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Smart Grid Interoperability Laboratory

Annual Report 2019

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Contents

Abstract

Smart Grid Interoperability Laboratory – Annual Report 2019

The Smart Grid Interoperability Laboratory in Petten was inaugurated on 29 November 2018. The Smart Grid Interoperability Laboratory is designed to foster a common European approach to interoperable digital energy, focussing on the smart home, community and city levels. The facility in Petten is part of a larger activity of the JRC, as the science and knowledge service of the European Commission, encompassing electric vehicles, smart grids and batteries. The activities in 2019 are highlighted in this report.

Acknowledgements

The authors would like to thank the project leader Harald Scholz for his forward-looking view on integrating interoperability activities from the electric automotive sector. A special thanks goes as well to Philip Minnebo, who has played a significant role in the laboratory's quality and safety related issues. Last but not least nothing would have worked without a strong administrative support from the Unit, i.e. Gerda Gouwens and Dima Petrova.

Authors

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Executive summary

After the opening of the House of the Future in Petten as part of the JRC Smart Grid Interoperability Laboratory (SGIL) at the end of 2018, scientific activities started.

Smart homes are growing into smart communities and smart regions – even smart cities. In the future, we will live in an intelligent digital eco-system, where virtual power plants connect up sustainable energy systems, where electric cars behave as intelligent batteries, and where citizens produce energy as well as consuming it.

In order to achieve an intelligent digital eco-system, all systems need to be able to communicate with each other. They need to be interoperable. With that scope first test series had been undertaken in 2019, which are reported under chapter 4.

As a continuous activity the Laboratory is updated with new innovative digital products when possible. The tailor-made energy management system software is also further developed on a continuous base.

Policy context

The Energy Union set the scene in 2015 for an ambitious EU's positioning concerning energy, climate and clean mobility. Key objectives are the strengthening of the position of citizens while paving the way for innovative business. This approach is necessary to achieve the commitments of the Paris Agreement and the 2030 Energy Strategy, but also to enable the EU e-industry to be at the forefront of the global market. It recognizes the need for an integrated, coordinated and streamlined approach of EU policy and industrial R&D and business development with a global reach.

From the technological viewpoint, one major change is the massive introduction of ICT solutions in the energy field. This process of digitalization will result in an energy system characterised by extensive interconnections and exchanges of data between stakeholders, systems and devices. In this context, the potential of the market cannot be effectively realised if interoperability is not a cornerstone of efforts. Proprietary solutions, mainly if imposed by foreign companies, can greatly hamper the prospects for EU companies, and the empowerment of consumers.

The Tallinn e-Energy declaration[1] of 2017, signed by all Member States, asserted the vast potential for digital solutions in the energy sector and the requirement to ensure full interoperability between systems. The European Commission services are currently preparing both policy initiatives (DG CONNECT and DG ENER) in support of the 'Digitising European Industry' (DEI) strategy[2] and of the Clean Energy for All Europeans package (CEP)[3], and support to interoperability standardisation and testing with a hub of dedicated laboratories by JRC.

In line with this aim the JRC SGIL is prepared to contribute to the interoperability testing of digital solutions for the energy sector.

From e-mobility, to resilience of the energy grid passing via smart homes and grid integration, the SGIL is able to independently assess and support industry developments with respect to interoperability.

Key conclusions

The laboratory had been set-up and inaugurated in the end of 2018. In the coming years some use cases will be developed based on co-operation with industry, academia and research.

[1] https://www.eu2017.ee/tallinn-e-energy-declaration
[2] https://ec.europa.eu/digital-single-market/en/policies/digitising-european-industry
[3] https://ec.europa.eu/energy/en/topics/energy-strategy-and-energy-union/clean-energy-all-europeans

Related and future JRC work

In fact, the new JRC lab in Petten is part of a broader set of interoperability labs. It is connected with many other research facilities, including the Battery Energy Storage Testing facility on the same premises and the European Interoperability Centre for Electric Vehicles and Smart Grids in Ispra.

Quick guide

Chapter 1 gives a short introduction to the theme.
Chapter 2 describes the EC policy relevance, the motivations and the benefits for all stakeholders.
Chapter 3 describes the laboratory.
Chapter 4 reports about the activities related to the laboratory
Finally, conclusions are drawn in Chapter 5.
Annex

1 Introduction

Smart homes and communities are benefiting EU citizens. Our houses are quickly becoming smart homes, with smart thermostats, domestic appliances and security systems activated by apps on our smartphones. However, this is just the beginning. Smart homes are growing into smart communities and smart regions – even smart cities. In the future, we will live in an intelligent digital eco-system, where virtual power plants connect sustainable energy systems, where electric cars behave as intelligent batteries, and where citizens produce energy along with consuming it.

In order to achieve an intelligent digital eco-system, all systems need to be able to communicate with each other. They need to be interoperable. But as citizens, how do we know if the appliances we buy are compatible; as investors and producers, what gives us the confidence to invest in specific products and to design new components?

The European Commission has launched several initiatives for making interoperability a reality, such as:

- Various initiatives within the Transatlantic Economic Council (TEC);
- Mandate to the European Standardisation bodies on standards for smart grids and smart meters;
- Energy Union and Clean Energy for All Europeans policy packages;
- High level Meeting "Interoperability to create the Internet of Energy;"
- Calls in Horizon 2020 in the Pillar of Industrial Leadership.

At JRC-Petten, we offer to stakeholders a laboratory facility to evaluate interoperability in smart homes and communities, fostering the adoption of a common testing methodology. The work is carried out in conjunction with other JRC facilities supporting the interoperability of smart grids and electric vehicles. With these actions, JRC will contribute to the implementation of EU policies aiming at the clear energy transition and the digitalisation of energy.

Figure 1. JRC Petten site from the air

Source: JRC, 2018

2 Policy background

The Energy Union set the scene in 2015 for an ambitious EU's positioning concerning energy, climate and clean mobility. Key objectives are the strengthening of the position of citizens while paving the way for innovative business. This approach is necessary to achieve the commitments of the Paris Agreement and the 2030 Energy Strategy, but also to enable the EU e-industry to be at the forefront of the global market. It recognises the need for an integrated, coordinated and streamlined approach of EU policy and industrial R&D and business development with a global reach.

From the technological viewpoint, one major change is the massive introduction of ICT solutions in the energy field. This process of digitalization will result in an energy system characterised by extensive interconnections and exchanges of data between stakeholders, systems and devices. In this context, the potential of the market cannot be effectively realised if interoperability is not a cornerstone of efforts. Proprietary solutions, mainly if imposed by foreign companies, can greatly hamper the prospects for EU companies, and the empowerment of consumers.

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In line with this aim the JRC SGIL is prepared to contribute to the interoperability testing of digital solutions for the energy sector.

From e-mobility, to resilience of the energy grid passing via smart homes and ~~transmission~~ grid integration, the SGIL is able to independently assess and support industry developments with respect to interoperability.

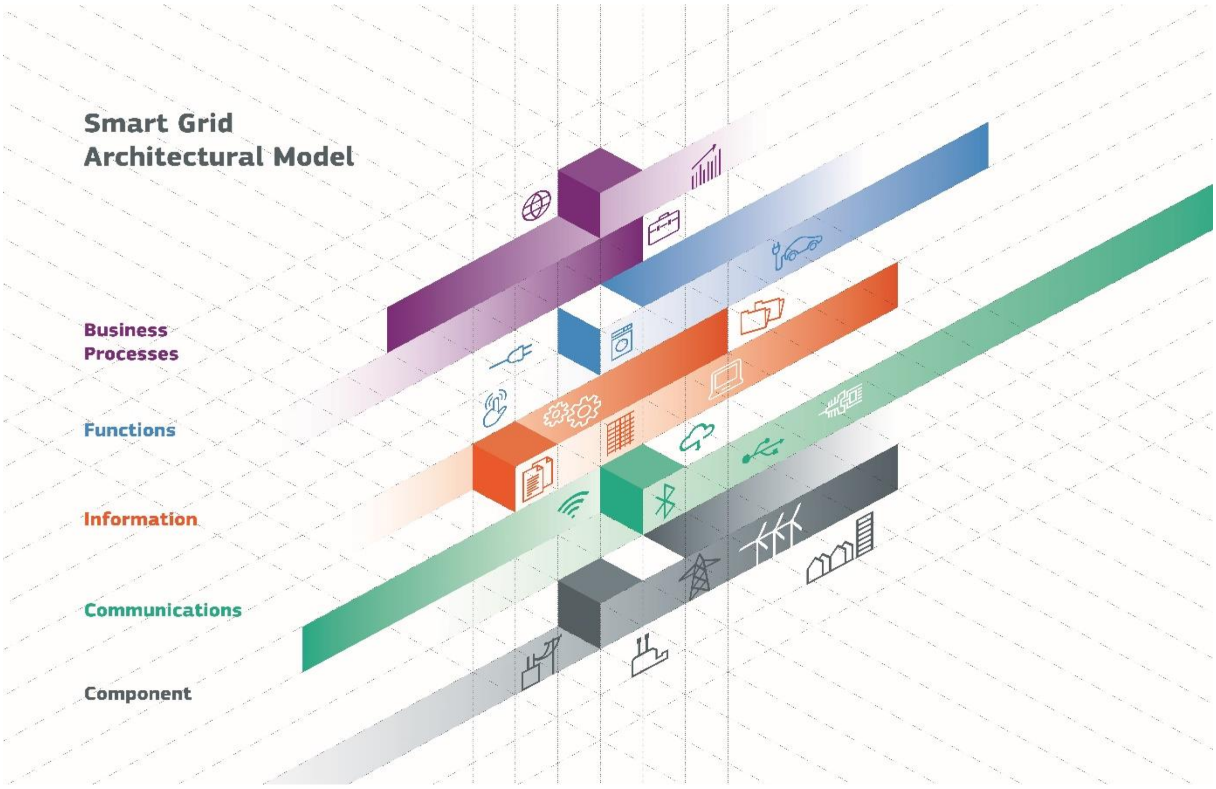
2.1 Why is interoperability important?

