*Smart system of renewable energy storage based on **IN**tegrated E**V**s and b**A**tteries to empower mobile, **D**istributed and centralised **E**nergy storage in the distribution grid*

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WP4
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Abbreviations and Acronyms

*List of abbreviations **only** related to this deliverable.*

Please complete the following proposed one, deleting the unnecessary items.

Acronym	Description
BMS	Battery Management System
CA	Consortium Agreement
CON	consumers
DER	Distributed energy resources
DoA	Description of Action (annex I of the Grant Agreement)
DSO	Distributor System Operator
EC	European Commission
EV	Electric Vehicle
GA	Grant Agreement
GPRS	General Packed Radio Service
GSM	Global system for Mobile
IEC	International Electrotechnical Commission
IED	Intelligent Electrical Device
IEEE	Institute of Electrical and Electronics Engineers
LAN	Local Area Network
PC	Project Coordinator
PCC	Project Coordination Committee
PO	Project Officer
PV	Photo voltaic Panel
QM	Quality Management
RTU	Remote Terminal Unit
SCADA	Supervisory Control And Data Acquisition
SGAM	Smart Grid Architecture Model

TCC	**Technical Coordination Committee**
TCP	**Transmission Control Protocol**
TL	**Task Leader**
ToC	**Table of Contents**
UMTS	**Universal Mobile Telecommunications System**
WAN	**Wide Area Network**
WP	**Work Package**
WPL	**Work Package Leader**

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Executive summary

This deliverable is a part of the **WP7 Communications platform,** in task *T7.1 Communications Specification Plan*.

The deliverable examines the communication requirements of the envisaged INVADE communication Layer establishing the steps and baseline to be followed in the next tasks and WPs related with the Pilot developments, regarding all communications.

The document presents the communication use cases that will be required by the Business Process Layer (BPL) to control all relevant devices involved. The communication use cases shall be based on a high-level architect model known as Smart Grid Architecture Model (SGMA).

The given specifications of the communication protocols shall be the base for the final adoption of the communication protocols in the pilot implementation. The communication protocol for the project will be chosen among the specified options, as depicted in this deliverable D7.1.

This deliverable is directly related to the work packages WP4 (Architecture) and WP10 (Pilots) where all the communication protocols are defined and established in this deliverable and WP7 will be used in all the pilot sites.

1 Introduction

Main goal of INVADE project is to establish a smart management system connecting EV charger and Energy Storage device to the cloud system in order to empower mobile, Distributed and centralised Energy storage in the distribution grid. [1]

Tasks in WP 7 aims to provide a full bidirectional communication between underlying Physical Layer (PL) and the Cloud based business Process Layer.

The objective of the task T7.1 is to create plan that contains description of the quality of service and the communication use cases analysed during the task. This involves all the layers from physical devices to the final Cloud software in all the Pilots.

In the following section, we shall go through:

- Architecture
- Communication Specification Plan
- Communication use cases

2 Architecture

In this section, technical requirements for deploying a local market are introduced and the communication protocols that are commonly used in power system and at the same time meets the project needs are described.

2.1 SGAM

It is necessary to distinguish between different levels of communication when discussing the communication specifications. Figure 1 shows the SGAM Architecture which has been defined and treated in WP4:

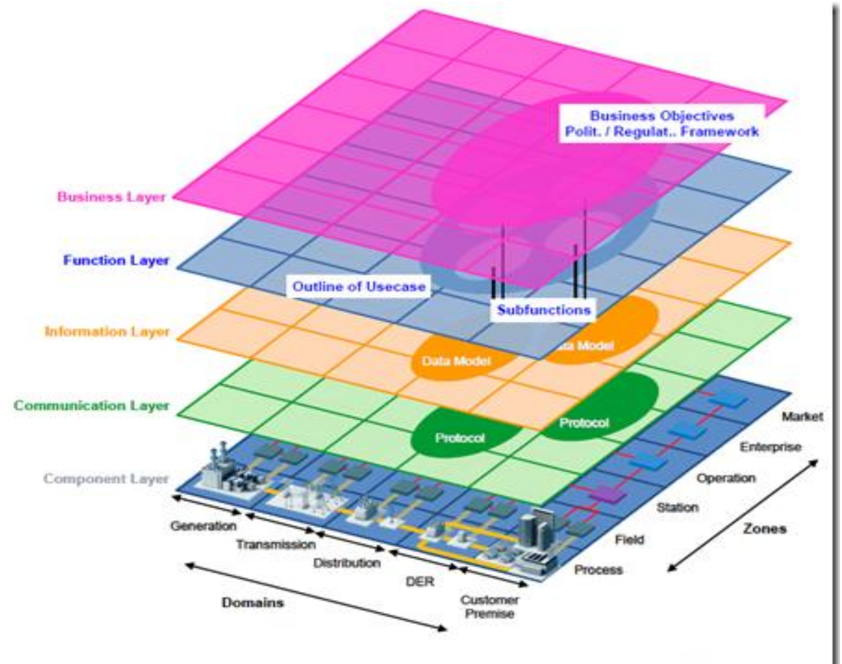


Figure 3 – Smart Grid Architecture Model (SGAM) [Source: SG-CG/M490/C]

Figure 1: SGAM Architecture

The system architecture in INVADE project is based on SGAM architecture which itself is based on different levels.

SGAM is a three dimensional model that allows the representation of the essential elements, participants and interactions in a Smart Grid. It was prepared by the Smart Grid Coordination Group (SG-CG) Reference Architecture Working Group (SG-CG/RA): CEN, CENELEC and ETSI. Using the SGAM nomenclature, the three axis used in the Smart Grid model contains the different zones (the hierarchical levels of power system management), domains (which cover the complete electrical energy conversion chain) and interoperability layers. These interoperability layers are: Business, Function, Information, Communication and Component layers. These zones are: Process, Field, Station, Operation, Enterprise and Market. The domains are: Bulk Generation, Transmission, Distribution, DER and Customers Premises. Each interoperability layer, zone and domain has an identifier (numbers for domains, lower case letter for zones and capital letters for interoperability layers) so as to easily locate it in the three-dimensional representation.

