectiveness in the different industrial context: in this case the parameters foreseen not only on the Massive Machine Type Communication (mMTC) but also in the Enhance Mobile Broadband (eMBB) play an import role.

It is possible to summarise in the following the requirements from 5G solutions, taking into account the indicators described in Section 3.2.1

5G Traffic Requirement	UC 2
User Density	Low
User Data Rate	High
Mobility	High
Infrastructure	Low
Traffic Type	Cont & burst
Latency	Low
Reliability	High
Availability	High
eMBB	X
uMTC (URLLC)	X
mMTC	-

Table 8 – UC 2 5G Traffic Requirements

KPIs ranges for the Use Case 2 are shown in the following table:

No	Description	Low	Medium	High
1	Device density (dev/km^2)	< 100		
2	Mobility (Km/h)			> 50 (fast moving vehicles)
3	Infrastructure	Macro cell coverage		
4	Traffic type			Continuous Burst

5	User Data Rate (Mb/s)		100 ÷ 1000 (≥ 1000 very high)
6	Latency (ms)	1 ÷ 10 (alarms)	> 50 (video)
7	Reliability		> 99,9 %
8	Availability		> 99,9 %

Table 9 – 5G KPI for UC2

3.3 UC3: Enabling resilience and high availability via Dispatchable Demand Response

3.3.1 Scenario Optimized Management of Aggregated Flexibility via Demand Response overview

The purpose of this use case is to illustrate the fundamental role to be played by 5G networks in smart grid as an enabler for aggregator and system operators (TSOs and DSOs) of new slicing application tailored for optimize network operation and manage load flexibility. For this reason the use case is naturally framed in two main scenarios: The first regarding the aggregator while the second for the DSO.

Using 5G network slicing for energy services ensure that network resources provided by carriers can be converted to mutually isolated network slices, to meet the differentiated network requirements of various services on the smart grid. Network slicing can also be used to collect data on electricity usage, for distributed power, for pile control at electric vehicle charging stations, for precise load control, and for other crucial services a smart power grid should offer.

The first scenario describes the “aggregated flexibility” via Demand Response and shows how aggregators/prosumers play an active role in energy flexibility management once they rely on the slicing functionality offered from 5G infrastructure. These actors being equipped with smart facilities for decentralized energy generation, local (stationary and movable) energy storage and flexible load management will exploit the network resources in a new way thanks to 5G potential.

These new services re-shaped on the light of 5G will allow

- Aggregated portfolio management and flexibility prediction by trading off individual flexibility prosumer-owned resources (including flexible loads, storage and EVs)
- Prosumer-level Flexibility Optimized Management through trading off individual comfort/wellness against flexible real time tariffs deployed in near real time via next generation smart meters
- Automated near Real time Demand Response for DER optimal flexibility provisioning to power network operators (TSOs/DSOs)
- EV fleets optimal recharging for Demand Response management to DSO

These new services involve individual flexibility owner resources that thanks to the NORM interfaces became IoT devices. Demand response program, coupled with smart data engineering and analytics that involve a great number of these IoT objects’ exploit the 5G IoT UC [10], with the availability of a connectivity technology which is at once truly ubiquitous, reliable, scalable, and cost-efficient significantly upgrades the insights available to utilities, enabling more operationally valuable DR and additional value-add services to the end customer.

As regards power network operators it is well known that TSOs and DSOs are facing increased network stability challenges while integrate growing shares of renewables for the purpose of network management. This problem require novel real time operation approaches for the optimized management of electricity network which may ideally combine optimized management and coordination of grid-owned and non grid-owned (prosumers) assets. To deal with the above challenges the power network operators are moving forward towards the large scale yet selective deployment of near real time Phasor Measurements Units (PMU) based fine grained monitoring wide area monitoring system (WAMS). PMU in fact can selectively and optimally be deployed to provide measurement data for

- Phase synchronization

- Weather conditions or conductor temperature or tension for TSO- level Dynamic line Rating.

PMU can provide 50/60 frames per seconds which will allow a real time improved state network estimation within the order of tens of milliseconds, thus greatly contributing to improve the near real time observability of the grid.

In this scenario NRG-5 will use low cost phasors (PMUs) coupled with next generation secure virtual smart meters to provide scalable and reliable finer grained information to enable improved smart grid self-recovery via power re-routing scenario completely

The addressed 5G requirements will be massive machine-type communication (MTC) and critical machine-type (UMTC) because each PMU will be and embedded IoT device with built-in 5G native interface. The high density of metering nodes either smart meters or PMU will demand medium to high bandwidth requirements enabling observability of distribution grid for full near real time control of large pools of DER..

3.3.1.1 Current situation

The stability and resilience of the energy grid in presence of high share of Renewable Energy Sources (RES) is a well-known problem: the mass integration of RES especially in LV and MV networks can raise technical issues concerning the stability and safety of the grid operation at the distribution level, such as voltage rise, frequency imbalance, fault equipment tripping etc. These issues for the DSO are mainly due to the intermittent nature of distributed energy generation and the bi-directionality of the power flow, particularly under high penetration of RES. In addition, renewable production is much more distributed than central power plants that are based on e.g. nuclear or fossil fuel. In order to avoid black-outs and to optimize the use of renewables a real time dynamic routing of electricity flows will be needed. This routing will require new electrical equipment but also a renewed supervision and control network for electricity distribution networks. On the same time the prosumer/aggregator side is continuously experiencing an evolution on smart meter development that are are constantly evolving towards ever shorter measurement intervals leading to the requirement on the future networks to carry short data packages from thousands of users. They will reach near real time application in coming years, enabling near real time optimisations of sections of the low and medium voltage infrastructure with impacts on the communications requirements of utilities towards the customers (residential and business) particularly in urban areas where 5G will become available and can address the communication needs of smart meters if the design targets are accordingly set.

Basically the enabler of this new tendency will be accomplished through the massive deploy of Smart Meter and PMU. For this purpose, the following UC will be declined following two sub-scenario addressing respectively the following goal:

- Keep the grid stabilized in case of massive utilization of distributed energy resources leveraging storage and load (both still and movable as EV).
- Use of (PMUs) coupled with next generation secure virtual smart meters to provide scalable and reliable finer grained information to enable improved smart grid self-recovery via power re-routing scenario.

3.3.1.2 Scenario description

In the context of this UC two realistic scenarios are studied in more detail. First a proper setting during which an aggregator manages a portfolio consisting of EV, Distribute Energy Storage (DES) and DERs with the goal of minimizing imbalance in the grid due to the unpredictable renewables PV output. Secondly a fault isolation and smart grid recovery via power flow re-routing scenario. Globally this use case proposes to manage in real-time the flow of utility charge by taking into account the energy requirements of charging point, the energy production and the charge reservation.

The key ingredient to implement this energy related scenario is the power flexibility. In electricity systems, flexibility [11] can be defined as a power adjustment sustained for a given duration in order to balance supply and demand at a given moment in time. Thus, a flexibility service [12] is a multidimensional service characterized by the following four attributes: (i) its direction (up or down); (ii) its electrical composition in capacity or power and its availability defined by (iii) starting time and (iv) duration (Figure 9)

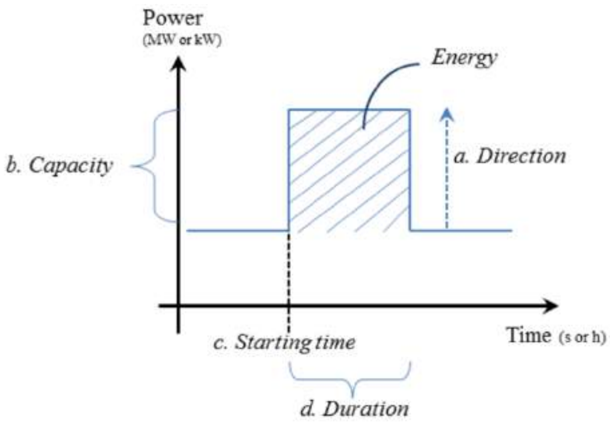

Figure 9 – Flexibility service

In order to satisfy the power network requirements the DSO can adopt a “power smoothing” strategy. Electricity storage technologies that operate on short timescales (seconds, minutes, hours) can be used to keep a more precise balance between electric supply and demand. These power quality management technologies can fill the gaps between actual electricity demand and an average, smooth demand curve that is easier for typical supply sources to follow (see chart below) [13].

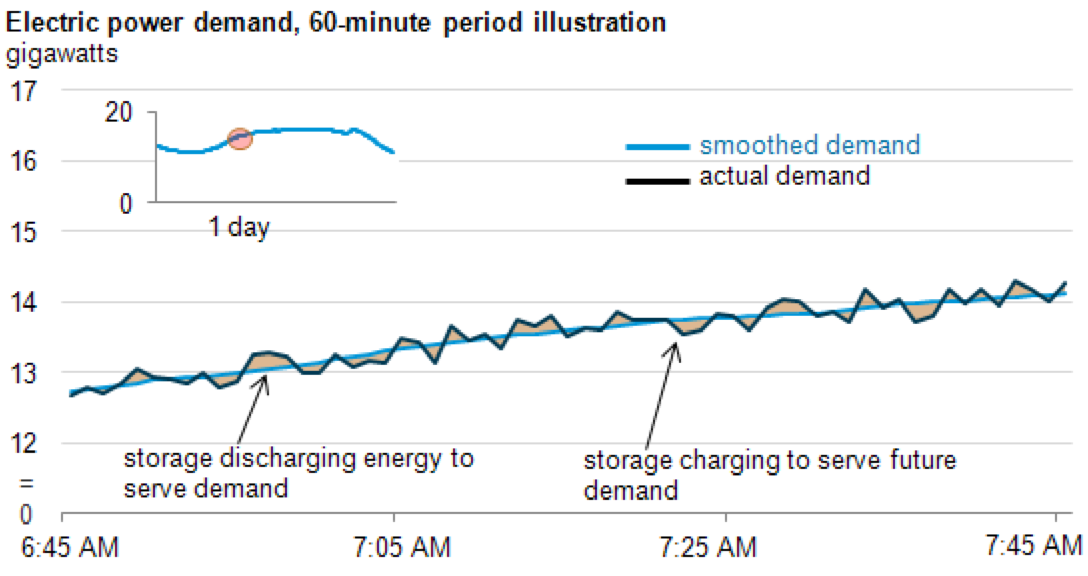

Figure 10 – Electric power demand

In this case a System Operator is facing a high RES production, so that it sends real time DR signal to the scheduler optimization, in order to avoid reverse power flow in the MV network by the means of a flexibility request in a specific amount of kW during a specific amount of time. This request is delivered to the portfolio devices. The flexibility obtained is the one resulting of the optimization plan [14] between EV batteries, RES generation [15] and storage units within the cluster of DES.