The digital transformation of the energy sector is already changing the way energy is produced, distributed and consumed, affecting not just industry, but also consumers and local communities. This revolution is characterised by the conjunction of renewable sources, smart grids, smart houses and electric vehicles, and is enabled by widespread application of information and communication technologies. The introduction of "internet of things" solutions in homes and buildings, for example, can interconnect appliances and devices to achieve energy efficiency.

A key challenge for digital energy, especially from the consumer’s point of view, is the interoperability of all the components, systems, applications and information involved. Interoperability is the ability of two or more items to work together, which is key to the creation of a single digital energy ecosystem. But digital energy results from the convergence of many different industrial sectors – electricity, power electronics, home appliances, telecoms and internet – all with their own standards, cultures and technical backgrounds.

Interoperability will not happen spontaneously and needs to be supported with dedicated policy, standardisation and technical instruments.

Figure 2. The different interoperability layers based on the Smart Grid Architectural Model (SGAM)



Source: JRC, 2018

2.2 What is the issue for the EU consumer?

Consumers (at all levels: citizens, private companies, public organisations) would benefit substantially from the certainty that the goods they purchase can be integrated without major inconvenience and that they are not locked-in by vendors. This is particularly significant in the case of smart houses, where commercial offers can hide the perils and shortcomings of proprietary solutions. Lack of interoperability will fragment markets and damage consumers.

2.3 What is the EU doing about interoperability?

The European Commission has identified interoperability, based on open standards, as an essential requirement for the fostering of markets for innovative energy products and services. The European standardisation bodies (CEN-CENELEC and ETSI) have been working to develop an approach that can guarantee the interoperability of solutions. This work is complicated by the vast range of standards used and the lack of a common methodology to demonstrate interoperability (annex 1).

It is in this context that the JRC SGIL was conceived to contribute to the interoperability testing of digital solutions for the energy sector.

2.4 Why a laboratory for the interoperability of smart homes?

It is now very timely to launch the Smart Grid Interoperability Lab and to demonstrate the House of the Future in JRC's Petten site. Smart Homes and communities are central to the energy transition. They set the pace for the connection of renewable energy sources (RES), the promotion of energy efficiency, the smooth management of distributed generation and the charging of electric vehicles, as well as the adoption of new services based on local storage solutions, smart appliances and Internet-of-Things (IoT).

Interoperability is the crucial element, not just enabling the overall integration of energy and ICT components, but unblocking open and fair markets based on seamless access to data and communication interfaces. Interoperability, building on existing standards, paves the way to an innovative digitalisation of energy.

This demonstrates the political emphasis placed on interoperability for Europe and provides the impetus to translate political goals into workable solutions.

Indeed it is now timely for the work of the European Commission towards interoperability of solutions and standardisation for smart energy grids, smart homes and smart meters to benefit consumers and industry. The "Clean Energy for All Europeans" package presented in November 2016 clearly stated that the development of more interoperable systems was required "in order to stimulate the further development and uptake of low-carbon, energy-efficient solutions across all sectors."

Additionally, the High-Level meeting organised by DG CONNECT and ENERGY in 2017 highlighted the need for aligning the standards regarding smart homes and smart grids, as a way for promoting the broad introduction of smart technologies and appliances. The link with public policies is clear: there is the collective interest of not fragmenting the internal market, of promoting European solutions worldwide, of sustaining public procurement and of empowering the end-users.

Nevertheless, policies, technologies and standards by themselves cannot secure the flourishing of the digital energy market. Policymakers, market players and consumers require a solid basis upon which to build up trust. Interoperability needs evidence and only systematic tests can provide it.

The work to be accomplished in the JRC Interoperability lab represents an important novelty: it will propose and disseminate the first complete and actionable interoperability testing methodology for digital energy and smart homes[4]. The approach to this issue has to be pan-European. A common approach to testing and reporting will facilitate the openness of information and the development of markets.

The creation of the lab thus represents a substantive step towards a more thorough European approach to interoperability. The future use and implementation of the common testing methodology by other laboratories and industry in Europe will secure a homogeneous and consistent reporting of the state-of-the-art of interoperable solutions.

Moreover, access to open and trustworthy information will reinforce the engagement of citizens. The vision is that of Interoperable digital energy systems for All Europeans, where each citizen can benefit with new products and services.

This is also an opportunity for Europe to play a leading role in the global scene. By unlocking the potential of interoperability and demonstrating its application, Europe's standards, technologies, solutions and industrial actors can gain markets and pioneer the worldwide adoption of clean and smart energy.

[4] Papaioannou I., Tarantola S., Lucas A., Kotsakis E., Marinopoulos A., Ginocchi M., Olariaga Guardiola M., Masera M., Smart grid interoperability testing methodology, EUR 29416 EN, Publications Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-96855-6, doi:10.2760/08049, JRC110455

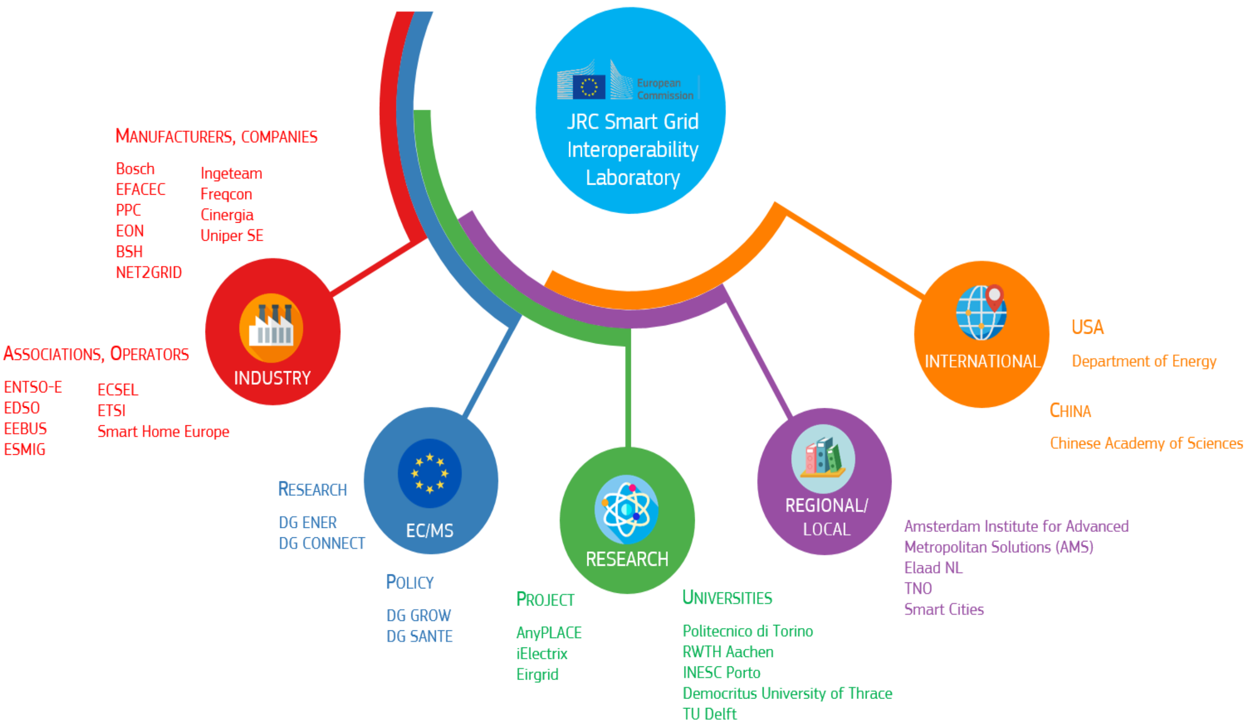
2.5 Smart Grid Interoperability Laboratory (SGIL) at JRC Petten: What do we do and for whom?

The SGIL at Petten has a clear objective: to promote the interoperability of digital energy in the interface between smart homes and smart grids. In order to do this, SGIL does:

- Test the interoperability of solutions, from the market and from research projects.
- Promote the use of a common interoperability testing methodology based on the CEN-CENELEC-ETSI framework.
- Network with other European laboratories and research centres for common initiatives.
- Network with European industrial actors in various sectors.
- Disseminate the results of testing campaigns.

Figure 2 shows an overview of stakeholders addressed by the SGIL.

Figure 3. Stakeholders addressed by the SGIL



Source: JRC, 2019

2.6 What is demonstrated in the SGIL?

- The implementation of a House of the Future platform, which examines the integration of solutions for white goods, home functions and other consumer electronics and their interconnection through smart meters to local grids.

- Some use cases taken from recent European projects.

- Integration with other JRC labs and facilities in European research centres.