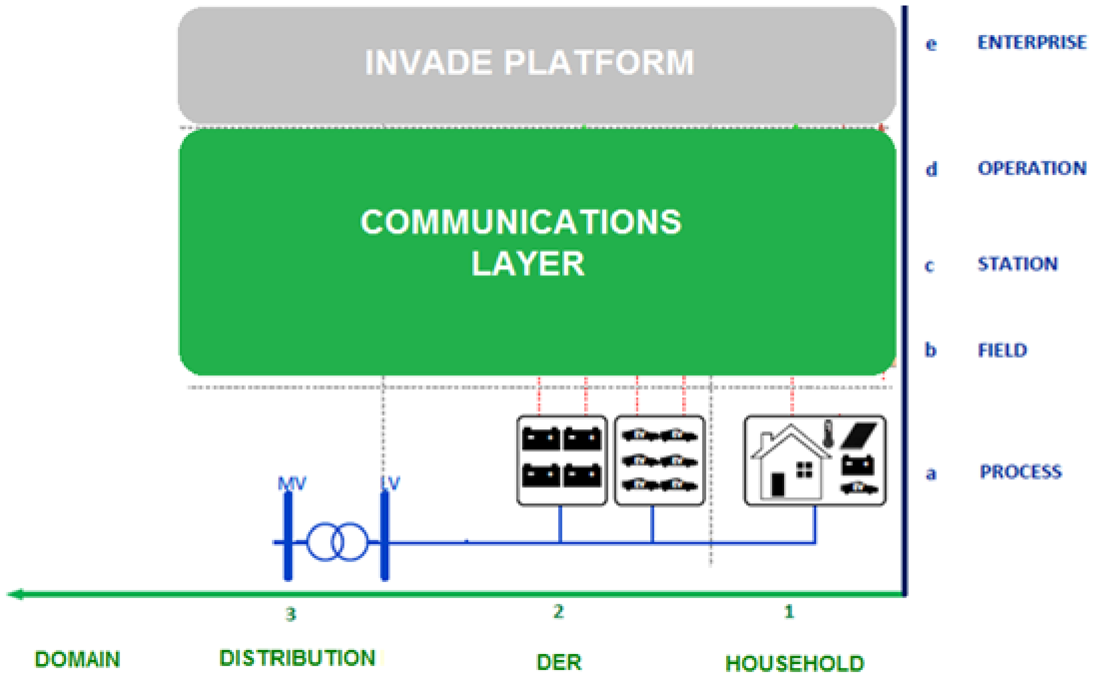


Figure 2: INVADE Communication Architecture based on SGAM

The first level of the architecture (Zone a - Process) is the level where field devices are Located. There are different kind of field devices, such as the equipment in Distributed Resources and devices installed in homes, such as smart meters or home local controllers.

The communication Layer is situated on the second level, which corresponds to zones b, c and d (field, station and operations). This layer defines the data exchange process between the different field devices and INVADE integration Platform. This data will be treated and used by different software applications which are developed in the project apart from the INVADE Platform. (Third Level) (SGAM - e Level: Enterprise).

These applications will connect with the INVADE integrated Platform.

2.2 Communication Layer

There are different types of devices involved in the communication Layer, i.e. Electric Vehicle (EV) charger, Consumer side Photo-Voltaic (PV) generation, Storage in the secondary substation and household devices. Each pilot site shall be a based on a combination of some of these devices.

There will be a need for the communication platform to establish communication between each of the devices and the cloud. In order to achieve this, some standard communication protocols are listed and defined. These communication protocols will be analysed in the next INVADE task. Thereby, the most appropriate communication protocol shall be chosen according to the characteristics of the selected equipment.

2.2.1 Communication protocols

Within the communication layer we will have to reflect on the singularity of the project, which includes different scenarios and pilots.

These pilots, although following the model of architecture SGAM, are composed of different elements and communication protocols between different devices.

A set of protocols most commonly used in the market shall be listed.

In order to standardize and considering the unique nature of each pilot at the same time, we shall a set of protocols most commonly used in the market shall be listed. There protocols are as follow:

2.2.1.1 IEC 60870-5-101

IEC 60870-5-101 [IEC101] is a standard for power system monitoring, control & associated communication for remote control, remote protection, and associated tele-communications for electric power systems.

Features

- Supports unbalanced (only master initiated message) & balanced (can be master/slave initiated) modes of data transfer.
- Link address and Application Service Data Unit (ASDU) addresses are provided for classifying the end station and different segments under the same.

- Possibility of classifying the data into different groups (1-16) to get the data according to the group by issuing specific group interrogation commands from the master & obtaining data under all the groups by issuing a general interrogation.
- Cyclic & Spontaneous data updating schemes are provided.
- Facility for time synchronization

2.2.1.2 IEC 60870-5-104

IEC 60870-5-104 (IEC 104) protocol is an extension of IEC 101 protocol with the changes in transport, network, link & physical layer services to suit the complete network access. The standard uses an open TCP/IP interface to network to have connectivity to the LAN (Local Area Network) and routers with different facility (ISDN, X.25, Frame relay etc.) can be used to connect to the WAN (Wide Area Network).

Generally, in energy systems, IEC 104 protocol is used for remote control centre and the IEC 101 protocol is used for communication with field RTU and field devices.

Features

- The IEC 60870-5-104 protocol defines the use of a TCP / IP network as a means of communication.
    - It is not necessary specific software network in the end systems
    - Facilitates that the end system will be provided with a remote specialist
    - Facilitates the routers provide telecommunications specialists

2.2.1.3 IEC-61850

IEC-61850 protocol is a standard that is used to connect substations IED´s with latencies requirements.

The IEC61850 IEDs get digitalized in the power grid data via process bus and merge units and communicates with each other using substation buses.

Real object-oriented approach for SA:

- Supports standardized device models using names instead of object/register numbers and indexes.
- Standardized Configuration Language (SCL).

- Feature rich with support for functions difficult to implement otherwise

2.2.1.4 Modbus (TCP or RS-485)

Modbus is a serial communication protocol, and it is now a common available means of connecting industrial electronic devices.