The items needed for the realization of this UC are as follows:

- **Distributed energy resources and Distributes energy storages** represented as a virtual functions that manage the underlying energy production and provides the consumption and production variation as flexibility output.
- **Electric Vehicles and Smart Chargers.** It is well known that smart chargers cannot charge all EVs simultaneously for the limitation of installation capacity of electric distribution system. For this reason, is needed a charging scheduling scheme to coordinate charging among all EVs connected to smart chargers so that the entire charging load of the EV set remains below the installation capacity while satisfying charging requests of connected EVs before their departure. The arrival, departure time, and residual battery capacity of every EV are different. In addition to avoiding overload, the charging scheme determines the charging priorities of all connected EVs so that charging fairness and the need of providing enough energy for every EV's battery before departure are both satisfied. The charging scheduling also aims to minimize the electricity bill by choosing appropriate time slots to charge during EV's stay in the parking station. Charging a high number of EVs at the same time in the same parking station could cause feeder overloads; it requests power smoothing, a management for which load feeding is properly scheduled and eventually delayed. This makes the EV charging in parking station a good candidate for DR. Scheduling of EV charging can thus be coordinated with utility's DR.

In this scenario, seven VNFs will be rolled out in order to

- provide booking of charge by optimal scheduler
- provide charging information in real time by charge point through OCPP web protocol
- provide EVs data to optimal scheduler like state of battery and geolocalization
- provide RES production to optimal scheduler
- provide DES information to optimal scheduler
- provide future weather forecasts
- receive result from the 5G NORM from DDR campaign

3.3.2 Actors, conditions and technologies involved

3.3.2.1 Storyline

NRG-5 will allow 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. In the case of electric mobility, 5G will reduce the latency of the network, in this way the charging point and EV should be monitored in real time, respecting the latencies below 5ms.

This Use Case falls under the DSO service related to keep the grid balanced and demonstrate the 5G high levels requirements. It is tailored to prevent future problems, mitigate the current problems due to the demands of the customers or recover from a fault in a way that do not trigger further grid problems. To this purpose the DSO exploits the potential of incorporating electric vehicles (EVs) in a low voltage distribution network with photovoltaic installations (PVs) batteries storages and DERs for minimizing mismatch between production and consumption of energy.

In the UC3, the DSO is interested to guarantee the grid stability, in both normal and fault conditions; at the same time the aggregator has to aggregate flexible devices and give the flexibility needed to the DSO. The owner of DER, DES, EVs and Photovoltaic (PV) arrays covers the role of a consumer and/or an energy producer. The reception by the DSO of a forecast of demand requires some special management.

Sequence of actions	Actors involved

1	Forecast request: periodically, the DSO operator consults the energy forecast service to know the forecast of PV production belonging to the microgrid energy forecast.	DSO operator, Optimal scheduler
2	Flexibility calculation: If there is a peak in the energy production it calculates the flexibility needed to minimize this mismatch. Details of the DR campaign requirements will be reported.	DSO, Optimal scheduler
3	DR campaign calculated: The optimal scheduler get the charging plan from EV and the available flexibility from DER, DES and calculate the flexibility needed from DSO. It then creates the DDR signal.	Optimal scheduler, 5G-NORM / Prosumer
4	DR campaign reception: DER, EV and DES Receive DR campaign and shift or move their charging plan in accordance with this flexibility request. Each of this device transform information from optimal scheduler in command for devices	DER, DES, EV Fleet owner
5	DR results: The optimal scheduler receives from the 5G NORM results from DDR campaign. The DR campaign result will be reported	5G-NORM, Optimal scheduler

Table 10 – UC 3 Storyline description

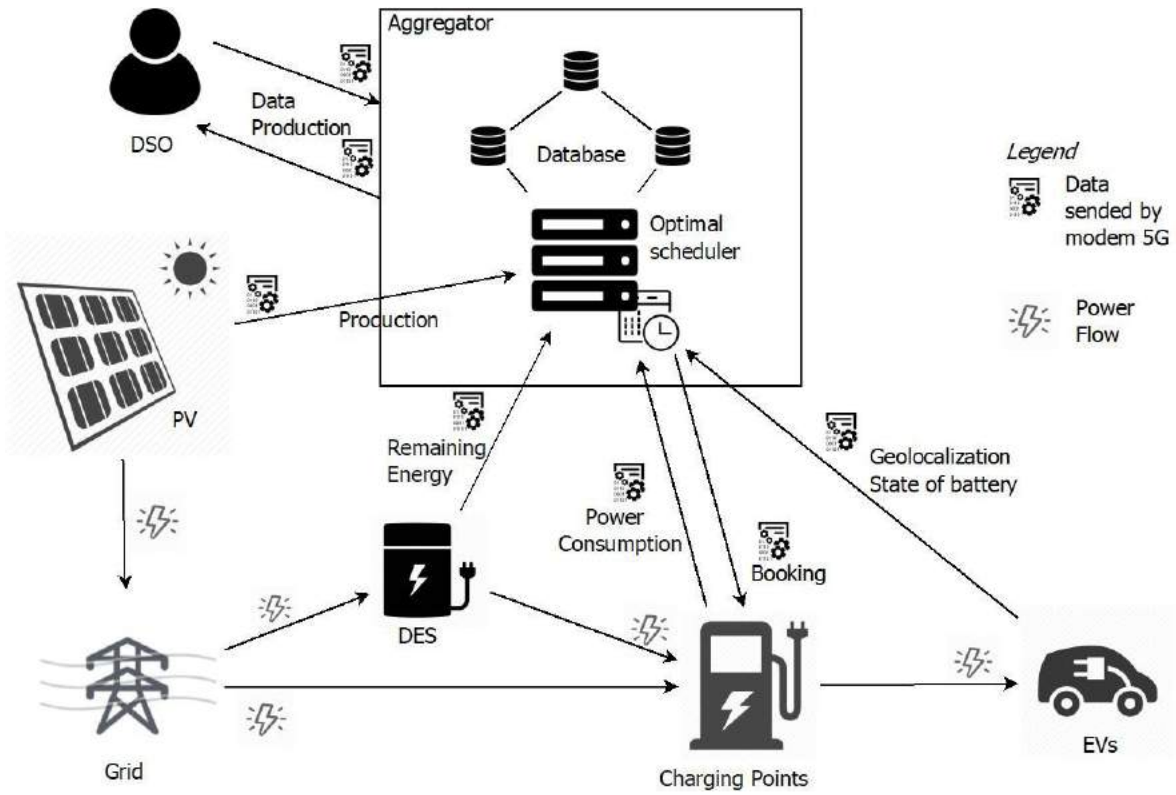

Figure 11 – UC 3 overview: NRG-5 technologies enabling dispatchable demand response

The final user of the service is the EV owner requesting access to a charging point. A booking message will be sent to the optimal scheduler that makes a chronology of charge booking, according to the weather forecast and the estimation of the PV production. Depending on the input received, the optimal scheduler will define the energy flow and will be able to communicate with several different devices through dedicated API. Besides, it will be connected to multiple databases in order to guarantee more security and atomicity of the internal network.

3.3.2.2 Goal(s)

The stability and resilience of the power network in the presence of high share of RES depends greatly on fast response. Given that most of the time storage is not available on-site, ultralow (below 5ms) response from the energy operation centre is of vital importance. The enablement of large scale DDR requires extreme (for today’s standards) communication requirements, as metering and associated computational process should be performed at very high frequencies. Moreover, the charging point and EV should be monitored in real time, respecting the latencies previously indicated.

3.3.2.3 Actors

Actor	Role in the UC3
Optimal Scheduler Manager	Plug-in EV, PV arrays and DES are source of power flexibility and each of them have to be managed to provide an optimization for producing the flexibility requested by the DSO. The optimal scheduler manager is in charge of management of the DR campaigns and overall operation for avoiding fault and production and generation mismatch.
Electric Vehicle Charging Station User (EVSE)	The EV used over the project will be the Renault ZOE, a Battery Electric Vehicle. It is allowed to manage charging for the EV in home as well as roaming location. The user of electric vehicle is the person that plugs the car in the charging station and decide the plan for the charging.
Distributed Energy Generation/ Injection User/Prosumer	DER, small-scale power generation sources located close to where electricity is used, provides an alternative to or an enhancement of the traditional electric power grid. It allows managing of electrical power generating/injection system to be used within the end user premise environment such as the home or the building. The user that owns the DER and the storage system is the “DER user prosumer”.
DSO Distribution System Operator	The actor in charge of quantify the flexibility request to be provided consequent a high production of RES. This flexibility have to be provided after an optimization problem involving EV, DES and RES.
5G-NORM	Smart Meter gathers data from EV, DES and RES and after a pre analysis it will provide to the optimal scheduler. Behind the 5G-NORM there is always a prosumer or a consumer.
Distributed Energy Storage User	A DES system is a packaged solution that stores energy for use at a later time. The system’s two main components are the DC-charged batteries and bi-directional inverter. The owner of DES can be both a prosumer if make available storage and a consumer if discharge the batteries.

Table 11 – UC 3 Actors

3.3.2.4 Preconditions

To develop the charging stations the following conditions are need:

- the ability to exchange data with SCADA;
- for the identification of user is necessary the RFID READER or a touch display;
- a microcontroller inside connect to the modem 5G and with RFID.

The central system will be characterised by 3 parts as follows:

- the first part will be able to storage the data received;
- the second part will be able to calculate optimal algorithms and other computational functions;
- the last part will be able to directly communicate in the network via 5G by using the OCPP protocol for the charging point and TCP/IP with the devices inside the EVs.

The EVs should be provided with a device connected to the modem 5G, and both of them must be able to communicate.

3.3.2.5 Postconditions

Although additional post conditions will come out according to statistic and error data, the main objectives to be achieved are as follows:

- the system have to guarantee the EV's charging, also in the "critical case";
- energy saving;
- managing data in real time;
- security rules inside the network.

3.3.3 Requirement definition

In Annex 0 the requirements list is presented with a short description of each one; for the Use Case 3 Enabling resilience and high availability via Dispatchable Demand Response is the target, it introduces new strategies for the Smart grid correlated to the Ultra Reliable Low Latency Communication (URLLC/uMTC).

The low latency of 5G will be fundamental as requirement for automated real-time grid switching to cope with all the applications based on reliable grids. It is possible to summarise in the following the requirements from 5G solutions taking into account the indicators described in the Methodology (§3.2.1): even more than in the other use cases, it is fundamental to underline the importance of the new architectural features available in the 5G context because are enabling new capabilities mandatory to realise the new expected services, in particular to provide an adequate experience when the opportunity described in the use case will be introduced. Also in this case, the traffic requirements will be different according to: i) data storage received; ii) calculate optimal algorithms and finally iii) charging point as reported in Table 12.

5G Traffic Requirement	UC 3.i	UC 3.ii	UC 3.iii
User Density	Medium	Medium	High
User Data Rate	Low	Medium	Medium
Mobility	High	N.A.	N.A.

Infrastructure	Medium	Medium	Medium
Traffic Type	Event driven	Continuous	Continuous
Latency	High - OBD	Low - Optimal scheduler	Low - Charging point
Reliability	High	High	High
Availability	High	High	-
eMBB	-	-	-
uMTC (URLLC)	-	X	-
mMTC	X	-	-

Table 12 - UC 3 - 5G Traffic Requirements

KPI ranges for the Use Case 3 are the following:

No	Description	Low	Medium	High
1	Device density (dev/km^2)		1000 ÷ 10.000	
2	Mobility (Km/h)			> 50 (fast moving vehicles)
3	Infrastructure	Macro cell coverage	Small amount of small cells (<10)	)
4	Traffic type	Continuous	Event driven	
5	User Data Rate (Mbps)	< 50	50 ÷ 100	
6	Latency (ms)	1 ÷ 10	10 ÷ 50	> 50
7	Reliability			> 99 %
8	Availability			> 99 %

Table 13 – 5G KPI for UC 3

4 5G Network requirements and KPIs

4.1 5G requirements

The demand for mobile broadband will continue to increase in the next years. The fifth generation of mobile technology (5G) will enable new applications, causing a lot of challenges to the network. The technological evolution of the 5G will be a profound transformation of the fixed and mobile network.