Box 1: Some concrete examples of problems to solve for consumers or businesses

a) *Carla wants to make her home in Italy smarter. She is looking for products to buy, but feels lost in the jungle of EU products and standards.*
By making use of the results of the JRC lab, Carla will be able to speedily select among products with demonstrable interoperability.

b) *George works in a retail company and would like to offer smart services, but finds the wide range of standards confusing.*
Taking advantage of the database of use cases and testing results carried out at JRC's and other European facilities, George will be able to select interoperable services and the related products.

c) *Pat and Ken are young entrepreneurs with an idea for a start-up, but the market is blocked by proprietary solutions.*
Pat and Ken can benefit from the Interoperability labs in several ways: by testing their idea for qualifying their solution and accelerating the innovation cycle; by browsing the database of testing cases for examining the technical state of the art; and by being part of an ecosystem that defends open standards vs monopolies.

2.7 Who is benefitting from SGIL activities?

Consumers

- Access to reliable information on interoperable energy-related products and services.
- More certainty about plug-and-play digital energy solutions.
- Proof that applications can enable energy efficiency and participation in the energy market.

Manufacturers

- Less market fragmentation, opening up global market opportunities.
- Lower production costs due to economies of scale.
- Benefits of using open standards.

Operators

- Better integration of distributed energy resources.
- Opportunity for new business models and services.
- More consistent approach to a comprehensive digital energy framework.

Standardisation

- Identification of gaps and misalignments in current standards.
- Recommendations for further global harmonisation.

3 Layout and equipment of the SGIL

Accommodated in a new tailor-made building, the lab features a testing space for the future components of smart homes – where apps can regulate the fridge temperature according to your energy saving preferences for example, or the energy left over in the electric vehicle battery can be used to power your washing machine at a time of your choosing.

On one floor, simulators and technical apparatus set the testing environment. They are used to analyse the electricity and data flows between the grid and the smart home components.

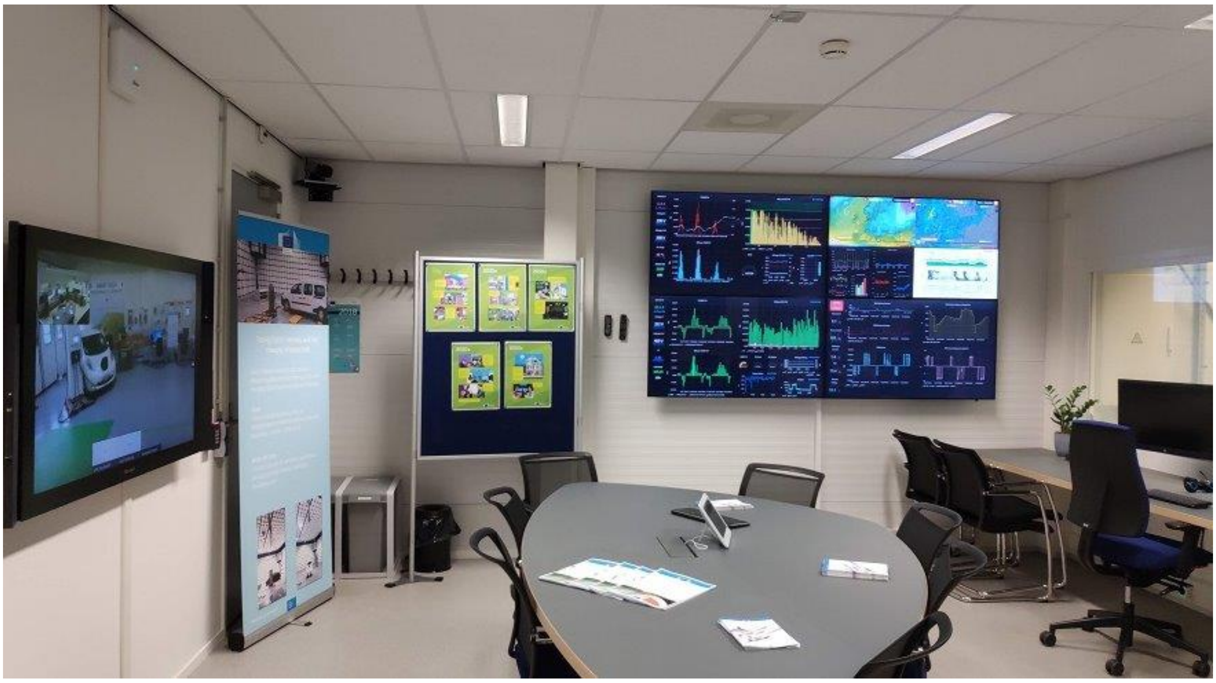
Figure 4. SGIL from the air

Source: JRC, 2019

Figure 5. Smart kitchen SGIL, first floor

Source: JRC, 2018

Figure 6. Control room SGIL, first floor



Source: JRC, 2018

Figure 7. SGIL, ground floor

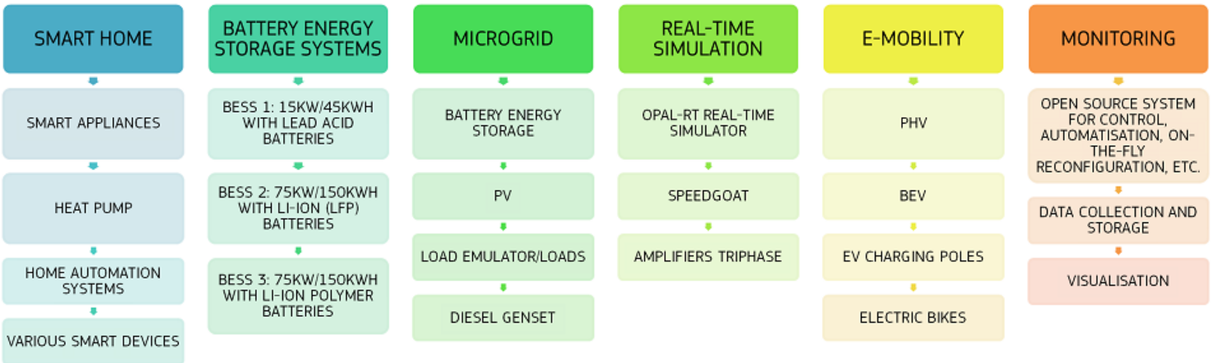
Source: JRC, 2018

Figure 8. Battery containers SGIL

Source: JRC, 2018

The SGIL is structured and composed according to figure 9.

Figure 9. Structure SGIL



Source: JRC, 2018

Some examples are shown hereunder.

Figure 10. 3 Large energy storage units (batteries)

Source: JRC, 2018

Figure 11. Microgrid SGIL

Source: JRC, 2018

Figure 12. Electric vehicles SGIL

Source: JRC, 2019

Figure 13. Real time simulation SGIL

Source: JRC, 2018

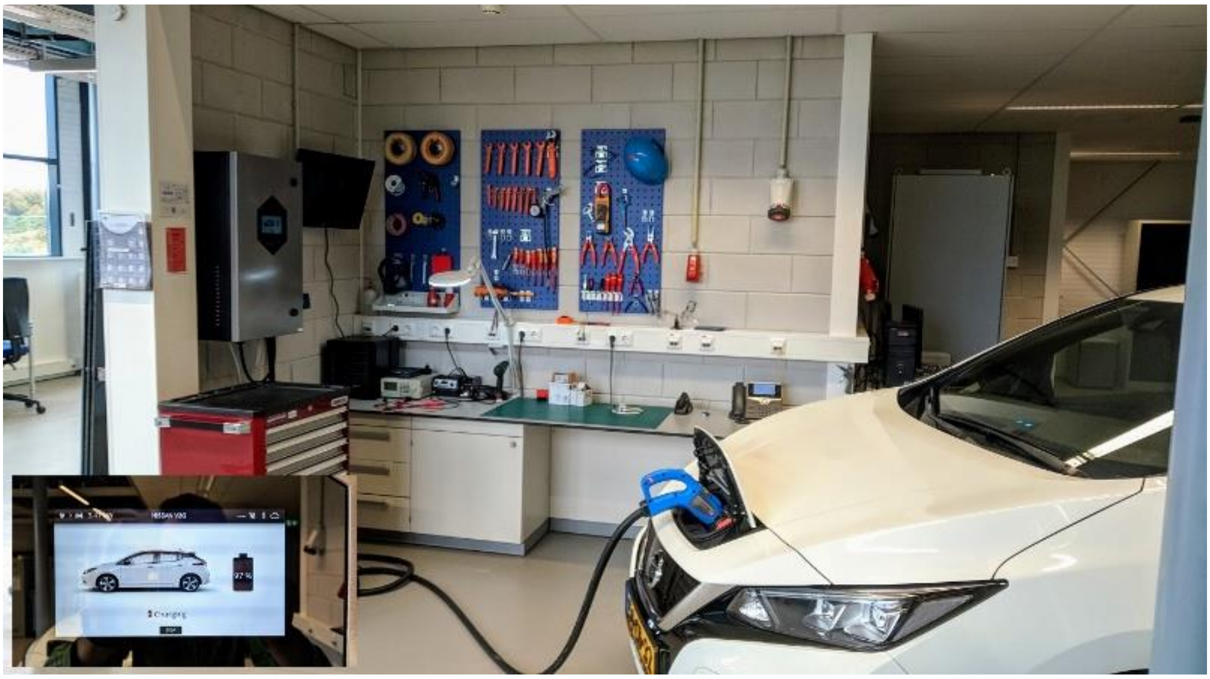
Figure 14. Smart Home appliances SGIL, first floor

Source: JRC, 2018

Figure 15. Diesel generator SGIL

Source: JRC, 2018

Figure 66. Vehicle to Grid (V2G) Charger, bidirectional flow of energy possible



Source: JRC, 2019

Figure 17. Prototype of Dutch Solar Design solar panels

Source: JRC, 2019

4 Scientific and experimental activities

4.1 Power quality-analysis with ElaadNL

Authors: Tim Slangen, Thijs van Wijk and Rick Roor from ELaadNL with Felix Covrig, Ioulia Papaioannou and Antonis Marinopoulos form the JRC SGIL

Summary: The number of EVs in The Netherlands, and worldwide, is rapidly increasing. These electric vehicles convert relatively large amounts of electricity from the grid from AC to DC to charge their batteries. This conversion can have an impact on the power quality of the grid. It is important to prevent power quality related issues, because a poor power quality will reduce the efficiency and uptime of the grid and of electronic equipment at the consumer level.