Modbus is often used to connect a supervisory computer with a Remote Terminal Unit (RTU) in Supervisory Control And Data Acquisition (SCADA) systems. Many of the data types are named after its use in driving relays: a single-bit physical output is called a *coil*, and a single-bit physical input is called a *discrete input* or a *contact*. [Ref]

Features

- The main reasons for the use of Modbus in the industrial environment are:
    - Developed with industrial applications in mind
    - Openly published and royalty-free
    - Easy to deploy and maintain
    - Moves raw bits or words without placing many restrictions on vendors
- There are many modems and gateways that support Modbus, as it is a very simple protocol. Some of them were specifically designed for this protocol. Different implementations use wireline, wireless communication (i.e. GPRS). One of the more common designs of wireless networks makes use of Mesh networking.

2.2.1.5 OCPP

The Open Charge Point Protocol (OCPP) is an application protocol for communication between EV charging stations and a central management system, also known as a charging station network, similar to cell phones and cell phone networks.

The protocol is an initiative of the E-Laad foundation in the Netherlands. Its aim was to create an open application protocol which allows EV charging stations and central management systems from different vendors to communicate with each other. It is in use by many vendors of EV charging stations and central management systems all over the world.

OCPP also makes it easier to create a **large-scale**, visible network that uses a range of different charging stations since there is a requirement for only one operating system. Proponents of OCPP also cite a reduction in development costs since software designed to provide additional functionality will only need to be developed once and not several times to fit with each individual operating system. Finally, OCPP will ease interoperability across the United States, and elsewhere, and minimize remedial work on systems. [Ref]

2.2.1.6 OSCP

OSCP 1.0 was officially released in May 2015.

The protocol can be used to communicate a 24-hour prediction of the local available capacity to the Charge Spot Operator. The Service Provider will fit the charging profiles of the electrical vehicles within the boundaries of the available capacity.

It is a protocol between charge point management system and energy management system of the site owner or the DSO system. Therefore, it is both applicable for site owners and DSO's.

The DSO or site owner produces a forecast of the available capacity over time and sends this to a back office that controls the charge spots. The two most important messages within OSCP are:

1. Information about available capacity for flexible loads
2. The possibility to return capacity or ask for extra

Other advantages are:

- Open protocol
- Lower costs for implementing charge-infra
- Optimal usage of the power net

2.2.1.7 OCPI

Open Charge Point Information protocol (OCPI) v2.1.1. is officially released in June 2017.

This protocol is used for a unified communication between charge point operator and service provider to facilitate:

- Roaming (peer to peer or via hub)
- Information about the location and availability of charge stations
- Information about the cost of charging (before charging, during and after)
- Automatic processing of billing via charge data records (CDRs)
- Remote access to charge stations
  - For remote charging via app
  - For ad hoc payment of charging (without subscription at service provider)
  - For sending EV driver charge profile to the charge point operator to support Smart Charging

The OCPI protocol is important in this project as it is the main link to send Smart Charging profiles to the operator to control the charge session. And OCPI takes care of sending real time charging session info and transactions to service providers to keep track of the energy usage during the charge process. The collection of generated CDRs can be used for analyzing the usage of chargers and that way it can be used for prediction of charging and energy usage in the future. Finally, OCPI can be used to send static and dynamic information about location and availability of charge stations, including info about max power consumption; this is useful to determine how much energy might be needed in a certain area.

2.2.2 Consumer Premises Networks

2.2.2.1 Wi-Fi (WLAN communication)

The Wi-Fi protocol is commonly used in a Business Area Network (BAN) to connect the end devices to the smart meter. It can be also used in residential market for the same purpose.

The great success of WLAN is in its ability to communicate using open frequencies. However, it is necessary to keep in mind that regulation on managing the spectrum varies from country to country.

Advantages

- Adds flexibility to network structures by reducing connections between cables.
- Uses electromagnetic waves to transmit and receive data over radio waves medium.
- They combine data connectivity with user mobility contribute.

Disadvantages

- Higher loss-rates due to interference
    - emissions of, e.g., engines, lightning
- Lower security, simpler active attacking
    - radio interface accessible for everyone, base station can be simulated, thus attracting calls from mobile phones
- Always shared
    - medium secure access mechanisms important

2.2.2.2 PLC

PLC communication has grown and changed over the many years since the controller's inception decades ago. Industrial needs and technological advances have kept PLC communication evolving.

All of these communications require two things:

- A physical connection or layer, which is the wiring and connection components, and
- A shared protocol, which is the common language allowing each device to understand what the bits and bytes in the communication messages mean.

PLC can be used in different areas. One of the use is the communication between the smart meter and Home Area Network (HAN). It is also used for communication between a concentrator and smart meters.

2.2.2.3 Zigbee

Zigbee is based on IEEE 802.15.4 standards. More precisely it is defined as a Personal Area Network (PAN), and therefore it is mostly used in low power, short range application.

Network topologies

ZigBee supports three network topologies:

- Star topology: The coordinator is in the centre.
- Topology in tree: the coordinator will be the root of the tree.
- Mesh topology: at least one of the nodes will have more than two connections.

The most interesting topology is the mesh topology. This allows that if, at a given moment, a node fails and falls way, can continue communication between all other nodes because all the paths are redone. The management of paths depends on the coordinator.

Zigbee is mostly used at household level connecting smart meters and smart home devices.

2.2.3 Neighborhood Area Network

2.2.3.1 GSM

GSM is a cellular network, which means that cell phones connect to it by searching for cells in the immediate vicinity. There are five different cell sizes in a GSM network—macro, micro, pico, femto, and umbrella cells. The coverage area of each cell varies according to the implementation environment. GSM is a public, non-proprietary standard. This makes it very powerful GSM internationally communicating over 170 countries and covering not very accessible land areas.

GSM is commonly used for communication between smart meters and concentrators. It is also used to connect concentrator and Data Centers/ Head End Systems.

2.2.3.2 GPRS

The actual transmitting data trend at higher speeds led to the emergence of a development within GSM, General Packet Radio Service (GPRS).