Compared to previous generations of wireless communication technologies, including the 4G, the driver for developing the 5G is to increase mobile broadband capacity to provide specific functionality not only for consumers, but also for Industries and society in general, and thus explode the potential of the Internet of Things (IoT). 5G will put requirements not only in radio access components, but also in core networks and in service platforms to handle a variety of scenarios (uses cases) with very different specificities: some of these are aimed at providing low latency in the order of few milliseconds and high reliability compared to fixed lines. To achieve this, the goal for 5G networks will be to improve the flexibility in the architecture.

The 5G will not be a universal technology, but a polymorphic technology, capable of adapting to a lot of uses to the most demanding requirements. In particular, 5G networks are not characterized by fixed radio parameters and spectrum blocks; in the case of 5G it will be possible to take into account any spectrum and any access technology in order to deliver the services. Taking into account the new mobile access paradigm: massive capacity, huge numbers of connections, and ultra-fast network speeds using the device-to-device communications, dynamic spectrum refarming and radio access infrastructure sharing. In this way, the 5G intends to become a "facilitator" of a variety of services required by a wide variety of heterogeneous industrial sectors, such as utilities, healthcare, the media, industry and transport.

In addition, service providers will have to be able to adapt their networks to demand (“network as a service”), even in real time.

In the same way also the “Energy” context is changing: a “cross-industry“ transformation is happening based on the evolution of the wireless concept: 5G connectivity will provide new functionality and will allow new ways of defining performance monitoring. Also the assurance of these elements is changing, as well as the quality of service and how to evaluate the customer experience of the final users/prosumers.

When we consider the context of the “Energy”, in particular Smart Grid communication networks, it is fundamental to take into account that these networks consist of multiple domains. Each of these domains serves a specific area e.g. a distribution network or location like a secondary substation (transformation between medium and low voltage).

However, another way of understanding 5G exists today and it involves a next-generation radio access technology. This 5G conception defines a new generation, with specific targets for data rates and latency being identified, and in which against such criteria, new radio interfaces can be assessed.

Both of these approaches are important for the progression of the industry and society in general, but they are distinct sets of requirements associated with specific new services. However, the two views described are regularly taken as a single set and hence requirements from both the “hyper-connected” view and the “next-generation radio access technology” view are grouped together. The communication network domains in the NRG-5 context plays a significant role are the access networks and it is important to consider the stringent requirements above all in terms of real-time and reliability because of the overall communication network required in parallel to the power infrastructure to establish the Smart Grid. Using the new approach several of these domains might be realized as virtual instances on the same physical infrastructure, on the same 5G network infrastructure.

4.1.1 Current situation

As each generation of mobile technology has been motivated by the need to meet a requirement identified between that technology and its predecessor, the same situation is found between 4G and 5G.

UMTS was intended to be a universal system to support a wide range of services; anyway its evolution path has already shown how conventional system architectures do not provide the flexibility required by many of the incoming Digital Society uses cases. A more recent case, the transition from 3.5G to 4G services, has offered users access to considerably faster data speeds and lower latency rates, and therefore the way that people access and use the internet on mobile devices continues to change.

Currently, across the world operators are typically reporting that 4G customers consume around double the monthly amount of data of non-4G users, and in some cases three times as much. An increased level of video streaming by customers on 4G networks is often cited by operators as a major contributing factor to this.

In the same line, the Internet of Things (IoT) has also been discussed as a key differentiator for 4G, but in reality the challenge of providing low power, low frequency networks to meet the demand for widespread M2M deployment is not specific to 4G. In the 4G architecture, Control Plane and User Plane are pretty combined limiting the scalability and flexibility of the network. This principle will be broken in the 5G architecture with significant advantages.

Technologies of cloud computing, Software Defined Networking (SDN) and Network Function Virtualization (NFV) are key enablers for the transformation and evolution of traditional Telecom Networks.

Cloud computing provides a different way of implementing service provisioning, as well as elasticity, flexibility and agility. SDN separates control planes from forwarding planes and introduces SW programmability in the Network, enabling full automation in provisioning of services. NFV moves Network functions from vendor-specific HW appliances to SW applications running on top and allowing a more efficient use of HW resources, through dynamic and rapid allocation of resources to different workloads, leveraging on virtualization, and promising significant TCO savings by achieving scale economies. Above Technologies also put the basis for future evolutions of the Network, such as Mobile Edge Computing and Dedicated Core Network (DECOR) or 5G Network slicing.

Customer requests a proposal to transform the Network into a Telco Cloud more suitable to support the evolution of the new services

4.1.2 List of Requirements

According to the introduced aspects 5G, compared to previous technologies, has the ambition to cover extremely heterogeneous service classes as follows:

- enhanced Mobile Ultra Broadband (eMBB), optimized for Gbps video transmission and throughput (enabling, for example, Augmented / Virtual reality scenarios);

- Massive Machine Type Communication (mMTC) enabling to connect a massive number of devices through the ability to scale down in data rates, power and mobility to provide extremely lean and low-cost solutions (e.g. Smart Cities and enhanced Metering);
- Ultra Reliable and Low latency Communication (URLLC/uMTC) communication and very low latency, typical of many of the most demanding industry and vertical demand markets. This category includes new services that will transform industries with ultra-reliable and low-latency requirements, such as remote control of critical infrastructure (including Energy Management), and automated vehicles.

Standards are evolving and involve several international bodies

- 3GPP defines the overall system, producing the specifications of Radio Access and Core Network; first version of 5G standard R15 will be completed in the middle of 2018; full version of 5G standard R16 will be completed at the end of 2019. After the meeting held in March, 3GPP member agreed to accelerate that 5G standard process planning the “Non-standalone New Radio (NR)” issuing by the end of 2017.
- ITU defines the technical requirements and identifies the spectrum to be used for the new system; it will call for candidate proposal for 5G in the 2nd half of 2017 and the final approval of 5G standards will be in 2020.
- ETSI NFV ISG develops solutions for virtualization; from international innovation projects (eg H2020 5GPPP) and the activities of standardization bodies (eg 3GPP, ITU-T, GSMA, ETSI etc.) it emerges that SDN and NFV will be two fundamental components of the 5G core technologies; the first will enable software decoupling from hardware systems and the second will work on network capabilities. In this way the 5G New Generation Core will be based on telecommunication cloud solution, with proven NFV technologies, network slicing and network function virtualized infrastructure (NFVI) platform.

Figure 12 – standardization roadmap

In **2020, 5G** will be launched initially in areas where higher performance is required, e.g., dense urban area. **Beyond 2020**, deployment areas for 5G are gradually expanded while introducing additional technologies and frequency bands (= **5Ge**).

Today the network solutions are based on a relatively static and closed architecture; on the contrary these features, decoupling the two levels of hardware and software, will be the pillars to offer a new networking flexibility. Besides the new solution will also help move network resources to the most peripheral areas of the network (Edge Computing), and closer to users, lowering the latency values as required by some digital services, even within the energy industry.

The flexibility offered by SDN and NFV will be used to develop virtual architectures, or "network slice" consisting of a set of virtualized resources that share the same physical infrastructure:

A first element of innovation in the new 5G core network architecture is the separation of user mobility **Control Plane (CP)** from **User Plane (UP)**. Splitting between CP and UP will increase the flexibility and will allow to allocate network capabilities that handle the User Plane (payload) more effectively, depending on the type of service they have to transport; for example, for services where very low latency is required, the User Plane Functions (UPFs) and service platforms will be deployed as close as possible to the devices to be controlled.

5G networks will deliver a step change of ultrafast, low latency (i.e. quicker reaction times), reliable, mobile connectivity, that is able to support ever larger data requirements, as well as wide-ranging new applications. In particular, as we introduced, 5G networks will be dynamically tailored to meet the needs of the individuals or services that will use them at any moment in time, giving users all the communications capability they need.

Another 5G pillar - needed to cope with some use case requesting ultra-bandwidth – is the availability of new multiple bands of spectrum. 5G needs radio spectrum within three key frequency ranges to deliver widespread coverage and support all use cases.

The three ranges are:

- Sub-1 GHz,
- 1-6 GHz and
- above 6 GHz.

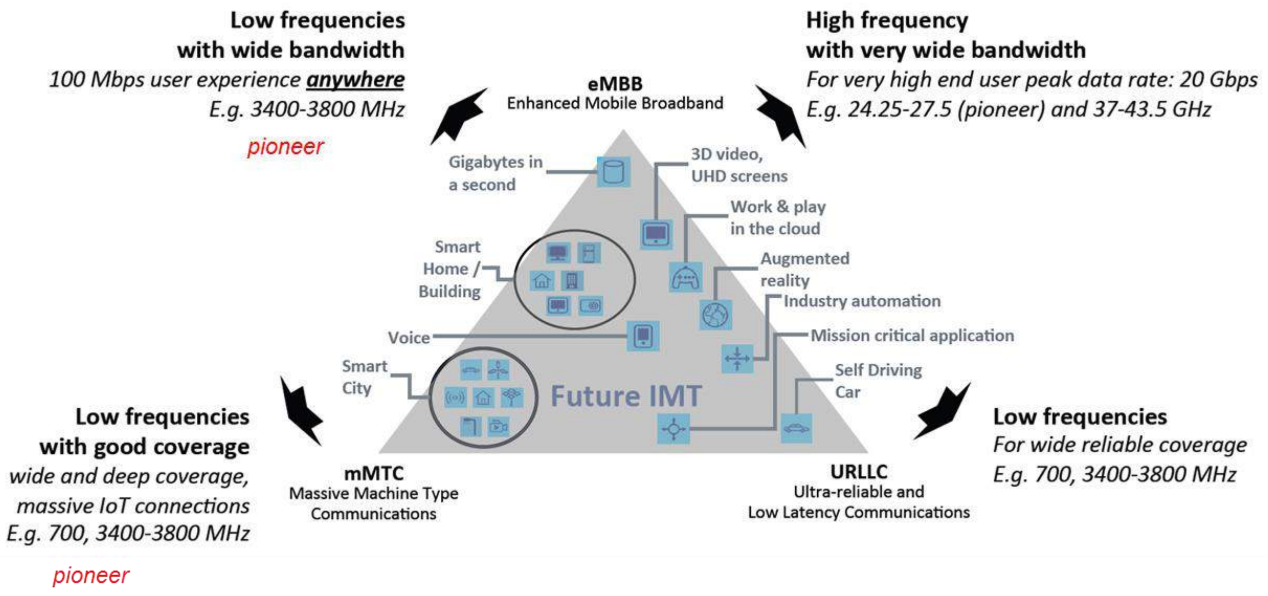

Figure 13: Mapping between use cases and radio spectrum

Devices will also have to support the new frequency bands; besides in the 5G network, devices could connect to multiple Network Slices at the same time, each of which can be optimized to offer a specific service: in fact a Network Slice is a logical network that includes a set of features combined to provide certain network features and services.