To assess the impact charging electric vehicles may have on the power quality of the electricity grid, ElaadNL is testing electric vehicles on their behaviour and measuring the quality of the intake current and effect on the grid voltage. During these tests, the supra-harmonics (distortions between 2 kHz and 150 kHz) are a frequently observed source of distortions. These might lead to higher energy losses in the grid, malfunctioning electronic appliances and might even lead to the unexpected behaviour of electric (safety) equipment, as RCD's. The exact behaviour of supra-harmonics in the grid is still unknown and unregulated by any norms which is why more research on the subject is necessary.

To learn more about this situation, ElaadNL performed some testing at the JRC SGIL and measure the influence the supra-harmonic distortions, as introduced by electric vehicles, can have on a household grid. Because this distortion in the household grid will also be influenced by the distribution grid type, or if the household is in "island mode" (temporarily not connected to the grid), it would be best if this can also be simulated. The SGIL is uniquely suitable for performing these tests. It has the following characteristics;

- Set up as a modern, near-futuristic household including smart devices, LED lights, heat pump.
- Multiple solar panels and inverters present
- Possibility to simulate different types of electricity grids
- Possibility to test in island mode
- Possibility to feed-in a selection of supra-harmonic distortions

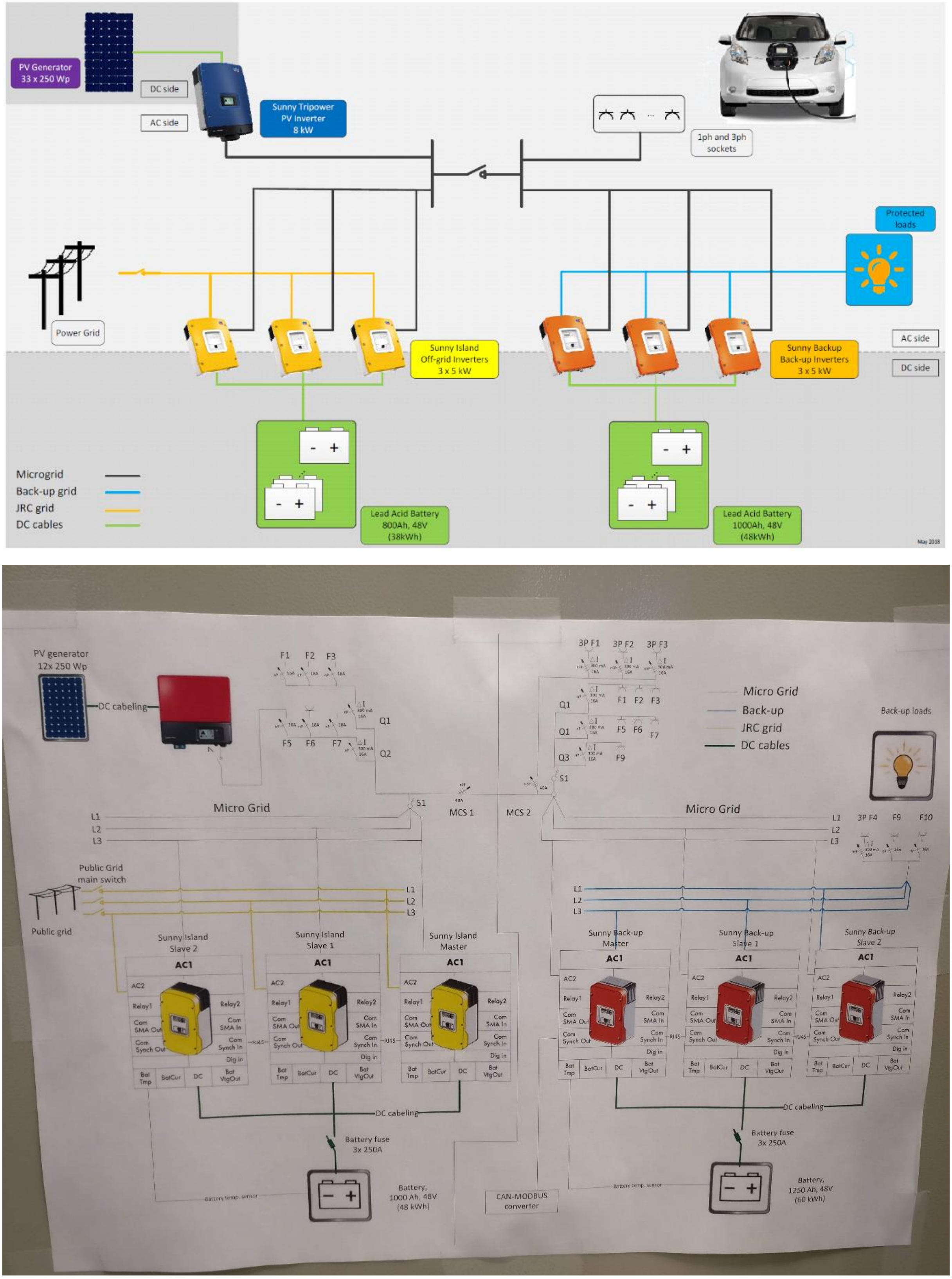
The flexibility of the SGIL allowed for multiple test scenario's, based on (for instance) the following variables;

- Different grid types / island mode (changing the "strength" of the grid)
- Excluding / including other devices (like solar energy inverters, washing machines) to see the effect of different sources of distortion / absorption.
- One supra-harmonic frequency / multiple supra-harmonic frequencies (effect on the voltage, transfer through the grid) measurements at different locations in/outside the house for a fixed source of distortion
- (Optional: determining impedance characteristics of the grid for different frequencies; attenuation versus frequency)

More formalized, the following test plan was designed for the scientific measurements at the SGIL, to investigate the behaviour and impact of supra-harmonic currents in a future household. This plan applied for both the "micro-grid/island mode" and the "grid-connected mode" which are both tested (in different days) and compared afterwards.

- EVs are always connected at the same location (1ph/3ph sockets)
- EVs are used as main variable, as this is easiest to achieve; also they are a significant source of supra-harmonics
- Inverters (either PV or battery) are always turned on (for island experiment)
- Measurement minimally include voltage (up to 250kHz) and current
- Measurements for each scenario are at least done at the 2 first locations:
  - At *each* Electric Vehicle Supply Equipment (EVSE) supply terminals (only relevant ones)
  - At the terminals of an inverter (either PV or battery)
  - At a socket nearby household devices (kitchen, laundry, control room), at a significant electrical distance from the first two locations.
- Scenarios, *for each measurement location,* are listed below (sequence):
  - Baseload
  - Baseload + EV-1
  - Baseload + EV-1 + EV-2
  - Baseload + EV-1 + EV-2 + EV-3
  - Baseload + EV-2
  - Baseload + EV-2 + EV-3
  - Etc.

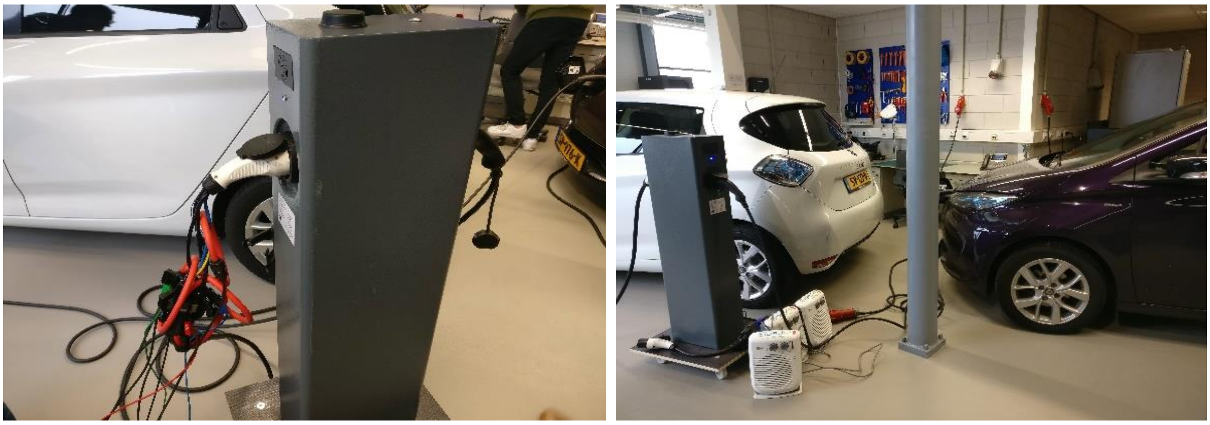
Figure 18. Test scheme supra-harmonics



Source: JRC/ELaad, 2019

The measurements were initially performed at the following locations (see figures 19-21).