GPRS extends the GSM Packet circuit switched data capabilities and makes the following services possible:

- SMS messaging and broadcasting
- "Always on" internet access
- Multimedia messaging service (MMS)
- Push to talk over cellular (PoC)
- Instant messaging and presence—wireless village
- Internet applications for smart devices through wireless application protocol (WAP)
- Point-to-point (P2P) service: inter-networking with the Internet (IP)
- Point-to-Multipoint (P2M) service: point-to-multipoint multicast and point-to-multipoint group calls

GPRS is commonly used for communication between smart meters and concentrators. It is also used to connect concentrator and data centre/ head end systems. In some cases, PLC communication is not possible due to physical difficulties. GPRS is the best solution to send metering data to the head end system.

2.2.3.3 WiMAX

WiMAX stands for Worldwide Interoperability for Microwave Access.

The WiMAX technology offers around 72 Mega Bits per second without any need for the cable infrastructure.

WiMAX us commonly used in the communication between RTU´s, devices and concentrators inside substations. In some cases, it might not be the best solution to connect to the end systems due to the distance issues.

WiMAX technology is based on Standard IEEE 802.16. WiMAX promises the availability of broadband service to residences and businesses that are currently under-served, including low-density rural locations in developed countries, as well as in emerging markets. It will also provide a flexible solution to end users for whom current provisioning timeframes are prohibitive, or for whom wired infrastructure is not available. WiMAX technology represents an expanding opportunity for service providers, equipment manufacturers, and chipset suppliers operating in both licensed and license exempt bands.

2.2.4 Wired communication media

Wired communication are commonly used inside CPN or Substation area, connecting different devices with RTU or concentrators or connecting the RTU to the Network connected to the acquisition software.

2.2.4.1 Twisted pair cable copper (RS-485)

This media is commonly used in a substation and secondary substation level. RTU´s and field devices use RS-485 for the communication.

The necessary equipment and the cable itself are robust and their price is not high. Furthermore, the installation is simple, being able to provide even wide wires within submarine power cables. RS485 specification indicates a maximum distance of 1,200 meters to 4 Mb/s. The disadvantages of using copper connections are that there is no inherent isolation between devices and drivers used for communication and they will be susceptible to be affected by transient voltage levels.

2.2.4.2 Optical fiber

Fiber optic cables provides a high bandwidth communication for longer distances. Also they have the advantage of electrical isolation and immunity to electrical noise. There are two types of fibre optic cables available: single-mode optical fiber and multi-mode.

Bandwidth and distance that can be achieved with laser devices based communication and fiber optic cables using single-mode are greater than those achieved with communication devices based LED cables and multi-mode fiber. The bandwidth that can be obtained depend on the type of communication device used, being those with a higher price those which can obtain a higher bandwidth. For single-mode cables fiber, the bandwidth would be up to 2 Gb/s over distances up to 100 km. With fiber optic cable multi-mode, you can achieve bandwidths of up to 100 Mb / s for distances up to 6 km.

Like RS-485, Optical fiber is also used to connect field devices and RTU´s. It can also be used to connect to the Head End Systems.

The disadvantages of fiber optic cables are having less robustness compared to copper and specialized tools required to perform the connection, which was not necessary with twisted pair cables.

2.2.4.3 Ethernet

Ethernet is a family of computer networking technologies commonly used in Local Area Networks (LAN), Metropolitan Area Networks (MAN) and Wide Area Networks (WAN).

The original 10BASE5 Ethernet uses coaxial cable as a shared medium, while the newer Ethernet variants use twisted pair and fiber optic links in conjunction with hubs or switches. Over the course of its history, Ethernet data transfer rates have been increased from the original 2.94 megabits per second (Mbit/s) to the latest 100 gigabits per second (Gbit/s). The Ethernet standards comprise several wirings and signalling variants of the OSI physical layer in use with Ethernet.

Ethernet is also used to connect field devices to the head en systems.

2.3 Communication with INVADE Cloud Platform

Communication between the communication layer and INVADE platform will be based on pure software communication.

Despite all the possibilities for this achievement, the one that is the most approved for all the partners is the Web Service connectors. Apart from the method, which is already clear, it needs to be defined the types of messages, format, data, that will be part of the next tasks and deliverables.

2.3.1 Web Service

A **Web service** is a method of communication between two electronic devices over a network. It is a software function provided at a network address over the Web with the service *always on*.

Different software applications developed in different programming languages are often executed different platforms. These applications can use web services to exchange data on computer networks like the Internet. Interoperability is achieved by adopting open standards. OASIS and the W3C organizations are the committees responsible for the architecture and regulation of Web services. To improve interoperability between different implementations of Web services has created the WS-I organization responsible for developing profiles to define more fully these standards. It is a machine that responds to requests from Web clients and sends the requested resources.

These are some different web services that use mark-up languages:

- JSON-RPC
- JSON-WSP
- Web template
- Web Services Description Language (WSDL) from the W3C
- Web Services Conversation Language (WSCL)
- WS-Metadata Exchange
- XML-RPC - XML - Remote Procedure Call

3 Communications Specification Plan

To determine the characteristics of the layer we must go into details of the equipment and systems that will be part of the entire system in order to perform an analysis as complete as possible counting on the different architectures on pilot sites. Every pilot will use different protocols and equipment although the final data will be sent to the common INVADE platform.

3.1 Defining the system architecture

For each Pilot, communication have to be identified in order to establish the procedures for the information exchange.