According to this general scenario we have to explore the elements that in the NRG-5 project play the fundamental role and relevance according to the specific context selected for each use case to reach many goals are:

1. operational efficiency, through automated Operations, Administration, Maintenance, and Provisioning
2. support of business transformation, through agility and automation of service chaining

In the NRG-5 project the ambition is to combine the requests coming from two different contexts (Utilities and Telco) to realise the different proposed use cases:

- **Use case 1: Smart metering:** to be considered as the straightforward evolution of current M2M for the metering segment to enrich functionalities (i.e. transmitting real-time information also towards the customer) already provided by meters used by Utilities; this use case is correlated to Massive Machine Type Communication **(mMTC);**
- **Use case 2: Video control:** drones could be used to setup video streaming to remotely control distributed infrastructures; this use case is correlated to enhance Mobile Ultra Broadband **(eMBB).**
- **Use case 3: Smart grid: production of electricity** with renewable resources introduces new distributed models, thus the contribution of prosumers becomes more and more important. This new model requests the development of new power control systems; this use case is correlated to Ultra Reliable Low Latency Communication **(URLLC/uMTC).**

The architecture from the Telco point of view has to decouple the network control and forwarding functions, enabling the network control to become directly programmable and the underlying infrastructure to be abstracted for applications and network services; virtualization and process automation technologies as foreseen in NRG-5 developing the NFV and the Orchestration will provide complete separation between the Application and Infrastructure layers, decoupling their respective lifecycles and improving the capability to reduce the time to have the foreseen solution in each scenario, as described in the use cases.

According to the requirements of the 5G services, efficiency and, above all, flexibility is required for network architecture, specifically in terms of data interoperability, scalability, trust and access. The 5G network will have to provide services (of different nature and purpose) taking into account an approach customer (in some cases "device") oriented.

4.2 KPIs

This families of Use Cases targets the Smart Energy vertical domain and the NRG-5 defined use cases covers all three groups of MTC communications and aims to examine how already defined 5G radio features could be used in Energy use cases and define NFV to support the use case requirements.

However, an analysis based solely on this grouping is not sufficient, since different use cases may have different characteristics (e.g., mobility and data traffic patterns) and hence different values for requirements (e.g., delay, reliability, user throughput etc). The extreme diversities of services, as well as the vast number of end devices that will have to be supported, yield a unprecedented set of requirements that has to be taken into consideration.

Is it well known in fact that the 5G use cases demand very diverse and sometimes extreme requirements. It is anticipated that a single solution to satisfy all the extreme requirements at the same time may lead to over-specification and high cost then with the aim to provide a list covering as much as possible the 5G requirements we provide different tier of KPIs for the creation of a KPIs cartography, that is the ID card of the project.

In order to frame the UCs and related scenario of NRG-5 we have decided first to focus on four use case families described by the NGMN white paper that match all the NR5 UCs in a certain family of Use Cases and then provide two more tier of KPIs : operational and 5GPPP KPIs.

A family can be viewed as a consolidation of related use cases for a general scenario.
As mentioned in the NGMN paper [Elh15], the use case families are not meant to be exhaustive with full coverage of all technical aspects related to 5G. The main scope is instead to show the

needed flexibility and illustrate the wide span of different requirements posted by the aggregated use cases.
The overall requirements and KPIs have been grouped according to the NRG5 project aspects (Table 14), to the network (Table 15, Table 16, Table 17), operational (Table 18**Errore. L'origine riferimento non è stata trovata.**) and the 5G PPP KPIs (Table 19).

The complete set of targets values will be defined, for the different 3 Use Cases in the activities related to the deploy the project pilots demonstrators. During the pilot the KPIs values will be get based on measurements from the real implementations. The expected ranges values will be compared with the real ones. Initialy the 5G-PPP values will be considered for this analysis.

Groups-Families	Categories	NRG-5 Use cases
xMBB/eMBB – extreme Mobile Broadband access everywhere	• 50+ Mbps everywhere. • Ultra low-cost broadband access for low ARPU areas.	UC2
mMTC - Massive internet of things	• Massive low-cost/long-range/low-power MTC • Broadband MTC	UC1, UC3
uLLC - Low latency Communication	• Ultra low latency	UC1, UC2
uMTC - Ultra reliable communication	• Ultra-high reliability & Ultra low latency • Ultra-high availability and reliability	UC1, UC2, UC3

Table 14 – Families and NRG-5 UCs

4.2.1 Telco KPI

Different requirements are coming according to the NRG-5 context: the access network domain is characterized by the communicating end points, like Smart Meters. The diameter of the region to be covered is typically <10km. For end-points which shall be dispatched (in terms of load or generation) in case of a power grid stability problem some real-time capability is required: from electric point of view the requirements are:

- Bandwidth: 1 kbps per residential user (even if the user is positioned in the basement)
- E2E Latency (guaranteed upper bound): <1s from the control center / meter data management center/ secondary substation to the Smart Meters
- Packet-loss: no specific requirement as long as E2E Latency requirement can be covered (TCP-based communication is dominant)
- Availability: 99% equal to 9 h downtime p.a.
- Failure Convergence Time: <1s
- Crisis situations management it is not handled.

According to the **UC1** ("Realizing decentralized, trusted lock-in free "Plug & Play vision") we have the deal with Managing energy network stability and resilience via demand management; in this case, to cope with

- Dispatchable Demand Response

- Coordinated charging of Electric Vehicles
- Relies on extensive metering/monitoring of fixed/mobile assets

the following 5G Requirement have to be considered

- Optimisation requires continuous measurement with low latency
- Lots of mobile devices requiring connectivity

Based on the requirement definitions, the following requirements from the Telco point of view have to be considered:

No	Description	Requirement	Comment
1	**Device density**	≥ 1000 (high)	Supported by using 5G this requirement can be satisfied
2	**Mobility**	< 3km/h (low/pedestrian)	5G supports mobility of up to 500km/h, however, it depends on the speed of the device and the transmission rate (increasing the speed of the device, decreases the transmission rate that can be achieved); for this mobility threshold (<3km/h) the supported throughout is of the order of 100s of Mbits
3	**Infrastructure**	big number of small cells (>10)	5G supports micro, pico and femto cells (ultra dense networks supported) for an efficient frequency spatial reuse
4	**Traffic type**	burst/periodic	5G supports both types of traffic
5	**User data rate**	50 ÷ 100 Mbps (medium)	Check point 2 (mobility requirement)
6	**Latency**	1 ÷ 10 ms (low)	The low latency od 1ms can be supported by 5G direct communication between the smart meters and the xMEC. The latency of 10ms on the backhaul connection segment is supported by 5G, but not by 4G
7	**Reliability**	> 99 % (high)	Can be ensured by security, privacy, resilience, high availability, supported by vAAA, vBCP, cloud benefits, SDN benefits and availability thanks to re-allocation and redundancy of VMs in general
8	**Availability**	> 99 % (high)	Can be achieved by the use of benefits of a cloud platform in terms of HA (high availability) mode enabled and VM re-allocation

Table 15 – 5G telecom requirements for UC1

In the case of **UC2**: Enabling aerial Predictive Maintenance for utility infrastructure, to cope with

- Maintenance of critical infrastructure
- Incident detection (e.g. intrusion)

- Work site support (supporting engineers in field)
- Measurement and recording via multiple cameras and sensors

the following 5G Requirement have to be considered

- **massive bandwidth on demand at potential remote locations**
- **low latency for alarms**

Based on the requirement definitions, we can review the following requirements from the Telco point of view:

No	Description	Requirement	Comment
1	**Device density**	<1000 (low)	By using 5G this requirement can be satisfied
2	**Mobility**	>50ms (high)	5G supports mobility of up to 500km/h, however, it depends on the speed of the device and the transmission rate (increasing the speed of the device, decreases the transmission rate that can be achieved). With 4G there are limitations, especially in the case of higher throughput requirements
3	**Infrastructure**	macro cell coverage	5G supports macro cell coverage
4	**Traffic type**	continuous/burst	5G supports both types of traffic
5	**User data rate**	100 ÷ 1000 Mbps (≥ 1000 very high)	Check point 2 (mobility requirement)
6	**Latency**	1 ÷ 10 ms (alarms - low); > 50ms (video - high)	The low latency od 1ms can be supported by 5G direct communication between the drone and the xMEC,. The latency of 10ms on the backhaul connection segment is supported by 5G , while the 50ms latency can by supported by both 5G and 4G
7	**Reliability**	> 99 % (high)	Can be ensured by security, privacy, resilience, high availability, supported by vAAA, vBCP, cloud benefits, SDN benefits and availability thanks to re-allocation and redundancy of VMs in general
8	**Availability**	> 99 % (high)	Can be achieved by the use of benefits of a cloud platform in terms of HA (high availability) mode enabled and VM re-allocation

Table 16 – 5G telecom requirements for UC2Finally, in the UC3 for managing energy network stability and resilience via demand management, to cope with

- Dispatchable Demand Response
- Coordinated charging of Electric Vehicles
- Relies on extensive metering/monitoring of fixed/mobile assets

the following 5G Requirement have to be considered

- **Optimisation requires continuous measurement with low latency**
- **Lots of mobile devices requiring connectivity**

No	Description	Requirement	Comment
1	**Device density**	1000 ÷ 10000 (medium)	5G can support up to 10^6 devices per km^2
2	**Mobility**	>50 km/h (high/fast moving vehicles)	5G supports mobility of up to 500km/h, however, it depends on the speed of the EV and the transmission rate (increasing the speed of the device, decreases the transmission rate that can be achieved); for this mobility threshold (>50km/h) the supported throughout is of the order of several 10s of Mbits
3	**Infrastructure**	Macro cell coverage (low); small amount of small cells (<10)	5G supports macro, micro, pico and femto cells (ultra dense networks supported) for wide coverage and efficient frequency spatial reuse
4	**Traffic type**	continuous/event-driven	5G supports both types of traffic
5	**User data rate**	<50 Mbps (low); 50 ÷ 100 Mbps (medium)	Check point 2 (mobility requirement)
6	**Latency**	1 ÷ 10 ms (low); 10 ÷ 50ms (medium); >50ms (high)	The low latency od 1ms can be supported by 5G direct communication between the smart meters or IEDs and the xMEC. The latency of 10ms on the backhaul connection segment is supported by 5G, but not by 4G. Latency of over 50ms can by supported by both 5G and 4G
7	**Reliability**	> 99 % (high)	Can be ensured by security, privacy, resilience, high availability, supported by vAAA, vBCP, cloud benefits, SDN benefits and availability thanks to re-allocation and redundancy of VMs in general

8	**Availability**	> 99 % (high)	Can be achieved by the use of benefits of a cloud platform in terms of HA (high availability) mode enabled and VM re-allocation

Table 17 – 5G telecom requirements for UC3

4.2.2 Operational KPIs

Different KPIs focus on operational efficiency as described in [16]. These KPIs have to measure the e2e service quality, monitoring the service providers on the base of the transport already provided by the Telco. In this way it will be possible to include also the "non-functional requirements" to describe different aspects like for example the "Asset Management" or the "Cost efficiency". In the first case it is required an efficient asset handling using the information extracted by the network, while in the second one, it could be possible to explore how the communication solutions provided by 5G do not only need to assure technical feasibility, but also suitable from a business viewpoint, i.e. even if the offering of an advanced 5G communication solution is technically possible and standardized.