Figure 19. EV Terminals of a charging station (to which different EVs are connected in the mentioned combinations)

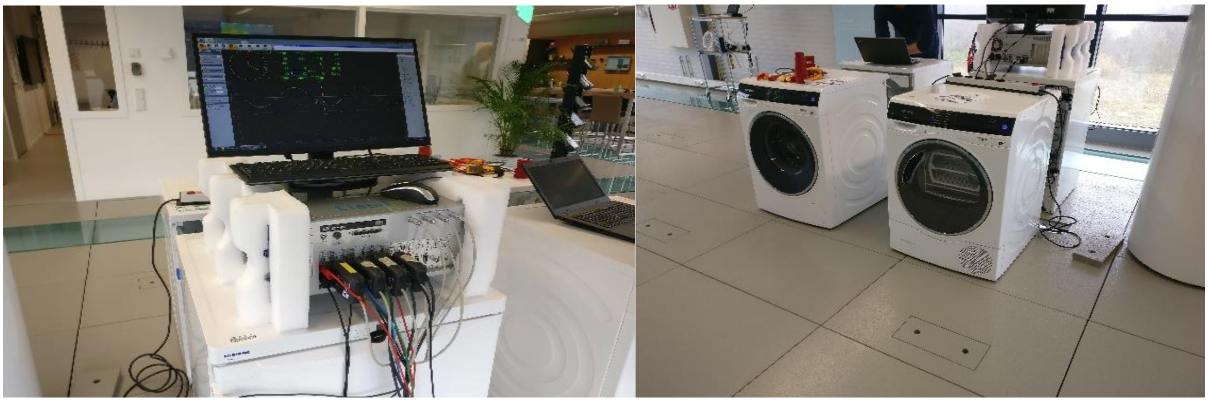


Source: JRC, 2019

Figure 20. Central electrical cabinet on the conductors of the battery storage-unit (on which the currents and distortions caused by the EV are visible)

Source: JRC, 2019

Figure 21. Different locations in the SGIL, at the connection of several appliances (washing machine/dryer (both at a large physical and electrical distance from the EV)



Source: JRC, 2019

Conclusion: In grid-connected mode, observations largely match expectation based on past measurements. Interaction between EVs and inverters are probably present, but it is the question whether it is significant. Influence from laundry devices and induction-cooking plate seem negligible, although distortion from the EVs is also visible over here. In micro-grid mode, preliminary observations and conclusions match hypothesis (based on literature) on the fact that supra-harmonics mainly propagate between the devices causing them (due to EMC-filters). Voltage is influenced by the EVs and affects the currents drawn by other devices. EV-1 has for unknown reasons difficulty with the micro-grid, especially in combination with the PV-inverter and probably some other factors. Further analysis by the engineers will give more insight and will be useful to avoid this problem in the future.

4.2 Data-driven simulation modelling for smart neighbourhoods with the Democritus University of Thrace (Greece)

Authors: Felix Covrig and Antonis Marinopoulos (JRC), Theofilos Papadopoulos, Georgios Kryonidis and Georgios Barzegkar Ntovom (DUTH)

Summary: SGIL has started a project together with a team from the Power Systems Laboratory of Democritus University of Thrace, Greece. The goal of the project "Data-driven simulation modelling for smart neighbourhoods" is to create a software tool to allow the joint performance of smart neighbourhoods and smart homes. The tool will be used and can be extended to investigate smart grid strategies and technologies in order to improve the performance of the network operation in terms of reliability, security, and optimality.

The smart homes are modelled using daily time-series of power demand resulting from the combination of load consumption, a photovoltaic (PV) roof-top system and a battery energy storage system (BESS) that operates using self-consumption strategy. The load consumption in specific is a time-series stochastically created using input from the real consumption data from more than 20 different types of devices (washing machine, dryer, fridge, heat pump, EV, etc).

The time-series of power demand for the different devices are taken either from public available data or from existing measurements taken in previous projects of the University and SGIL, or from new data obtained from measurements of smart devices in the SGIL in Petten. For this last type of measurement data, a series of experiments were carried out at the SGIL Petten, during two visits from the University team in July and October 2019.

Conclusion: Currently, there is a first version of the tool, which is based on Python for the smart home/neighbourhood model part and OpenDSS for the power flow simulations. The team is preparing a conference paper, where the complete dataset will be presented, and later a journal article where the whole model will be presented along with a number of interesting study cases. By that time, an updated version of the tool will be available, in order to include among others weekly simulations and the possibility to run unbalanced power flow.

4.3 Global Grid Integration Project (GGIP) testing event 19-22 November 2019

Authors: Felix Covrig, Harald Scholz, Antonis Marinopoulos, Ioulia Papaioannou

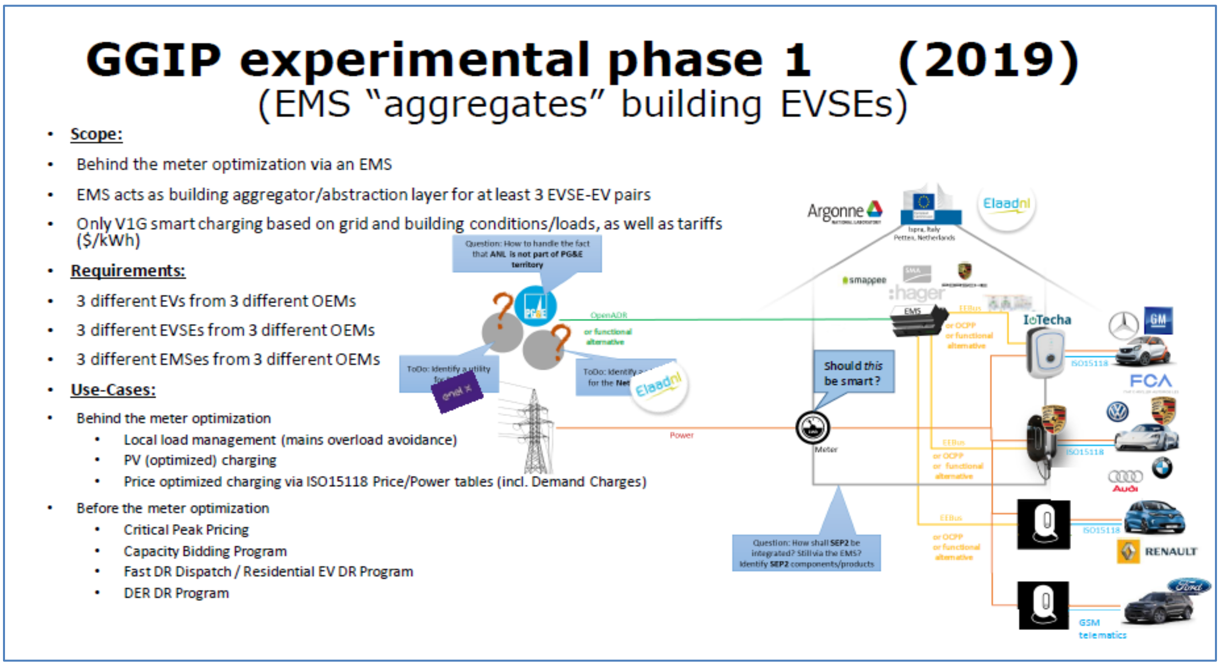
Figure 22. Impressions of the GGIP testing event

Source: JRC, 2019

Summary: Between 19th and 22nd of November (2019) a GGIP testing event was taking place in the Smart Grid Interoperability Laboratory Petten. GGIP is a research project which combines independent global efforts in the context of Smart Grids and Smart EV Charging. The project is conducted by a transatlantic multi-industry Consortium led by JRC, ElaadNL and the Argonne National Laboratory (ANL, DoE, US).