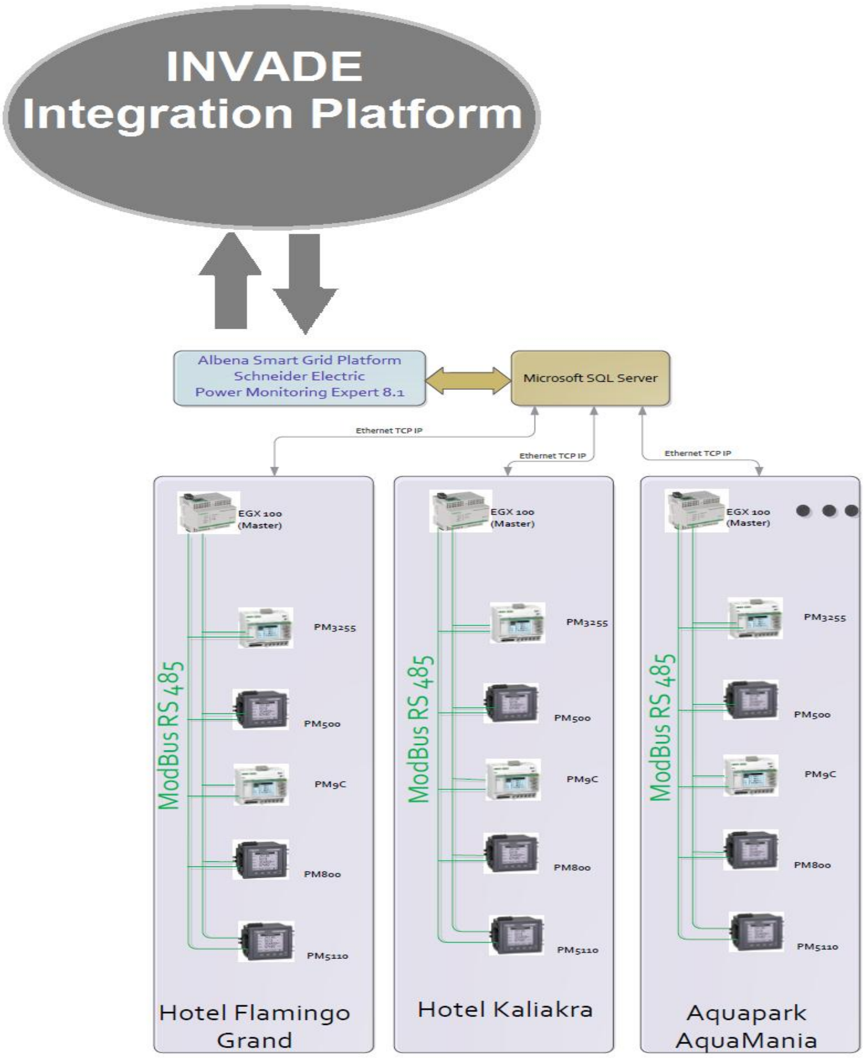
The general devices involved in the pilots are:

a. **Household Resources:** including storage, electric vehicle chargers and controllable loads.
b. **RTU**: Electric data acquisition and control device that connects on real time with the SCADA and the DER Controllers.
c. **SCADA**: Software acquisition and control
d. **Mete**r: Smart meter
e. **INVADE Platform**: Cloud Software for collecting information from head end systems and Smart devices and communicating with market tools (billing programs, customer programs, etc.)

f. **Local controller**: Communicates with the resources and consumers, RTU or INVADE system
g. **Home automation cloud:** Cloud App for collecting information from Household resources and communicating with INVADE platform.

3.1.1 Bulgaria

Bulgaria Pilot will join both the elements involved in a secondary substation corresponding with different hotels with new technologies, such as PV generation or storage. All the new elements will be connected to main grid and SCADA and will be connected to the INVADE Integration platform.



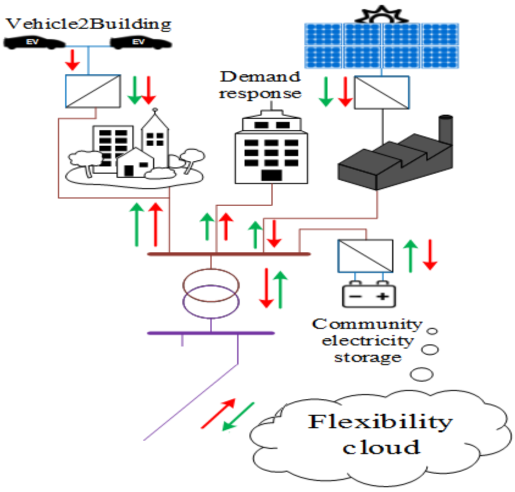


Figure 3: Bulgarian Pilot Architecture

a. Local Smart Meter (PMx) ←→ RTU (EGx100)

The communication protocol of the link is given by the capacities of IED equipment. They must be able to establish communication using Modbus protocol.

b. RTU ←→ SCADA

The RTU will use a standard protocol like Ethernet TCP to establish real time connection with Albena Smart Grid Platform (SCADA) for power monitoring. At the same time, the data stored in a SQL database.

c. SCADA ←→ INVADE Platform

To establish communication between the SCADA system and INVADE Integration Platform, Web services or a similar integration service shall be used.

For the devices like Storage, EV or PV panels, the architecture shall be based on the same structure, using controllers, meters and RTU to gain control over these new devices.

During the project execution time the communication plan shall be updated according to the final pilot deployment.

For the rest of new developments, Storage and PV panels, the architecture shall be the same with the same type of RTU and meters.

3.1.2 Spain

Spain pilot will include secondary substation devices, such as batteries, transformers, and the possibility to add users with PV generation and EV chargers.

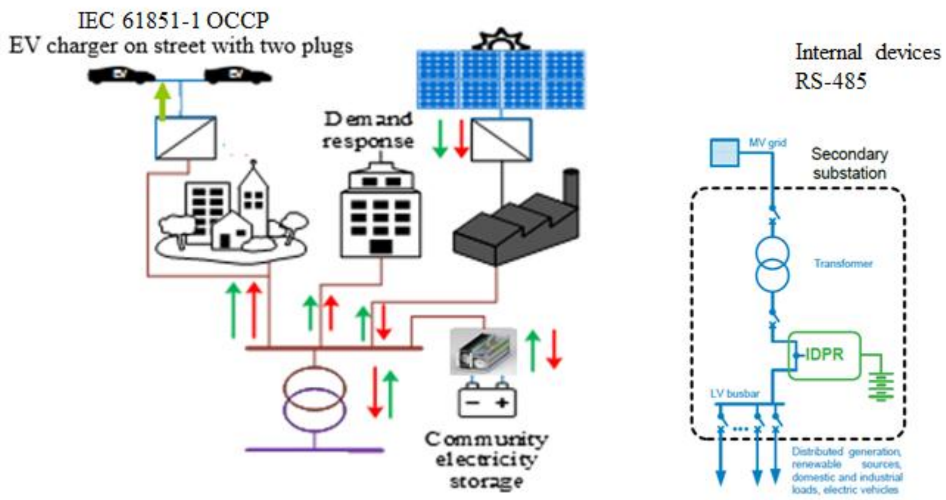


Figure 4: Spanish Pilot Architecture

a. SCADA ←→ RTU

The communication between RTU´s and the SCADA in Estabanell will be using the standard IEC60870-5-104 with the proper profile from Estabanell.

b. RTU ←→Analyzer, Protections and Field Devices

The communication between the RTU and the different devices installed in secondary substation and electric network, will use the MODBUS RS-485.

c. RTU ←→ *Power electronics*

The communication protocol is not defined at the moment. Modbus RS-485 is currently deployed as a medium for communication.

d. Power electronics ←→ BMS

Depending on the final solution the protocols will be selected in the next months.

e. SCADA ←→ INVADE Platform

To establish communication between the SCADA system and INVADE Integration Platform, Web services or otherwise (JSON, etc.) will be used or a similar integration services.