More details in the following table for other aspects:

2nd group: Service- Application		
009	Connectivity	Required to assure ubiquitous coverage including all the elements.
010	Accessibility (service)	Correlated to the "Availability" KPI.
011	Service usage	From a technical perspective this means that guarantees for average values are not sufficient; in the NRG-5 use case it will be required to guarantee for max/min values; besides it is required a monitoring and management.
012	90-90-90	Required to save up to 90% of energy per service provided and to reduce time in the initial service deployment and onboarding phase from 90 hours to 90 minutes.
013	Service establishment time	For remote services there might be the need to spontaneously setup a communication path towards a dedicated station which provides specific QoS in the range of 10min to 1 hour.
014	QoS flow perform.	Support a set of different configurations for the traffic for each network components in order to obtain the expected QoS value.
015	Busy hour flow invocation capacity	Enhancing the wireless area capacity for different service capabilities when the request is done during the BH.

016	Maximum event response time	Able to deal with very tightle response time to enriched experience to the final users when a service is requested.
3th group: Virtualisation		
017	QoS Flow installation time	Deal with the installation of each components to increase the benefits for the involved operators
018	QoS Flow removal time	Deal with the de-installation of each components to reduce the impacts for the involved operators
019	VM installation time	Reduce the costs of installing dedicated infrastructures, in particular as far as concerning the Virtual machines for the provided flexibility
020	VM removal time	Reduce the costs when it is necessary to remove dedicated infrastructures, in particular as far as concerning the Virtual machines
021	Memory/CPU usage	Control the usage of Memory and reduce the costs of installing dedicated infrastructures, in particular as far as concerning the Virtual machines for the provided flexibility
022	% of parameters exchanged	It is important to control this exchange of data among the different components
023	Node discovery time	discovery of a new node and/or multi-domain orchestrator systems
024	Single touch orchestration	It is the minimum number of workflow interventions to provision a multi-domain service; for this reason it is a measure of automation of the complete process
025	Seamless service offers in multiple domains	The degree to which connectivity, network and compute/storage resources can be integrated together seamlessly
026	Re-scaling of compute/storage	Re-scaling of compute/storage into and out of a service depending on demand

Table 18 – 5G operational requirement

4.2.3 5G-PPP KPIs

It is also required to map the use case families to some corresponding business cases identified in vertical industries to have a comprehensive vision of the global impacts taking into account the performance and business aspects described in 5G-PPP- KPIs [14] to harmonize viewpoints of different projects including NRG-5.

Item	Description	KPI	5G-PPP KPIs: Performance	5G-PPP KPIs Societal:	5G-PPP KPIs Business-related
Interoperability	The Interoperability among the different components is requested: in particular, it is requested that the network architectural components provide external APIs to allow the access the offered functionality or for managing the VNF or other components.	Accessible information and functionality of NRG-5 components	P4: Creating a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision.	S2: Reduction of energy consumption per service up to 90% (as compared to 2010); S3: European availability of a competitive industrial offer for 5G systems and technologies; S4: Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications;	B2: Target SME participation under this initiative commensurate with an allocation of 20% of the total public funding;
Resource Monitoring	It is required that the information both from physical and virtual components are monitored; to reach this goal it is necessary to include in the provisioning phase of the architectural components all the elements necessary to achieve these data collections.	We include all the different retrievable information from networks	P5: Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.	S2: Reduction of energy consumption per service up to 90% (as compared to 2010); S4: Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications;	

	Using these elements it will be possible to evaluate the value of the different parameters involved in the SLA				
Dynamic configuration of virtual resources	virtualization management it is requested; in particular it is requested that the components have to support the dynamic configuration and scaling of virtual resources. The programming model of NRG-5 must support scalability of a VNF depending on the user demand	Time to reconfigure the deployment of VNFs	P2: Saving up to 90% of energy per service provided.	S2: Reduction of energy consumption per service up to 90% (as compared to 2010); S3: European availability of a competitive industrial offer for 5G systems and technologies S4: Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications;	B2: Target SME participation under this initiative commensurate with an allocation of 20% of the total public funding;
Hardware and network acceleration	It is necessary to evaluate if to improve the VNF performance hardware and/or network accelerators are required.	VNF performance in terms of processing speed and resource consumption.	P4: Creating a secure, reliable and dependable Internet with a “zero perceived” downtime for services provision.	S3: European availability of a competitive industrial offer for 5G systems and technologies S4: Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications;	
Service function chaining	It is necessary to evaluate if it is possible offer different services composed by many VNFs. Also the Service	Number of services and VNFs in the chain supported without impacting on the	P1: Providing 1000 times higher wireless area capacity and more varied service	S1 Enabling advanced User controlled privacy; S2: Reduction of energy consumption per service up to	B2: Target SME participation under this initiative commensurate with an allocation of 20% of the total public

	mapping complexity and time will be evaluated.	network performance	capabilities compared to 2010. P3: Reducing the average service creation time cycle from 90 hours to 90 minutes. P6: Enabling advanced user controlled privacy.	90% (as compared to 2010); S3: European availability of a competitive industrial offer for 5G systems and technologies S4: Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications;	funding;
Multiple IoT Sensor Vendors	In the project it is necessary to support traffic _ from different IoT sensor vendors	The information coming from the different sensors must be processed in the same way	P1: Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010. P3: Reducing the average service creation time cycle from 90 hours to 90 minutes. P5: Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.	S3: European availability of a competitive industrial offer for 5G systems and technologies S4: Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications	

Table 19 – 5G-PPP- KPIs

To complete this analysis we can map the use case families not only with some corresponding business cases identified in vertical industries but also with the different NRG-5 Use cases: in the following table a synthesis is suggested. In particular the different use cases allow to realise many conditions in which is possible to monitor how the 5G-KPPP could be match in the different contexts.

5G-PPP KPI	Relevance for NRG-5	Use case
Interoperability		
P4	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.	UC1, UC2, UC3
S2	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.	UC1
S3	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 functionality may be offloaded from drones to xMEC).	UC1, UC2, UC3
B2	NRG-5 will increase European competitiveness for industry and especially SME's. NRG-5 will: Address 5G communication issues to eliminate risks that hinder investment in services • Develop its solutions based on open platforms and offer them as open source, promoting pan-European standards for interfaces that lower market entry barriers especially for SME's • Provide novel innovation concepts, concrete solution guidelines and close to market implementations that will serve as development stimuli for novel SME products; • Bring together creative forces of local markets and promote innovation with a focus on SME's • The SMEs involved in NRG-5 for increasing their market penetration in non-European countries, especially considering that NRG-5's budget allocation for SMEs is 18.5% of the total allocated budget.	UC1, UC2, UC3
Resource Monitoring		
P5	New functions such as vTSD, vSON, and vMME will increase reliability and minimize latency, while MCM will further increase scalability and minimize latency and energy consumption as virtual representations on the xMEC will enable instantaneous response to massive requests, while hardware constrained devices may minimize energy.	UC1, UC2, UC3

S2	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.	UC1, UC2, UC3
S4	Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications	UC1, UC2
Dynamic configuration of virtual resources		
B2	NRG-5 will increase European competitiveness for industry and especially SME's. NRG-5 will: Address 5G communication issues to eliminate risks that hinder investment in services • Develop its solutions based on open platforms and offer them as open source, promoting pan-European standards for interfaces that lower market entry barriers especially for SME's • Provide novel innovation concepts, concrete solution guidelines and close to market implementations that will serve as development stimuli for novel SME products; • Bring together creative forces of local markets and promote innovation with a focus on SME's • The SMEs involved in NRG-5 for increasing their market penetration in non-European countries, especially considering that NRG-5's budget allocation for SMEs is 18.5% of the total allocated budget	UC1, UC2, UC3
Hardware and network acceleration		
P4	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.	UC2, UC3
S3	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 functionality may be offloaded from drones to xMEC).	
S4	Stimulation of new economically-viable services of high societal value like U-HDTV and M2M applications	
Service function chaining		
P1	NRG-5 will highlight the requirements of the Smart Energy Vertical Sector and identify the limitations of current network infrastructures and finally propose a hybrid telecoms and energy (electricity and gas) infrastructure via virtualization technologies and next generation xMEC, smart meters and drones	UC1,UC2,UC3
P3	The VNF catalogue will enable a new range of services to be created in minutes by means of proper VNF-FG	UC1,UC2,UC3

P6	NORM enables the massive and lock-in free integration of end-users' infrastructure requesting more stringent capacity and privacy (Massive IoT application)	UC1
S2	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.	UC1, UC3
S3	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 functionality may be offloaded from drones to xMEC).	
S4	NRG-5 will stimulate new services of high societal value like U-HDTV and M2M applications;	UC1,UC2,UC3
B2	NRG-5 will increase European competitiveness for industry and especially SME's. NRG-5 will:Address 5G communication issues to eliminate risks that hinder investment in services; - Develop its solutions based on open platforms and offer them as open source, promoting pan- European standards for interfaces that lower market entry barriers especially for SME's;	
Multiple IoT Sensor Vendors		
P1	NRG-5 will highlight the requirements of the Smart Energy Vertical Sector and identify the limitations of current network infrastructures and finally propose a hybrid telecoms and energy (electricity and gas) infrastructure via virtualization technologies and next generation xMEC, smart meters and drones	UC1,UC2,UC3
P3	The VNF catalogue will enable a new range of services to be created in minutes by means of proper VNF-FG	UC1,UC2,UC3
P5	New functions such as vTSD, vSON, and vMME will increase reliability and minimize latency, while MCM will further increase scalability and minimize latency and energy consumption as virtual representations on the xMEC will enable instantaneous response to massive requests, while hardware constrained devices may minimize energy consuming functions (e.g. RF activity and complex processing)	UC1, UC2,UC3

S3	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 functionality may be offloaded from drones to xMEC).	UC1, UC3
S4	NRG-5 will stimulate new services of high societal value like U-HDTV and M2M applications;	

Table 20 – UCs - Relevance and impact on 5G-PPP KPIs

The following figure depicted the KPIs flow from NRG-5 to EC, through 5G PPP.