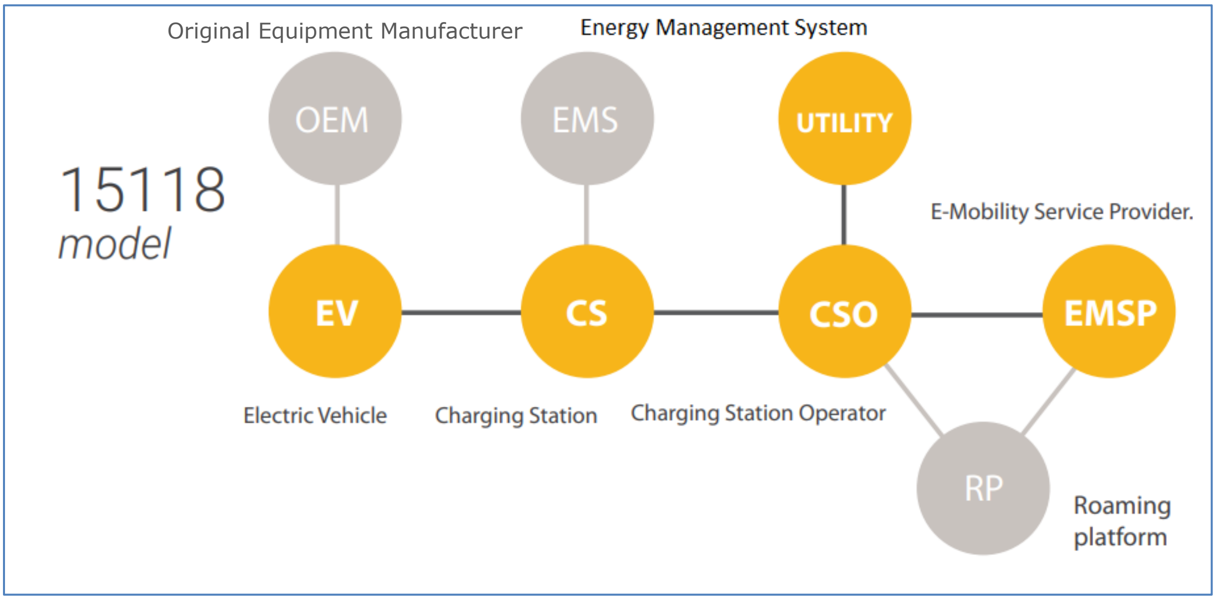
Smart Charging is the collective term for a variety of techniques, protocols and adjusted infrastructure to optimize and balance the electricity grid in case of large amounts of electric vehicles charging at the same time. Furthermore, it provides ways to make better use of the available sustainable energy from wind and solar. In short, smart charging offers faster charging when there is an abundance of sustainable energy available, while slowing the charging speed when congestion on the grid is looming.

Figure 23. GGIP experimental phase 1



Source: JRC, 2019

Figure 24. The 15118 model



Source: JRC, 2019

Participants were from JRC, ELaadNL, Porsche, Ford, BMW, Daimler, GM, FCA, ANL, ANL, KEO, EVbox, SMAPPEE, GRID X, OpenADR, TRIALOG, ebee, EEBUS, WIRELANE, INNOGY, KOSTAL, HAGER, IOTECHA, PG&E

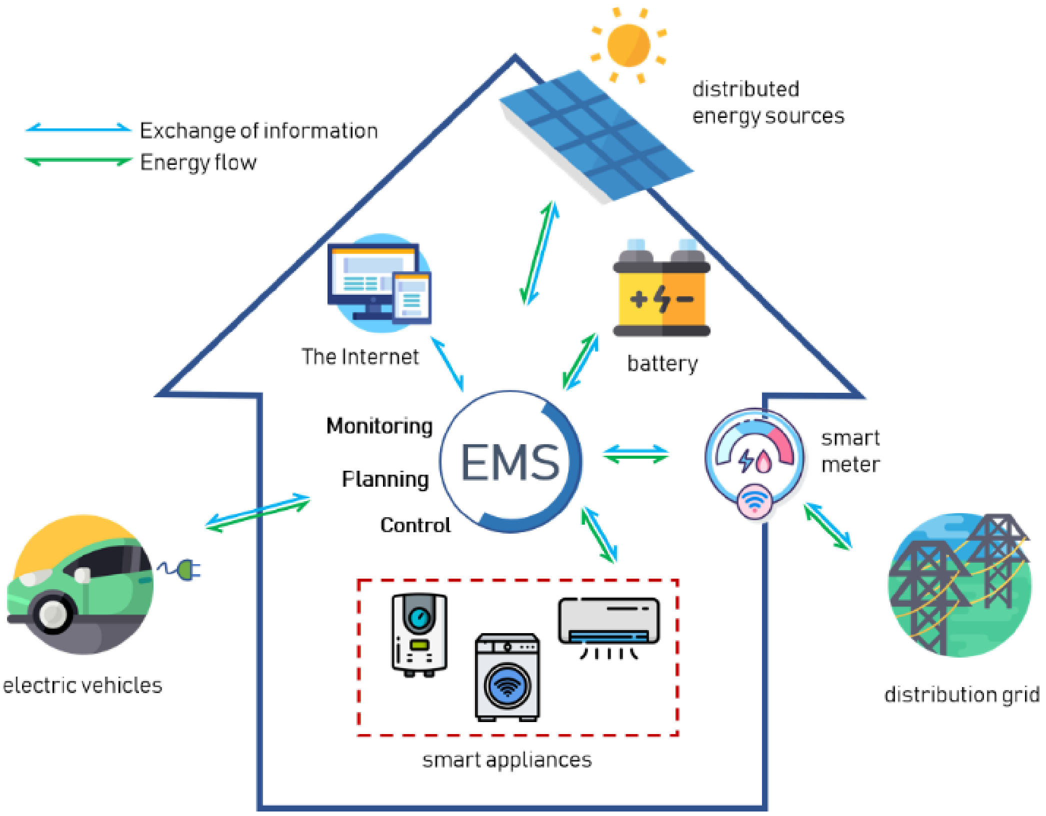
Conclusion: During the event, standards like ISO/IEC 15118 and OCPP (Open Charge Point Protocol) were tested to ensure base level interoperability for smart charging between electric vehicles and charge spots. In a nutshell, ISO/IEC 15118 is an international standard that outlines the digital communication protocol that an EV and charging station should use to recharge the EV's high-voltage battery.

4.4 In-house energy management system (PyEMS)

Authors: Catalin-Felix Covrig and Miguel Angel Munoz Diaz

Summary: The PyEMS is a Python package that helps to implement an EMS for a building or house tailored to the user needs. The scope of the PyEMS is to extend the capabilities of existing Home Automation programs with the mathematical and data pre-processing tools required for smart energy planning.

Figure 25. Energy Management System in a Smart Home



Icons made by monkik, Nikita Golubev, smashicons and freepik from www.flaticon.com

Source: JRC & www.flaticon.com, 2019

We exemplify the general idea of our Energy Management System implemented with PyEMS in the following case. For this example, we consider a smart house with a photovoltaic installation, some devices (loads) and a battery. The house is equipped with a server that runs a Home Automation (HA) software like Home Assistant or OpenHab and has a database to store the measurement of consumption and loads. This HA is in charge of integrating devices, collecting measurements and events and sending instructions to operate the smart appliances. The measurements collected by the different sensors and meters are stored in the database. We also have access to a weather prognosis for the next days that we retrieve from a website and we assume that the electricity prices are known in advance.

In this context, an EMS can determine the target state of charge of the battery. As the computation requires some time and the measurements are in nature discrete values, the strategy adopted is to periodically run the EMS at regular intervals called time steps. The target is to accommodate as much renewable energy as possible, making use of it in the more expensive periods.

We also installed and developed the Open Charge Point Protocol (OCP software needed for the V2G charger. OCPP is the global open communication protocol between the charging station and the central system of the charging station operator. This protocol handles the charging transaction and in addition can exchange information between the vehicle and the electricity grid. OCPP was initiated by ElaadNL in the Netherlands and has been extended and improved upon over the past eight years by the pioneers in the international EV charging industry. OCPP is currently hosted by the Open Charge Alliance, a Dutch foundation with up to 100 members from 25 countries on 4 continents. OCPP has been downloaded more than 17.000 times by developers worldwide and is considered the de facto global standard.

We connected the Petten and Ispra labs on the real time simulation network. This was supposed to lead to the European Real-time Integrated Co-simulation laboratory. Real time simulation is reproducing the behaviour of a physical system through running its computer-based model at the same rate as actual wall clock time. In other words, in real time simulation, when the simulation clock reaches a certain time, the same amount of time has passed in the real world. For example, if a process takes 1 second to finish in the real world, the simulation would take 1 second as well. Real time simulation is typically used for high-speed simulations, closed-loop testing of protection and control equipment, and generally all "What-if" analyses. Real time simulation is actually simulating a system, which could realistically respond to its environment, when the inputs/outputs of the simulation are synchronous with the real world.

We also connected the SGIL and ANL (Interoperability and Grid Integration - Energy Systems Division) on the data side.

Conclusion: Energy management Systems (EMS) will play an important role in the smart buildings of the future. Increasing complexity in the integration of smart devices and distributed energy sources requires smart controllers to address interoperability problems and get the most out of them. The PyEMS toolkit is also a valuable tool for researchers and analysts who seek to simulate different control strategies and determine the best one.

4.5 Testing of 3 battery energy storage systems (BESS) with a common energy management system

Authors: Paul Vandenbergh, Arturs Purvins, Felix Covrig and Antonis Marinopoulos

Abstract: In the SGIL we investigated for this study how a pool of battery storage units can be jointly operated in a coordinated way. Such a virtual battery storage power plant has the potential to provide grid services like: peak shaving, energy shifting, back-up power, short-term fast reserve, voltage quality, etc. In our setup, a central EMS (EMS) is defining an optimal dispatch strategy based on: 24 hours ahead forecasts for the demand, the solar generation and electricity prices. The EMS is sending power import and export set-point requests to the Battery Management Systems (BMS) of the three storage units. These requests might or might not be allowed by the BMS, depending on the State of Charge (SOC) and the State of Health (SOH) of the storage unit. We analysed the performance in terms of energy efficiency and interoperability between the central energy management system and the three BMS.

Conclusion: We analysed the performance of 3 BMS in terms of energy efficiency and in terms of interoperability at the Function Layer of SGAM with a central energy management system. Overall, we detected an underestimation of stand-by and conversion losses by the EMS. The estimation of remaining import/export energy capacity by the EMS proved also to be problematic when SOC levels are getting close to upper or lower limits. This lead to some EMS requests not being satisfied. Overall the performances of the three systems are not so different.