3.1.3 Netherlands

Netherland Pilot will be focused on a residential and Building management, including home resources, EV and Storage, always focusing on EV as most important part of the Pilot.

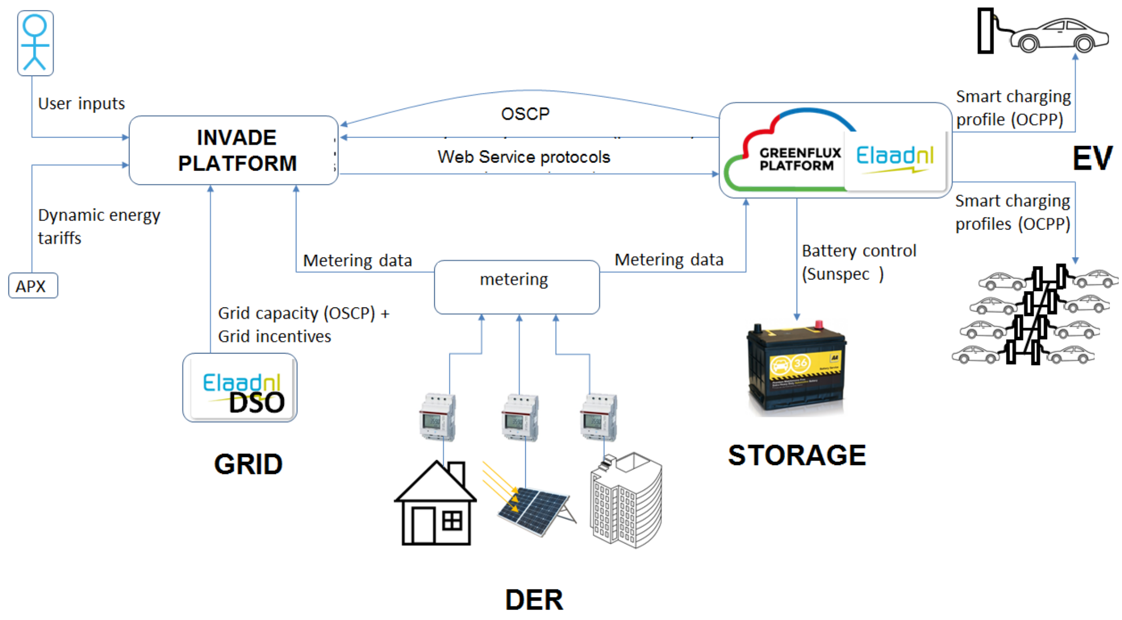


Figure 5: Netherlands Pilot Architecture

The communications involved in the Netherlands pilot are:

a. DER ←→ SM (Smart Meter)

All the devices connected at household level shall be connected to the smart energy meter that is in charge of sending the energy information. This data can be sent to both the INVADE platform and the Collector system (Greenflux / Elaad) using device specific protocols.

b. SM ←→ INVADE Platform

Smart Meter will send the energy information to the INVADE cloud platform.

c. SM ←→ Greenflux/Elaad Cloud Software

Smart Meter will send the energy information to the Greenflux cloud platform.

d. STORAGE ←→ Greenflux/Elaad Cloud Software

Storage devices depends on the final solution that shall be adopted during the project execution. Communication protocols shall be defined accordingly.

e. EV CHARGERS ←→ Greenflux/Elaad Cloud Software

EV chargers will be connected with the Greenflux/Elaad Cloud Software using the standard protocol OCPP protocol (OCPP 1.6 or Higher).

Via OCPI static and dynamic information about chargers and charge profiles are exchanged with the Greenflux cloud software.

f. Greenflux/Elaad Cloud Software←→ INVADE Platform

The connection between these two platforms will be using standard protocols and communications services (Web services, such as JSON messages, etc.), possibly in the form of OSCP.

OCPI is used to exchange charge profiles and charge station information between Greenflux/Elaad cloud system and the INVADE platform.

3.1.4 Norway

Norway pilot will be based on Household level, where all the controllable resources shall be included, as well as residential PV generation or EV charging.