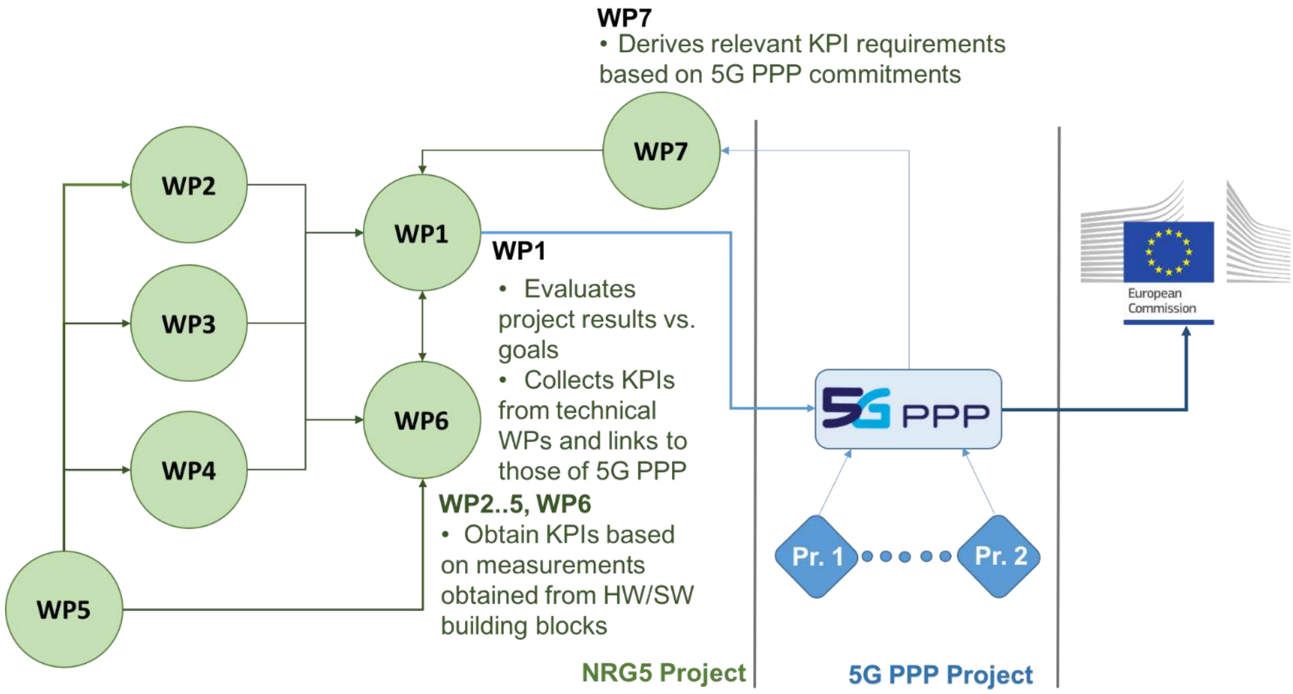

Figure 14 - NRG-5 KPI flow

5 Conclusions

5G Mobile networks will be the next more important phase of mobile telecommunication standard beyond the current 4G / 4.5 G deployments: in particular, many of the enhancement in the LTE Advanced are essential building blocks for anticipate the 5G introduction and will enable different and important features of the use cases for 5G. The 5G will offer the opportunity to address many fundamental requirements coming from the foreseen services and applications, above all in the reliable grids context: 5G enables potential new opportunities with significant economic impacts.

In particular, the NRG-5 use cases are fundamental to demonstrate how the 5G has the potential to enable a platform to address a wide range of conditions. For example, in the case of smart meter deployment it is important to consolidate the different technology to make smart metering (all utilities type, energy, gas, water) more accessible to many kind of utilities involved. The requirement “low latency” plays an important role in the NRG-5 context because in the smart grid this requirement will be attractive to develop new rules to cope with the downtime penalisation or with the customised energy cost for each prosumer/end user.

The UC1 presented in NRG-5 takes into account a large number of connected devices transmitting low volume data of non- delay- sensitive data. The Use case requirements allow an assessment of the impact of the 5G technology introduction in the real context of the smart grid market; they will target fundamental market as described in the NRG-5 context and will highlight the fundamental advantage coming from the 5G technology adoption. The “UC1” family focusing on massive connectivity of objects covers requirements of Grid access, backbone and backhaul; more generally it could be applied in other industrial context as Seamless intra-/inter-enterprise communication, allowing the monitoring of assets distributed in larger areas, the efficient coordination of cross value chain activities and the optimization of logistic flows.

“Broadband everywhere” UC family, as implemented in UC2 focusing on high availability for eMBB service in areas with limited infrastructure can extend also the with xMBB aspects for on-board entertainment. In the UC2 (drones) the requirements are useful to demonstrate how commercial drones have the potential to benefit multiple industries in different context (like, agriculture, manufacturing, public safety, transport). It is important underline that in NRG-5 it could be possible to evaluate according to the expressed requirements how the drones introduction will give more advantages, above all reducing the cost compared with the sustained ones. All the Use cases are useful to demonstrate how the 5G solutions offer tools for the Configuration, Administration and Support Services during the operation phases deal with the incremental complexity, increasing when using the new network capabilities, it is possible to move from connectivity to network functions to realise the slices correlated to the requested service. In general the Use Case with Enriched Connectivity, focusing on next-generation connectivity services allow to demonstrate the opportunities offered by the Virtual Network Function in different domains.

Using the Massive IoT (MIoT) as described in the UC1/UC2/UC3 it could be demonstrated how it is possible to combine the different data to improve the monitoring of the infrastructures to reduce the distribution cost and the losing of each kind of “resource” (energy/gas/water). The potential of 5G is to provide robust solution to deal with a lot of kind of equipment guaranteeing also the security when the sensor/equipment is used not only to improve the mobile broadband user experience, but also evolving and address the particular requirements of MIoT deployments and for the Mother context as the critical services in the Energy context.

Some of the benefits of the 5G introduction are expected to be realised because of different technological features that will enhanced the mobile broadband experience; in particular the UC2 (eMBB-class) will be important to address the human centric use case for access to multimedia contents/video/ contents/data; 5G solution will enable networks to operate in a more efficient way with a lower cost of bit per sec. The eMBB use cases (e.g. UC2) of NRG-5 project allows to demonstrate the opportunities also in the case of the MCS and MIoT applications, where reliable and low latency application are requested. In this case stringent requirements are requested as throughput, latency, as the industrial manufacturing control (e.g. predictive maintenance using images from drones) or production process (e.g in the energy context) and in particular in the distribution automation in smart grid.

Besides, 5G communication represents a pillar for the integration of DERs and EV in the further Energy ecosystem because it requires the control of the feeding of renewable energy in the distribution network. The DDR strategy depicted in the UC3 can give an important contribution in this regard but it needs an extremely fast and accurate information system. The energy flow must constantly monitor through device at each node of the flow path, to decide the type of charging of EVs more suitable for the grid. The use of the 5G will allow the stability and resilience of the energy grid in the presence of high share of RES, greatly depends on the fast response. Given that most of the times storage is not available on-site, ultralow response from the energy operation center is vital. The enablement of large scale DDR requires extreme (for today's standards) communication requirements as metering and associated computational processes should be performed at very high frequencies.

Based on the UC analysis depicted in this document it is evident that NRG-5 use case scenarios cover differently the 5G PPP list of 5G traffic requirements as summarized in Table 19.

5G Traffic Requirement	UC 1	UC 2.i	UC 2.ii	UC 3.i	UC 3.ii	UC 3.iii
User Density	High	Low	Low	Medium	Medium	High
User Data Rate	Medium	High	High	Low	Medium	Medium
Mobility	Static	High	High	High	N.A.	N.A.
Infrastructure	High (*)	Low	Low	Medium	Medium	Medium
Traffic Type	Period / Event driven	Burst	Continuous	Event driven	Continuous	Continuous
Latency	Low	Low - alarms	High– video	High - OBD	Low - Optimal scheduler	Low - Charging point
Reliability	High	High	High	High	High	High
Availability	High	High	High	High	High	-
eMBB/xMBB	-	-	X	-	-	-
uMTC	X	X	X	-	X	-

(URLLC)						
mMTC	X	-	-	X	-	-

Table 21 – 5G TELCO requirements for UC1, UC2 and UC3

In conclusion, 5G has to incorporate a wide range of diverse use case characteristics that are associated with a complex set of requirements: novel technology components are needed, as well as some disruptive techniques. All the NRG-5 use cases are relevant to demonstrate how an efficient integration of the 5G access technologies could help to address the requirements in terms of smart grid solutions handling.

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7 List of figures

8 List of tables

9 Acronyms

AMI	Advanced Metering Infrastructure
AMR	Automated Meter Reading
CP	Commercial Period
DER	Distributed Energy Resources
DLMS/COSEM	Device Language Message Specification/COmpanion Specification for Energy Metering
DR	Demand Response
DSO	Distribution System Operator
EV	Electric Vehicle
GPRS	General Packet Radio Service
HD	High Definition
ICT	Information Communication Technology
LV	Low Voltage
MDM	Meter Data Management
MEC	Mobile Edge Cloud
MTC	Machine Type Communications
MV	Medium Voltage
NFV	Network Function Virtualization
NORM	Next Generation Open Real Time Smart Meter (from H2020 SUCCESS project)
NS	Network Service
PLC	Power Line Carrier (Communications)
PMU	Phasor Measurement Unit
PQ	Power Quality
PV	Photo Voltaic
QoS	Quality of Service
RES	Renewable Energy Sources
SCADA	Supervisory Control And Data Acquisition

SFC	Service Function Chain
SG	Smart Grid
SM	Smart Meter
SMG	Smart Meter Gateway
SMX	Smart Meter eXtension
TAP	Transaction Ahead Period
TELCO	Telecommunications Company
TEP	Transaction Execution Period
TP	Transaction Period
TSP	Transaction Settlement Period
UC	Use Case
UHF	Ultra-High Frequency
VEE	Validation, Estimation, Editing
VNF	Virtual Network Function
VNFFG	Virtual Network Functions Forwarding Graph
VNFFP	Virtual Network Functions Forwarding Path
vAAA	virtual Authentication, Authorization, Accounting (services)
vBCP	virtual Blockchains Processing
vDFC	virtual Drones Flight Control
vMCM	virtual Machine Cloud Machine
vMPA	virtual Media Processing and Analysis
vSON	virtual Self Organizing Networks
vTSD	virtual Terminal Servers Discovery
xMEC	extended Mobile Edge Cloud

10 Annexes

10.1 Annex 1: Metodology

10.1.1 Requirements analysis

The methodology helped project partners to describe, formalize and track the project requirements in an explicit and unambiguous manner. Requirements have been defined by 5 steps:

1. Requirement definition involving energy utilities and technology providers (ASM, ENGIE, RGAZ, EMOT)
2. Revision of the requirements by technical partners (ENG, SiLO)
3. Definition of 5G requirements by TELCO companies (W3, BIT, HIS)
4. Utility requirements adjustment to 5G
5. Final revision

10.1.1.1 Specification process

The overall process is depicted in Figure 154. After an initial specification of requirements, the partners have specified conflicts, dependencies and objections. After specifying them, they can iteratively revise the specification and identify additional issues until it is free of conflicts, dependencies and objections. The result will constitute the final list of requirements.

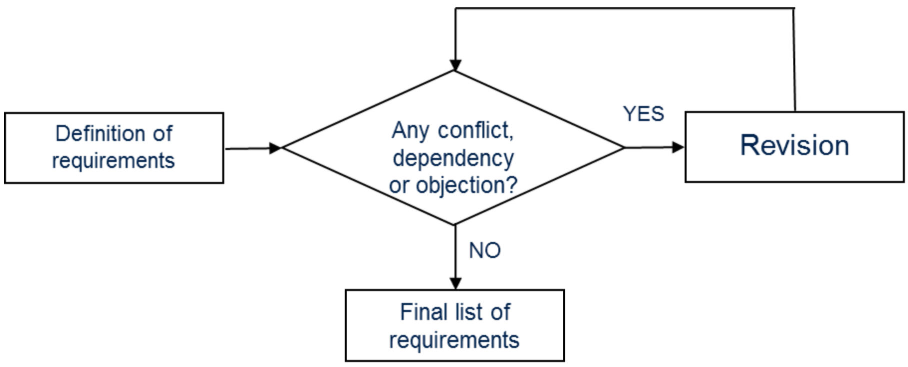

Figure 15 – Requirement Specification and Validation Process

10.1.1.2 Requirement definition

Four fields have been defined in order to specify properly the requirement:

- **ID**: it is composed by an alphabetical code identifies the scope of this requirement. It is also Appended by a sequential number. This ID uniquely identifies each requirement.
- **Description**: A one sentence statement which describes the intention of the requirement.
- **Rationale**: A justification of the requirement.
- **Acceptance criteria**: A measurement of the requirement for further verification that the solution matches the original requirement.