A correct evaluation by the EMS of the available BESS capability in terms of power and energy remains challenging in all cases (with or without feedback). A simple strategy to guarantee a good interoperability is to operate the BESS at SOC values far from the upper and lower limits and to allow SOC re-calibration by allowing regular cell balancing. Without such measures, results have shown that there is a high risk that the BESS will respond with a much lower power output than expected.

Link: https://pubsy.jrc.cec.eu.int/workflow/download/114317_167994, Testing of three Battery Energy Storage Systems with a common Energy Management System

4.6 Living laboratory pilot project

Authors: Felix Covrig, Ioulia Papaioannou, Stefano Tarantola, Antonios Marinopoulus, Federico Maniaci, Georgios Tentzos

Summary: Before smart city technologies are put into operation, they need to be tested under real-life conditions in agile and safe environments and checked to be interoperable with a multitude of ICT devices, power systems, infrastructures, energy consuming and/or storing devices as well as energy management systems in (ideally prosumer-)buildings. Practical usability, safety, regulatory and security issues, including privacy and data protection, and interactions between many stakeholders are key and require systematic evaluation of realistic use cases.

A modern way of creating an environment that enables such innovation and paves the way to start-up development is the living lab. The living lab addresses aspects of everyday life and work activities, such as building-related energy flows, mobility, well-being, healthcare, security, water, waste, and more. At stake is improving the quality of life of residents and making the city prosperous, inclusive, sustainable and resilient. In this framework, the pilot JRC Living Lab on Future Urban Ecosystems, based in Ispra and Petten, can play a very important role in the scientific progress in the field. The effect on the internal mobility patterns and energy use of JRC staff and visitors following the introduction of new technologies, energy management and mobility services will be easily visible. The research at the JRC will shed light on the combination of policies and technologies that can effectively reduce the demand for private transport in favour of shared mobility options and increase sustainability in energy use. It will also allow the most important factors enabling the necessary transition to be identified.

For that purpose, an open Call for Living Lab Experiments[5] was published by the JRC, focused on digital energy solutions and future mobility challenges. The SGIL Living Lab team has analysed their possible themes for a pilot initiative and came up with

1) the use of the SGIL's EMS for analysing the whole Petten site's staff energy consumption, related to offices, laboratories, weather conditions, etc. and

2) to set up testing environments for energy related experiments stemming from the open Call.

[5] https://ec.europa.eu/jrc/en/research-facility/living-labs-at-the-jrc/call-expression-interest-future-mobility-and-digital-energy-solutions

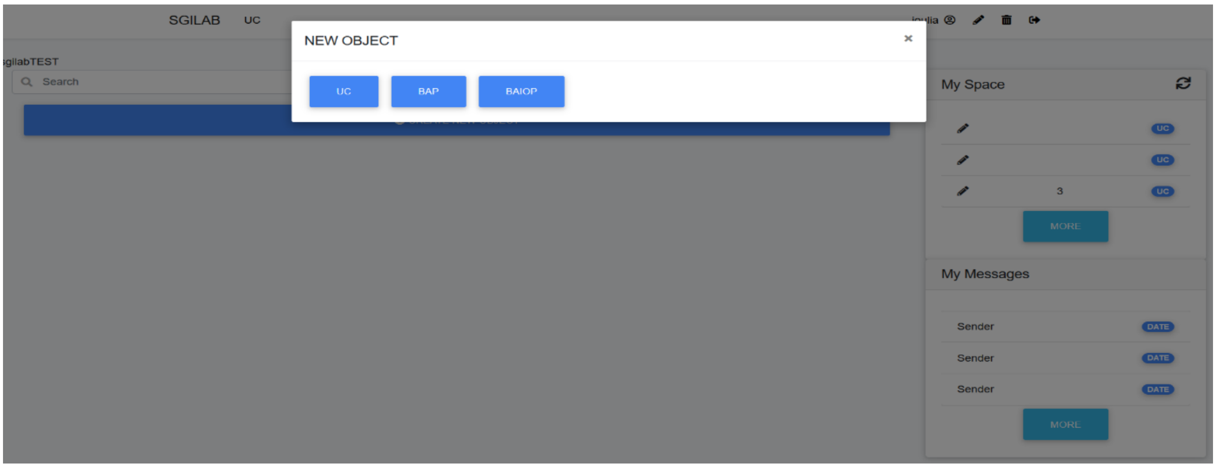
Lately, first discussions have been taking place to anticipate the living lab use of the planned EV charging stations on site in order to investigate patterns of use.

4.7 European methodology interoperability database

Authors: Vangelis Kotsakis, Ioulia Papaioannou, Antonios Marinopoulus, Felix Covrig

Summary: Presently the SGIL team is designing a database based on the SGIL Interoperability methodology and discussing in close collaboration with the database designer on the user interface and the inputs to create a user friendly system where the different steps of the methodology like Use Case creation, Basic Application Profile and Basic Application Profile creation will be facilitated. The system will help the user through drop down menus (e.g. list of actors and standards) and preselected options to design the interoperability test specifications based on the templates provided by the methodology.

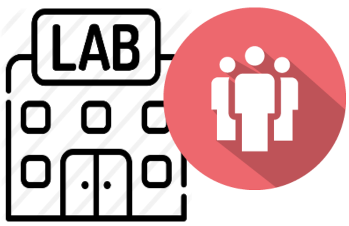
Figure 26. Screenshot of the European Methodology Interoperability Database



Source: JRC, 2019

4.8 SGIL Visits

Summary: In the first year after inauguration, the SGIL was visited from different stakeholders (partner DGs, networks, universities, industry, associations, etc.), EC bodies (Scientific Committee, Board of Governors, Central Staff Committee, etc.) and of interested parties from the neighborhood (health campus, city or municipality, school, trainees, clubs, etc.). Altogether, these were over 40 visits with different scopes and detail of presentation.



5 Conclusions

The construction of the Smart Grid Interoperability Laboratory in Petten is an additional piece in the JRC support to EC policy in the area of Digital Energy. Interoperability has received a high level of attention and therefore, the SGIL was constructed for testing interoperability of future smart homes. JRC developed a widely accepted European Interoperability Testing Methodology based on the Smart Grid Architectural Model, which serves as a basis for testing use cases. Next to the enlargement of the laboratory testing capabilities, use cases will be defined and carried out. These use cases come from European industry or research consortia. First tests were carried out in 2019 and mentioned in this 2019 Annual Report of the SGIL. In parallel, a database is being designed for the collection and dissemination of the use cases examined.

References

Papaioannou I., Tarantola S., Lucas A., Kotsakis E., Marinopoulos A., Ginocchi M., Olariaga Guardiola M., Masera M., 'Smart grid interoperability testing methodology', EUR 29416 EN, Publications, Office of the European Union, Luxembourg, 2018, ISBN 978-92-79-96855-6, doi:10.2760/08049, JRC11045531-34.

List of abbreviations

ANL	Argonne National Laboratory
BESS	Battery Energy Storage System
BMS	Battery Management System
CEN	European Standardisation Committee
CENELEC	European Committee for Electrotechnical Standardization
CEP	Clean Energy for all Europeans Package
DEI	Digitising European Industry
DoE	Department of Energy (USA)
DUTH	Democritus University Thrace
EMS	Energy Management System
ETSI	European Telecommunications Standards Institute
EV	Electric Vehicle
EVSE	Electric Vehicle Supply Equipment
GGIP	Global Grid Integration Project
HA	Home Automation
IoT	Internet of Things
LED	Light-emitting Diode
OCPP	Open Charge Point Protocol
OpenDSS	Open Distribution System Simulator
PQ	Power Quality
PV	Photovoltaic
PyEMS	Python based Energy Management System
RCD	Residual Current Device
RES	Renewable Energy Sources
SGAM	Smart Grid Architecture Model
SGIL	Smart Grid Interoperability Laboratory
SOC	State Of Charge
SOH	State of Health
TEC	Transatlantic Economic Council
V2G	Vehicle to Grid

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Annexes

Annex 1. Developing Interoperability for Europe

The digitalisation of energy integrates components from different sectors: electricity, heating and cooling, information, communications, business processes and home appliances. The interconnection of those different systems, designed and developed according to different standards, brings about the problem of their interoperability. All those elements have to work together in order to have workable solutions in the market.

The lack of interoperability obstructs and delays the implementation of the digital energy solutions, affecting also the deployment of –among others– distributed renewable energy sources, smart homes and electric vehicles.

For tackling this conundrum, the European Commission set up the ***Smart Grids Task Force*** in 2009 for receiving advice on relevant issues regarding the deployment and development of Smart Grids. Based on the work of this expert group, the European Commission issued mandates in 2011 to European Standardisation Organisations (ESOs) –CEN, CENELEC and ETSI– to develop and update technical standards: M/441 'Standardization Mandate of Smart Meters', M/468 'Standardization Mandate concerning the charging of electric vehicles' and M/490 'Standardization Mandate for Smart Grids'.