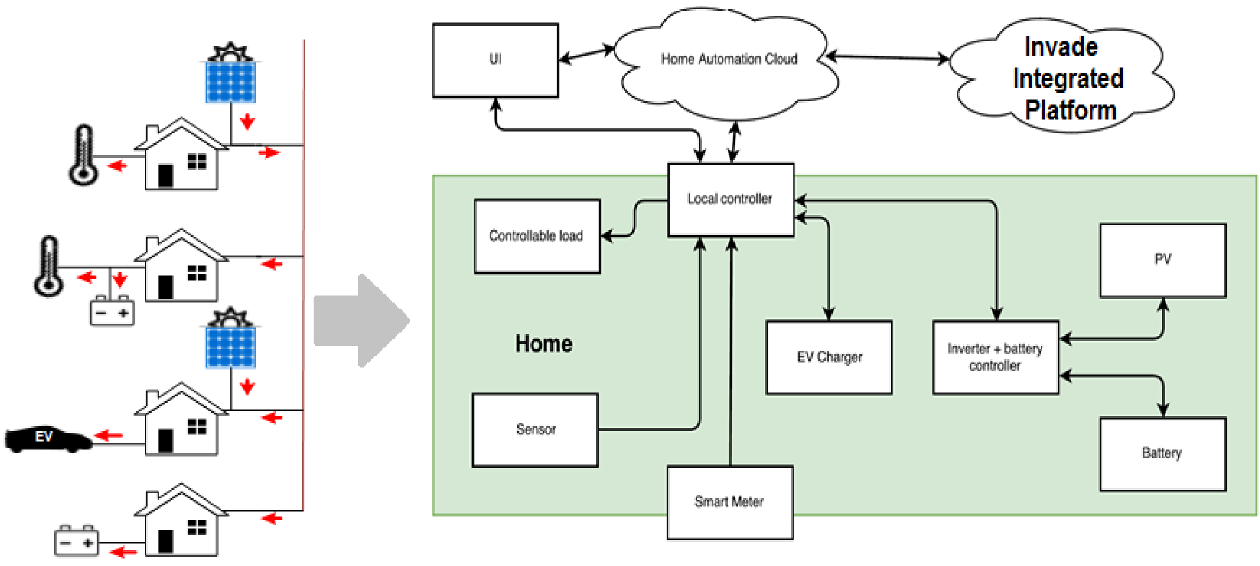


Figure 6: Norwegian Pilot Architecture

a. DER ←→ SM (Smart Meter)

All the devices connected at household level shall be connected using specifics protocols to a local controller which is the one in charge of sending the energy information to the Home Automation cloud app.

b. SM ←→ INVADE Platform

Smart Meter will send the energy information to the INVADE platform

c. SM ←→ Home Automation Cloud Software

Smart Meter will send the energy information to the Home Automation cloud platform

d. STORAGE ←→ Home Automation Cloud Software

Storage devices depends on the final solution that shall be adopted during the project execution. Communication protocols shall be defined accordingly.

e. EV CHARGERS ←→ Home Automation Cloud

EV charger shall be connected using the standard protocol OCPP protocol with the Home Automation cloud Software

f. Home Automation cloud ←→ INVADE Platform

Both cloud applications shall be connected using Web services technology.

3.1.5 Germany

German Pilot will focus its work on the development of the smart grid solutions over secondary substation, including PV generation, and Storage. Households with Controllable devices will also be part of the pilot.

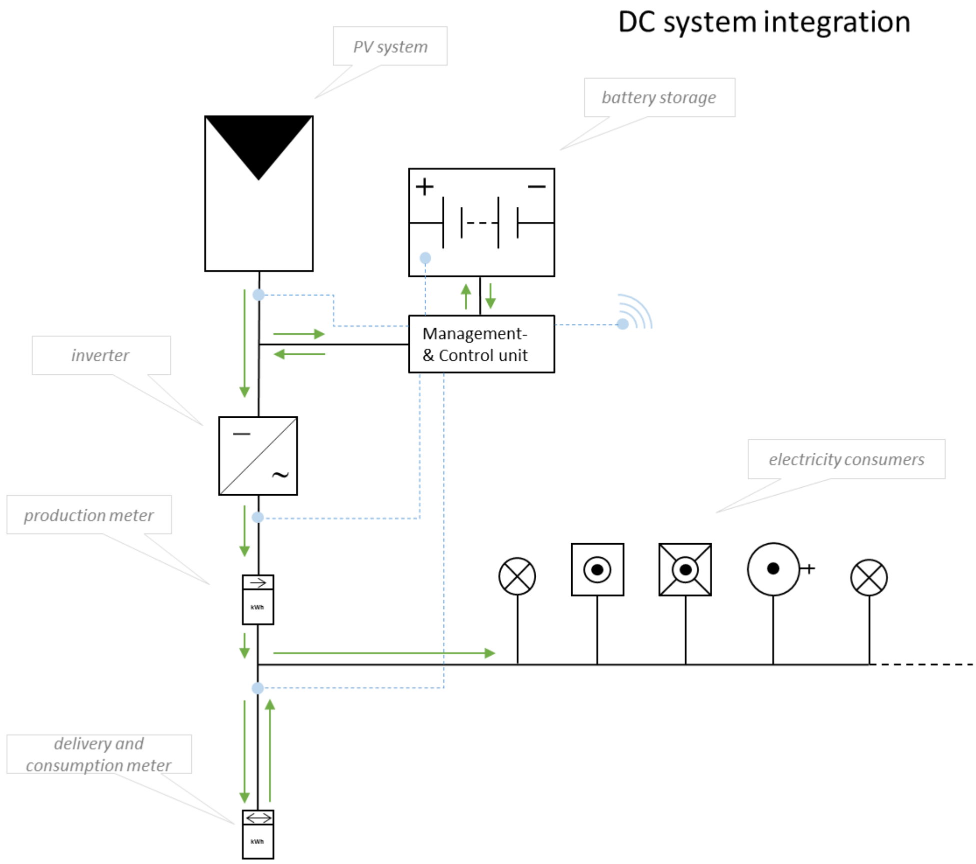


Figure 7: German Pilot Architecture

a. Electricity consumers ←→ Smart Meter (Delivery and Consumption meter)

All the devices connected at household level shall be connected using specific communication protocols to an energy smart meter that shall send the energy information to the INVADE cloud platform.

b. Production Meter (PM) ←→ Smart Meter (SM)

Smart Meter will communicate and receive the information from the Production which is the one connected to the PV and Storage System

c. PM ←→ Inverter

Energy information will be exchanged between PM and Inverter

d. Inverter ←→PV System

Energy information will be exchanged between PM and Inverter. Inverter shall be controlled by the INVADE Cloud Platform.

e. Storage←→ Inverter

f. Storage ←→ Management INVADE Platform

A storage device, such as battery, shall be connected to a Gateway. This Gateway shall be connected to the INVADE Cloud Platform.

g. INVADE platform ←→ Smart Meter (SM)

Finally, communications between SM and INVADE platform shall be achieved in order to establish a bidirectional communication for sending and receiving electrical information and control signals.

4 Communication Use Cases

The communication use cases (UC) are the explanation of the minimum information exchanged between the INVADE integration Platform and the different actors involved in the Communication Layer.

Use cases are limited to communication layer environment and they don´t take into account the external agents that are not involved in it directly (end users, business users, etc.).