10.1.1.3 Revision

After the initial definition of requirements, the revision process started. At this stage, conflicts and dependencies between requirements have been detected by the partners involved in the UC refining and then solved successfully.

10.2 Annex 2 (UC1 Requirements)

[Requirement ID]	[Description]	[Rationale]	[Acceptance criteria]
UC1_000	The VNF shall be able to work with several types of data	The VNF will support several different functionalities	Different kind of data is accepted by the VNF
UC1_001	The VNF shall be able to apply different algorithms on the data	The VNF will support several different functionalities	There exists a procedure to configure the VNF to execute different algorithms, depending on the desired functionality
UC1_002	The VNF should be able to store data	Several important features to be developed within the project work on big amounts of data	
UC1_003	Data quality assessment and substitution	Bad data should be identified, marked as such and substituted by an estimated value whenever possible	
UC1_004	Temporal and spatial integration	Raw measurements from every single metering source are likely to be integrated temporally and/or spatially for subsequent management and analysis. The data has to be timestamped and marked with physical coordinates.	

UC1_005	Periodic data analysis is supported	A set of analysis will be periodically performed over the new received data. The VNF will support the periodic (prescheduled) execution of analysis algorithms	
UC1_006	The VNF shall be able to apply privacy policies on different segments of data		
UC1_007	The VNF shall be able to communicate with a defined number of protocols		
UC1_008	The VNF will be able to work as a distributed system		
UC1_009	The VNF will have a real time data section, which will allow much higher number of transactions than on persistent database section		
UC1_010	The VNF will need a concept of key management for the data security features.		
UC1_011	The VNF will allow data anonymisation by using anonymus labels in some databases and personal reference in other databases. The applications allow and gives meaning for the		

	aggregated data (e.g. aggregated active powers of a cluster of end-users)		
UC1_012	Triggered data analysis is supported	A set of analysis will be performed triggered by certain events (such as reception of new data). The VNF will support execution of analysis algorithms upon preconfigured triggers	
UC1_013	Phasor Measurement Units (PMUs) in strategical places in order to monitor the stability / quality of the grid.		An optimized deployment of the PMUs
UC1_014	Smart meters infrastructure should be deployed and integrated into the smart grid		A correct deployment of the smart meters
UC1_015	Smart meter must have a public IP network connection (internet)		Having a way of communication between the smart meters and the interested actors
UC1_016	Real data in real-time from smart meters, sensors, metering, etc. must be available for various actors, based on their rights to have access to that data		Availability to have all the required measured data
UC1_017	Data owners will decide for which purposes their data can be used (Role	The VNF will support several different functionalities, requiring different data	Access control mechanism is put in place, cheking whether end users have

	Based Access Control - RBAC should be implemented at the user side of the smart meter)	(mostly coming from the prosumers). Those will have the capacity to limit the scopes where their data is used	given permission to use their data for each of the functionalities of the VNF
UC1_018	Smart meters infrastructure should be deployed and integrated into the grid		A correct deployment of the smart meters
UC1_019	Smart meter must have a network connection		Having a way of communication between the smart meters and the interested actors
UC1_020	The systems designed within must be based on open standards (as much as possible).	Open Standards will allow the smooth integration of external systems	Compatibility Test
UC1_022	Systems shall have appropriate interfaces for working with and securely exchange data with operational facilities	Establish a secure line between apps and operating facilities and data	Communication establishment in lab testing
UC1_023	End Users should be grouped by consumption profiles and invited to interact in favor of more energy efficiency	In order to activate the consumers' interest for energy efficiency, it is better to have peer to peer group	
UC1_024	System should be designed following the principles of modularity, scalability and interoperability	It is about the possibility to build the systems as independent but interoperable blocks. It also means interaperable with not tools. It is also important for the exploitation	TheNRG-5 solution must be suitable for market needs in terms of interoperability and scalability

		of project results	
UC1_025	Prosumers / end-users will be able to connect point-to-point for direct Blockchain transactions		
UC1_026	Clusters of 5G-NORM should be synchronized by using PTP functionality in the cluster zone		
UC1_027	Events will be registered in a way that it will not be possible to dispute their content and existence	When events of interest are happening in the system, these are registered in a way that no one can challenge that they have happened or dispute the data concerning them.	A secure and traceable way for registering events and making them accessible, provided the appropriate rights are verified, is implemented
UC1_028	Private data and data coming from measurements will be protected, so as not to reveal the actual identity of the individual(s) involved.	The protection of private data needs to take place when generated, in transit and in storage.	Depending on the particular use of the data, encryption, anonymization and aggregation could be employed, or some combination of them
UC1_029	Data gathered or made available as part of a registration process will be used only for the intended purpose and only with proper authorisation.	Access to data will be given only after an authentication and authorisation process.	The use of data is connected with the authorisation level that has been obtained.
UC1_030	Measurement events will be made available for further processing as soon as they became available.	In order to support the efficient handling of the data and to achieve the most effective results, real time gathering and processing	Real time registration of events

		of measurement data is necessary.	
UC1_031	Measurement data will be communicated in a real time fashion, as soon as they become available, to support their further processing.	Real time communications with low latency are required, so as to support the real time processing of transported data.	Real time communication of data measurements
UC1_032	The communication infrastructure will be able to support the concurrent communications of multimillion SM devices distributed in local, regional or national level.	Having a plethora of end-customers, which could be well in the millions range, it is mandatory to support the concurrent communication with, practically, all of them.	Possibility to interconnect millions of SM devices, in a real time fashion
UC1_033	The energy consumer will be able to have a lock-in free energy service in a dynamic fashion.	The energy consumer is able to switch between retail energy providers on demand, so as to minimise energy consumption related costs.	Possibility to switch from one energy utility to another in a matter of seconds or few minutes, once there is a contractual agreement established.
UC1_034	The energy prosumer will be able to have a lock-in free energy service in a dynamic fashion.	The energy prosumer is able to switch between wholesale energy providers on demand, so as to maximise his benefits from selling energy.	Possibility to switch from one energy utility to another in a matter of seconds or few minutes, once there is a contractual agreement established.
UC1_035	The energy micro-contracts will have a temporal and/or spatial validity and it will not be possible to be disputed.	The micro-contract will identify the two participating entities and the conditions mutually agreed in a non-disputable manner.	The trust between the contracting parties is enforced and the whole process is well accepted.

10.3 Annex 3 (UC2 Requirements)

[Requirement ID]	[Description]	[Rationale]	[Acceptance criteria]
UC2_001	The VNF shall be able to work with any kind of camera (among the same type: visible, thermal).	Using best-in-class sensors and cameras for detailed survey and inspection data – - Revealing the finest cracks and heat leaks and cold. - Checking the infrastructure in general and the accesses.	Combine multiple cameras / sensors for high definition visible imaging as well as thermal long wave, short wave, RGB, and optical gas imaging.
UC2_002	The VNF shall be able to analyse videos or images from different sensors *while in flight*.	Pilot will be able to choose between all embedded sensors (For example standard camera or Thermal camera).	Use their vision sensors together with advanced image recognition algorithms to allow the drones to recognize and tracks objects.
UC2_003	The VNF shall be able to drive the drone among common maintenance paths for multiple and autonomous failure detection	Structural maintenance. Fault detection. Locate assembly errors. Determine fault location. Object detection.	Identify erosion, cracks and general wear & tear with high-resolution cameras. Locate leaks and faults using gas sniffers and thermal cameras. Detect assembly errors and reach dangerous or areas difficult to access with 30x zoom cameras. Easily relocate a defect in 3D with geo-referenced data. Automatically detect, track and label plant equipment and infrastructure
UC2_004	The VNF shall cover a wide range of installations within the plant	Aerial and buried pipelines; compressors stations; dehydration plant; group of wells; well head; etc.	

UC2_005	Drone shall be weather and mechanical resistant	Temperature resistant Rain Proof Dust Resistant Impact/shock Resistant Carbon fiber construction of drones to be able to work in heavy winds, resistant to magnetic interferences and temperature variations.	IP55W rated. The fuselage effectively shields the electrical components inside against heavy rain and dust intrusion. Fly in wind speeds of up to 16m/s, the harsh cold of the arctic or blistering heat of the desert.
UC2_006	Full system shall be built-in failsafe.	Buit-in redundancies in order to avoid incident in flight.	Redundant electronics. Redundant propulsion system, at least 6 rotors. Redundant communication links (RF, WiFi, satellite, other …) Redundant power supply.
UC2_007	VNF shall be able to allow drone remote controlled	Remotely controlled with a mobile ground station keeps the operator away from the site avoiding critical situations.	The flight plan will be programmed using GPS or GLONASS coordinates. Real-time transfer inspection data into any digital asset management system for in depth analysis.
UC2_008	Drone shall have long time exploitation	Low power rotors consumption. Redundant batteries. Multiple rotors for extended flight time	Large batteries autonomous.
UC2_009	Drone controller shall be suitable for vDFC VNF integration	The goal is to keep the frequency of maintenance performed low to avoid both unplanned breakdowns and performing unnecessary preventive maintenance tasks	The vDFC VNF will perform the waypoint flight planning software for swarm drones, for carrying out complex surveying project with minimum time and effort.