The ***Mandate M/490*** had the precise goal of accelerating the standardisation process required for the deployment of Smart Grids in Europe. The Mandate 490 explicitly stated:

> *The objective of this mandate is to develop or update a set of consistent standards within a common European framework that integrating a variety of digital computing and communication technologies and electrical architectures, and associated processes and services, that will achieve **interoperability** and will enable or facilitate the implementation in Europe of the different high level Smart Grid services and functionalities as defined by the Smart Grid Task Force that will be flexible enough to accommodate future developments.*

To work on mandate M/490, the ***Smart Grid Coordination Group (SG-CG)*** was set-up in July 2011. After work on standards, in 2014 the group produced a report on Smart Grid Interoperability, highlighting the urgent need for a shared European approach to its testing. The report[6] sketched a first set of methodologies for including interoperability requirements during system design, and then ascertaining them through testing. The report states:

> *As more and more ICT components are connected to the physical electrical infrastructure, interoperability is a key requirement for a robust, reliable and secure Smart Grid infrastructure. The way to achieve Smart Grid system interoperability is through detailed system specification, through use of standards, and through **testing**.*
>
> *...*
>
> *Although the majority of Smart Grid equipment is based on (inter)national standards, this does not automatically result in an interoperable Smart Grid infrastructure. This is partly due to misunderstanding of what interoperability means, what can be expected from it and what should be done to realize it.*

In 2015 the European Commission set up a ***Smart Grid standards expert group*** with the aim of supporting the work on interoperability, standards and functionalities applied in the large scale roll-outs of smart

6 ftp://ftp.cencenelec.eu/EN/EuropeanStandardization/HotTopics/SmartGrids/SGCG_Interoperability_Report.pdf.

metering in EU Member States. The work included an extensive survey,[7] and responses by the Member States.[8]

An important aspect has been the link between the European Union and USA. In successive dialogues in the context of the Trans-Atlantic Economic Council (TEC), and ratified by the EU-US Energy Council, both parties ratified the importance of cooperation in interoperability. A TEC Joint Statement in November 2011[9] called for "*working jointly towards the objective of common or compatible* standards" and launched a cooperation pilot project, agreeing on the establishment of two Electric Vehicle/Smart Grid Interoperability Centres, one at Argonne National Laboratories and one at JRC. This was complemented with a Letter of Intent (LoI) between JRC and the US Department of Energy (DOE) declaring the interest on closer co-operation on interoperability matters. This cooperation was later confirmed during the inauguration of the Argonne National Lab interoperability facilities for electric vehicles in 2013.

In parallel, the Trans-Atlantic Business Council identified e-mobility and smart grids as a key growth sector in both USA and EU where collaboration in standards, regulation and interoperability could be of great value.

In 2015, the TEC meeting reiterated the shared interests for EU-US cooperation on e-vehicles and smart grids, highlighting that the work on interoperability and the joint work between the labs in DOE and JRC was a priority. This demonstrated the high political support to the initiative. One relevant phrase of the TEC facilitators says (27 March 2015):

> *In view of this success in the field of charging devices, facilitators encouraged Argonne National Laboratory and DG JRC to continue their active cooperation towards implementation of the Letter of Intent between the DG JRC and the DOE to test and verify equipment, connectivity technologies, communication protocols, and standards.*

Other relevant activities in Europe

⇒ DG CNECT/ENER - High level Meeting "Interoperability to create the Internet of Energy"

On 11 May 2017 DG ENER and DG CNECT organised a high-level meeting on how interoperability of communication and data exchange can ensure that Europe will benefit from the new opportunities that the IoT will create in the energy transition. The main questions were around interoperability, such as: What can public authorities do to ensure interoperability? What interoperability is needed to develop the smart home of the future that is for the benefit of consumers? What interoperability is needed for an efficient smart grid that fosters innovative energy services.[10]

⇒ DG ENER - Smart Grids Task Force Expert Group 1 Electricity and Gas Data Format and Procedures

Following the decision of the Smart Grids Task Force on 17/02/2017, a Working Group on Energy Data Format and Procedures was formed with the overall task to collect information and investigate the potential for setting up a common format and procedure for energy data exchange in the EU-28. There have been some first reflections on this issue captured in a recent study on "My Energy Data"[11] drafted as an interim report by an ad-hoc group of the Expert Group 1 (EG1) of the Smart Grids Task Force.

The main objective of this Group is to work towards a common interoperable energy data format and procedures at European level, achieve consensus among key stakeholders on best practice, and propose what

[7] https://ec.europa.eu/energy/sites/ener/files/documents/Annex%20C_Survey%20Result_for%20EG1%20Report.xls
[8] https://ec.europa.eu/energy/sites/ener/files/documents/Annex%20%20D_%20to%20EG1%20Report.pdf
[9] https://www.state.gov/p/eur/rls/or/178419.htm
[10] https://ec.europa.eu/energy/en/events/high-level-meeting-interoperability-create-internet-energy

should be the scope and coverage of further and more specific secondary EU legislation (i.e. implementing act) to set such common arrangements.

Uniting the existing various arrangements into a common data format and procedure at EU level will bring together diverging national practices, facilitate interoperability and uptake of new services, boost internal market competition and keep administrative costs under control.

The tasks were divided into four ad-hoc working teams (subgroups) dealing respectively with three processes – change of supplier, billing, emerging services – and the horizontal issue of interoperability. JRC takes part in the latter.

The final aim is to achieve consensus among key stakeholders on best practices, and finally frame recommendations to propose what should be the scope and coverage of a secondary EU legislation to set-up such common arrangements ensuring interoperability. The outcome of this work will also facilitate the discussions of the Council with the Parliament for the Article 24 "Interoperability requirements and procedures for access data" of the Recast of the Electricity Directive, and will directly feed into testing requirements.

⇒ DG CNECT/ENER - H2020 Call Interoperable and smart homes and grids

Within H2020 a Call is dedicated to the topic 'Interoperable and smart homes and grids,'[12] where the aim is to exploit the Internet of Things (IoT) architectures models that allow for combining services for home or building comfort and energy management, based on platforms, that enable the integration of relevant digital technologies. With deadline on 14 November 2018, the project is planned to begin in the 2Q 2019.

The envisaged architecture should allow for third-party contributions that may lead to new value-added services both in energy and the home/building domain. This shall be done by developing interoperability and seamless data sharing, through aligning existing standards from the utility and ICT domains, across the devices and systems to enable innovative building energy management services, with the aim to save costs to consumers, to facilitate the integration of renewable energy from distributed intermittent sources and to support energy efficiency.

The JRC SGIL in Petten, in agreement with DG ENER/CNECT, intends to provide technical support to the selected project consortium.

⇒ DG CNECT/DG SANTE – Health

Smart or digital health will become more and more of importance in patient's diagnostic and therapeutic methods. New approaches have as central components telemedicine and remote care, with dedicated appliances and services that rely on reliable energy and communications. The security and interoperability of health data and devices are key issues. Interoperability is explicitly requested in the Medical Device Regulation EU 2017/745, as well as in the Medical Device Directive 98/79/EC 'in-vitro diagnostic medical devices ".

In this respect, DG CNECT animates the Digital Health and Care Task Force and sponsors different research activities in H2020, planning to continue with them in the future for facilitating the sustainability and quality of health and care provision, as a consequence of demographic change and improvements in medical treatment.

The JRC SGIL considers providing support to these initiatives at different levels:

- Interoperability testing of devices;
- Participating in the JRC Transversal Activity on Evidence-based Health Project;

[12] http://ec.europa.eu/research/participants/portal/desktop/en/opportunities/h2020/topics/dt-ict-10-2018-19.html

- Setting up collaboration with leading European digital health/Telehealth research institutes and clinics;
- Information exchange on interoperability issues in digital health with DG DIGIT and DG ENER.

⇒ DG GROW – Smart Grid flagship studies

At the end of 2015, the Executive Agency for Small and Medium-sized Enterprises, under coordination of DG GROW and supported by the JRC, launched a tender grouped into two lots for studies on: 1) smart grid lighthouse projects; and 2) barriers and opportunities for smart grids deployment.

The purpose of the studies was twofold: 1) to identify what makes smart grid projects attractive to investors with the aim of stimulating investment towards this industry; and 2) analyse existing obstacles and opportunities for deployment of these technologies in EU to help identify where support is most needed and most relevant for smart grid deployment and European industrial competitiveness and growth.

The basis for the studies was the JRC inventory of smart grids projects and the main findings were presented in the context of the Expert Group on smart grid industrial policy of the EC Smart Grid Task Force. Amongst them, as also stated by the European Economic and Social Committee (2017), the objectives of the Clean Energy Package highly depend on the value the interactions between operators, service providers and consumers, and the availability of interoperable solutions.

⇒ CEN-CENELEC-ETSI - Coordination Group on Smart Energy Grids (CG-SEG)

After the dissolution of the Smart Grid Coordination Group in 2015, CEN-CENELEC-ETSI set up the CG-SEG for continuing with the work on standardisation. CG-SEG complements work of the European Commission Smart Grid Task Force (SGTF) Expert Groups.

CG-SEG identified some legislative proposals from the Clean Energy Package (CEP) with the highest impact on standardisation. Of these 'priority topics', two refer to interoperability:

5. Data Management, format and interoperability (CEP-EMD-1)

7. Interoperability with Consumer Energy Management systems (CEP-EMD-3)

In addition, the European Parliament (EP) amendment to Article 24 (Data format) of the Proposal for a revised Electricity Market Directive explicitly requests that interoperability standards for a common European data format be drawn up by the relevant European standards organization.

JRC takes part in the CG-SEG, taking into consideration their technical positions, and providing feedback from the work in the laboratory, mainly regarding the testing procedures. It is expected that CG-SEG will formally endorse the testing methodology and tools developed by JRC.

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