Electrical state variables are needed from all agents connected to the grid and they are defined as:

- Active power
- Reactive power
- Voltage in the connection point
- Current in the connection point
- Etc. (it is needed to be defined during the execution time)

There are different use cases, one for each type of agent:

- **EV charging station**
- **Storage**
- **Generation**
- **Household**

The following sections describe each UC.

4.1 EV charging station

Use Case ID:	UC-1-EV_Ch
Use Case Name:	EV charging station communicating with the INVADE Integration Platform
Actors:	- EV charging station/point - INVADE Integration Platform

	- Cloud Platform (Greenflux / Lyse / Estabanell)
Description:	This UC describes the information exchanged between the INVADE platform and the EV charger (EV_Ch). The EV_Ch has to send the information to the INVADE platfor using another software (Greenflux in Netherlands or Home automation cloud in Norway). According to the charger capabilities, the system can: - Receive active power consumed or generated - Receive reactive power, inductive or capacitive - Read other variables.
Pre-conditions:	- EV owner parks in the EV_Ch and plug it. - The owner identifies its needs and is authorised - EV owner has established the needed contract with its conditions - The EV_Ch is connected to the main supply
Post-conditions:	During the charge or discharge: - The EV_Ch modifies its energy consumed/generated - The EV_Ch modifies its power factor
Information exchanged:	INVADE Platform → Charger - Electrical state variables set-points Charger → INVADE Platform - Electrical state variables measurements - Charging power - Charging range capacity
Exceptions:	- No valid identification - No communications available
Assumptions:	- The EV owners will have an ID card to access the charger functionalities. - The charger dashboard will permit to access other external EV owners with their credit card. - The EV owner will send its requirements through a dashboard in the charging point or through its mobile phone.

Table 1: EV charging station use case

4.2 Storage

Use Case ID:	UC-2-STO
Use Case Name:	Storage communications
Actors:	- Storage unit (Battery and Storage management controller) - INVADE Platform - Meter - RTU - SCADA (optional depending on the Pilot Site)
Description:	This UC describes the information exchanged between the INVADE platform and the Storage unit (STO). The STO has to communicate with the INVADE platform and local SCADA´s According to the storage unit capabilities, INVADE platform can: - Modify the active power consumption or generation

	- Modify reactive power, inductive or capacitive - Maintain the voltage and frequency in the connection point - Change and read different variables.
Pre-conditions:	- The STO is connected to the grid - The STO unit is connected to the CP - The STO unit has established the needed contract previously with its conditions - The STO is available
Post-conditions:	During the charge or discharge: - The STO modifies its energy consumed/generated - The STO modifies its power factor - The STO gives grid support contributing to voltage control - The STO gives grid support contributing to frequency control
Information exchanged:	INVADE → Storage - Electrical state variables, set-points Storage → invade - Electrical state variables, measurements - State of charge - Lifespan - Temperature - Real capacity - Charge rate
Exceptions:	- No valid identification - No communications available
Assumptions:	- The storage system can provide the information required - The storage can control its active and reactive power - The storage can give support contributing to voltage and frequency control.

Table 2: Storage use case

4.3 Photovoltaic Generator

Use Case ID:	UC-3-GEN
Use Case Name:	Generator communications with INVADE platform
Actors:	- Generator unit - INVADE Platform - Inverter - Local controller
Description:	This UC describes the information exchanged between the cloud INVADE platform and the Generator unit (GEN). According to the GEN unit capabilities, INVADE can: - Modify the active power generation - Modify reactive power, inductive or capacitive - Maintain the voltage and frequency in the connection point
Pre-conditions:	- The GEN unit is connected to the grid - The GEN unit is connected to the CP - The GEN unit has established the needed contract previously with its conditions - The GEN unit is available

Post-conditions:	- The GEN modifies its energy generated - The GEN modifies its power factor - The GEN gives grid support contributing to voltage control - The GEN gives grid support contributing to frequency control
Information exchanged:	INVADE → Generation unit - Electrical state variables set-points Generation unit → INVADE - Electrical state variables measurements - Weather information - Generation capacity over the maximum
Exceptions:	- No valid identification - No communications available
Assumptions:	- The generation unit can provide the information - The generation unit can control its active and reactive power - The generation unit can give support contributing to voltage and frequency control.

Table 3: Generator use case

4.4 Household

Use Case ID:	UC-5-CON
Use Case Name:	Household electricity consumers communications with INVADE
Actors:	- Household - INVADE - Local controller – Smart Meter
Description:	This UC describes the information exchanged between the INVADE and the consumer (CON) at household level, including different electricity loads inside households. The consumer receives set-points from the INVADE platform and could have different types of resources: storage, generation, demand side management, electric vehicle,etc. According to the CON resources capabilities, INVADE can: - Modify the active power produced/consumed - Modify reactive power, inductive or capacitive
Preconditions:	- The consumer is connected to the grid - The consumer is connected to the CP - The consumer has established the needed contract previously with its conditions
Post-conditions:	- The CON modifies its energy consumed/generated - The CON modifies its power factor -
Information exchanged:	INVADE→ Consumer - Electrical state variables set-points of all resources Consumer → INVADE - Electrical state variables measurements of all resources - State of charge of EV - State of charge of Storage

	- Lifespan of Storage - Room temperature - Outside temperature - Capacity of deferrable loads - Generation capacity over the maximum
Assumptions:	- The CON can provide the information - The CON can control its active and reactive power

Table 4: Consumer use case

5 Conclusions

The report has been aimed at exploring the most adequate communication protocol choices, considering the existence of a wide variety of products, protocols and elements well suited to be deployed in the local markets.

The work carried out will allow focusing on some more specific requirements in later stages of the project, which will then be further analysed and treated in a deeper way.

Among all the possibilities analysed, the characteristics of the systems that shall be installed in different pilots will be chosen in accordance with the best options in terms of technical, economic and pilots' dimensions and objectives.

The final adoption of the specific multi-layer communication protocols in each implementation will always be coherent with an established architecture, and based upon the proposed standard protocols. This will be based on the agreement between WP7 and WP10 partners involved in all the Pilot developments in Spain, Germany, Norway, Bulgaria and Netherlands.

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