UC2_010	The VNFs shall be compatible with NRG-5 edge cloud accelerator		
UC2_011	Drone shall be compliant with their environment and local regulation.	The goal is to analyse certification requirements in a normal operative (ATEX, IEEx, INMETRO andCivil Aviation Rules)	
UC2_012	The VNF shall have autonomous functionalities for drone diving.	Autonomous scenario of flight plan Automatic "return to home" function Automatic return to power refill station Autopilot function	
UC2_013	Top collision avoidance drones and obstacle detection explained	The obstacle detection and avoidance technology have front, behind below and side obstacle avoidance sensor or georeferenced data.	Detect objects and then take action to avoid the obstacle whether to stop, go around or above the object using the obstacle avoidance algorithm.
UC2_014	The VNF shall have authentication and authorisation functionalities	VNFs should support different level of users to differentiate the showed information	
UC2_015	Ergonomic / intuitive HMI of the VNFs	To allow none professional pilot with basics pre-requisite.	
UC2_016	The drone should be aware of where other objects are in full 3D space, as well as its own location, direction and velocity.	Such insights enable the drone to calculate critical metrics such as distance to the ground and other objects, therefore time to impact with these objects.	The drone can therefore plan its course, as well as take appropriate corrective action en route.
UC2_017	Image quality optimization	High quality still and video source images are critical to the robust implementation of any subsequent vision processing capabilities.	New electronic image and video stabilization approaches may eliminate in the future the need for expensive mechanical components, such as gimbals and customized, multi-element

			optical lenses..
UC2_18	5G performance requirement for predictive maintenance Trial	TRIAL Performance required : ○ Broadband : 30 Mb ○ Radio Latency : < 20 ms ○ Time of connection (reselection) : Minimum 90 seconds ○ Q.o.S: 99.98 ○ Handover: Yes with preselection as possible (in case of dual base stations provided for this trial.	Acceptance criteria are limited to the camera capacity and quality. Embedded camera shall perform HD or 4K service which equal to a requested bandwidth of 30 Mb/s for the new announced cameras. Latency is not critical for this use case, it could be for all remote activities which are engaged the DDR platform. Optimal 5G bandwidth capacity shall be tested in labs.
UC2_19	The VNF shall allow the drone controlled remotely, in an interactive manner.	An authorised pilot sited in the remote control centre will be able to fly the drone, interactively and in real time, based on the video streams received from the drone and the location of the drone on a GPS map.	
UC2_20	The VNF shall be able to capture data from the drone sensors, as well as flight data from the drone and transmit it in real time to control centre.	Having the video data of the drone and the flight data available in a real time fashion, will enable the efficient resolution of the incident.	Real-time interaction and communication of data
UC2_21	The VNF shall allow the flight control of the drone, as well as the data captured by the on-board sensors will be made available to the control centre in a continuous	This is critical, so as to be able to make the right decisions in the right time.	Interactive control of the drone, based on the images or conditions received by the on-board sensing devices

	and uninterrupted fashion.		
UC2_22	The analysis/processing VNF capabilities/service need to be adaptive so as to accommodate the changing flight, environmental and weather conditions.	As the flight, environmental or weather conditions may change very fast, the video processing needs also to be adjusted in a way that will allow filtering out or minimising the impact of noise or obstacles introduced over time.	Dynamic adjustment of the necessary processing capacity for video/image processing.

10.4 Annex 4 (UC3 Requirements)

[Requirement ID]	[Description]	[Rationale]	[Acceptance criteria]
UC3_001	Different models of EV's should easily be integrated in vDER	We should allow EV fleet managers to integrate different models of EV	
UC3_002	Charging speed of charging station can be manually set	The EV fleet manager should be able (perhaps in specific cases) to manually set the EV charging to full speed, overruling the planning.	
UC3_003	vDER must provide API's to allow integration in other fleet mgmt tools		
UC3_004	vDER collects data from vehicles and charging stations on one platform	vDER should allow to analyse data coming from EV's and EVSE directly.	

UC3_005	Different models of charging stations should easily be integrated in vDER	Different manufacturers of charging stations exist, they all should be easily be integrated into the VNF.	
UC3_006	vDER should have a simple mechanism to link the availability / calendar of each car to the charging control engine	Car sharing providers use different scheduling tools to schedule car usage.	
UC3_007	The vDER will receive the state of the distribution network from a Cockpit.		
UC3_008	The vDER will receive the DSO flexibility needs through a Cockpit		
UC3_009	The vDER will calculate the aggregated flexibility capabilities of the EVSEs under its management		
UC3_010	The vDER will reschedule the EVSE charging sessions to meet DSO needs		
UC3_011	The vDER wil allow EVSE booking		
UC3_012	The vDER will establish a two way communication with DSOs	vDER should take account of the DSO needs for charging and distribution grid balance	
UC3_013	The vDER sould have a link to energy markets (Energy Exchange, Balancing and Ancillary Services Markets)		
UC3_014	Fleet manager using vDER should own at least a few charging stations	Only own charging stations can be fully integrated with vDER to achieve the goals of vDER	

UC3_015	EVSE unique identifier		
UC3_016	Smart card or unique digital token per user		
UC3_017	The users have to provide their personal data, EV data and preferences in the context of EV.		
UC3_018	Clear identification of the EVSE on its casing.	To allow user to physically find the charging station.	
UC3_019	The end user should be registered and authorised in order to charge and/or book an EV in the system.		
UC3_020	List of available charging stations with booking possibilities		
UC3_021	EV status available (SOC)		
UC3_022	Notification of near charging stations		
UC3_023	vDER should perform and make use of grouping of EVSE in regulation areas.		
UC3_024	vDER must provide real or near real time monitoring of the EVSE equipment (and the EV fleet) to the EVSE manager (and EV-fleet manager).		
UC3_025	Anonymising charging data to assure data privacy in case of private EVs.		
UC3_026	vDER should provide charging constraints of electric vehicles (such as minimum charging		

	power/current).		
UC3_027	vDER shall provide historical consumption and charging session data from each EVSE.		
UC3_028	vDER gathers data from EVs: location, SOC, status of the car,... via API's	Data of EVs will be available from servers of the manufacturer or the fleet manager. EVSE should be easily configurable so that this data can be plugged in, per car.	
UC3_029	The EVSE operator or the fleet manager has an updated list of known users (for authentication process)		
UC3_030	The EV user has a valid account in the vDER for the authentication process.		
UC3_031	The EV user only will provide flexibility to the system allowing the system to module his charging session if he wants. If not, his car will be charged asap		
UC3_032	The EVSE Operator or the EV Fleet manager will be able to configure the EVSE network through the vDER (EVSE location, number of sockets, maximum and minimum power, etc.)		
UC3_033	The vDER will calculate the EV load forecasting per regulation are or for the whole system		
UC3_034	The vDER will calculate the reference load profile per regulation area	The reference load profile is the first charging profile that the EVSE follows before applying power modulation to provide flexibility	

UC3_035	The vDER will schedule the type 2-3 charging sessions of the EVSE network following a economic criterion if no other grid or RES requests are triggered.	Other requests may be triggered to support the grid, to maximise RES integration or to contribute to the household energy management (V2H)	
UC3_036	Before starting with the charging session schedule processes, the data collection from EVSE should be performed to have historical data and to know the status of the EVSEs.		
UC3_037	The vDER will modulate the power output of his EVSE network to help the DSO with the grid operation		
UC3_038	The vDER will modulate the power output of his EVSE network to maximase the RES integration answering the flexibility requests performed by the RESCOs or Aggregators through the STaaS/VPP		
UC3_039	vDER allows setting a pricing model for booking an EVSE: reservation cost, cancellation cost, extending booking cost,....	Booking requires the implementation of related price aspects.	
UC3_040	vDER has a console at an EVSE or a hub of EVSE's	When vDER manages a hub of EVSE's, instead of one, a separate console for welcoming, authenticating and directing users is possible, as opposed to every EVSE having their own interaction screen.	
UC3_041	EVSEs can be grouped as one hub	All EVSE on one site, can be grouped as a hub, and managed together accordingly (one console at the site for user interaction, booking,...)	

UC3_042	vDER should allow grouping EVSEs in one hub, sharing the same location	EVSE's on the same location, should be managed together to increase efficiency in their use (e.g. by booking).	
UC3_043	The Forecasting module will connect with weather data forecasts in order to estimate the upcoming demand		
UC3_044	Energy Storage should be used in order to provide flexibility to the demand response		
UC3_045	A central data management unit should be responsible for capturing real time and historical information required for the extraction of the different profiling types	Big Data Repository to provide access on the data streams required by the profiling engine	
UC3_046	Input values (capacity, response capability, location, time) will set the configuration parameters for the analytics process	Input parameters for the analytics process	
UC3_047	Algorithms should strive for maximal lifespan of battery		
UC3_048	Algorithms for selection of best suited combinations of storage units have to consider type of storage, availability of storage system, power capability, remaining energy content, current aging status, efficiency, demand and production forecasts		
UC3_049	Tool must collect and process data from storage systems		
UC3_050	Tool must be linked to Energy Market		

UC3_051	Algorithms have to define if participation of storage systems in energy market/energy transfer is beneficial or not. (Aging of system+loss of energy+unavailability during period vs. income)		
UC3_052	Not only energy transfer to/from energy market but also to/from other storage systems should be considered		
UC3_053	Aggregated data from storage systems should be anonymised		
UC3_054	Tool must include billing function. If necessary data transfer with smart meters has to be established as well		
UC3_055	Tool should integrate Renewable Energy Generation		
UC3_056	The tool should notify the user for the uses		
UC3_057	The tools needs to take into account the needs from the demand response module		
UC3_058	VNF shall allow both short-term and long-term contracts	The needs for energy storage and production may range from minutes to months	
UC3_059	The system must be able to measure the unit's response and verify its operation is consistent with the acknowledge event		
UC3_060	The system shall support a minimum number of simultaneous dispatch of control signals to		

	different types of devices		
UC3_061	system should detect and avoid attempted intrusions by unauthorized persons		
UC3_062	The tool should prevent access to data (energy, meteorological, customer contracts, etc.) from unauthorized persons or client applications.		
UC3_063	The tool downtime should not exceed a specific value during upgrade operations		
UC3_064	Decentralized energy generators and/or energy consumers portfolio (including their characteristics)		
UC3_065	Receiving notifications and requests by (DSO) about status of the distribution Grid		
UC3_066	Nominal battery characteristics		
UC3_067	Power and energy capability of the storage system in order to meet the black start requirements		
UC3_068	Implementation of an algorithm that calculates the best option to manage an energy production surplus.		
UC3_069	STaaS/VPP should provide islanding mode in case of a power outage.		
UC3_070	It should support Automated Demand Response.		

UC3_071	Bidirectional communication between DSO and involved energy stakeholders is established.		
UC3_072	Contractual agreements between the DSO and the rest of the actors are in place.	The rules for performing the various transactions should be clearly described.	
UC3_073	The proprietor of the unit (if different from the DSO) has signed a contract with the DSO that describes the conditions that apply regarding the load control actions.	The technical characteristics (e.g. ramping ability, available capacity) of the unit should be known. Furthermore, the notice, frequency and duration events, remuneration/penalties based on ramping ability and accuracy of the response should be specified.	
UC3_074	Reliable calculation of customer response to control signals.		
UC3_075	Characteristics of load control actions (timeframe, triggering events) should be well-established.	The technical characteristics and the constraints of the available resources should be taken into account.	
UC3_076	The resource operator has signed a contract with the DSO that describes the conditions that apply regarding the load control actions	The contract describes in detail the notice, frequency and duration of the events as well as remuneration/penalties for conformance/non-conformance to the control actions.	
UC3_077	The Prosumers, EVs and other local energy resources have signed a contract with the resource operator for load control actions.	The contract describes in detail the notice, frequency and duration of the events as well as the remuneration for participation/conformance to control signals and penalties for non-conformance.	
UC3_078	Actors portfolio (characteristics) is known.	The specific characteristics should be	

		available per actor/customer. These include the technical (capacity, the ramping ability) and economic characteristics per actor/customer.	
UC3_079	The optimization algorithm is robust.	The optimization algorithm should be able to produce a solution in all cases with only minor exceptions. For these exceptions, a backup plan should be in place (e.g. by using less advanced algorithms).	
UC3_080	The optimization algorithm produces reliable results.	Depending on the type of the problem and of the solver used, the status report of the solver should indicate one of the acceptable termination states, while the solution is reached within the pre-specified tolerances.	
UC3_081	Adequate amount of pieces of equipment for monitoring the distribution network is installed.	The observability analysis is used to determine the minimum number of network points for installing the necessary monitoring equipment.	
UC3_082	Regulation allows islanded operation of part of the distribution network.	Operating part of the distribution network in island mode is only possible if so prescribed by the regulatory framework.	